Intergovernmental Panel on Climate Change

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Volume 1

General Guidance and Reporting

Edited by Simon Eggleston, Leandro Buendia,
Kyoko Miwa, Todd Ngara and Kiyoto Tanabe

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IPCC National Greenhouse Gas Inventories Programme
Technical Support Unit

% Institute for Global Environmental Strategies
2108 -11, Kamiyamaguchi
Hayama, Kanagawa
JAPAN, 240-0115

Fax: (81 46) 855 3808
http://www.ipcc-nggip.iges.or.jp

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GENERAL GUIDANCE AND REPORTING

Coordinating Lead Authors
Newton Paciornik (Brazil) and Kristin Rypdal (Norway)

Review Editors
Sadedin Kherfan (Syrian Arab Republic) and Klaus Radunsky (Austria)

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CHAPTER 1

INTRODUCTION TO THE 2006 GUIDELINES

Authors

Kristin Rypdal (Norway), Newton Paciornik (Brazil)

Simon Eggleston (TSU), Justin Goodwin (UK), William Irving (USA), Jim Penman (UK), and Mike Woodfield (UK)

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1 INTRODUCTION TO THE 2006 GUIDELINES

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 Guidelines*) were produced at the invitation of the United Nations Framework Convention on Climate Change (UNFCCC) to update the *Revised 1996 Guidelines* and associated *good practice guidance*[1] which provide internationally agreed[2] methodologies intended for use by countries to estimate greenhouse gas inventories to report to the UNFCCC. This chapter provides an introduction to the *2006 Guidelines* for a broad range of users, including countries and inventory compilers setting out to prepare inventory estimates for the first time. Sections 1.1 to 1.3 describe the overarching framework of these *Guidelines*, focusing on scope, approach, and structure. Sections 1.4 through 1.5 present step-by-step guidance on how to use the *2006 Guidelines* for compiling a greenhouse gas inventory.

1.1 CONCEPTS

Inventories rely on a few key concepts for which there is a common understanding. This helps ensure that inventories are comparable between countries, do not contain double counting or omissions, and that the time series reflect actual changes in emissions.

Anthropogenic emissions and removals

Anthropogenic emissions and removals means that greenhouse gas emissions and removals included in national inventories are a result of human activities. The distinction between natural and anthropogenic emissions and removals follows straightforwardly from the data used to quantify human activity. In the Agriculture, Forestry and Other Land Use (AFOLU) Sector, emissions and removals on managed land are taken as a proxy for anthropogenic emissions and removals, and interannual variations in natural background emissions and removals, though these can be significant, are assumed to average out over time.

National territory

National inventories include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction. There are some special issues that are described in Section 8.2.1 of Volume 1. For example, emissions from fuel use in road transport is included in the emissions of the country where the fuel is sold and not where the vehicle is driven, as fuel sale statistics are widely available and usually much more accurate.

Inventory year and time series

National inventories contain estimates for the calendar year during which the emissions to (or removals from) the atmosphere occur. Where suitable data to follow this principle are missing, emissions/removals may be estimated using data from other years applying appropriate methods such as averaging, interpolation and extrapolation. A sequence of annual greenhouse gas inventory estimates (e.g., each year from 1990 to 2000) is called a time series. Because of the importance of tracking emissions trends over time, countries should ensure that a time series of estimates is as consistent as possible.

Inventory reporting

A greenhouse gas inventory report includes a set of standard reporting tables covering all relevant gases, categories and years, and a written report that documents the methodologies and data used to prepare the estimates. The *2006 Guidelines* provide standardised reporting tables, but the actual nature and content of the tables and written report may vary according to, for example, a country's obligations as a Party to the UNFCCC. The *2006 Guidelines* provide worksheets to assist with the transparent application of the most basic (or Tier 1) estimation methodology.

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[1] The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (*1996 Guidelines*, IPCC, 1997), The Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (*GPG2000*, IPCC, 2000), and The Good Practice Guidance for Land Use, Land-use Change and Forestry (*GPG-LULUCF*, IPCC, 2003).

[2] See the Report of the Fourth Session of the Subsidiary Body for Scientific and Technological Advice (FCCC/SBSTA/1996/20), paragraph 30; decisions 2/CP.3 and 3/CP.5 (UNFCCC reporting guidelines for preparation of national communications by Parties included in Annex I to the Convention, part I: UNFCCC reporting guidelines on annual inventories), decision 18/CP.8, revising the guidelines adopted under decisions 3/CP.5, and 17/CP.8 adopting improved guidelines for the preparation of national communications from Parties not included in Annex I to the Convention, and subsequent decisions 13/CP.9 and decision 15/CP.10.

Greenhouse gases

The following greenhouse gases are covered in the *2006 Guidelines*[3]:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs)
- sulphur hexafluoride (SF_6)
- nitrogen trifluoride (NF_3)
- trifluoromethyl sulphur pentafluoride (SF_5CF_3)
- halogenated ethers (e.g., $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$)
- and other halocarbons not covered by the Montreal Protocol including CF_3I, CH_2Br_2 $CHCl_3$, CH_3Cl, CH_2Cl_2 [4]

The gases listed above have global warming potentials (GWPs) identified by the IPCC prior to finalisation of the *2006 Guidelines*. A GWP compares the radiative forcing of a tonne of a greenhouse gas over a given time period (e.g., 100 years) to a tonne of CO_2. The *2006 Guidelines* also provide methods for gases for which GWP values were not available prior to finalisation, i.e., $C_3F_7C(O)C_2F_5$, C_7F_{16}, C_4F_6, C_5F_8 and c-C_4F_8O.

These gases are sometimes used as substitutes for gases that are included in the inventory and countries are encouraged to provide estimates for them.

Other gases

The *2006 Guidelines* also provide information for the reporting of the following precursors: nitrogen oxides (NO_x), ammonia (NH_3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and sulphur dioxide (SO_2) although methods for estimating emissions of these gases are not given here.

Sectors and Categories

Greenhouse gas emission and removal estimates are divided into main sectors, which are groupings of related processes, sources and sinks:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste
- Other (e.g., indirect emissions from nitrogen deposition from non-agriculture sources[5])

Each sector comprises individual categories (e.g., transport) and sub-categories (e.g., cars). Ultimately, countries will construct an inventory from the sub-category level because this is how IPCC methodologies are set out, and total emissions calculated by summation. A national total is calculated by summing up emissions and removals for each gas. An exception is emissions from fuel use in ships and aircraft engaged in international transport which is not included in national totals, but is reported separately.

In order to calculate a national total it is necessary to choose an approach to include harvested wood products (HWP). Countries can select any of the approaches reflected in Chapter 12 of Volume 4 for the AFOLU Sector to do this.

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[3] The halogenated gases are typically emitted in smaller amounts than CO_2, CH_4 and N_2O, but may have long atmospheric lifetimes and strong radiative forcing effects.

[4] For these gases, emissions could be estimated following the methods described in Section 3.10.2 of Volume 3 if necessary data are available, and then could be reported under sub-category 2B10 'Other'.

[5] Estimates include N_2O emissions from deposition of anthropogenic nitrogen (N) from NOx/NH3 wherever deposited and from whatever source (but not allocated to specific sectors). The reason for this is that emission factors for nitrogen deposited are of the same magnitude for agricultural sources as for other nitrogen sources, even when the N is deposited in the ocean.

Reporting is generally organised according to the sector actually generating emissions or removals. There are some exceptions to this practice, such as CO_2 emissions from biomass combustion for energy, which are reported in AFOLU Sector as part of net changes in carbon stocks. Where CO_2 emissions are captured from industrial processes or large combustion sources, emissions should be allocated to the sector generating the CO_2 unless it can be shown that the CO_2 is stored in properly monitored geological storage sites as set out in Chapter 5 of Volume 2.

1.2 ESTIMATION METHODS

As with the *1996 Guidelines* and *IPCC Good Practice Guidance* the most common simple methodological approach is to combine information on the extent to which a human activity takes place (called *activity data* or *AD*) with coefficients which quantify the emissions or removals per unit activity. These are called *emission factors (EF)*. The basic equation is therefore:

$$Emissions = AD \bullet EF$$

For example, in the energy sector fuel consumption would constitute activity data, and mass of carbon dioxide emitted per unit of fuel consumed would be an emission factor. The basic equation can in some circumstances be modified to include other estimation parameters than emission factors. Where time lags are involved, due for example to the time it takes for material to decompose in a landfill or leakage of refrigerants from cooling devices, other methods are provided, for example first order decay methods. The *2006 Guidelines* also allow for more complex modelling approaches, particularly at higher tiers.

Though this simple equation is widely used, the *2006 Guidelines* also contain mass balance methods, for example the stock change methods used in the AFOLU sector which estimates CO_2 emissions from changes over time in carbon content of living biomass and dead organic matter pools.

Carbon dioxide from the combustion or decay of short-lived biogenic material removed from where it was grown is reported as zero in the Energy, IPPU and Waste Sectors (for example CO_2 emissions from biofuels[6,7], and CO_2 emissions from biogenic material in Solid Waste Disposal Sites (SWDS)). In the AFOLU Sector, when using Tier 1 methods for short lived products, it is assumed that the emission is balanced by carbon uptake prior to harvest, within the uncertainties of the estimates, so the net emission is zero. Where higher Tier estimation shows that this emission is not balanced by a carbon removal from the atmosphere, this net emission or removal should be included in the emission and removal estimates for AFOLU Sector through carbon stock change estimates. Material with long lifetime is dealt with in the HWP section.

IPCC methods use the following concepts:

Good Practice: In order to promote the development of high quality national greenhouse gas inventories a collection of methodological principals, actions and procedures were defined in the previous guidelines and collectively referred to as *good practice*. The *2006 Guidelines* retain the concept of *good practice* including the definition introduced with *GPG2000*. This has achieved general acceptance amongst countries as the basis for inventory development and says that inventories consistent with *good practice* are those which *contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable.*

Tiers: A *tier* represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as *higher tier* methods and are generally considered to be more accurate.

Default data: Tier 1 methods for all categories are designed to use readily available national or international statistics in combination with the provided default emission factors and additional parameters that are provided, and therefore should be feasible for all countries.

Key Categories: The concept of *key category*[8] is used to identify the categories that have a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions and removals. *Key Categories* should be the priority for countries during inventory resource allocation for data collection, compilation, quality assurance/quality control and reporting.

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6 CO_2 emissions from the use of biofuels should be reported as an information item for QA/QC purposes.

7 In these guidelines peat is assumed *not* to be a biofuel.

8 Chapter 4 of Volume 1 provides more details of *key categories* and approaches to identifying *key categories* for national inventories.

Decision Trees: Decision trees for each category help the inventory compiler navigate through the guidance and select the appropriate tiered methodology for their circumstances based on their assessment of *key categories*. In general, it is *good practice* to use higher tier methods for *key categories*, unless the resource requirements to do so are prohibitive.

1.3 STRUCTURE OF THE GUIDELINES

Volumes: The *2006 IPCC Guidelines* contain 5 volumes, one for each sector (Volumes 2-5) and one for general guidance applicable to all sectors (Volume 1).

- Volume 1: General Guidance and Reporting
- Volume 2: Energy
- Volume 3: Industrial Processes and Product Use (IPPU)
- Volume 4: Agriculture, Forestry and Other Land Use (AFOLU)
- Volume 5: Waste

This five-volume structure means the cross referencing will be required between two volumes at most: Volume 1 (General Guidance and Reporting), and the relevant sectoral volume.

Chapters: Volume 1 contains chapters that provide detailed cross-cutting guidance by topic as described in more detail in Section 1.5. Volumes 2-5 contain chapters that provide methodological guidance for specific emission and removal categories, along with specific recommendations for uncertainty, QA/QC, time series consistency, and reporting. The volume and chapter structure is presented in Table 1 in the Overview of the *2006 Guidelines*.

Annexes: Annexes are intended to include additional often detailed information beyond what is necessary for a Tier 1 estimate, for example extended data tables.

Appendices: The *2006 IPCC Guidelines* present some technical material in appendices, where emissions or removals are poorly understood and where there is insufficient information available to develop reliable, globally applicable, default methods for a particular source or sink. Countries may use appendices as a basis for further methodological development, but a national inventory can be considered complete without the inclusion of estimates for these sources.

Worksheets: Worksheets are tools designed to provide easy calculation of Tier 1 methodologies. Worksheets are not provided for higher tiers, although they can also be used where the higher tier method is similar to Tier 1 (e.g., where national data is used instead of default data). Some more complex approaches are provided in spreadsheets in the attached CD.

Reporting Tables: The reporting tables are intended to give sufficient detail required for transparent reporting of national greenhouse gas inventories and follow a disaggregated category list. They include summary tables, sectoral tables, background tables and trend tables. The background tables include summary activity data for increased transparency and to facilitate comparison of data across countries. Reporting tables also include results of a *key category* analysis and uncertainty assessment. Reporting also includes memo items (emissions to be reported but not included in national totals) and information items for increased transparency.

1.4 INVENTORY QUALITY

These *guidelines* provide guidance on ensuring quality on all steps of the inventory compilation – from data collection to reporting. They also provide tools to focus resources on the areas where they will most benefit the overall inventory and encourage continuous improvement. Experience has demonstrated that using a *good practice* approach is a pragmatic means of building inventories that are consistent, comparable, complete, accurate and transparent – and maintaining them in a manner that improves inventory quality over time. Indicators of inventory quality are:

Transparency: There is sufficient and clear documentation such that individuals or groups other than the inventory compilers can understand how the inventory was compiled and can assure themselves it meets the *good practice* requirements for national greenhouse gas emissions inventories. Documentation and reporting guidance is provided in Chapter 8, Reporting Guidance and Tables, of Volume 1 and in the respective chapters of Volume 2-6 (see also Volume 1, Chapter 6, QA/QC and Verification).

Completeness: Estimates are reported for all relevant categories of sources and sinks, and gases. Geographic areas within the scope of the national greenhouse gas inventory are recommended in these *Guidelines*. Where elements are missing their absence should be clearly documented together with a justification for exclusion (see Volumes 2-5).

Consistency: Estimates for different inventory years, gases and categories are made in such a way that differences in the results between years and categories reflect real differences in emissions. Inventory annual trends, as far as possible, should be calculated using the same method and data sources in all years and should aim to reflect the real annual fluctuations in emissions or removals and not be subject to changes resulting from methodological differences. (See Chapter 2: Approaches to Data Collection, Chapter 4: Methodological Choice and Identification of Key Categories, and Chapter5: Time Series Consistency in Volume 1.)

Comparability: The national greenhouse gas inventory is reported in a way that allows it to be compared with national greenhouse gas inventories for other countries. This comparability should be reflected in appropriate choice of key categories (see Volume 1, Chapter 4), and in the use of the reporting guidance and tables and use of the classification and definition of categories of emissions and removals presented in Table 8.2 of Chapter 8, and Volumes 2-5.

Accuracy: The national greenhouse gas inventory contains neither over- nor under-estimates so far as can be judged. This means making all endeavours to remove bias from the inventory estimates (see especially Chapter 2, Approaches to Data Collection, and Chapter 3, Uncertainties, in Volume 1 and Volumes 2-5).

Uncertainty assessment (details provided in Chapter 3 of Volume 1) is an important component of *good practice* in national greenhouse gas inventory development. The uncertainty analysis characterises the range and likelihood of possible values for the national inventory as a whole as well as for its components. Awareness of the uncertainty of parameters and results provides inventory compilers with insight when evaluating suitable data for the inventory during the data collection and compilation phases. Uncertainty assessment also helps identify the categories that contribute most to the overall uncertainty, which helps the inventory compiler prioritise future inventory improvements.

The *2006 Guidelines* encourage continuous improvement and rigor through QA/QC and verification activities. A number of concepts and tools in Chapter 6 in Volume 1 are provided to support efficient inventory management, checking and continuous improvement. These activities will ensure that the best use of limited resources can be made and a quality consistent with *good practice* is achieved for each inventory.

Regular communication and consultation with providers of data is recommended throughout the inventory activities (from data collection to final reporting). This communication will build working relationships between data supplier and inventory compilers that will benefit the inventory both in terms of efficiency and quality. This activity will also help to keep the inventory compilers informed of the development of new datasets and even provide opportunities to influence the planning and specifications of data provider's data collection activities.

1.5 COMPILING AN INVENTORY

Compiling a greenhouse gas inventory is a step-by-step process. This section provides guidance on these steps for the *inventory compiler*, i.e., the person, persons or institutions who put together or compose the inventory from materials gathered from several sources. Compilation includes the collection of data, estimation of emissions and removals, checking and verification, uncertainty assessment and reporting.

Before undertaking estimates of emissions and removals from specific categories an inventory compiler should become familiar with the material in Volume 1 *General Guidance and Reporting*. This Volume provides *good practice guidance* on issues that are common to all the estimation methods covered by the sector-specific guidance provided in Volumes 2 to 5 and reporting instructions.

Summary of Volume 1:

- **Data collection:** Collection of data is a fundamental part of inventory preparation. Chapter 2 of Volume 1 provides guidance on initiating and maintaining a data collection program. It covers evaluating existing sources of data, and planning new emission measurements and surveys, extensive reference is made to guidance provided by other organisations. The chapter links the data collection process to the other general issues.

- **Uncertainty assessment:** Estimates of uncertainty are needed for all relevant source and sink categories, greenhouse gases, inventory totals as a whole, and their trends. Chapter 3, Uncertainties, provides practical guidance for estimating and combining uncertainties, along with a discussion of the conceptual underpinnings of inventory uncertainty. Uncertainty issues related to specific category of emissions and removals are addressed in Volumes 2-5.

- **Key category analysis:** *Good practice guidance* on how to identify *key categories* of emissions and removals is provided in Chapter 4, Methodological Choice and Identification of Key Categories. The *key category* concept is used, together with the decision trees in Volumes 2-5, to guide users in their methodological choice for each category. These decision trees are the critical link between methodological choice in the sector-specific volumes and the identification of *key categories* in Volume 1.

- **Time series consistency:** Ensuring the time series consistency of inventory estimates is essential for establishing confidence in reported inventory trends. Chapter 5, Time Series Consistency, provides methods for ensuring time-series consistency in cases where it is not possible to use the same method and/or data over the entire period. This chapter also provides *good practice guidance* on when to recalculate estimates for previous years and methods for accounting for changes in emissions and removals over time.

- **Quality Assurance (QA) and Quality Control (QC):** A QA/QC system is an important part of inventory development. Chapter 6, QA/QC and Verification, describes the general QA/QC aspects to consider when compiling an inventory of emissions and removals. *Good practice guidance* on sector specific quality control checks are addressed in Volumes 2-5. Chapter 6 also describes techniques for verifying inventories using external data.

- **Precursors and indirect N_2O emissions:** Volume 1 also includes cross-sectoral guidance on dealing with precursors and indirect emissions of N_2O from deposition of nitrogen compounds (resulting from NO_x and NH_3 emissions) in Chapter 7, Precursors and Indirect Emissions.

- **Reporting:** Chapter 8, Reporting Guidance and Tables, specifically addresses issues related to reporting, including definitions of national territory, gases and reporting categories. Notation keys are introduced to account for completeness and transparency in reporting. The definitions of categories of sources and sinks take into account the structure of the sector guidance in Volume 2-5. The sectoral and summary reporting tables to be applied for reporting emissions and removals of each category are included in Chapter 8. Reporting tables on uncertainties, *key category* analysis, and emission trends have also been developed and are included in Chapter 8.

Volumes 1 and Volumes 2 to 5 are complementary. After the compilers tasked with preparing estimates for specific emission and removal categories have familiarised themselves with the general guidance in Volume 1 they should use the specific sectoral volume(s) appropriate to their categories so that they can apply the requirements in a manner appropriate to their national circumstances. Figure 1.1 illustrates the steps of a typical inventory cycle. Quality control measures should be implemented at each step and should be documented according to the requirements of QA/QC and documentation given in Chapter 6 of Volume 1.

1. The first step for a revised or new greenhouse gas inventory is to identify the *key categories* for the inventory so that resources can be prioritised. Where an inventory already exists, the *key categories* can be identified quantitatively from the previous estimates (see Volume 1 Chapter 4). For a new inventory the compiler will have to make a preliminary assessment based on local knowledge and expertise about large emission sources and inventories in countries with similar national circumstances or, if possible, make preliminary Tier 1 estimates to assist in identifying *key categories*.

   Assessing the *key categories* helps the inventory compiler to focus effort and resources on the sectors that contribute most to the overall inventory or inventory uncertainty and so helps to ensure that the best possible inventory is compiled for the available resources.

2. Once the *key categories* have been identified, the inventory compiler should identify the appropriate method for estimation for each category in the particular country circumstances. The sector-specific decision trees in Volumes 2-5 and the generalised decision tree in Chapter 4 of Volume 1 provide guidance on selecting appropriate methods. The selection of methods will be determined by the classification of a category as *key* or not *key*, and by both the data and the resources available. Guidance on data collection is provided in Chapter 2 of Volume 1.

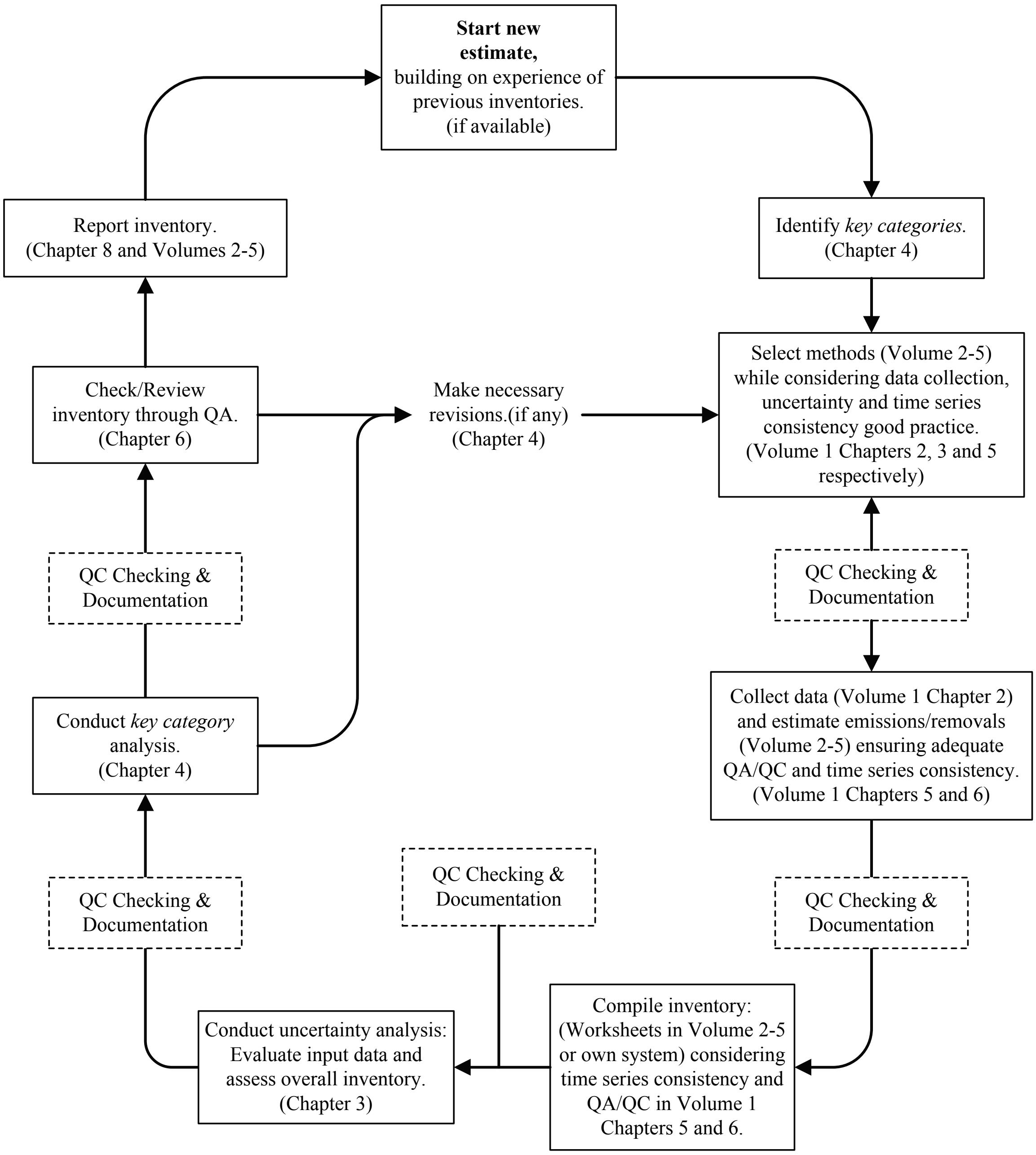
3. Data collection should follow the selection of the appropriate methods. (See Chapter 2, 5 and 7 in Volume 1). Data collection activities should consider time series consistency and establish and maintain good verification, documentation and checking procedures (QA/QC) to minimise errors and inconsistencies in the inventory estimates. Data on uncertainties should if possible be collected at the same time. Guidance on the collection of new data in a cost effective way and on uncertainties is provided in Chapter 2 and Chapter 3 of Volume 1 respectively. QA/QC activities should continue throughout this process to minimise errors and document data sources, methods and assumptions. The results of the data collection may lead to refinement of the methods chosen.

4. Emissions and removals are estimated following the methodological choice and data collection. Care should be taken to follow the general guidance in Chapter 5, Time Series Consistency in Volume 1 especially if the data are incomplete for some years.

5. Once the inventory estimates are complete, the next step is to perform an uncertainty analysis and key category analysis (see Chapters 3 and 4 in Volume 1). These analyses may identify categories for which a higher tier should be used and additional data collected.
6. Following the completion of the final quality assurance (QA) checks, the final step in the inventory process is to report the inventory (See Chapter 8 in Volume 1). The aim here is to present the inventory in an as concise and clear way as possible to enable users to understand the data, methods and assumptions used in the inventory. Provision of concise relevant background information and explanations in the reports helps to ensure the inventory (including the report) is transparent.

The inventory compiler should base future inventory revisions on previous inventories. Thus an iterative process builds on and improves the inventory each time a new inventory is compiled as illustrated in Figure 1.1. When a revised inventory is compiled, all years estimates should be reviewed for consistency and updated integrating any feasible improvements where necessary. Chapter 5 in Volume 1 gives advice on compiling consistent time series and provides *good practice* approaches for achieving time series consistency.

Figure 1.1 Inventory development cycle



Box 1.1 provides an example on using the *2006 Guidelines* throughout the inventory cycle when estimating emissions from enteric fermentation.

BOX 1.1
USING THE FLOW DIAGRAM (FIGURE 1.1) AND THE 2006 GUIDELINES – LIVESTOCK EXAMPLE

Inventory compilers tasked with preparing estimates for specific emission and removal categories need to familiarise themselves with guidance in two Volumes: the relevant guidance in a sectoral volume (e.g., Volume 4, Agriculture, Forestry and Other Land Use), and the general guidance in Volume 1. Along with the diagram (see Figure 1.1) this box describes how the guidance in the two Volumes is used for estimating methane emissions from Enteric Fermentation:

Start with your previous inventory where available and prioritise categories for estimation.

- The inventory compiler can begin with the overall results of the previous national inventory, particularly the key category assessment, as a preliminary step to selecting methods and data (Chapter 4 of Volume 1).

Familiarise yourself with general and sector specific QA/QC requirements.

- Prior to collecting all the data and estimating emissions, the inventory compiler should consult the general guidance in implementing Quality Control (QC) procedures in Chapter 6 of Volume 1 (QA/QC and Verification) along with the specific QC procedures for enteric fermentation described in Chapter 10 of Volume 4. QC procedures should be implemented at every step of the inventory cycle. This will include regular checking and clear documentation of data sources methods and assumptions.

Choose appropriate methods based on category importance and data availability.

- The inventory compiler should consult the decision tree and methodological guidance in Chapter 10 of Volume 4 to select an appropriate method. In this example, enteric fermentation is a key category, which indicates that normally Tier 2 or 3 should be selected.

- The general guidance in Chapter 2 (Approaches to Data Collection) of Volume 1 and Chapter 10 of Volume 4 will guide the inventory compiler in choosing appropriate emission factor, activity data and other estimation parameters. This may include identifying or choosing from existing data or collection and classification of new data.

Collect the data necessary for the latest year and a consistent time series and uncertainty estimation.

- The next step involves collection of the needed data for all years. The availability of data may sometimes restrict use of higher tier methods for key categories.

- Chapter 5 (Time Series Consistency) of Volume 1 should be used if preparing estimates for more than one year. This guidance is particularly relevant if the selected method is different from the one used in previous inventories or the sources of data or their classification have changed. This can imply the need for recalculations of previous estimates or splicing of data series. Chapter 10 of Volume 4 should be consulted for source-specific guidance on time-series consistency.

- In estimating uncertainties, inventory compilers should also refer to the general guidance on uncertainty in Chapter 3 of Volume 1 - paying particular attention to guidance on concepts and methods – and the uncertainty section of the enteric fermentation livestock chapter for source-specific information (for example default uncertainties). Ideally, the inventory compiler should collect activity data, emission factors, and uncertainty information at the same time because this is the most efficient strategy.

Estimate emissions/removals consistent with the guidance.

- The next step is to estimate methane emissions from enteric fermentation for all relevant years. Relevant guidance for this step includes the specific guidance for enteric fermentation in Volume 4, Chapter 10 relating to completeness, reporting and documentation, and time series consistency sections.

- The enteric fermentation emissions and uncertainty data are used subsequently as input into the compilation of the overall inventory, the estimation of category-specific and overall uncertainty, and the key category assessment. The results of these steps may require changes or revisions to the original estimate of emissions of enteric fermentation.

BOX 1.1 (CONTINUED)

Check and review the estimates.

- Following the Quality Assurance (QA) guidance in Volume 1, the inventory compiler should arrange for review of the estimate and documentation by technical experts not involved in the preparation of the inventory. External reviewers may suggest improvements or identify errors that would require a recalculation of the enteric fermentation estimate.

Report the estimates.

- The *IPCC Guidelines* provide guidance on reporting information on enteric fermentation in two places: the enteric fermentation chapter of Volume 4, and the reporting tables in Chapter 8 of Volume 1. The inventory compiler should consult both chapters for a complete description of reporting guidance.

Note: In the case of an initial inventory effort, with no previous key category analysis, a qualitative assessment of enteric fermentation could be used. See Chapter 2 and Chapter 4 of Volume 1. In this example, it can be concluded that methane from enteric fermentation is key in most inventories and should therefore be considered initially key.

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CHAPTER 2

APPROACHES TO DATA COLLECTION

Authors

Justin Goodwin (UK), Mike Woodfield (UK)

Mirghani Ibnoaf (Sudan), Matthias Koch (Germany), and Hong Yan (China)

Contributing Authors

Christopher Frey (USA), Rosemary Montgomery (United Nation Statistical Division),
Tinus Pulles (Netherlands), Deborah Ottinger Schaeffer (USA), and Karen Treanton (IEA)

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2 APPROACHES TO DATA COLLECTION

2.1 INTRODUCTION

Data[1] collection is an integral part of developing and updating a greenhouse gas inventory. Formalised data collection activities should be established, adapted to countries' national circumstances, and reviewed periodically as a part of implementing *good practice.* In most cases generating new source data will be limited by the resources available and prioritisation will be needed, taking account the results of *key category* analysis set out in Chapter 4, Methodological Choice and Identification of Key Categories. Data collection procedures are necessary for finding and processing existing data, (i.e., data that are compiled and stored for other statistical uses than the inventory), as well as for generating new data by surveys or measurement campaigns. Other activities include maintaining data flows, improving estimates, generating estimates for new categories and/or replacing existing data sources when those currently used are no longer available.

The methodological principles of data collection that underpin *good practice* are the following:

- Focus on the collection of data needed to improve estimates of *key categories* which are the largest, have the greatest potential to change, or have the greatest uncertainty.
- Choose data collection procedures that iteratively improve the quality of the inventory in line with the data quality objectives.
- Put in place data collection activities (resource prioritisation, planning, implementation, documentation etc.) that lead to continuous improvement of the data sets used in the inventory.
- Collect data/information at a level of detail appropriate to the method used.
- Review data collection activities and methodological needs on a regular basis, to guide progressive, and efficient, inventory improvement.
- Introduce agreements with data suppliers to support consistent and continuing information flows.

This chapter provides general guidance for collecting existing national/international data and new data. The material is intended both for countries establishing a data collection strategy for the first time and for countries with established data collection procedures. It is applicable to emission factor, activity, and uncertainty data collection. It covers:

- Developing a data collection strategy to meet data quality objectives regarding timeliness, and also consistency, completeness, comparability, accuracy, and transparency using guidance provided in Chapter 6, QA/QC and Verification, of this volume,
- Data acquisition activities including generating new source data, dealing with restricted data and confidentiality, and using expert judgement,
- Turning the raw data into a form that is useful for the inventory.

Advice related to selecting emission factors focuses on understanding and generating measured data as well as addressing where to find and when to use default factors. Guidance on activity data focuses on generating and using new census & survey data as well as providing guidance on the use of existing international data sets.

The chapter draws on information from a range of institutions and where possible additional documents have been identified and referenced so that users can find more detailed information. Sector specific data collection issues - like selecting the appropriate activity data for a particular category of emissions by sources and removals by sinks - are described in the sector specific Volumes 2-5.

2.2 COLLECTING DATA

This section provides general guidance for collecting existing data, generating new data, and adapting data for inventory use. The guidance is applicable to emission factors, activity and uncertainty data collection. It

[1] Data can be defined as factual information (e.g., measurements or statistics) used as a basis for reasoning, discussion, or calculation. Data collection is the activity of acquiring and compiling information from different sources.

discusses separately specific issues relating to new data and existing data. Specific guidance for the collection/calculation of emission factors and the collection of activity and uncertainty data is provided subsequently. Throughout the data collection activities the inventory compiler should maintain QA/QC records about the data collected according to the guidance provided in Chapter 6 of Volume 1. While collecting data it is *good practice* to be aware of future data collection needs.

Maintaining supply of inventory data

It is *good practice* to engage data suppliers in the process of inventory compilation and improvement by involving them in activities such as:

- Offering an initial estimate for the category, pointing out the potentially high uncertainties and inviting potential data suppliers to collaborate in improving estimates,
- Scientific or statistical workshops on the inventory inputs and outputs,
- Specific contracts or agreements for regular data supply,
- Regular/annual informal updates on the methods that use their data,
- Establishment of terms of reference or memoranda of understanding for government and/or trade organisations providing data to clarify what is needed for the inventory, how it is derived and provided to the inventory compiler and when.

These activities will help to ensure that the most appropriate data are available for the inventory and that the data are properly understood by the inventory compiler. It will also help to establish links to data providing organisations.

Where appropriate, it may be useful to explore existing or new legal arrangements as means of guaranteeing the delivery of data to the inventory.

Restricted data and confidentiality

Data providers might restrict access to information because it is confidential, unpublished, or not yet finalised. Typically, this is a mechanism to prevent inappropriate use of the data, unauthorised commercial exploitation, or sensitivity to possible imperfections in the data. Sometimes, however, the organisation simply does not have the resources required to compile and check the data. It is advisable, where possible, to cooperate with data providers to find solutions to overcome their concerns by:

- explaining the intended use of the data,
- agreeing, in writing, to the level at which it will be made public,
- identifying the increased accuracy that can be gained through its use in inventories,
- offering cooperation to derive a mutually acceptable data sets,
- and/or giving credit/acknowledgement in the inventory to the data provided.

The protection of confidentiality is one of the fundamental principles of a national statistical agency (NSA[2] - see: http://unstats.un.org/unsd/methods/statorg/). NSAs are committed to safeguarding information that plainly reveals the operations, belongings, attitudes or any other characteristics of individual respondents. If respondents are not convinced that the information they provide to the NSA is absolutely confidential, the quality of the information collected may suffer. Detailed individual data must therefore be treated and aggregated so as to draw out the information that is important to the user, without disclosing individual data. This is more likely to be an issue for business statistics, especially where a few companies dominate the sector, than for other data.

Sometimes, depending on the size and structure of the original sample, raw data can be aggregated in a way that protects confidentiality and yet produces useful information for emission inventory purposes. If, however, there is a need to preserve confidentiality the NSA, or the body that originally collected the data, are normally the only ones that can carry out this additional treatment of the raw data.

Some countries have special arrangements to mask data (i.e., make data anonymous with respect to companies or facilities) to allow researchers access. Inventory compilers may investigate the possibility of making such arrangements. However, as this reprocessing will be required regularly (annually if possible), a better solution would probably be for NSAs to incorporate this into their own work programmes. While this will require an initial investment in data processing, it will probably be quicker and less expensive in the long run. Once the

[2] Any main national official data collection organisation is referred to here as national statistical agency.

reprocessing system is set up it can be reused every time the survey is repeated, with low marginal costs. An added advantage is that the information will then be in the public domain so that others can validate the figures reported in the inventories.

Many agencies collect ancillary data during operations for other purposes, such as registration of businesses or vehicles, collection of taxes, granting of licences, allocation of grants and subsidies. Such information is usually also covered by confidentiality clauses. In general, such clauses foresee the use of the data for statistical purposes, and NSAs have the right of access to such data. Often these administrative data form the basis for sample stratification and selection and NSAs will have experience in handling them, perhaps even developing specialist software that allows the required information to be drawn out without breaching the confidentiality rules.

For all these reasons, when existing data need to be reprocessed, it is strongly recommended to work together with NSAs or the statistical service of the relevant ministry, not only to protect confidentiality, but also for cost savings.

Expert judgement

Expert judgement on methodological choice and choice of input data to use is ultimately the basis of all inventory development and sector specialists can be of particular use to fill gaps in the available data, to select data from a range of possible values or make judgements about uncertainty ranges as described in Section 3.2.2.3. Experts with suitable backgrounds can be found in government, industrial trade associations, technical institutes, industry and universities.

The goal of expert judgement may be choosing the proper methodology; the parameter value from ranges provided; the most appropriate activity data to use; the most appropriate way to apply a methodology; or determining the appropriate mix of technologies in use. A degree of expert judgement is required even when applying classical statistical techniques to data sets, since one must judge whether the data are a representative random sample and, if so, what methods to use to analyze the data. This requires both technical and statistical judgement. Interpretation is especially needed for data sets that are small, highly skewed or incomplete[3]. In all cases the aim is to be as representative as possible in order to reduce possible bias and increase accuracy. Formal methods for obtaining (or eliciting) data from experts are known as expert elicitation, see Annex 2A.1 for details.

2.2.1 Gathering existing data

Although the list below is not exhaustive, it provides a starting point for possible sources of country specific data:

- National Statistics Agencies
- Sectoral experts, stakeholder organisations
- Other national experts
- IPCC Emission Factor Database
- Other international experts
- International organisations publishing statistics e.g., United Nations, Eurostat or the International Energy Agency, OECD and the IMF (which maintains international activity as well as economic data)
- Reference libraries (National Libraries)
- Scientific and technical articles in environmental books, journals and reports.
- Universities
- Web search for organisations & specialists
- National Inventory Reports from Parties to the United Nations Framework Convention on Climate Change

Screening of available data

It is best to start data collection activities with an initial screening of available data sources. This will be an iterative process where details of data that are available are built up. This screening process may be slow and require questioning until a final judgement can be made about the usefulness of a data set for the inventory.

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[3] Methods for characterising sampling distributions for the mean are described by Cullen and Frey (1999), Frey and Rhodes (1996), and Frey and Burmaster (1999).

The purpose for which data were originally collected may be an important indicator of reliability. Regulatory authorities and official statistical bodies have a responsibility to take representative samples and accurate measurements, and so they often adopt agreed standards. Often official statistics (because they have a more elaborate review process) take a long time to become available but preliminary data may be available at an earlier stage. These preliminary data can be used provided that their validity is documented and can be checked against the data quality objectives set by the quality management system described in Chapter 6.

Refining Data Requirements

Once the inventory compiler has selected a data set, unless published data simply can be used in their original form, the next step will be to develop a more formal specification and data request. This formalisation enables efficient annual updating (through knowing what to ask for, from whom, and when) while complying with QA/QC requirements for documentation (see Chapter 6, QA/QC and Verification). A clear definition of data requirements will ensure that when data are delivered they are as expected. The specification should include details such as:

- Definition of the data set (e.g., time series, sectors and sub-sector detail, national coverage, requirements for uncertainty data, emission factors and/or activity data units),
- Definition of the format (e.g., spreadsheet) and structure (e.g., what different tables are needed and their structure) of the data set,
- Description of any assumptions made regarding national coverage, the sectors included, representative year, technology/management level, and emission factors or uncertainty parameters,
- Identification of the routines and timescales for data collection activities (e.g., how often is the data set updated and what elements are updated),
- Reference to documentation and QA/QC procedures,
- Contact name and organisation,
- Date of availability.

It can be useful to seek commitment to these specifications from the organisation providing the data. Maintaining and updating these specifications on a regular basis, in case data requirements change, can also help to document the data sources and provide up-to-date guidance for routine data collection activities. It is not unusual for the delivery of data sets to be delayed so incorporating early warning routines to detect and manage delays can be useful.

Choosing between published national and international data

In most cases it is preferable to use national data since national data sources are typically more up to date and provide better links to the originators of the data. Most international datasets rely on nationally-derived data, and in some cases data from reputable international bodies may be more accessible and more applicable to the inventory. In some cases, groups such as international trade associations or international statistical bodies will have country specific datasets for industries or other economic sectors that are not held by national organisations. Often international data have undergone additional checking and verification and may have been adjusted with the aim of increasing consistency, though this will not necessarily lead to improved estimates if the adjusted data are recombined with national information. Countries are encouraged to develop and improve national sources of data to avoid being reliant on international data. Cross-checking national data sets with any available international data can help to assess completeness and identify possible problems with either data set.

Surrogate data

It is preferable to use data that are directly related to the item being quantified rather than to use surrogate data (i.e., alternative data that have a correlation with the data that they are replacing). In some cases, however, directly applicable data may be unavailable or have gaps (e.g., if survey and sampling programmes may be infrequent). In these cases surrogate data can help fill gaps and generate a consistent time series or a country average. For example, where a country has information to apply a higher tier method for some but not all of its facilities, then surrogate data can be used to fill the gaps. The surrogate data should be physically and statistically related to the emissions from the set of facilities for which information is not available. These alternative data should be selected based on country-specific circumstances and information, and a relationship between the data and emissions (i.e., an emission factor) developed using information from a representative subset of facilities whose emissions are known. The use of surrogate data to obtain an initial estimate of an emission or removal can help prioritise resources.

In selecting and using surrogate data to estimate emissions or removals, it is *good practice* for countries to perform the following steps:

(i) Confirm and document the physical relationship between emissions/removals and the surrogate activity data.

(ii) Confirm and document a statistically significant correlation between emissions/removals and the surrogate activity data.

(iii) Using regression analysis, develop a country-specific factor relating emissions/removals to the surrogate data.

An example of this approach is given in Box 2.1 and further explanation and equation (Equation 5.2) given in Section 5.3 of Chapter 5, Time Series Consistency.

BOX 2.1

EXAMPLE OF USING ALTERNATIVE DATA TO APPROXIMATE ACTIVITY DATA

The U.S. receives emission estimates for SF_6 associated with electrical equipment based on a mass-balance approach from electric power systems representing about 35 percent of the total length of U.S. transmission lines. (In the U.S., transmission lines are defined as lines carrying electricity at or above 34.5 kV.) To estimate emissions from the remaining systems, the U.S. uses kilometres of transmission lines as alternative activity data. In the U.S., SF_6 is primarily used in equipment rated at or above 34.5 kV, and kilometres of transmission lines are therefore expected to be a good predictor of emissions. In addition, statistical analysis has demonstrated a high correlation between emissions and kilometres of transmission lines. Given these relationships, the U.S. uses regression factors relating transmission kilometres to emissions. These factors are then applied to the total transmission kilometres of the systems whose emissions are being estimated. Germany has also used the length of transmission lines to estimate emissions from closed pressure systems for a set of utilities that did not respond to an industry survey. Estimates are based on the electric power systems from utilities for which both transmission kilometres and emissions data were available. The resulting estimates were later confirmed by more comprehensive surveys in subsequent years. Information on equipment banks, available nationally from equipment manufacturers and distributors were used to estimate emissions from sealed-pressure systems.) Transmission kilometres are likely to be a good predictor of emissions where most SF_6 is used in high voltage transmission equipment, as in the U.S. Where a high percentage of SF_6 is used in medium voltage distribution equipment or in gas-insulated substations, another type of data may be appropriate, such as the combined length of transmission and distribution lines or the number of substations. Combinations of these or other types of data may also be used although this increases the probability that one or more of the types of data will not be available for all the systems whose emissions are to be estimated.

2.2.2 Generating new data

It may be necessary to generate new data if representative emission factors, activity data or other estimation parameters do not exist, or cannot be estimated from existing sources. Generation of new data may entail measurement programmes for industrial process or energy related emissions, sampling of fuels for carbon content, land-use change and forestry sampling activities, or new census or surveys for activity data. Generation of new data is best undertaken by those with appropriate expertise (e.g., measurements carried out by competent organisations using appropriately calibrated equipment or surveys and censuses by any national statistical authority). These activities are often resource intensive and are most appropriately considered when the category is *key* and there are no other options. To optimise resource use it is recommended as far as possible to generate the required data from an extension of existing programmes rather than the initiation of totally new ones. More specific details for emission factor and activity data are outlined in the respective sections of this chapter. Where guidelines exist for activities that are defined in detail by other official bodies, such as statistical offices and measurement standards committees, these are also referenced in these sections.

Generating data by measurement

Measurements should be used in the context of advice in the sectoral Volumes 2-5, for example to determine or revise emission factors, destruction/abatement efficiency factors and activity rates. Measurements can also be used to quantify greenhouse gas emissions directly or to calibrate and verify models that are used to generate data.

When considering using measurement data it is *good practice* to check whether it covers a representative sample, i.e., that is typical of a reasonable proportion of the whole category – and also whether a suitable measurement method has been used. The best measurement methods are those that have been developed by official standards organisations and field-tested to determine their operational characteristics.[4] Using standardised measurement methods improves the consistency of measured data and provides the inventory compiler with additional information about the method such as statistical uncertainty levels, lower detection limits, sensitivity, and upper limits of measurement etc. The International Standards Organisation (ISO) standards, European Standards (EN) or suitable validated national standards of, e.g., U.S. Environmental Protection Agency (USEPA), or the Association of German Engineers (Verein Deutscher Ingenieure, VDI), may meet these criteria. It is *good practice* for the inventory compiler to document any measurement or quality management standards that have been used, and to bear in mind the data requirements of the uncertainty analysis in Chapter 3, Uncertainties, of Volume 1.

Reliable and comparable results can be achieved using a well-designed measurement programme with defined objectives; suitable methods; clear instructions to the measurement personnel; defined data processing and reporting procedures, and adequate documentation. Table 2.1 sets out the elements of such an approach.

TABLE 2.1
GENERIC ELEMENTS OF A MEASUREMENT PROGRAMME

Measurement objective	Clear statement of the parameter(s) to be determined, e.g., HFC-23 emissions from HCFC-22 production.
Methodology protocol	Description of the measurement methodology to be used. This should include: • The components to be measured and any associated reference conditions; • Methods to ensure that representative samples are taken that reflect the nature of the source category and the measurement objective [a]; • The identification of any standard techniques to be used; • The analytical equipment needed and its operational requirements; • Any source/sink or installation access requirements; • Any accuracy, precision or uncertainty requirements; • Data capture requirements to be met; • QA/QC regimes to be followed.
Measurement plan with clear instructions to the measurement personnel	Measurement plan specifies for those carrying out the measurements that includes: • Number of sampling points for each parameter to be measured and how these are to be selected; • Number of individual measurements to be made for each sampling point and set of conditions; • Measurement dates and periods of the measurement campaign; • Reporting arrangements; • Additional source or process related information to be collected to enable data processing or interpretation of the results; • Conditions (or range of conditions) of the source (or for industrial plant the capacity, load, fuel or feedstock) to be met during the measurements; • Personnel responsible for the measurements, who else is involved and the resources to be used.
Data processing and reporting procedures, and documentation	Data processing requirements, including; • Reporting procedures that will form an account of the measurements, the description of the measurement objectives, and the measurement plan; • Documentation requirements to enable the results to be traced back through the calculations to the collected basic data and process operating conditions.

[a] When making eco-system measurements particular care is required in defining the sampling requirements – see Volume 4.

[4] For example, repeatability, reproducibility detection limit, tolerance to interference, etc.

General guidance to ensure the quality of measured data to determine better emission factors and other parameters are provided in Section 2.2.2.

Relationship of data to models

Although models are frequently used to assess complex systems and can be used to generate data, models are a means of data transformation and do not remove the need for data to drive them.

2.2.3 Adapting data for inventory use

Whether using existing data, making new measurements or combining the two it is important to ensure that the level of detail and coverage of the data match, including sectors/process/abatement, location, land type, compound and years included.

Gaps in data sets

Greenhouse gas inventories require consistent estimates across time series and between categories. This section introduces approaches to fill gaps if data are missing for one or more years or the data do not represent the year or national coverage required. Examples of data gaps or inconsistencies and guidance for addressing them are presented below.

- **Filling gaps in periodic data:** Gaps in the time series will exist when data are available at less than annual frequency. For example, time consuming and expensive surveys relating to natural resources - such as national forest inventories - are compiled at intervals of every fifth or tenth year. Time series data may need to be inferred to compile a complete annual estimate for the years between surveys, and for fore- and back-casts (e.g., where estimates are needed for 1990 – 2004 and survey data are only available for 1995 and 2000). Chapter 5, Time Series Consistency, provides details on splicing and extrapolation methods to fill these gaps.

- **Time series revision:** In order to meet deadlines, statistical organisations may use modelling and assumptions to complete the most recent year of their estimates. These estimates are then refined the following year when all the data have been processed. Data may have been subject to further revision of historic data to correct errors or to update new methodologies. It is important that the inventory compiler look for these changes in the source data time series and integrate them into the inventory. Chapter 5 of this Volume contains more guidance on this issue.

- **Incorporating improved data:** While the ability of countries to collect data generally improves over time so they can implement higher tier methods, the data may not necessarily be suitable for earlier years for the higher tiers. For example when direct sampling and measurement programs are introduced there may be inconsistencies in the time series as the new program cannot measure past conditions. Sometimes this can be addressed if the new data are sufficiently detailed (e.g., if emission factors for modern abated plant can be distinguished from those of older unabated plant) and the historic activity data can be stratified using expert judgement or surrogate data. Chapter 5 provides more details on methods of incorporating improved data consistently across a time series.

- **Compensating for deteriorating data:** Splicing techniques, as described in Chapter 5 on Time Series Consistency, can be used to manage data sets that have deteriorated over time. Deterioration can occur as the result of changing priorities within governments, economic restructuring, or diminishing resources. For example, some countries with economies in transition no longer collect certain data sets that were available in the base year, or these data sets may contain different definitions, classifications and levels of aggregation. The international data sources discussed in the activity data section (see Section 2.2.5) may provide another source of relevant activity data.

- **Incomplete coverage:** When data do not fully represent the whole country, e.g., measurements for 3 of 10 plants or survey data of the agricultural activity for 80 percent of the country, then the data can still be used but needs to be combined with other data to calculate a national estimate. In these cases expert judgement (see Section 2.2 above for details) or the combination of these data with other data sets (surrogate or exact data) can be used to calculate a national total. In some cases survey or census data are collected in a rolling national programme that samples different provinces or sub-sectors yearly with a repeat cycle that builds a complete data set after a period of years. It is recommended that, bearing in mind that time series consistency, assumptions made in one year must also apply to the other years, and that data providers be requested to compute representative yearly data with a complete coverage.

Combining data sets numerically

Sometimes an inventory compiler will be presented with several potential datasets to use for the same estimate e.g., a series of independent measurements for the carbon content of a fuel. If the data refer to the same quantity and were collected in a reasonably uniform manner then combining them will increase accuracy and precision. Combination can be achieved by pooling the raw data and re-estimating the mean and 95 percent confidence limits, or by combining summary statistics using the relationships set out in statistical textbooks. It also is possible to combine measurements of a single quantity made using different methods that produce results with different underlying probability distributions. However, the methods for doing this are more complex, and in most cases, it will probably be sufficient to use expert judgement to decide whether to average the results, or to use the more reliable estimate and discard the other.

When using data that are not homogeneous (e.g., because of the presence of abatement technology at some plant but not others) the inventory estimate should be stratified (subdivided) so that each stratum is homogeneous and the national total for the source category will then be the sum of the strata. The uncertainty estimates can then be obtained using the methods set out in Chapter 3 by treating each stratum in the same way as an individual category. Inhomogeniety may be identified by specific knowledge of the circumstances of individual plants or technology types, or by a detailed data analysis, e.g., scatter plots of estimated emissions/removals against activity data.

Empirical data sets may contain outliers – data points that lie outside the main probability distribution and are regarded as unrepresentative. These may be identified by some rule, for example lying more than three standard deviations from the mean. Before taking this path the inventory compiler should consider whether the apparently anomalous data do in fact indicate some other set of circumstances (e.g., plant in start-up conditions) that should really be represented separately in the inventory estimate.

Multi-year averaging: Countries should report annual inventory estimates that are based on best estimates for actual emissions and removals in that year. Generally, single year estimates provide the best approximation of real emissions/removals and a time series of single year estimates prepared according to *good practice* can be considered consistent. Countries should, where possible, avoid using multi-year averaging of data that would result in over- or under-estimates of emissions over time, increased uncertainty, or reduced transparency, comparability or time-series consistency of the estimates. However, in some specific cases that are described for specific sectors in Volume 2-5, multi-year averaging may be the best or even the only way to estimate data for a single year. In the case of high or uncertain annual variability – as in the growth of various tree species in a year – and where there is higher confidence in the average annual growth rate over a period of years then multi-year averaging can improve the quality of the overall estimate.

Non-calendar year data: It is *good practice* to use calendar year data whenever the data are available. If calendar year data are unavailable, then other types of annual year data (e.g., non-calendar fiscal year data e.g., April – March) can be used provided that it is used consistently over the time series and the collection period for the data is documented. Similarly, different collection periods can be used for different emission and removal categories, again provided that the collection periods are used consistently over time and documented this is acceptable. It is *good practice* to use the same collection periods consistently over the time series to avoid bias in the trend. Animal population data may, for example, have been collected in the summer and so may not correspond with the annual average. The data should be corrected where possible to represent the calendar year. If uncorrected data are used, it is *good practice* for the inventory compiler to make consistent use of either calendar year data or fiscal year data for all years in the time series.

Regional inventory data

In some circumstances regional activity statistics and emission datasets are more detailed, up-to-date, accurate and/or complete than national datasets. In these cases a regionally compiled and then aggregated inventory can result in a better quality inventory for a country than one compiled using averaged national statistics and datasets. In such cases, and in order to fulfil the requirements of *good practice*, inventories can be compiled entirely or in part on a regional basis provided that:

- Each regional component is compiled in a way that is consistent with *good practice* QA/QC, choice of tiers, time series consistency and completeness.
- The approach used to aggregate the regional inventories and fill any gaps at a national level is transparent and in line with the *good practice* methods provided in the *Guidelines*.
- The final country inventory complies with the *good practice* quality requirements of completeness, consistency, comparability, timeliness, accuracy and transparency. In particular the sector estimates calculated at different regions, and then aggregated in the final inventory, should be self-consistent. There should be no emissions or removals omitted or double counted in the aggregated inventory and the different parts of the inventory should use assumptions and data consistently as far as practical and appropriate.

2.2.4 Emission factors and direct measurement of emissions

This section provides generic advice for the derivation or review of emission factors or other estimation parameters; this includes specialised literature sources, using measured data, and further remarks on combining data sets. It is *good practice* when developing emission factors or other estimation parameters to follow the stepwise approach to data collection described above:

- Setting priorities,
- Developing a strategy for accessing the data,
- Collecting and processing the data.

Volumes 2-5 provide advice on the selection and use of emission factors or other estimation parameters for specific categories.

Literature sources

Inventory compilers commonly rely on the available literature to find emission factors or other estimation parameters. Table 2.2 lists a variety of potential literature sources in order of descending likelihood of the data being representative and appropriate for national circumstances. It is *good practice*, for countries to use their own, peer-reviewed, published literature because this should provide the most accurate representation of their country's practices and activities. If there are no country-specific peer-reviewed studies available, then the inventory compiler can use IPCC default factors and Tier 1 methods as indicated by the decision trees in Volumes 2 to 5, or Tier 2 methods with data from Emission Factor Database (EFDB), or other literature values e.g., modelled/estimated energy data from international bodies that reflect national circumstances. The order of presentation in Table 2.2 is indicative only, and inventory compiler should assess each data source individually to make a determination of suitability.

A literature review is a useful approach for gathering and selecting from among a variety of possible data sources. Literature reviews can be time-consuming because many lead to old data and in addition the use of conversion units may generate artificial differences. Journal papers can sometimes be accessible through web without a subscription and libraries may facilitate search and access. Specialised literature sources relevant to emission factors are:

- National and international testing facilities (e.g., road traffic testing facilities),
- Industrial trade associations (technical papers such as reports, guidelines, standards, sectoral surveys or similar technical material),
- National authorities with responsibility for regulating emissions from industrial processes.

Literature reviews should be fully documented so that the data used for the inventory is transparent (see Chapter 6, QA/QC and Verification). It is also helpful to record the sources not used, providing an explanation of why, to save time in later literature review activities.

TABLE 2.2
POTENTIAL SOURCES OF LITERATURE DATA

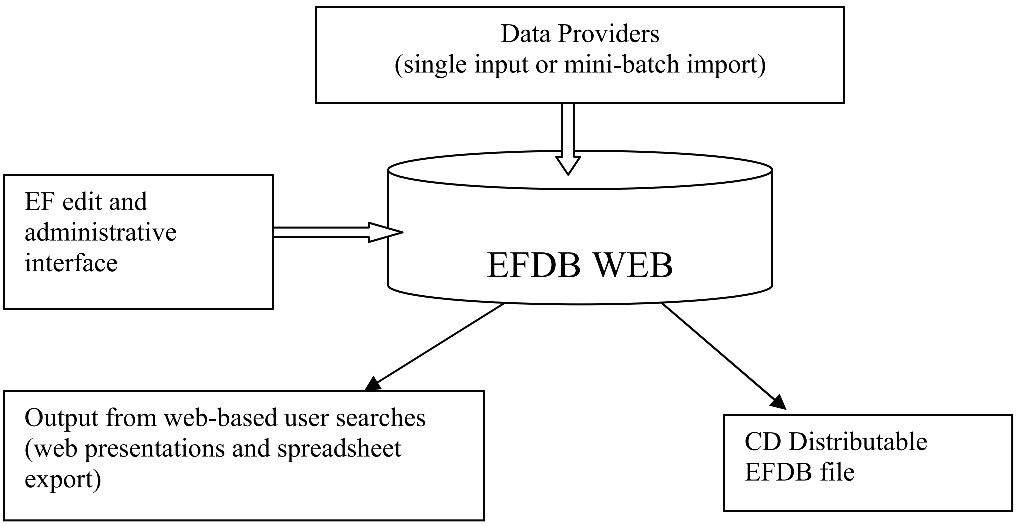
Literature Type	Where to find it	Comments
IPCC Guidelines	IPCC website	Provide agreed default factors for Tier 1 methods but may not be representative of national circumstances.
IPCC Emission Factor Database (EFDB)	IPCC website	Described in more detail below. May not be representative of processes in your country or appropriate for *key category* estimates.
EMEP/CORINAIR Emission Inventory Guidebook	EEA (European Environment Agency website)	Useful defaults or for cross-checking. May not be representative of processes in your country or appropriate for *key category* estimates.
International Emission Factor Databases: USEPA	USEPA website	Useful defaults or for cross-checking. May not be representative of processes in your country or appropriate for *key category* estimates.
Country-specific data from international or national peer reviewed journals	National reference libraries, environmental press, environmental news journals	Reliable if representative. Can take time to be published.
National testing facilities (e.g., road traffic testing facilities)	National laboratories	Reliable. Need to make sure the factors are representative and that standard methods are used.
Emission regulating authority records and papers, or pollution release and transfer registries	Industrial process regulating authority	Regularly updated and plant-specific. Quality is dependent on the regulatory requirements, which may not extend to the methods used for estimating/measuring.
Industry, technical and trade papers	Specific trade association Publications, libraries, and Web search	Sector-specific and up-to-date. QA/QC is needed to check for bias in data and to ensure the test conditions and measurement standards are understood.
Other specific studies, census, survey, measurement and monitoring data	Universities (environmental, measurement and monitoring departments)	Need to make sure the factors are representative and that standard methods are used.
International Emission Factor Databases: OECD	OECD website	Useful defaults or for cross-checking. May not be representative of processes in your country or appropriate for *key category* estimates.
Emission factors or other estimation parameters for other countries	National Inventory Reports from Parties to UNFCCC, other inventory documentation, web search, national library	Appropriate for inventory use. Useful defaults or for cross-checking. May not be representative of processes in your country or appropriate for *key category* estimates.

IPCC Emission Factor Database

The Emission Factor Database (EFDB) is a continuously revised web-based information exchange forum for emission factors and other parameters relevant for the estimation of emissions or removals of greenhouse gases at national level. The database can be queried over the internet via the home pages of the IPCC, IPCC-NGGIP or directly at http://www.ipcc-nggip.iges.or.jp/EFDB/main.php.[5] The IPCC distributes a CD-ROM with a copy of the database and a query tool at regular intervals.[6] It is designed as a platform for experts and researchers to communicate new emission factors or other parameters to a worldwide audience of potential end users. The EFDB is intended to become a recognised library where users can find emission factors and other parameters with background documentation or technical references. The criteria for inclusion of data in the database (see Figure 2.2) are:

- *Robustness*: The value would be unlikely to change, within the accepted uncertainty of the methodology, if there were to be a repetition of the original measurement programme or modelling activity.
- *Applicability*: An emission factor can only be applicable if the source and its mix of technology, operating and environmental conditions and abatement and control technologies under which the emission factor was measured or modelled are clear, and allow the user to see how it can be applied.
- *Documentation*: Access information to the original technical reference is provided to evaluate the robustness and applicability as described above.

Figure 2.1 Process for including data in the EFDB



The EFDB invites experts and researchers all over the world to populate the EFDB with their data. The proposal of new emission factors (and other parameters) from data providers will be assessed by the Editorial Board of the EFDB for inclusion into the database. When the proposed new data comply with well-defined quality criteria of robustness, applicability and documentation they are included in the database. These procedures enable the user to judge the applicability of the emission factor or other parameter for use in their inventory and the responsibility of using this information appropriately however will always remain with the users.

[5] Information, including manuals, on how to retrieve data from or contribute new data to the EFDB can also be found at this web site.

[6] To receive a copy of the EFDB CD-ROM, please contact IPCC NGGIP Technical Support Unit.

Data obtained by measurements

This section applies the guidance in Section 2.2.2 to assessing the quality of measurement data for determination of emissions, emission factors and abatement or destruction efficiencies. Volume 4 provides specific guidance on the use of samples and surveys in Agriculture, Forestry, and Other Land Use (AFOLU) Sector.

In this approach the emissions can be determined directly (i.e., using continuous emission monitoring systems) or calculated. Where emissions depend on variable combustion, process and operating conditions, and technologies (e.g., methane and nitrous oxide from combustion), direct monitoring is likely to be the most accurate way to determine emissions.

When reviewing energy or industrial plant data, it is important to ensure that the measurements are representative of the specific activity and do not include extraneous components. For example stack measurements may exclude losses to the atmosphere through evaporation or poorly burned fuel (that is emitted as volatile organic compounds (VOC); these should be included in the reported emissions totals. More details of measurement issues are included in the Industrial Processes and Product Use (IPPU) Volume.

In implementing the elements of measurement programme identified in Section 2.2.2 is *good practice* to:

- distinguish between different components in a mixed fuel/raw material feed e.g., coal and wood in a mixed fuel boiler;
- specify how the chemical composition of fuels and raw materials should be determined from the analyses of samples taken from delivery trucks/tankers, pipelines, or stockpiles;
- ensure representative sampling of exhaust gases;
- use instruments with known performance characteristics or perform relative accuracy audits against established standard reference methods.

Most gas analysers determine the volume concentration of gaseous components (volume/volume) and so unless conditions can be shown to be stable it will be necessary to measure the exhaust gas flow rate, pressure, temperature, and water vapour content, so that the greenhouse gas emission can be converted to reference conditions for temperature and pressure (e.g., 273 K and 101.3 kPa, dry) or quoted on a mass emission basis. Other measurements are usually needed to calculate process specific conversion and oxidation efficiency factors and, if the fuel/raw materials used are not dry, a moisture analysis will be required. Related measurements should be made simultaneously, or in such a way that ensures the correct functional relationship between the variables being sampled, otherwise integrated flows or emissions derived from the measurements are likely to be incorrect.

It is *good practice* to use scales, and flow meters, that are of a known quality, calibrated, maintained, and regularly inspected, when using measurements to calculate activity rates e.g., from measured fuel or raw material feed rates (or sometimes from production data). Measurement equipment can be of variable quality and it is important that there is regular maintenance and calibration procedures in place and that these are subject to regular QA/QC review. When recording is carried out on a continuous basis it is *good practice* to monitor and record any time when meters are not working and the data capture rate is reduced – the advice on gap filling (in Section 2.2.3, Adapting data for inventory use) can, however, enable imperfect data sets to be repaired sufficiently for some purposes – such as the generation of emission factors.

It is also *good practice,* as part of the measurement programme to include in the scope of a monitoring protocol how and other measurements are to be carried out, if the fuel/raw materials are not dry or there are contaminants that could adversely affect the measurement process, moisture.

Quality management is an important factor to take into account. ISO 17025:2005 ‘General requirements for the competence of testing and calibration laboratories’ describes a useful QA/QC regime for testing and measurement. It encourages the use of standard methods by qualified personnel using suitability tested equipment. It also encourages a quality management system which should cover traceable calibration artefacts; taking and storing samples; any subsequent analysis; and the reporting of results. The standards listed in Table 2.3 are relevant to greenhouse gas emissions measurement and should be used where applicable.

TABLE 2.3 **STANDARD MEASUREMENT METHODS FOR EXHAUST GAS**		
	Existing international standard methods	**Other widely used standard methods[4]**
CO_2	ISO 12039:2001 Stationary source emissions - Determination of carbon monoxide, carbon dioxide and oxygen - Performance characteristics and calibration of an automated measuring method [1] ISO 10396:2006 Stationary source emissions - Sampling for the automated determination of gas concentrations	US EPA Method 3 - Gas analysis for the determination of dry molecular weight US EPA Method 3A - Determination of oxygen and carbon dioxide concentrations in emissions from stationary sources (instrumental analyser procedure)
N_2O	ISO 11564:1998 Stationary source emissions - Determination of the mass concentration of nitrogen oxides - Naphthylethylenediamine photometric method	Standard being developed by ISO TC 264 – Air Quality
Gas velocity	ISO 10780:1994 Air Quality - Stationary source emissions - Measurement of velocity and volume flow rate of gas streams in ducts. *S-Type pitot tube* ISO 3966:1977 Measurement of fluid flow in closed conduits - velocity area method using Pitot static tubes [2]. *L-Type Pitot tube* ISO 14164:1999 Stationary source emissions. Determination of the volume flow rate of gas streams in ducts -automated method. *Dynamic pressure method for continuous, in situ/crossduct, measurements*	US EPA method 1 - Sample and velocity traverses for stationary sources US EPA Method 1A - Sample and velocity traverses for stationary sources with small stacks or ducts US EPA Method 2 - Determination of stack gas velocity and volumetric flow rate (Type S pitot tube) (or alternatively Methods 2F, 2G, 2H and CTM-041)[5]
General [3]	ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories ISO 10012:2003 Measurement management systems - Requirements for measurement processes and measuring equipment	PrEN 15259:2005 Air Quality – Measurement of stationary source emissions - measurement strategy, measurement planning and reporting, and design of measurement sites EN61207-1:1994 Expression of performance of gas analyzers - Part 1 General
	Standards under development	
CH_4	None	US EPA Method 3C - Determination of carbon dioxide, methane, nitrogen and oxygen from stationary sources (i.e., landfills) Standard being developed by ISO TC 264 - Air Quality
H_2O		EN 14790 [6] US EPA Method 4 - Determination of moisture content in stack gases
PFC, SF_6, HFC, FCs	None	(N.B. Where available sector specific methodologies are referenced in the sector specific volumes)

[1] This standard describes the performance characteristics, detection principles and the calibration procedures for automated measuring systems for the determination of carbon dioxide and other substances in the flue gases emissions from stationary sources. The reported concentration range of this standard is 6 - 62500 mg m-3 with a measurement uncertainty of <10 percent of the measured value.

[2] This standard has been withdrawn pending revision; nevertheless it is widely used in the absence of anything better.

[3] While these standards are not associated with a reference method for a specific greenhouse gas category, they have direct application to QC activities associated with estimations based on measured emission values.

[4] US EPA Methods, e.g., Method 1, 1A, 2, 3, etc., are EPA test methods that are available in Title 40 of the Code of Federal Regulations (CFR) Part 60, Appendices. These test methods are developed by the Office of Air Quality Planning and Standards in the Office of Air and Radiation. 40 CFR Part 60 is published each year by the Office of the Federal Register, and is available from the U.S. Government Printing Office. Although the test methods generally do not change from year to year, users should check for the most recent version of 40 CFR Part 60, Appendices.

[5] Methods 2F and 2G correct the measured flow rates for angular (non-axial) flow. Method 2H (for circular stacks) and conditional test method CTM-041 (for rectangular stacks and ducts) are used to correct the measured flow rates for velocity decay near the stack wall, using a 'wall effects adjustment factor'.

[6] Water measurement is needed to correct measured gas volume to standard 'dry' conditions.

2.2.5 Activity data

This section provides general advice for the production or review of activity data. This includes:

- Information on specialised data sources,
- Conducting surveys and censuses,
- Where appropriate, the use of measurement related data.

It is *good practice* when producing suitable activity data to follow the stepwise approach to set priorities for action according to the importance of the sector, putting in place a strategy for accessing the data needed, collecting the data needed, and processing it to produce the data needed for inventory purposes. This section provides generic advice relevant to the choice of activity data to use.

Volumes 2-5 provide advice on the selection and use of activity data for specific categories.

Data Sources

National and International Literature

As described in Section 2.2.1, it is preferable to use data from such bodies as National Statistical Agencies, and national regulatory authorities responsible for the permitting of industrial and other processes subject to pollution emission legislation.

There will be occasions, however, when other sources of specialised literature provide activity data i.e. UN statistics, US Geological Survey (USGS) reports on commodities, and technical reports, guidelines, standards, sectoral surveys issued by industrial trade associations.

Surveys & Census information

Survey and census information (see Box 2.2) provide the best agricultural, production and energy statistics that can be used for greenhouse gas inventories. Generally these data are compiled by national statistical agencies (NSA) or relevant ministries for national policy purposes or to comply with international demand for data, or other activities that are outside of the direct control of the inventory compiler although the needs of the inventory can sometimes trigger or influence surveys or censuses.

BOX 2.2
THE DIFFERENCE BETWEEN CENSUS AND SURVEY DATA

Survey data are derived from sampling and do not include real data for the whole population. Surveys should assess a representative sample (in the context of the survey purpose), so that the results can be expanded to provide an estimate of the full population. A survey could, for example, assess the number of animals in a country or region by surveying a discrete selection of farms and groups of farms in a country or region. Using more general surrogate data and assumptions would then derive the national or regional total.. Both the representativeness of the sample and the methods used to gross-up need careful review.

Census data are based on a complete count of the whole population, i.e., an actual count of all the animals in a region or country. A census is usually limited in detail and diversity to only the most important national statistics such as human and livestock population. It is expensive and time consuming and this is a significant limiting factor for specific national inventory applications. Often census data are used as a reliable surrogate for extrapolating survey data to national statistics.

***Using existing census and survey data*:** In some countries the NSA is a single agency who is responsible for all national statistics, while in others the task is split among multiple agencies each of which collect official statistics related to their field, i.e., a country's agriculture ministry may be responsible for carrying out agricultural surveys and censuses. This has the advantage that the ministry is likely to have the specialist knowledge required to define adequately the data to be collected and to have at their disposal the administrative information to help stratify and select the sample to be surveyed, for example, a register of businesses working in the area covered by the remit of the ministry. In these cases ministries may have their own statistics departments (or will work closely with any NSA) to provide the specialist with statistical knowledge, which is essential to avoiding many of the common pitfalls in data collection.

Where available these data sets can be used either directly (if they represent the geographical and sectoral coverage required) or as part of hybrid data set in combination with other information necessary to derive the detail and geographical coverage required.

***Developing new Surveys*:** Developing new surveys, especially surveys of consumers or households, is relatively expensive because sample size and proper conduct of the fieldwork, data processing, analysis, and reporting are all demanding. Considerable effort would be required to check the reliability and consistency of data, even when response rates appear to be otherwise satisfactory. Unless they can be consistently repeated, surveys are only able to give measurements relating to one point in time. Bearing this in mind, and also taking into account the length of time such surveys take to design, execute and analyse - for the development of a major survey, planning typically starts about 18 months before data collection starts, with results available a year or more after the data collection period - attention should first be paid to the possibility of obtaining regular and consistent data from existing sources, such as recombining data collected for other purposes, or using administrative data.

Where new data collection is unavoidable, the NSA and/or the relevant ministry can identify what surveys are ongoing or planned, and can explore the possibility of adding new questions or modules to these surveys to fill the data gaps. One of the many advantages of working with a NSA or ministry is that they will design the method of collection and the questionnaire to take into account the needs of as many users as possible. This reduces costs as well as the burden on businesses and other respondents, making it more likely that they will complete the questionnaire. Also, selecting the survey sample requires a reliable sampling frame, for example, census data or business registers. The NSA or relevant ministry will have ready access to such sources, and experience in using them. They will have teams of qualified and experienced statisticians, experts in sample selection, questionnaire design, data handling and verification, and the necessary software to process the data. They may also have teams of interviewers experienced in telephone or personal surveying. All of these factors contribute to the success of any survey and equally importantly, to keeping costs down.

***General Guidelines for Planning Surveys & Census*:** It is *good practice* to plan each step with all subsequent steps in mind, from data collection, processing and analysis to dissemination of output. For example, the questionnaire and other data collection procedures should be developed only after thinking through how the data will be processed and analysed, and the nature of the statistical information that will eventually be reported. In particular, planning needs to cover:

- Budget issues: Costs will always be a major consideration. The total budget needs to be calculated and resources allocated to each phase of the process. Uncontrolled spending on each phase until the budget is depleted can lead to the collection of data without the necessary resources to produce and disseminate high quality output.
- Staffing issues, including management of the interviewer workforce: Staff resources need to be planned to ensure that people with the right skills are available at the appropriate times in all phases of the process. If interviewers are used rather than self-completion questionnaires, the interviewer workforce is likely to be the largest single cost in the collection.
- Project management and timetable issues: Good project management is essential to ensure a smooth-running collection. Adequate time needs to be allocated to each phase of the collection process. A thorough pre-testing of the questionnaire will help ensure that the data collected are reliable and valid.

The American Statistical Association’s brochure on how to plan a survey is a useful source of help when setting up a new survey, and can be downloaded from http://www.amstat.org/sections/srms/brochures/survplan.pdf. The UN’s guidelines for conducting household surveys in developing and transition countries provide detailed information on how to set up sample surveys based on direct questions to households, and can be found on http://unstats.un.org/unsd/HHsurveys/part1_new.htm. Another useful source is ‘Basic Steps in Conducting Surveys’, available at http://www.energy.ca.gov/marketinfo/documents/98-10_LANG2.PDF.

Moreover, many organisations contribute to statistical capacity building and will provide assistance to developing countries wishing to set up new surveys; the UNEP, UNDP, and the World Bank are the implementing agencies of the Global Environment Facility.

References to guidance for performing surveys or censuses for energy, industrial processes, agriculture, forestry and waste are given in the Annex 2A.2.

Three important steps are needed before deciding whether a survey is required, and what modules it should contain:

- Review what data are likely to be available through existing data systems, including planned surveys. Remember that published statistics are based on detailed data that have been treated and aggregated to draw out the information that is important to the main user. In some cases, depending on the size and structure of the original sample, those raw data can be recombined in different ways to produce data that are appropriate for another user.

- Explore administrative sources of data. While the administrative records may not initially be easy to use for inventory purposes, once the system has been reorganised and restructured to produce the relevant data, it can become the regular source of the relevant information, at little marginal cost. More and more countries are beginning to realise the cost benefits of using administrative data for statistics, and in some cases, National Statistical Agencies (NSAs) are obliged by law to explore the use of administrative data to provide statistics before deciding to launch an expensive new survey.
- Explore the possibility of incorporating new questions or modules into existing surveys.

If, after exploring the possibility to make use of existing data, data gaps still remain, then approach the NSA or ministry about carrying out a new survey. Provided the financial resources are made available, the NSA or ministry will be able to provide the all-important expertise. Also explore whether other partners might be interested in sharing the work and resources needed for it.

References

Cullen A.C. and Frey H.C. (1999). *The Use of Probabilistic Techniques in Exposure Assessment*: *A Handbook for Dealing with Variability and Uncertainty in Models and Inputs*. Plenum: New York, 335 pages.

Frey H.C. and Burmaster D.E. (1999). ‘Methods for characterizing variability and uncertainty: comparison of bootstrap simulation and likelihood-based approaches,’ *Risk Analysis*, 19(1):109-130, February 1999.

Frey H.C. and Rhodes D.S. (1996). ‘Characterizing, simulating, and analyzing variability and uncertainty: an illustration of methods using an air toxics emissions example’, *Human and Ecological Risk Assessment*: an International Journal, 2(4):762-797, December 1996.

Annex 2A.1 A protocol for expert elicitation

Wherever possible, expert judgement should be elicited using an appropriate protocol. An example of a well-known protocol for expert elicitation, Stanford/SRI protocol, has been adapted and is described below.

- Motivating: Establish a rapport with the expert, and describe the context of the elicitation. Explain the elicitation method to be used and the reason it was designed that way. The elicitor should also try to explain the most commonly occurring biases to the expert, and to identify possible biases in the expert.
- Structuring: Clearly define the quantities for which judgements are to be sought, including, for example, the year and country, the source/sink category, the averaging time to be used (one year), the focus activity data, emission factor or, for uncertainty, the mean value of emission factors or other estimation parameter, and the structure of the inventory model. Clearly identify conditioning factors and assumptions (e.g., resulting emissions or removals should be for typical conditions averaged over a one-year period).
- Conditioning: Work with the expert to identify and record all relevant data, models, and theory relating to the formulation of the judgements.
- Encoding: Request and quantify the expert's judgement. The specific qualification will differ for different elements and be present in the form of a probability distribution for uncertainty, and an activity or emission factor estimate for activity data and emission factors. If appropriately managed, information on uncertainty (probability density function) can be gathered at the same time as gathering estimates of activity or emission factor. The section on encoding in Chapter 3 describes some alternative methods to use for encoding uncertainty.
- Verification: Analyze the expert's response and provide the expert with feedback as to what has been concluded regarding his or her judgement. Is what has been encoded really what the expert meant? Are there inconsistencies in the expert's judgement?

Possible Biases in Expert Elicitation

Elicitation protocols should be designed to overcome the biases that can be introduced by the rules of thumb (sometimes called heuristics) that experts use when formulating judgements.

The most common unconscious biases introduced by rules of thumb are:

- Availability bias: This is basing judgements on outcomes that are more easily remembered.
- Representativeness bias: This is basing judgements on limited data and experience without fully considering other relevant evidence.
- Anchoring and adjustment bias: This is fixating on a particular value in a range and making insufficient adjustments away from it in constructing representative estimate.

To counteract the first two potential sources of biases, elicitation protocols should include a review of relevant evidence. In order to counteract the third potential source of bias, it is important to ask the expert to make judgments regarding extreme values first, before asking for judgments regarding the best estimate or central values for an uncertainty distribution.

There is also the possibility of more conscious biases:

- Motivational bias is a desire by an expert to influence an outcome or to avoid contradicting prior positions on an issue.
- Expert bias arises from an unqualified expert's desire to appear as a true expert in the field. This would typically lead to overconfident estimates of uncertainty.
- Managerial bias is a situation in which an expert makes judgements that achieve organisational goals, rather than judgements that reflect the actual state of knowledge regarding an inventory input.
- Selection bias occurs when the inventory compiler selects the expert who tells it what it wants to hear.

The best way to avoid these biases is to be careful in the selection of experts. Expert judgments can be elicited from individuals or groups. Groups can be useful for sharing knowledge and hence could be part of the motivation, structuring, and conditioning steps of the elicitation. However, group dynamics occasionally introduce other biases. Thus, it is usually preferable to elicit judgement on an individual basis. When eliciting judgments independently for a given quantity from two or more experts, it is possible that different views on distributions (or ranges) will be obtained. In some cases, the differences may not lead to a significant difference in the overall estimate for the inventory, such as when the inventory is not sensitive to the particular quantity. Thus, in these cases, disagreements among experts do not matter significantly to the overall assessment. However, when judgments differ, and when the quantity for the judgments is made is important to the overall inventory, there are two main approaches that can be used. One is to estimate resulting emissions or removals and perform the uncertainty analysis separately for each set of judgments and compare the results. The other is to ask the experts to weight the judgments and combine them into one assessment. The former approach is preferred where possible, but the latter is acceptable provided that the judgments are weighted and not averaged. The difference is that weighting enables sampling from each of the expert's estimations, whereas averaging can produce intermediate values that are not supported by any of the expert's judgement. A similar situation can occur when comparing predictions with alternative models, as described in the section of 'Combining Data Sets Numerically' in Section 2.2.3. The distinction between weighting and averaging is explained there. Although the development of weighting schemes can be complex, it is reasonable to start with assuming equal weights for each expert and refine the development of weights only as needed or as appropriate for a given situation.

Expert judgement documentation

The subjective nature of expert judgment increases the need for quality assurance and quality control procedures to improve comparability of emission and uncertainty estimates between countries. It is recommended that expert judgments are documented as part of the national archiving process, and inventory compilers are encouraged to review expert judgments, particularly for *key categories*. Table 2A.1 below shows an example of the document elements necessary to provide transparent expert judgment (Column 1) and an example of the data to record (Column 2).

Such documentation will save the compiler a considerable amount of time in reporting and documenting the inventory through the enhanced transparency of the inventory. More general text on documentation, checking and review of methods is included in Chapter 6, QA/QC and Verification, of Volume 1. These principles should also be applied to the use of expert judgement in inventory compilation and uncertainty assessment.

TABLE 2A.1
EXAMPLE OF DOCUMENTATION OF EXPERT JUDGEMENT

Documentation Element	**Documentation Example**
Reference number for judgement	*EJIPPU2005-001*
Date	*14th January 2005*
Name of expert(s) involved	*Dr Anne N Other*
Experts' background (references, roles, etc.)	*Nitric Acid Process emissions and abatement industrial expert*
The quantity being judged	*National emission factor for emissions of N_2O from Nitric Acid Plant*
The logical basis for judgement, including any data taken into consideration. This should include the rationale for the high end, low end, and central tendency of any uncertainty distribution	*An absence of measurement data for 9 out of the 10 Nitric Acid plant. The single plant estimate has been recommended as the basis for a national factor to be applied to national nitric acid production.*
The result: e.g., activity value, emission factor or for uncertainty the probability distribution, or the range and most likely value and the probability distribution subsequently inferred	*8.5 kgN_2O/tonne nitric acid produced for 1990 – 2003*
Identification of any ***external reviewers***	*Nitric Acid Trade Association*
Results of any external review	*See document: e:/2003/ExpertJudgement/ EJIPPU2005-001.doc*
Approval by inventory compiler specifying date and person	*25th January 2005, Dr S.B Else*

Annex 2A.2 General guidance on performing surveys

Survey data are often compiled using financial/fiscal incentives for reporting. This may introduce possible bias if the incentives favour a certain bias in reporting. For example, taxation may encourage under reporting while incentives may encourage over reporting. In addition differential taxation of different categories using the same fuels may skew reporting, e.g., over-reporting of fuel used in low taxation categories and under reporting of fuels used in high taxation categories.

ENERGY SURVEYS

Energy statistics are a fundamental component of emissions inventories and there is great potential for double counting. The best way to avoid double-counting is to compile energy balances according to the basic principles, concepts and methods developed at international level. The United Nations publication *Energy Statistics*: *A Manual for Developing Countries* (1991) serves as a guide for developing countries for the comprehensive, reliable and regular collection of energy statistics. Various sources of inconsistencies, such as sources of data, concepts and definitions and time spans/coverage, are discussed in detail for all types of energy commodities and recommendations are provided to minimise or eliminate them. English and French versions can be downloaded from: http://unstats.un.org/unsd/pubs/gesgrid.asp?ID=51. This publication should be used in conjunction with two other UN publications:

- Concepts and Methods in Energy Statistics, with Special Reference to Energy Accounts and Balances (1982) which considers: the nature of energy statistics and the kinds of policy problems for which they are required; the conceptual and methodological issues to which these problems give rise; and the possible conventions that might be adopted for dealing with some of these issues. It also examines the key role played by quantitative overall energy balances; the desirable features of such balances - whether used for analysing the past or for speculating about the future; the classification problems posed by energy statistics; and the relationship between such data and other economic statistics and accounting frameworks. The document is out of print but English, French and Russian versions can be downloaded from: http://unstats.un.org/unsd/pubs/gesgrid.asp?ID=20.
- Energy Statistics: Definitions, Units of Measure and Conversion Factors (1987), which contains detailed information on terminologies for energy commodities, units of measurement and conversion from one unit to another. It provides internationally adopted definitions, conversion factors and descriptive tables for analysis and comparison of international energy statistics. The document is out of print, but English, French, Russian and Spanish versions can be downloaded from: http://unstats.un.org/unsd/pubs/gesgrid.asp?ID=37.

Also IEA has published an Energy Statistics Manual providing useful background information for collecting, reporting and understanding energy statistics available for free download at:

http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1461.

The UN Statistics manual for developing countries in English and French can be downloaded at http://unstats.un.org/unsd/publication/SeriesF/SeriesF_56E.pdf.

See also http://unstats.un.org/unsd/pubs/gesgrid.asp?mysearch=energy&sort=title for other UN Energy titles.

Enerdata, Eurostat also provide additional data sets on energy and other statistics.

In some cases energy data are not available at the level of detail necessary to estimate emissions, e.g., for non CO_2 emissions of road transport where the emissions are highly dependant on the use of catalytic converters in petrol vehicles, in these cases additional survey or census data should be used to make estimates e.g., vehicle sales and traffic survey data.

INDUSTRY SURVEYS

Greenhouse gas inventories require data on the production of industrial commodities and, if possible, on the production processes. For the purpose of collecting harmonised statistics on industrial production, standardised commodity lists have been established at international level, and countries are encouraged to adopt these lists for their own purposes, as this will be most cost efficient. These lists are updated regularly to take account of new products being developed. The revised list will be based on the Central Product Classification (CPC) and will be fully compatible with the International Standard Industrial Classification (ISIC), the European Union's PRODCOM commodities list and the Harmonised Nomenclature System (HS) used for foreign trade statistics. The revised industrial commodities list and guidelines for countries will be available on the UNSD website, http://unstats.un.org/unsd/methods.htm when finalised. The CPC, ISIC and HS classifications can be found at http://unstats.un.org/unsd/cr/registry/regct.asp?Lg=1. Detailed chemical industry data (production per country of many products and process data) can acquired from SRI Consulting (www.sriconsulting.com): Process data on aluminium production can be obtained from Aluminium Verlag (www.aluverlag.de); Steel process information can be acquired from IISI (www.worldsteel.com).

It is more difficult to obtain information on production processes used by industry. Business registers may contain this information, but the logistics of keeping this up to date are formidable. Industry associations that bring together businesses working in a common field can often be a useful source of help. As specialists in their field they will have an insider's knowledge of the most common processes used, and may even be willing to survey their members at regular intervals to assess penetration of new processes. In the 1990's Eurostat produced the NOSE-p list – a Nomenclature of Sources of Emissions that links processes to industries. This needs to be revised, but remains a useful starting point for countries starting work in this area.

Data on industrial production and production processes are also extremely useful in producing statistics on industrial waste, see below.

Production data used to estimate emissions from consumption of a product or fuel should, wherever possible incorporate the import/export statistics for that commodity. Production statistics may, with care, be used as a surrogate for consumption when net import or exports are thought to be significant but not quantifiable. However, since there is a possibility of incompleteness or overestimation due to underreporting of imports and/or exports, the completeness of accounting of imports and exports should be checked with the statistical office.

Where production data are used, care should be taken to identify whether the data represents gross or net production (i.e., with or without internal recycling). For some categories these figures could differ by 5 to 10 percent e.g., steel, aluminium and glass. Whatever production statistics are used appropriate emission factors should be applied and the inventory complier should be sensitive to any tax or financial influences that might lead to over or under-reporting of emissions.

AGRICULTURAL SURVEYS AND CENSUSES

Since its establishment, the Food and Agriculture Organization of the United Nations, (FAO) has promoted national censuses of agriculture through its Programme for the World Census of Agriculture; see http://www.fao.org/es/ess/census/default.asp; the Programme is prepared by the Statistics Division of FAO in collaboration with many experienced agricultural statisticians all over the world - see 'Programme for the World Census of Agriculture 2000': FAO Statistical Development Series No. 5, 1995, http://www.fao.org/es/ess/census/agcenp12.asp.

The Programme is complemented by practical information on the steps involved in actually conducting an agricultural census. See 'Conducting Agricultural Censuses and Surveys' FAO, 1995, http://www.fao.org/es/ess/census/agcensus.asp.

Other guidance from FAO on conducting agricultural surveys includes:

- '*Sampling Methods for Agricultural Surveys*', FAO Statistical Development Series No. 3 (1989); which presents the foundations of probability sampling theory and the basic concepts involved. It concentrates on sample design, which covers only part of the overall design of agricultural sample surveys. The different sampling methods are discussed, including simple random sampling, stratification, systematic sampling, probability proportional to size sampling, cluster sampling, multi-stage sampling, multi-phase sampling, and area sampling. Also discussed are: sample design issues, such as sample allocation to strata and to different stages of sampling; weighting and sample estimation methods, such as unbiased and ratio estimates; and methods of estimating sampling errors, including replicated methods. Some practical problems involved in designing and conducting sample surveys are also discussed, including frame problems and evaluation of sampling and non-sampling errors.

- '*Collecting Data on Livestock*', FAO Statistical Development Series No. 4 (1992); which presents a general framework for livestock statistics within the context of a national agricultural statistics system. Different data collection methods are discussed, with particular reference to the problems of nomadic livestock. Guidelines for undertaking livestock censuses are also provided. Concepts and definitions for the collection of data on livestock products (meat, milk, eggs, wool and skins) are presented, along with a discussion of statistics on cost of production and feed/fodder.

- '*Multiple Frame Agricultural Surveys: Volume 1&2*', FAO Statistical Development Series No. 7 and 10 (1996&1998). National Current Agricultural Survey Programmes, established to obtain reliable and timely baseline data on the agricultural sector, are based on one of three sampling survey methods: list sample designs (commonly farm sampling designs), area sample designs, and multiple frame designs. Multiple frame designs are those which combine an area sample with complementary list (farm) samples. Multiple frame sampling methods should constitute the statistical foundation of the National Agricultural Survey Programmes in a larger range of countries, because of their advantages to the traditional farm sampling methods.

Volume 1 is a comprehensive introduction to establishing and conducting area and multiple frame probability sample survey programmes, with a focus on methods and practices applicable in developing countries. It provides a general classification of alternative agricultural survey designs with an indication of their respective advantages and limitations. It examines several aspects that have to be considered to establish and conduct a periodic agricultural survey programme based on multiple frame sampling methods, i.e., the probability selection and estimation methods, the survey organisation, the equipment and materials needed, data collection, summarisation and processing. The book includes a detailed description of a category of multiple frame survey designs considered especially useful for developing countries.

Volume 2 presents the area and multiple frame survey methods for Agricultural Survey Programmes currently used in a wide range of countries. It provides actual examples of the application of the survey methods presented in the first volume.

FOREST SURVEYS

The FAO is also the lead organisation collecting data on forestry. The Forestry Department of FAO is undertaking an important programme of support to national forest assessments. Information on this programme - including on the sampling design, intensity, plot configuration and variables to collect can be found at the following websites:

www.fao.org/forestry/site/24673/en (overview) and www.fao.org/forestry/site/3253/en (more detailed info)

The FAO has also produced an on-line Knowledge Reference for forest resource assessments see www.fao.org

Other relevant publications include:

- Manual of forest inventory FAO Forestry Paper 27 (FAO, 1981), http://www.fao.org/icatalog/search/dett.asp?aries_id=2587 (available in French only).
- Forest volume estimation and yield prediction. FAO Forestry Paper 22/1 and 22/2 (FAO, 1980), http://www.fao.org/icatalog/inter-e.htm.
- Community forestry: rapid appraisal, Community Forestry Note 3 (FAO, 1989), http://www.fao.org/icatalog/search/result.asp?subcat_id=16.

WASTE SURVEYS

In general, industries will have a good idea of the volume and composition of waste that they produce each year, as they often have to pay to have it removed and appropriately treated. Therefore surveys to industry should result in reliable data on waste generated and its composition. However, this is such a sensitive area that the response rate is often very low and the data may be unreliable.

Much industrial waste is an unavoidable by-product, the type and volume of which is directly proportional to the volume of production, and will depend on the technology used in the production process. Therefore for each technology type, a waste factor can be produced. Much of the available statistics on industrial waste are the results of models based on these factors together with information on industrial production and the distribution of the main technological processes used in the industry being assessed. A useful source for this is the European Environment Agency's report 'Development and application of waste factors: an overview' see http://reports.eea.eu.int/technical_report_37/en which provides an overview of waste factors, their derivation and application and experiences in using them, based on reports and available literature. For municipal waste, direct surveys are not the best way to estimate volumes or composition. Their main disadvantage is that they are costly and the respondents often have little idea of the real volume of waste they generate, nor of its composition, resulting in large uncertainties in the resulting figures.

The most common estimation method for municipal waste is simply to weigh a sample of the waste collection vehicles before and after collection, and to gross up to cover the whole population. The sample will need to cover vehicles collecting in a wide range of areas: urban and rural, wealthy and poor, with and without gardens, etc. and covering several periods throughout the year, so that the sample can be seen as representative for the whole population and the whole year. Estimation of the composition of municipal waste is more complicated. Panels of households can be set up to monitor their waste generation and composition more closely and over time. Panels are basically small samples that remain constant over time, and therefore are well suited to monitor trends. Because the panel will need to be very actively involved in weighing and analyzing the contents of their waste bins, it is often necessary to pay the participants for their input, and this can be a serious limiting factor. Therefore factors for composition are often based on research projects and technical studies carried out in research institutes, sometimes but not always at the request of the relevant municipality or ministry.

CHAPTER 3

UNCERTAINTIES

Authors

Christopher Frey (USA), Jim Penman (UK)

Lisa Hanle(USA), Suvi Monni (Finland), and Stephen Ogle (USA)

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3 UNCERTAINTIES

3.1 INTRODUCTION

This chapter provides guidance in estimating and reporting uncertainties associated with both annual estimates of emissions and removals, and emission and removal trends over time. It is written from the viewpoint of the inventory compiler and provides, with examples, two approaches for combining category uncertainties into uncertainty estimates for total national net emissions and the trend.

3.1.1 Overview of uncertainty analysis

Uncertainty estimates are an essential element of a complete inventory of greenhouse gas emissions and removals. They should be derived for both the national level and the trend estimate, as well as for the component parts such as emission factors, activity data and other estimation parameters for each category. This guidance therefore develops a structured approach to estimating inventory uncertainty. It includes methods for:

- Determining uncertainties in individual variables used in the inventory (e.g., estimates of emissions from specific categories, emission factors, activity data);
- Aggregating the component uncertainties to the total inventory;
- Determining the uncertainty in the trend; and
- Identifying significant sources of uncertainty in the inventory to help prioritise data collection and efforts to improve the inventory.

While the methods outlined below are intended to estimate uncertainties for the national inventory, it is important to recognize that some uncertainties that are not addressed by statistical means may exist, including those arising from omissions or double counting, or other conceptual errors, or from incomplete understanding of the processes that may lead to inaccuracies in estimates developed from models.

An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice. For this reason, the methods used to attribute uncertainty values must be practical, scientifically defensible, robust enough to be applicable to a range of categories of emissions by source and removals by sinks, methods and national circumstances, and presented in ways comprehensible to inventory users. A reference section is provided for more detailed and more theoretical information on topics discussed in this chapter.

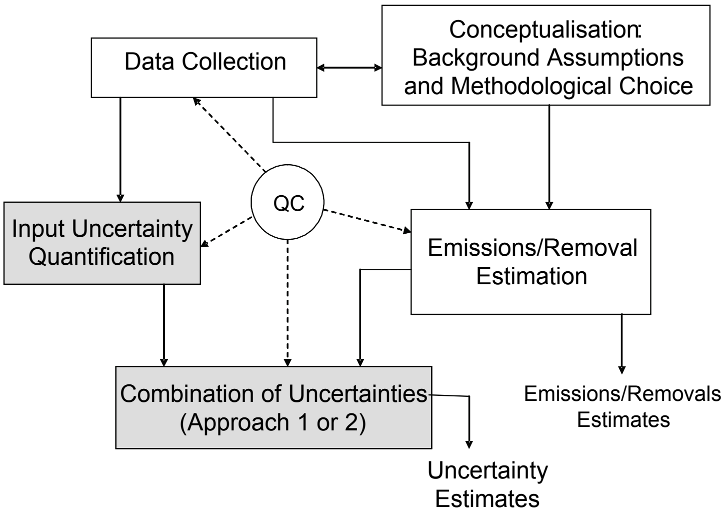
Quantitative uncertainty analysis is performed by estimating the 95 percent confidence interval of the emissions and removals estimates for individual categories and for the total inventory. The definition of the 95 percent confidence interval is given in Section 3.1.3, Key Concepts and Terminology.

3.1.2 Overall structure of uncertainty analysis

This section provides a brief overview of the overall structure of uncertainty analysis, as illustrated in Figure 3.1. Emissions/removals estimates are based on: (1) conceptualisation; (2) models; and (3) input data and assumptions (e.g., emission factor and activity data). Each of these three can be a source of uncertainty. The analysis begins with a *conceptualisation.* This is a set of assumptions regarding the structure of an inventory or of a sector. These assumptions typically include the scope of geographic area, temporal averaging time, categories, emissions or removal processes, and gases that are included. The assumptions and the methodological choice determine the needs for data and information. There can be some interaction between data and assumptions and methodological choice, indicated by the two-way arrow in the figure. For example, the ability to disaggregate categories, which may be necessary for higher tier methodologies, can depend on the availability of data. Data, whether empirical or based on expert judgment, should undergo appropriate data collection and QC procedures, as detailed in Chapters 2, Approaches to Data Collection, and Chapter 6, Quality Assurance/Quality Control and Verification, respectively.

Models can be as simple as arithmetic multiplication of activity and emission factors for each category and subsequent summation over all categories, but they may also include complex process models specific to particular categories. The data and information obtained from data collection become input to a more specific knowledge base of data and judgment for uncertainty, as shown in the figure and as discussed in detail in Section 3.2.1, Sources of Data and Information. Specific causes of uncertainty in the conceptualisation, models, and data are discussed in Section 3.2.1 and techniques for quantifying uncertainties in input data are set out in Section 3.2.2. These necessary data include percentage uncertainty estimates and underlining probability density functions (PDFs - discussed in Section 3.1.4) for input to an emission inventory uncertainty analysis. Methods for combining input uncertainties to arrive at uncertainty estimates for single categories and the overall inventory result are detailed in Section 3.2.3. Two Approaches are given for combining uncertainties. Approach 1 is a relatively simple spreadsheet-based calculation procedure based upon some assumptions to simplify the calculations. Approach 2 is based upon Monte Carlo simulation and can be applied more generally. Either approach provides an estimate of the overall uncertainties associated with the total greenhouse gas inventory.

Figure 3.1 Overall structure of a generic uncertainty analysis



Note: Shaded Boxes are the focus of this Chapter.

3.1.3 Key concepts and terminology

Definitions associated with conducting an uncertainty analysis include *uncertainty*, *accuracy*, *precision* and *variability*. These terms are sometimes used loosely and may be misunderstood. They have in fact clear statistical definitions that should be used in order to be clear about what is being quantified and reported. Several definitions are given here, in alphabetical order:

***Accuracy*:** Agreement between the true value and the average of repeated measured observations or estimates of a variable. An accurate measurement or prediction lacks bias or, equivalently, systematic error.

***Bias*:** Lack of accuracy. Bias (systematic error), can occur because of failure to capture all relevant processes involved or because the available data are not representative of all real-world situations, or because of instrument error.

***Confidence Interval*:** The true value of the quantity for which the interval is to be estimated is a fixed but unknown constant, such as the annual total emissions in a given year for a given country. The confidence interval is a range that encloses the true value of this unknown fixed quantity with a specified confidence (probability). Typically, a 95 percent confidence interval is used in greenhouse gas inventories. From a traditional statistical perspective, the 95 percent confidence interval has a 95 percent probability of enclosing the true but unknown value of the quantity. An alternative interpretation is that the confidence interval is a range that may safely be declared to be consistent with observed data or information. The 95 percent confidence interval is enclosed by the 2.5^{th} and 97.5^{th} percentiles of the PDF.

***Precision*:** Agreement among repeated measurements of the same variable. Better precision means less random error. Precision is independent of accuracy.

***Probability density function (PDF)*:** The PDF describes the range and relative likelihood of possible values. The PDF can be used to describe *uncertainty* in the estimate of a quantity that is a fixed constant whose value is not exactly known, or it can be used to describe inherent *variability*. The purpose of the uncertainty analysis for the emission inventory is to quantify *uncertainty* in the unknown fixed value of total emissions as well as emissions and activity pertaining to specific categories. Thus, throughout this chapter it is presumed that the PDF is used to estimate uncertainty, and not variability, unless otherwise stated.

Random errors**:** Random variation above or below a mean value. Random error is inversely proportional to precision. Usually, the random error is quantified with respect to a mean value, but the mean could be biased or unbiased. Thus, random error is a distinct concept compared to systematic error.

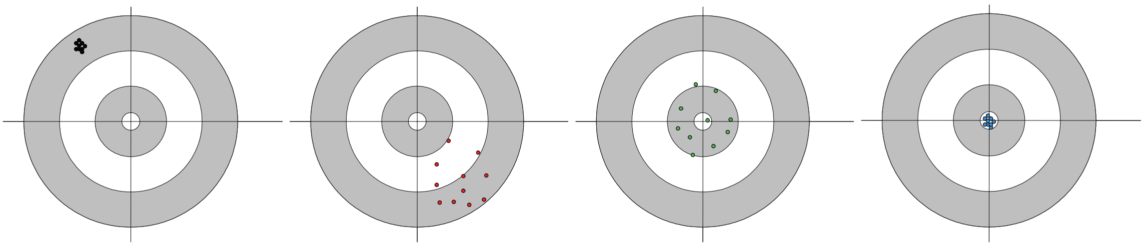
Systematic error**:** Another term for *bias*, which refers to lack of accuracy.

Uncertainty**:** Lack of knowledge of the true value of a variable that can be described as a probability density function (PDF) characterising the range and likelihood of possible values. Uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods.

Variability**:** Heterogeneity of a variable over time, space or members of a population (Morgan and Henrion, 1990; Cullen and Frey, 1999). Variability may arise, for example, due to differences in design from one emitter to another (inter-plant or spatial variability) and in operating conditions from one time to another at a given emitter (intra-plant variability). Variability is an inherent property of the system or of nature, and not of the analyst.

Figure 3.2 Illustration of accuracy and precision

(a) inaccurate but precise; (b) inaccurate and imprecise; (c) accurate but imprecise; and (d) precise and accurate



(a) (b) (c) (d)

Inventories should be accurate in the sense that they are neither over- nor underestimated as far as can be judged, and precise in the sense that uncertainties are reduced as far as practicable. Figure 3.2 provides a conceptual comparison of accuracy and precision. An accurate inventory is one that is free of bias but that could be precise or imprecise. A precise inventory may appear to have low uncertainty but if the inventory is inaccurate, then the inventory systematically over- or under-estimates the true emissions or removals. Inaccuracy, or bias, can occur because of failure to capture all relevant emissions or removal processes or because the available data are not representative of real-world situations. There is no predetermined level of precision, in part because of the inherent variability of some categories.

3.1.4 Basis for uncertainty analysis

The chapter uses two main statistical concepts – the probability density function (PDF) and confidence interval defined in the previous section. While this chapter focuses on aspects of uncertainty that are amenable to quantification, there are typically nonquantifiable uncertainties as well. The quantitative uncertainty analysis tends to deal primarily with random errors based on the inherent variability of a system and the finite sample size of available data, random components of measurement error, or inferences regarding the random component of uncertainty obtained from expert judgement. In contrast, systematic errors that may arise because of imperfections in conceptualisation, models, measurement techniques, or other systems for recording or making inferences from data, can be much more difficult to quantify. As mentioned in Section 3.5, Reporting and Documentation, it is *good practice* for potential sources of uncertainty that have not been quantified to be described, particularly with respect to conceptualisation, models, and data and to make every effort to quantify them in the future.

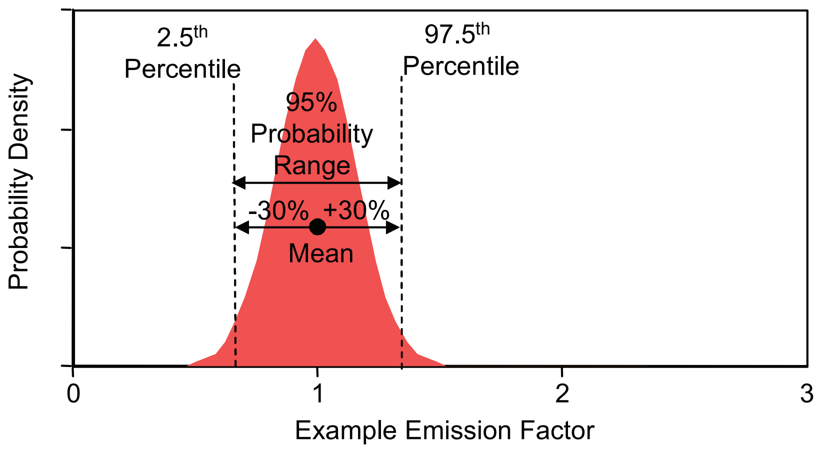
Good practice requires that bias in conceptualisations, models, and inputs to models be prevented wherever possible, such as by using appropriate QA/QC procedures. Where biases cannot be prevented, it is *good practice* to identify and correct them when developing a mean estimate of the inventory. In particular, the point estimate that is used for reporting the inventory should be free of biases as much as it is practical and possible. Once biases are corrected to the extent possible, the uncertainty analysis can then focus on quantification of the random errors with respect to the mean estimate.

Good practice requires the use of a 95 percent confidence interval for quantification of random errors. This may also be expressed as a percentage of the central estimate. Where the PDF is symmetrical the confidence interval can be conveniently expressed as plus or minus half the confidence interval width divided by the estimated value of the variable (e.g., ± 10%). Where the PDF is not symmetrical upper and lower limits of the confidence interval need to be specified separately (e.g., -30%,+50%).

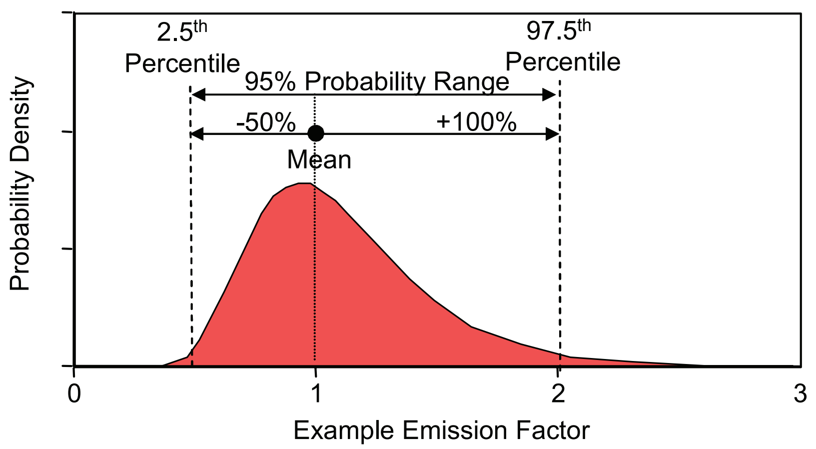
If the range of uncertainty for a non-negative variable is small enough relative to the mean value, then the uncertainty often can be described as a symmetric range with respect to a mean value, as shown in Figure 3.3(a). For example, if the mean emissions are 1.0 units, the 2.5th percentile of uncertainty is 0.7 units, and the 97.5th percentile of uncertainty is 1.3 units, then the uncertainty range could be described as 1.0 units ±30%. However, when the relative range of uncertainty is large, and if the uncertainty is regarding a variable that must be non-negative (such as an emission factor), then the uncertainty range becomes asymmetric with respect to the mean, as shown in Figure 3.3(b). As an example, if the mean emissions are 1.0 units, the 2.5th percentile of uncertainty is 0.5 units, and the 97.5th percentile of uncertainty is 2.0 units, then the range of uncertainty can be described as 1.0 units -50% to +100%. In situations such as the latter, it is often more convenient to summarise uncertainties in a multiplicative, rather than additive, manner. In this particular example, the lower end of the 95 percent probability range is a half the mean, and the upper end is a multiplier of 2 larger than the mean. Such a range is commonly summarised as a "factor of 2." An uncertainty of a "factor of n" refers to a range bounded at the low end by (mean/n) and at the high end by (mean × n). Thus, a factor of 10 uncertainty would have a range of 0.1×mean to 10×mean. The factor 10 uncertainty is also often called "an order of magnitude". Higher powers of 10 are referred to as "orders of magnitude;" for example, a factor of 10^3 would be referred to as three orders-of-magnitude.

Figure 3.3 Examples of symmetric and asymmetric uncertainties in an emission factor

(a) Example of a symmetric uncertainty of ±30% relative to the mean



(b) Example of an asymmetric uncertainty of -50% to +100% relative to the mean, or a factor of two



3.1.5 Causes of uncertainty

Inventory estimates of emissions and removals differ from the true underlying value for many reasons. Some causes of uncertainty (e.g., sampling error or limitations on instrument accuracy) may generate well-defined, easily characterised estimates of the range of potential uncertainty. Other causes of uncertainty (e.g., biases) may be much more difficult to identify and quantify (Rypdal and Winiwarter, 2001). It is *good practice* to account, as far as possible, for all causes of uncertainties in an uncertainty analysis and clearly document if some causes of uncertainties have not been included.

The inventory developer should consider eight broad causes of uncertainty[1]:

- *Lack of completeness*: This is a case where measurement or other data are not available either because the process is not yet recognized or a measurement method does not yet exist. Typically, this cause can lead to incomplete conceptualisation, which results in bias, but can also contribute to random error depending on the situation.
- *Model*: Models can be as simple as a constant multiplier (e.g., an emission factor) and increase in complexity, such as for complicated process models. The use of models to estimate greenhouse gas emissions and removals can introduce uncertainty, including both bias and random error, for a variety of reasons:
  - (i) Models are a simplification of real systems and therefore are not exact. For example, computer programming may involve errors or approximations; model resolution may not be representative, and spatial and temporal coverage may not be fully representative;
  - (ii) Interpolation is application of a model within a range of inputs for which the model is considered to be valid. However, in some cases, a 'hidden extrapolation' can occur when the model is evaluated based on combinations of values of its inputs for which validation has not been done (Cullen and Frey, 1999).
  - (iii) Extrapolation (application of the model beyond the domain for which model predictions are known to be valid) can lead to uncertainty;
  - (iv) Alternative formulations of the model may result in different estimates; and
  - (v) Model inputs including activity data and parameters are generally approximated based on limited information that create additional uncertainties beyond the model formulation.
- *Lack of data*: In some situations, there simply may not yet be data available that would be necessary to characterise a particular emission or removal. In these situations, a common approach is to use proxy (or surrogate) data for analogous or similar categories or to use interpolation or extrapolation as a basis for making estimates.
- *Lack of representativeness of data*: This source of uncertainty is associated with lack of complete correspondence between conditions associated with the available data and the conditions associated with real world emissions/removals or activity. For example, emissions data may be available for situations in which a plant is operating at full load but not for situations involving start-up or load changes. In this case, the data are only partly relevant to the desired emission estimate. Lack of representativeness typically leads to bias.
- *Statistical random sampling error*: This source of uncertainty is associated with data that are a random sample of finite size and typically depends on the variance[2] of the population from which the sample is extracted and the size of the sample itself (number of data points). It can often be reduced by increasing the number of independent samples taken. Here, it is *good practice* to distinguish properly between *variability* and *uncertainty*, as previously defined. For purposes of uncertainty analysis of inventories, one is typically interested in uncertainty in the annual average at the national level, rather than the entire range of variability that might occur over shorter periods of time or small geographic scales. Larger sample sizes will not reduce the inherent variability, but will lead to narrower confidence intervals that are a basis for estimating the random component of uncertainty.

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[1] Further discussion can be found in Morgan and Henrion (1990) and Cullen and Frey (1999).

[2] The *variance of a whole population* of values is the average of the square of the difference between individual values in the population and the mean value. The *variance of a sample drawn from a population* is the sum of the squares of differences between values in the sample and the mean of the sample, divided by the number of values in the sample less 1.

- *Measurement error*: Measurement error, which may be random or systematic, results from errors in measuring, recording and transmitting information; finite instrument resolution; inexact values of measurement standards and reference materials; inexact values of constants and other parameters obtained from external sources and used in the data-reduction algorithm (e.g., default values from the *IPCC Guidelines*); approximations and assumptions incorporated in the measurement method and estimation procedure; and/or variations in repeated observations of the emission or removal or associated variable under apparently identical conditions.

- *Misreporting or misclassification*: Uncertainty here may be due to incomplete, unclear, or faulty definition of an emission or removal. This cause of uncertainty typically leads to bias.

- *Missing data*: Uncertainties may result where measurements were attempted but no value was available. An example are measurements that are below a detection limit. This cause of uncertainty can lead to both bias and random error. When measured values are below a detection limit, an upper bound on the uncertainty can be estimated. There are rigorous statistical techniques for dealing with non-detected data as well as other types of missing data, such as data that are missing at random (Cohen and Whitten, 1998; Gelfand, 1996; Zhao and Frey, 2004b). These techniques may involve estimation or imputation in portions of the distribution where data are not available.

Particularly on the issue of extrapolation, uncertainty occurs when extrapolating from recent source and sink data for the purpose of estimating an inventory for a year of interest for which data are not yet available (see also Chapter 5, Time Series Consistency). Usually, the extrapolated estimates are reported as 'provisional' estimates and then later are updated when the relevant data become available. However, until the update occurs, the provisional inventory might be used. The additional uncertainty associated with extrapolation is a type of model uncertainty. Errors associated with extrapolation can be systematic, random, or both. If there is a history of extrapolations and subsequent correction, then it is possible to develop data regarding the distribution of the errors that have been observed in the past. If there are biases in the provisional estimates, then the mean of this distribution will not be zero and the biases can be quantified. This distribution would represent error in the ability to predict actual source and sink fluxes based upon the extrapolation methods used in the past. If the extrapolation methods change, then expert judgement could be used to quantify the uncertainty.

Where a PDF for the mean can be identified, various causes of uncertainty can be quantified by statistical means. As noted in Section 3.2, uncertainties can be quantified by statistical analysis of empirical data, by encoding (quantifying) of expert judgement in the form of PDFs, or by combinations of both. However, there can be structural uncertainties that are not easily incorporated into a quantitative uncertainty analysis in the form of a PDF. Examples of structural uncertainties include possible misidentification or mis-specification of the system to be analysed, as well as possible problems associated with the models that are used, e.g., inappropriateness of the model, or model errors. These latter types of situations are typically outside the scope of statistics (ISO 1993)[3], although probabilistic methods for dealing with model uncertainties have been proposed (e.g., Evans *et al*., 1994). For example, expert judgement can be used to assign weights to alternative models.

Table 3.1 suggests how different causes of uncertainties can be treated in an analysis. Some causes of uncertainties (e.g., misreporting/misclassification) may be reduced or eliminated by implementing QA/QC procedures and improvements in data collection and/or methodologies when identified.

[3] There are some opportunities for addressing these sources of uncertainty. For example, uncertainties associated with model error at least partly can be addressed by comparing modelled output with measured values. Depending on how modelled outputs compare with measurements, one can identify biases associated with the model that may vary depending on the type of system being modelled.

TABLE 3.1
TYPICAL STRATEGIES FOR DEALING WITH DIFFERENT CAUSES OF UNCERTAINTIES

Causes of Uncertainty	Strategy			Other Comments [1]
	Evaluated Conceptualisation and Model Formulation	Empirical and Statistical	Expert judgement	
Lack of completeness	√			Have key components of the system been omitted? If so, what is the quantifiable or nonquantifiable effect on systematic error? Proper QA/QC should help avoid this.
Model (bias and random errors)	√	√	√	Is the model formulation complete and accurate? What is the uncertainty in model predictions based on validation of the model? What is the estimate of model accuracy and precision based on expert judgment if statistical validation data are not available?
Lack of data			√	If data are lacking, can expert judgment be used to make inferences based on analogous (surrogate, proxy) data or theoretical considerations? May be related to lack of completeness and model uncertainty.
Lack of representativeness of data	√	√	√	
Statistical random sampling error		√		E.g., statistical theory for estimating confidence intervals based on variability in the data and sample size.
Measurement error: random component		√	√	
Measurement error: systematic component (bias)	√		√	QA/QC and verification may provide insight.
Misreporting or Misclassification		√	√	Proper QA/QC should help avoid this.
Missing data		√	√	Statistical or judgment-based approaches to estimating uncertainty because of non-detected measurements or other types of missing data.

[1] It is *good practice* to apply procedures for QA/QC and verification prior to or combining with developing uncertainty estimates according to the guidance in Chapter 6. The QA/QC and verification procedures provide a useful basis for preventing mistakes and for identifying (and preferably correcting) biases. Furthermore, QA/QC should prevent or help detect and correct misreporting and misclassification errors, and there should be iteration between uncertainty analysis and QA/QC if application of the uncertainty methods uncovers potential QA/QC problems.

3.1.6 Reducing uncertainty

Uncertainties should be reduced as far as is practicable during the process of compiling an inventory, and it is particularly important to ensure that the model and the data collected are fair representations of the real world. When focusing efforts to reduce uncertainty, priority should be given to those inputs to the inventory that have the most impact on the overall uncertainty of the inventory, as opposed to inputs that are of minor or negligible importance to the assessment as described in Chapter 4, Methodological Choice and Identification of Key Categories. Tools for prioritising where uncertainties should be reduced include *key category* analysis (see Chapter 4) and assessment of the contribution of uncertainties in specific categories to the total uncertainty in the inventory (see Section 3.2.3). Depending on the cause of uncertainty present, uncertainties could be reduced in seven broad ways:

- *Improving conceptualisation*: Improving the inclusiveness of the structural assumptions chosen can reduce uncertainties. An example is better treatment of seasonality effects that leads to more accurate annual estimates of emissions or removals for the AFOLU Sector.
- *Improving models*: Improving the model structure and parameterisation can lead to better understanding and characterisation of the systematic and random errors, as well as reductions in these causes of uncertainty.

- *Improving representativeness*: This may involve stratification or other sampling strategies, as set out in Section 3.2.1.2. This is particularly important for categories in the agriculture, forestry and land use parts of an inventory, but also applies elsewhere, e.g., wherever different technologies are operating within a category. For example, continuous emissions monitoring systems (CEMS) can be used to reduce uncertainty for some sources and gases as long as the representativeness is guaranteed. CEMS produces representative data at the facilities where it is used, but in order to be representative of an entire source category, CEMS data must be available for a random sample or an entire set of individual facilities that comprise the category. When using CEMS both concentration and flow will vary, requiring simultaneous sampling of both attributes.
- *Using more precise measurement methods*: Measurement error can be reduced by using more precise measurement methods, avoiding simplifying assumptions, and ensuring that measurement technologies are appropriately used and calibrated. See Chapter 2, Approaches to Data Collection.
- *Collecting more measured data*: Uncertainty associated with random sampling error can be reduced by increasing the sample size. Both bias and random error can be reduced by filling in data gaps. This applies both to measurements and surveys.
- *Eliminating known risk of bias*: This is achieved by ensuring instrumentation is properly positioned and calibrated (see Section 2.2 in Chapter 2), models or other estimation procedures are appropriate and representative as indicated by the decision trees and other advice on methodological choice in sectoral volumes, and by applying expert judgements in a systematic way.
- *Improving state of knowledge*: Generally, improving the understanding of the categories and the processes leading to emissions and removals can help to discover, and correct for, problems of incompleteness. It is *good practice* to continuously improve emissions and removal estimates based on new knowledge (see Chapter 5, Time Series Consistency).

3.1.7 Implications of methodological choice

Choice of methodological tier for emissions and removals estimation can affect the uncertainty analysis in two different ways. Firstly, moving to higher tier inventory methods should typically reduce uncertainties, provided the higher tier methods are well implemented, because they should reduce bias and better represent the complexity of the system. Secondly, moving to higher tier methods may result in increased estimates of uncertainty in some circumstances. Often, this increase in the estimated uncertainty does not actually represent a decrease in knowledge; rather, it typically reveals a more realistic acknowledgment of the limitations of existing knowledge. This may occur where there was an incomplete accounting of the greenhouse gas emissions in the lower tier method, or where application of higher tier methods reveals additional complexity and uncertainties that were not fully apparent in the lower tier method. This really means that the uncertainty was underestimated previously and moving to the higher tier method in reality produces a more accurate estimate of uncertainty. In some cases, an increase in uncertainty may occur for one inventory development method versus another because each method has different data requirements. For example, sometimes aggregate estimates of emissions are more accurate because they are based upon or can be compared to easily measured values, whereas disaggregated estimates may require additional assumptions for which data or the capability to verify estimates are not as readily available. The appropriate level of disaggregation can differ within and between categories.

3.2 QUANTIFYING UNCERTAINTIES

After identifying the causes of uncertainties associated with inventory estimates, the inventory compiler should collect the appropriate information to develop national, and category-specific estimates of uncertainty at the 95 percent confidence interval. Ideally, emission and removal estimates and uncertainty ranges would be derived from category-specific measured data. Since it may not be practical to measure every emission source or sink category in this way, other methods for quantifying uncertainty may be required. The pragmatic approach for producing quantitative uncertainty estimates is to use the best available estimates, which are often a combination of measured data, published information, model outputs, and expert judgement. The sectoral guidance in Volumes 2 to 5 of *these Guidelines* provides default uncertainty estimates for use with the methods described in this chapter.

Although uncertainties determined from measured data are often perceived to be more rigorous than uncertainty estimates based on models, and similarly, model-based estimates are often perceived as more rigorous than those based on expert judgement, the actual hierarchy depends on the category and/or country-specific circumstances. In particular it is *good practice* to ensure that uncertainties are representative for the application in the inventory and national circumstances and includes all causes of uncertainty listed in Table 3.1.

This section is organised into three major subsections that are interrelated. Section 3.2.1 focuses on sources of data and information that can be used to identify and, where possible, quantify uncertainties. Section 3.2.2 focuses on methods for attempting to prevent or correct for biases and for quantifying the random component of uncertainty in the inputs to models. Section 3.2.3 presents two Approaches for combining uncertainties in inputs in order to arrive at uncertainty estimates for single emission and removal categories and the total emission inventory.

3.2.1 Sources of data and information

This section identifies sources of data and information for acquiring quantitative estimates of uncertainty. There are three broad sources of data and information: information contained in models; empirical data associated with measurements of emissions, and activity data from surveys and censuses; and quantified estimates of uncertainties based upon expert judgement.

3.2.1.1 UNCERTAINTIES ASSOCIATED WITH MODELS

A model is a representation of a real-world system. Modelling typically involves choices regarding what to include versus what to exclude, as well as choices regarding the level of detail (or aggregation) for those phenomena that are included in the model. Thus, the model typically does not exactly mimic the real-world system. The structure of the model is often thought of in terms of the equations used and in terms of inputs and outputs of the model (Kirchner, 1990). More generally, a model may be thought of as a hypothesis regarding how the real-world system behaves. Thus, there are two key considerations in model uncertainty: (1) has the correct, most relevant real-world system been identified, and have conceptualisations been constructed in a way that properly serve as the basis for model development; and (2) is the model an accurate representation of the chosen system. C*onceptualisation uncertainty* describes the lack of proper identification of the system for which a model should be developed and of the conceptualisation(s) of interest. *Model uncertainty* describes the lack of proper model development relative to the intended system and conceptualisation(s).

Conceptualisation Uncertainty**:** The failure to specify properly appropriate and relevant inventory structural assumptions is known as conceptualisation uncertainty (Cullen and Frey, 1999) and typically results in a bias in estimates. The causes of conceptualisation uncertainty typically include descriptive errors, errors in professional judgement, and incomplete specification of the assumptions (EPA, 1997).

Model uncertainty**:** Uncertainty arises from imperfections in how the chosen conceptualisations are modelled. Sometimes these imperfections occur because of limitations of available data. A model may have other sources of structural errors, such as failure to properly take into account the sensitivity of emissions to ambient conditions or other factors. Modelling can be a basis for estimating emissions or removals for specific categories as well as for managing data in the entire inventory. In some cases, model uncertainty can be significant. It is typically poorly characterised and may not be characterised at all.

3.2.1.2 EMPIRICAL DATA FOR SOURCES AND SINKS AND ACTIVITY

This section describes sources of empirical data, and their implications for uncertainty, and is relevant to measured emissions data, data obtained from literature, and activity data.

UNCERTAINTY ESTIMATES OBTAINED FROM MEASURED EMISSIONS/REMOVALS DATA

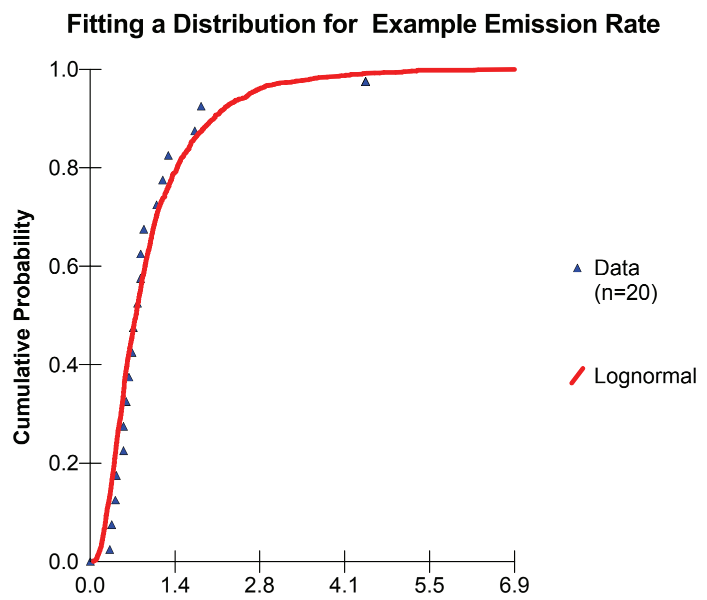
This section assumes that *good practices* are used to obtain the data, as outlined in Chapters 2 and Chapter 6, Quality Assurance/Quality Control and Verification. When estimating uncertainty from measured emissions data, considerations include: (a) representativeness of the data and potential for bias; (b) precision and accuracy of the measurements; (c) sample size and inter-individual variability in measurements, and their implications for uncertainty in mean annual emissions/removals; (d) inter-annual variability in emissions/removals and whether estimates are based upon an average of several years or on the basis of a particular year.

Representative sampling (or sampling design) implies that measurements are made for typical system characteristics, operating conditions, time periods, and/or geographic areas of interest. The precision and accuracy of individual measurements will depend upon the equipment and protocols used to make the measurements. The sample size will often be a trade-off between the desirability for more data and the cost of making measurements. In some cases, such as for continuous monitoring, the sample size may be large enough to effectively serve as a census, rather than a partial sample, of data. In general the variability in the data from one short-term time period (e.g., hour, day, week) to another will depend upon the characteristics of the category. If the goal is to develop an estimate of annual average emissions or removals, then judgement may be required as to whether measurements conducted over a short term are representative of rates over a longer time period and, if not, whether the measurement programme can be expanded to additional time periods. For example, flux measurements (data on emission factors) should represent the entire year. In the AFOLU Sector this is crucial, since emissions are highly dependent on climatic conditions which typically are not the same for the growing period and winter period.

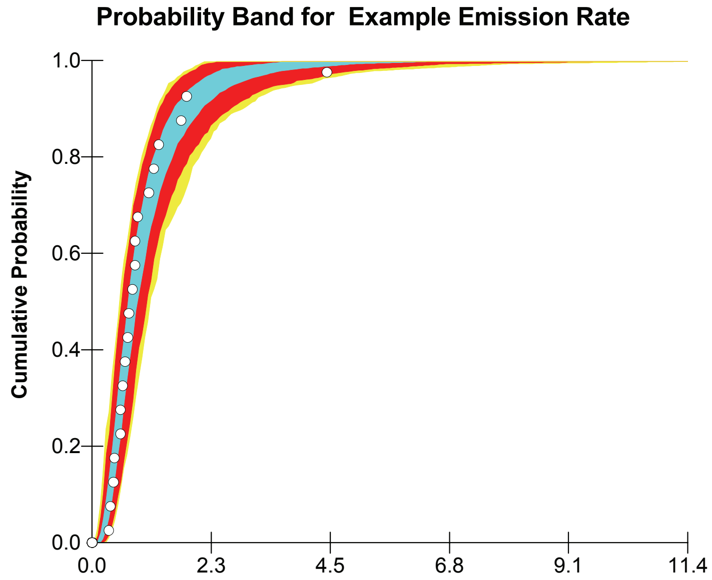
Figure 3.4 Example of uncertainty in emission measurements and mean emission rate

(a) Fitted distribution for inter-unit variability in emissions;
(b) Uncertainty in fitted distribution because of small sample size (n=20);
(c) Uncertainty in mean emission rate.

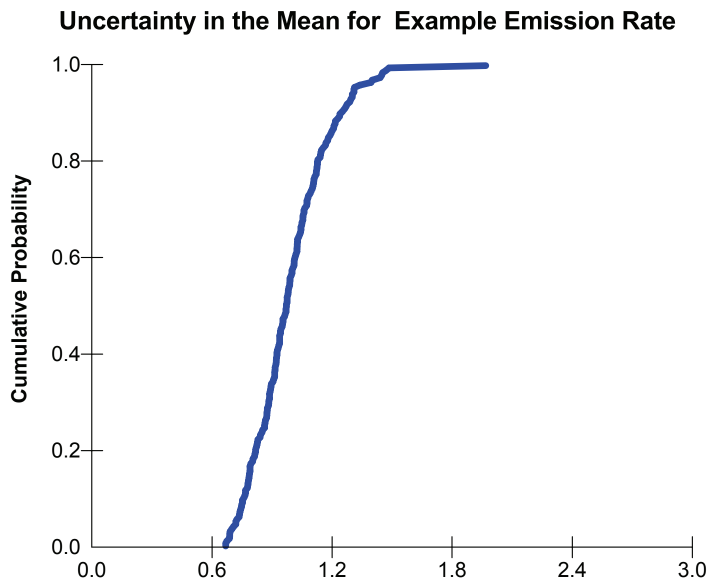
(a) Inter-Unit Variability



(b) Uncertainty in Distribution of Variability



(c) Uncertainty in Mean



For a second example, suppose that one wishes to estimate the uncertainty in national annual emissions for a particular category, such as emissions from gasoline-fuelled passenger automobiles. The rate of emission varies from one individual vehicle to another, illustrated by the inter-unit variability shown in Figure 3.4(a). Because the distribution for inter-vehicle variability is estimated from a small, finite sample of data that could be subject to random sampling error, there is uncertainty regarding what the true but unknown population distribution for inter-vehicle variability might be, as suggested in Figure 3.4(b). There is also intra-unit variability in emissions over time for any particular vehicle. However, for purposes of the national annual estimate, the focus is on the combined contribution of all such vehicles to total emissions during a year long time frame. In this case, we are not interested in the range of inter-vehicle variability, but rather in the range of uncertainty for the average emission rate among all such vehicles (e.g., Figure 3.4(c)). Often, the range of uncertainty is substantially less than that for inter-vehicle (or, more generally, inter-unit) variability (e.g., Frey and Zheng, 2002). Therefore, when the objective of an analysis requires that the assessment be based upon uncertainty in the mean, rather than variability among individual units, it is important to properly focus the analysis on the former. Failure to do so can lead to a misleading over-estimate of the range of uncertainty.

In the case of continuous monitoring of point emissions, or a periodic sampling scheme that captures typical activity patterns, there may be adequate and representative empirical data upon which to base an estimate of uncertainty in mean annual emissions. For example, if there are several years of such data, then the average annual emissions over several years can be quantified, and the distribution of annual emissions from year-to-year can be used to assess a 95 percent confidence interval in the annual average. Provided that the annual average is based upon data from many individual categories, it is unlikely that there will be correlation of errors between years. This has implications for estimation of uncertainty in trends, as discussed in Section 3.3, Uncertainty and Temporal Autocorrelation. However, for diffuse categories, such as agricultural crops, there could be high autocorrelations if they are determined by climate, and this could affect the representativeness of the data for a particular assessment purpose.

Where continuous emission measurements are not available, there may be periodic emission measurements available from which to estimate uncertainty. If these measurements can be linked to representative activity data, which of course is crucial, then it is possible to determine a site-specific emission factor, together with an associated PDF to represent annual emissions. This can be a complex task. To achieve representativeness it may be necessary to partition (or stratify) the data to reflect typical operating conditions. For example:

- Start-up and shut down can give different emission rates relative to activity data. In this case, the data should be partitioned, with separate emission factors and probability density functions derived for steady state, start-up and shut down conditions.

- Emission factors can depend on load. In this case, the total emissions estimation and uncertainty analysis may need to be stratified to take account of load, expressed, for example, as percentage of full capacity. This could be done by regression analysis and scatter plots of the emission rate against likely controlling variables (e.g., emissions versus load) with load becoming part of the activity data needed.

- Measurements taken for another purpose may not be representative. For example, methane measurements made for safety reasons at coal mines and landfills may not necessarily reflect total emissions because they may have been made only when methane emissions were suspected of being high, as a compliance check. In such cases, the ratio between the measured data and total emissions should be estimated for the uncertainty analysis.
- Systematic short-term measurements might not adequately sample episodic events (such as rainfall) that initiate large fluxes of short duration that may nevertheless account for a major fraction of annual emissions. If the sampling strategy misses a significant proportion of these events, then the annual average emission estimate could be substantially biased. Nitrous oxide emissions from agricultural soils can fall into this class.

If the data sample size is large enough, standard statistical goodness-of-fit tests can be used, in combination with expert judgement, to help in deciding which PDF to use for describing variability in the data (partitioned if necessary) and how to parameterise it. However, in many cases, the number of measurements from which to make an inference regarding uncertainty will be small. Theoretically, as long as there are three or more data points, and they are a random representative sample of the variable of interest, it is possible to apply statistical techniques to estimate the values of the parameters of many two-parameter distributions (e.g., normal, lognormal) that can be used to describe variability in the data set (Cullen and Frey, 1999, pp. 116-117). While it is commonly perceived that one must have approximately 8 or 9 data points, and preferably more, as the basis for fitting a distribution to data, the more fundamental and key assumption that must be made in order to fit a distribution to data is that the data are a random, representative sample. If this assumption is valid, then the sample size influences the width of the confidence intervals for any statistic estimated from the sample. As a matter of preference, many analysts may prefer to have a minimum sample size, but this preference is not related to the key issue of representativeness. Data do not become more representative only because of an increase in sample size.

With small sample sizes, there will be large uncertainties regarding the parameter estimates that should be reflected in the quantification of uncertainty for use in the inventory. Furthermore, it is typically not possible to rely on statistical methods to differentiate goodness-of-fit of alternative parametric distributions when sample sizes are very small (Cullen and Frey, 1999, pp. 158-159). Therefore judgement will be required in selecting an appropriate parametric distribution to fit to a very small data set. In situations where the coefficient of variation (standard deviation divided by the mean) is less than approximately 0.3 and is known with reasonable confidence, a normal distribution may be a reasonable assumption (Robinson, 1989). When the coefficient of variation is large and the variable is non-negative, then a positively skewed distribution such as a lognormal may be appropriate. Guidance on the selection of distributions is elaborated in Sections 3.2.2.2 and 3.2.2.4 below.

In cases with large data sets, the uncertainty in the mean can often be estimated as plus or minus 1.96 (or approximately 2) multiples of the standard error, where the standard error is the sample standard deviation divided by the square root of the sample size. This calculation is based on an assumption of a normal distribution. However, in cases of a small number of samples/measurements that will often be the case in determining emission factors, the multiple of 1.96 is replaced with a “coverage factor,” referred to as k, that is obtained from the student’s t-distribution. For small sample sizes, k is greater than 1.96 for a 95 percent interval, but asymptotically approaches 1.96 as the sample size increases to approximately 30 or more. However, in cases where the uncertainty in the mean is not a symmetric distribution, then numerical methods such as bootstrap simulation can be used instead to obtain the confidence interval for the mean.

Where an annual estimate is based on an average over several years, the uncertainty in the average represents the uncertainty in an average year and not the inter-annual variability. If the objective is to estimate uncertainty in source or sink fluxes for a specific year, then *good practice* is to make a best estimate of the annual total and to quantify uncertainty associated with the models and data used consistent with the one year time period. If, instead, an averaged annual estimate is used, then the uncertainty in the estimate when applied to a specific year would be described by the inter-annual variability (including measurement errors) relative to the mean, whereas when applied to an average year it would be the confidence interval of the average.

UNCERTAINTY ESTIMATES FOR EMISSION FACTORS AND OTHER PARAMETERS OBTAINED FROM PUBLISHED REFERENCES

When site-specific data are unavailable, inventories should where possible be based on emission factors derived from published studies specific to the conditions in that country. Where sufficient country-specific information is unavailable, information may be derived from other published studies if those studies are reflective of conditions in the country, or emission factors or other estimation parameters may be drawn from sectoral Volumes 2 to 5 of these *Guidelines*. Factors provided in the sectoral volumes have been derived for circumstances that are judged to be typical. There are uncertainties associated with the original measurements, as well as with the use of the factors in circumstances other than those associated with the original measurements.

Where published emission factors or other estimation parameters are used, the associated uncertainties should be estimated from:

- *Original research including country-specific data*: For measurement-based emission factors, the data from the original measurement programme or experiments may enable an assessment of the uncertainty and possibly the PDF. Well-designed measurement programmes and experiments will provide sample data that cover the range of types of plants and their maintenance, size and age, so that the factors and their uncertainties can be used directly. In other cases, expert judgement, taking into account the causes of uncertainty identified in Table 3.1, will be needed to extrapolate from the measurements to the full population of plants in that particular category (detail on how to elicit expert judgement is elaborated in Section 3.2.1.3).
- *Default Values from Guidelines*: For most emission factors and other estimation parameters, sectoral guidelines provide default uncertainty estimates that should be used in the absence of other information. Unless clear evidence to the contrary is available, the PDFs are assumed to be normal. However, the inventory compiler should evaluate the representativeness of the default for its own national circumstances. If the default is judged to be not representative and the category is important to the inventory, improved assumptions based upon expert judgement should be developed, assuming sufficient original research is unavailable to derive country-specific emission factors or other estimation parameters.

Default methods represent a compromise between the level of detail that 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. Default methods are often simplifications, and may 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 activities in a particular country. For example, the uncertainty relating to default carbon emission factors for the global population of fossil fuel combustion sources may be characterised as quite low (5-10 percent) in the IPCC methodology; but national experts for a particular country may know that the characteristics of such fuels in their country vary from global average values. In such a country, use of default values would introduce a larger uncertainty, and thus it is *good practice* to use country-specific estimates where possible. Thus the applicability of default uncertainty values should always be considered.

Another example is the use of default values to estimate country-specific emissions and removals of the AFOLU Sector. Uncertainty could be high unless the suitability of the available default parameters to a country's circumstances is known. The application of default data in a country or region that has very different characteristics from those of the category data can lead to large systematic (bias) errors in estimates of emissions or removals.

UNCERTAINTIES ASSOCIATED WITH ACTIVITY DATA

Activity data are often more closely linked to economic activity than are emission factors are. However, unlike emission factor data, there is typically no statistical sample of alternative activity data estimates readily available to fit distributions and estimate uncertainty. There are often well established price incentives and fiscal requirements for accurate accounting of economic activity. Activity data therefore tend to have lower uncertainties and a lower correlation between years than emission factor data. Activity data are often collected and published regularly by national statistical agencies, which may have already assessed the uncertainties associated with their data as part of their data collection procedures. These previously developed uncertainty estimates can be used to construct PDFs. This information will not necessarily have been published, so it is recommended to contact the statistical agencies directly. Since economic activity data are not usually collected for the purpose of estimating greenhouse gas emissions and removals, it is *good practice* to assess the applicability of the uncertainty estimates before using them.

There are several approaches that may be helpful in assessing the uncertainty of activity data in particular circumstances:

***Activity data based on complete samples* (*censuses*):** Census data are activity data that are based, in principle, on counting every instance of a particular activity. Census typically includes both systematic and random errors. Systematic errors arise through systematic undercounting or double counting. Random errors are typically the sum of a range of commonplace errors. Random errors usually can be expected to be normally distributed and serially uncorrelated. Because activity data are usually collected by the same people, using the same processes, for each observation, systematic errors are likely to take approximately the same value each year. There are several approaches to identifying the potential uncertainty of activity data for complete samples. These approaches are often an integrated part of a QA/QC plan:

- To check for the size of random errors, look for fluctuations over time, and differential fluctuations in series that ought to be highly correlated with the data of interest.

- To check for bias errors, cross-check the data of interest with other, related information. One might, for instance, look up and down the supply chain for fuels, comparing coal production, coal import/export, and reported consumption. Or, one might study activities for which data are collected independently but which ought to be highly correlated with the data of interest, for instance reported fuel input vs. electricity output. One might also look at activity data of different frequencies (e.g., monthly, annual), if they are collected using different approaches.
- Interpretation of statistical differences, within, for instance, national energy data are an example of cross-checking. The comparison between energy-related carbon dioxide emissions derived from the IPCC reference approach is a formal cross-check with emissions estimates derived from other sources.

Census-based activity data are often ‘precise but inaccurate’ in the taxonomy shown in Figure 3.2, the random errors are small, but there may be larger bias errors. Cross-checking can suggest upper and lower bounds for possible bias errors, and sometimes will permit an actual estimate of the bias error. A possible bias error lurking within these bounds may often be characterised as a truncated uniform distribution: cross-checking shows that the unobservable true value must lie within a particular range, but there may be no reason to think any point within that range is more or less likely. However, because the bias errors in activity data are likely to be highly correlated, the difference between the reported value and the unknown true value is likely to be about the same every year, and this characteristic should be taken into account when estimating trend uncertainty.

***Activity data based on random samples*:** Some kinds of activity data are derived from sample surveys, for instance consumer surveys, land use surveys, or forest cover surveys. In these cases, the data will be subject to sampling errors, which will be normally distributed and uncorrelated over time. The agency conducting the sample will normally be able to advise on sampling error. If this information is unavailable, it may be possible to identify or infer the sample and population sizes and calculate sampling error directly.

3.2.1.3 EXPERT JUDGEMENT AS A SOURCE OF INFORMATION

In many situations, directly relevant empirical data are not available for sources, sinks, or activity inputs to an inventory. In such situations, a practical solution to dealing with the absence of adequate data is to obtain well-informed judgements from domain experts regarding best estimates and uncertainties of inputs to the inventory. Chapter 2, Approaches to Data Collection, discusses the basis of formal expert elicitation protocols. In particular, Section 2.2 and Annex 2A.1 provides a general treatment of expert judgment and elicitation. Annex 2A.1 provides details regarding expert elicitation protocol. In this chapter, methods for encoding uncertainties based upon expert judgement are recommended in Section 3.2.2.3.

3.2.2 Techniques for quantifying uncertainties

This section discusses key techniques for quantifying uncertainties, building upon the sources of data and information described in the previous section. This section focuses on uncertainty in models, statistical analysis of empirical data, identifying and selecting PDFs, and methods for encoding expert judgement regarding uncertainties.

3.2.2.1 UNCERTAINTY IN MODELS

Conceptualisation and model uncertainty can be more difficult to address than the uncertainties in the inputs to a model. The most significant concern with conceptualisation and model uncertainties is that they have the potential to produce substantial bias in emissions and removal estimates. Approaches to deal with these causes of uncertainties should aim therefore to evaluate and correct for known or suspected biases.

It is clear that proper specification of a conceptualisation is set by the *2006 Guidelines*, the interpretation of which depends on input from experts and stakeholders who are familiar with the systems for which emissions or removals are to be estimated. A conceptualisation should be complete, within the scope of *these Guidelines*, in enumerating all key components without producing redundancy or overlap, and it should be applicable to the geographic scope, time period, and agreed set of greenhouse gases covered.

Model uncertainty is typically dealt with in several ways. One approach is to simply acknowledge the limitations of models that are used and to qualitatively discuss the implications for uncertainty in estimates obtained using the model. However, qualitative caveats are not useful in providing quantitative insight regarding the possible magnitude of uncertainty, and by themselves are not considered *good practice*. There are at least three major approaches for estimating uncertainty: (1) comparison of model results with independent data for purposes of verification; (2) comparison of the predictions of alternative models; and (3) expert judgement regarding the magnitude of model uncertainty. These approaches can be used in combination.

Comparison of model predictions with independent data can be used to assess the precision and accuracy of the model, and is an important aspect of verification, as discussed in Chapter 6. Such comparisons can reveal whether the model systematically over- or under-predicts the quantities of interest. However, it can be difficult to obtain data for direct verification of a model. Nonetheless, sometimes these types of comparisons are the best or only available ones, and might help in identifying unexplained inconsistencies that, in turn, might imply model bias that could be corrected for by parameter choice.

In other cases, there may be alternative models that could be used to make predictions for the same quantities of interest. To the extent that the alternative models are based upon different data or theoretical assumptions, a comparison of model predictions may provide useful insight regarding the magnitude of disagreement. The fact that two or more models disagree is not conclusive proof that either of the models is wrong, since both or all of the models could be wrong.

Based on the results of the comparison of the model used for inventory development with independent data and/or alternative models, it may be desirable to revise model assumptions or parameters to reduce the bias. The remaining uncertainty can then be quantitatively assessed by expert judgement about how uncertainties in the data used to drive the model and the model parameters combine, or more formally by Monte Carlo analysis.

3.2.2.2 STATISTICAL ANALYSIS OF EMPIRICAL DATA

Statistical analysis of empirical data is an approach that can be employed to quantify uncertainty in inventories, emission factors and other estimation parameters, and it can be summarised as the following major steps (e.g., Frey and Zheng, 2002):

Step 1: Compilation and evaluation of a database for emission factors, activity data and other estimation parameters. Such data typically represent variability.

Step 2: Visualisation of data by developing empirical distribution functions (in which the data are plotted vertical according to their rank order and are plotted horizontally according to their numerical value – see Cullen and Frey, 1999, for details) for individual activity and emission factors.

Step 3: Fitting, evaluation, and selection of alternative PDF models for representing variability in activity data and emission factor data.

Step 4: Characterisation of uncertainty in the mean of the distributions for variability. If the standard error of the mean is small enough (as discussed in Section 3.2.1.2), a normality assumption can be made regardless of the sample size or skewness of the data. If the standard error of the mean is large, then either a lognormality assumption can be made, or other methods can be employed (e.g., bootstrap simulation) to estimate uncertainty in the mean. Publicly available software tools could be used to assist with the latter.

Step 5: Once uncertainties have been appropriately specified, these can be used as input to a probabilistic analysis for purposes of estimating uncertainty in total emissions.

Step 6: Sensitivity analysis is recommended to determine which of the input uncertainties to an inventory contributes most substantially to the overall uncertainty, and to prioritise efforts to develop good estimates of these key uncertainties (see Chapter 4, Methodological Choice and Identification of Key categories).

Step 3 typically involves; identification of candidate parametric PDFs to fit to the data, estimation of the parameters of such distributions, and evaluation of goodness-of-fit (e.g., Cullen and Frey, 1999). Rigorous methods can be applied to data sets that contain values below the detection limit of a measurement method, called *non-detects* (e.g., Zhao and Frey, 2004a). Distributions can be used in combination even when the data contain two or more subgroups that cannot otherwise be separated (e.g., Zheng and Frey, 2004).

3.2.2.3 METHODS FOR ENCODING EXPERT JUDGEMENTS

When empirical data are lacking or are not considered fully representative for all causes of uncertainty (Table 3.1), expert judgement may be necessary for estimating uncertainty. This section focuses on methods for encoding (quantifying) expert judgement regarding uncertainty in the form of PDFs. Encoding is the process of converting an expert's judgement regarding uncertainty into a quantitative PDF. Chapter 2 provides guidance on the definition of an expert, considerations in choosing expert(s), sources of possible bias in expert judgement and how to avoid them, and a recommended protocol for expert elicitation. In the context of uncertainties, a key goal of expert elicitation is to characterise the state of knowledge regarding possible values of a particular variable. Therefore, it is neither necessary nor desirable to attempt to force consensus among experts; rather, it is more useful to take into account the full range of values when obtaining judgements from two or more experts for the same variable.

The goal of the process of eliciting (obtaining) expert judgement is to develop a PDF taking into account relevant information such as:

- Is the category similar to others? How is the uncertainty likely to compare?
- How well is the emission or removal process understood? Have all possible sources or sinks been identified?
- Are there physical limits on how much the emission factor or other estimation parameter can vary? Mass balance considerations or other process data may place an upper limit on emissions or removal rates.
- Are the emissions and removal estimates consistent with independent data that might be used to help verify the inventory?

A key concern with expert elicitation is to overcome the typical heuristic biases of *availability*, *representativeness*, and *anchoring and adjustment* (as described in Chapter 2, Annex 2A.1, Protocol for Expert Elicitation) to avoid the potential problem of obtaining an 'overconfident' estimate of uncertainty. 'Overconfidence' refers to a situation in which the estimated range of uncertainty is too narrow. It is desirable to avoid overconfidence so as not to underestimate the true uncertainty. It is *good practice* to use a formal elicitation protocol, such as the Stanford/SRI protocol that is detailed in Chapter 2, Annex 2A.1. In particular, these protocols include several steps prior to the actual encoding step for the purpose of familiarising the expert with the purpose and methods of the elicitation and encouraging the expert to think about all relevant data, models, theories, and other inference approaches. With this background, the expert is in a better position to make an unbiased estimate of uncertainty.

The method to be used for encoding should depend upon the expert's familiarity with PDFs. Some commonly used methods are:

- Fixed Value: Estimate the probability of being higher (or lower) than an arbitrary value and repeat, typically three or five times. For example, what is the probability that an emission factor would be less than 100?
- Fixed Probability: Estimate the value associated with a specified probability of being higher (or lower). For example, what is the emission factor such that there is only a 2.5 percent probability (or 1 in 40 chance) that the emission factor could be lower (or higher) than that value.
- Interval Methods: This method focuses on the median and the quartiles. For example, the expert would be asked to choose a value of the emission factor such that it is equally likely that the true emission factor would be higher or lower than that value. This yields the median. Then the expert would divide the lower range into two bins such that he or she felt it to be equally likely (25 percent probability) that the emission factor could be in either bin, and this would be repeated for the other end of the distribution. Finally, either fixed probability or fixed value methods could be used to get judgements for extreme values.
- Graphing: The expert draws his/her own distributions. This should be used cautiously because some experts are overconfident about their knowledge of PDFs.

An example of an expert elicitation that results in encoding (quantification) of a PDF is given in Box 3.1.

Sometimes the only available expert judgement will consist of a range, perhaps quoted together with a most likely value. Under these circumstances the following rules are considered *good practice*:

- Where experts only provide an upper and a lower value, assume that the probability density function is uniform and that the range corresponds to the 95 percent confidence interval.
- Where experts also provide a most likely value (which is often likely to be the same as the point estimate used in developing the inventory), assume a triangular probability density function using the most likely values as the mode and assume that the upper and lower values each exclude 2.5 percent of the population. The distribution needs not to be symmetrical. Other reasonable distribution choices, such as a normal or lognormal distribution, can be made given appropriate justifications.

Some other sources of information on expert elicitation include Spetzler and von Holstein (1975), Morgan and Henrion (1990), Merkhofer (1987), Hora and Iman (1989), and NCRP (1996).

The subjective nature of expert judgement increases the need for quality assurance and quality control procedures to improve comparability of uncertainty estimates between countries. Therefore expert judgements should be documented as part of the national archiving process, and inventory compilers are encouraged to apply QA/QC procedures to expert judgements, particularly for *key categories* (see Chapter 6).

Documentation requirements for expert judgement are discussed in Annex 2A.1 of Chapter 2.

BOX 3.1
A BRIEF EXAMPLE OF DETAILED EXPERT JUDGEMENT

Suppose that the inventory compiler has identified an expert for emissions of CH_4 from power plants and wishes to obtain his/her judgement regarding the uncertainty in annual average emissions for this category. As part of the motivation step, the elicitor has explained to the expert the general purpose of the analysis and the expert elicitation protocol to be used. In the structuring step, the elicitor works with the expert to set up the specific elicitation protocol. For example, although all the inventory compiler may want is an annual average uncertainty estimate, the expert may tell the elicitor that he/she prefers to provide judgements separately for start-up, part load, and full load operation of the plant, and that these three judgements should be weighted in order to come up with the combined uncertainty for an annual average. After structuring the problem, the elicitor then reviews the expert information relevant to the assessment, such as measurements that may have been made on similar types of power plants or other combustion sources. In the elicitation step, the elicitor might ask the expert for an upper value such that there is only a one in 40 chance (2.5 percent probability) of obtaining a higher value. After getting the value, the elicitor asks the expert to explain the logical basis for this estimate, such as the scenario of operation at the plant that might lead to such a high emission rate. Then the process might be repeated for the lower end of the range, and perhaps for the median, 25th percentile, and 75th percentile. A mixture of fixed value and fixed probability questions might be used. The elicitor should plot these on a graph so that any inconsistencies can be identified and corrected during the time available with the expert. In the verification step, the elicitor would make sure that the expert is comfortable that their judgement has been well represented. The elicitor might also see how the expert would react to the possibility of values outside of the interval for which judgements were provided, so as to ensure that the expert is not being overconfident.

3.2.2.4 GOOD PRACTICE GUIDANCE FOR SELECTING PROBABILITY DENSITY FUNCTIONS

Prior to selecting a PDF, it is *good practice* to account for biases in the data to the extent possible. As noted previously, data collection and QA/QC procedures can assist in preventing or correcting biases. For example, if national statistics on timber harvest exist, but it is also suggested that these statistics have a bias of 5 percent, then the mean estimate can be adjusted by 5 percent prior to estimating the random component of the uncertainty. It is *good practice* that adjustments for bias should be done in developing the point estimate emission inventory. Another consideration is that the amount of bias can change over time as data measurement or collection procedures change, or as the geographic and temporal scope of data collection changes. Thus, the bias corrections may be different for different years.

However, to the extent that biases are believed or known to exist in data even after QA/QC procedures have been applied, then either empirical or judgment based techniques can be applied to account for the bias. Apparent biases can arise in probabilistic analysis for at least two reasons: (1) a fitted distribution may have a mean that is different from the most likely value used in the point estimate of the inventory (e.g., a skewed triangular distribution based on expert judgment); and (2) the mean value of a prediction from a nonlinear model that has uncertain inputs can be different from the point estimate obtained from the same model if only point estimates of the mean values of the inputs are used. Thus, there are some types of biases that may be revealed only after an uncertainty analysis has been done.

TYPES OF PROBABILITY DENSITY FUNCTIONS

There are many PDFs outlined in the statistical literature that often represent particular real situations. The choice of a particular type of PDF depends, at least in part, on the domain of the function (e.g., can it have both positive or negative values, or only non-negative values), the range of the function (e.g., is the range narrow or does it cover orders-of-magnitude), the shape (e.g., symmetry), and processes that generated the data (e.g., additive, multiplicative). These considerations are elaborated below in a brief discussion of many commonly used distributions of practical importance. Examples of such functions and the situations they represent are[4]:

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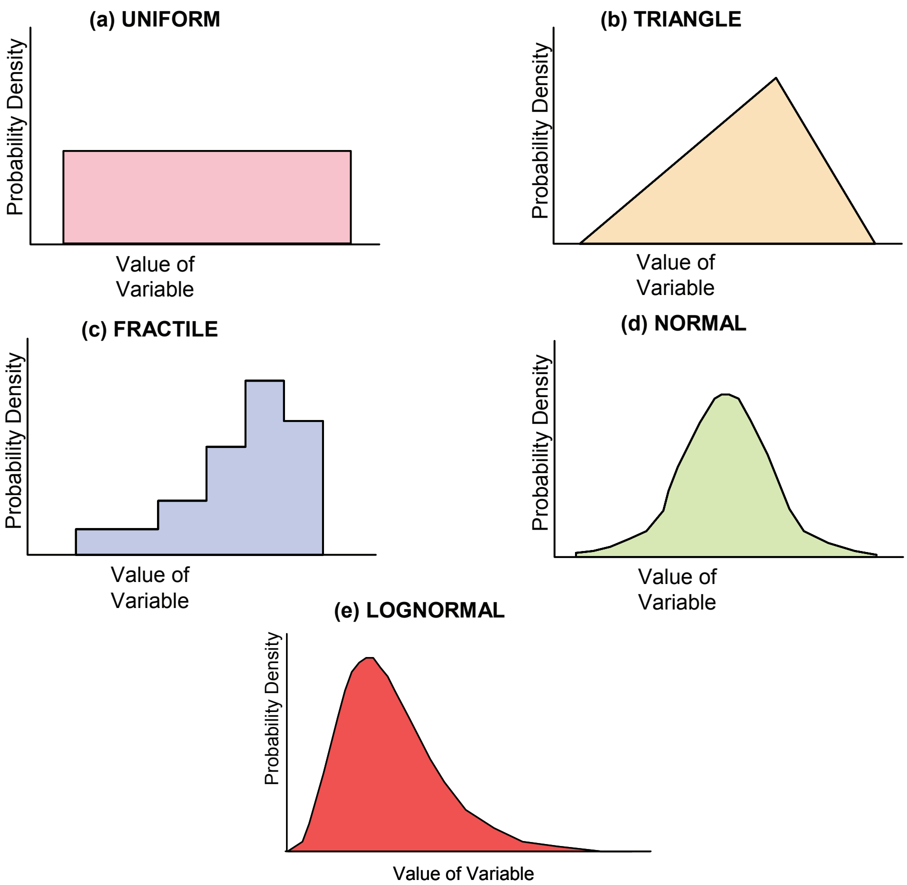
[4] Further information on methods for developing distributions based upon statistical analysis of data are described and illustrated by Cullen and Frey (1999). Other useful references include Hahn and Shapiro (1967), Ang and Tang (1975) D'Agostino and Stephens (1986), Morgan and Henrion (1990), and U.S.EPA (1996, 1997, 1999). Some examples of probabilistic analyses applied to emission inventories are given by Frey and Zheng (2002) and Frey and Zhao (2004).

- *The normal distribution* is most appropriate when the range of uncertainty is small, and symmetric relative to the mean. The normal distribution arises in situations where many individual inputs contribute to an overall uncertainty, and in which none of the individual uncertainties dominates the total uncertainty. Similarly, if an inventory is the sum of uncertainties of many individual categories, however, none of which dominates the total uncertainty, then the overall uncertainty is likely to be normal. A normality assumption is often appropriate for many categories for which the relative range of uncertainty is small, e.g., fossil fuel emission factors and activity data.
- *The lognormal distribution* may be appropriate when uncertainties are large for a non-negative variable and known to be positively skewed. The emission factor for nitrous oxide from fertiliser applied to soil provides a typical inventory example. If many uncertain variables are multiplied, the product asymptotically approaches lognormality. Because concentrations are the result of mixing processes, which are in turn multiplicative, concentration data tend to be distributed similar to a lognormal. However, real-world data may not be as tail-heavy as a lognormal distribution. The Weibull and Gamma distributions have approximately similar properties to the lognormal but are less tail-heavy and, therefore, are sometimes a better fit to data than the lognormal.
- *Uniform distribution* describes an equal likelihood of obtaining any value within a range. Sometimes the uniform distribution is useful for representing physically-bounded quantities (e.g., a fraction that must vary between 0 and 1) or for representing expert judgement when an expert is able to specify an upper and lower bound. The uniform distribution is a special case of the Beta distribution.
- *The triangular distribution* is appropriate where upper and lower limits and a preferred value are provided by experts but there is no other information about the PDF. The triangular distribution can be asymmetrical.
- *Fractile distribution* is a type of empirical distribution in which judgements are made regarding the relative likelihood of different ranges of values for a variable, such as illustrated in Figure 3.5. This type of distribution is sometimes useful in representing expert judgement regarding uncertainty.

Figure 3.5 Examples of some commonly used probability density function models (e.g., based on Frey and Rubin, 1991)



ISSUES TO CONSIDER WHEN DEVELOPING THE PROBABILITY DENSITY FUNCTION

The following describes how inventory compilers can satisfy the principles of comparability, consistency and transparency in emissions inventories when selecting a PDF:

- Where empirical data are available, the first consideration should be whether a normal distribution would be appropriate as a representation of uncertainty. If the variable must be non-negative, then the standard deviation of the normal distribution should not exceed 30 percent of the mean value to avoid an unacceptably high probability of erroneously predicting negative values. Truncation of the lower tail of the normal distribution should generally be avoided, because it changes the mean and other statistics of the distribution. Typically, a better alternative to truncation is to find a more appropriate distribution that is a better fit to the data. For example, for positively skewed data that must be non-negative, lognormal, Weibull, or Gamma distributions often can provide an acceptable fit; however, an empirical distribution of the data can also be used;
- Where expert judgement is used, the distribution function adopted might typically be normal or lognormal, supplemented by uniform, triangular, or fractile distributions as appropriate;
- Other distributions may be used where there are compelling reasons, either from empirical observations or from expert judgement supported by theoretical argument.

The issue of identifying which function best fits a set of data can be difficult. One approach is to use the square of the skewness and the kurtosis to look for functional forms that can fit the data (Cullen and Frey, 1999). Kurtosis and skewness should only be applied if there are sufficient data from which to estimate these values. The function is then fitted to the data by least squares fit or other means. Tests are available to assess the goodness-of-fit, including the chi-squared test and others (Cullen and Frey, 1999). In many cases, several functions will fit the data satisfactorily within a given probability limit. These different functions can have radically different distributions at the extremes where there are few or no data to constrain them, and the choice of one function over another can systematically change the outcome of an uncertainty analysis. Cullen and Frey (1999) reiterate the advice of previous authors in these cases that *it must be knowledge of the underlying physical processes that governs the choice of a probability function*. What the tests provide, in the light of this physical knowledge, is guidance on whether this function does or does not satisfactorily fit the data.

In order to use empirical data as a basis for developing PDFs, the first critical step is to determine if the data are a random, representative sample, in the case of a sample from a population. Some key questions to ask regarding the data include:

- Are the data representative of the conditions pertaining to the emission or activity factors specific to national circumstances? For example, in AFOLU, are the data representative of management practices and other national circumstances?
- Are the data a random sample?
- What is the averaging time associated with the data set, and is it the same as for the assessment (which will be for annual emissions in a given year)? For example, emissions data might be measured during a short time period and not for an entire year. Thus, expert judgment may be required in order to extrapolate short term data to a longer term basis.

If the data are a random, representative sample, then the distribution can be established directly using classical statistical techniques, even if the sample size is small. Ideally the available data will represent an annual average but may be necessary to convert data using an appropriate averaging time. For normal distributions the 95 percent confidence interval would be plus or minus twice the estimated standard deviation of the population. In other cases, the data may represent an exhaustive census of the sum of all activity (e.g., total energy use for a particular fuel). In this case, information regarding errors in the measurements or survey instruments would form a basis for assessing uncertainty. The range of uncertainty of activity data might be bounded by using independent methods or consistency checks. For example, fuel consumption data can be compared with estimates of production, including estimates of production via different methods.

There is a distinction between uncertainty in the mean and variability in the data for situations in which the data represent intra-country variability within a category. Since the goal is to estimate annual average emissions at the level of an individual country, data that represent intra-country variability should be averaged over the entire geographic area of the country, and uncertainty in this average should be assessed and used as the basis for the inventory. Conversely, if international data are available at an aggregate level, without supporting details as to how such data can be disaggregated by country, there is a mismatch in scale that is more difficult to correct. Typically, in this case, the uncertainty will tend to increase as the geographic scope decreases, i.e., if the number of categories included decreases and if site-specific emissions data are not available. Thus uncertainty ranges that are developed for aggregated international data may have to be widened for applicability to individual countries. In the absence of any empirical basis for estimating the relative range of uncertainty at the country level versus the aggregated international level, expert judgement can be used.

For a sample of an underlying population, the need is to evaluate whether the data are random and representative of the population. If so, classical statistical methods can be used to define the distribution. If not, then some combination of data analysis and elicitation of expert judgement regarding distributions will be required. In the former case, Cullen and Frey (1999) suggest exploration of the data set using summary statistics and graphics to evaluate essential features (e.g., central tendency, range of variation, skewness). The insights obtained by examining the data, combined with knowledge of the processes that generated the data, should be considered when selecting a mathematical or numerical representation of the distribution for input into Approaches 1 or 2. (See Section 3.2.3.)

If a parametric distribution is selected as a candidate for fitting to the data set, techniques such as 'maximum likelihood estimation[5]' or the 'method of matching moments[6]' can be used to estimate the parameters of the distribution. The goodness-of-fit of the distribution can be evaluated in numerous ways, including comparison of the fitted cumulative distribution function (CDF) with the original data set, probability plots, and goodness-of-fit tests (e.g., Cullen and Frey, 1999). It is important that the selection of a parametric distribution to represent a data set should be based not solely upon goodness-of-fit tests, but upon similarities in processes that generated the data versus the theoretical basis for a distribution (e.g., Hahn and Shapiro, 1967).

If the data are averaged over less than one year, it may be necessary to extrapolate the uncertainty over the year. Consider an example in which the data set represents variability in daily average emissions measurements for a particular category. One approach, described in detail by Frey and Rhodes (1996), is to fit a parametric distribution to the data set for daily variability, use a numerical technique known as bootstrap simulation to estimate uncertainty in the parameters of the distribution, and use Monte Carlo simulation to simulate randomised annual averages of the emission factor. Using bootstrap simulation, the uncertainty in the sampling distribution for the parameters of the fitted distribution can be simulated (e.g., Efron and Tibshirani, 1993; Frey and Rhodes, 1996; Frey and Bammi, 2002).

DEPENDENCE AND CORRELATION AMONG INPUTS

This section provides a brief overview of issues pertaining to dependence and correlation among inputs. More details on this topic can be found in Morgan and Henrion (1990), Cullen and Frey (1999), and Smith *et al*. (1992).

When setting up a probabilistic analysis it is preferable to define the model so that the inputs are as statistically independent as possible. For example, rather than to try to estimate activity data for many subcategories for which data are derived at least in part by differences, it may be better to assign uncertainties to better known aggregate measures of activity. For example, residential fuel use might be estimated as the difference between total consumption and usage in the transportation, industrial, and commercial sectors. In this case, the estimate of uncertainty in residential fuel use is negatively correlated with the uncertainties in fuel use in the other subcategories, and may even be very large compared to the uncertainty in total consumption. Therefore, rather than trying to estimate uncertainties separately for each subcategory, it may be more practical to estimate uncertainty for aggregated categories, for which good estimates and cross-checks may be available.

Dependencies, if they exist, may not always be important to the assessment of uncertainties. Dependencies among inputs will matter only if the dependencies exist between two inputs to which the uncertainty in the inventory is sensitive and if the dependencies are sufficiently strong. In contrast, weak dependencies among inputs, or strong dependencies among inputs to which the uncertainty in the inventory is insensitive, will be of relatively little consequence to the analysis. Of course, some interdependencies are important and failure to account for those relationships can lead to misleading results. Positive correlations between inputs tend to increase the range of uncertainty in the output, whereas negative correlations tend to decrease the range of uncertainty in the output. However, positive correlations in uncertainties when comparing two years as part of trend analysis will decrease uncertainty in the trend.

Techniques can be considered for incorporating dependencies into the analysis including:

- stratifying or aggregating the categories to minimise the effect of the dependencies;

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5 The method of maximum likelihood selects as estimates the values of the parameters that maximise the likelihood of the observed sample (e.g., Holland and Fitz-Simons, 1982).

6 The method of moments finds estimators of unknown parameters by equating corresponding sample and population moments. The method is easy to employ and provides consistent estimators. In many cases, the method of moments estimators are biased (Wackerly, Mendenhall III and Scheaffer, 1996; pp. 395-397).

- modelling the dependence explicitly;
- simulating correlation using restricted pairing methods (that are included in many software packages);
- use of resampling techniques in cases where multivariate datasets are available;
- considering bounding or sensitivity cases (e.g., one case assuming independence and another case assuming complete positive correlation); and
- time series techniques can be used to analyse or simulate temporal autocorrelation.

As a simple example, Zhao and Frey (2004a) evaluated the implications of whether or not emission factor uncertainty estimates for different categories obtained from the same data source should be considered as dependent or independent among the categories, and found that it did not matter to the overall inventory uncertainty. Of course, this result is specific to the particular case studies and should be tested in other applications. As a more complex example, given in Box 3.2, Ogle *et al*. (2003) accounted for dependencies in tillage management factors, which were estimated from a common set of data in a single regression-type model, by determining the covariance[7] between factors for reduced tillage and no-till management, and then using that information to generate tillage factor values with appropriate correlation during a Monte Carlo simulation[8]. One should consider the potential for correlations among input variables and focus on those that would be likely to have the largest dependencies (e.g., applying management factors for the same practice in different years of an inventory, or correlations among management activities from one year to the next).

BOX 3.2
EXAMPLE OF MONTE CARLO UNCERTAINTY ASSESSMENT DEALING WITH CORRELATIONS

Ogle *et al*. (2003) performed a Monte Carlo analysis to assess uncertainty in a Tier 2 inventory that addressed changes in soil C attributed to land use and management of agricultural lands in the United States. Management factors were estimated from about 75 published studies using linear mixed effect models. PDFs were derived for the management effect at a depth of 30 cm following 20 years after its implementation. Reference stocks were estimated using a National Soil Survey Characterisation Database, which contained pedon data collected by United States Department of Agriculture (USDA). PDFs were based on the mean and variance from about 3700 pedons, taking into account the spatial autocorrelation of pedon locations due to clumped distribution patterns. The land use and management activity data were recorded in the USDA National Resources Inventory, which tracks agricultural land management at more than 400,000 point locations in the United States, along with supplemental data on tillage practices provided by the Conservation Technology and Information Center (CTIC). The Monte Carlo analysis was implemented using a commercially available software package and code developed by U.S. analysts. Their analysis accounted for dependencies between estimation parameters that were derived from common datasets. For example factors for set-aside lands and land use change between cultivated and uncultivated conditions were derived from a single regression analysis using an indicator variable for set-asides, and hence were interdependent. Their analysis also accounted for dependencies in the land use and management activity data. When simulating input values, factors were considered completely dependent from the base and current year in the inventory because the relative influence of management on soil C was assumed to be the same regardless of the year when a practice was implemented. As such, factors were simulated with identical random seed values. In contrast, reference carbon stocks for the various soil types in each climate region were simulated independently, with different random seeds, because stocks for each region were constructed from separate independent sets of data. U.S. analysts chose to use 50,000 iterations for their Monte Carlo analysis. This was satisfactory because they were only reporting one digit after the decimal, and simulation results were considered relatively stable at that level of significance. Ogle *et al*. (2003) estimated that mineral soils gained an average of 10.8 Tg C yr^{-1} between 1982 and 1997, with a 95 percent confidence interval ranging from 6.5 to 15.3 Tg C yr^{-1}. In contrast, managed organic soils lost an average of 9.4 Tg C yr^{-1}, ranging from 6.4 to 13.3 Tg C yr^{-1}. Further, Ogle *et al*. (2003) found that the variability in management factors contributed 90 percent of the overall uncertainty for the final estimates of soil carbon change.

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[7] The covariance between two variables (*x* and *y*) measures the mutual dependence between them. The covariance of a sample consisting of *n* pairs of values is the total of the products of the deviation of individual *x* values from the mean *x* value times the deviation of the corresponding individual *y* value from the mean of the *y* values, divided by (*n*-1).

[8] More discussion and examples of these types of methods are given in Cullen and Frey (1999), Morgan and Henrion (1990), and USEPA (1996). These documents also contain reference lists with citations to relevant literature.

3.2.3 Methods to combine uncertainties

Once the uncertainties in activity data, emission factor or emissions for a category have been determined, they may be combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. Results from sampling theory, as described in Section 2.5.1, Measurement-Based Tier 3 Inventories, of Chapter 2 in Volume 4 for the AFOLU Sector, may be used in cases where sampling is applied for direct measurement of, e.g., carbon stock changes. In these situations, sampling theory provides an estimate of the uncertainty in emissions/removals for a given category, without need to separately characterise an activity and emission factor.

Two approaches for the estimation of combined uncertainties are presented in the following sections: Approach 1 uses simple error propagation equations, while Approach 2 uses Monte Carlo or similar techniques. Either Approach may be used for emission sources or sinks, subject to the assumptions and limitations of each Approach and availability of resources. Complementary step by step explanation of the statistical calculation methods of Approaches is given in Sections 3.7.1 and 3.7.2.

Biases should be addressed prior to applying either Approach 1 or 2, as set out in Section 3.2.2.1. For example, as discussed in Section 3.2.2.1, an assessment of bias, and potential disagreements among modelling approaches, should be conducted, and any action identified to improve the inventory estimate should be taken. Approaches 1 and 2 focus on quantifying the random component of the uncertainty of the inventory results where known sources of bias have been removed. The inventory estimates may still include unknown bias and in the analysis all errors are assumed behaving as random (Winiwarter and Rypdal, 2001).

3.2.3.1 APPROACH 1: PROPAGATION OF ERROR

Approach 1 is based upon error propagation and is used to estimate uncertainty in individual categories, in the inventory as a whole, and in trends between a year of interest and a base year. The key assumptions, requirements, and procedures are described here.

Approach 1 should be implemented using Table 3.2, Approach 1 Uncertainty Calculation, that can be set up on commercial spreadsheet software. The table is completed at the category level using uncertainty ranges for activity data and emission factors consistent with the sectoral *good practice guidance*[9]. Different gases should be entered separately as CO_2 equivalents.

KEY ASSUMPTIONS OF APPROACH 1

In Approach 1 uncertainty in emissions or removals can be propagated from uncertainties in the activity data, emission factor and other estimation parameters through the error propagation equation (Mandel, 1984, Bevington and Robinson, 1992). If correlations exist, then either the correlation can be included explicitly or data can be aggregated to an appropriate level such that correlations become less important. Approach 1 also theoretically requires that the standard deviation divided by the mean value is less than 0.3. In practice, however, the approach will give informative results even if this criterion is not strictly met and some correlations remain. Approach 1 assumes that the relative ranges of uncertainty in the emission and activity factors are the same in the base year and in year *t*. This assumption is often correct or approximately correct. If any of the key assumptions of Approach 1 do not apply, then either an alternative version of Approach 1 can be developed (e.g., see Section 3.4) or Approach 2 can be used instead.

Where the standard deviation divided by the mean is greater than 0.3 the reliability of Approach 1 can be improved. The section 'Dealing with Large and Asymmetric Uncertainties in the Results of Approach 1' in this section describes how to do this.

KEY REQUIREMENTS OF APPROACH 1

In order to quantify uncertainty using Approach 1, estimates of the mean and the standard deviation for each input are required, as well as the equation through which all inputs are combined to estimate an output. The simplest equations include statistically independent (uncorrelated) inputs.

9 Where estimates are derived from models, enter the uncertainty associated with the activity data used to drive the model, and enter the uncertainty associated with the model parameters instead of the emission factor uncertainty. It may be necessary to use expert judgement, or error propagation calculations associated with the model structure. If it is impractical to separate the uncertainty estimate obtained from a model for a category into separate activity and emission factor components, then enter the total uncertainty for the category in the emission factor column and assign zero uncertainty to the activity factor column.

Once the uncertainties in the categories have been determined, they may be combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. As discussed further below, these uncertainty estimates can be combined using two convenient rules for combining uncorrelated uncertainties under addition and multiplication.

PROCEDURE OF APPROACH 1

The Approach 1 analysis estimates uncertainties by using the error propagation equation in two steps. First, the Equation 3.1 approximation is used to combine emission factor, activity data and other estimation parameter ranges by category and greenhouse gas. Second, the Equation 3.2 approximation is used to arrive at the overall uncertainty in national emissions and the trend in national emissions between the base year and the current year.

Uncertainty of an Annual Estimate

The error propagation equation[10] yields two convenient rules for combining uncorrelated uncertainties under addition and multiplication:

- Where uncertain quantities are to be combined by multiplication, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added, with the standard deviations all expressed as coefficients of variation, which are the ratios of the standard deviations to the appropriate mean values. This rule is approximate for all random variables. Under typical circumstances this rule is reasonably accurate as long as the coefficient of variation is less than approximately 0.3. This rule is not applicable to division.

  A simple equation (Equation 3.1) can then be derived for the uncertainty of the product, expressed in percentage terms:

EQUATION 3.1
COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

Where:

U_{total} = the percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total and expressed as a percentage);

U_i = the percentage uncertainties associated with each of the quantities.

- Where uncertain quantities are to be combined by addition or subtraction, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms (this rule is exact for uncorrelated variables).

  Using this interpretation, a simple equation (Equation 3.2) can be derived for the uncertainty of the sum, expressed in percentage terms:

EQUATION 3.2
COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + \ldots + (U_n \bullet x_n)^2}}{\left| x_1 + x_2 + \ldots + x_n \right|}$$

Where:

U_{total} = the percentage uncertainty in the sum of the quantities (half the 95 percent confidence interval divided by the total (i.e., mean) and expressed as a percentage). This term 'uncertainty' is thus based upon the 95 percent confidence interval;

x_i and U_i = the uncertain quantities and the percentage uncertainties associated with them, respectively.

The greenhouse gas inventory is principally the sum of products of emission factors, activity data and other estimation parameters. Therefore, Equations 3.1 and 3.2 can be used repeatedly to estimate the uncertainty of the

[10] As discussed more extensively in Annex 1 of the *Good Practice Guidance and Uncertainty Management* (*GPG2000*, IPCC, 2000), and in Annex I of the *Revised 1996 IPCC Guidelines* (Reporting Instructions) (*1996 IPCC Guidelines*, IPCC, 1997).

total inventory. In practice, uncertainties found in inventory categories vary from a few percent to orders of magnitude, and may be correlated. This is not consistent with the assumptions of Equations 3.1 and 3.2 that the variables are uncorrelated, and with the assumption of Equation 3.2 that the coefficient of variation is less than about 30 percent, but under these circumstances, Equations 3.1 and 3.2 may still be used to obtain an approximate result.

Uncertainty in the Trend

Trend uncertainties are estimated using two sensitivities:

- *Type A sensitivity*: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1 percent increase in emissions or removals of a given category and gas in both the base year and the current year.
- *Type B sensitivity*: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1 percent increase in emissions or removals of a given category and gas in the current year only.

The Type A and Type B sensitivities are merely intermediate variables that simplify the calculation procedure. The results of the analysis are not constrained to a change of only one percent, but instead depend upon the range of uncertainty for each category.

Conceptually, Type A sensitivity arises from uncertainties that affect emissions or removals in the base year and the current year equally, and Type B sensitivity arises from uncertainties that affect emissions or removals in the current year only. Uncertainties that are fully correlated between years will be associated with Type A sensitivities, and uncertainties that are not correlated between years will be associated with Type B sensitivities. Emission factor (and other estimation parameters) uncertainties will tend to have Type A sensitivities, and activity data uncertainties will tend to have Type B. However, this association will not always hold and it is possible to apply Type A sensitivities to activity data, and Type B sensitivities to emission factors to reflect particular national circumstances. Type A and Type B sensitivities are simplifications introduced for the approximate analysis of correlation.

Once the uncertainties introduced into the national inventory by Type A and Type B sensitivities have been calculated, they can be summed using the error propagation equation (Equation 3.1) to give the overall uncertainty in the trend.

Worksheet for Approach 1 Uncertainty Calculation

The columns of Table 3.2, Approach 1 Uncertainty Calculation, are labelled A to M and contain the following information, of which the derivation of key equations is given in Section 3.7.1 in Section 3.7, Technical Background Information.

- A and B show the IPCC category and greenhouse gas.
- C and D are the inventory estimates in the base year and the current year[11] respectively, for the category and gas specified in Columns A and B, expressed in CO_2 equivalents.
- E and F contain the uncertainties for the activity data and emission factors respectively, derived from a mixture of empirical data and expert judgement as previously described in this chapter, entered as half the 95 percent confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95 percent confidence interval is that the value entered in Columns E and F corresponds to the familiar plus or minus value when uncertainties are loosely quoted as ‘plus or minus *x* percent’, so expert judgements of this type can be directly entered in the spreadsheet. If uncertainty is known to be highly asymmetrical, enter the larger percentage difference between the mean and the confidence limit.
- G is the combined uncertainty by category derived from the data in Columns E and F using the error propagation equation (Equation 3.2). The entry in Column G is therefore the square root of the sum of the squares of the entries in Columns E and F.
- H shows the uncertainty in Column G as a percentage of total national emissions in the current year. The entry in each row of Column H is the square of the entry in Column G multiplied by the square of the entry in Column D, divided by the square of total at the foot of Column D. The value at the foot of Column H is an estimate of the percentage uncertainty in total national net emissions in the current year, calculated from the entries above using Equation 3.1. This total is obtained by summing the entries in Column H and taking the square root.

[11] The current year is the most recent year for which inventory data are available.

- I shows how the percentage difference in emissions between the base year and the current year changes in response to a one percent increase in category emissions/removals for both the base year and the current year. This shows the sensitivity of the trend in emissions to a systematic uncertainty in the estimate (i.e., one that is correlated between the base year and the current year). This is the Type A sensitivity as defined above.
- J shows how the percentage difference in emissions between the base year and the current year changes in response to a one percent increase in category emissions/removals in the current year only. This shows the sensitivity of the trend in emissions to random error in the estimate (i.e., one, that is not correlated, between the base year and the current year). This is the Type B sensitivity as described above.
- K uses the information in Columns I and F to show the uncertainty introduced into the trend in emissions by emission factor uncertainty, under the assumption that uncertainty in emission factors is correlated between years. If the user decides that the emission factor uncertainties are not correlated between years then the entry in Column J should be used in place of that in Column I and the result multiplied by $\sqrt{2}$.
- L uses the information in Columns J and E to show the uncertainty introduced into the trend in emissions by activity data uncertainty, under the assumption that uncertainty in activity data is not correlated between years. If the user decides that the activity data uncertainties are correlated between years then the entry in Column I should be used in place of that in Column J and the $\sqrt{2}$ factor does not then apply.
- M is an estimate of the uncertainty introduced into the trend in national emissions by the category in question. Under Approach 1, this is derived from the data in Columns K and L using Equation 3.2. The entry in Column M is therefore the sum of the squares of the entries in Columns K and L. The total at the foot of this column is an estimate of the total uncertainty in the trend, calculated from the entries above using the error propagation equation. This total is obtained by summing the entries in Column M and taking the square root. The uncertainty in the trend is a *percentage point* range relative to the inventory trend. For example, if the current year emissions are 10 percent greater than the base year emissions, and if the trend uncertainty at the foot of Column M is reported as 5 percent, then the trend uncertainty is 10%±5% (or from 5% to 15% increase) for the current year emissions relative to the base year emissions.
- Explanatory footnotes go at the bottom of the table and give documentary references of uncertainty data (including measured data) or other relevant comments.

An example of the spreadsheet with all the numerical data completed is provided in Section 3.6, Approach 1 uncertainty calculation example. Details of this approach are given in Section 3.7.1 and derivation of the uncertainty in the trend is in Section 3.7.2.

TABLE 3.2
APPROACH 1 UNCERTAINTY CALCULATION

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year *t*	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data Note A	Input data Note A	$\sqrt{E^2 + F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\left\lvert \frac{D}{\sum C} \right\rvert$	$I \bullet F$ Note C	$J \bullet E \bullet \sqrt{2}$ Note D	$K^2 + L^2$
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
E.g., 1.A.1. Energy Industries Fuel 1	CO_2											
E.g., 1.A.1. Energy Industries Fuel 2	CO_2											
Etc...	…											
Total		$\sum C$	$\sum D$				$\sum H$					$\sum M$
					Percentage uncertainty in total inventory:		$\sqrt{\sum H}$				Trend uncertainty:	$\sqrt{\sum M}$

Note A: If only total uncertainty is known for a category (not for emission factor and activity data separately), then:

- If uncertainty is correlated across years, enter the uncertainty into Column F, and enter 0 in Column E;
- If uncertainty is not correlated across years, enter the uncertainty into Column E, and enter 0 in Column F

Note B: Absolute value of: $$\frac{0.01 \bullet D_x + \sum D_i - (0.01 \bullet C_x + \sum C_i)}{(0.01 \bullet C_x + \sum C_i)} \bullet 100 - \frac{\sum D_i - \sum C_i}{\sum C_i} \bullet 100$$

Where:

C_x, D_x = entry from row x of the table from the corresponding column, representing a specific category

$\sum C_i$, $\sum D_i$ = Sum over all categories (rows) of the inventory of the corresponding column

Note C: In the case where no correlation between emission factors is assumed, sensitivity B should be used and the result multiplied by √2:

$$K_x = J_x \bullet F_x \bullet \sqrt{2}$$

Note D: In the case where correlation between activity data is assumed, sensitivity A should be used and the √2 is not required:

$$L_x = I_x \bullet E_x$$

DEALING WITH LARGE AND ASSYMMETRIC UNCERTAINTIES

Section 3.7.3 provides details on how the results from Approach 1 can be interpreted if the relative range of uncertainty is large for a quantity that must be non-negative. The error propagation method that is the basis for Approach 1 works well if the uncertainties are relatively small, meaning that the standard deviation divided by the mean is less than 0.3. If the uncertainties are larger, Approach 1 may continue to be used, providing informative results. However without any corrections, this approach will tend to underestimate uncertainty of the multiplicative (or quotient) terms. Furthermore, if the relative uncertainties are large for non-negative quantities, then the uncertainty ranges are typically asymmetric, and Approach 1 does not quantify such asymmetry. A second option is to use Approach 2, however this may not be always feasible. A third option is to use Approach 1 with corrections. For example, as discussed in more detail later in Section 3.7.3, an uncertainty of -65% to +126% relative to the mean might be estimated to be simply plus or minus 100 percent. This example can be properly addressed with some corrections to the results of Approach 1. The advantage of using the correction applied to Approach 1 (where applicable), rather than Approach 2, is that relatively simple spreadsheet-based calculation methods can be used and it is not necessary to use specialised Monte Carlo simulation software.

3.2.3.2 APPROACH 2: MONTE CARLO SIMULATION

The Monte Carlo analysis is suitable for detailed category-by-category assessment of uncertainty, particularly where uncertainties are large, distribution is non-normal, the algorithms are complex functions and/or there are correlations between some of the activity sets, emissions factors, or both.

In Monte Carlo simulation, pseudo-random samples of model inputs are generated according to the PDFs specified for each input. The samples are referred to as 'pseudo-random' because they are generated by an algorithm, referred to as a pseudo-random number generator (PRNG), that can provide a reproducible series of numbers (according to the random seeds assigned as input to the PRNG) but for which any series has properties of randomness. Details are available elsewhere (e.g., Barry, 1996). If the model has two or more inputs, then random samples are generated from the PDFs for each of the inputs, and one random value for each input is entered into the model to arrive at one estimate of the model output. This process is repeated over a desired number of iterations to arrive at multiple estimates of the model output. The multiple estimates are sample values of the PDF of the model output. By analyzing the samples of the PDF for the model output, the mean, standard deviation, 95 percent confidence interval, and other properties of the output PDF can be inferred. Because Monte

Carlo simulation is a numerical method, the precision of the results typically improves as the number of iterations is increased. More details regarding the methodology of Monte Carlo simulation, as well as regarding similar techniques such as Latin Hypercube sampling (LHS), are given by Hahn and Shapiro (1967); Ang and Tang (1984); and Morgan and Henrion (1990).

KEY ASSUMPTIONS OF APPROACH 2

Under Approach 2, the simplifying assumptions required for Approach 1 can be relaxed. Thus, numerical statistical techniques, particularly the Monte Carlo technique, as they can be generally applied, are more appropriate than Approach 1 for estimating uncertainty in emissions/removals (from uncertainties in activity measures and emission factors/estimation parameters) when:

- uncertainties are large;
- their distribution are non-Gaussian;
- algorithms are complex functions;
- correlations occur between some of the activity data sets, emission factors, or both;
- uncertainties are different for different years of the inventory.

KEY REQUIREMENTS OF APPROACH 2

Monte Carlo simulation requires the analyst to specify PDFs (see Fishman, 1996) that reasonably represent each model input for which the uncertainty is quantified. The PDFs may be obtained by a variety of methods, as described in Section 3.2.2.4 including statistical analysis of data or expert elicitation. A key consideration is to develop the distributions for the input variables to the emission/removal calculation model so that they are based upon consistent underlying assumptions regarding averaging time, location, and other conditioning factors relevant to the particular assessment (e.g., climatic conditions influencing agricultural greenhouse gas emissions).

Monte Carlo analysis can deal with probability density functions of any physically possible shape and width, as well as handling varying degrees of correlation (both in time and between source/sink categories). Monte Carlo analysis can deal with simple models (e.g., emission inventories that are the sum of sources and sinks, each of which is estimated using multiplicative factors) as well as more complex models (e.g., the first order decay for CH_4 from landfills).

PROCEDURES OF APPROACH 2

The principle of Monte Carlo analysis is to select random values of emission factor, activity data and other estimation parameters from within their individual probability density functions, and to calculate the corresponding emission values. This procedure is repeated many times, using a computer, and the results of each calculation run build up the overall emission probability density function. Monte Carlo analysis can be performed at the category level, for aggregations of categories or for the inventory as a whole. Statistical software packages are readily available – some of which include Monte Carlo algorithms that are very user-friendly[12].

Like all methods, Monte Carlo analysis only provides satisfactory results if it is properly implemented. This requires the analyst to have scientific and technical understanding of the inventory. Of course, the results will only be valid to the extent that the input data, including any expert judgements, are sound.

The Monte Carlo approach consists of four clearly defined steps shown in Figure 3.7. Only the first of these requires effort from the user, the remainder being handled by the software package. The emission inventory calculation, the PDFs, and the correlation values should be set up in the Monte Carlo package. The software performs the subsequent steps. In some cases, the inventory compiler may decide to set up its own programme to run a Monte Carlo simulation; this can be done using statistical software. The Section, 'Choosing a simulation technique and sample size' below contains a short discussion of various software packages.

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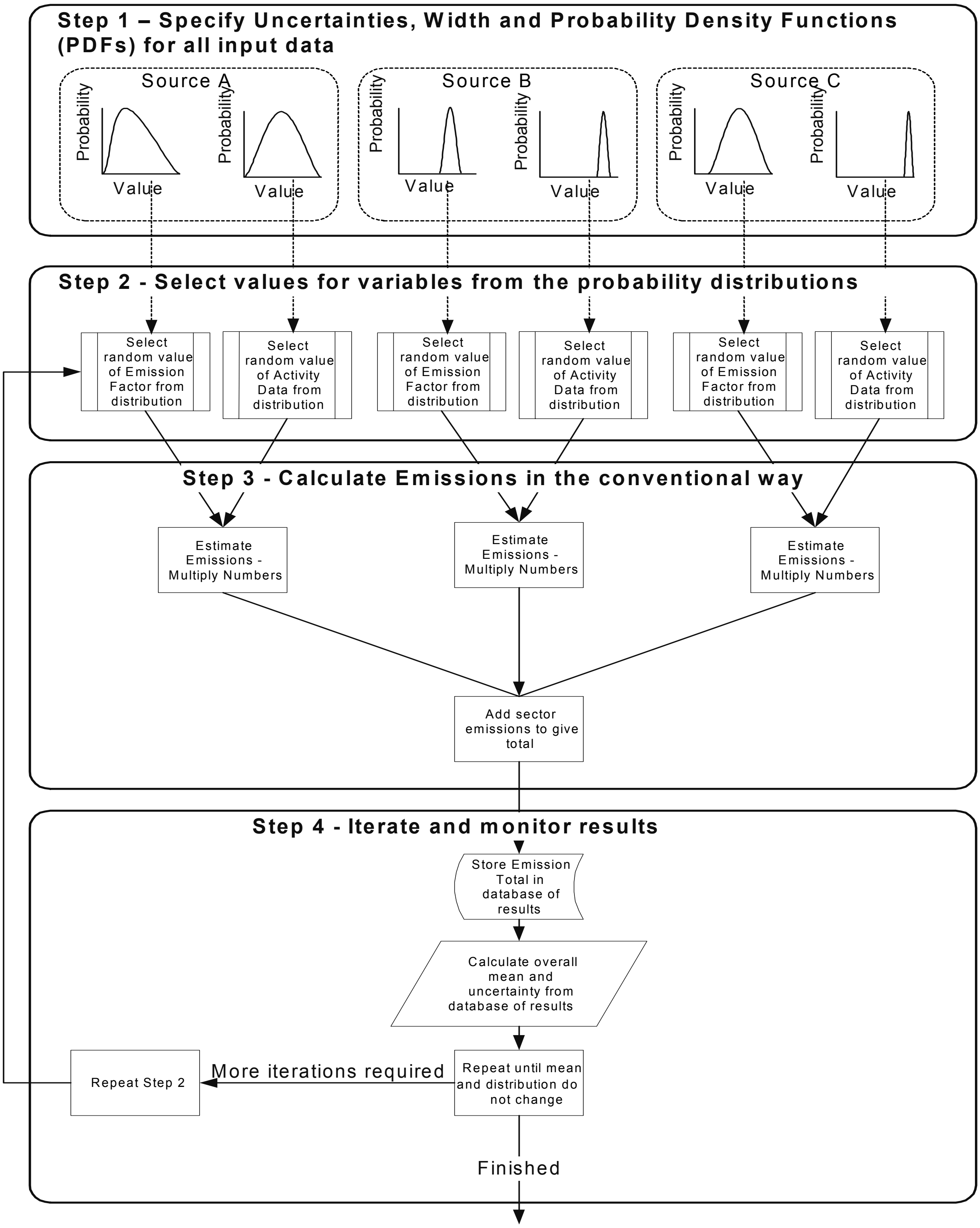
[12] Winiwarter and Rypdal (2001), Eggleston *et al*. (1998) and Monni et al. (2004) provide examples of Monte Carlo analysis applied to national greenhouse gas inventories to estimate uncertainties both in overall emissions and emissions trends. Another example of the use of Monte Carlo analysis is given in McCann *et al*. (1994). More detailed descriptions and applications of this method are presented in Bevington and Robinson (1992), Manly (1997), Morgan and Henrion (1990), and Cullen and Frey (1999). A brief example of the application of Monte Carlo analysis is provided in Box 3.2 based on Ogle *et al*. (2003).

Figure 3.6 Illustration of Monte Carlo method



Step 1: Specify category uncertainties. This includes estimation parameters and activity data, their associated means and PDFs, and any correlations. The uncertainties can be assessed following the guidance in Sections 3.2.1 and 3.2.2. For guidance on assessment of correlations, see 'Dependence and correlation among inputs' in this section and Box 3.2.

Step 2: Select random variables. Select input values. Input values are the estimates applied in the inventory calculation. This is the start of the iterations. For each input data item, a number is randomly selected from the PDF of that variable.

Step 3: Estimate emissions and removals. The variables selected in Step 2 are used to estimate annual emissions and removals based on input values. Correlations of 100 percent are easy to incorporate, and good Monte Carlo packages allow other correlations to be included. Since the emission calculations should be the same as those used to estimate the national inventory, the Monte Carlo process could be fully integrated into the annual emission estimates.

Step 4: Iterate and monitor results. Iterate and monitor results. The calculated total from Step 3 is stored, and the process then repeats from Step 2. The results from the repetitions are used to calculate the mean and the PDF.

APPROACH 2 UNCERTAINTIES IN TRENDS

The Approach 2 Monte Carlo method can be used to estimate uncertainties in the trend as well as in the absolute emission value in a given year. The procedure is a simple extension of that described in the previous section.

The trend is defined here as the percentage difference[13] between the base year and the year of interest (year *t*). Therefore, the Monte Carlo analysis needs to be set up to estimate both years simultaneously. The following steps show the procedure.

Step 1: Specify source/sink category uncertainties. Determine the probability density functions for emission factors, activity data and other estimation parameters. This is the same process as described above except that it needs to be done for both the base year and the current year, and relationships between the data need to be considered. For many categories, the same emission factor will be used for each year (i.e., the emission factors for both years are 100 percent correlated). In these cases, one distribution is described and the value selected from it is used for each year in step 3. Changes in the technologies or practices will alter the emission factor over time. In this case, two emission factors should be used, that have a lower or zero correlation. If the emission factors contain a random element or vary unpredictably from year to year, then separate emission factors should also be used (e.g., with fossil fuel carbon content that can change according to the market supply of the fuel and also contains its own uncertainty). Generally, uncertainty in activity data are assumed to be uncorrelated between years, and so two distributions should be input, even if their parameters are the same, so that two different random selections from these distributions will be generated in step 3. The computer package used may well enable other correlations to be set up and these capabilities could be used if sufficient information is available. However, this will probably be necessary in only a few cases.

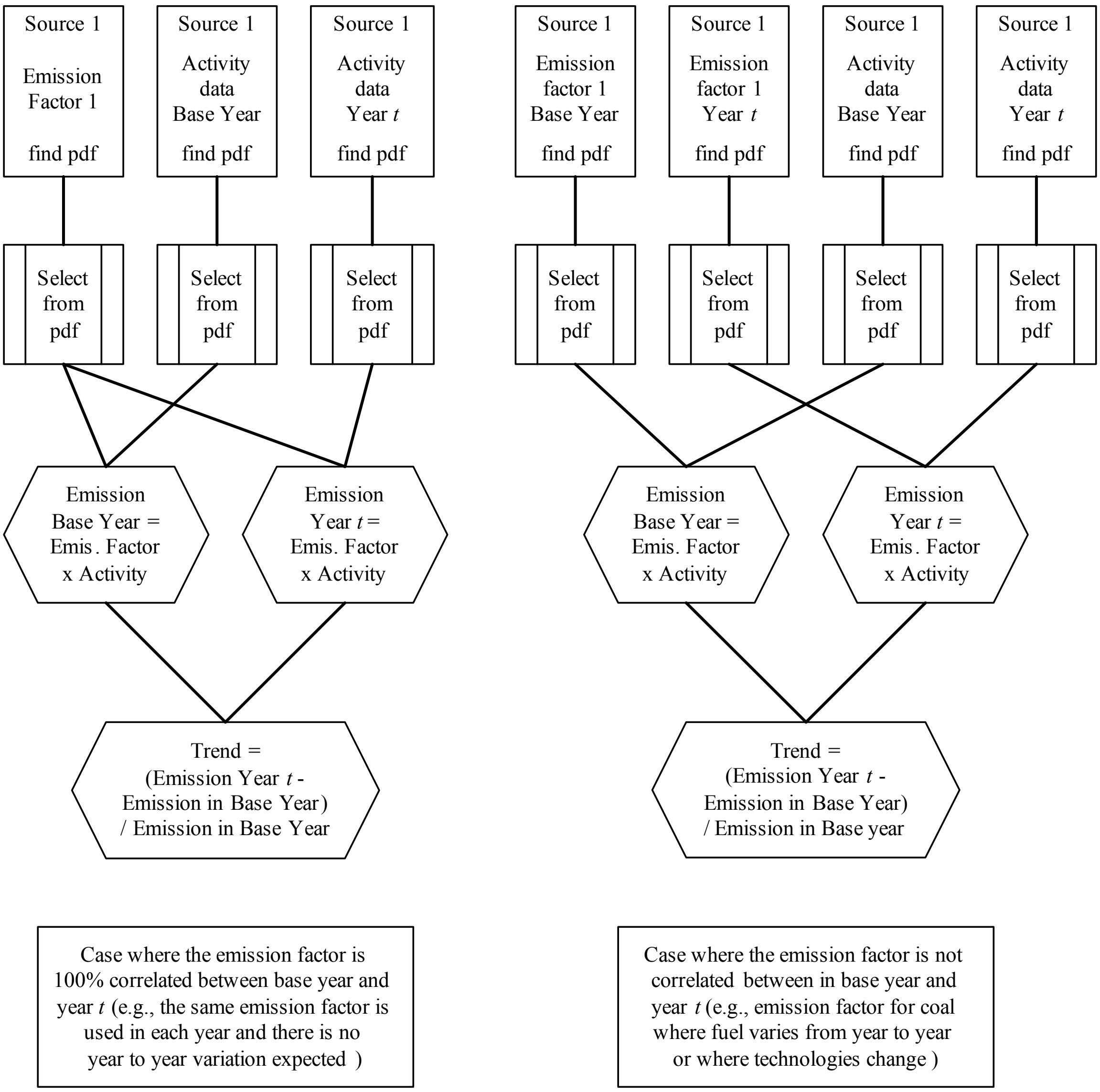
Step 2: Select random variables. The computer program will proceed as previously described, taking into account of any correlation between probability density functions (PDF). Figure 3.7, below, shows the calculation scheme for trend analysis.

Step 3: Estimate Emissions. As in the previous description, the variables selected in Step 2 will be used to estimate the total emissions.

Step 4: Results. The emissions total calculated in Step 3 is stored in a data file. The process then repeats from Step 2 until there is adequate convergence of the results. Considerations for this are the same as described above. A range of results is estimated at the same time including total and sectoral emissions/removals for the base year, total and sectoral emissions/removals for year *t*, and the percentage differences (trends) between these for the total and any sectors of interest.

[13] percentage difference = (value in year *t* - value in base year) / value in base year

Figure 3.7 Calculation scheme for Monte Carlo analysis of the absolute emissions and the trend of a single category, estimated as emission factor times an activity rate



CHOOSING A SIMULATION TECHNIQUE AND SAMPLE SIZE

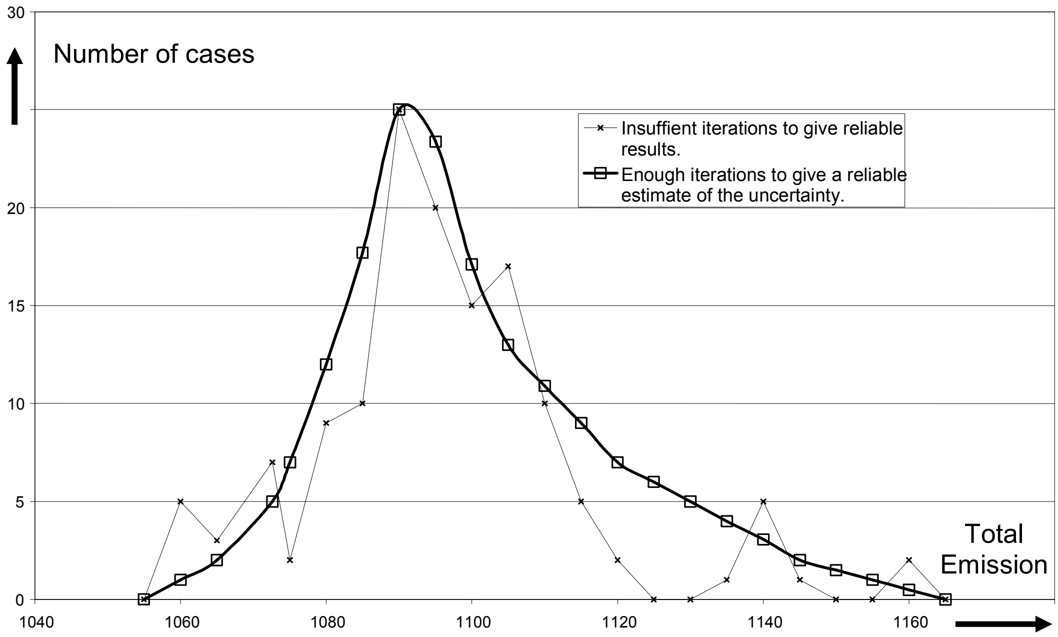
Several commercially available software tools can be used to perform Monte Carlo simulation. These tools can be stand-alone or used as add-ins to commonly used spreadsheet programs. Many software tools offer an option of different sampling methods, including random Monte Carlo simulation and variations of Latin Hypercube Sampling (LHS), which can produce 'smoother' looking model output distributions for sample sizes of only a few hundred samples. The disadvantage of using LHS is that one must decide ahead of time how many iterations to use. This is because two or more LHS simulations cannot be combined since they will use overlapping strata, leading to difficulties in interpreting results. In some cases, LHS can yield underestimates of the higher moments of PDFs, since the stratification method also can preclude clustering of very high or low values as can occur in random data sets. The overall suggestion is to use random Monte Carlo simulation as the default method, because it will give flexibility to continue a random simulation to larger and larger simulation sample sizes if necessary until the model output distribution converges[14] .

[14] Cullen and Frey (1999) provide more information on the comparison of LHS and Monte Carlo simulation (pp. 207-213).

The number of iterations can be determined either by setting the number of model runs, a priori, such as 10,000 and allowing the simulation to continue until reaching the set number, or by allowing the mean to reach a relatively stable point before terminating the simulation. For example, when the estimate for the 95 percent confidence range is determined to within ± 1%, then an adequately stable result has been found. This can be checked by plotting a frequency plot of the estimates of the emission. This plot should be reasonably smooth (see Figure 3.8).

Another alternative is to assess the precision of the current number of replicates based on the standard errors of the percentiles that were used to construct 95 percent confidence intervals. If the range of the confidence intervals for each percentile (2.5 and 97.5) is less than the reported precision, then the number of iterations should be adequate (e.g., emissions are reported values to a single digit after the decimal and the percentile confidence intervals are less than 0.1, such as 0.005). Therefore, the Monte Carlo percentile estimates are unlikely to change in the reported digits for other simulations with the same number of iterations.

Figure 3.8 Example frequency plots of the results of a Monte Carlo simulation



3.2.3.3 HYBRID COMBINATIONS OF APPROACHES 1 AND 2

For some inventories, it may be possible to use Approach 1 for most but not all of the source and sink categories. For example, many sources and sinks can be quantified using emission factors and activity data, but for some it is necessary to use a model or a more complex calculation procedure. Furthermore, dependencies may be important for some categories but not others, or the range of uncertainties may be large for some categories and not others. For these cases, a Monte Carlo-based method is more flexible and would typically produce better results.

If an inventory compiler has completed Approach 2 for only a subset of categories, the results can be combined with Approach 1 to produce an estimate of the uncertainty in national total emissions and the trend. This can be achieved by entering information at a disaggregated level, if correlations do not prevent doing so, into Approach 1. If there are significant correlations among a subset of categories, then the subset could be treated individually in Approach 2 but as an aggregation of categories in Approach 1. In the latter case, total emissions for the aggregation of the subset in the base year and in year *t* is entered in Columns C and D of the Approach 1 table. The results of the Approach 2 analysis for the uncertainty in total emissions in year *t* will be entered in Column G, and the results of the Approach 2 analysis for the contribution to the trend in national total emissions will be entered in Column M. The uncertainty contributions of the affected categories can be combined with those of other categories using the error propagation rules of Approach 1.

In some cases, most of the category uncertainties in an inventory might be estimated using Approach 2, with relatively few estimated using Approach 1. It is possible to incorporate Approach 1 estimates of uncertainty for some categories into an Approach 2 methodology for combining uncertainties for the total inventory. This is done by using the uncertainty half-range obtained from Approach 1 to specify an appropriate PDF model to represent uncertainty for each category as part of the Monte Carlo simulation. Typically, a normal distribution would be a reasonable choice if the uncertainty range is small enough and a lognormal distribution is often appropriate if the uncertainty range is large. See also the section of 'Dealing with Large and Asymmetric Uncertainties in the Results of Approach 1' in Section 3.2.3.1 for more discussion of normal versus lognormal distribution assumptions.

3.2.3.4 COMPARISON BETWEEN APPROACHES

Two Approaches for uncertainty analysis have been presented:

- *Approach 1*: Estimation of uncertainties by category using Equations 3.1 and 3.2, and simple combination of uncertainties by category to estimate overall uncertainty for one year and the uncertainty in the trend.
- *Approach 2*: Estimation of uncertainties by category using Monte Carlo analysis, followed by the use of Monte Carlo techniques to estimate overall uncertainty for one year and the uncertainty in the trend.

Monte Carlo analysis can also be used in a restricted way within Approach 1 to combine activity data and emission factor uncertainties that have very wide or non-normal PDFs or both. This approach can also help deal with categories within Approach 1 that are estimated by process models, rather than by the classical 'emission factor times activity data' calculation. The choice between Approaches is discussed in Section 3.2.3.5 below.

Use of either Approach will provide insight into how individual categories and greenhouse gases contribute to uncertainty in total emissions in any year and to the emissions trend over time.

Application of Approach 2 to the UK inventory (Baggott *et al.*, 2005) suggests that the 95 percent confidence interval is asymmetric and lies between about 6 percent below and 17 percent above the mean estimated value in 2003. The result for the UK takes into account the large relative range of uncertainty for N_2O flux from soils as well as the large contribution to total emissions from fossil fuel combustion. Application of Approach 1 to the same inventory suggests an uncertainty of about ±17%. On the trend, between 1990 and 2003, UK total net emissions in CO_2 equivalent are estimated to have fallen by 13 percent. Application of the Approach 2 suggests that 95 percent confidence interval is roughly symmetrical and lies between -11% and -16%. The corresponding Approach 1 result gives a range of about ±2% (i.e., -11% to -15%). So both methods give similar magnitudes in the trend uncertainty.

In the case of Finland, as shown in Section 3.6, year 2003 uncertainty (including both sources and sinks of greenhouse gases) was -14 to +15% according to Approach 2, and ±16% with Approach 1. For Finland, carbon stock changes in the AFOLU Sector are the dominant sources of uncertainty, while fossil fuels contribute the largest share to total emissions. Since the approximations inherent in Approach 1 mean that it cannot deal with asymmetry, this comparison is encouraging. Physically, the reason for the asymmetry identified under Approach 2 is that the uncertainty range of some very uncertain categories is constrained by the knowledge that the emissions cannot be less than zero. The Approach 2 method can make use of this extra knowledge, but the Approach 1 method cannot. In case of trend from 1990 to 2003 the uncertainty in Finland was -18 to +23% (percentage points) with Approach 2 and ±19% (percentage points) with Approach 1.

A separate evaluation of Approach 1 and Approach 2 for case studies based on synthetic inventory data revealed excellent agreement when the same set of input assumptions were used and when uncertainties were relatively small (Frey, 2005). For example, in a case study for which Approach 1 produced an estimate of ±6% in the current year inventory, and ±10% in the trend (in terms of percentage points relative to the mean percentage change), results from Approach 2 for the same input assumptions produced essentially the same result. When the uncertainty ranges were doubled for the emission factors and activity data, the uncertainty in the base estimates continued to agree well for Approach 1 and Approach 2, at approximately ±13% of the mean total emissions. The uncertainty in the trend was approximately ±20% (percentage points) in both cases. However, the uncertainty in the trend was slightly asymmetric in the Approach 2 result, at -19% to +22%. Thus, as the ranges of uncertainty increase, it is expected that Approach 2 will more appropriately characterise the range and skewness of uncertainties than Approach 1.

Although Approaches 1 and 2 focus on propagation of the random component of uncertainty through a model, it is *good practice* to combine methods for dealing with model uncertainty with either of the Approaches. An example of how to deal with model uncertainty in the context of Tier 3 is given in Box 3.3.

Furthermore, although Approach 1 is based upon key simplifying assumptions, it is possible to increase the flexibility of this approach by increasing the complexity of the error propagation equations. For example, error propagation equations that contain additional terms can more accurately propagate uncertainty for multiplicative and quotient models and when uncertainties are skewed.

BOX 3.3
DEALING WITH MODEL UNCERTAINTY IN A PROBABILISTIC ANALYSIS

A Tier 3 modelling approach is designed for flexibility so that a national inventory can be conducted using a more highly refined model representing national circumstances than in Tier 1 or 2. In particular, it is *good practice* to address uncertainties attributed to model inputs and structure. Input uncertainty deals with activity data and possibly other ancillary information that is needed to describe the environmental setting, such as climate and soil characteristics in an inventory for the AFOLU Sector. Uncertainty in model structure is attributed to imperfect algorithms and parameterisation. Empirically-based approaches are commonly used for assessing structural uncertainties (Monte *et al.* 1996). This approach involves comparing modelled emissions estimates with measurements from experiments or a national monitoring network, which was designed for validation of model-based inventories, addressing both the bias and variance in modelled values (Falloon and Smith 2003).

A statistically-derived relationship may be used to quantify uncertainties in model structural error for a Tier 3 inventory, addressing imprecision based on the estimated variance, or a similar measure such as the Root Mean Squared Error, while also dealing with biases based on statistically significant differences between modelled and measured values (Falloon and Smith 2003). In practice, modelled emissions would be adjusted for biases to more accurately represent emissions for reporting purposes. Further, a statistically-derived relationship would yield a measure of variance for each condition that would be associated with the modelled values, similar to uncertainties attributed to emission factors in Tier 1 and 2 approaches. To complete the assessment, uncertainties in model inputs, such as activity data, would be combined with model structural uncertainty using error propagation equations or a Monte Carlo approach.

3.2.3.5 GUIDANCE ON CHOICE OF APPROACH

Where the conditions for applicability are met (relatively low uncertainty, no correlation between sources except those dealt with explicitly by Approach 1), Approach 1 and Approach 2 will give identical results. However, and perhaps paradoxically, these conditions are most likely to be satisfied where Tier 2 and Tier 3 methods are widely used and properly applied in the inventory, because these methods should give the most accurate and perhaps also the most precise results. There is therefore no direct theoretical connection between choice of Approach and choice of Tier. In practice, when Tier 1 methods are applied, Approach 1 will usually be used while the ability to apply Approach 2 is more likely where Tier 2 and 3 methods are being used, moreover for quantifying the uncertainty of emissions/removal estimates of complex systems such as in the AFOLU Sector.

When Approach 2 is selected, as part of QA/QC activities inventory agencies also are encouraged to apply Approach 1 because of the insights it provides and because it will not require a significant amount of additional work. Where Approach 2 is used, its estimates of overall uncertainty are to be preferred when reporting uncertainties (see Section 3.2.3.3).

3.3 UNCERTAINTY AND TEMPORAL AUTOCORRELATION

Where emission factors, sources of activity data or estimation methods vary within a time series the associated sources of uncertainty may also change. Approach 2 can take explicit account of this when setting up the component PDFs. In Approach 1 the current percentage uncertainties should be entered in the table, and in cases where changes throughout the time series mean that the assumption of good correlation of uncertainty in emission factors between years is no longer valid, Type A sensitivity should be used in place of Type B. If annual data are autocorrelated, then there will typically be less difference when comparing two years than if they are not autocorrelated, assuming that the autocorrelation is positive.

The issue of 'time series' can refer to inter-annual comparison of emissions in a Year *t* versus a base year, as has been set forth in Table 3.2 and the general reporting table given in Table 3.3, or it can refer to a broader set of statistical methodologies for taking into account temporal autocorrelation. With regard to the latter interpretation, statistical time series techniques can be used to more accurately take into account temporal autocorrelations in order to reduce the estimate of uncertainty. For example, if emissions vary on a short term basis, such as for power plant emissions, the emissions at a given time period often depend on what the emissions were in the immediately preceding time periods as well as on the emissions at previous points in a cycle. For example, a power plant may require some amount of time in order to achieve a significant change in load. Thus, the emissions in a current hour are constrained somewhat depending on what emissions were in the previous hour. Furthermore, a power plant may respond to daily fluctuations in load, which are similar from one day to the next. Thus, the emissions at a given hour of the day may be correlated to those at a given hour of a preceding day. Likewise, there can be longer-term seasonal cycles, such as from one year to the next, that might induce a temporal correlation. Statistical time series methods can be fit to an adequate sample of empirical data in order to explain these temporal correlations. The unexplained portion of the model response is referred to as a random or white noise term. The white noise term is an indication of uncertainty in the ability to predict the emissions output. A detailed example of the application of time series models to emissions estimation is given by Abdel-Aziz and Frey (2003).

3.4 USE OF OTHER APPROPRIATE TECHNIQUES

The guidance offered here is not meant to preclude the use of other improved methods. For example, in applying Approach 1, an inventory compiler may wish to derive a similar approach from the generalised error propagation equations in order to account for more complex correlations or for differences in ranges of uncertainty in year *t* versus the base year. Such improvements are consistent with *good practice* as long as they are appropriately documented and justified. Furthermore, this document does not cover all situations that may be faced by an analyst. Therefore, the inventory compiler is encouraged to refer to the references cited in the end of the chapter for additional suggestions on how to perform uncertainty analyses.

3.5 REPORTING AND DOCUMENTATION

A great deal of effort can be expended in collecting information and data for a quantified uncertainty assessment and implementing a model to combine uncertainties across parameters, categories, and the entire inventory. However, all that effort can result in little benefit to a country's inventory if steps are not also taken to report and document the findings of an uncertainty assessment so that they can lead to real improvements in the quality of data collected and the inventory as a whole. The integration of a country's uncertainty assessment efforts with the implementation of data quality investigations within its QA/QC system can help solve this problem.

Given the large number of inputs and assumptions needed to document an uncertainty analysis, it is not feasible to report all information. The information reported should be sufficient to provide the key assumptions, choice of methods and detailed results. Overall, documentation should be sufficient to support the estimates and enable duplication of the uncertainty estimates. In particular, the documentation should touch upon the following issues (as they pertain to a particular variable):

- Which causes of uncertainty are addressed (see Table 3.1).
- Which methods for addressing uncertainty were used (see Table 3.1).
- What is the source of any data or models that were used as the basis for estimating uncertainty.
- For an estimate of bias, explain what is the magnitude of the error expressed on a relative or absolute basis as appropriate (specify which and give proper units).
- If uncertainty was estimated based upon data, explain how uncertainty was distinguished from variability and how the appropriate geographic extent, averaging time (e.g., annual), and other representativeness considerations were addressed in selecting and analyzing data. Provide a brief summary of the data itself, including the mean, sample standard deviation, and sample size. Provide additional detail as appropriate if data were stratified or contain other components of uncertainty (e.g., precision and accuracy of measurement methods used to obtain the data).
- For an estimate of random error in the form of a range or a distribution, provide sufficient information to uniquely specify the range (e.g., plus or minus percentage variation relative to the mean, or parameters of a PDF).

- For estimates of uncertainty based upon expert judgement, the following information should be documented and archived:
  - (i) reference number for judgement;
  - (ii) date;
  - (iii) name of expert(s) involved;
  - (iv) experts' background (references, roles, etc.);
  - (v) the variable being judged;
  - (vi) the logical basis for judgement, including any data taken into consideration. This should include the rationale for the high end, low end, and central tendency of the distribution;
  - (vii) the resultant PDF, or the range and most likely value and the PDF subsequently inferred;
  - (viii) identification of any external reviewers;
  - (ix) results of any external review;
  - (x) approval by inventory compiler, specifying date and person.
- Explanation of any correlation or dependencies that were accounted for between two or more inputs or with respect to autocorrelation.
- Explanation of any special considerations that might be unique to a particular country or situation, such as the use of various statistical techniques for dealing with non-detects, mixture distributions, extrapolation, and so on.
- Explanation of differences in results between Approach 1 and 2.

In addition to documentation of the uncertainty estimates for inputs to an inventory, documentation should be provided regarding the general approach used and whether it is based primarily on Approach 1 or Approach 2. Any modifications to these Approaches should be explained and appropriately justified.

The reporting of uncertainties also requires a discussion of limitations and caveats for any quantitative uncertainty estimates produced that are suspected to present an incomplete representation of all causes of uncertainty. During the process of collecting information on inputs for an uncertainty assessment (e.g., empirical or expert judgement as a basis for PDFs, characterisations of conceptualisation and model uncertainty), the likely causes of the various uncertainties identified—including potential biases—should be documented. These likely causes should be documented whether or not they were quantified and include any specific recommendations available regarding how they can be reduced.

Similarly, when reporting and interpreting the results from a quantitative uncertainty assessment, it is important to keep in mind the limitations of the approach used to combine uncertainties. For example, although Approach 1 can address some causes of correlation, any possible biases associated with other causes of correlations that might exist (e.g., between categories) that are identified in the course of an uncertainty assessment should be documented.

Table 3.3 is a generalised table for reporting uncertainty of an inventory, regardless of the Approach followed. If the point estimate and the mean estimate of emissions/removals are not the same value, it is *good practice* for the uncertainty ranges shown in Columns E, F, G, and J to be estimated relative to point estimates used when reporting the national inventory. If the point estimate and the mean estimates differ, then it is advisable to consider why they differ and possibly revisit the point estimate in order to identify and account for bias.

TABLE 3.3
GENERAL REPORTING TABLE FOR UNCERTAINTY

A	B	C	D	E		F		G		H	I	J		K
IPCC category	Gas	Base year emissions /removals	Year *t* emissions /removals	Activity data uncertainty		Emission factor/estimation parameter uncertainty (combined if more than one estimation parameter is used)		Combined uncertainty		Contribution to variance in Year *t*	Inventory trend in national emissions for year *t* increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year		Approach and Comments
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	
E.g., 1.A.1. Energy Industries Fuel 1	CO_2													
E.g., 1.A.1. Energy Industries Fuel 2	CO_2													
Etc...	…													
Total										1.000				

Notes:

Column C: Base year emissions in Gg CO_2 equivalent by category and gas.

Column D: Year *t* emissions in Gg CO_2 equivalent by category and gas. Year *t* is the year of interest or the current year.

Columns E and F: Uncertainties in activity and emission factor estimates (Columns E and F) should be reported where possible, but it is understood that some calculation methods for some categories may not be amenable to this type of reporting. Thus, where this information is not available, the table entry can be left blank.

Column G: An uncertainty estimate for each category should be reported, relative to the mean estimate, even if uncertainties cannot be further disaggregated by activity and emission factor in a particular case. For the foot of the table, report the uncertainty in the total inventory. This must be obtained through the Approach 1 or 2 calculations, and cannot be determined simply by summing quantities in the columns.

Column H: Report the 'contribution to uncertainty'. It is estimated dividing the variance of each category by the total variance of the inventory ($\sigma_x^2 / \sum \sigma_x^2$). If Approach 1 has been used, it is calculated dividing each entry in Column H of Table 3.2 by the value, in the same column, in the line 'Total' of Table 3.2. General methodology to be applied when Approach 2 is used and when uncertainty is asymmetric is provided in Section 3.2.3.

Column I: Report the inventory trend, estimated as:

$$Mean\,Trend\,(\%) = \left(\frac{Year\,t\,emissions - Base\,year\,emissions}{Base\,year\,emissions} \right) \bullet 100 \ .$$

Report separately for each category by row and report for the total inventory at the foot of the column.

Column J: This is the uncertainty in the trend by category. For the 'total' at the foot of the table, the overall uncertainty in the trend for the entire inventory should be given. The uncertainty in the trend is based on *percentage points* with respect to the inventory trend. For example, if the inventory trend is -5%, and if the 95% probability range of the trend is -8% to -3%, then the uncertainty in trend is reported as -3% to +2%.

Column K: Indicate whether Approach 1 or Approach 2 was used, and include any other comments that might help clarify the methodology or information sources.

General Comments on Columns E, F, G, and J: For each of these columns, two subcolumns are provided to facilitate reporting of uncertainty ranges that are asymmetric. For example, if the uncertainty range is -50% to +100%, then '50' should be reported the subcolumn headed as '(-)%' and '100' should be reported in the column headed as '(+)%'.

3.6 EXAMPLES

This section presents two examples of uncertainty estimates for inventories, both based upon the Finnish 2003 greenhouse gas emission inventory. These examples are country-specific and are shown here only for the purpose of illustrating procedures and general insights. The specific uncertainty estimates and results will differ among countries.

The example of Table 3.4 is based upon Approach 1, and is shown in the general format of the Approach 1 worksheet (Table 3.2). The results indicate that the net emissions in year *t*, which is 2003 in this example, is 67,730 Gg CO_2 equivalent with an uncertainty of ±15.9%, which corresponds to a 95 percent probability range of 56,970 to 78,490 Gg CO_2 equivalent. Based upon the total base year and year *t* inventories reported in the table, the average trend is a 42 percent increase in emissions from 1990 to 2003. The uncertainty in the trend is ±19% (percentage points), which corresponds to a 95 percent probability range for the trend of 24% to 61% with respect to the base year emissions.

The example of Table 3.5 is based upon Approach 2, and is shown in the format of the General Reporting Table for Uncertainty shown in Table 3.3. The results indicate that the net emissions in year *t* are 67,730 Gg CO_2 equivalent with an uncertainty range of -14 to +15 percent, which corresponds to a 95 percent probability range of 58,490 to 78,130 Gg CO_2 equivalent. Based upon the total base year and year *t* inventories reported in the table, the average trend is a 42 % increase in emissions from 1990 to 2003. The uncertainty in the trend is -18 to +23% (percentage points) which corresponds to a 95 percent probability range for the trend of 25% to 65% with respect to the base year emissions.

These examples illustrate that the results from Approaches 1 and 2 can be very similar when the overall uncertainty is relatively small. However, Approach 2 is a more flexible approach that enables quantification of asymmetry in probability ranges, such as for the year *t* inventory.

TABLE 3.4
EXAMPLE OF AN APPROACH 1 UNCERTAINTY ANALYSIS FOR FINLAND (BASED ON STATISTICS FINLAND, 2005)

The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**	**Emission factor /estimation parameter uncertainty**	**Combined uncertainty**	**Contribution to variance by source/sink category in year *t***	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
1.A Fuel Combustion Activities												
Liquid	CO_2	27 232	27 640	2%	2%	3%	0.0001	0.2320	0.5806	0.46%	1.64%	0.03%
Solid	CO_2	15 722	22 753	2%	3%	3%	0.0001	0.0080	0.4780	0.02%	1.08%	0.01%
Gas	CO_2	5 073	9 350	1%	1%	1%	0.0000	0.0447	0.1964	0.04%	0.28%	0.00%
Peat	CO_2	5 656	10 676	4%	5%	7%	0.0001	0.0552	0.2243	0.28%	1.36%	0.02%
1.A.1 Energy Industries												
Liquid	CH_4	6	7	2%	75%	75%	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N_2O	26	30	2%	75%	75%	0.0000	0.0001	0.0006	0.01%	0.00%	0.00%
Solid	CH_4	9	16	2%	75%	75%	0.0000	0.0001	0.0003	0.01%	0.00%	0.00%
	N_2O	85	162	2%	50%	50%	0.0000	0.0009	0.0034	0.04%	0.01%	0.00%
Gas	CH_4	4	9	1%	75%	75%	0.0000	0.0001	0.0002	0.01%	0.00%	0.00%
	N_2O	18	51	1%	50%	50%	0.0000	0.0005	0.0011	0.03%	0.00%	0.00%
Biomass	CH_4	2	31	20%	50%	54%	0.0000	0.0006	0.0006	0.03%	0.02%	0.00%
	N_2O	10	80	20%	150%	151%	0.0000	0.0014	0.0017	0.21%	0.05%	0.00%
Peat	CH_4	5	7	5%	50%	50%	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
	N_2O	141	226	5%	150%	150%	0.0000	0.0005	0.0047	0.08%	0.03%	0.00%
1.A.2 Manufacturing Industries and Construction												
Liquid	CH_4	9	7	2%	75%	75%	0.0000	0.0001	0.0001	0.01%	0.00%	0.00%
	N_2O	39	41	2%	75%	75%	0.0000	0.0003	0.0009	0.02%	0.00%	0.00%
Solid	CH_4	4	2	2%	75%	75%	0.0000	0.0001	0.0001	0.01%	0.00%	0.00%
	N_2O	108	90	2%	50%	50%	0.0000	0.0013	0.0019	0.07%	0.01%	0.00%

TABLE 3.4 (CONTINUED)
EXAMPLE OF AN APPROACH 1 UNCERTAINTY ANALYSIS FOR FINLAND (BASED ON STATISTICS FINLAND, 2005)

The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	**Gas**	**Base year emissions or removals** Gg CO_2 equivalent	**Year *t* emissions or removals** Gg CO_2 equivalent	**Activity data uncertainty** %	**Emission factor /estimation parameter uncertainty** %	**Combined uncertainty** %	**Contribution to variance by source/sink category in year *t***	**Type A sensitivity** %	**Type B sensitivity** %	**Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty** %	**Uncertainty in trend in national emissions introduced by activity data uncertainty** %	**Uncertainty introduced into the trend in total national emissions** %
Gas	CH_4	5	6	1%	75%	75%	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N_2O	17	19	1%	50%	50%	0.0000	0.0001	0.0004	0.01%	0.00%	0.00%
Biomass	CH_4	20	19	15%	50%	52%	0.0000	0.0002	0.0004	0.01%	0.01%	0.00%
	N_2O	111	81	15%	150%	151%	0.0000	0.0016	0.0017	0.24%	0.04%	0.00%
Peat	CH_4	4	3	5%	50%	50%	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
	N_2O	56	29	5%	150%	150%	0.0000	0.0011	0.0006	0.16%	0.00%	0.00%
1.A.3 Transport												
a. Civil Aviation	CH_4	0.4	0.3	5%	100%	100%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	4	4	5%	150%	150%	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
b. Road Transportation												
Gasoline	CH_4	78	40	1%	50%	50%	0.0000	0.0015	0.0008	0.07%	0.00%	0.00%
Cars with Catalytic Converters	N_2O	32	410	1%	378%	378%	0.0005	0.0076	0.0086	2.89%	0.01%	0.08%
Cars without Catalytic Converters	N_2O	59	22	1%	259%	259%	0.0000	0.0013	0.0005	0.34%	0.00%	0.00%
Diesel	CH_4	12	6	1%	50%	50%	0.0000	0.0002	0.0001	0.01%	0.00%	0.00%
	N_2O	68	84	1%	158%	158%	0.0000	0.0003	0.0018	0.04%	0.00%	0.00%
Natural gas	CH_4	0.0	2	1%	50%	50%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	0.0	0.0	1%	150%	150%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
c. Railways	CH_4	0.2	0.2	5%	110%	110%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	2	1	5%	150%	150%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

TABLE 3.4 (CONTINUED)
EXAMPLE OF AN APPROACH 1 UNCERTAINTY ANALYSIS FOR FINLAND (BASED ON STATISTICS FINLAND, 2005)

The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**	**Emission factor /estimation parameter uncertainty**	**Combined uncertainty**	**Contribution to variance by source/sink category in year *t***	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
d. Water-borne Navigation												
Residual Oil & Gas/Diesel Oil	CH_4	0.5	1	10%	100%	100%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	2	3	10%	150%	150%	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
Gasoline	CH_4	7	4	20%	100%	102%	0.0000	0.0001	0.0001	0.01%	0.00%	0.00%
	N_2O	0.4	0.6	20%	150%	151%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
e. Other Transportation												
Gasoline&Diesel	CH_4	5	6	30%	50%	58%	0.0000	0.0000	0.0001	0.00%	0.01%	0.00%
Gasoline	N_2O	1	1	30%	150%	153%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Diesel	N_2O	4	4	30%	150%	153%	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
1.A.4 Other Sectors												
Liquid	CH_4	19	15	3%	75%	75%	0.0000	0.0002	0.0003	0.02%	0.00%	0.00%
	N_2O	56	47	3%	75%	75%	0.0000	0.0007	0.0010	0.05%	0.00%	0.00%
Solid	CH_4	2	0.6	10%	75%	76%	0.0000	0.0001	0.0000	0.00%	0.00%	0.00%
	N_2O	0.5	0.3	10%	50%	51%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Gas	CH_4	0.1	0.3	5%	75%	75%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	1	1	5%	50%	50%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	CH_4	282	307	15%	150%	151%	0.0000	0.0020	0.0064	0.30%	0.14%	0.00%
	N_2O	56	61	15%	150%	151%	0.0000	0.0004	0.0013	0.06%	0.03%	0.00%
Peat	CH_4	1	1	25%	50%	56%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	1	2	25%	150%	152%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

TABLE 3.4 (CONTINUED)
EXAMPLE OF AN APPROACH 1 UNCERTAINTY ANALYSIS FOR FINLAND (BASED ON STATISTICS FINLAND, 2005)

The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	**Gas**	**Base year emissions or removals** Gg CO_2 equivalent	**Year *t* emissions or removals** Gg CO_2 equivalent	**Activity data uncertainty** %	**Emission factor /estimation parameter uncertainty** %	**Combined uncertainty** %	**Contribution to variance by source/sink category in year *t***	**Type A sensitivity** %	**Type B sensitivity** %	**Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty** %	**Uncertainty in trend in national emissions introduced by activity data uncertainty** %	**Uncertainty introduced into the trend in total national emissions** %
1.A.5 Non-Specified												
Liquid	CH_4	2	2	7%	75%	75%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	6	9	7%	75%	75%	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
Gas	CH_4	0.3	0.4	13%	75%	76%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N_2O	1	2	13%	50%	52%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
1.B Fugitive Emissions from Fuels												
1.B.2 Oil and Natural Gas												
a.ii. Oil – Flaring	CO_2	123	63	50%	0%	50%	0.0000	0.0024	0.0013	0.00%	0.09%	0.00%
a.iii.4 Oil – Refining	CH_4	8	10	2%	90%	90%	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
b.iii.4 Natural Gas - Transmission and Storage	CH_4	4	12	3%	0%	3%	0.0000	0.0001	0.0003	0.00%	0.00%	0.00%
b. iii.5 Natural gas - Distribution	CH_4	0	40	5%	0%	5%	0.0000	0.0008	0.0008	0.00%	0.01%	0.00%
2 Industrial Processes and Product Use												
2.A.1 Cement Production	CO_2	786	500	2%	5%	5%	0.0000	0.0130	0.0105	0.06%	0.03%	0.00%
2.A.2 Lime Production	CO_2	383	513	2%	3%	4%	0.0000	0.0007	0.0108	0.00%	0.03%	0.00%
2.A.3 and 2.A.4 Limestone and Dolomite Use[1]	CO_2	99	148	7%	9%	11%	0.0000	0.0002	0.0031	0.00%	0.03%	0.00%
2.A.3 and 2.A.4 Soda Ash Use[1]	CO_2	18	20	7%	2%	7%	0.0000	0.0001	0.0004	0.00%	0.00%	0.00%
2.B.2 Nitric Acid Production	N_2O	1 595	1 396	5%	100%	100%	0.0004	0.0184	0.0293	1.84%	0.21%	0.03%
2.B.8.b Ethylene	CH_4	4	5	5%	20%	21%	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
2.B.10 Other	CO_2	60	147	12%	5%	13%	0.0000	0.0013	0.0031	0.01%	0.05%	0.00%
2.C.1 Iron and Steel Production	CH_4	5	9	3%	20%	20%	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%

TABLE 3.4 (CONTINUED)
EXAMPLE OF AN APPROACH 1 UNCERTAINTY ANALYSIS FOR FINLAND (BASED ON STATISTICS FINLAND, 2005)

The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**	**Emission factor /estimation parameter uncertainty**	**Combined uncertainty**	**Contribution to variance by source/sink category in year *t***	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
2.D Non-Energy Products from Fuels and Solvent Use	CO_2	640	830	50%	5%	50%	0.0000	0.0017	0.0174	0.01%	1.23%	0.02%
2.F.1 Refrigeration and Air Conditioning	HFCs	0	578	26%	0%	26%	0.0000	0.0121	0.0121	0.00%	0.45%	0.00%
2.F.2 Foam Blowing Agents	HFCs	0	25	24%	0%	24%	0.0000	0.0005	0.0005	0.00%	0.02%	0.00%
2.F.4 Aerosols	HFCs	0	63	10%	0%	10%	0.0000	0.0013	0.0013	0.00%	0.02%	0.00%
2.G.1 Electrical Equipment	SF_6	87	22	88%	0%	88%	0.0000	0.0021	0.0005	0.00%	0.06%	0.00%
2.G.3.a Medical Applications	N_2O	62	40	30%	20%	36%	0.0000	0.0010	0.0008	0.02%	0.04%	0.00%
2.H.3 Other (grouped data of f-gases)	HFCs, PFCs, SF_6	8	21	38%	0%	38%	0.0000	0.0002	0.0004	0.00%	0.02%	0.00%
3 AFOLU												
3.A.1 Enteric Fermentation	CH_4	1 868	1 537	0%	31%	31%	0.0000	0.0235	0.0323	0.72%	0.00%	0.01%
3.A.2 Manure Management	CH_4	215	222	0%	16%	16%	0.0000	0.0018	0.0047	0.03%	0.00%	0.00%
3.A.2 Manure Management	N_2O	623	461	0%	83%	83%	0.0000	0.0089	0.0097	0.74%	0.00%	0.01%
3.B.1.a Forest Land Remaining Forest Land												
carbon stock change in biomass	CO_2	-23 798	-21 354	0%	35%	35%	0.0122	0.2640	0.4486	9.24%	0.00%	0.85%
3.B.2.a Cropland Remaining Cropland												
net carbon stock change in mineral soils	CO_2	-535	-1 113	0%	100%	100%	0.0003	0.0074	0.0234	0.74%	0.00%	0.01%
net carbon stock change in organic soils	CO_2	1 813	1 324	20%	90%	92%	0.0003	0.0264	0.0278	2.37%	0.79%	0.06%

TABLE 3.4 (CONTINUED)
EXAMPLE OF AN APPROACH 1 UNCERTAINTY ANALYSIS FOR FINLAND (BASED ON STATISTICS FINLAND, 2005)

The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**	**Emission factor /estimation parameter uncertainty**	**Combined uncertainty**	**Contribution to variance by source/sink category in year *t***	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
3.B.3.a Grassland Remaining Grassland												
net carbon stock change in mineral soils	CO_2	-1 181	2 907	0%	100%	100%	0.0018	0.0964	0.0611	9.64%	0.00%	0.93%
net carbon stock change in organic soils	CO_2	109	67	30%	90%	95%	0.0000	0.0019	0.0014	0.17%	0.06%	0.00%
3.B.4.ai Peatlands Remaining Peatlands	CO_2	503	547	15%	208%	208%	0.0003	0.0036	0.0115	0.74%	0.08%	0.01%
3.B.4.ai Peatlands Remaining Peatlands	CH_4	5	6	15%	208%	208%	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
3.C.1.a Biomass Burning in Forest Lands	CO_2	180	91	10%	70%	71%	0.0000	0.0035	0.0019	0.24%	0.03%	0.00%
3.C.1.a Biomass Burning in Forest Lands	CH_4	16	8	10%	70%	71%	0.0000	0.0003	0.0002	0.02%	0.00%	0.00%
3.C.1.a Biomass Burning in Forest Lands	N_2O	2	1	10%	70%	71%	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
3.C.2 Liming	CO_2	618	277	20%	20%	28%	0.0000	0.0127	0.0058	0.25%	0.16%	0.00%
3.C.4 Direct N_2O Emissions from Managed Soils: Agricultural Soils	N_2O	3 486	2 608	0%	227%	227%	0.0077	0.0494	0.0548	11.23%	0.00%	1.26%
3.C.4 Direct N_2O Emissions from Managed Soils: N Fertilizers Application, Forest Land	N_2O	27.0	11.3	10%	380%	380%	0.0000	0.0006	0.0002	0.22%	0.00%	0.00%
3.C.5 Indirect N_2O Emissions from Managed Soils	N_2O	735	592	0%	334%	334%	0.0009	0.0095	0.0124	3.18%	0.00%	0.10%
4 Waste												
4.A Solid Waste Disposal	CH_4	3 678	2 497	0%	43%	43%	0.0003	0.0574	0.0525	2.47%	0.00%	0.06%

TABLE 3.4 (CONTINUED)
EXAMPLE OF AN APPROACH 1 UNCERTAINTY ANALYSIS FOR FINLAND (BASED ON STATISTICS FINLAND, 2005)

The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**	**Emission factor /estimation parameter uncertainty**	**Combined uncertainty**	**Contribution to variance by source/sink category in year *t***	**Type A sensitivity**	**Type B sensitivity**	**Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty**	**Uncertainty in trend in national emissions introduced by activity data uncertainty**	**Uncertainty introduced into the trend in total national emissions**
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
4.D.1 Domestic Wastewater Treatment and Discharge												
sparsely populated areas	CH_4	118	95	15%	32%	35%	0.0000	0.0015	0.0020	0.05%	0.04%	0.00%
densely populated areas	CH_4	12	13	5%	104%	105%	0.0000	0.0001	0.0003	0.01%	0.00%	0.00%
sparsely populated areas	N_2O	21	18	10%	380%	380%	0.0000	0.0002	0.0004	0.09%	0.01%	0.00%
densely populated areas	N_2O	84	66	5%	380%	380%	0.0000	0.0011	0.0014	0.43%	0.01%	0.00%
4.D.2 Industrial Wastewater Treatment and Discharge	CH_4	22	19	10%	104%	105%	0.0000	0.0003	0.0004	0.03%	0.01%	0.00%
4.D.2 Industrial Wastewater Treatment and Discharge	N_2O	28	17	5%	380%	380%	0.0000	0.0005	0.0004	0.17%	0.00%	0.00%
4.E Other: N input from Fish Farming	N_2O	8	3	10%	380%	380%	0.0000	0.0002	0.0001	0.07%	0.00%	0.00%
Total		**47 604**	**67 730**				**0.0252**					**0.0349**
					Percentage uncertainty in total inventory		**15.9%**				**Trend uncertainty**	**18.7%**

[1] Uncertainty assessment was made at the aggregation level used by Finland in 2003 inventory, and therefore glass production could not be separated.

TABLE 3.5
EXAMPLE OF REPORTING OF APPROACH 2 UNCERTAINTY ANALYSIS USING GENERAL REPORTING TABLE FOR UNCERTAINTY
Emissions, removals and uncertainties are from National Inventory of Finland for year 2003 (Statistics Finland, 2005). The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E		F		G		H	I	J		K
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty		Emission factor uncertainty		Combined uncertainty		Contribution to variance in year *t*[a]	Inventory trend in national emissions for year *t* increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year		Approach and Comments
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	Approach 2
1.A Fuel Combustion Activities														
Liquid	CO_2	27 232	27 640	2	2	2	2	3	3	0.0061	1	-3	3	
Solid	CO_2	15 722	22 753	2	2	3	3	3	3	0.0061	45	-3	3	
Gas	CO_2	5 073	9 350	1	1	1	1	1	1	0.0002	84	-3	3	
Peat	CO_2	5 656	10 676	4	4	5	5	6	7	0.0050	89	-11	11	
1.A.1 Energy Industries														
Liquid	CH_4	6	7	2	2	75	10	75	12	0.0000	18	-32	39	
	N_2O	26	30	2	2	75	10	75	12	0.0000	15	-30	39	
Solid	CH_4	9	16	2	2	75	10	75	12	0.0000	91	-43	59	
	N_2O	85	162	2	2	50	50	50	50	0.0001	91	-23	25	
Gas	CH_4	4	9	1	1	75	10	76	11	0.0000	140	-57	87	
	N_2O	18	51	1	1	50	50	51	50	0.0000	188	-37	39	
Biomass	CH_4	2	31	20	20	50	50	52	57	0.0000	1 370	-398	544	
	N_2O	10	80	20	20	70	150	71	154	0.0001	729	-260	374	
Peat	CH_4	5	7	5	5	50	50	50	50	0.0000	37	-18	21	
	N_2O	141	226	5	5	70	150	70	148	0.0007	60	-33	41	
1.A.2 Manufacturing Industries and Construction														
Liquid	CH_4	9	7	2	2	75	10	75	12	0.0000	-19	-21	27	
	N_2O	39	41	2	2	75	10	75	12	0.0000	4	-25	30	

TABLE 3.5 (CONTINUED)
EXAMPLE OF REPORTING OF APPROACH 2 UNCERTAINTY ANALYSIS USING GENERAL REPORTING TABLE FOR UNCERTAINTY
Emissions, removals and uncertainties are from National Inventory of Finland for year 2003 (Statistics Finland, 2005). The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E		F		G		H	I	J		K
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**		**Emission factor uncertainty**		**Combined uncertainty**		**Contribution to variance in year *t*[a]**	**Inventory trend in national emissions for year *t* increase with respect to base year**	**Uncertainty introduced into the trend in total national emissions with respect to base year**		**Approach and Comments**
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	Approach 2
Solid	CH_4	4	2	2	2	75	10	74	12	0.0000	-44	-13	20	
	N_2O	108	90	2	2	50	50	50	50	0.0000	-17	-11	12	
Gas	CH_4	5	6	1	1	75	10	75	11	0.0000	35	-35	45	
	N_2O	17	19	1	1	50	50	50	50	0.0000	13	-14	16	
Biomass	CH_4	20	19	15	15	50	50	51	53	0.0000	-7	-20	26	
	N_2O	111	81	15	15	70	150	70	151	0.0001	-28	-20	27	
Peat	CH_4	4	3	5	5	50	50	50	50	0.0000	-29	-9	11	
	N_2O	56	29	5	5	70	150	70	150	0.0000	-49	-11	14	
1.A.3 Transport														
a. Civil Aviation	CH_4	0.4	0.3	5	5	57	100	57	100	0.0000	-12	-12	15	
	N_2O	4	4	5	5	70	150	70	148	0.0000	-1	-17	21	
b. Road Transportation														
Gasoline	CH_4	78	40	1	1	50	50	50	50	0.0000	-49	-6	6	
Cars with Catalytic Converters	N_2O	32	410	1	1	94	378	94	392	0.0174	1 176	-446	643	
Cars without Catalytic Converters	N_2O	59	22	1	1	86	259	86	259	0.0000	-63	-11	16	
Diesel	CH_4	12	6	1	1	50	50	50	50	0.0000	-51	-5	5	
	N_2O	68	84	1	1	99	158	99	157	0.0001	23	-59	94	
Natural gas	CH_4		2	1	1	50	50	49	50					
	N_2O		0.0	1	1	70	150	70	149					
c. Railways	CH_4	0.2	0.2	5	5	60	110	60	110	0.0000	-30	-11	13	
	N_2O	2	1	5	5	70	150	70	149	0.0000	-30	-13	17	

TABLE 3.5 (CONTINUED)
EXAMPLE OF REPORTING OF APPROACH 2 UNCERTAINTY ANALYSIS USING GENERAL REPORTING TABLE FOR UNCERTAINTY
Emissions, removals and uncertainties are from National Inventory of Finland for year 2003 (Statistics Finland, 2005). The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E		F		G		H	I	J		K
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**		**Emission factor uncertainty**		**Combined uncertainty**		**Contribution to variance in year *t*[a]**	**Inventory trend in national emissions for year *t* increase with respect to base year**	**Uncertainty introduced into the trend in total national emissions with respect to base year**		**Approach and Comments**
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	Approach 2
d. Water-borne Navigation														
Residual Oil & Gas/Diesel Oil	CH_4	1	1	10	10	57	100	57	99	0.0000	2	-19	22	
	N_2O	2	3	10	10	70	150	70	149	0.0000	36	-30	39	
Gasoline	CH_4	7	4	20	20	57	100	59	104	0.0000	-42	-16	22	
	N_2O	0.4	1	20	20	70	150	71	154	0.0000	56	-49	71	
e. Other Transportation														
Gasoline & Diesel	CH_4	5	6	30	30	50	50	54	63	0.0000	15	-43	67	
Gasoline	N_2O	1	1	30	30	70	150	72	156	0.0000	9	-41	67	
Diesel	N_2O	4	4	30	30	70	150	72	158	0.0000	-5	-37	60	
1.A.4 Other Sectors														
Liquid	CH_4	19	15	3	3	75	10	74	13	0.0000	-19	-18	20	
	N_2O	56	47	3	3	75	10	76	13	0.0000	-15	-21	25	
Solid	CH_4	2	1	10	10	75	10	76	20	0.0000	-72	-6	8	
	N_2O	0.5	0.3	10	10	50	50	51	52	0.0000	-27	-12	14	
Gas	CH_4	0.1	0.3	5	5	75	10	75	15	0.0000	132	-49	62	
	N_2O	1	1	5	5	50	50	50	50	0.0000	124	-27	32	
Biomass	CH_4	282	307	15	15	70	150	71	151	0.0013	9	-28	38	
	N_2O	56	61	15	15	70	150	71	150	0.0000	9	-28	38	
Peat	CH_4	1	1	25	25	50	50	53	60	0.0000	1	-32	46	
	N_2O	1	2	25	25	70	150	71	155	0.0000	13	-38	57	
1.A.5 Non-Specified														
Liquid	CH_4	2	2	7	7	75	10	75	17	0.0000	43	-31	46	
	N_2O	6	9	7	7	75	10	75	17	0.0000	45	-33	43	

TABLE 3.5 (CONTINUED)
EXAMPLE OF REPORTING OF APPROACH 2 UNCERTAINTY ANALYSIS USING GENERAL REPORTING TABLE FOR UNCERTAINTY
Emissions, removals and uncertainties are from National Inventory of Finland for year 2003 (Statistics Finland, 2005). The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E		F		G		H	I	J		K
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**		**Emission factor uncertainty**		**Combined uncertainty**		**Contribution to variance in year *t*[a]**	**Inventory trend in national emissions for year *t* increase with respect to base year**	**Uncertainty introduced into the trend in total national emissions with respect to base year**		**Approach and Comments**
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	Approach 2
Gas	CH_4	0.3	0.4	13	13	75	10	75	23	0.0000	64	-41	55	
	N_2O	1	2	13	13	50	50	51	52	0.0000	64	-31	37	
1.B Fugitive Emissions from Fuels														
1.B.2 Oil and Natural Gas														
a.ii Oil – Flaring	CO_2	123	63					50	50	0.0000	-49	-29	85	b
a.iii.4 Oil – Refining	CH_4	8	10	2	2	90	90	90	90	0.0000	27	-41	53	
b.iii.4 Natural Gas - Transmission and storage	CH_4	4	12					3	3	0.0000	236	-113	334	b
b.iii.5 Natural Gas - Distribution	CH_4	0	40					5	5	0.0000				b,c
2 Industrial Processes														
2.A.1 Cement Production	CO_2	786	500	2	2	5	5	5	5	0.0000	-36	-2	2	
2.A.2 Lime Production	CO_2	383	513	2	2	3	3	4	4	0.0000	34	-4	4	
2.A.3 and 2.A.4 Limestone and Dolomite Use	CO_2	99	148	4	7	9	5	10	10	0.0000	50	-13	14	d
2.A.3 and 2.A.4 Soda Ash Use	CO_2	18	20	4	7	2	1	5	7	0.0000	10	-9	10	d
2.B.2 Nitric Acid Production	N_2O	1 595	1 396	5	5	57	100	57	100	0.0126	-13	-7	8	
2.B.8.b Ethylene	CH_4	4	5	5	5	20	20	20	21	0.0000	32	-9	10	
2.B.10 Other	CO_2	60	147	8	12	5	5	10	13	0.0000	145	-35	40	
2.C.1 Iron and Steel Production	CH_4	5	9	3	3	20	20	20	20	0.0000	85	-8	8	
2.D Non-Energy Products from Fuels and Solvent Use	CO_2	640	830	50	50	5	5	50	50	0.002	30	-71	156	
2.F.1 Refrigeration and Air Conditioning	HFCs, PFCs	0	578					11	26	0.0001	4 584 122	-519 745	1 206 234	b
2.F.2 Foam Blowing Agents	HFCs		25					24	24	0.0000				b,c
2.F.4 Aerosols	HFCs		63					10	10	0.0000				b,c

TABLE 3.5 (CONTINUED)
EXAMPLE OF REPORTING OF APPROACH 2 UNCERTAINTY ANALYSIS USING GENERAL REPORTING TABLE FOR UNCERTAINTY
Emissions, removals and uncertainties are from National Inventory of Finland for year 2003 (Statistics Finland, 2005). The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E		F		G		H	I	J		K
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**		**Emission factor uncertainty**		**Combined uncertainty**		**Contribution to variance in year *t*[a]**	**Inventory trend in national emissions for year *t* increase with respect to base year**	**Uncertainty introduced into the trend in total national emissions with respect to base year**		**Approach and Comments**
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	Approach 2
2.G.1 Electrical Equipment	SF_6	87	22					88	88	0.0000	-75	-22	41	b
2.G.3.a Medical Applications	N_2O	62	40	30	30	20	20	34	38	0.0000	-36	-23	35	
2.H.3 Other (grouped data of f-gases)	HFCs, PFCs, SF_6	8	21					38	38	0.0000	164	-123	292	b
3 AFOLU														
3.A.1 Enteric Fermentation	CH_4	1 868	1 537					20	31	0.0015	-18	-3	3	b
3.A.2 Manure Management	CH_4	215	222					16	16	0.0000	3	-4	5	b
3.A.2 Manure Management	N_2O	623	461					83	27	0.0006	-26	-15	17	b
3.B.1.a Forest Land remaining Forest Land														
carbon stock change in biomass	CO_2	-2 3798	-2 1354					35	35	0.5662	-10	-19	25	b
3.B.2.a Cropland Remaining Cropland														
net carbon stock change in mineral soils	CO_2	-535	-1 113					99	101	0.0125	108	-242	393	b
net carbon stock change in organic soils	CO_2	1 813	1 324	20	20	90	90	89	95	0.0152	-27	-32	54	
3.B.3.a Grassland Remaining Grassland														
net carbon stock change in mineral soils	CO_2	-1 181	2 907					99	100	0.0852	-346	-2223	1067	b
net carbon stock change in organic soils	CO_2	109	67	30	30	90	90	90	103	0.0000	-39	-29	50	
3.B.4.ai Peatlands Remaining Peatlands	CO_2	503	547	15	15	80	208	80	212	0.0074	9	-32	48	
3.A.4.ai Peatlands Remaining Peatlands	CH_4	5	6	15	15	80	208	80	208	0.0000	6	-32	46	
3.C.1.a Biomass Burning in Forest Lands	CO_2	180	91	10	10	70	70	71	71	0.0000	-50	-12	15	
3.C.1.a Biomass Burning in Forest Lands	CH_4	16	8	10	10	70	70	70	71	0.0000	-49	-12	15	
3.C.1.a Biomass Burning in Forest Lands	N_2O	2	1	10	10	70	70	70	72	0.0000	-50	-11	15	
3.C.2 Liming	CO_2	618	277	20	20	20	3	25	22	0.0000	-55	-11	15	

TABLE 3.5 (CONTINUED)
EXAMPLE OF REPORTING OF APPROACH 2 UNCERTAINTY ANALYSIS USING GENERAL REPORTING TABLE FOR UNCERTAINTY

Emissions, removals and uncertainties are from National Inventory of Finland for year 2003 (Statistics Finland, 2005). The aggregation level and uncertainty estimates are country-specific for Finland, and do not represent recommended uncertainties or level of aggregation for other countries.

A	B	C	D	E		F		G		H	I	J		K
IPCC category	**Gas**	**Base year emissions or removals**	**Year *t* emissions or removals**	**Activity data uncertainty**		**Emission factor uncertainty**		**Combined uncertainty**		**Contribution to variance in year *t*[a]**	**Inventory trend in national emissions for year *t* increase with respect to base year**	**Uncertainty introduced into the trend in total national emissions with respect to base year**		**Approach and Comments**
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	Approach 2
3.C.4 Direct N_2O Emissions from Managed Soils: Agricultural Soils	N_2O	3 486	2 608					76	227	0.2170	-25	-19	29	b
3.C.4 Direct N_2O Emissions from Managed Soils: N Fertilizers Application, forest land	N_2O	27	11	10	10	94	380	94	386	0.0000	-58	-17	32	
3.C.5 Indirect N_2O Emissions from Managed Soils	N_2O	735	592					81	334	0.0303	-19	-19	25	b
4 Waste														
4.A Solid Waste Disposal	CH_4	3 678	2 497					43	43	0.012	-32	-14	16	b
4.D.1 Domestic Wastewater Treatment and Discharge														
sparcely populated areas	CH_4	118	95	15	15	32	20	34	27	0.000	-20	-16	20	
densely populated areas	CH_4	12	13					60	109	0.000	9	-16	20	b
sparcely populated areas	N_2O	21	18	10	10	94	380	94	378	0.000	-13	-29	40	
densely populated areas	N_2O	84	66	5	5	94	380	94	378	0.000	-21	-25	34	
4.D.2 Industrial Wastewater Treatment and Discharge	CH_4	22	19					61	109	0.000	-15	-17	22	b
4.D.2 Industrial Wastewater Treatment and Discharge	N_2O	28	17	5	5	94	380	94	388	0.000	-37	-19	27	
4.E Other: N input from Fish Farming	N_2O	8	3	10	10	94	380	94	391	0.000	-62	-12	18	
Total		47 604	67 730					14	15		42	-18	23	

[a] Entries to Column H are obtained by dividing the variance of each category (obtained from the Monte Carlo simulation tool) by the total variance of the inventory.

[b] A more complex method for estimation of uncertainties is used, and therefore activity data and emission factor uncertainties are left blank. The resulting uncertainty is shown in Column G

[c] Trend not calculated, when base year emissions are zero

[d] Uncertainty assessment was made in the aggregation level used by Finland in 2003 inventory, and therefore glass production could not be separated.

3.7 TECHNICAL BACKGROUND INFORMATION

3.7.1 Approach 1 variables and equations

This section covers the basis for the statistical calculation methods used in Approach 1 as complementary information to Section 3.2.3.1, Approach 1: Propagation of Error, and Table 3.2, Approach 1 Uncertainty Calculation. Key variables and equations used for the calculation are defined in this section.

Explanation of the variables

$C_{x,}$ = Value of an entry in Column C and row *x*, emissions or removals of each category of base year inventory

$\sum C_i$ = Sum of emissions and removals over all categories (rows) of the base year inventory

$D_{x,}$ = Value of an entry in Column D and row *x*, emissions or removals of each category of the year of inventory *t*

$\sum D_i$ = Sum of emissions and removals over all categories (rows) of the year of inventory *t*

Column A-F

Input data of emissions and removals, activity data and emission factor uncertainties of each category

Column G

Combined uncertainty using error propagation equation. See Equation 3.1 in Section 3.2.3.1.

$$G_x = \sqrt{E_x^{\ 2} + F_x^{\ 2}}$$

Column H

Contribution to uncertainty. See also Equation 3.2 in Section 3.2.3.1.

$$H_x = \frac{(G_x \bullet D_x)^2}{\left(\sum D_i\right)^2}$$

The total emission uncertainty is obtained using the error propagation equation:

$$\frac{\sqrt{\sum (G_i \bullet D_i)^2}}{\sum D_i} = \sqrt{\sum H_i}$$

Column I

Entries in Column I show how the difference in emissions between the base year and the year *t* changes in response to a 1 percent increase in emissions of category *x* emissions in the base year and year *t*. This shows the sensitivity of the trend in emissions to a systematic uncertainty in the emission estimate – i.e., one that is correlated between the base year and year *t*. This sensitivity is described as Type A sensitivity.

I_x = percentage trend if category *x* is increased by 1 percent in both years – percentage trend without increase

$$= \frac{0.01 \bullet D_x + \sum D_i - (0.01 \bullet C_x + \sum C_i)}{(0.01 \bullet C_x + \sum C_i)} \bullet 100 \ - \ \frac{\sum D_i - \sum C_i}{\sum C_i} \bullet 100$$

Column J

Entries in Column J show how the difference in emissions between the base year and year *t* changes in response to a 1 percent increase in the emissions of category *x* in year *t* only. This shows the sensitivity of the trend in emissions to random uncertainty error in the emissions estimate – i.e., one that is not correlated between the base year and year Y. This sensitivity is described as Type B sensitivity.

J_x = percentage trend if category *x* is increased by 1 percent in year *t* – percentage trend without increase

$$= \frac{0.01 \bullet D_x + \sum D_i - \sum C_i}{\sum C_i} \bullet 100 - \frac{\sum D_i - \sum C_i}{\sum C_i} \bullet 100$$

$$= \frac{D_x}{\sum C_i}$$

Column K
Under the assumption that the same emission factor is used in both years and the actual emission factors are fully correlated, the percent error introduced by it is equal in both years. Therefore the formula for the uncertainty introduced on the trend by the emission factor is:

$$\begin{aligned} K_x &= \text{sensitivity A} \bullet \text{uncertainty of emission factor} \\ &= I_x \bullet F_x \end{aligned}$$

In case no correlation between emission factors is assumed, sensitivity B should be used and the result needs to be increased by √2 for the reason given below in the main derivation for Column L:

$$\begin{aligned} K_x &= \text{sensitivity B} \bullet \text{uncertainty of emission factor} \bullet \sqrt{2} \\ &= J_x \bullet F_x \bullet \sqrt{2} \end{aligned}$$

Column L
The trend is the difference between the emissions in the base year and in the year *t*. Therefore the uncertainty of the activity data of the base year and year *t* has to be taken into account. The two uncertainties combined using the error propagation equation and the assumption that the uncertainty is the same in the base year and year *t* is:

$$\begin{aligned} &= \sqrt{(\text{uncertainty (activity data, base year)})^2 + (\text{uncertainty (activity data, year } t))^2} \\ &\approx \sqrt{(\text{uncertainty (activity data, year } t))^2 \bullet 2} \\ &= E_x \bullet \sqrt{2} \end{aligned}$$

Since activity data in both years are assumed to be independent, Column L equals:

L_x = sensitivity B • combined uncertainty of activity data of both years

$$= J_x \bullet E_x \bullet \sqrt{2}$$

In case correlation between activity data is assumed, sensitivity A should be used and the √2 factor does not apply.

$$L_x = I_x \bullet E_x$$

Column M
Uncertainty introduced on the trend by the uncertainty in the activity data and the emissions factor.

$$M_x = K_x^2 + L_x^2$$

The entries M_i in Column M are combined to obtain the total uncertainty of the trend using the error propagation equation as follows:

$$\text{Total uncertainty of the trend} = \sqrt{\sum M_i}$$

3.7.2 Approach 1 – details of the equations for trend uncertainty

The following steps show how to calculate trend uncertainty using Types A and B sensitivities (see also Section 3.2.3.1).

1) The method for assessing level uncertainty in year Y assumes that categories and gases are uncorrelated, or are aggregated until the aggregated categories can be treated as uncorrelated.

2) The uncertainty in the trend in total emissions from the country (the quantity at the foot of Column M) is estimated as:

$$U_T = \sqrt{\sum_{i=1}^{N} U_i^2}$$

where U_T is the uncertainty in the trend in total emissions from the country and U_i is the uncertainty introduced into U_T by the category *i* and gas.

3) We take

$$U_i = \sqrt{(U_{E,i}^2 + U_{A,i}^2)}$$

where $U_{E,i}$ is the uncertainty introduced into U_i by the uncertainty associated with the emission factor of the category i and gas, and $U_{A,i}$ is the uncertainty introduced into U_i by the uncertainty associated with the activity data of the category i and gas.

4) We know from Columns E and F what the uncertainties related to activity data and emission factors for the category i and gas are in percentage terms, but we do not yet know how these uncertainties affect the trend in the total emissions, which is what we need for $U_{E,i}$ and $U_{A,i}$. For this we write

$U_{E,i} = A_i u_{e,i}$ and $U_{A,i} = B_i u_{a,i}$

Where A_i is the Type A sensitivity associated with the category i and gas, and $u_{e,i}$ the percentage uncertainty associated with the emission factor in Column F, and B_i is the Type B sensitivity associated with the category i and gas, and $u_{a,i}$ the percentage uncertainty associated with the activity data in Column E. Essentially Type A and Type B sensitivities are elasticities relating respectively a percentage difference that is self-correlated between the base year and year Y, and one which is uncorrelated, to the percentage change in total emissions. The method allows for this assumption to be inverted, or for both emission factor and activity data to be self-correlated between years, or for neither to be self-correlated.

5) The Type A and Type B sensitivities are calculable from formulae for the trend in terms of sums over categories and gases in the base year and in year Y. The additional factor of √2 is introduced because an uncorrelated uncertainly might affect either the base year or the year Y. The current formulation assumes for Type B sensitivity that the emissions in year Y are not too different from those in the base year; if this were not the case we would have to introduce separate consideration of the base year and year Y for the uncorrelated uncertainties, rather than using the √2 factor.

DERIVATION OF TYPE A SENSITIVITY

The trend can be written as (assuming that 1990 is a base year):

$$100 \bullet \left(\frac{\sum_{i=1}^{N} e_{i,y} - \sum_{i=1}^{N} e_{i,1990}}{\sum_{i=1}^{N} e_{i,1990}} \right)$$

If the category i and gas is increased by 1 percent throughout (consistent with the assumption that Type A sensitivity captures the effect of uncertainties which are correlated between years) the trend becomes:

$$100 \bullet \left(\frac{\sum_{i=1}^{N} e_{i,y} + 0.01\, e_{i,y} - \left(\sum_{i=1}^{N} e_{i,1990} + 0.01\, e_{i,1990} \right)}{\sum_{i=1}^{N} e_{i,1990} + 0.01\, e_{i,1990}} \right)$$

and the sensitivity A_i becomes:

$$100 \bullet \left(\frac{\sum_{i=1}^{N} e_{i,y} + 0.01\, e_{i,y} - \left(\sum_{i=1}^{N} e_{i,1990} + 0.01\, e_{i,1990} \right)}{\sum_{i=1}^{N} e_{i,1990} + 0.01\, e_{i,1990}} \right) - 100 \bullet \left(\frac{\sum_{i=1}^{N} e_{i,y} - \sum_{i=1}^{N} e_{i,1990}}{\sum_{i=1}^{N} e_{i,1990}} \right)$$

This is the same as the expression given for the Type A sensitivity in Note B on page 6.18 of the *GPG2000*.

TYPE B SENSITIVITY

The Type B sensitivity we assume that the category i and gas is increased by 1 percent in year y only. In this case the trend becomes:

$$100 \bullet \left(\frac{\sum_{i=1}^{N} e_{i,y} + 0.01\, e_{i,y} - \sum_{i=1}^{N} e_{i,1990}}{\sum_{i=1}^{N} e_{i,1990}} \right)$$

So the sensitivity B_i becomes:

$$100 \bullet \left(\frac{\sum_{i=1}^{N} e_{i,y} + 0.01\, e_{i,y} - \sum_{i=1}^{N} e_{i,1990}}{\sum_{i=1}^{N} e_{i,1990}} \right) - 100 \bullet \left(\frac{\sum_{i=1}^{N} e_{i,y} - \sum_{i=1}^{N} e_{i,1990}}{\sum_{i=1}^{N} e_{i,1990}} \right)$$

All the terms on the numerator cancel out between the brackets except for 0.01 $e_{i,y}$ which becomes $e_{i,y}$ when multiplied by 100. So the expression for B_i simplifies to $e_{i,y} \Big/ \sum_{i=1}^{N} e_{i,1990}$ which is the expression at the top of Column J on page 6.16 of the *GPG2000*.

3.7.3 Dealing with large and asymmetric uncertainties in the results of Approach 1

This section provides guidance on how to correct for biases in large estimates of uncertainty from Approach 1 and how to convert the uncertainty ranges into asymmetric 95 percent probability ranges based upon a lognormal distribution.

Correction of uncertainty estimate for large uncertainties: The approximate error propagation method of Approach 1 produces an estimate of the uncertainty half range (U), expressed as a percentage relative to the mean, of the inventory results. As the uncertainty in the total inventory uncertainty becomes larger, the error propagation approach systematically underestimates the uncertainty unless the model is purely additive. However, most inventories are estimated based upon the sum of terms, each of which is a product (e.g., of emission factors and activity data). The error propagation approach is not exact for such multiplicative terms. Results from empirical studies show that in some cases uncertainty estimated using Approach 1 could be underestimated; the analyst could use a correction factor, for example that proposed in Frey (2003). Frey (2003) evaluated the performance of an analytical approach for combining uncertainty in comparison to a Monte Carlo simulation with large sample sizes for many cases involving different ranges of uncertainty for additive, multiplicative, and quotient models. Error propagation and Monte Carlo simulated estimates of the uncertainty half-range of the model output agreed well for values of less than 100 percent. As the uncertainty in the total inventory increased to higher levels, there was a systematic under-estimation of uncertainty in the total inventory by the error propagation approach. The relationship between the simulated and error propagation estimates was found to well-behaved. Thus, a correction factor was developed from the comparison that is applicable if *U* for the total inventory uncertainty is large (e.g., greater than 100 percent) and is given by:

EQUATION 3.3
CORRECTION FACTOR FOR UNCERTAINTY HALF-RANGE

$$F_C = \left[\frac{\left(-0.720 + 1.0921 U - 1.63 \bullet 10^{-3}\, U^2 + 1.11 \bullet 10^{-5}\, U^3 \right)}{U} \right]^2$$

Note: Use if $U > 100\%$ and if the model contains multiplicative or quotient terms

Not necessarily reliable for $U > 230\%$

Not necessary for models that are purely additive.

Where:

U = ½-range for uncertainty estimated from error propagation, in units of percent

F_c = Correction factor for analytical estimate of the variance, dimensionless ratio of corrected to uncorrected uncertainty

The empirically-based correction factor produces values from 1.06 to 1.69 as *U* varies from 100% to 230%. The correction factor is used to develop a new, corrected, estimate of the total inventory uncertainty half-range, $U_{corrected}$, which in turn is used to develop confidence intervals.

EQUATION 3.4
CORRECTED UNCERTAINTY HALF-RANGE

$$U_{corrected} = U \bullet F_C$$

Where:

$U_{corrected}$ = Corrected ½-range for uncertainty estimated from error propagation, in units of %

The errors in the analytical estimate of the variance are generally small for uncertainty half-ranges (*U*) of less than approximately 100 percent. If the correction factor is applied for $U > 100\%$ for values of *U* up to 230%, the typical error in the estimate of *U* is expected to be within plus or minus 10 percent in most cases. The correction factor will not necessarily be reliable for larger uncertainties because it was calibrated over the range of 10% to 230%.

Calculation of asymmetric confidence intervals for large uncertainties: In order to calculate confidence intervals for the model output based upon only the mean and half-range for uncertainty, a distribution must be assumed. For models that are purely additive, and for which the half range of uncertainty is less than approximately 50 percent, a normal distribution is often an accurate assumption for the form of the model output. In this case, a symmetric uncertainty range with respect to the mean can be assumed. For multiplicative models, or when the uncertainty is large for a variable that must be non-negative, a lognormal distribution is typically an accurate assumption for the form of the model output. In such cases, the uncertainty range is not symmetric with respect to the mean, even though the variance for the total inventory may be correctly estimated from Approach 1. Here, we provide a practical methodology for calculating approximate asymmetric uncertainty ranges based upon the results of error propagation, based upon a methodology developed by Frey (2003). A key characteristic of the 95 percent confidence intervals is that they are approximately symmetric for small ranges of uncertainty and they are positively skewed for large ranges of uncertainty. The latter result is necessary for a non-negative variable.

The parameters of the lognormal distribution can be defined in several ways, such as in terms of the geometric mean and geometric standard deviation. The geometric mean can be estimated based upon the arithmetic mean and the arithmetic standard deviation:

EQUATION 3.5
ASYMMETRIC CONFIDENCE INTERVALS – GEOMETRIC MEAN

$$\mu_g = \exp\left\{ \ln(\mu) - \frac{1}{2} \ln\left(1 + \left[\frac{U}{200} \right]^2 \right) \right\}$$

Where:

μ_g = geometric mean

μ = arithmetic mean

The geometric standard deviation is given by:

EQUATION 3.6
ASYMMETRIC CONFIDENCE INTERVALS – GEOMETRIC STANDARD DEVIATION

$$\sigma_g = \exp\left\{ \sqrt{ \ln\left(1 + \left[\frac{U}{200} \right]^2 \right) } \right\}$$

Where:

σ_g = geometric standard deviation

A confidence interval can be estimated based upon the geometric mean, geometric standard deviation, and the inverse cumulative probability distribution of a standard normal distribution (with a logarithmic transformation):

EQUATION 3.7
LOWER/UPPER UNCERTAINTY HALF-RANGE FROM ERROR PROPAGATION

$$U_{low} = \left(\frac{\exp\{\ln(\mu_g) - 1.96 \ln(\sigma_g)\} - \mu}{\mu} \right) \times 100$$

$$U_{high} = \left(\frac{\exp\{\ln(\mu_g) + 1.96 \ln(\sigma_g)\} - \mu}{\mu} \right) \times 100$$

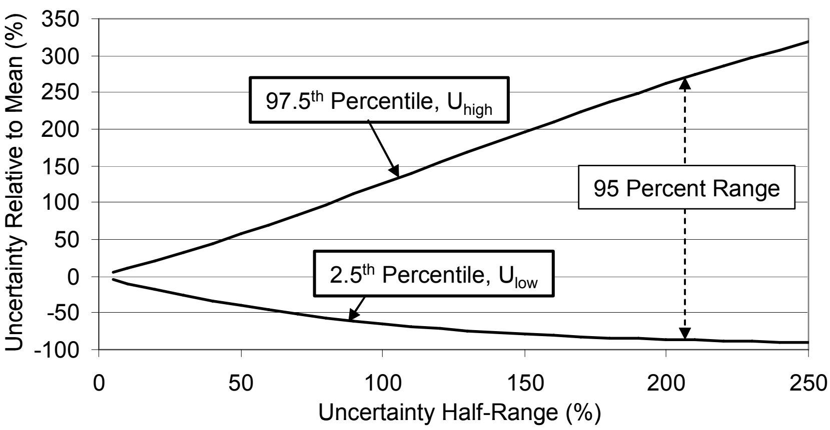
Where:

U_{low} = Lower ½-range for uncertainty estimated from error propagation, in units of %.

U_{high} = Upper ½-range for uncertainty estimated from error propagation, in units of %.

To illustrate the use of these equations, consider an example. Suppose the mean is 1.0 and the ½-range of uncertainty estimated from error propagation is 100 percent. In this case, the geometric mean is 0.89 and the geometric standard deviation is 1.60. The 95 percent probability range as a percentage relative to the mean is given by the interval from U_{low} to U_{high} of Equations 3.7. In the example, the result is -65% to +126%. In contrast, if a normal distribution had been used as the basis for uncertainty estimation, the range would have been estimated as approximately ±100% and there would be a probability of approximately two percent of obtaining negative values. Figure 3.9 illustrates the sensitivity of the lower and upper bounds of the 95 percent probability range, which are the 2.5th and 97.5th percentiles, respectively, calculated assuming a lognormal distribution based upon an estimated uncertainty half-range from an error propagation approach. The uncertainty range is approximately symmetric relative to the mean up to an uncertainty half-range of approximately 10 to 20 percent. As the uncertainty half-range, *U*, becomes large, the 95 percent uncertainty range shown in Figure 3.9 becomes large and asymmetric. For example, if *U* is 73 percent, then the estimated probability range is approximately -50% to +100%, or a factor of two.

Figure 3.9 Estimates of asymmetric ranges of uncertainty with respect to the arithmetic mean assuming a lognormal distribution based upon uncertainty half-range calculated from a propagation of error approach



3.7.4 Methodology for calculation of the contribution to uncertainty

The methodology for calculation of contribution to uncertainty is based upon apportioning the variance of the inventory to the variance of each category.

If the uncertainty is symmetric, then the variance is estimated, on a category basis, as:

EQUATION 3.8
CONTRIBUTION OF CATEGORY X – VARIANCE FOR SYMMETRIC UNCERTAINTY

$$\sigma_x^2 = \left(D_x \frac{U_x}{200} \right)^2$$

Where:

U_x = uncertainty half-range for category *x*, in units of percent;

D_x = the total emissions or removals for category *x*, corresponding to the entries in Column D of Table 3.5.

σ_x^2 = the variance of emissions or removals for category *x*.

Even if the uncertainty is asymmetric, the variance can be estimated based on the arithmetic standard deviation or the coefficient of variation. The variance is simply the square of the arithmetic deviation. The variance for the category can be estimated from the coefficient of variation, v_x, as:

EQUATION 3.9
CONTRIBUTION OF CATEGORY X – VARIANCE FOR ASYMMETRIC UNCERTAINTY

$$\sigma_x{}^2 = (D_x \upsilon_x)^2$$

Once the variance is known for a category, the variances should be summed over all categories. The result is the approximate total variance in the inventory. However, this result is not likely to agree exactly with a Monte Carlo simulation result for the inventory for at least one and possibly more reasons: (1) because of sample fluctuations in the Monte Carlo simulation, the Monte Carlo estimate of the variance may differ somewhat from the true value; (2) the analytical calculation is based upon assumptions of normality or lognormality of the distributions for combined uncertainty for individual categories, whereas Monte Carlo simulation can accommodate a wide variety of distribution assumptions; and (3) the Monte Carlo simulation may account for nonlinearities and dependencies that are not accounted for in the analytical calculation for contribution to variance. If the emission inventory calculations are linear or approximately linear, without any substantial correlations, then the results should agree fairly well. Furthermore, methods for estimating 'contribution to variance' for Monte Carlo methods are approximate. For those methods that potentially can account for all contributions to variance (e.g., Sobol's method, Fourier Amplitude Sensitivity Test), the measures of sensitivity are more complex (e.g., Mokhtari *et al*., 2006). Thus, the methodology described here is a practical compromise.

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CHAPTER 4

METHODOLOGICAL CHOICE AND IDENTIFICATION OF KEY CATEGORIES

Authors

Anke Herold (Germany), Suvi Monni (Finland)

Erda Lin (China), and C. P. (Mick) Meyer (Australia)

Contributing Authors

Ketil Flugsrud (Norway)

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4 METHODOLOGICAL CHOICE AND IDENTIFICATION OF KEY CATEGORIES

4.1 INTRODUCTION

This chapter addresses how to identify *key categories*[1] in a national inventory. Methodological choice for individual source and sink categories is important in managing overall inventory uncertainty. Generally, inventory uncertainty is lower when emissions and removals are estimated using the most rigorous methods provided for each category or subcategory in the sectoral volumes of these *Guidelines*. However, these methods generally require more extensive resources for data collection, so it may not be feasible to use more rigorous method for every category of emissions and removals. It is therefore *good practice* to identify those categories that have the greatest contribution to overall inventory uncertainty in order to make the most efficient use of available resources. By identifying these *key categories* in the national inventory, inventory compilers can prioritise their efforts and improve their overall estimates. It is *good practice* for each country to identify its national *key categories* in a systematic and objective manner as presented in this chapter. Consequently, it is *good practice* to use results of key category analysis as a basis for methodological choice. Such a process will lead to improved inventory quality, as well as greater confidence in the estimates that are developed.

4.1.1 Definition

A *key category* is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Whenever the term *key category* is used, it includes both source and sink categories.

4.1.2 Purpose of the key category analysis

As far as possible, *key categories* should receive special consideration in terms of three important inventory aspects.

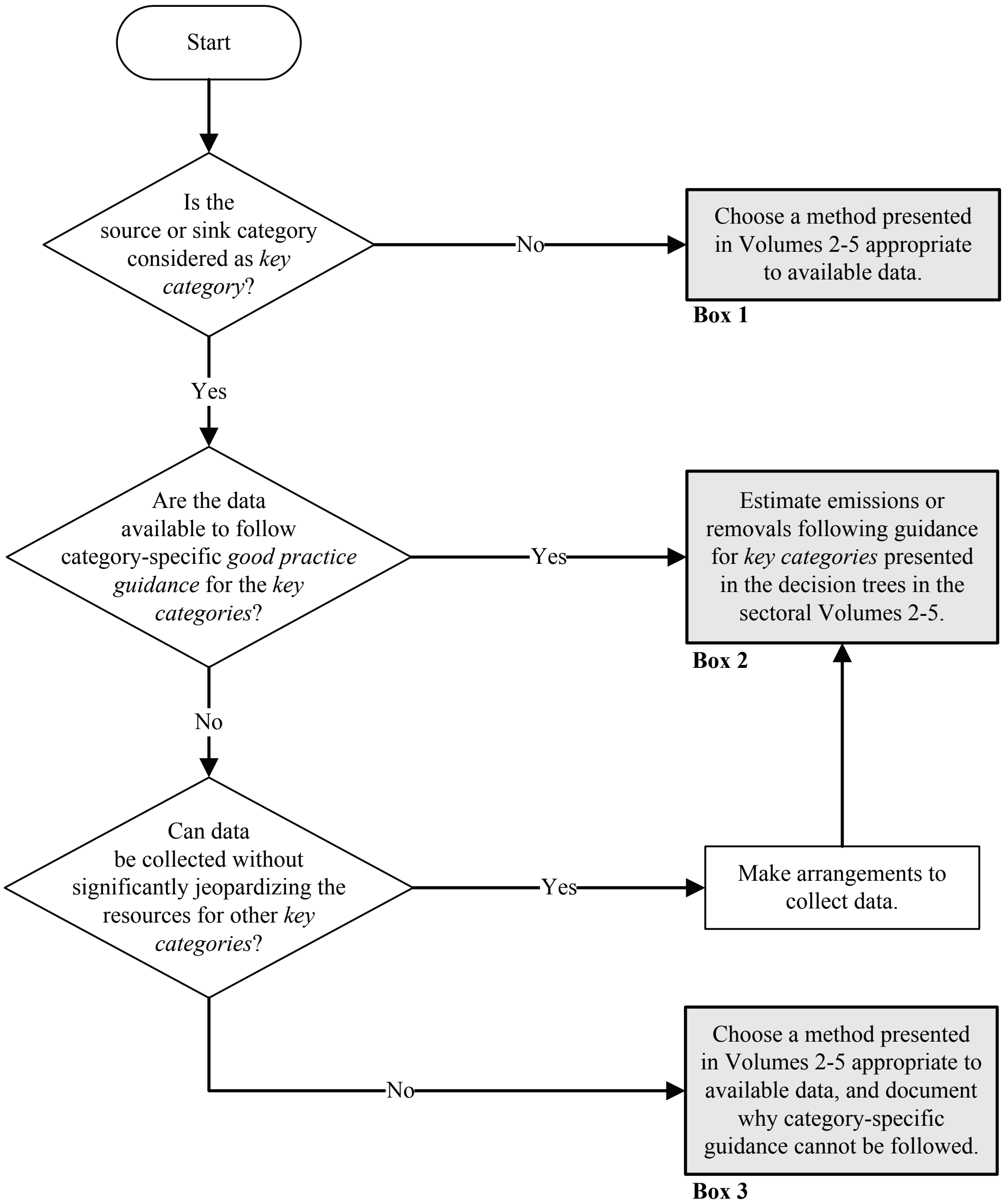
Firstly, identification of *key categories* in national inventories enables limited resources available for preparing inventories to be prioritised. It is *good practice* to focus the available resources for the improvement in data and methods onto categories identified as *key*.

Secondly, in general, more detailed higher tier methods should be selected for *key categories*. Inventory compilers should use the category-specific methods presented in sectoral decision trees in Volumes 2-5 (see Figure 4.1). For most sources/sinks, higher tier (Tier 2 and 3) methods are suggested for *key categories*, although this is not always the case. For guidance on the specific application of this principle to *key categories*, it is *good practice* to refer to the decision trees and sector-specific guidance for the respective category and additional *good practice guidance* in chapters in sectoral volumes. In some cases, inventory compilers may be unable to adopt a higher tier method due to lack of resources. This may mean that they are unable to collect the required data for a higher tier or are unable to determine country specific emission factors and other data needed for Tier 2 and 3 methods. In these cases, although this is not accommodated in the category-specific decision trees, a Tier 1 approach can be used, and this possibility is identified in Figure 4.1. It should in these cases be clearly documented why the methodological choice was not in line with the sectoral decision tree. Any *key categories* where the good practice method cannot be used should have priority for future improvements.

Thirdly, it is *good practice* to give additional attention to *key categories* with respect to quality assurance and quality control (QA/QC) as described in Chapter 6, Quality Assurance/Quality Control and Verification, and in the sectoral volumes.

[1] In Good Practice Guidance for National Greenhouse Gas Inventories (*GPG2000*, IPCC, 2000), the concept was named 'key source categories' and dealt with the inventory excluding the LULUCF Sector.

Figure 4.1 Decision Tree to choose a Good Practice method



4.1.3 General approach to identify key categories

Any inventory compiler who has prepared a national greenhouse gas inventory will be able to identify *key categories* in terms of their contribution to the absolute level of national emissions and removals. For those inventory compilers who have prepared a time series, the quantitative determination of *key categories* should include an evaluation of both the absolute level and the trend of emissions and removals. Some *key categories* may be identified only when their influence on the trend of the national inventory is taken into account.

Section 4.2 sets out general rules for identification of *key categories*, whereas the methodological approaches for determination of *key categories* are provided in Section 4.3. Both basic Approach 1 and Approach 2 which takes uncertainties into account are described. In addition to making a quantitative determination of *key categories*, it is *good practice* to consider qualitative criteria which is described in more detail in Section 4.3.3. Guidance on reporting and documentation of the key category analysis is provided in Section 4.4. Section 4.5 gives examples for key category identification.

4.2 GENERAL RULES FOR IDENTIFICATION OF KEY CATEGORIES

The results of the *key category* identification will be most useful if the analysis is done at the appropriate disaggregation level of categories. Table 4.1, Suggested aggregation level of analysis for Approach 1, lists the source and sink categories that are recommended and identifies special considerations related to the disaggregation of the analysis, where relevant. For example, the combustion of fossil fuels is a large emission source category that can be broken down into subcategories of 1st, 2nd or 3rd order, and even to the level of individual plants or boilers. Countries may adapt the recommended level of analysis in Table 4.1 to their national circumstances. In particular countries using Approach 2 will probably choose the same level of aggregation that was used for the uncertainty analysis. In some cases, disaggregation to very low levels should be avoided since it may split an important aggregated category into many small subcategories that are no longer *key*. The following guidance describes *good practice* in determining the appropriate level of disaggregation of categories to identify *key categories*:

- The analysis should be performed at the level of IPCC categories or subcategories at which the IPCC methods and decision trees are generally provided in the sectoral volumes.
- Each greenhouse gas emitted from each category should be considered separately, unless there are specific methodological reasons for treating gases collectively. For example, carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are emitted from road transportation. The key category analysis for this source should be performed for each of these gases separately because the methods, emission factors and related uncertainties differ for each gas. In contrast, a collective analysis of all chemical species of hydrofluorocarbons (HFCs) is appropriate for the category 'Product Uses as Substitutes for Ozone Depleting Substances'.
- If data are available, the analysis should be performed for emissions and removals separately within a given category. For example, the land use categories and the pool estimates can include emissions and removals that may cancel or almost cancel at the aggregated level for the categories presented in Table 4.1. In cases where emissions and removals cancel out and where methods do not allow to estimate emissions and removals separately, the inventory compiler should include further disaggregated subcategories in the key category analysis (e.g., including two different areas, one area where carbon stock decreases occur and another area where carbon stock increases take place), in particular when the data for reported subcategories clearly show significant carbon stock changes at more disaggregate level. Similar considerations may apply in the Energy and IPPU (Industrial Processes and Product Use) Sectors, for example, in a situation where CO2 is being captured for storage.
- Table 4.1 shows the recommended level of analysis.2 Countries may choose to perform the quantitative analysis at a more disaggregated level than suggested in this table. In this case, possible cross-correlations between categories and/or subcategories should be taken into account when performing the key category analysis. When using Approach 2, the assumptions about such correlations should be the same when assessing uncertainties and identifying key categories (see Chapter 3, Uncertainties).
- The categories and gases included in Table 4.1 are those for which estimation methods are provided in the sectoral volumes. If countries develop estimates for new categories or gases for which GWPs become available, these should be added to the analysis under Miscellaneous for the appropriate sector. It is not possible to include gases for which no GWP is available since the analysis is performed using CO2-equivalent emissions3.
- Indirect N2O emissions from deposition of NOx and other nitrogen compounds from categories other than AFOLU (Agriculture, Forestry and Other Land Use) Sector's are included in the key category analysis in category 5A, Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3. However, the 2006 Guidelines do not provide decision trees or methodological guidance for estimating emissions from NOx and NH3, and therefore identification of indirect N2O as key does not have an effect on the methodological choice.

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[2] Most correlations between categories can be avoided by using the aggregation level of this table. Some correlations remain, e.g., in fuel use between stationary combustion and transportation and for HFCs. In practice, the effect of correlations for key category analysis should be taken into account in the disaggregation level used for the Approach 2 assessment (for more advice on correlations in uncertainty analysis, see Chapter 3.)

[3] The methodology is also applicable for other weighting scheme, but for the derivation of threshold for Approach 1 and 2 and for the examples in Section 4.5 CO_2-equivalent values were calculated using the global warming potentials (GWP) over a 100 year horizon of the different greenhouse gases, provided by the IPCC in its Second Assessment Report.

For each *key category* where relevant (see Table 4.1 below), the inventory compiler should determine if certain subcategories are particularly significant. Usually, for this purpose, the subcategories should be ranked according to their contribution to the aggregate *key category*. Those subcategories that contribute together more than 60 percent to the *key category* should be treated as particularly significant. It may be appropriate to focus efforts towards methodological improvements of these most significant subcategories. For those categories where subcategories need to be identified it is clearly mentioned in the appropriate decision trees in Volumes 2-5. In some cases and alternative method to identify these subcategories is used.

TABLE 4.1 **SUGGESTED AGGREGATION LEVEL OF ANALYSIS FOR APPROACH 1 [a]**			
Source and Sink Categories to be Assessed in Key Category Analysis		**Gases to be Assessed [c]**	**Special Considerations**
Category Code [b]	**Category Title [b]**		
Energy			
1A1	Fuel Combustion Activities - Energy Industries	CO_2, N_2O, CH_4	Disaggregate to main fuel types.
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	CO_2, N_2O, CH_4	Disaggregate to main fuel types.
1A3a	Fuel Combustion Activities - Transport - Civil Aviation	CO_2, N_2O, CH_4	Domestic aviation only.
1A3b	Fuel Combustion Activities - Transport - Road transportation	CO_2, N_2O, CH_4	
1A3c	Fuel Combustion Activities - Transport - Railways	CO_2, N_2O, CH_4	
1A3d	Fuel Combustion Activities - Transport - Water-borne Navigation	CO_2, N_2O, CH_4	Disaggregate to main fuel types. Domestic Water-borne navigation only.
1A3e	Fuel Combustion Activities - Transport - Other Transportation	CO_2, N_2O, CH_4	If this category is *key*, the inventory compiler should determine which subcategories are significant.
1A4	Fuel Combustion Activities - Other Sectors	CO_2, N_2O, CH_4	Disaggregate to main fuel types.
1A5	Fuel Combustion Activities - Non-Specified	CO_2, N_2O, CH_4	Disaggregate to main fuel types.
1B1	Fugitive emissions from fuels - Solid Fuels	CO_2, CH_4	
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO_2, CH_4	If this category is *key*, the inventory compiler should determine which subcategories are significant.
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural gas	CO_2, CH_4	If this category is *key*, the inventory compiler should determine which subcategories are significant.
1C	Carbon Dioxide Transport and Storage	CO_2	If this category is *key*, the inventory compiler should determine which subcategories are significant.
1	Miscellaneous	CO_2, CH_4, N_2O	Assess whether other sources in the Energy Sector not listed above should be included. Key category analysis has to cover all emission sources in the inventory. Therefore all categories not presented above should be either aggregated with some other category, where relevant, or assessed separately.
Industrial Processes and Product Use			
2A1	Mineral industry - Cement Production	CO_2	
2A2	Mineral Industry - Lime Production	CO_2	
2A3	Mineral Industry - Glass Production	CO_2	

TABLE 4.1 (CONTINUED)
SUGGESTED AGGREGATION LEVEL OF ANALYSIS FOR APPROACH 1 [a]

Source and Sink Categories to be Assessed in Key Category Analysis		Gases to be Assessed [c]	Special Considerations
Category Code [b]	**Category Title [b]**		
2A4	Mineral Industry - Other Process Uses of Carbonates	CO_2	If this category is *key*, the inventory compiler should determine which subcategories are significant.
2B1	Chemical Industry - Ammonia Production	CO_2	
2B2	Chemical industry - Nitric Acid Production	N_2O	
2B3	Chemical industry - Adipic Acid Production	N_2O	
2B4	Chemical industry - Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	If this category is *key*, the inventory compiler should determine which subcategories (caprolactam, glyoxal and glyoxylic acid) are significant.
2B5	Chemical industry - Carbide Production	CO_2, CH_4,	
2B6	Chemical industry - Titanium Dioxide Production	CO_2	
2B7	Chemical Industry - Soda Ash Production	CO_2	
2B8	Chemical Industry - Petrochemical and Carbon Black Production	CO_2, CH_4	If this category is *key*, the inventory compiler should determine which subcategories are significant.
2B9	Chemical Industry - Fluorochemical Production	HFCs, PFCs, SF_6, and other halogenated gases	All gases should be assessed jointly. If this category is *key*, the inventory compiler should determine which subcategories/gases (e.g., HFC-23 from HCFC-22 production) are significant.
2C1	Metal Industry - Iron and Steel Production	CO_2, CH_4	
2C2	Metal Industry - Ferroalloys Production	CO_2, CH_4	
2C3	Metal Industry - Aluminium Production	PFCs, CO_2	PFCs should be assessed jointly. CO_2 should be assessed separately.
2C4	Metal Industry - Magnesium Production	CO_2, SF_6, PFCs, HFCs, other halogenated gases	Methods for HFCs, PFCs and other halogenated gases are only provided at Tier 3 level. If they are not included in the inventory it is *good practice* to use qualitative considerations. (See Section 4.3.3.)
2C5	Metal Industry - Lead Production	CO_2	
2C6	Metal Industry - Zinc Production	CO_2	
2D	Non-Energy Products from Fuels and Solvent Use	CO_2	If this category is *key*, the inventory compiler should determine which subcategories are significant.
2E	Electronics Industry	SF_6, PFCs, HCFs, other halogenated gases	All gases should be assessed jointly. If this category is *key*, the inventory compiler should determine which subcategories are significant.
2F1	Product Uses as Substitutes for Ozone Depleting Substances - Refrigeration and Air Conditioning	HFCs, PFCs	All HFC and PFC gases should be assessed jointly.
2F2	Product Uses as Substitutes for Ozone Depleting Substances - Foam Blowing Agents	HFCs	All HFC gases should be assessed jointly.

TABLE 4.1 (CONTINUED) SUGGESTED AGGREGATION LEVEL OF ANALYSIS FOR APPROACH 1 [a]			
Source and Sink Categories to be Assessed in Key Category Analysis		**Gases to be Assessed [c]**	**Special Considerations**
Category Code [b]	**Category Title [b]**		
2F3	Product Uses as Substitutes for Ozone Depleting Substances - Fire Protection	HFCs, PFCs	All HFC and PFC gases should be assessed jointly.
2F4	Product Uses as Substitutes for Ozone Depleting Substances - Aerosolls	HFCs, PFCs	All HFC and PFC gases should be assessed jointly.
2F5	Product Uses as Substitutes for Ozone Depleting Substances - Solvents	HFCs, PFCs	All HFC and PFC gases should be assessed jointly.
2F6	Product Uses as Substitutes for Ozone Depleting Substances - Other Applications	HFCs, PFCs	All HFC and PFC gases should be assessed jointly.
2G	Other Product Manufacture and Use	SF_6, PFCs, N_2O	All PFC gases and SF_6 should be assessed jointly. If this category is *key*, the inventory compiler should determine which subcategories are significant. N_2O should be assessed separately.
2	Miscellaneous	CO_2 , CH_4, N_2O, HFCs, PFCs, SF_6, other halogenated gases	Assess whether other sources in the Industrial Processes and Product Use Sector not listed above should be included. Key category analysis should cover all emission sources in the inventory. Therefore all categories not presented above should be either aggregated with some other category, where relevant, or assessed separately.
Agriculture, Forestry and Other Land Use			
3A1	Enteric Fermentation	CH_4	If this category is *key*, the inventory compiler should determine which animal categories are significant. For *key categories*, decision trees for livestock population characterisation as well as for CH_4 emissions estimation should be followed.
3A2	Manure Management	CH_4, N_2O	If this category is *key*, the inventory compiler should determine which animal categories and waste management systems are significant. For *key categories*, decision trees for livestock population characterisation as well as for CH_4 or N_2O emissions estimation should be followed.
3B1a	Forest Land Remaining Forest Land	CO_2	If this category is *key*, the inventory compiler should determine which pools (biomass, DOM, mineral soils, organic soils) are significant and should then follow the guidance for *key categories* in decision trees for carbon stock changes for the significant pools.
3B1b	Land Converted to Forest Land	CO_2	If this category is *key*, the inventory compiler should determine which pools and subcategories are significant.
3B2a	Cropland Remaining Cropland	CO_2	If this category is *key*, the inventory compiler should determine which pools are significant.

TABLE 4.1 (CONTINUED) SUGGESTED AGGREGATION LEVEL OF ANALYSIS FOR APPROACH 1 [a]			
Source and Sink Categories to be Assessed in Key Category Analysis		**Gases to be Assessed [c]**	**Special Considerations**
Category Code [b]	**Category Title [b]**		
3B2b	Land Converted to Cropland	CO_2	Assess the impact of forest land converted to cropland in a separate category. [d] If this category is *key*, the inventory compiler should determine which pools and subcategories are significant
3B3a	Grassland Remaining Grassland	CO_2	If this category is *key*, the inventory compiler should determine which pools are significant.
3B3b	Land Converted to Grassland	CO_2	Assess the impact of forest land converted to grassland in a separate category. [d] If this category is *key*, the inventory compiler should determine which pools and subcategories are significant.
3B4ai	Peatlands Remaining Peatlands	CO_2, N_2O	
3B4aii	Flooded land remaining Flooded land	CO_2	
3B4b	Land Converted to Wetlands	CO_2	Assess the impact of forest land converted to wetland in a separate category (see below). [d] If this category is *key*, the inventory compiler should determine which pools and subcategories are significant.
3B5a	Settlements Remaining Settlements	CO_2	If this category is *key*, the inventory compiler should determine which pools are significant.
3B5b	Land Converted to Settlements	CO_2	Assess the impact of forest land converted to settlements in a separate category. [d] If this category is *key*, the inventory compiler should determine which pools and subcategories are significant.
3C1	Biomass Burning	CH_4, N_2O	
3C2	Liming	CO_2	
3C3	Urea Application	CO_2	
3C4	Direct N_2O Emissions from Managed soils	N_2O	If this category is *key*, the inventory compiler should determine which subcategories are significant.
3C5	Indirect N_2O Emissions from Managed soils	indirect N_2O	If this category is *key*, the inventory compiler should determine which subcategories are significant.
3C6	Indirect N_2O Emissions from Manure Management	indirect N_2O	
3C7	Rice Cultivations	CH_4	
3D1	Harvested Wood Products	CO_2	Use of *key* category analysis is optional.
3	Miscellaneous	CO_2, CH_4, N_2O	Assess whether other sources or sinks in the AFOLU Sector not listed above should be included. Key category analysis has to cover all emission sources and sinks in the inventory. Therefore all categories not presented above should be either aggregated with some other category, where relevant, or assessed separately.

TABLE 4.1 (CONTINUED)
SUGGESTED AGGREGATION LEVEL OF ANALYSIS FOR APPROACH 1 [a]

Source and Sink Categories to be Assessed in Key Category Analysis		**Gases to be Assessed [c]**	**Special Considerations**
Category Code [b]	**Category Title [b]**		
Waste			
4A	Solid Waste Disposal	CH_4	If this category is *key*, the inventory compiler should determine which subcategories are significant.
4B	Biological Treatment of Solid Waste	CH_4, N_2O	
4C	Incineration and Open Burning of Waste	CO_2, N_2O, CH_4	
4D	Wastewater Treatment and Discharge	CH_4, N_2O	Assess whether domestic or industrial wastewater treatment is a significant subcategory.
4	Miscellaneous	CO_2, CH_4, N_2O	Assess whether other sources in the Waste Sector not listed above should be included. Key category analysis has to cover all emission sources in the inventory. Therefore all categories not presented above should be either aggregated with some other category, where relevant, or assessed separately.
5A	Indirect N_2O Emissions from the atmospheric deposition of nitrogen in NO_x and NH_3	indirect N_2O	
5B	Other	CO_2, N_2O, CH_4, SF_6, PFCs, HCFs	Include sources and sinks reported under 5B. Key category assessment has to cover all emission sources in the inventory. Therefore all categories not presented above should be either aggregated with some other category, where relevant, or assessed separately.

[a] In some cases, inventory compilers may modify this list of IPCC categories to reflect particular national circumstances.
[b] The categories should include the respective codes and be consistent with the IPCC terminology.
[c] All the gases in this column are to be assessed separately, except 'Miscellaneous' category, where gases can be assessed jointly. There may also be some new gases other than those listed here, and those should also be assessed separately.
[d] In the quantitative key category analysis, conversion of forest land is spread out under the different land-use change categories. Countries should identify and sum up the emission estimates associated with forest conversion to any other land category and compare the magnitude to the smallest category identified as key. If its size is larger than the smallest category identified as key it should be considered key.

4.3 METHODOLOGICAL APPROACHES TO IDENTIFY KEY CATEGORIES

It is *good practice* for each country to identify its national *key categories* in a systematic and objective manner, by performing a quantitative analysis of the relationships between the level and the trend of each category's emissions and removals and total national emissions and removals.

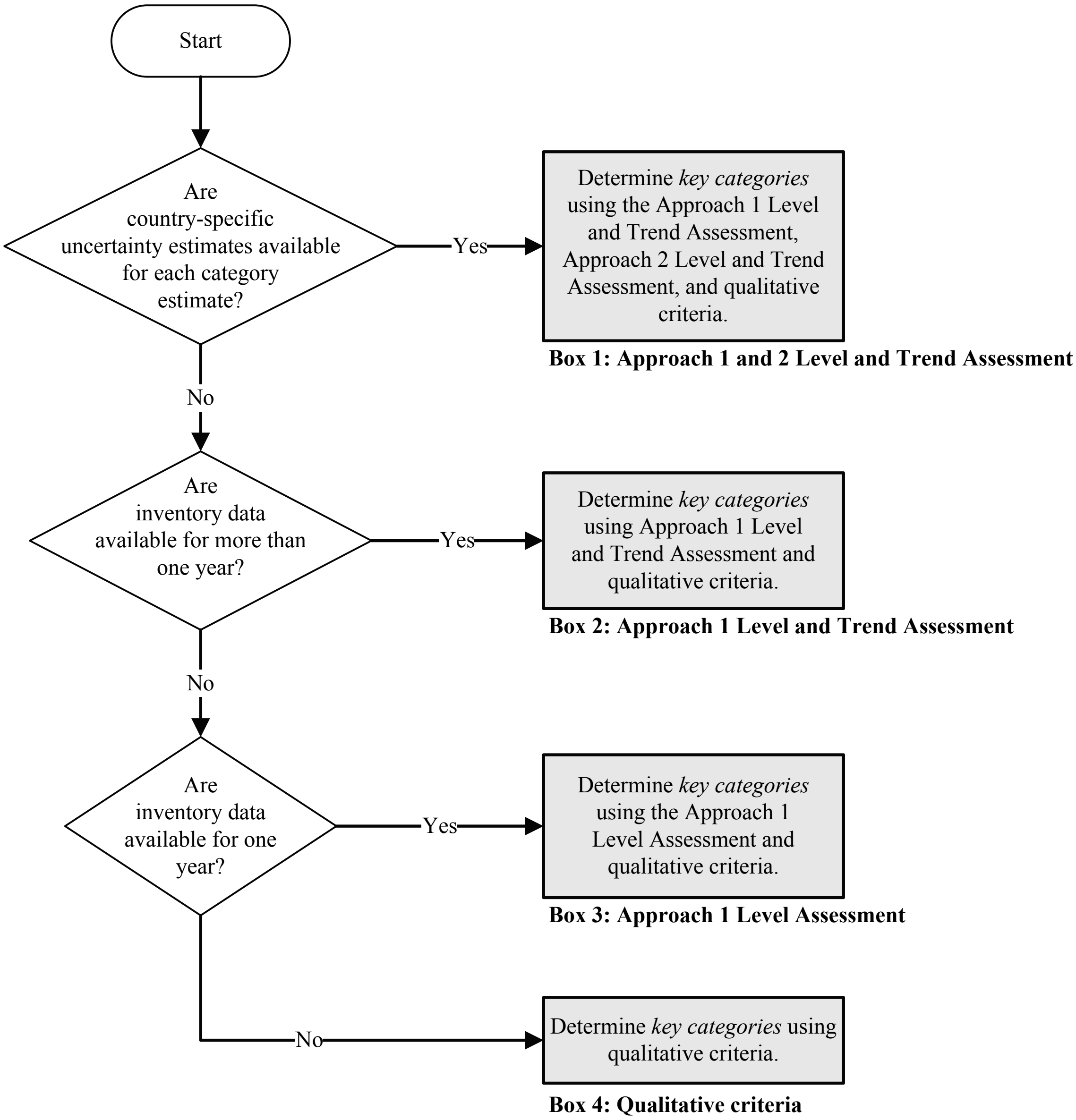
Two Approaches for performing the key category analysis have been developed. Both Approaches identify *key categories* in terms of their contribution to the absolute level of national emissions and removals and to the trend of emissions and removals.

In Approach 1, *key categories* are identified using a pre-determined cumulative emissions threshold. *Key categories* are those that, when summed together in descending order of magnitude, add up to 95 percent of the total level[4]. The method is described in more detail in Section 4.3.1, Approach 1 to identify key categories.

[4] The pre-determined threshold has been determined based on an evaluation of several inventories, and is aimed at establishing a general level where 90% of inventory uncertainty will be covered by key categories.

Approach 2 to identify *key categories* can be used by inventory compilers, if category uncertainties or parameter uncertainties are available. Under Approach 2, categories are sorted according to their contribution to uncertainty. This approach is described in more detail in Section 4.3.2, Approach 2 to identify key categories. Results of Approach 2 are additional to Approach 1. If both the Approach 1 and the Approach 2 assessment have been performed, it is *good practice* to report the results of the Approach 2 analysis in addition to the results of Approach 1. Results of both Approach 1 and 2 should be used when setting priorities to inventory preparation. Figure 4.2, Decision Tree to identify key categories, illustrates how inventory compilers can determine which Approach to be used for the identification of *key categories*.

Figure 4.2 Decision Tree to identify key categories



Any country that has developed a greenhouse gas inventory can perform Approach 1 Level Assessment to identify the categories whose level has a significant effect on total national emissions and removals. Those inventory compilers that have developed inventories for more than one year will also be able to perform Approach 1 Trend Assessment and identify categories that are *key* because of their contribution to the total trend of national emissions and removals.

4.3.1 Approach 1 to identify key categories

Approach 1 to identify *key categories* assesses the influence of various categories of sources and sinks on the *level*, and possibly the *trend*, of the national greenhouse gas inventory. When the inventory estimates are available for several years, it is *good practice* to assess the contribution of each category to both the level and trend of the national inventory. If only a single year's inventory is available, a level assessment should be performed.

Approach 1 can readily be accomplished using a spreadsheet analysis. Tables 4.2 and 4.3 in the following sections illustrate the format of the analysis. Separate spreadsheets are suggested for the level and trend assessments because it is necessary to sort the results of the analysis according to two different columns. It is more difficult to track the process if the analyses are combined in the same table. In both tables, columns A through D are inputs of the national inventory data. Section 4.5 illustrates the application of the Approach 1 to the Finnish inventory.

LEVEL ASSESSMENT

The contribution of each source or sink category to the total national inventory level is calculated according to Equation 4.1:

EQUATION 4.1
LEVEL ASSESSMENT (APPROACH 1)

Key category level assessment = | source or sink category estimate | / total contribution

$$L_{x,t} = \left|E_{x,t}\right| / \sum_{y}\left|E_{y,t}\right|$$

Where:

$L_{x,t}$ = level assessment for source or sink x in latest inventory year (year t).

$\left|E_{x,t}\right|$ = absolute value of emission or removal estimate of source or sink category x in year t

$\sum_{y}\left|E_{y,t}\right|$ = total contribution, which is the sum of the absolute values of emissions and removals in year t calculated using the aggregation level chosen by the country for key category analysis. Because both emissions and removals are entered with positive sign[5], the total contribution/level can be larger than a country's total emissions less removals.[6]

Key categories according to Equation 4.1 are those that, when summed together in descending order of magnitude, add up to 95 percent of the sum of all $L_{x,t}$.

Table 4.2 presents a spreadsheet that can be used for the level assessment. An example of the use of the spreadsheet is given in Section 4.5.

TABLE 4.2
SPREADSHEET FOR THE APPROACH 1 ANALYSIS – LEVEL ASSESSMENT

A	B	C	D	E	F	G
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**Latest Year Estimate $E_{x,t}$ [in CO_2-equivalent units]**	**Absolute Value of Latest Year Estimate $\lvert E_{x,t}\rvert$**	**Level Assessment $L_{x,t}$**	**Cumulative Total of Column F**
Total				$\sum_{y}\lvert E_{y,t}\rvert$	1	

Where:

Column A: code of IPCC categories (See Table 8.2 in Chapter 8, Reporting Guidance and Tables.)

Column B: description of IPCC categories (See Table 8.2 in Chapter 8.)

Column C: greenhouse gas from the category

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5 Removals are entered as absolute values to avoid an oscillating cumulative value Lx,t as could be the case if removals were entered with negative signs, and thus to facilitate straightforward interpretation of the quantitative analysis.

6 This equation can be used in any situation, regardless of whether the national greenhouse gas inventory is a net source (as is most common) or a net sink.

Column D: value of emission or removal estimate of category *x* in latest inventory year (year *t*) in CO_2-equivalent units

Column E : absolute value of emission or removal estimate of category *x* in year *t*

Column F : level assessment following Equation 4.1

Column G: cumulative total of Column F

Inputs to Columns A-D will be available from the inventory. The total of Column D presents the net emissions and removals. In Column E, absolute values are taken from each value in Column D. The sum of all entries in Column E is entered in the total line of Column E (note that this total may not be the same as the total net emissions and removals). In Column F, the level assessment is computed according to Equation 4.1. Once the entries in Column F are computed, the categories in the table should be sorted in descending order of magnitude according to Column F. After this step, the cumulative total summed in Column F can be calculated into Column G. *Key categories* are those that, when summed together in descending order of magnitude, add up to 95 percent of the total in Column G. Where the method is applied correctly, the sum of entries in Column F must be 1. The rationale for the choice of the 95 percent threshold for the Approach 1 builds on Rypdal and Flugsrud (2001) and is also presented in *GPG2000*, Section 7.2.1.1 in Chapter 7.

It is also *good practice* to examine categories identified between threshold of 95 percent and 97 percent carefully with respect to the qualitative criteria (see Section 4.3.3).

The level assessment should be performed for the base year of the inventory and for the latest inventory year (year *t*). If estimates for the base year have changed or been recalculated, the base year analysis should be updated. Key category analysis can also be updated for other recalculated years. In many cases, however, it is sufficient to derive conclusions regarding methodological choice, resource prioritisation or QA/QC procedures without an updated key category analysis for the entire inventory time series. Any category that meets the threshold for the base year or the most recent year should be identified as *key*. However, the interpretation of the results of the key category analysis should take longer time series than the most recent year into account if key category analyses are available. Because some categories having emissions/removals that fluctuate from year to year may be identified as *key categories* in one year but not in the next year. Therefore, for categories between thresholds of 95 and 97 percent it is suggested to compare the most recent key category analysis with the assessments for three or more previous years. If a category has been *key* for all or most previous years according to the either level or trend assessments or both (the two assessments should be considered separately), they should be identified as *key* in the latest year estimate except in cases where a clear explanation can be provided why a category may no longer be *key* in any future years. These additional categories should be addressed in the reporting table for *key categories* by using a column for comments (see Table 4.4 and reporting table for *key categories* in Section 4.4 for more information). The qualitative criteria presented in Section 4.3.3 may also help to identify which categories with fluctuating emissions or removals should be considered as *key categories*.

TREND ASSESSMENT

The purpose of the trend assessment is to identify categories that may not be large enough to be identified by the level assessment, but whose trend is significantly different from the trend of the overall inventory, and should therefore receive particular attention. The Trend Assessment can be calculated according to Equation 4.2 if more than one year of inventory data are available.

EQUATION 4.2
TREND ASSESSMENT (APPROACH 1)

$$T_{x,t} = \frac{\left|E_{x,0}\right|}{\sum_y \left|E_{y,0}\right|} \bullet \left| \left[\frac{\left(E_{x,t} - E_{x,0}\right)}{\left|E_{x,0}\right|} \right] - \frac{\left(\sum_y E_{y,t} - \sum_y E_{y,0}\right)}{\left|\sum_y E_{y,0}\right|} \right|$$

Where:

$T_{x,t}$ = trend assessment of source or sink category *x* in year *t* as compared to the base year (year 0)

$|E_{x,0}|$ = absolute value of emission or removal estimate of source or sink category *x* in year 0

$E_{x,t}$ and $E_{x,0}$ = real values of estimates of source or sink category *x* in years *t* and 0, respectively

$\sum_y E_{y,t}$ and $\sum_y E_{y,0}$ = total inventory estimates in years *t* and 0, respectively

The trend of category refers to the change in the source or sink category emissions or removals over time, computed by subtracting the base year (year 0) estimate for source or sink category *x* from the latest inventory year (year *t*) estimate and dividing by the absolute value of the base year estimate.

The total trend refers to the change in the total inventory emissions (or removals) over time, computed by subtracting the base year (year 0) estimate for the total inventory from the latest year (year *t*) estimate and dividing by the absolute value of the base year estimate.

In circumstances where the base year emissions for a given category are zero, the expression may be reformulated to avoid zero in the denominator (see Equation 4.3).

EQUATION 4.3
TREND ASSESSMENT WITH ZERO BASE YEAR EMISSIONS

$$T_{x,t} = \left| E_{x,t} \,/\, \sum_y \left| E_{y,0} \right| \right|$$

The trend assessment identifies categories whose trend is different from the trend of the total inventory, regardless whether category trend is increasing or decreasing, or is a sink or source. Categories whose trend diverges most from the total trend should be identified as *key*, when this difference is weighted by the level of emissions or removals of the category in the base year.

Table 4.3 outlines a spreadsheet that can be used for the Approach 1 Trend Assessment.

TABLE 4.3
SPREADSHEET FOR THE APPROACH 1 ANALYSIS – TREND ASSESSMENT

A	B	C	D	E	F	G	H
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**Base Year Estimate $E_{x,0}$**	**Latest Year Estimate $E_{x,t}$**	**Trend Assessment $T_{x,t}$**	**% Contribution to Trend**	**Cumulative Total of Column G**
Total					$\sum_y T_{y,t}$	1	

Where:

Column A: code of IPCC categories (See Table 8.2 in Chapter 8.)

Column B: description of IPCC categories (See Table 8.2 in Chapter 8.)

Column C: greenhouse gas from the category

Column D: base year estimate of emissions or removals from the national inventory data, in CO_2-equivalent units. Sources and sinks are entered as real values (positive or negative values, respectively).

Column E: latest year estimate of emissions or removals from the most recent national inventory data, in CO_2-equivalent units. Sources and sinks are entered as real values (positive or negative values, respectively).

Column F: trend assessment from Equation 4.2 (from Equation 4.3 for zero base year emissions)

Column G: percentage contribution of the category to the total of trend assessments in last row of Column F, i.e., $T_{x,t} \,/\, \sum_y T_{y,t}$.

Column H: cumulative total of Column G, calculated after sorting the entries in descending order of magnitude according to Column G.

The entries in Columns A, B, C and E should be identical to those used in the Table 4.2, Spreadsheet for the Approach 1 analysis - Level Assessment. The base year estimate in Column D is always entered in the spreadsheet, while the latest year estimate in Column E will depend on the year of analysis. The value of $T_{x,t}$

(which is always positive) should be entered in Column F for each category of sources and sinks, following Equation 4.2, and the sum of all the entries entered in the total line of the table. The percentage contribution of each category to the total of Column F should be computed and entered in Column G. The categories (i.e., the rows of the table) should be sorted in descending order of magnitude, based on Column G. The cumulative total of Column G should then be computed in Column H. *Key categories* are those that, when summed together in descending order of magnitude, add up to more than 95 percent of the total of Column F. An example of Approach 1 analysis for the level and trend is given in Section 4.5.

The trend assessment treats increasing and decreasing trends similarly. However, for the prioritisation of resources, there may be specific circumstances where countries may not want to invest additional resources in the estimation of *key categories* with decreasing trends. Underlying reasons why a category showing strong decreasing trend could be *key* include activity decrease, mitigation measures leading to reduced emission factors or abatement measures (e.g., F-gases, chemical production) changing the production processes. In particular for a long-term decline of activities (not volatile economic trends) and when the category is not *key* from the level assessment, it is not always necessary to implement higher tier methods or to collect additional country-specific data if appropriate explanations can be provided why a category may not become more relevant again in the future. This could be the case e.g., for emissions from coal mining in some countries where considerable number of mines are closed or where certain production facilities are shut down. Regardless of the method chosen, countries should endeavour to use the same method for all years in a time series, and therefore it may be more appropriate to continue using a higher tier method if it had been used for previous years.

For other reasons of declining trends such as the introduction of abatement measures or other emission reduction measures, it is important to prioritise resources for the estimation of such categories that were identified as *key* in the trend assessment. Irrespective of the methodological choice, inventory compilers should clearly and precisely explain and document categories with strongly decreasing trends and should apply appropriate QA/QC procedures.

KEY CATEGORY ANALYSIS FOR A SUBSET OF INVENTORY ESTIMATES

The IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (*GPG-LULUCF*, IPCC, 2003) provided guidance on how to conduct a key category analysis using a stepwise approach, identifying first the *key* (source) categories for the inventory excluding LULUCF (Land Use, Land-Use Change and Forestry), and secondly repeating the key category analysis for the full inventory including the LULUCF categories to identify additional *key categories*. This two step approach is now integrated into one general approach. However, inventory compilers may still want to conduct a key category analysis using a subset of inventory estimates. For example inventory compilers may choose to include only emission sources in order to exclude the effects of removals from the level assessment or in order to exclude the influence of different trends for carbon fluxes from the other emission trends (see examples in Tables 4.7 and 4.8). It is *good practice* to document on what subsets the analysis was performed and the differences in results comparing with an integrated analysis.

4.3.2 Approach 2 to identify key categories

The Approach 2 to identify *key categories* of sources and sinks is based on the results of the uncertainty analysis described in Chapter 3 Uncertainties, in this Volume. Inventory compilers are encouraged to use Approach 2 in addition to Approach 1 if possible, because it will provide additional insight into the reasons why particular categories are *key* and will assist in prioritising activities to improve inventory quality and reduce overall uncertainty. For example, the order of categories resulting from Approach 2 can provide useful information for prioritisation of improvement activities.

APPLICATION OF UNCERTAINTY ESTIMATES TO IDENTIFY KEY CATEGORIES

The key category analysis may be enhanced by incorporating the national category uncertainty estimates developed in accordance with methods provided in Chapter 3. Uncertainty estimates based on the Approach 1 described in Chapter 3 are sufficient for this purpose, however, estimates based on the Approach 2 for Uncertainty Assessment should be used when available. The category uncertainties are incorporated by weighting the Approach 1 Level and Trend Assessment results according to the category percentage uncertainty. The *key category* equations are presented below.

LEVEL ASSESSMENT

Equation 4.4 describes the Approach 2 Level Assessment including uncertainty.

EQUATION 4.4
LEVEL ASSESSMENT (APPROACH 2)

$$LU_{x,t} = \left(L_{x,t} \bullet U_{x,t} \right) / \sum_{y} \left[\left(L_{y,t} \bullet U_{y,t} \right) \right]$$

Where:

$LU_{x,t}$ = level assessment for category x in latest inventory year (year t) with uncertainty

$L_{x,t}$ = computed as in Equation 4.1

$U_{x,t}$ = category percentage uncertainty in year t calculated as described in Chapter 3 and reported in Column G in Table 3.3. If the uncertainty reported in Table 3.3 is asymmetrical, the larger uncertainty should be used. The relative uncertainty will always have a positive sign.

After computing level assessment with uncertainty, results should be sorted according to decreasing order of magnitude, similarly as in Approach 1. The *key categories* are those that add up to 90 percent of the sum of all $LU_{x,t}$. This 90 percent was the basis for the derivation of the threshold used in the Approach 1 analysis (Rypdal and Flugsrud, 2001). The categories identified by the level assessment with Uncertainty that are different from categories identified by Approach 1 should also be treated as *key categories*. In addition, the order of *key categories* identified by Approach 2 may be of use for those who are planning to improve inventories.

TREND ASSESSMENT

Equation 4.5 shows how the Approach 2 Trend Assessment can be expanded to include uncertainty.

EQUATION 4.5
TREND ASSESSMENT (APPROACH 2)

$$TU_{x,t} = \left(T_{x,t} \bullet U_{x,t} \right)$$

Where:

$TU_{x,t}$ = trend assessment for category x in latest inventory year (year t) with uncertainty

$T_{x,t}$ = trend assessment computed as in Equation 4.2

$U_{x,t}$ = category percentage uncertainty in year t calculated as described in Chapter 3. Note that this is the same uncertainty as in the total of Column G of Table 3.3 in Chapter 3, not the uncertainty assessment for trend. The relative uncertainty will always have a positive sign.

After computing trend assessment with uncertainty, results should be sorted according to decreasing order of magnitude. The *key categories* are those that add up to 90 percent of the total value of the total $TU_{x,t}$. This 90 percent was the basis for the derivation of the threshold used in the Approach 1 analysis (Rypdal and Flugsrud, 2001). The *key categories* according to trend assessment with Uncertainty should be treated as *key categories* and should be added to the list of *key categories* from Approach 1, if they are different from categories identified by Approach 1. In addition, the order of *key Categories* identified by Approach 2 may be of use for those who are planning to improve inventories.

INCORPORATING MONTE CARLO ANALYSIS

In Chapter 3, Monte Carlo analysis is presented as the Approach 2 for quantitative uncertainty assessment. Whereas the Approach 1 uncertainty analysis is based on simplified assumptions to develop uncertainties for each category, Monte Carlo types of analysis can handle large uncertainties, complex probability density functions, correlations or complex emission estimation equations. The output of the Approach 2 Uncertainty Analysis can be used directly in Equations 4.4 and 4.5. If uncertainties are asymmetrical, the larger percentage difference between the mean and the confidence limit should be used.

Monte Carlo analysis or other statistical tools can also be used to perform a sensitivity analysis to directly identify the principal factors contributing to the overall uncertainty. Thus, a Monte Carlo or similar analysis can be a valuable tool for a key category analysis. Inventory compilers are encouraged to use the method, for example, to analyze more disaggregated subcategories (by modelling correlations), emission factors and activity data separately (to identify key parameters rather than *key categories*). The use of these methods should be properly documented.

4.3.3 Qualitative criteria to identify key categories

In some cases, the results of the Approach 1 or Approach 2 analysis of *key categories* may not identify all categories that should be prioritised in the inventory system. If quantitative key category analysis has not been carried out due to lack of completeness in the inventory, it is *good practice* to use qualitative criteria to identify *key categories.* The criteria below address specific circumstances that may not be readily reflected in the quantitative assessment. These criteria should be applied to categories not identified in the quantitative analysis, and if additional categories are identified they should be added to the list of *key categories*. It is particularly important to consider these criteria if the trend assessment has not been compiled. Although it is important to implement a trend assessment as part of *good practice* if data are available, early identification using qualitative criteria could be used until such assessment is available. Followings are the examples of points in qualitative criteria.

- *Mitigation techniques and technologies*: If emissions from a category have decreased or removals have increased through the use of climate change mitigation techniques, it is *good practice* to identify such categories as *key*. This will ensure that such categories are prioritised within the inventory and that better quality estimates are prepared to reflect the mitigation effects as closely as possible. It will also ensure that the methods used are transparent with respect to mitigation which is important for assessing inventory quality.
- *Expected growth*: The inventory compiler should assess which categories are likely to show increase of emissions or decrease of removals in the future. The inventory compiler may use expert judgement to make this determination. It is encouraged to identify such categories as *key*.
- *No quantitative assessment of Uncertainties performed*: Where Approach 2 including uncertainties in the key category analysis is not used, inventory compilers are still encouraged to identify categories that are assumed to contribute most to the overall uncertainty as *key*, because the largest reductions in overall inventory uncertainty can be achieved by improving estimates of categories having higher uncertainties. The qualitative consideration should take into account whether any methodological improvements could reduce uncertainties significantly. This could, for example, be applied to a small net flux results from the subtraction of large emissions and removals, which can imply a very high uncertainty.
- *Completeness*: Neither the Approach 1 nor the Approach 2 gives correct results if the inventory is not complete. The analysis can still be performed, but there may be *key categories* among those are not estimated. In these cases it is *good practice* to examine qualitatively potential *key categories* that are not yet estimated quantitatively by applying the qualitative considerations above. The inventory of a country with similar national circumstances can also often give good indications on potential *key categories*. Chapter 2, Approaches to Data Collection, gives suggestions for methods to approximate activity data that can be used to compile preliminary estimates of emissions/removals from a category. This preliminary analysis can be used to conclude whether a category potentially can be *key* and prioritise data collection of this category.

4.4 REPORTING AND DOCUMENTATION

It is *good practice* to clearly document the results of the key category analysis in the inventory report. This information is essential for explaining the choice of method for each category. In addition, inventory compilers should list the criteria by which each category was identified as *key* (e.g., level, trend, or qualitative), and the method used to conduct the quantitative key category analysis (e.g., Approach 1 or Approach 2). Tables 4.2 and 4.3 should be used to record the results of the key category analysis. Table 4.4 should be used to present a summary of the key category analysis. The notation keys: L = *key category* according to level assessment; T = *key category* according to trend assessment; and Q = *key category* according to qualitative criteria; should be used to describe the assessment method used. The Approach used to identify the *key category* should be included as L1, L2, T1 or T2. In the column for comments, reasons for a qualitative assessment can be provided.

TABLE 4.4 SUMMARY OF KEY CATEGORY ANALYSIS				
Quantitative method used: Approach 1/Approach 1 and Approach 2				
A	**B**	**C**	**D**	**E**
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**Identification criteria**	**Comments**

4.5 EXAMPLES OF KEY CATEGORY ANALYSIS

The application of the Approach 1 and 2 to the Finnish greenhouse gas inventory for the reporting year 2003 is shown in Tables 4.5 to 4.11. Both the level and the trend assessment were conducted using estimates of emissions, removals and uncertainties from the national inventory of Finland (Statistics Finland, 2005). Although a qualitative assessment was not conducted in this example, it was not anticipated that additional categories would have been identified.

The results of the Approach 1 Level Assessment are shown in Table 4.5 with *key categories* in bold. The results of the Approach 1 Trend Assessment are shown in Table 4.6, with *key categories* in bold. Tables 4.7 and 4.8 present an Approach 1 Level and Trend key category analysis using a subset of emissions and removals. In this example, it was decided to include other categories (reported in Tables 4.5 and 4.6) than CO_2 from category 3B (Land). The results of Approach 2 Level and Trend Assessments are provided in Tables 4.9 and 4.10. Table 4.11 finally summarises the results of the key category analysis.

TABLE 4.5
EXAMPLE OF APPROACH 1 LEVEL ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 (with key categories in bold)

A	B	C	D	E	F	G
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	$E_{x,t}$ (Gg CO_2 eq)	$\lvert E_{x,t} \rvert$ (Gg CO_2 eq)	$L_{x,t}$	**Cumulative Total of Column F**
3B1a	**Forest land remaining Forest land**	**CO_2**	**-21 354**	**21 354**	**0.193**	**0.193**
1A1	**Energy Industries: Solid**	**CO_2**	**17 311**	**17 311**	**0.157**	**0.350**
1A3b	**Road Transportation**	**CO_2**	**11 447**	**11 447**	**0.104**	**0.454**
1A1	**Energy Industries: Peat**	**CO_2**	**9 047**	**9 047**	**0.082**	**0.536**
1A1	**Energy Industries: Gas**	**CO_2**	**6 580**	**6 580**	**0.060**	**0.595**
1A4	**Other Sectors: Liquid**	**CO_2**	**5 651**	**5 651**	**0.051**	**0.646**
1A2	**Manufacturing Industries and Construction: Solid**	**CO_2**	**5 416**	**5 416**	**0.049**	**0.695**
1A2	**Manufacturing Industries and Construction: Liquid**	**CO_2**	**4 736**	**4 736**	**0.043**	**0.738**
1A1	**Energy Industries: Liquid**	**CO_2**	**3 110**	**3 110**	**0.028**	**0.767**
3B3a	**Grassland Remaining Grassland**	**CO_2**	**2 974**	**2 974**	**0.027**	**0.793**
3C4	**Direct N_2O Emissions from managed soils**	**N_2O**	**2 619**	**2 619**	**0.024**	**0.817**
4A	**Solid Waste Disposal**	**CH_4**	**2 497**	**2 497**	**0.023**	**0.840**
1A2	**Manufacturing Industries and Construction: Gas**	**CO_2**	**2 174**	**2 174**	**0.020**	**0.859**
3A1	**Enteric Fermentation**	**CH_4**	**1 537**	**1 537**	**0.014**	**0.873**
1A2	**Manufacturing Industries and Construction: Peat**	**CO_2**	**1 498**	**1 498**	**0.014**	**0.887**
2B2	**Nitric Acid Production**	**N_2O**	**1 396**	**1 396**	**0.013**	**0.900**
1A5	**Non-Specified: Liquid**	**CO_2**	**1 083**	**1 083**	**0.010**	**0.909**
2D	**Non-Energy Products from Fuels and Solvent Use**	**CO_2**	**830**	**830**	**0.008**	**0.917**
1A3e	**Other Transportation**	**CO_2**	**651**	**651**	**0.006**	**0.923**
3C5	**Indirect N_2O Emissions from managed soils**	**N_2O**	**592**	**592**	**0.005**	**0.928**

TABLE 4.5 (CONTINUED) EXAMPLE OF APPROACH 1 LEVEL ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 (with key categories in bold)						
A	B	C	D	E	F	G
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,t}$ (Gg CO_2 eq)**	**$\lvert E_{x,t} \rvert$ (Gg CO_2 eq)**	**$L_{x,t}$**	**Cumulative Total of Column F**
2F1	**Refrigeration and Air Conditioning**	**HFCs, PFCs**	**578**	**578**	**0.005**	**0.933**
3B4ai	**Peatlands remaining Peatlands**	**CO_2**	**547**	**547**	**0.005**	**0.938**
1A3d	**Water-borne Navigation**	**CO_2**	**519**	**519**	**0.005**	**0.943**
1A3b	**Road Transportation**	**N_2O**	**516**	**516**	**0.005**	**0.948**
2A2	**Lime Production**	**CO_2**	**513**	**513**	**0.005**	**0.952**
2A1	Cement Production	CO_2	500	500	0.005	0.957
3A2	Manure Management	N_2O	461	461	0.004	0.961
1A5	Non-Specified: Gas	CO_2	363	363	0.003	0.964
1A3a	Civil Aviation	CO_2	316	316	0.003	0.967
1A4	Other Sectors: Biomass	CH_4	307	307	0.003	0.970
3C2	Liming	CO_2	277	277	0.003	0.972
1A1	Energy Industries: Peat	N_2O	226	226	0.002	0.975
1A4	Other Sectors: Gas	CO_2	225	225	0.002	0.977
3A2	Manure Management	CH_4	222	222	0.002	0.979
3B2a	Cropland Remaining Cropland	CO_2	211	211	0.002	0.980
2	Miscellaneous	CO_2, HFCs, PFCs, SF_6	168	168	0.002	0.982
1A1	Energy Industries: Solid	N_2O	162	162	0.001	0.983
2A3 and 2A4	Limestone and Dolomite Use[a]	CO_2	148	148	0.001	0.985
1A3c	Railways	CO_2	134	134	0.001	0.986
1A4	Other Sectors: Peat	CO_2	131	131	0.001	0.987
4D	Wastewater Treatment and Discharge	CH_4	128	128	0.001	0.988
4D	Wastewater Treatment and Discharge	N_2O	102	102	0.001	0.989
3C1	Biomass Burning	CO_2	91	91	0.001	0.990
1A2	Manufacturing Industries and Construction: Solid	N_2O	90	90	0.001	0.991
1A2	Manufacturing Industries and Construction: Biomass	N_2O	81	81	0.001	0.992
1A1	Energy Industries: Biomass	N_2O	80	80	0.001	0.992
1B2aii	Oil - Flaring[b]	CO_2	63	63	0.001	0.993
2F4	Aerosols	HFCs	63	63	0.001	0.994
1A4	Other Sectors: Biomass	N_2O	61	61	0.001	0.994
1B2b	Fugitive Emissions from Fuels - Natural gas	CH_4	52	52	0.000	0.995
1A1	Energy Industries: Gas	N_2O	51	51	0.000	0.995
1A3b	Road Transportation	CH_4	47	47	0.000	0.995
1A4	Other Sectors: Liquid	N_2O	47	47	0.000	0.996
1A2	Manufacturing Industries and Construction: Liquid	N_2O	41	41	0.000	0.996
2G	Other Product Manufacture and Use	N_2O	40	40	0.000	0.997
1A1	Energy Industries: Biomass	CH_4	31	31	0.000	0.997
1A1	Energy Industries: Liquid	N_2O	30	30	0.000	0.997
1A2	Manufacturing Industries and Construction: Peat	N_2O	29	29	0.000	0.997
1A4	Other Sectors: Solid	CO_2	25	25	0.000	0.998
2F2	Foam Blowing Agents	HFCs	25	25	0.000	0.998
2G	Other Product Manufacture and Use	SF_6	22	22	0.000	0.998
2A3 and 2A4	Soda Ash Use[a]	CO_2	20	20	0.000	0.998
1A2	Manufacturing Industries and Construction: Gas	N_2O	19	19	0.000	0.998
1A2	Manufacturing Industries and Construction: Biomass	CH_4	19	19	0.000	0.999
1A1	Energy Industries: Solid	CH_4	16	16	0.000	0.999

TABLE 4.5 (CONTINUED) EXAMPLE OF APPROACH 1 LEVEL ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 (with key categories in bold)						
A	**B**	**C**	**D**	**E**	**F**	**G**
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,t}$ (Gg CO_2 eq)**	**$\vert E_{x,t}\vert$ (Gg CO_2 eq)**	**$L_{x,t}$**	**Cumulative Total of Column F**
1A4	Other Sectors: Liquid	CH_4	15	15	0.000	0.999
1B2a	Fugitive Emissions from Fuels – Oil	CH_4	10	10	0.000	0.999
2C1	Iron and Steel Production	CH_4	9	9	0.000	0.999
1A5	Non-Specified: Liquid	N_2O	9	9	0.000	0.999
1A1	Energy Industries: Gas	CH_4	9	9	0.000	0.999
3C1	Biomass Burning	CH_4	8	8	0.000	0.999
1A1	Energy Industries: Peat	CH_4	7	7	0.000	0.999
1A2	Manufacturing Industries and Construction: Liquid	CH_4	7	7	0.000	0.999
1A1	Energy Industries: Liquid	CH_4	7	7	0.000	0.999
1A3e	Other Transportation	CH_4	6	6	0.000	1.000
1A2	Manufacturing Industries and Construction: Gas	CH_4	6	6	0.000	1.000
3	Miscellaneous	CH_4	6	6	0.000	1.000
2B8	Petrochemical and Carbon Black Production	CH_4	5	5	0.000	1.000
1A3e	Other Transportation	N_2O	5	5	0.000	1.000
1A3d	Water-Borne Navigation	CH_4	5	5	0.000	1.000
1A3a	Civil Aviation	N_2O	4	4	0.000	1.000
1A3d	Water-Borne Navigation	N_2O	4	4	0.000	1.000
4	Miscellaneous	N_2O	3	3	0.000	1.000
1A2	Manufacturing Industries and Construction: Peat	CH_4	3	3	0.000	1.000
1A2	Manufacturing Industries and Construction: Solid	CH_4	2	2	0.000	1.000
1A5	Non-Specified: Liquid	CH_4	2	2	0.000	1.000
1A5	Non-Specified: Gas	N_2O	2	2	0.000	1.000
1A4	Other Sectors: Peat	N_2O	2	2	0.000	1.000
1A4	Other Sectors: Gas	N_2O	1	1	0.000	1.000
1A4	Other Sectors: Peat	CH_4	1	1	0.000	1.000
1A3c	Railways	N_2O	1	1	0.000	1.000
3C1	Biomass Burning	N_2O	1	1	0.000	1.000
1A4	Other Sectors: Solid	CH_4	1	1	0.000	1.000
1A5	Non-Specified: Gas	CH_4	0.4	0.4	0.000	1.000
1A4	Other Sectors: Solid	N_2O	0.3	0.3	0.000	1.000
1A3a	Civil Aviation	CH_4	0.3	0.3	0.000	1.000
1A4	Other Sectors: Gas	CH_4	0.3	0.3	0.000	1.000
1A3c	Railways	CH_4	0.2	0.2	0.000	1.000
Total			67 729	110 438	1	

[a] Example was based on 2003 inventory of Finland, and therefore glass production could not be separated as recommended in these *Guidelines*. This does not affect categories identified as *key*.

[b] Example was based on 2003 inventory of Finland, and therefore flaring was separated from other fugitive emissions from oil (1B2a). According to these *Guidelines*, all emissions under 1B2a should be treated together in key category analysis. This would not affect categories identified as *key* in this example.

TABLE 4.6
EXAMPLE OF APPROACH 1 TREND ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 (with key categories in bold)

A	B	C	D	E	F	G	H
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,0}$ (Gg CO_2 eq)**	**$E_{x,t}$ (Gg CO_2 eq)**	**Trend Assessment $T_{x,t}$**	**% Contribution to Trend**	**Cumulative Total of Column G**
3B1a	**Forest Land remaining Forest Land**	**CO_2**	**-23 798**	**-21 354**	**0.078**	**0.147**	**0.147**
1A1	**Energy Industries: Solid**	**CO_2**	**9 279**	**17 311**	**0.042**	**0.079**	**0.227**
1A3b	**Road Transportation**	**CO_2**	**10 800**	**11 447**	**0.040**	**0.076**	**0.302**
1A4	**Other Sectors: Liquid**	**CO_2**	**6 714**	**5 651**	**0.040**	**0.075**	**0.378**
1A2	**Manufacturing Industries and Construction: Solid**	**CO_2**	**6 410**	**5 416**	**0.038**	**0.072**	**0.450**
3B3a	**Grassland Remaining Grassland**	**CO_2**	**-1 071**	**2 974**	**0.037**	**0.069**	**0.519**
1A1	**Energy Industries: Peat**	**CO_2**	**3 972**	**9 047**	**0.035**	**0.066**	**0.585**
1A1	**Energy Industries: Gas**	**CO_2**	**2 659**	**6 580**	**0.029**	**0.054**	**0.639**
4A	**Solid Waste Disposal**	**CH_4**	**3 678**	**2 497**	**0.028**	**0.053**	**0.692**
3C4	**Direct N_2O Emissions from managed soils**	**N_2O**	**3 513**	**2 619**	**0.024**	**0.046**	**0.738**
1A2	**Manufacturing Industries and Construction: Liquid**	**CO_2**	**4 861**	**4 736**	**0.022**	**0.042**	**0.780**
3B2a	**Cropland Remaining Cropland**	**CO_2**	**1 277**	**211**	**0.017**	**0.031**	**0.811**
3A1	**Enteric Fermentation**	**CH_4**	**1 868**	**1 537**	**0.012**	**0.022**	**0.833**
2B2	**Nitric Acid Production**	**N_2O**	**1 595**	**1 396**	**0.009**	**0.017**	**0.849**
1A2	**Manufacturing Industries and Construction: Gas**	**CO_2**	**2 094**	**2 174**	**0.008**	**0.016**	**0.865**
1A2	**Manufacturing Industries and Construction: Peat**	**CO_2**	**1 561**	**1 498**	**0.007**	**0.014**	**0.879**
2A1	**Cement Production**	**CO_2**	**786**	**500**	**0.006**	**0.012**	**0.891**
3C2	**Liming**	**CO_2**	**618**	**277**	**0.006**	**0.012**	**0.903**
1A1	**Energy Industries: Liquid**	**CO_2**	**2 607**	**3 110**	**0.006**	**0.012**	**0.914**
2F1	**Refrigeration and Air Conditioning**	**HFCs, PFCs**	**0**	**578**	**0.006**	**0.011**	**0.925**
3C5	**Indirect N_2O Emissions from managed soils**	**N_2O**	**735**	**592**	**0.005**	**0.009**	**0.934**
3A2	**Manure Management**	**N_2O**	**623**	**461**	**0.004**	**0.008**	**0.942**
1A3b	**Road Transportation**	**N_2O**	**160**	**516**	**0.003**	**0.006**	**0.948**
1A3e	**Other Transportation**	**CO_2**	**644**	**651**	**0.003**	**0.005**	**0.953**
3B4ai	Peatlands Remaining Peatlands	CO_2	503	547	0.002	0.003	0.956
3C1	Biomass Burning	CO_2	180	91	0.002	0.003	0.959
1A3a	Civil Aviation	CO_2	320	316	0.001	0.003	0.962
1A3c	Railways	CO_2	191	134	0.001	0.003	0.965
1B2aii	Flaring[b]	CO_2	123	63	0.001	0.002	0.967
2G	Other Product Manufacture and Use	SF_6	87	22	0.001	0.002	0.969
1A4	Other Sectors: Biomass	CH_4	282	307	0.001	0.002	0.971
4D	Wastewater Treatment and Discharge	CH_4	153	128	0.001	0.002	0.973
4D	Wastewater Treatment and Discharge	N_2O	133	102	0.001	0.002	0.974
1A4	Other Sectors: Gas	CO_2	98	225	0.001	0.002	0.976
3A2	Manure Management	CH_4	215	222	0.001	0.002	0.977
2D	Non-Energy Products from Fuels and Solvent Use	CO_2	640	830	0.001	0.002	0.979
1A3b	Road Transportation	CH_4	90	47	0.001	0.002	0.981
1A2	Manufacturing Industries and Construction: Biomass	N_2O	111	81	0.001	0.002	0.982
2	Miscellaneous	CO_2, HFCs, PFCs, SF_6	68	168	0.001	0.001	0.983
1A1	Energy Industries: Biomass	N_2O	10	80	0.001	0.001	0.985
1A2	Manufacturing Industries and Construction: Solid	N_2O	108	90	0.001	0.001	0.986
2F4	Aerosols	HFCs	0	63	0.001	0.001	0.987

TABLE 4.6 (CONTINUED)
EXAMPLE OF APPROACH 1 TREND ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 (with key categories in bold)

A	B	C	D	E	F	G	H
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,0}$ (Gg CO_2 eq)**	**$E_{x,t}$ (Gg CO_2 eq)**	**Trend Assessment $T_{x,t}$**	**% Contribution to Trend**	**Cumulative Total of Column G**
1A2	Manufacturing Industries and Construction: Peat	N_2O	56	29	0.001	0.001	0.988
2G	Other Product Manufacture and Use	N_2O	62	40	0.000	0.001	0.989
1A5	Non-Specified: Gas	CO_2	222	363	0.000	0.001	0.990
1B2b	Fugitive Emissions from Fuels - Natural Gas	CH_4	4	52	0.000	0.001	0.991
1A4	Other Sectors: Peat	CO_2	123	131	0.000	0.001	0.992
1A1	Energy Industries: Solid	N_2O	85	162	0.000	0.001	0.993
1A5	Non-Specified: Liquid	CO_2	734	1083	0.000	0.001	0.993
2A2	Lime Production	CO_2	383	513	0.000	0.001	0.994
1A4	Other Sectors: Liquid	N_2O	56	47	0.000	0.001	0.995
1A1	Energy Industries: Biomass	CH_4	2	31	0.000	0.001	0.995
1A1	Energy Industries: Gas	N_2O	18	51	0.000	0.000	0.996
2F2	Foam Blowing Agents	HFCs	0	25	0.000	0.000	0.996
1A1	Energy Industries: Peat	N_2O	141	226	0.000	0.000	0.997
1A4	Other Sectors: Solid	CO_2	33	25	0.000	0.000	0.997
1A4	Other Sectors: Biomass	N_2O	56	61	0.000	0.000	0.997
3C1	Biomass Burning	CH_4	16	8	0.000	0.000	0.998
1A2	Manufacturing Industries and Construction: Liquid	N_2O	39	41	0.000	0.000	0.998
1A4	Other Sectors: Liquid	CH_4	19	15	0.000	0.000	0.998
1A2	Manufacturing Industries and Construction: Biomass	CH_4	20	19	0.000	0.000	0.998
4	Miscellaneous	N_2O	8	3	0.000	0.000	0.998
2A3 and 2A4	Limestone and Dolomite Use[a]	CO_2	99	148	0.000	0.000	0.999
1A1	Energy Industries: Liquid	N_2O	26	30	0.000	0.000	0.999
1A3d	Water-borne Navigation	CH_4	8	5	0.000	0.000	0.999
2A3 and 2A4	Soda Ash Use[a]	CO_2	18	20	0.000	0.000	0.999
1A3d	Water-borne Navigation	CO_2	361	519	0.000	0.000	0.999
1A2	Manufacturing Industries and Construction: Liquid	CH_4	9	7	0.000	0.000	0.999
1A2	Manufacturing Industries and Construction: Gas	N_2O	17	19	0.000	0.000	0.999
1A1	Energy Industries: Solid	CH_4	9	16	0.000	0.000	0.999
1A2	Manufacturing Industries and Construction: Solid	CH_4	4	2	0.000	0.000	0.999
1A1	Energy Industries: Gas	CH_4	4	9	0.000	0.000	1.000
1A4	Other Sectors: Solid	CH_4	2	1	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction: Peat	CH_4	4	3	0.000	0.000	1.000
1A3e	Other Transportation	N_2O	5	5	0.000	0.000	1.000
2C1	Iron and Steel Production	CH_4	5	9	0.000	0.000	1.000
3	Miscellaneous	CH_4	5	6	0.000	0.000	1.000
1A3a	Civil Aviation	N_2O	4	4	0.000	0.000	1.000
3C1	Biomass Burning	N_2O	2	1	0.000	0.000	1.000
1A3e	Other Transportation	CH_4	5	6	0.000	0.000	1.000
1A1	Energy Industries: Liquid	CH_4	6	7	0.000	0.000	1.000
1B2a	Fugitive Emissions from Fuels - Oil	CH_4	8	10	0.000	0.000	1.000
1A3c	Railways	N_2O	2	1	0.000	0.000	1.000
1A4	Other Sectors: Peat	CH_4	1	1	0.000	0.000	1.000
1A4	Other Sectors: Gas	N_2O	1	1	0.000	0.000	1.000
1A4	Other Sectors: Peat	N_2O	1	2	0.000	0.000	1.000
2B8	Petrochemical and Carbon Black Production	CH_4	4	5	0.000	0.000	1.000

TABLE 4.6 (CONTINUED) EXAMPLE OF APPROACH 1 TREND ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 (with key categories in bold)							
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,0}$ (Gg CO_2 eq)**	**$E_{x,t}$ (Gg CO_2 eq)**	**Trend Assessment $T_{x,t}$**	**% Contribu-tion to Trend**	**Cumulative Total of Column G**
1A2	Manufacturing Industries and Construction: Gas	CH_4	5	6	0.000	0.000	1.000
1A4	Other Sectors: Solid	N_2O	0.5	0.3	0.000	0.000	1.000
1A1	Energy Industries: Peat	CH_4	5	7	0.000	0.000	1.000
1A5	Non-Specified: Gas	N_2O	1	2	0.000	0.000	1.000
1A3a	Civil Aviation	CH_4	0.4	0.3	0.000	0.000	1.000
1A3c	Railways	CH_4	0.2	0.2	0.000	0.000	1.000
1A5	Non-Specified: Liquid	N_2O	6	9	0.000	0.000	1.000
1A4	Other Sectors: Gas	CH_4	0.1	0.3	0.000	0.000	1.000
1A3d	Water-borne Navigation	N_2O	3	4	0.000	0.000	1.000
1A5	Non-Specified: Gas	CH_4	0.3	0.4	0.000	0.000	1.000
1A5	Non-Specified: Liquid	CH_4	2	2	0.000	0.000	1.000
Total			47 604	67 729	0.531	1	

[a] Example was based on 2003 inventory of Finland, and therefore glass production could not be separated as recommended in these *Guidelines*. This does not affect categories identified as *key*.

[b] Example was based on 2003 inventory of Finland, and therefore flaring was separated from other fugitive emissions from oil (1B2a). According to these *Guidelines*, all emissions under 1B2a should be treated together in key category analysis. This would not affect categories identified as key in this example.

TABLE 4.7 EXAMPLE OF APPROACH 1 LEVEL ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 USING A SUBSET (CO_2 from category 3B was excluded from the analysis). Only *key categories* are presented.						
A	**B**	**C**	**D**	**E**	**F**	**G**
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,t}$ (Gg CO_2 eq)**	**$\lvert E_{x,t} \rvert$ (Gg CO_2 eq)**	**$L_{x,t}$**	**Cumulative Total of Column F**
1A1	Energy Industries: Solid	CO_2	17 311	17 311	0.203	0.203
1A3b	Road Transportation	CO_2	11 447	11 447	0.134	0.337
1A1	Energy Industries: Peat	CO_2	9 047	9 047	0.106	0.443
1A1	Energy Industries: Gas	CO_2	6 580	6 580	0.077	0.520
1A4	Other Sectors: Liquid	CO_2	5 651	5 651	0.066	0.586
1A2	Manufacturing Industries and Construction: Solid	CO_2	5 416	5 416	0.063	0.650
1A2	Manufacturing Industries and Construction: Liquid	CO_2	4 736	4 736	0.055	0.705
1A1	Energy Industries: Liquid	CO_2	3 110	3 110	0.036	0.742
3C4	Direct N_2O Emissions from managed soils	N_2O	2 619	2 619	0.031	0.772
4A	Solid Waste Disposal	CH_4	2 497	2 497	0.029	0.802
1A2	Manufacturing Industries and Construction: Gas	CO_2	2 174	2 174	0.025	0.827
3A1	Enteric Fermentation	CH_4	1 537	1 537	0.018	0.845
1A2	Manufacturing Industries and Construction: Peat	CO_2	1 498	1 498	0.018	0.863
2B2	Nitric Acid Production	N_2O	1 396	1 396	0.016	0.879
1A5	Non-Specified: Liquid	CO_2	1 083	1 083	0.013	0.892
2D	Non-Energy Products from Fuels and Solvent Use	CO_2	830	830	0.010	0.901
1A3e	Other Transportation	CO_2	651	651	0.008	0.909
3C5	Indirect N_2O Emissions from Managed Soils	N_2O	592	592	0.007	0.916
2F1	Refrigeration and Air Conditioning	HFCs, PFCs	578	578	0.007	0.923

Table 4.7 (Continued) Example of Approach 1 Level Assessment for the Finnish GHG inventory for 2003 using a subset (CO_2 from category 3B was excluded from the analysis). Only *key categories* are presented.						
A	**B**	**C**	**D**	**E**	**F**	**G**
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,t}$** **(Gg CO_2 eq)**	**$\lvert E_{x,t} \rvert$** **(Gg CO_2 eq)**	**$L_{x,t}$**	**Cumulative Total of Column F**
1A3d	Water-borne Navigation	CO_2	519	519	0.006	0.929
1A3b	Road Transportation	N_2O	516	516	0.006	0.935
2A2	Lime Production	CO_2	513	513	0.006	0.941
2A1	Cement Production	CO_2	500	500	0.006	0.947
3A2	Manure Management	N_2O	461	461	0.005	0.952
....						
Total			85 352	85 352	1	

Table 4.8 Example of Approach 1 Trend Assessment for the Finnish GHG inventory for 2003 using a subset (CO_2 from category 3B was excluded from the analysis). Only *key categories* are presented.							
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,0}$** **(Gg CO_2 eq)**	**$E_{x,t}$** **(Gg CO_2 eq)**	**Trend assessment** **$T_{x,t}$**	**% Contribu-tion to Trend**	**Cumulative Total of Column G**
1A1	Energy Industries: Solid	CO_2	9 279	17 311	0.086	0.194	0.194
1A1	Energy Industries: Peat	CO_2	3 972	9 047	0.060	0.135	0.329
1A1	Energy Industries: Gas	CO_2	2 659	6 580	0.048	0.107	0.436
1A4	Other Sectors: Liquid	CO_2	6 714	5 651	0.035	0.078	0.514
1A2	Manufacturing Industries and Construction: Solid	CO_2	6 410	5 416	0.033	0.074	0.588
4A	Solid Waste Disposal	CH_4	3 678	2 497	0.028	0.062	0.650
3C4	Direct N_2O Emissions from Managed Soils	N_2O	3 513	2 619	0.023	0.052	0.702
1A3b	Road Transportation	CO_2	10 800	11 447	0.023	0.051	0.752
1A2	Manufacturing Industries and Construction: Liquid	CO_2	4 861	4 736	0.016	0.036	0.788
3A1	Enteric Fermentation	CH_4	1 868	1 537	0.010	0.023	0.811
2F1	Refrigeration and Air Conditioning	HFCs, PFCs	0	578	0.008	0.018	0.830
2B2	Nitric Acid Production	N_2O	1 595	1 396	0.008	0.017	0.846
3C2	Liming	CO_2	618	277	0.007	0.015	0.861
2A1	Cement Production	CO_2	786	500	0.006	0.014	0.876
1A2	Manufacturing Industries and Construction: Peat	CO_2	1 561	1 498	0.005	0.012	0.888
1A2	Manufacturing Industries and Construction: Gas	CO_2	2 094	2 174	0.005	0.011	0.899
1A3b	Road Transportation	N_2O	160	516	0.005	0.010	0.909
3C5	Indirect N_2O Emissions from Managed Soils	N_2O	735	592	0.004	0.009	0.919
3A2	Manure Management	N_2O	623	461	0.004	0.009	0.928
1A5	Non-Specified: Liquid	CO_2	734	1 083	0.003	0.006	0.934
3C1	Biomass Burning	CO_2	180	91	0.002	0.004	0.938
1A3e	Other Transportation	CO_2	644	651	0.002	0.004	0.942
1A4	Other Sectors: Gas	CO_2	98	225	0.001	0.003	0.946
1A3c	Railways	CO_2	191	134	0.001	0.003	0.949
1A5	Non-Specified: Gas	CO_2	222	363	0.001	0.003	0.952
....							
Total			70 692	85 352	0.445	1	

TABLE 4.9
EXAMPLE OF APPROACH 2 LEVEL ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003
The aggregation level used is country-specific, and does not represent recommended aggregation level. Only *key categories* are presented.

A	B	C	D	E	F	G
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,t}$ (Gg CO_2 eq)**	**$\lvert E_{x,t} \rvert$ (Gg CO_2 eq)**	**$LU_{x,t}$**	**Cumulative Total of Column F**
3B1a	Forest Land Remaining Forest Land: carbon stock change in biomass	CO_2	-21 354	21 354	0.23	0.23
3C4	Direct N_2O Emissions from Managed Soils: Agricultural Soils	N_2O	2 608	2 608	0.18	0.41
3B3a	Grassland Remaining Grassland: net carbon stock change in mineral soils	CO_2	2 907	2 907	0.09	0.50
3C5	Indirect N_2O Emissions from Managed Soils	N_2O	592	592	0.06	0.56
1A3b	Road Transportation: Cars with Catalytic Converters	N_2O	410	410	0.05	0.61
2B2	Nitric Acid Production	N_2O	1 396	1 396	0.04	0.66
3B2a	Cropland Remaining Cropland: net carbon stock change in organic soils	CO_2	1 324	1 324	0.04	0.70
3B4ai	Peatlands Remaining Peatlands	CO_2	547	547	0.04	0.73
3B2a	Cropland Remaining Cropland: net carbon stock change in mineral soils	CO_2	-1 113	1 113	0.03	0.77
4A	Solid Waste Disposal	CH_4	2 497	2 497	0.03	0.80
1A	Fuel Combustion Activities: Liquid	CO_2	27 640	27 640	0.02	0.82
1A	Fuel Combustion Activities: Solid	CO_2	22 753	22 753	0.02	0.85
1A	Fuel Combustion Activities: Peat	CO_2	10 676	10 676	0.02	0.87
3A1	Enteric Fermentation	CH_4	1 537	1 537	0.01	0.88
1A4	Other Sectors: Biomass	CH_4	307	307	0.01	0.90
2D	Non-Energy Products from Fuels and Solvent Use	CO_2	830	830	0.01	0.91

TABLE 4.10 EXAMPLE OF APPROACH 2 TREND ASSESSMENT FOR THE FINNISH GHG INVENTORY FOR 2003 The aggregation level used is country-specific, and does not represent recommended aggregation level. Only *key categories* are presented.							
A	B	C	D	E	F	G	H
IPCC Category Code	**IPCC Category**	**Greenhouse Gas**	**$E_{x,0}$** **(Gg CO_2 eq)**	**$E_{x,t}$** **(Gg CO_2 eq)**	**Trend Assessment with Uncertainty** **$TU_{x,t}$**	**% Contri-bution to Trend**	**Cumulative Total of Column G**
3C4	Direct N_2O Emissions from Managed Soils: Agricultural Soils	N_2O	3 486	2 608	5.42	0.24	0.24
3B3a	Grassland Remaining Grassland: net carbon stock change in mineral soils	CO_2	-1 181	2 907	3.62	0.16	0.40
3B1a	Forest Land Remaining Forest Land: carbon stock change in biomass	CO_2	-23 798	-21 354	2.71	0.12	0.52
3C5	Indirect N_2O Emissions from Managed Soils	N_2O	735	592	1.54	0.07	0.58
1A3b	Road Transportation: Cars with Catalytic Converters	N_2O	32	410	1.45	0.06	0.65
3B2a	Cropland Remaining Cropland: net carbon stock change in organic soils	CO_2	1 813	1 324	1.21	0.05	0.70
4A	Solid Waste Disposal	CH_4	3 678	2 497	1.20	0.05	0.75
2B2	Nitric Acid Production	N_2O	1 595	1 396	0.89	0.04	0.79
3B2a	Cropland Remaining Cropland: net carbon stock change in mineral soils	CO_2	-535	-1 113	0.82	0.04	0.83
3B4ai	Peatlands Remaining Peatlands	CO_2	503	547	0.36	0.02	0.85
3A2	Manure Management	N_2O	623	461	0.36	0.02	0.86
3A1	Enteric Fermentation	CH_4	1 868	1 537	0.35	0.02	0.88
1A	Fuel Combustion Activities: Liquid	CO_2	27 232	27 640	0.32	0.01	0.89
4D1	Domestic Wastewater Treatment and Discharge: densely populated areas	N_2O	84	66	0.20	0.01	0.90

TABLE 4.11
SUMMARY OF KEY CATEGORY ANALYSIS FOR FINLAND
Quantitative method used: Approach 1 and Approach 2

A	B	C	D	E
IPCC Category Code	**IPCC Category**	**Greenhouse gas**	**Identification criteria**	**Comments[a]**
1A	Fuel Combustion Activities: Liquid	CO_2	L2, T2	Aggr
1A	Fuel Combustion Activities: Solid	CO_2	L2	Aggr
1A	Fuel Combustion Activities: Peat	CO_2	L2	Aggr
1A1	Energy Industries: Solid	CO_2	L1, T1	
1A1	Energy Industries: Peat	CO_2	L1, T1	
1A1	Energy Industries: Gas	CO_2	L1, T1	
1A1	Energy Industries: Liquid	CO_2	L1, T1	
1A2	Manufacturing Industries and Construction: Solid	CO_2	L1, T1	
1A2	Manufacturing Industries and Construction: Liquid	CO_2	L1, T1	
1A2	Manufacturing Industries and Construction: Gas	CO_2	L1, T1	
1A2	Manufacturing Industries and Construction: Peat	CO_2	L1, T1	
1A3b	Road Transportation	CO_2	L1, T1	
1A3b	Road Transportation	N_2O	L1, T1	
1A3b	Road Transportation: Cars with Catalytic Converters	N_2O	L2, T2	Aggr
1A3c	Railways	CO_2		Tsub
1A3d	Water-borne Navigation	CO_2	L1	
1A3e	Other transportation	CO_2	L1, T1	
1A4	Other Sectors: Liquid	CO_2	L1, T1	
1A4	Other Sectors: Gas	CO_2		Tsub
1A4	Other Sectors: Biomass	CH_4	L2	
1A5	Non-Specified: Liquid	CO_2	L1	
1A5	Non-Specified: Gas	CO_2		Tsub
2A1	Cement Production	CO_2	T1	
2A2	Lime Production	CO_2	L1	
2B2	Nitric Acid Production	N_2O	L1, L2, T1, T2	
2D	Non-Energy Products from Fuels and Solvent Use	CO_2	L1, L2	
2F1	Refrigeration and Air Conditioning	HFCs, PFCs	L1, T1	
3A1	Enteric Fermentation	CH_4	L1, L2, T1, T2	
3A2	Manure Management	N_2O	T1, T2	
3B1a	Forest Land Remaining Forest Land	CO_2	L1, L2, T1, T2	
3B2a	Cropland Remaining Cropland	CO_2	L2, T1, T2	
3B3a	Grassland Remaining Grassland	CO_2	L1, T1	
3B3a	Grassland Remaining Grassland: net carbon stock change in mineral soils	CO_2	L2, T2	Aggr
3B4ai	Peatlands Remaining Peatlands	CO_2	L1, L2, T2	
3C2	Liming	CO_2	T1	
3C4	Direct N_2O Emissions from Managed Soils	N_2O	L1, T1	
3C4	Direct N_2O Emissions from Managed Soils: Agricultural Soils	N_2O	L2, T2	Aggr
3C5	Indirect N_2O Emissions from Managed Soils	N_2O	L1, L2, T1, T2	
3C1	Biomass Burning	CO_2		Tsub
4A	Solid Waste Disposal	CH_4	L1, L2, T1, T2	
4D1	Domestic Waste Waster Treatment and Discharge: densely populated areas	N_2O	T2	Aggr

[a] Tsub denotes a category that was only identified by trend assessment for a subset without category 3B. Level assessment of the subset did not identify additional categories when compared with Approach 1 analysis of the total inventory. Aggr denotes a category identified by Approach 2, where aggregation level has been different than in Approach 1.

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CHAPTER 5

TIME SERIES CONSISTENCY

Authors

William Irving (USA)

Hideaki Nakane (Japan), and Jose Ramon T. Villarin (Philippines)

Contributing Authors

Ruta Bubniene (Lithuania)

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5 TIME SERIES CONSISTENCY

5.1 INTRODUCTION

The time series is a central component of the greenhouse gas inventory because it provides information on historical emissions trends and tracks the effects of strategies to reduce emissions at the national level. As is the case with estimates for individual years, emission trends should be neither over nor underestimated as far as can be judged. All emissions estimates in a time series should be estimated consistently, which means that as far as possible, the time series should be calculated using the same method and data sources in all years. Using different methods and data in a time series could introduce bias because the estimated emission trend will reflect not only real changes in emissions or removals but also the pattern of methodological refinements.

This chapter describes *good practice* in ensuring time series consistency. Section 5.2 provides guidance on common situations in which time series consistency could be difficult to achieve: carrying out recalculations, on adding new categories, and on accounting for technological change. Section 5.3 describes techniques for combining or “splicing” different methods or data sets to compensate for incomplete or missing data. Additional guidance on reporting and documentation and QA/QC of time series consistency is given in Sections 5.4 and 5.5.

5.2 ENSURING A CONSISTENT TIME SERIES

5.2.1 Recalculations due to methodological changes and refinements

A methodological change in a category is a switch to a different tier from the one previously used. *Methodological changes* are often driven by the development of new and different data sets. An example of a methodological change is the new use of a higher tier method instead of a Tier 1 default method for an industrial category because a country has obtained site-specific emission measurement data that can be used directly or for development of national emission factors.

A *methodological refinement* occurs when an inventory compiler uses the same tier to estimate emissions but applies it using a different data source or a different level of aggregation. An example of a refinement would be if new data permit further disaggregation of a livestock enteric fermentation model, so that resulting animal categories are more homogenous or applies a more accurate emission factor. In this case, the estimate is still being developed using a Tier 2 method, but it is applied at a more detailed level of disaggregation. Another possibility is that data of a similar level of aggregation but higher quality data could be introduced, due to improved data collection methods.

Both methodological changes and refinements over time are an essential part of improving inventory quality. It is *good practice* to change or refine methods when:

- *Available data have changed*: The availability of data is a critical determinant of the appropriate method, and thus changes in available data may lead to changes or refinements in methods. As countries gain experience and devote additional resources to preparing greenhouse gas inventories, it is expected that data availability will improve.[1]
- *The previously used method is not consistent with the IPCC guidelines for that category*: Inventory compilers should review the guidance for each category in Volumes 2-5.
- *A category has become key*: A category might not be considered *key* in a previous inventory year, depending on the criteria used, but could become *key* in a future year. For example, many countries are only beginning to substitute HFCs and PFCs for ozone depleting substances being phased out under the Montreal Protocol. Although current emissions from this category are low, they could become *key* in the future based on trend or level. Countries anticipating significant growth in a category may want to consider this possibility before it becomes key.

[1] Sometimes collection of data may be reduced which can result in a less rigorous methodological outcome.

- *The previously used method is insufficient to reflect mitigation activities in a transparent manner*: As techniques and technologies for reducing emissions are introduced, inventory compilers should use methods that can account for the resulting change in emissions or removals in a transparent manner. Where the previously used methods are insufficiently transparent, it is *good practice* to change or refine them. See Section 5.2.3 for further guidance.

- *The capacity for inventory preparation has increased*: Over time, the human or financial capacity (or both) to prepare inventories may increase. If inventory compilers increase inventory capacity, it is *good practice* to change or refine methods so as to produce more accurate, complete and transparent estimates, particularly for *key categories*.

- *New inventory methods become available*: In the future, new inventory methods may be developed that take advantage of new technologies or improved scientific understanding. For example, remote-sensing technology improvements in emission monitoring technology may make it possible to monitor directly more types of emission sources.

- *Correction of errors*: It is possible that the implementation of the QA/QC procedures described in Chapter 6, Quality Assurance and Quality Control and Verification, will lead to the identification of errors or mistakes in the inventory. As noted in that chapter, it is *good practice* to correct errors in previously submitted estimates. In a strict sense, the correction of errors should not be considered a methodological change or refinement. This situation is noted here, however, because the general guidance on time series consistency should be taken into consideration when making necessary corrections.

BOX 5.1
RECALCULATION IN THE AGRICULTURE FORESTRY AND OTHER LAND USE (AFOLU) SECTOR

It is anticipated that the use of recalculation techniques in the AFOLU Sector will be particularly important. The development of inventory methods and interpolation/extrapolation tools (models) for this sector is ongoing and it is anticipated that changes to the methods of many countries will occur over time due to the complexity of the processes involved. In simple cases, sampling or experimentation may provide country-specific emission factors, which might require a time series recalculation. More complicated situations can also arise. For example:

- The instruments used to collect activity data may change through time, and it is impossible to go back in time to apply the new instrument. For example, land clearing events can be estimated by the use of satellite imagery, but the satellites available for this work change or degrade through time. In this case, the overlap method described in Section 5.3.3.1 is most applicable.

- Some data sources such as forest inventories required for AFOLU categories may not be available annually because of resource constraints. In this case, interpolation between years or extrapolation for years after the last year with measured data available may be most appropriate. Extrapolated data may be recalculated when final data become available (see Sections 5.3.3.3 and 5.3.3.4 on interpolation and extrapolation).

- Emissions and removals from AFOLU typically depend on past land use activity. Thus, data must cover a large historical period (20-100 years), and the quality of such data will often vary through time. Overlap, interpolation or extrapolation techniques may be necessary in these cases.

- The calculation of emission factors and other parameters in AFOLU may require a combination of sampling and modelling work. Time series consistency must apply to the modelling work as well. Models can be viewed as a way of transforming input data to produce output results. In most cases where changes are made to the data inputs or mathematical relationships in a model, the entire time series of estimates should be recalculated. In circumstances where this is not feasible due to available data, variations of the overlap method could be applied.

5.2.2 Adding new categories

The addition to the inventory of a new category or subcategory requires the calculation of an entire time series, and estimates should be included in the inventory from the year emissions or removals start to occur in the country. A country should make every effort to use the same method and data sets for each year. It may be difficult to collect data for previous years, however, in which case countries should use the guidance on splicing in Section 5.3.3 to construct a consistent time series.

A country may add new categories or new gases to the inventory for a variety of reasons:

- **A new emission or removal activity is occurring**: Some emission processes, particularly in the Industrial Processes and Product Use (IPPU) Sector, only occur as a result of specific technological processes. For example, the use of substitutes for ozone-depleting substances (ODS substitutes) has been phased in at very different rates in different parts of the world. Some applications may only now be starting to occur in some countries.
- **Rapid growth in a very small category**: A category that previously was too small to justify resources for inclusion in the national inventory, could experience sudden growth and should be included in future inventories.
- **New IPCC categories**: The *2006 IPCC Guidelines* contain some categories and subcategories which were not covered in the *1996 IPCC Guidelines* (IPCC, 1997). As a result, countries may include new estimates in future national inventories. Countries should include estimates for new categories and subcategories for the entire time series.
- **Additional inventory capacity:** A country may be able to use more resources or employ additional experts over time, and thus include new categories and subcategories in the inventory.

If a new emission-causing activity began after the base year, or if a category previously regarded as insignificant (see Section 4.1.2 in Chapter 4, Methodological Choice and Identification of Key Categories, for reasons for not estimating emissions/removals from an existing source/sink) has grown to the point where it should be included in the inventory, it is *good practice* to document the reason for not estimating the entire time series.

5.2.3 Tracking increases and decreases due to technological change and other factors

Emission inventories can track changes in emissions and removals through changing activity levels or changing emission rates, or both. The way in which such changes are included in methodologies can have a significant impact on time series consistency.

Changes in activity levels

National statistics typically will account for significant changes in activity levels. For example, fuel switching from coal to natural gas in electricity generation will be reflected in the national fuel consumption statistics. Further disaggregation of activity data can provide more transparency to indicate specifically where the change in activity is occurring. This approach is relevant when changes are taking place in one or more subcategories, but not throughout the entire category. To maintain time series consistency, the same level of disaggregation into subcategories should so far as possible be used for the entire time series, even if the change began recently.

Changes in emission rates

Research may indicate that the average rate of emissions/removals per unit of activity has changed over the time series. In some cases, the factors leading to a technological change may also make it possible to use a higher tier method. For example, an aluminium plant manager who introduces measures to reduce the frequency and intensity of anode effects may also collect plant-specific parameters that can be used to estimate a new emission factor, This new factor might not be appropriate for estimating emissions for earlier years in the time series, before the technological change occurred. In these cases it is *good practice* to use the updated emission factor or other estimation parameters or data to reflect these changes. Since a general assumption is that emission factors or other estimation parameters do not change over time unless otherwise indicated, countries should clearly document the reason for using different factors or parameters in the time series. This is particularly important if sampling or surveying occurs periodically and emission factors or estimation parameters for years in between are interpolated rather than measured.

Capture, destruction, or combustion of emissions

Larger point sources such as chemical manufacturing facilities or power plants might generate emissions but prevent them from being released to the atmosphere through capture and storage (e.g., CO_2), destruction (e.g., HFC-23) or combustion (e.g., CH_4). These activities do not necessarily change the average emissions generated per unit of activity, and therefore it is not *good practice* to use different emission factors for different years. Instead, the inventory compiler should estimate total emissions generated and emissions reduced separately, and then subtract reductions from the total generation to arrive at an estimate for total emissions to the atmosphere.

5.3 RESOLVING DATA GAPS

5.3.1 Issues with data availability

For a complete and consistent time series, it is necessary to determine the availability of data for each year. Recalculating previous estimates using a higher tier method, or developing estimates for new categories will be difficult if data are missing for one or more years. Examples of data gaps are presented below:

- ***Periodic data*****:** Natural resource or environmental statistics, such as national forest inventories and waste statistics, may not cover the entire country on an annual basis. Instead, they may be carried out at intervals such as every fifth or tenth year, or region-by-region, implying that national level estimates can only be directly obtained once the inventory in every region has been completed. When data are available less frequently than annual, several issues arise. First, the estimates need to be updated each time new data become available, and the years between the available data need to be recalculated. The second issue is producing inventories for years after the last available data point and before new data are available. In this case, new estimates should be extrapolated based on available data, and then recalculated when new data become available.
- ***Changes and gaps in data availability*****:** A change in data availability or a gap in data is different from periodically available data because there is unlikely to be an opportunity to recalculate the estimate at a later date using better data. In some cases, countries will improve their ability to collect data over time, so that higher tier methods can be applied for recent years, but not for earlier years. This is particularly relevant to categories in which it is possible to implement direct sampling and measurement programs because these new data may not be indicative of conditions in past years. Some countries may find that the availability of certain data sets decreases over time as a result of changing priorities within governments, economic restructuring, or limited resources. Some countries with economies in transition no longer collect certain data sets that were available in the base year, or if available these data sets may contain different definitions, classifications and levels of aggregation.

5.3.2 Non-calendar year data

When using non-calendar year data, it is *good practice* to use the same collection period consistently over the time series as described in Section 2.2.3 in Chapter 2, Approaches to Data Collection. Countries should not use different collection periods within the same time series because this could lead to a bias in the trend.

5.3.3 Splicing techniques

Splicing in this context refers to the combining or joining of more than one method to form a complete time series. Several splicing techniques are available if it is not possible to use the same method or data source in all years. This section describes techniques that can be used to combine methods to minimise the potential inconsistencies in the time series. Each technique can be appropriate in certain situations, as determined by considerations such as data availability and the nature of the methodological modification. Selecting a technique requires an evaluation of the specific circumstances, and a determination of the best option for the particular case. It is *good practice* to perform the splicing using more than one technique before making a final decision and to document why a particular method was chosen. The principal approaches for inventory recalculations are summarised in Table 5.1.

5.3.3.1 OVERLAP

The overlap technique is often used when a new method is introduced but data are not available to apply the new method to the early years in the time series, for example when implementing a higher tier methodology. If the new method cannot be used for all years, it may be possible to develop a time series based on the relationship (or overlap) observed between the two methods during the years when both can be used. Essentially, the time series is constructed by assuming that there is a consistent relationship between the results of the previously used and new method. The emission or removal estimates for those years when the new method cannot be used directly are developed by proportionally adjusting the previously developed estimates, based on the relationship observed during the period of overlap. In this case, the emissions or removals associated with the new method are estimated according to Equation 5.1:[2]

EQUATION 5.1
RECALCULATED EMISSION OR REMOVAL ESTIMATE COMPUTED USING THE OVERLAP METHOD

$$y_0 = x_0 \bullet \left(\frac{1}{(n-m+1)} \bullet \sum_{i=m}^{n} \frac{y_i}{x_i} \right)$$

Where:

y_0 = the recalculated emission or removal estimate computed using the overlap method

x_0 = the estimate developed using the previously used method

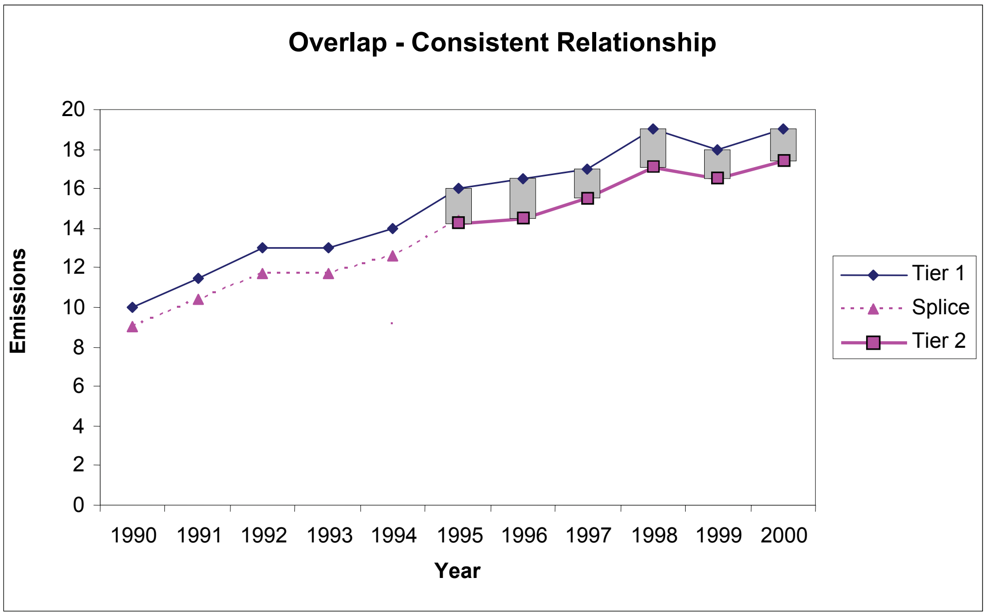
y_i and x_i are the estimates prepared using the new and previously used methods during the period of overlap, as denoted by years m through n

A relationship between the previously used and new methods can be evaluated by comparing the overlap between only one set of annual estimates, but it is preferable to compare multiple years. This is because comparing only one year may lead to bias and it is not possible to evaluate trends.

Figure 5.1 shows a hypothetical example of a consistent overlap between two methods for the years in which both can be applied. In Figure 5.2 there is no consistent overlap between methods and it is not *good practice* to use the overlap technique in such a case.

Other relationships between the old and new estimates may also be observed through an assessment of overlap. For example, a constant difference may be observed. In this case, the emissions or removals associated with the new method are estimated by adjusting the previous estimate by the constant amount equal to the average difference in the years of overlap.

Figure 5.1 Consistent overlap

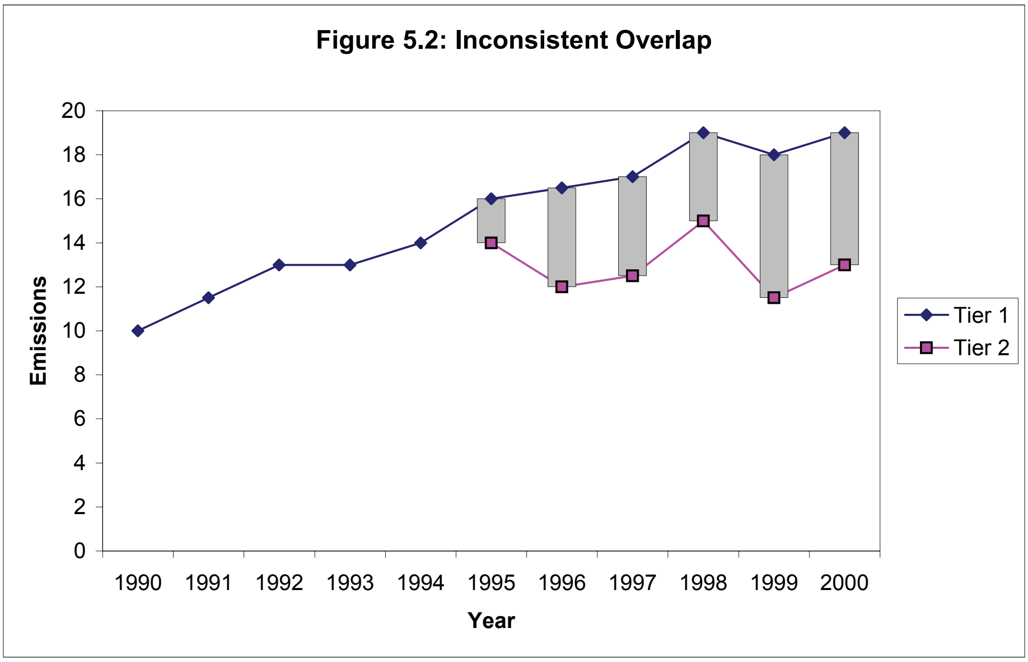


[2] Overlap Equation 5.1 is preferred to the equation described in *Good Practice Guidance for National Greenhouse Gas Inventories* (*GPG2000*, IPCC, 2000):

$$y_0 = x_0 \bullet \left(\sum_{i=m}^{n} y_i \Big/ \sum_{i=m}^{n} x_i \right)$$

because the latter gives more weight to overlapping years with the highest emissions. However in practical cases the results will often be very similar and continued use of the previous equation is consistent with *good practice* where its use gives satisfactory results.

Figure 5.2 Inconsistent overlap



5.3.3.2 SURROGATE DATA

The surrogate method relates emissions or removals to underlying activity or other indicative data. Changes in these data are used to simulate the trend in emissions or removals. The estimate should be related to the statistical data source that best explains the time variations of the category. For example, mobile source emissions may be related to trends in vehicle distances travelled, emissions from domestic wastewater may be related to population, and industrial emissions may be related to production levels in the relevant industry. See Chapter 2, Approaches to Data Collection.

In its simplest form, the estimate will be related to a single type of data as shown in Equation 5.2:

EQUATION 5.2

EMISSION/REMOVALS TREND ESTIMATES USING SURROGATE PARAMETERS

$$y_0 = y_t \bullet \left(s_0 / s_t \right)$$

Where:

y = the emission/removal estimate in years 0 and *t*

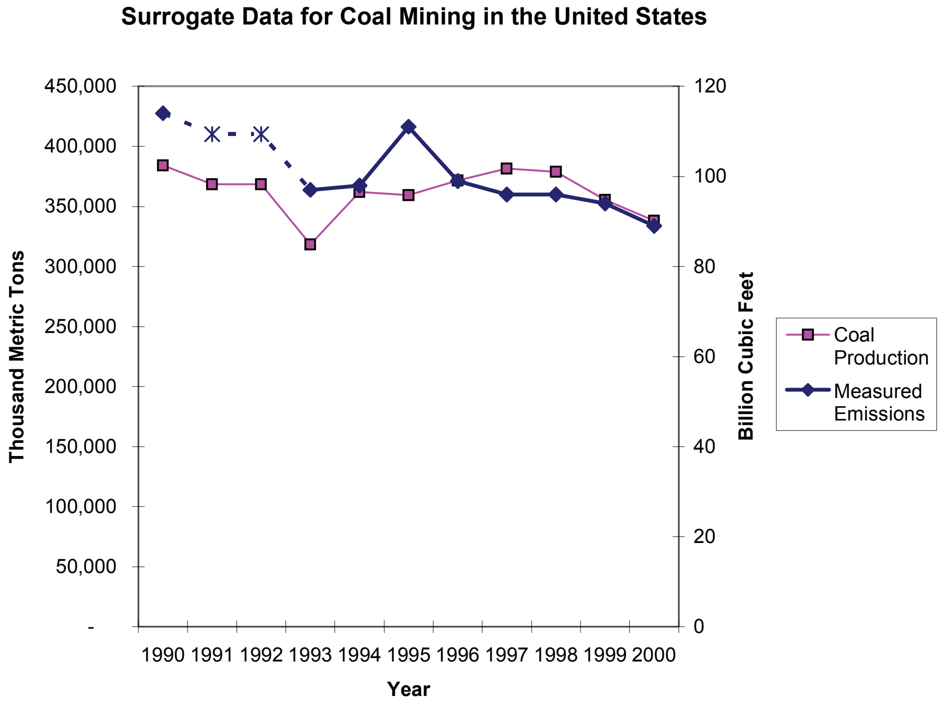
s = the surrogate statistical parameter in years 0 and *t*

Although the relationship between emissions/removals and surrogate can be developed on the basis of data for a single year, the use of multiple years might provide a better estimate.

Box 5.2 provides an example of the use of surrogate data for estimating methane emissions from underground coal mining in the United States. In some cases, more accurate relationships may be developed by relating emissions to more than one statistical parameter. Regression analysis may be useful in selecting the appropriate surrogate data parameters. Using surrogate methods to estimate otherwise unavailable data can improve the accuracy of estimates developed by the interpolation and trend extrapolation approaches discussed below.

BOX 5.2
CASE STUDY OF SURROGATE DATA –
METHANE EMISSIONS FROM UNDERGROUND COAL MINING IN THE UNITED STATES

On a quarterly basis, the U.S. Mine Safety and Health Administration (MSHA) measures methane emissions levels at underground mines with detectable levels of methane in their ventilation air. USEPA uses these measurements as a basis for calculating national emissions from underground coal mining. These data were not available for the years 1991-1992, however, because of restructuring within the Department of Labor. To estimate emissions for these years, USEPA used total underground coal production as a surrogate data set. The graph below shows the relationship between underground coal production and measured emissions, which are closely but not perfectly correlated. Differences reflect the fact that individual mines vary greatly in their emission rates, and as production levels at mines change over time, the weighted average emission rate also changes. USEPA applied Equation 5.2 to estimate emissions for 1991 and 1992 using Tier 3 emissions data and coal production for 1990. These data points are crossed by the dashed line in the graph. Note that this procedure is very similar to an overlap with the Tier 1 method because coal production is the recommended activity data for Tier 1. Comparison of implied emission factors from estimates using surrogate data with Tier 1 default factors would be a useful QA/QC check.

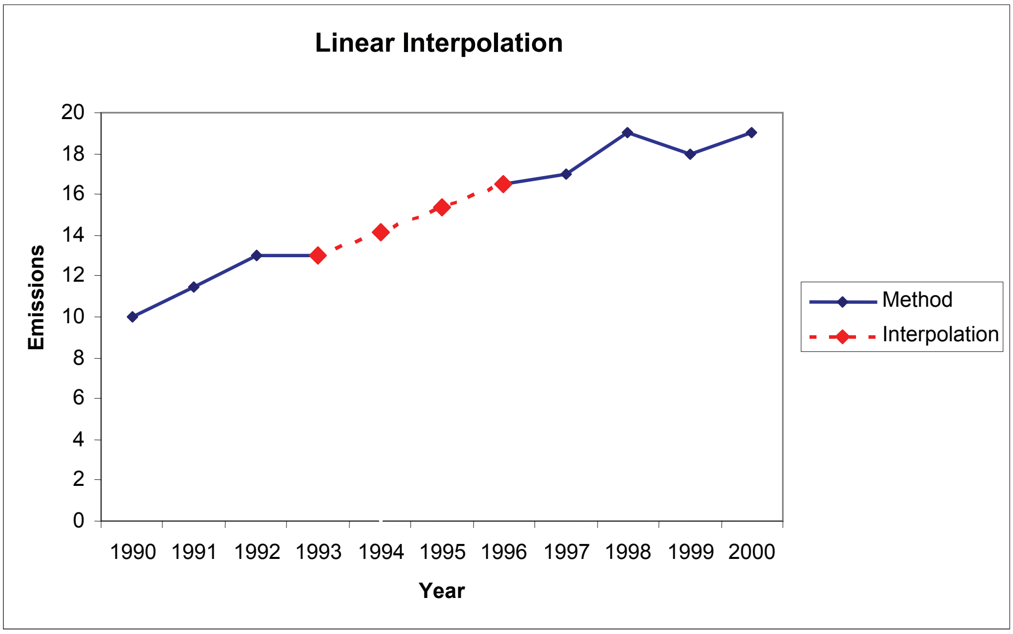


5.3.3.3 INTERPOLATION

In some cases it may be possible to apply a method intermittently throughout the time series. For example, necessary detailed statistics may only be collected every few years, or it may be impractical to conduct detailed surveys on an annual basis. In this case, estimates for the intermediate years in the time series can be developed by interpolating between the detailed estimates. If information on the general trends or underlying parameters is available, then the surrogate method is preferable.

Figure 5.3 shows an example of linear interpolation. In this example, data for 1994 and 1995 are not available. Emissions were estimated by assuming a constant annual growth in emissions from 1993-1996. This technique is appropriate in this example because the overall trend appears stable, and it is unlikely that actual emissions for 1994 and 1995 are substantially different from the values predicted through interpolation. For categories that have volatile emission trends (i.e., they fluctuate significantly from year to year), interpolation will not be according to *good practice* and surrogate data will be a better option. It is *good practice* to compare interpolated estimates with surrogate data as a QA/QC check.

Figure 5.3 Linear interpolation



5.3.3.4 TREND EXTRAPOLATION

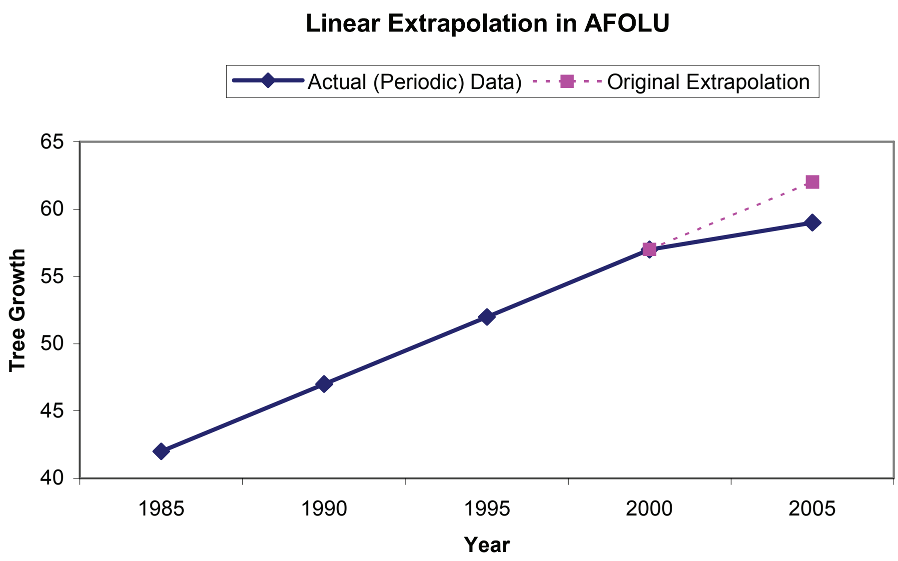
When detailed estimates have not been prepared for the base year or the most recent year in the inventory, it may be necessary to extrapolate from the closest detailed estimates. Trend extrapolation is conceptually similar to interpolation, but less is known about the actual trend. Extrapolation can be conducted either forward (to estimate more recent emissions or removals) or backward (to estimate a base year). Trend extrapolation simply assumes that the observed trend in emissions/removals during the period when detailed estimates are available remains constant over the period of extrapolation. Given this assumption, it is clear that trend extrapolation should not be used if the change in trend is not constant over time. In this situation it will be more appropriate to consider using extrapolations based on surrogate data. Extrapolation should also not be used over long periods of time without detailed checks at intervals to confirm the continued validity of the trend. In the case of periodic data, however, extrapolations will be preliminary and the data point will be recalculated at a later stage.

Box 5.3 in this Section shows an example in which activity data for forests are available only at periodic intervals, and data for the most recent years are not yet available. Data for recent years can be extrapolated on the basis of a consistent trend, or on the basis of appropriate data. It should be noted, however, that the uncertainty of the extrapolated estimates increases in proportion to the length of time over which the extrapolation is made. Once the latest set of periodic data becomes available, it will be necessary to recalculate the part of the time series that had been estimated using trend extrapolation.

The example in Box 5.3 assumes a linear extrapolation, which is likely to be appropriate for the forest land category. Non-linear extrapolations are possible, and may be more appropriate given an observed trend, (e.g., exponential growth in the use of ODS Substitutes). Countries using non-linear extrapolation should provide clear documentation for the choice and explain why it is more appropriate than linear extrapolation.

BOX 5.3
CASE STUDY ON PERIODIC DATA, USING EXTRAPOLATION

Consider a case where a national forest inventory is conducted every 5 years. Estimates of several types of required data (e.g., tree growth) will therefore only be obtained at certain intervals. On the assumption that growth is on average reasonably stable between years, inventory estimates for the years after the last available data should be made using extrapolations of past estimates (i.e., tree growth trends). As shown in the figure below, a biomass estimate for 2005 for a plot is obtained in this way, although the latest measurement was made in 2000. The trend between 1995 and 2000 is simply extrapolated linearly. In practice, a log scale might be used to accommodate exponential behaviour but this is not considered for this simple example. Also, extrapolation can be improved using surrogate data or more sophisticated modelling taking into account parameters influencing the parameter we want to extrapolate.



Unlike periodically available data, when data are not available for the first years in the time series (e.g., base year and pre base year data on for example waste disposal and land use) there is no possibility of filling in gaps with future surveys. Trend extrapolation back in time is possible but should be done in combination with other splicing techniques such as surrogate data and overlap. Some countries that have undergone significant administrative and economic transitions since 1990 do not have consistent activity data sets for the entire time series, particularly if national data sets covered different geographic areas in previous years. To extrapolate backwards in these cases, it is necessary to analyze the relationship between different activity data sets for different periods, possibly using multiple surrogate data sets.

5.3.3.5 OTHER TECHNIQUES

In some cases, it may be necessary to develop a customised approach to best estimate the emissions over time. For example, the standard alternatives may not be valid when technical conditions are changing throughout the time series (e.g., due to the introduction of mitigation technology). In this case, it will be necessary to carefully consider the trends in all factors known to influence emissions or removals over the period. Where customised approaches are used, it is *good practice* to document them thoroughly, and in particular to give special consideration to how the resultant emissions estimates compare to those that would be developed using the more standard alternatives.

5.3.3.6 SELECTING THE MOST APPROPRIATE TECHNIQUE

The choice of splicing technique involves expert judgement, and depends on an expert assessment of the volatility of emissions trend, the availability of data for two overlapping methods, the adequacy and availability of surrogate data sets, and the number of years of missing data. Table 5.1 summarises the requirements for each technique and suggests situations in which they may or may not be appropriate. Countries should use Table 5.1 as a guide rather than a prescription.

TABLE 5.1
SUMMARY OF SPLICING TECHNIQUES

Approach	Applicability	Comments
Overlap	Data necessary to apply both the previously used and the new method must be available for at least one year, preferably more.	• Most reliable when the overlap between two or more sets of annual estimates can be assessed. • If the trends observed using the previously used and new methods are inconsistent, this approach is not *good practice.*
Surrogate Data	Emission factors, activity data or other estimation parameters used in the new method are strongly correlated with other well-known and more readily available indicative data.	• Multiple indicative data sets (singly or in combination) should be tested in order to determine the most strongly correlated. • Should not be done for long periods.
Interpolation	Data needed for recalculation using the new method are available for intermittent years during the time series.	• Estimates can be linearly interpolated for the periods when the new method cannot be applied. • The method is not applicable in the case of large annual fluctuations.
Trend Extrapolation	Data for the new method are not collected annually and are not available at the beginning or the end of the time series.	• Most reliable if the trend over time is constant. • Should not be used if the trend is changing (in this case, the surrogate method may be more appropriate). • Should not be done for long periods.
Other Techniques	The standard alternatives are not valid when technical conditions are changing throughout the time series (e.g., due to the introduction of mitigation technology).	• Document customised approaches thoroughly. • Compare results with standard techniques.

5.4 REPORTING AND DOCUMENTATION OF TREND INFORMATION

If the same method and data sources are used throughout the time series, and there have been no recalculations, then following the reporting guidance for each category should be sufficient to ensure transparency. Generally, countries should explain inventory trends for each category, giving particular attention to outliers, trend changes, and extreme trends. Countries should provide additional documentation if they have recalculated previous estimates and if they have used the techniques in this chapter to splice methodologies.

Recalculations: In addition to following the category-specific guidance on each category provided in Volumes 2-5, countries should clearly document any recalculations. The documentation should explain the reason for the recalculation and the effect of the recalculation on the time series. Countries can also include a graph that shows the relationship between the previous data trend and the new data trend. Table 5.2 provides an example of how recalculations can be documented either for reporting purposes or for internal tracking.

TABLE 5.2 CATEGORY-SPECIFIC DOCUMENTATION OF RECALCULATIONS											
Category/Gas	**Emissions and Removals (Gg)**										
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Previous Data (PD)											
Latest Data (LD)											
Difference in percent =100●[(LD–PD)/PD]											
Documentation (reason for recalculation):											

Splicing techniques: Countries should provide documentation of any splicing techniques used to complete a time series. The documentation should identify the years in which data for the method were not available, the splicing technique used, and any surrogate or overlap data used. Graphical plots, such as those shown in Section 5.3 can be useful tools for documenting and explaining the application of splicing techniques.

Mitigation: The category-specific guidance in Volumes 2-5 provide targeted guidance on specific information that should be reported for each category, including mitigation and reductions. Generally, countries should document the approach used to track mitigation activities and provide all relevant parameters such as abatement utilisation, destruction efficiency, updated emission factors etc.

5.5 TIME SERIES CONSISTENCY QA/QC

The most effective way to ensure the quality of a time series is to apply both general and category-specific checks to the entire time series (see Chapter 6). For example, the outlier and implied emission factor checks in Chapter 6 will help to identify possible inconsistencies in the time series. Category-specific checks are particularly important because they are targeted to unique features of each category.

As described above, plotting and comparing the results of splicing techniques on a graph is a useful QA/QC strategy. If alternative splicing methods produce different results, countries should consider which result is most realistic. In some cases, additional surrogate data can be used to check the spliced time series.

A side by side comparison of recalculated estimates with previous estimates can be a useful check on the quality of a recalculation. This can be done through a tabular comparison as shown in Table 5.2, or as a graphical plot. It is important to note, however, that higher tier methods may produce different trends than lower tier methods because they more accurately reflect actual conditions. Differences in trends do not necessarily suggest a problem with the recalculated estimate.

Where it is possible to use more than one approach to tracking the effects of mitigation activities, countries should compare the results of multiple approaches. If the results differ by more than would be expected, it is *good practice* to explain the reason for the differences and evaluate whether or not a different approach should be used. For disaggregated higher tier estimates, implied emission/removal factors can be a useful tool for checking the consistency of the trend and the plausibility of mitigation estimates.

In some cases activity data collection may have been interrupted or drastically changed. This situation causes challenges for time series consistency. In this situation it is *good practice* to examine closely documentation of the previous data collection system to get a good understanding of how changes in data collection, including definitions and delimitations, have affected the data used in the inventory and any implications for inconsistencies in time-series. If appropriate documentation is not available, an alternative is to compile indicators (e.g., emissions per unit production or emissions per car) and compare these between countries with a similar economic structure, across time-series and in the overlap of the two data collection methods.

In some cases a country may have undergone changes in geographical coverage, e.g., a country may have divided into two or more new countries. In this situation it is *good practice* to compare the inventory data with estimates from regional statistics for the years prior to the split. It can also be recommended to collaborate with other countries that were once part of the same country to ensure completeness and avoid-double counting. If regional statistics are not available and such collaboration is not possible, it is *good practice*, to compare appropriate indicators as described above for the country prior to a split with the data used in the inventory.

If inconsistencies are identified, it is *good practice* to correct them and, if necessary, apply appropriate splicing techniques as described in this chapter.

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CHAPTER 6

QUALITY ASSURANCE / QUALITY CONTROL AND VERIFICATION

Authors

Wilfried Winiwarter (Austria), Joe Mangino (USA)

Ayite-Lo N. Ajavon (Togo), and Archie McCulloch (UK)

Contributing Author

Mike Woodfield (UK)

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6 QUALITY ASSURANCE/QUALITY CONTROL AND VERIFICATION

6.1 INTRODUCTION

An important goal of IPCC inventory guidance is to support the development of national greenhouse gas inventories that can be readily assessed in terms of quality. It is *good practice* to implement quality assurance/quality control (QA/QC) and verification procedures in the development of national greenhouse gas inventories to accomplish this goal. The procedures as described in this chapter also serve to drive inventory improvement.

The guidance is designed to achieve practicality, acceptability, cost-effectiveness, incorporation of existing experience, and the potential for application on a world-wide basis. A QA/QC and verification system contributes to the objectives of *good practice* in inventory development, namely to improve transparency, consistency, comparability, completeness, and accuracy of national greenhouse gas inventories.

QA/QC and verification activities should be integral parts of the inventory process. The outcomes of QA/QC and verification may result in a reassessment of inventory or category uncertainty estimates and to subsequent improvements in the estimates of emissions or removals. For example, the results of the QA/QC process may point to particular variables within the estimation methodology for a certain category that should be the focus of improvement efforts.

The terms 'quality control', 'quality assurance', and 'verification' are often used in different ways. The definitions of QC, QA, and verification in Box 6.1 will be used for the purposes of this guidance.

BOX 6.1
DEFINITIONS OF QA/QC AND VERIFICATION

Quality Control (QC) is a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. It is performed by personnel compiling the inventory. The QC system is designed to:

(i) Provide routine and consistent checks to ensure data integrity, correctness, and completeness;

(ii) Identify and address errors and omissions;

(iii) Document and archive inventory material and record all QC activities.

QC activities include general methods such as accuracy checks on data acquisition and calculations, and the use of approved standardised procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting. QC activities also include technical reviews of categories, activity data, emission factors, other estimation parameters, and methods.

Quality Assurance (QA) is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon a completed inventory following the implementation of QC procedures. Reviews verify that measurable objectives (data quality objectives, see Section 6.5, QA/QC Plan.) were met, ensure that the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability, and support the effectiveness of the QC programme.

Verification refers to the collection of activities and procedures conducted during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of the inventory. For the purposes of this guidance, verification refers specifically to those methods that are external to the inventory and apply independent data, including comparisons with inventory estimates made by other bodies or through alternative methods. Verification activities may be constituents of both QA and QC, depending on the methods used and the stage at which independent information is used.

Before implementing QA/QC and verification activities, it is necessary to determine which techniques should be used, and where and when they will be applied. QC procedures may be *general* with a possible extension to *category specific* procedures. There are technical and practical considerations in making these decisions. The technical considerations related to the various QA/QC and verification techniques are discussed in general in this chapter, and specific applications to categories are described in the category-specific guidance in Volumes 2 to 5. The practical considerations involve assessing national circumstances such as available resources and expertise, and the particular characteristics of the inventory (e.g., whether or not a category is *key*).

6.2 PRACTICAL CONSIDERATIONS IN DEVELOPING QA/QC AND VERIFICATION SYSTEMS

In practice inventory compilers do not have unlimited resources. Quality control requirements, improved accuracy and reduced uncertainty need to be balanced against requirements for timeliness and cost effectiveness. A *good practice* system for QA/QC and verification seeks to achieve that balance, and also to enable continuous improvement of inventory estimates. Judgements to select the respective parameters will need to be made on the following:

- Resources allocated to QA/QC for different categories and the compilation process;
- Time allocated to conduct the checks and reviews of emissions and removal estimates;
- Frequency of QA/QC checks and reviews on different parts of the inventory;
- The level of QA/QC appropriate for each category;
- Availability and access to information on activity data, emission factors and other estimation parameters, including uncertainties and documentation;
- Acquisition of additional data specifically required, e.g., alternative data sets for comparisons and checks;
- Procedures to ensure confidentiality of inventory and category information, when required;
- Requirements for documenting and archiving information;
- Whether increased effort on QA/QC will result in improved estimates and reduced uncertainties;
- Whether sufficient independent data and expertise are available to conduct verification activities.

In order to prioritise QA/QC and verification efforts for certain categories, particularly in terms of activities requiring more intensive analysis and review, the following questions should be asked to identify where to focus such activities in a given inventory development cycle:

- Is this source/sink a *key category* according to the definition and methodologies presented in Chapter 4, Methodological Choice and Identification of Key Categories? Has the category been designated as *key* for qualitative reasons? For example:
  - Is there considerable uncertainty associated with the estimates for this category?
  - Have there been significant changes in the characteristics of this category, such as technology changes or management practices?
  - Have significant changes occurred recently in the estimation methodology used for this category?
  - Are there significant changes in the trends of emissions or removals for this category?
- Does the methodology use complex modelling steps or large inputs from outside databases?
- Are emission factors or other parameters associated with the estimation methodology significantly different to recognized IPCC defaults or data used in other inventories?
- Has a significant amount of time passed since emission factors or other parameters have been updated for this category?
- Has a significant amount of time passed since this category last underwent thorough QA/QC and verification procedures?

- Has there been a significant change in how data are processed or managed for this category, such as a database platform change or change in modelling software?
- Is there a potential overlap with estimates reported under other categories (for example because of common activity data) that can generate double counting or incomplete estimates?

Answering *yes* to the above questions should help identify those sources/sinks where category specific QA/QC and verification activity should be prioritised. Also, the timing of the QA/QC activity should coincide with changes in the category. One time changes in methodologies or data processing, for example, may only require intensified QA/QC within the inventory cycle where those changes occurred.

In terms of the implementation of QA/QC procedures, there should be no difference between confidential and publicly available data; both should carry descriptions of the measurement and calculation procedures and the steps taken to check and verify the values reported. These procedures may be carried out on the confidential data by either the provider of the information or by the inventory compiler and, in either case, confidential source data should be protected and archived accordingly. However, the QA/QC procedures that are implemented need to remain transparent and their description available for review. For example, when data are aggregated across categories at a national level to protect confidentiality, the report should contain a description of the relevant QA/QC procedures.

6.3 ELEMENTS OF A QA/QC AND VERIFICATION SYSTEM

The following are the major elements of a QA/QC and verification system to be implemented in tracking inventory compilation, which are covered in detail in the following sections:

- Participation of an inventory compiler who is also responsible for coordinating QA/QC and verification activities and definition of roles/responsibilities within the inventory;
- A QA/QC plan;
- General QC procedures that apply to all inventory categories ;
- Category-specific QC procedures;
- QA and review procedures;
- QA/QC system interaction with uncertainty analyses;
- Verification activities;
- Reporting, documentation, and archiving procedures.

A complete QA/QC and verification system will typically consist of the elements mentioned above. General QC procedures should be applied routinely to all categories and to the inventory compilation as a whole. In addition, category-specific procedures based on the prioritisation considerations discussed in Section 6.2 should be used. Verification activities may be directed at specific categories or the inventory as a whole, and their application will depend on the availability of independent estimation methodologies that can be used for comparison.

6.4 ROLES AND RESPONSIBILITIES

The inventory compiler should be responsible for coordinating the institutional and procedural arrangements for inventory activities. It is *good practice* for the inventory compiler to define specific responsibilities and procedures for the planning, preparation, and management of inventory activities, including:

- Data collection;
- Selection of methods, emission factors, activity data and other estimation parameters;
- Estimation of emissions or removals;
- Uncertainty assessment;
- QA/QC and verification activities;
- Documentation and archiving.

The inventory compiler may designate responsibilities for implementing and documenting QA/QC procedures to other agencies or organisations, such as in cases where national activity data are provided by a central statistical agency. The inventory compiler should ensure that other organisations involved in the preparation of the inventory are following applicable QA/QC procedures and that appropriate documentation of these activities is available.

The inventory compiler is also responsible for ensuring that the QA/QC plan is developed and implemented. It is *good practice* for the inventory compiler to designate a QA/QC coordinator as the person responsible for ensuring that the objectives of the QA/QC process as set out in the QA/QC plan (see Section 6.5) are met.

6.5 QA/QC PLAN

A QA/QC plan is a fundamental element of a QA/QC and verification system. The plan should, in general, outline the QA/QC and verification activities that will be implemented and the institutional arrangements and responsibilities for implementing those activities. The plan should include a scheduled time frame for the QA/QC activities that follows inventory preparation from its initial development through to final reporting in any year.

The QA/QC plan is an internal document to organise and implement QA/QC and verification activities that ensure the inventory is fit for purpose and allow for improvement. Once developed, it can be referenced and used in subsequent inventory preparation, or modified as appropriate (notably, when changes in processes occur or on advice of independent reviewers). A key component of a QA/QC plan is the list of *data quality objectives*, against which an inventory can be measured in a review. Data quality objectives are concrete targets to be achieved in the inventory preparation. They should be appropriate, realistic (taking national circumstances into account) and allow for an improvement of the inventory. Where possible, data quality objectives should be measurable. Such data quality objectives may be based upon and refined from the following inventory principles:

- Timeliness
- Completeness
- Consistency (internal consistency as well as time series consistency)
- Comparability
- Accuracy
- Transparency
- Improvement

As part of the QA/QC plan, it is *good practice* to accommodate procedural changes and a feedback of experience. Conclusions from previous reviews need to be used to improve the procedures. Such changes can also concern data quality objectives and the QA/QC plan itself. The periodic review and revision of the QA/QC plan is an important element to drive the continued inventory improvement.

In developing and implementing the QA/QC plan, it may be useful to refer to relevant standards and guidelines published by outside groups involved in inventory development. For example, the International Organization for Standardization (ISO) introduced specifications for quantification, monitoring, and reporting of greenhouse gas emissions and removals (ISO 14064) in organisations. These and other relevant ISO standards are listed in Box 6.2. Also, there are guidelines for corporate and entity level QA/QC and verification techniques, which may be reflected in the overall inventory QA/QC process for categories whose estimates rely on data prepared under those guidelines. Examples of such guidelines include the Greenhouse Gas Protocol developed by the World Business Council for Sustainable Development and the World Resources Institute (The greenhouse gas protocol – A corporate accounting and reporting standard. ISBN 156973-568-9), the Guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC, as well as a variety of other regional and national guidelines for emissions trading and reporting systems.

Any specific details of a QA/QC and verification system should be defined in the QA/QC plan so that national circumstances can be taken into account.

BOX 6.2
ISO STANDARDS RELATED TO QUALITY MANAGEMENT SYSTEMS

The International Organization for Standardization (ISO) series programme provides standards for data documentation and audits as part of a quality management system. Within the ISO series, there are several standards that relate to the compilation of greenhouse gas inventories, independent validation and verification, and the accreditation and the requirements for validation and verification bodies.

ISO 14064-1:2006 Greenhouse gases – Part 1: Specification with guidance at the organisation level for quantification and reporting of greenhouse gas emissions and removals

ISO 14064-2:2006 Greenhouse gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements

ISO 14064-3:2006 Greenhouse gases – Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions

Many of the *good practice* principles of quality management derive from a series of generic quality related standards and their subsidiary parts. Inventory compilers may find these documents useful as source material for developing QA/QC plans for greenhouse gas inventories.

ISO 9000:2000 Quality management systems – Fundamentals and vocabulary

ISO 9001:2000 Quality management systems – Requirements

ISO 9004:2000 Quality management systems – Guidelines for performance improvements

ISO 10005:1995 Quality management – Guidelines for quality plans

ISO 10012:2003 Measurement management systems – Requirements for measurement processes and measuring equipment

ISO/TR 10013:2001 Guidelines for quality management system documentation

ISO 19011:2002 Guidelines for quality and/or environmental management systems auditing

ISO 17020:1998 General criteria for the operation of various types of bodies performing inspection

Source: http://www.iso.org/

6.6 GENERAL QC PROCEDURES

General QC procedures include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source and sink categories. Table 6.1, General inventory level QC procedures, lists the general QC checks that the inventory compiler should use routinely throughout the preparation of the inventory. The checks in Table 6.1 should be applied irrespective of the type of data used to develop the inventory estimates. They are equally applicable to categories where default values or national data are used as the basis for the estimates. The results of these QC activities and procedures should be documented as set out in Section 6.11.1, Internal Documentation and archiving, below.

Although general QC procedures are designed to be implemented for all categories and on a routine basis, it may not be necessary or possible to check all aspects of inventory input data, parameters and calculations every year. Checks may be performed on selected sets of data and processes. A representative sample of data and calculations from every category may be subjected to general QC procedures each year. In establishing criteria and processes for selecting sample data sets and processes, it is *good practice* for the inventory compiler to plan to undertake QC checks on all parts of the inventory over an appropriate period of time as determined in the QA/QC plan.

TABLE 6.1
GENERAL INVENTORY QC PROCEDURES

QC Activity	Procedures
Check that assumptions and criteria for the selection of activity data, emission factors, and other estimation parameters are documented.	• Cross-check descriptions of activity data, emission factors and other estimation parameters with information on categories and ensure that these are properly recorded and archived.
Check for transcription errors in data input and references.	• Confirm that bibliographical data references are properly cited in the internal documentation. • Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors.
Check that emissions and removals are calculated correctly.	• Reproduce a set of emissions and removals calculations. • Use a simple approximation method that gives similar results to the original and more complex calculation to ensure that there is no data input error or calculation error.
Check that parameters and units are correctly recorded and that appropriate conversion factors are used.	• Check that units are properly labelled in calculation sheets. • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • Check that temporal and spatial adjustment factors are used correctly.
Check the integrity of database files.	• Examine the included intrinsic documentation (see also Box 6.4) to: - confirm that the appropriate data processing steps are correctly represented in the database. - confirm that data relationships are correctly represented in the database. - ensure that data fields are properly labelled and have the correct design specifications. - ensure that adequate documentation of database and model structure and operation are archived.
Check for consistency in data between categories.	• Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emission/removal calculations.
Check that the movement of inventory data among processing steps is correct.	• Check that emissions and removals data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. • Check that emissions and removals data are correctly transcribed between different intermediate products.
Check that uncertainties in emissions and removals are estimated and calculated correctly.	• Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate. • Check that qualifications, assumptions and expert judgements are recorded. • Check that calculated uncertainties are complete and calculated correctly. • If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using uncertainty calculations according to Approach 1).
Check time series consistency.	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Check methodological and data changes resulting in recalculations. • Check that the effects of mitigation activities have been appropriately reflected in time series calculations.

TABLE 6.1 (CONTINUED) GENERAL INVENTORY QC PROCEDURES	
QC Activity	**Procedures**
Check completeness.	• Confirm that estimates are reported for all categories and for all years from the appropriate base year to the period of the current inventory. • For subcategories, confirm that entire category is being covered. • Provide clear definition of 'Other' type categories. • Check that known data gaps that result in incomplete estimates are documented, including a qualitative evaluation of the importance of the estimate in relation to total emissions (e.g., subcategories classified as 'not estimated', see Chapter 8, Reporting Guidance and Tables).
Trend checks.	• For each category, current inventory estimates should be compared to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any differences. Significant changes in emissions or removals from previous years may indicate possible input or calculation errors. • Check value of implied emission factors (aggregate emissions divided by activity data) across time series. - Do any years show outliers that are not explained? - If they remain static across time series, are changes in emissions or removals being captured? • Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series.
Review of internal documentation and archiving.	• Check that there is detailed internal documentation to support the estimates and enable reproduction of the emission, removal and uncertainty estimates. • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. • Check that the archive is closed and retained in secure place following completion of the inventory. • Check integrity of any data archiving arrangements of outside organisations involved in inventory preparation.

In some cases, estimates are prepared for the inventory compiler by outside consultants or agencies. The inventory compiler should ensure that the consultants/agencies are aware of the QC procedures listed in Table 6.1 and that these procedures are performed and recorded. In cases where the inventory relies upon official national statistics – as is often the case for activity data – QC procedures may already have been implemented on these national data. However, it is *good practice* for the inventory compiler to confirm that national statistical agencies have implemented QC procedures equivalent to those in Table 6.1. Because activity data may have been collected for other purposes using standards and data quality objectives different from the inventory, additional QC checks may be necessary.

In applying general QC procedures, particular attention should also be given to parts of the inventory development that rely on external, and shared databases. Note that this requirement also includes the case of confidential data. An example of this situation is where a national database may be used for compiling information for a large number of point emission sources. The inventory compiler needs to confirm that quality control of data coming from integrated databases has taken place, or QC should be conducted by the inventory compiler if existing protocols from the data provider are not adequate.

Due to the quantity of data that needs to be checked for some categories, automated checks are encouraged where possible. For example, one of the most common QC activities involves checking that data typed into a computer database are correct. A QC procedure could be set up to use an automated range check (based on the range of expected values of the input data from the original reference) for the input values as recorded in the database (see e.g., Winiwarter and Schimak, 2005). A combination of manual and automated checks may constitute the most effective procedures in checking large quantities of input data.

6.7 CATEGORY-SPECIFIC QC PROCEDURES

Category-specific QC complements general inventory QC procedures and is directed at specific types of data used in the methods for individual source or sink categories. These procedures require knowledge of the specific category, the types of data available and the parameters associated with emissions or removals, and are performed in addition to the general QC checks listed in Table 6.1. Category-specific procedures are applied on a case-by-case basis focusing on *key categories* (see Chapter 4, Methodological Choice and Identification of Key Categories) and on categories where significant methodological and data revisions have taken place. In particular, inventory compilers applying higher tier methods in compiling national inventories should utilise category-specific QC procedures to help evaluate the quality of national approaches. Specific applications of category-specific QC procedures are provided in the Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU), and Waste Volumes of this report (Volumes 2 to 5).

Category-specific QC activities include both emissions (or removals) data QC and activity data QC. The relevant QC procedures will depend on the method used to estimate the emissions or removals for a given category. If outside agencies develop estimates, the inventory compiler may, upon review, reference the QC activities of the outside agency as part of the QA/QC plan. There is no need to duplicate QC activities if the inventory compiler is satisfied that the QC activities performed by the outside agency meet the requirements of the QA/QC plan.

Several of the checking procedures mentioned in this section draw on comparisons with independent datasets. It is important to understand that discrepancies will not always indicate a problem – especially if alternate datasets are *a priori* expected to be less relevant and for this reason are not used for calculations directly. It should be an aim of inventory compilation to address and if possible explain such discrepancies.

6.7.1 Emissions factor QC

The following sections describe QC checks on IPCC default emission factors, country-specific emission factors, and direct emission measurements from individual sites (used either as the basis for a site-specific emission factor or directly for an emissions estimate). While the term ‘emissions’ is used in this section, the same types of activities are applicable to calculation parameters for ‘removals’ as well. Inventory compilers should take into account the practical considerations discussed in Section 6.2, Practical Considerations in Developing QA/QC and Verification Systems, when determining what level of QC activities to undertake.

6.7.1.1 IPCC DEFAULT EMISSION FACTORS

When using IPCC default emission factors, it is *good practice* for the inventory compiler to assess the applicability of these factors to national circumstances. This assessment may include an evaluation of national conditions compared to the context of the studies upon which the IPCC default emission factors were based. If there is insufficient information on the context of the IPCC default emission factors, the inventory compiler should take account of this in assessing the uncertainty of the national emissions estimates based on the IPCC default emission factors.

If possible, a supplemental activity is to compare IPCC default emission factors with site or plant-level factors to determine their representativeness relative to actual sources in the country. This supplementary check is *good practice* even if data are only available for a small percentage of sites or plants.

6.7.1.2 COUNTRY-SPECIFIC EMISSION FACTORS

Country-specific emission factors may be developed at a national or other aggregated level within the country based on prevailing technology, science, local characteristics and other criteria. These factors are not necessarily site-specific, but are used to represent a source/sink category or subcategory of the country. The following types of QC checks should be used to evaluate the quality of country-specific factors.

***QC checks on the background data used to develop emission factors*:** It is important to assess the adequacy of the emission factors and the QA/QC performed during their development. If emission factors are based on site-specific or source-level testing, then the inventory compiler should check if the measurement programme included appropriate QC procedures (see Section 6.7.1.3 on QC for direct emission measurements).

Frequently, country-specific emission factors will be based on secondary data sources, such as published studies or other literature.[1] In these cases, the inventory compiler could attempt to determine whether the QC activities conducted during the original preparation of the data are consistent with the applicable QC procedures outlined in Table 6.1 and whether any limitations of the secondary data have been identified and documented. The inventory compiler could also attempt to establish whether the secondary data have undergone peer review and record the scope of such a review. Specifically, it is important to investigate any potential conflicts-of-interest, when the interests of a data provider, e.g., financial interests, might influence results.

If the QA/QC associated with the secondary data is inadequate, the inventory compiler should attempt to establish QA/QC checks on the secondary data. The inventory compiler should also reassess the uncertainty of any emissions estimates derived from the secondary data. The inventory compiler may also want to consider if any alternative data, including IPCC default values, may provide a better estimate of emissions from this category.

***QC checks on Models*:** Because models are means of extrapolating and/or interpolating from a limited set of known data, they often require assumptions and procedural steps to represent the entire inventory area. If QA/QC associated with models is inadequate or not transparent, the inventory compiler should attempt to establish checks on the models and data. In particular, the inventory compiler should check the following:

(i) Appropriateness of model assumptions, extrapolations, interpolations, calibration-based modifications, data characteristics, and their applicability to the greenhouse gas inventory methods and national circumstances;

(ii) Availability of model documentation, including descriptions, assumptions, rationale, and scientific evidence and references supporting the approach and parameters used for modelling;

(iii) Types and results of QA/QC procedures, including model validation steps, performed by model developers and data suppliers. Responses to these results should be documented;

(iv) Plans to periodically evaluate and update or replace assumptions with appropriate new measurements. Key assumptions may be identified by performing sensitivity analyses;

(v) Completeness in relation to the IPCC source/sink categories.

***Comparison with IPCC default factors*:** Inventory compilers should compare country-specific factors with relevant IPCC default emission factors, taking into consideration the characteristics and properties on which the default factors are based. The intent of this comparison is to determine whether country-specific factors are reasonable, given similarities or differences between the national source/sink category and the 'average' category represented by the defaults. Large differences between country-specific factors and default factors do not necessarily indicate problems, but nevertheless may point to quality issues if the differences can not be explained.

***Comparisons of emission factors between countries*:** Between-country emission factor comparisons can be combined with historic trends by plotting, for different countries, the reference year value (e.g., 1990), the most recent year value, and the minimum and maximum values. This analysis could be made for each source/sink category and possible aggregations. Comparisons between countries can also be made using aggregate emissions divided by activity data (implied emission factors). This type of comparison may enable outlier detection based on the statistical distribution of values from the sample of countries considered. When using between-country emission factor comparisons as a QC check, it is important to investigate similarities and differences in national circumstances for the relevant category. If source/sink category characteristics are dissimilar between countries, this diminishes the effectiveness of this check.

***Comparison to plant-level emission factors*:** A supplementary step is to compare the country-specific factors with site-specific or plant-level factors if these are available. For example, if there are emission factors available for a few plants (but not enough to support a bottom-up approach) these plant-specific factors could be compared with the aggregated factor used in the inventory. This type of comparison provides an indication of both the reasonableness of the country-specific factor and its representativeness.

[1] Secondary data sources refer to reference sources for inventory data that are not designed for the express purpose of inventory development. Secondary data sources typically include national statistical databases, scientific literature, and other studies produced by agencies or organisations not associated with the inventory development.

6.7.1.3 DIRECT EMISSION MEASUREMENTS

Emissions from a category may be estimated using direct measurements in the following ways:

- Sample emissions measurements from a facility may be used to develop a representative emission factor for that individual site, or for the entire category (i.e., for development of a national level emission factor);
- Continuous emissions monitoring (CEM) data may be used to compile an annual estimate of emissions for a particular process. Properly implemented, CEM can provide a complete set of quantified emissions data across the inventory period for an individual facility process, and does not have to be correlated back to a process parameter or input variable like an emission factor.

The data provider should check all measurements as part of the QC activities . The use of standard measurement methods improves the consistency of resulting data and knowledge of the statistical properties of the data. If standard reference methods for measuring specific greenhouse gas emissions (and removals) are available, inventory compilers should encourage plants to use these. Plants and facilities that implement direct measurements as part of official regulatory requirements may have mandated measurement QC standards already in place. If specific standard methods are not available, the inventory compiler should confirm whether nationally or internationally recognised standard procedures to quantify performance characteristics of air quality measurement (such as ISO 10012) are used to characterize the measurements, and whether the measurement equipment is calibrated, maintained, and situated such that it gives a representative result. Additional details on using direct measurements are provided in Chapter 2, Approaches to Data Collection, specifically in Table 2.2.

Where direct measurement data from individual sites are in question, discussions with site managers can be useful to encourage improvement of the QA/QC practices at the sites. Also, supplementary QC activities are encouraged for bottom-up methods based on site-specific emission factors where significant uncertainties remain in the estimates. Site-specific factors can be compared between sites and also to IPCC or national level defaults. Distinct differences between sites or between a particular site and the IPCC defaults should elicit further review and checks on calculations. Large differences should be explained and documented.

6.7.2 Activity data QC

The estimation methods for many categories rely on the use of activity data and associated input variables that are not directly prepared by the inventory compiler. Activity data at a national level are normally drawn from secondary data sources or site-specific data prepared by site or plant personnel from their own measurements. Inventory compilers should take into account the practical considerations discussed in Section 6.2 when determining the level of QC activities to undertake.

6.7.2.1 NATIONAL LEVEL ACTIVITY DATA

Following are fundamental QC checks that should be considered for assessing the quality of national level activity data. In all cases, it is important to have a well-defined and documented data set from which appropriate checks can be developed.

***QC checks of reference source for national activity data*:** When using national activity data from secondary data, it is *good practice* for the inventory compiler to evaluate and document the associated QA/QC activities. This is particularly important with regard to activity data, since most activity data are originally prepared for purposes other than as input to estimates of greenhouse gas emissions. Many statistical organisations, for example, have their own procedures for assessing the quality of the data independently of what the end use of the data may be.

The inventory compiler should determine if the level of QC associated with secondary activity data includes, at a minimum, those QC procedures listed in Table 6.1. In addition, the inventory compiler may check for any peer review of the secondary data and document the scope of this review. If the QA/QC associated with the secondary data is adequate, then the inventory compiler can simply reference the data source and document the applicability of the data for use in its estimates (see Box 6.3 for an example of this procedure).

If the QC associated with the secondary data is inadequate or if the data have been collected using standards/definitions that deviate from this guidance, then the inventory compiler should establish QA/QC checks on the secondary data. The uncertainty of estimates should be reassessed in the light of the findings. The inventory compiler should also reconsider how the data are used and whether any alternative data and international data sets may provide a better estimate of emissions or removals. If no alternative data sources are available, the inventory compiler should document the inadequacies associated with the secondary data QC as part of its summary report on QA/QC.

BOX 6.3 EVALUATION OF DATA QUALITY ON EXTERNAL DATA IN THE TRANSPORTATION SECTOR
Countries typically use either fuel usage or kilometer (km) statistics to develop emissions estimates. The national statistics on fuel usage and km travelled by vehicles are usually prepared by a specialised agency. However, it is the responsibility of the inventory compiler to determine which QA/QC activities were implemented by the agency that prepared the original fuel usage and km statistics for vehicles. Questions that may be asked in this context are: • Does the statistical agency have a QA/QC plan that covers the collection and handling of the data? • Was an adequate sampling protocol used to collect data on fuel usage or km travelled? • How recently was the sampling protocol reviewed? • Has any potential bias in the data been identified by the statistical agency? • Has the statistical agency identified and documented uncertainties in the data? • Has the statistical agency identified and documented errors in the data?

***Comparisons with independently compiled data sets*:** Where possible, a comparison check of the national activity data with independently compiled activity data sources should be undertaken. For example, many of the agricultural source-categories rely on government statistics for activity data such as livestock populations and production by crop type. Comparisons can be made to similar statistics prepared by the United Nations Food and Agriculture Organization (FAO). Similarly, the International Energy Agency (IEA) maintains a database on national energy production and usage that can be used for checks in the energy. Industry trade associations, university research, and scientific literature are also possible sources of independently derived activity data to use in comparison checks. Activity data may also derive from balancing approaches – see Section 6.7.2.2 for a description and an example. As part of the QC check, the inventory compiler should ascertain whether alternative activity data sets are really based on independent data. International information is often based on national reporting which is not independent from the data used in the inventory. Available scientific or technical literature may also be used for a national inventory. In some cases, the same data are treated differently by different agencies to meet varying needs. Comparisons may need to be made at a regional level or with a subset of the national data since many alternative references for such activity data have limited scope and do not cover the entire nation.

***Comparisons with samples*:** The availability of partial data sets at sub-national levels may provide opportunities to check the reasonableness of national activity data. For example, if national production data are being used to calculate the inventory for an industrial category, it may also be possible to obtain plant-specific production or capacity data for a subset of the total population of plants. Extrapolation of the sample production data to a national level can then be done using a simple approximation method. The effectiveness of this check depends on how representative the sub-sample is of the national population, and how well the extrapolation technique captures the national population.

***Trend checks of activity data*:** National activity data should be compared with previous year's data for the category being evaluated. *Activity* data for most categories tend to exhibit relatively consistent changes from year to year without sharp increases or decreases. If the national activity data for any year diverge greatly from the historical trend, they should be checked for errors. If a calculation error is not detected, the reason for the sharp change in activity should be confirmed and documented. A more thorough approach to take advantage of similarities between years has been described in Chapter 5, Time Series Consistency.

6.7.2.2 SITE-SPECIFIC ACTIVITY DATA

Some estimation methods rely on the site-specific activity data used in conjunction with IPCC default or country-specific emission factors. Site or plant personnel typically prepare these estimates of activity, often for purposes not related to greenhouse gas inventories. QC checks should focus on any inconsistencies between sites to check whether these reflect errors, different measurement techniques, or real differences in emissions, operating conditions or technology. A variety of QC checks can identify errors in site-level activity data.

***QC checks of measurement protocol*:** The inventory compiler should establish whether individual sites carried out measurements using recognised national or international standards. If the measurements conform to recognised national or international standards and a QA/QC process is in place, then no further QA/QC will be necessary. Acceptable QC procedures in use at the site may be directly referenced. If the measurements do not conform to standard methods and QA/QC is not acceptable, then the inventory compiler should carefully evaluate use of these activity data.

***Comparisons between sites and with national data*:** Comparisons of activity data from different reference sources and geographic scales can play a role in confirming activity data. For example, in estimating PFC emissions from primary aluminium smelting, many inventory compilers use smelter-specific activity data to prepare the inventory estimates. A QC check of the aggregated activity data from all aluminium smelters against national production statistics for the industry can identify major omissions or over-counting. Also, a comparison of production data across different sites, possibly with adjustments made for plant capacities, can indicate the reasonableness of the production data. Similar comparisons of activity data can be made for other manufacturing-based source categories where there are published data on national production. Any identified outliers should be investigated to determine if the difference can be explained by the unique characteristics of the site or there is an error in the reported activity data.

***Production and consumption balances*:** Site-specific activity data checks may also be applied to methods based on product usage. For example, one method for estimating SF_6 emissions from the use in electrical equipment relies on an account balance of gas purchases, gas sales for recycling, the amount of gas stored on site (outside of equipment), handling losses, refills for maintenance, and the total holding capacity of the equipment system. This account balance system should be used at each facility where the equipment is in place. A QC check of overall national activity could be made by performing the same kind of account balancing procedure on a national basis. This national account balancing would consider national sales of SF_6 for the use in electrical equipment, the nation-wide increase in the total handling capacity of the equipment that may be obtained from equipment manufacturers, and the quantity of SF_6 destroyed in the country. The results of the bottom-up and top-down account balancing analyses should agree, or large differences should be explained. Similar accounting techniques can be used as QC checks on other categories based on gas usage, e.g., substitutes for ozone-depleting substances, to check consumption and emissions.

6.7.3 Calculation-related QC

The principles described above for the input data are similarly applicable to all calculation procedures used to prepare a national greenhouse gas inventory. Checks of the calculation algorithm will safeguard against duplication of inputs, unit conversion errors, or similar calculation errors. These checks can be independent 'back-of-the-envelope' calculations, which simplify the algorithms to arrive at an approximate method. If the original calculation and the simple approximate method disagree, it is *good practice* to examine both approaches to find the reason for discrepancy. Further checks on the calculation procedure will require external data (see Section 6.10, Verification).

It is a prerequisite that all calculations leading to emission or removal estimates should be fully reproducible. It is *good practice* to discriminate between input data, the conversion algorithm of a calculation and the output. Not only does the output need to be recorded, but also the input, the conversion algorithm, and how this algorithm accesses the input. Box 6.4 provides practical hints how to record a calculation procedure in standard spreadsheet or database calculations. Such an approach allows for intrinsic documentation of the work, and for easy understanding of the calculation procedure. The documentation should be retained with the material archived in support of the completed inventory.

BOX 6.4
DOCUMENTATION OF CALCULATIONS

When using spreadsheets:

- Clearly reference to the data source of any numbers typed into the spreadsheet (see above documentation criteria for data sources).
- Provide subsequent calculations, in the form of formulas, so that auditing tools can be used to track back from a result to the source data, and calculations can be evaluated by analysing the formulae.
- Clearly mark cells in the spreadsheet containing derived data as 'results' and annotate them as to how and where they are then used.
- Document the spreadsheet itself specifying its name, version, authors, updates, intended use and checking procedures so that it can be used as a data source of the derived results and referenced further on in the inventory process.

When using databases:

- Clearly reference the source data tables using a referencing column that links to the data source.
- Use queries when processing the data, where practical, as these provide the means to track back to the source data tables.
- Where queries are not practical and new tables of data need to be generated, make sure that scripts or macros of the commands used to derive the new data set are recorded and referenced in a referencing column of the dataset.
- Document the database itself specifying its name, version, authors, intended use and checking procedures so that it can be used as a data source of the derived results and referenced further on in the inventory process.

6.8 QA PROCEDURES

Quality assurance comprises activities outside the actual inventory compilation. *Good practice* for QA procedures includes reviews and audits to assess the quality of the inventory, to determine the conformity of the procedures taken and to identify areas where improvements could be made. QA procedures may be taken at different levels (internal/external), and they are used in addition to the general and category-specific QC procedures described in Section 6.7. The inventory may be reviewed as a whole or in parts. The objective of QA implementation is to involve reviewers that can conduct an unbiased review of the inventory and who may have a different technical perspective. It is important to use QA reviewers that have not been involved in preparing the inventory. Preferably these reviewers would be independent experts from other agencies or national or international experts or groups not closely connected with the national inventory compilation, e.g., inventory experts of other countries. Where third party reviewers who are independent from the inventory compiler are not available, persons who are at least not involved in the portion being reviewed can also perform QA.

It is *good practice* for inventory compilers to conduct a basic expert peer review of all categories before completing the inventory in order to identify potential problems and make corrections where possible. However, this will not always be practical due to timing and resource constraints. *Key categories* should be given priority as well as categories where significant changes in methods or data have been made. Inventory compilers may also choose to perform more extensive peer reviews or audits as QA procedures within the available resources. In smaller countries, where there may not be external expertise in all technical areas, the inventory compiler should consider contacting inventory compilers from other countries as part of an external review.

More specific information on QA procedures related to individual categories is provided in the category-specific QA/QC sections in Volumes 2-5.

EXPERT PEER REVIEW

Expert peer review consists of a review of calculations and assumptions by experts in relevant technical fields. This procedure is generally accomplished by reviewing the documentation associated with the methods and results, but usually does not include rigorous certification of data or references such as might be undertaken in an audit.[2] The objective of the expert peer review is to ensure that the inventory's results, assumptions, and methods are reasonable as judged by those knowledgeable in the specific field. Also, where a country has formal stakeholder and public review mechanisms in place, these reviews can supplement expert peer reviews although they should not replace them.

There are no standard tools or mechanisms for expert peer review of greenhouse gas inventories, and its use should be considered on a case-by-case basis. If there is a high level of uncertainty associated with an estimate for a category, expert peer review may provide information to improve the estimate, or at least to better quantify the uncertainty. Effective peer reviews often involve identifying and contacting key independent organisations or research institutions to identify the most appropriate individuals to conduct the review. It is preferable for this expert input to be sought early in the inventory development process so that the experts can provide review of methods and data acquisition that could affect final calculations.

The results of expert analyses from the UNFCCC processes[3] should also be considered as part of the overall QA improvement process. Results and suggestions from these processes can provide valuable feedback on areas where the inventories can be improved. However, these processes should only be considered as supplements to a nationally organised QA and review procedures.

The results of expert peer review, and the response of the inventory compiler to those findings, may be important to general acceptance of the final inventory. All expert peer reviews should be well documented, preferably in a report or checklist format that shows the findings and recommendations for improvement.

AUDITS

For the purpose of *good practice* in inventory preparation, audits may be used to evaluate how effectively the inventory compiler complies with the minimum QC specifications outlined in the QC plan. It is important that the auditor be independent of the inventory compiler as much as possible so as to be able to provide an objective assessment of the processes and data evaluated. Audits may be conducted during the preparation of an inventory, following inventory preparation, or on a previous inventory. Audits are especially useful when new estimation methods are adopted, or when there are substantial changes in existing methods. In contrast to an expert peer review, audits do not focus on the result of calculation. Instead, they provide an in-depth analysis of the respective procedures taken to develop an inventory, and on the documentation available. It is *good practice* for the inventory compiler to develop a schedule of audits at strategic points in the inventory development. For example, audits related to initial data collection, measurement work, transcription, calculation and documentation may be conducted. Audits can be used to verify that the QC steps identified in Table 6.1 have been implemented, that category-specific QC procedures have been implemented according to the QC plan, and that the data quality objectives have been met.

6.9 QA/QC AND UNCERTAINTY ESTIMATES

The QA/QC process and uncertainty analyses provide valuable feedback to one another. Staff involved in the QA/QC and uncertainty analyses can identify critical components of the inventory estimates and data sources that contribute to both the uncertainty level and inventory quality and which should therefore be a primary focus of inventory improvement efforts. This information should ultimately be useful in improving the methods and data sources used for the estimates. For example, the uncertainty analysis can provide insights into weaknesses in the estimate, the sensitivity of the estimate to different variables, and the greatest contributors to uncertainty, all of which can assist in setting priorities for improving data sources or methodologies.

Some of the uncertainty estimation methods rely on the use of measured data associated with the emission factors or activity data to develop probability density functions from which uncertainty estimates can be made. In the absence of measured data, many uncertainty estimates will rely on expert judgement. It is *good practice* to apply QC procedures to uncertainty estimation to confirm that calculations are correct and data and calculations well documented. The assumptions on which uncertainty estimation has been based should be documented for each category. Calculations of category-specific and aggregated uncertainty estimates should be checked and any errors addressed. For uncertainty estimates involving expert judgement, the qualifications of experts should also

[2] Formal expert review as defined by government agencies in some countries may include standardised procedures and other elements of a thorough audit, as described in this Chapter.

[3] Examples of relevant processes include inventory reviews of Annex I Parties, reviews of National Communications and feedback from the Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention (CGE).

be checked and documented, as should the process of eliciting expert judgement, including information on the data considered, literature references, assumptions made and scenarios considered. Chapter 2, Approaches to Data Collection, contains advice on how to document expert judgements on uncertainties.

6.10 VERIFICATION

For the purposes of this guidance, verification activities include comparisons with emission or removal estimates prepared by other bodies and comparisons with estimates derived from fully independent assessments, e.g., atmospheric concentration measurements. Verification activities provide information for countries to improve their inventories and are part of the overall QA/QC and verification system. Correspondence between the national inventory and independent estimates increases the confidence and reliability of the inventory estimates by confirming the results. Significant differences may indicate weaknesses in either or both of the datasets. Without knowing which dataset is better, it may be worthwhile to re-evaluate the inventory. This section describes approaches that can be used to verify inventory estimates at both the source/sink category and inventory wide levels.

The considerations for selecting verification approaches include: scale of interest, costs, desired level of accuracy and precision, complexity of design and implementation of the verification approaches, availability of data, and the required level of expertise needed for implementation. Not all approaches will be available to every inventory compiler due to some of these criteria, particularly the techniques included in 'comparisons with atmospheric measurements' described in Section 6.10.2, which can be resource and data intensive. However, there are a number of relatively simple, comparison techniques that should be available to most inventory compilers, and that can be valuable tools in the overall QA/QC and verification system. As much information required may be available on a national level, we will refer to these as national activities. The same concept can easily be transferred to other spatial units, if data are available.

Where verification techniques are used, they should be reflected in the QA/QC plan. The limitations and uncertainties associated with the verification technique itself should be thoroughly investigated prior to its implementation so that the results can be properly interpreted.

6.10.1 Comparisons of national estimates

There are a number of practical verification techniques that do not require specialised modelling expertise or extended analyses. Most of these can be considered as method-based comparisons that consider the differences in national estimates based on using alternative estimation methodologies for the same category or set of categories. These comparisons look for major calculation errors and exclusion of major source categories or sub-source categories. Method-based comparisons can be designed around the multi-tier level of methods outlined for each category in the sector guidance, through comparisons to independent estimates developed by other institutions, and, to a limited extent, through cross-country comparisons. The choice of method will depend on the method used in the inventory, a clear definition and correlation of categories between methods, and the availability of alternative data.

These checks can be extremely useful in confirming the reasonableness of national inventory estimates and may help identify any gross calculation errors. Some of these techniques, such as the compilation of the reference approach for Energy Sector estimates, should be considered as part of the inventory development process.

Discrepancies between inventory data and data compiled using alternative methods do not necessarily imply that the inventory data are in error. When analysing discrepancies, it is important to consider that there may be large uncertainties associated with the alternative calculations themselves.

***Applying lower tier methods*:** Lower tier IPCC methods typically are based on 'top-down' approaches that rely on highly aggregated data at a summary category level. Inventory compilers using higher tier, 'bottom-up' approaches may consider using comparisons to lower-tier methods as a simple verification tool. As an example, for carbon dioxide (CO_2) from fossil fuel combustion, a reference calculation based on apparent fuel consumption per fuel type is specified as a verification check in the Energy Sector procedures (see Volume 2: Energy). This reference approach estimate can be compared to the sum of sectoral-based estimates from a Tier 1, 2, or 3 approach. While the quality of the reference approach is typically lower than that of the sectoral approach, it remains useful as a simple approximation method. It is less sensitive to errors due to its simplicity and can be used as a top-down completeness check. Another example, where emissions are calculated as the sum of sectoral activities based on the consumption of a specific commodity, e.g., fuels or products like hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) or sulphur hexafluoride (SF_6), the emissions could be estimated using apparent consumption figures, e.g., national total production + import – export ± stock changes, taking into consideration any possible time lags in actual emissions.

Similar checks can be performed for industrial type sources, e.g., nitrous oxide (N_2O) estimates for nitric acid production, where inventory estimates were determined for each individual production plant based on plant-specific data. The check of emission estimates would consist of the comparison between the sum of the individual plant-level emission estimates and a top-down emission estimate based on national nitric acid production figures and IPCC default Tier 1 factors. Large differences do not necessarily indicate that there are problems with the inventory estimate. As lower tier methods typically rely on more highly aggregated data, there may be relatively large uncertainties with the Tier 1 approach compared to an inventory estimated using a bottom up approach based on *good practice*. If differences cannot easily be explained, the inventory compiler may consider the following questions in any further QA/QC checks:

- Are there inaccuracies associated with any of the individual plant estimates (e.g., an extreme outlier may be accounting for an unreasonable quantity of emissions)?
- Are the plant-specific emission factors significantly different from each other?
- Are the plant-specific production rates consistent with published national level production rates?
- Is there any other explanation for a significant difference, such as the effect of controls, the manner in which production is reported or possibly undocumented assumptions?

This is an example of how the results of a relatively simple emission check can lead to a more intensive investigation of the representativeness of the emissions data. Knowledge of the category is required to isolate the parameter that is causing the difference in estimates and to understand the reasons for the difference.

Applying higher tier methods**:** Higher tier IPCC methods typically are based on detailed 'bottom-up' approaches that rely on highly disaggregated data and a well-defined subcategorisation of sources and sinks. Inventory compilers may find that they can not fully implement a higher tier approach because they are lacking sufficient data or resources. However, the availability of even partial estimates for a subcategory of sources may provide a valuable verification tool for the inventory. An estimate based on higher tier data derived from a proportion of the total sources in a country can be extrapolated to the national level, provided that the sample is representative. Such an extrapolation can be used to corroborate the national estimate.

Comparisons with independently compiled estimates**:** Comparisons with other independently compiled inventory data on national level (if available) are a quick option to evaluate completeness, approximate emission (removal) levels and correct category allocations. Although the inventory compiler is ultimately responsible for preparing the national greenhouse gas inventory, other independent publications on this subject may be available e.g., from scientific literature or publication by other institutes or agencies. For example, national level CO_2 emissions estimates associated with the combustion of fossil fuel are compiled by the International Energy Agency (IEA) and the Carbon Dioxide Information and Analysis Centre (CDIAC). Estimates of emissions of other pollutants are available from the Emission Database for Global Atmospheric Research (EDGAR) (http://www.mnp.nl/edgar/). If independently compiled datasets use IPCC Tier 1 methodologies, the same considerations discussed above will apply.

While national data are normally considered more reliable as they are able to accommodate more detailed country-specific information, and international data are normally compiled at a lower tier, these international data sets provide a good basis for comparison as they are consistent between countries. The comparisons can be made for different greenhouse gases at national, sectoral, category, and subcategory levels, as far as the differences in definitions enable them. Before conducting these types of comparisons, it is important to check the following items.

- Confirm that the underlying data for the independent estimate are not the same as that used for the inventory; a comparison is only meaningful if data being compared are different.
- Determine if the relationships between the sectors and categories in the different inventories can be defined and matched appropriately.
- Account for the data quality (e.g., QA/QC system or review) and for any known uncertainties in the estimate used for the comparison to help interpret results.

Comparisons of intensity indicators between countries**:** Emission (removal) intensity indicators, e.g., those commonly referred to as 'implied emission (removal) factors', may be compared between countries (e.g., emissions per capita, industrial emissions per unit of value added, transport emissions per car, emissions from power generation per kWh of electricity produced, emissions from dairy ruminants per tonne of milk produced). These indicators provide a preliminary check and verification of the order of magnitude of the emissions or removals. Different practices and technological developments as well as the varying nature of the source categories will be reflected in the emission intensity indicators. Thus differences between countries need to be expected. However, these checks may flag potential anomalies at the country or sector level.

6.10.2 Comparisons with atmospheric measurements

An ideal condition for verification is the use of fully independent data as a basis for comparison. Measurements of atmospheric concentrations potentially provide such datasets, and recent scientific advances allow using such data as a basis for emission modelling. The approach is particularly valuable as it is independent of standard estimation method drivers, such as sector activity data and implied emission factors. The scale of such models can be designed around local, regional, or global boundaries and can provide information on either level or trends in emissions. Some brief examples of these techniques are provided in this section; however, further discussion and elaboration can be found in more comprehensive summaries on the use of these methods for inventory verification (Rypdal *et al*., 2005; Bergamaschi *et al*., 2004; Benkovitz, 2001; Benjey and Middleton, 2002; NACP, 2002).

It should be recognized that the complexity as well as the limited application potential of atmospheric models to inventory verification, particularly at a national level, can restrict their utility to many inventory compilers. In addition, many of the techniques will require specialised modelling skills and resources in order to appropriately correlate the atmospheric data back to the inventory for comparison, and be cost- and labour intensive. Depending on specific conditions, results may be only applicable to parts of a country, to groups of countries, or to specific categories or gases. The required analysis time will also typically extend beyond an inventory cycle, thus making these types of comparisons more applicable for long term verification programs. In many cases, the uncertainties associated with the atmospheric models themselves may not be sufficiently quantified or may be too large for the model to be used effectively as a verification tool.

In contrast to the other methods described in this chapter, comparisons with atmospheric measurements cannot therefore be a standard tool for verification to be applied by an inventory compiler. Still a considerable scientific progress in this area needs to be noted and inventory compilers may wish to take advantage of the potential of this approach, as it gives independent data for verification. If applicable, national inventory compilers may also consider joining forces with neighbouring countries, in cases when emission modelling from atmospheric measurement is more reliable for larger entities than countries.

Despite the limitations given, there are a number of evolving techniques that deserve to be mentioned here:

***Inverse Modelling*:** The concentrations of greenhouse gases in air samples are measured at monitoring sites and can be used to provide emission estimates by a technique known as inverse modelling. Inverse models calculate emission fluxes from concentration measurements and atmospheric transport models. For local and regional estimation, complex mathematical and statistical models are required together with continuous, or quasi-continuous, measurements that capture all pollution incidents. The source discrimination of air sampling-derived emissions requires highly precise and labour-intensive analysis, which may prevent the applicability of inverse modelling approaches to source-specific emissions verification. In contrast to national inventories, flux assessments from inverse modelling include the effect of natural sources/sinks as well as international transport. Considering the limited monitoring network currently available for many of the greenhouse gases and the resulting uncertainties in the model results, inverse modelling is not likely to be frequently applied as a verification tool of national inventories in the near future. Even the availability of satellite-borne sensors for greenhouse gas concentration measurements (see Bergamaschi *et al*., 2004) will not fully resolve this problem, due to limitations in spatial, vertical and temporal resolution. However, there is increasing scientific recognition for the potential of these techniques for both level and trend verification of national inventories.

Inverse modelling techniques are undergoing rapid development and are being applied now in national inventories estimates (O'Doherty *et al*., 2003), European emission estimates (Manning *et al*., 2003) and to provide geographical distributions of emissions within the European Union (Ryall *et al*., 2001). Ultimately, the application of these techniques relies on a comparison of the uncertainty between the calculated inventory estimates and the inverse model-derived estimates (Rypdal *et al*., 2005, Bergamaschi *et al*., 2004). Where the uncertainty of the model results is less than the calculated inventory uncertainty, the model can be used to improve the inventory. Also, where the model results are significantly different from the inventory, this can point to missing sources or possibly large calculation errors.

Fluorinated gases and methane (CH_4) are considered the most suitable greenhouse gases for which inverse modelling could provide verification of emission estimates (Rypdal *et al.*, 2005, Bergamaschi *et al.*, 2004). The fluorinated compounds are considered good candidates for inverse modelling verification because: they have virtually no natural source interference in the atmospheric measurements, there can be considerable uncertainties in inventory methods, they are long-lived, and the loss mechanisms are well known. Methane is considered a favourable candidate because of the generally high uncertainty in emission estimates resulting from inventory methodologies, and the strong atmospheric signal to noise ratio of measurements. Modelling of CO_2 emissions for national inventory verification is probably not a priority since the inventory methods already have low uncertainties, except where agriculture, forestry and other land-use is dominant. The impacts of large natural sources and sinks on atmospheric measurements make a correlation to strictly anthropogenic sources difficult. However, it may improve understanding of contributions from forests and natural sources and sinks. Due to the large uncertainties associated with some of the N_2O inventory methodologies verification through atmospheric measurements would be desirable. However, the influence of natural sources and sinks on measurements, as well as the long atmospheric lifetime lead to a poor signal to noise ratio in measured concentrations. Thus further investigations are required before inverse modelling can successfully be applied to the verification of inventories of N_2O.

***Continental Plumes*:** A strong difference between source and non-source regions may generally be found between a continent and an ocean where routine measurements of the difference between background air concentrations and the offshore plume concentrations, coupled with wind vector analysis or trajectory analysis, may provide an indication of emissions on a broad scale (Cape *et al*., 2001; Derwent *et al*., 2001). For example, a number of greenhouse gases, including chlorofluorocarbons (CFCs), N_2O and CH_4 from the European continental plume have been detected at Mace Head, Ireland. These results have then been used for subsequent quantification of the European emission source strength by inverse modelling (Derwent *et al*., 1998a, 1998b; Vermeulen *et al*., 1999).

***Use of Proxy Emission Databases*:** In the cases where one of the components measured in the air samples has a well characterised emission inventory (a 'marker' or 'tracer' compound), the emissions of greenhouse gases may be estimated from atmospheric measurements of their concentration ratio to this marker compound. The technique is appropriate if sources of the compounds are co-located, and it has been used in the U.S.A., for example with carbon monoxide (CO) as the marker (Barnes *et al*., 2003a, 2003b), and in the EU employing radon (^{222}Rn: Biraud *et al*., 2000).

***Global Dynamic Approaches*:** Trends over time in the atmospheric concentration of particular compounds may also indicate a change in the global balance between sources and sinks and give an estimate of the globally aggregated emissions, constraining the total of national emissions from an aggregate perspective and possibly indicating areas of weakness in the inventories. Such approaches have been taken for CH_4 (Dlugokencky *et al*., 1994), sulphur hexafluoride (SF_6) (Maiss and Brenninkmeijer, 1998), PFC-14 and carbon tetrafluoride (CF_4) (Harnisch and Eisenhauer, 1998). These methods can be applicable to cover a large proportion of global emissions, and monitoring is possible on a routine basis.

6.11 DOCUMENTATION, ARCHIVING AND REPORTING

6.11.1 Internal documentation and archiving

It is *good practice* to document and archive all information relating to the planning, preparation, and management of inventory activities. This includes:

- Responsibilities, institutional arrangements, and procedures for the planning, preparation, and management of the inventory process;
- Assumptions and criteria for the selection of activity data and emission factors;
- Emission factors and other estimation parameters used, including references to the IPCC document for default factors or to published references or other documentation for emission factors used in higher tier methods;
- Activity data or sufficient information to enable activity data to be traced to the referenced source;
- Information on the uncertainty associated with activity data and emission factors;
- Rationale for choice of methods;
- Methods used, including those used to estimate uncertainty and those used for recalculations;
- Changes in data inputs or methods from previous inventories (recalculations);
- Identification of individuals providing expert judgement for uncertainty estimates and their qualifications to do so;

- Details of electronic databases or software used in the production of the inventory, including versions, operating manuals, hardware requirements and any other information required to enable their later use;
- Worksheets and interim calculations for category estimates, and aggregated estimates and any re-calculations of previous estimates;
- Final inventory report and any analysis of trends from previous years;
- QA/QC plans and outcomes of QA/QC procedures;
- Secure archiving of complete datasets, to include shared databases that are used in inventory development. This is particularly important for categories that rely on the multi-step development of emissions from a large set of primary data from outside sources.

It is *good practice* for inventory compilers to maintain this documentation for every inventory produced and to provide it for review. It is *good practice* to maintain and archive this documentation in such a way that every inventory estimate can be fully documented and reproduced if necessary.

Records of QA/QC procedures are important information to enable continuous improvement to inventory estimates. It is *good practice* for records of QA/QC activities to include the checks/audits/reviews that were performed, when they were performed, who performed them, and corrections and modifications to the inventory resulting from the QA/QC activity. An example checklist to use for recording QC activities at both the general and category-level is provided in Annex 6A.1.

6.11.2 Reporting

It is *good practice* to report a summary of implemented QA/QC activities and key findings as a supplement to each country's national inventory, which itself is described in Volumes 2-5 and by the tables in this volume. However, it is not practical or necessary to report all the internal documentation that is retained by the inventory compiler. In this summary, the inventory compiler should focus on the following activities.

- Reference to a QA/QC plan, its implementation schedule, and the responsibilities for its implementation should be discussed.
- Describe which activities were performed internally and what external reviews were conducted for each source/sink category and on the entire inventory.
- Present the key findings, describing major issues regarding quality of input data, methods, processing, or estimates for each category and show how they were addressed or plan to be addressed in the future.
- Explain significant trends in the time series, particularly where trend checks point to substantial divergences. Any effect of recalculations or mitigation strategies should be included in this discussion.

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Annex 6A.1 QC checklists

FORMS AND CHECKLISTS FOR QUALITY CONTROL FOR SPECIFIC SOURCE CATEGORIES

This annex contains a number of example forms that provide means to record both general and category-specific QC activities. These forms are only examples, and inventory compilers may find other means to effectively record their QA/QC activities (to be defined in the QA/QC plan). Refer to the *IPCC Guidelines* chapters on QA/QC and Verification, Data Collection, and for each category as described in Volume 2-5 for more detailed guidance on developing QC checks.

A1. GENERAL QC CHECKLIST

(to be completed for each category and for each inventory)

A2. CATEGORY-SPECIFIC QC CHECKLIST (CHECKS TO BE DESIGNED FOR EACH CATEGORY)

Part A: Data Gathering and Selection

Part B: Secondary Data and Direct Emission Measurement

A1. GENERAL QC CHECKLIST

Inventory Report: ___________ Source/Sink Category[4]: ____

Title(s) and Date(s) of Inventory Spreadsheet(s): ____

Source (sink) category estimates prepared by (name/affiliation): ______________________________________

INSTRUCTIONS FOR COMPLETING THIS FORM:

This form is to be completed for each source/sink category, and provides a record of the checks performed and any corrective actions taken. The form may be completed by hand or electronically. The form should be distributed and filed according as specified in the QA/QC plan. If appropriate actions to correct any errors that are found are not immediately apparent, the QC staff performing the check should discuss the results according to the procedures predefined in the QA/QC plan.

The first page of this form summarises the results of the checks (once completed) and highlights any significant findings or actions. The remaining pages in this form list categories of checks to be performed. The analyst has discretion over how the checks are implemented. Not all checks will be applicable to every category. Checks/rows that are not relevant or not available should indicate 'n/r' (not relevant) or 'n/a' (not available) so that no check and no row is left blank or deleted. Rows for additional checks that are relevant to the source/sink category should be added to the form.

The column for supporting documentation should be used to reference any relevant Supplemental Reports or Contact Reports providing additional information.

Summary of general QC checks and corrective action	
Summary of results of checks and corrective actions taken:	
Suggested checks to be performed in the future:	Any residual problems after corrective actions have been taken:

4 Use IPCC recognized source/sink category names. See Table 8.2 of Chapter 8.

Checklist for general QC checks (complete table for each category):

Item	Check completed			Corrective action		Supporting documents (provide reference)
	Date	Individual (first initial, last name)	Errors (Y/N)	Date	Individual (first initial, last name)	
DATA GATHERING, INPUT, AND HANDLING ACTIVITIES: QUALITY CHECKS						
1. Check a sample of input data for transcription errors						
2. Review spreadsheets with computerised checks and/or quality check reports						
3. Identify spreadsheet modifications that could provide additional controls or checks on quality						
4. Other (specify):						
DATA DOCUMENTATION: QUALITY CHECKS						
5. Check project file for completeness						
6. Confirm that bibliographical data references are included (in spreadsheet) for every primary data element						
7. Check that all appropriate citations from the spreadsheets appear in the inventory document						
8. Check that all citations in spreadsheets and inventory are complete (i.e., include all relevant information)						
9. Randomly check bibliographical citations for transcription errors						
10. Check that originals of new citations are in current docket submittal						
11. Randomly check that the originals of citations (including Contact Reports) contain the material & content referenced						
12. Check that assumptions and criteria for selection of activity data, emission factors and other estimation parameters are documented						
13. Check that changes in data or methodology are documented						
14. Check that citations in spreadsheets and inventory document conform to acceptable style guidelines						
15. Other (specify):						

Checklist for general QC checks (complete table for each category) (Continued):						
Item	**Check completed**			**Corrective action**		**Supporting documents (provide reference)**
	Date	**Individual (first initial, last name)**	**Errors (Y/N)**	**Date**	**Individual (first initial, last name)**	
CALCULATING EMISSIONS AND CHECKING CALCULATIONS						
16. Check that all calculations are included (instead of presenting results only)						
17. Check whether units, parameters, and conversion factors are presented appropriately						
18. Check if units are properly labelled and correctly carried through from beginning to end of calculation						
19. Check that conversion factors are correct						
20. Check that temporal and spatial adjustment factors are used correctly						
21. Check the data relationships (comparability) and data processing steps (e.g., equations) in the spreadsheets						
22. Check that spreadsheet input data and calculated data are clearly differentiated						
23. Check a representative sample of calculations, by hand or electronically						
24. Check some calculations with abbreviated calculations						
25. Check the aggregation of data within a category						
26. When methods or data have changed, check consistency of time series inputs and calculations						
27. Check current year estimates against previous years (if available) and investigate unexplained departures from trend						
28. Check value of implied emission/removal factors across time series and investigate unexplained outliers						
29. Check for any unexplained or unusual trends for activity data or other calculation parameters in time series						
27. Check for consistency with IPCC inventory guidelines and good practices, particularly if changes occur						
28. Other (specify):						

A2. CATEGORY-SPECIFIC QC CHECKLIST

Inventory Report: ___________ Source/sink Category[5]: ____

Key category (or includes a key subcategory): (Y / N): ____

Title(s) and Date(s) of Inventory Spreadsheet(s): ____

Category estimates prepared by (name/affiliation): ____

GENERAL INSTRUCTIONS FOR COMPLETING THIS FORM:

Category-specific checks focus on the particular data and methodology used for an individual source or sink category. The specificity and frequency of these checks will vary across source categories. The form may be completed by hand or electronically. Once completed, the form should be saved and included as part of the inventory archive, as defined in the QA/QC plan.

The first table on this form summarises generally the results of the category-specific checks and highlights any significant findings or corrective actions. The remaining pages in this form list categories of checks to be performed or types of questions to be asked. Part A checks are designed to identify potential problems in the estimates, factors, and activity data. Part B checks focus on the quality of secondary data and direct emission measurement. The analyst has discretion over how the checks are implemented. Checks/rows that are not relevant or not available should indicate 'n/r' (not relevant) or 'n/a' (not available) so that no check and no row is left blank or deleted. Rows for additional checks that are relevant to the category should be added to the form.

The column for supporting documentation should be used to reference any relevant Supplemental Reports or Contact Reports that provide additional information. Other sources may be included here, if they can be clearly referenced. Any documents associated with the category specific plan should be clearly referenced in the column for supporting documentation.

<table>
<tr><th colspan="2">Summary of category-specific QC activities</th></tr>
<tr><td colspan="2">Summary of results of checks and corrective actions taken:</td></tr>
<tr><td>Suggested checks to be performed in the future:</td><td>Any residual problems after corrective actions have been taken:</td></tr>
</table>

[5] Use IPCC recognized source/sink category names.

***ADDITIONAL INSTRUCTIONS FOR PART A*:**

The checklist below indicates the types of checks and comparisons that can be performed and is not intended to be exhaustive. Supplemental Reports, Contact Reports, or other documents may be used to report detailed information on the checks conducted. For example, a Supplemental Report could provide information on the variables or sub-variables checked, comparisons made, conclusions that were drawn and rationale for conclusions, sources of information (published, unpublished, meetings, etc.) consulted, and corrective actions required.

Category-specific checklist - Part A: Data gathering and selection							
Item		**Check completed**			**Corrective action**		**Supporting documents (provide reference)**
		Date	**Individual (first initial, last name)**	**Errors (Y/N)**	**Date**	**Individual (first initial, last name)**	
EMISSION DATA QUALITY CHECKS							
1.	Emission comparisons: historical data for source, significant sub-source categories						
2.	Checks against independent estimates or estimates based on alternative methods						
3.	Reference calculations						
4.	Completeness						
5.	Other (detailed checks)						
EMISSION FACTOR QUALITY CHECK							
6.	Assess representativeness of emission factors, given national circumstances and analogous emissions data						
7.	Compare to alternative factors (e.g., IPCC default, cross-country, literature)						
8.	Search for options for more representative data						
9.	Other (detailed checks)						
ACTIVITY DATA QUALITY CHECK: NATIONAL LEVEL ACTIVITY DATA							
10.	Check historical trends						
11.	Compare multiple reference sources						
12.	Check applicability of data						
13.	Check methodology for filling in time series for data that are not available annually						
14.	Other (detailed checks)						
ACTIVITY DATA QUALITY CHECK: SITE-SPECIFIC ACTIVITY DATA							
15.	Check for inconsistencies across sites						
16.	Compare aggregated and national data						
17.	Other (detailed checks)						

***ADDITIONAL INSTRUCTIONS FOR PART B*:**

Completing the QC checks on secondary data and direct emission measurement may require consulting the primary data sources or authors. The checklist below is intended to be indicative, not exhaustive. Additional information on appropriate checks can be found in the QA/QC, Data Collection, and sectoral chapters of the *IPCC Guidelines*.

Additional documentation is likely to be necessary to record the specific actions taken to check the data underlying the category estimates. For example, Supplemental Reports may be needed to record the data or variables that were checked, and the published references and individuals or organisations consulted as part of the investigation. Contact Reports should be used to report the details of personal communications. Supplemental Reports may also be used to explain the rationale for a finding reported in the summary, the results of research into the QC procedures associated with a survey, or checks of site measurement procedures. Be sure to provide references to all supporting documentation.

Category-specific checklist - Part B: Secondary data and direct emission measurement

Item	**Check completed**			**Corrective action**		**Supporting documents (provide reference)**
	Date	**Individual (first initial, last name)**	**Errors (Y/N)**	**Date**	**Individual (first initial, last name)**	
SECONDARY DATA: SAMPLE QUESTIONS REGARDING THE QUALITY OF INPUT DATA						
1. Are QC activities conducted during the original preparation of the data (either as reported in published literature or as indicated by personal communications) consistent with and adequate when compared against (as a minimum), general QC activities?						
2. Does the statistical agency have a QA/QC plan that covers the preparation of the data?						
3. For surveys, what sampling protocols were used and how recently were they reviewed?						
4. For site-specific activity data, are any national or international standards applicable to the measurement of the data? If so, have they been employed?						
5. Have uncertainties in the data been estimated and documented?						
6. Have any limitations of the secondary data been identified and documented, such as biases or incomplete estimates? Have errors been found?						
7. Have the secondary data undergone peer review and, if so, of what nature?						
8. Other (detailed checks)						
DIRECT EMISSION MEASUREMENT: CHECKS ON PROCEDURES TO MEASURE EMISSIONS						
9. Identify which variables rely on direct emission measurement						
10. Check procedures used to measure emissions, including sampling procedures, equipment calibration and maintenance.						
11. Identify whether standard procedures have been used, where they exist (such as IPCC methods or ISO standards).						
12. Other (detailed checks)						

CHAPTER 7

PRECURSORS AND INDIRECT EMISSIONS

Authors

Michael Gillenwater (USA), Kristina Saarinen (Finland),

and Ayite-Lo N. Ajavon (Togo)

Contributing Author

Keith A. Smith (UK)

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7 PRECURSORS AND INDIRECT EMISSIONS

7.1 INTRODUCTION

Although they are not included in global warming potential-weighted greenhouse gas emission totals, emissions of carbon monoxide (CO), oxides of nitrogen (NO_x), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO_2) are reported in greenhouse gas inventories. Carbon monoxide (CO), Nitrogen oxides (NO_x) and NMVOC in the presence of sunlight contribute to the formation of the greenhouse gas ozone (O_3) in the troposphere and are therefore often called 'ozone precursors'. Furthermore, NO_x emission plays an important role in the earth's nitrogen cycle. Sulphur Dioxide emissions lead to formation of sulphate particles, which also play a role in climate change. Ammonia (NH_3) is an aerosol precursor, but is less important for aerosol formation than SO_2.

Section 7.2 addresses the estimation and reporting of the precursors for national inventories. The methodologies for ambient air quality emission inventories have been elaborated in detail in the EMEP[1]/CORINAIR Emission Inventory Guidebook (Guidebook), and these methodologies for CO, NO_x, NMVOCs, and SO_2 emissions are referenced in this chapter rather than to be included in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 Guidelines*). Exceptions are for sources not well-covered by the Guidebook.

Section 7.3 addresses nitrous oxide (N_2O) emissions that result from the deposition of the nitrogen emitted as NO_x and NH_3. Nitrous oxide is produced in soils through the biological processes of nitrification and denitrification. Simply defined, nitrification is the aerobic microbial oxidation of ammonium to nitrate and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil atmosphere. One of the main controlling factors in this reaction is the availability of inorganic nitrogen in the soil and therefore deposition of nitrogen resulting from NO_x and ammonia (NH_3) will enhance emissions. N_2O emissions will also be enhanced if nitrogen is deposited in the ocean or in lakes. For this reason the *2006 Guidelines* include guidance for estimating N_2O emissions resulting from nitrogen deposition of all anthropogenic sources of NO_x and NH_3. Only agricultural sources of nitrogen were considered in the *Revised 1996 Guidelines* (IPCC, 1997).

Guidance is provided in Section 7.3 on estimating N_2O emissions from atmospheric deposition resulting from all categories except agricultural soil management and manure management. Section 7.3 provides information on NO_x emissions. Countries may use national methodologies to estimate emissions of NH_3 not originating from agriculture. NH_3 emissions are also covered in the EMEP/CORINAIR Emission Inventory Guidebook.

7.2 PRECURSOR EMISSIONS

Where the country already has inventories for precursors, the results should be reported in the inventory. In some countries, air pollutant emission inventories are collected via separate procedures than the inventory of direct greenhouse gases, and the methods to produce these inventories can differ from those for greenhouse gases. Also, while the greenhouse gas emissions and sinks inventories are often based on national statistics, air pollutant emission inventories are often developed using plant specific data. Countries should consider whether there is any scope for improving consistency between inventories or cross-checking estimates.

Detailed methodologies for estimating the emissions of precursors are provided in the EMEP/CORINAIR Emission Inventory Guidebook (http://reports.eea.eu.int/EMEPCORINAIR4/en). This guidebook has been developed for emission inventories of substances regulated under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) (see Box 7.1) and covers all source sectors and should therefore be considered as primary source of information for estimation of these emissions.

Table 7.1 provides a linkage between the IPCC categories and the corresponding methodology chapters in the EMEP/CORINAIR Guidebook. This table provides information on the specific EMEP/CORINAIR chapters that list methodologies for preparing NO_x, CO, NMVOCs, NH_3 and SO_2[2] inventories. It also includes information on the availability of methods and the significant precursor emissions from particular categories.

Some of the methodologies and emission factors in the EMEP/CORINAIR Guidebook are technology-specific and are relevant to conditions and categories in both developed and developing countries. However, for some

[1] Cooperative programme for the monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP).

[2] The EMEP/CORINAIR Nomenclature for Reporting (NFR) source categories have been developed to be compatible to the IPCC reporting categories.

sectors, like solvents, small combustion sources (biomass in particular) and open burning, differences between the developed and developing countries may be larger, and the EMEP/CORINAIR Guidebook should be used with great care.

BOX 7.1
CLRTAP AND EMISSION INVENTORY GUIDEBOOK

The Convention on Long-Range Transboundary Air Pollution has been in force since 1979 and includes eight protocols with requirements to reduce emissions and technical annexes on abatement techniques. More detailed information on the Convention is available at http://www.unece.org/env/lrtap/welcome.html. As emissions of oxides of nitrogen (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO_2) are reported both to the UNFCCC and UNECE CLRTAP it is important to ensure consistent methodologies and reporting between these two Conventions. (UNECE, 2003)

The EMEP/CORINAIR Guidebook has been prepared by the LRTAP Task Force on Emission Inventories and Projections (TFEIP) and is updated regularly by the Expert Panels under the TFEIP (http://tfeip-secretariat.org/unece.htm) to provide comprehensive information and methodologies for estimating emissions. The EMEP/CORINAIR Emission Inventory Guidebook is published by the European Environment Agency (EEA).

7.2.1 Inventory of precursors

An inventory of precursors typically includes oxides of nitrogen, carbon monoxide, non-methane volatile organic compounds, and emissions of sulphur compounds. When estimating emissions of these air pollutants, the use of detailed process or facility-specific data (bottom-up data) gives more accurate estimates than the use of general aggregated emission factors. For all pollutants and source categories it is critical to apply methodologies and emission factors that account for the presence of any emission controls or abatement measures. For large point sources many countries have a registry of individual air quality pollutant emissions reported by the plants. When using data reported by the plants it is good practice to ensure that emissions are not double counted with the top-down inventory data. Data reported by the plants can also be used to check completeness of the inventory.

7.2.1.1 ENERGY

For most countries, road transportation will be a major source of NO_x, CO, and NMVOC emissions. Public electricity and heat production will likely be the major source of SO_2 emissions in countries where coal is used extensively, and also an important source of NO_x emissions. Industrial combustion will also be a source of SO_2, NO_x and CO emissions and residential combustion a source of CO emissions. Oil production will likely be a source of NMVOC, NO_x, and, CO emissions in countries that produce oil and gas.

Most NO_x emissions resulting from fuel combustion are typically ‘fuel-NO’ that is formed from the conversion of chemically bound nitrogen in the fuel. The content of nitrogen in different fuel varies. Depending on the combustion temperature, thermal-NO_x can also be formed from nitrogen contained in the combustion intake air.

Carbon monoxide and NMVOCs are generated during under-stoichiometric combustion conditions and are dependent on a variety of factors, including fuel type and combustion conditions.

Emissions of sulphur oxides (SO_x) are primarily related to the sulphur content of the fuel, although some sulphur can be retained in the ash. Abatement in stationary combustion can reduce the amount emitted.

7.2.1.2 INDUSTRIAL PROCESSES AND PRODUCT USE

Industrial processes can generate NO_x, CO, NMVOC and SO_2 emissions. Emissions of these gases depend on the type of process, abatement techniques, and other conditions. Industrial process and product use emissions include both channelled emissions (e.g., point sources emissions from a stack) and diffuse emission sources. For example, diffuse emissions from the evaporation of solvents and storage and handling of products are typical primary sources of NMVOC emissions. In some cases, exceptional emissions (e.g., accidental releases) can constitute major emissions from source. Further guidance on estimating total emissions from an industrial site are provided in the EU IPPC (European Union Integrated Pollution Prevention and Control) Reference Document on Monitoring of

Emissions (EC, 2002) [3].

7.2.1.3 AGRICULTURE, FORESTRY AND OTHER LAND USE

The burning of crop residues emits NO_x as does the addition of nitrogen to the soils from nitrogen fertilizers and other nutrients. CO and SO_2 are emitted when biomass is burned. The primary sources of the NMVOC emissions are burning of crop residues and other plant wastes, and the anaerobic degradation of livestock feed and animal excreta. Plants, mainly trees and cereals, also contribute to NMVOC concentrations in the atmosphere.

The EMEP/CORINAIR Guidebook does not fully cover emissions from burning of biomass, therefore additional guidance is given in AFOLU Volume, Chapter 4.2.4 for Non-CO_2 emissions from biomass burning from *forest*, Chapter 5.2.4 and 5.3.4 for Non-CO_2 emissions from biomass burning in *Cropland*, and Chapter 6.2.4 and 6.3.4 for Non-CO_2 emissions from biomass burning in *Grassland* (CO, CH_4, N_2O, NO_x). Biomass burning when forest and grasslands are converted to other uses, forest fires, and biomass burning due to forest management practices are discussed in these chapters of Volume 4 for AFOLU sector.

7.2.1.4 WASTE

Emissions of NO_x, CO, and SO_2 are produced by domestic and municipal waste incineration processes as well as the incineration of sledges from wastewater treatment. NMVOC emissions can originate from wastewater treatment plants and solid waste disposal on land.

7.2.1.5 CARBON EMITTTED IN GASES OTHER THAN CO_2

The *2006 Guidelines* estimate carbon emissions in terms of the species which are emitted. Most of the carbon emitted in the form of non-CO_2 species eventually oxidises to CO_2 in the atmosphere and this amount can be estimated from the emissions estimates of the non-CO_2 gases. Box 7.2 provides an approach for making this calculation.

In some cases the emissions of these non-CO_2 gases contain very small amounts of carbon compared to the CO_2 estimate and it may be more accurate to base the CO_2 estimate on the total carbon. Examples are fossil fuel combustion (where the emission factor is derived from the carbon content of the fuel) and a few IPPU categories where the carbon mass balance can be estimated much better than individual gases.

BOX 7.2

CALCULATING CO_2 INPUTS TO THE ATMOSPHERE FROM EMISSIONS OF CARBON-CONTAINING COMPOUNDS

Methane, carbon monoxide (CO) or NMVOC emissions will eventually be oxidised to CO_2 in the atmosphere. These CO_2 inputs could be included in national inventories. They can be calculated from emissions of methane, CO and NMVOCs. The basic calculation principles are:

From CH_4: $\text{Inputs}_{CO2} = \text{Emissions}_{CH4} \bullet 44/16$

From CO: $\text{Inputs}_{CO2} = \text{Emissions}_{CO} \bullet 44/28$

From NMVOC: $\text{Inputs}_{CO2} = \text{Emissions}_{NMVOC} \bullet C \bullet 44/12$

Where C is the fraction carbon in NMVOC by mass (default = 0.6)

The carbon content in NMVOCs will vary depending on the source. Therefore, an inventory based on the speciation of the NMVOC compounds gives more accurate results.

In making these estimates inventory compilers should assess each category to ensure that this carbon is not already covered by the assumptions and approximations made in estimating CO_2 emissions. Relevant examples include carbon from;

- Fugitive emissions from energy use,
- Carbon from Non-CO_2 gases from IPPU,
- AFOLU emissions where non-CO_2 gases have been explicitly deducted.

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[3] Chapter 3.1 in EU IPPC Reference Document on Monitoring of Emissions, which is available from website http://eippcb.jrc.es/pages/ FActivities.htm.

7.2.2 Link to relevant methodology chapters in the EMEP/CORINAIR Emission Inventory Guidebook

Table 7.1 provides specific information on methodologies for preparing national emission inventories of NO_x, CO, NMVOCs, and SO_2. The table includes information on the availability of methodologies in the EMEP/CORINAIR Emission Inventory Guidebook and the expected significance of the emissions for each IPCC category under the *2006 Guidelines* (see Table 8.2 of Chapter 8 of this Volume) and gas. The Guidebook's codes are equivalents in function to the IPCC reporting categories under the *1996 Guidelines*. A mapping between the EMEP/CORINAIR Nomenclature for Reporting (NFR) and the IPCC common reporting framework (CRF) of the *1996 Guidelines* with categories under the *2006 Guidelines* is also provided in the table.

In case the inventory compiler does not find a corresponding category to a specific IPCC 2006 category in Table 7.1, it is advisable to attempt to find a similar category (e.g., a corresponding boiler size for another industrial branch) in Table 7.1 and apply the corresponding methodology in the EMEP/CORINAIR Emission Inventory Guidebook for this category or to search for other sources of information (see also Chapter 2 of this Volume).

The following codes are used to indicate whether the emissions from the specific source are relevant and covered by the Guidebook:

A = Emissions of this gas from this category are likely to be emitted and a methodology is provided in the EMEP/CORINAIR Guidebook.

NI = Emissions of this gas from this category are likely to be emitted, but a methodology is not currently included in the EMEP/CORINAIR Guidebook.

B = Emissions of this air pollutant from this category are likely to be emitted and the methodology may be included in the EMEP/CORINAIR Guidebook in the future.

NS = Emissions of this gas from this category not expected to be significant.

NO = Emissions of this gas from this category do not occur.

TABLE 7.1
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category				Source Sector	EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
IPCC category		CRF	NFR			Relevance of emissions from the category (see codes above the table)			
1 ENERGY									
1A1 Energy Industries	1A1a	1A1a	1A1a	Main Activity Electricity and Heat Production	B111 and B112	A	A	A	A
	1A1b	1A1b	1A1b	Petroleum Refining	B132 and B136	A	A	A	A
	1A1c	1A1c	1A1c	Manufacture of Solid Fuels and Other Energy Industries	B142, B146 and B152	A	A	A	A
1A2 Manufacturing Industries and Construction	1A2a	1A2a	1A2a	Iron and Steel	B111, B112, B323, B324, B325, B331, B332, B333	A	A	A	A
	1A2b	1A2b	1A2b	Non-ferrous Metals	B336, B337, B338, B339, B3310, B3322, B3323	A	A	A	A
	1A2c	1A2c	1A2c	Chemicals	B111 and B112	A	A	A	A
	1A2d	1A2d	1A2d	Pulp, Paper and Print	B3321	A	A	A	A
	1A2e	1A2e	1A2e	Food Processing, Beverages and Tobacco	B111 and B112	A	A	A	A
	1A2f	1A2f	1A2f	Non-Metallic Minerals	B3311, B3312, B3313, B3314, B3318, B3319, B3320, B3323	A	A	A	A
	1A2g			Transport Equipment	B111 and B112	A	A	A	A
	1A2h			Machinery	B111 and B112	A	A	A	A
	1A2i			Mining and Quarrying	B111 and B112	A	A	A	A
	1A2j			Wood and Wood Products	B111 and B112	A	A	A	A
	1A2k			Construction	B111 and B112	A	A	A	A
	1A2l			Textile and Leather	B111 and B112	A	A	A	A
	1A2m			Non-specified Industry	B111 and B112	A	A	A	A

TABLE 7.1 (CONTINUED)
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category				Source Sector	EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
IPCC category		CRF	NFR			Relevance of emissions from the category (see codes above the table)			
1A3 Transport	**1A3a**	**1A3a**		**Civil Aviation**					
	1A3ai International Aviation	1A3ai (i)	1A3ai (i)	International Aviation (LTO)	B851	A	A	A	A
	1A3aii Domestic Aviation	1A3ai(ii)	1A3ai(ii)	International Aviation (Cruise)	B851	A	A	A	A
		1A3aii(i)	1A3aii(i)	Civil Aviation (Domestic, LTO)	B851	A	A	A	A
		1A3aii(ii)	1A3aii(ii)	Civil Aviation (Domestic, Cruise)	B851	A	A	A	A
	1A3b	**1A3b**	**1A3b**	**Road Transportation**					
	1A3bi	1A3bi	1A3bi	R.T., Passenger cars	B710	A	A	A	A
	1A3bii	1A3bii	1A3bii	R.T., Light-duty vehicles	B710	A	A	A	A
	1A3biii	1A3biii	1A3biii	R.T., Heavy duty vehicles	B710	A	A	A	A
	1A3biv	1A3biv	1A3biv	R.T., Mopeds & Motorcycles	B710	A	A	A	A
	1A3bv	1A3bv	1A3bv	R.T., Evaporative Emissions	B760	NO	NO	A	NO
	1A3c	**1A3c**	**1A3c**	**Railways**	B810	A	A	A	A
	1A3d	**1A3d**	**1A3d**	**Water-borne Navigation**					
	1A3di	1A3di	1A3di	International Water-borne Navigation (International bunkers)/International maritime navigation	B842	A	A	A	A
	1A3dii	1A3dii	1A3dii	Domestic Water-borne Navigation//National Navigation	B810 and B842	A	A	A	A
	1A3e	**1A3e**	**1A3e**	**Other Transportation**					
	1A3ei	1A3ei	1A3ei	Pipeline Transport/Compressors	B561 and B152	B	B	A	B
	1A3eii	1A3eii	1A3eii	Off-road/Other mobile sources and machinery	B810	A	A	A	A
1A4 Other Sectors	**1A4a**	**1A4a**	**1A4a**	**Commercial/Institutional**	B111, B112, B216 and Small Combustion Installations *)	A	A	A	A
	1A4b	**1A4b**	**1A4b**	**Residential**					
	1A4b	1A4bi	1A4bi	Residential plants	B111, B112 and Small Combustion Installations *)	A	A	A	A
	1A4b	1A4bii	1A4bii	Household and gardening (mobile)	B111, B112 and Small Combustion Installations *)	A	A	A	A
	1A4c	**1A4c**	**1A4c**	**Agriculture/Forestry/Fishing/Fish farms**					
	1A4ci	1A4ci	1A4ci	Stationary	B111, B112 and B235	A	A	A	A
	1A4cii	1A4cii	1A4cii	Off-road Vehicles and Other Machinery	B111, B112, B235 and B810	A	A	A	A
	1A4ciii	1A4ciii	1A4ciii	National Fishing (mobile combustion)	B111, B112, B235 and B842	A	A	A	A
1A5 Non-Specified	**1A5a**	**1A5a**	**1A5a**	**Other, Stationary (including military)**	B111, B112, B216 and Small Combustion Installations *)	A	A	A	A
	1A5b	**1A5b**	**1A5b**	**Other, Mobile (including military)**	B810	A	A	A	A
1B Fugitive Emissions from Fuels	**1B1**	**1B1**	**1B1**	**Solid Fuel**					
	1B1a	1B1a	1B1a	Coal Mining and Handling, including Post-mining activities/Solid Fuel Transformation	B511	NO/A	NO	A	NO
	1B1b	1B1c	1B1c	Uncontrolled Combustion and Burning Coal Dumps /Other		NI	NI	NI	NI
	1B1c	1B1b	1B1b	Solid Fuel Transformation	B142 and B424	NI	NI	A	NI
	1B2	**1B2**	**1B2**	**Oil and Natural Gas**					
	1B2a	1B2a	1B2a	Oil					
	1B2ai	1B2c	1B2c	Venting	B521, B923 and B926	NI	NI	NI	NI
	1B2aii	1B2d	1B2d	Flaring	B521, B923 and B926	NI	NI	NI	NI

TABLE 7.1 (CONTINUED)
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category				Source Sector	EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
IPCC category		CRF	NFR			Relevance of emissions from the category (see codes above the table)			
1B Fugitive Emissions from Fuels	1B2aiii1	1B2ai	1B2ai	Exploration	B521 and B541	A	A	A	A
	1B2aiii2	1B2aii	1B2aii	Production and Upgrading	B521 and B541	A	A	A	A
	1B2aiii3	1B2aiii	1B2aiii	Transport	B521 and B541	A	A	A	A
	1B2aiii4	1B2aiv	1B2aiv	Refining	B521 and B541	A	A	A	A
	1B2aiii5	1B2av	1B2av	Distribution of Oil Products	B551	NO	NO	A/B	NO
	1B2aiii6	1B2avi	1B2avi	Other	B521 and B541	NO	NO	NO	NO
	1B2b	1B2b	1B2b	Natural Gas	B521 and B561	NO	NO	A	NO
	1B2bi	1B2c	1B2c	Venting	B521, B923 and B926	NI	NI	NI	NI
	1B2bii	1B2d	1B2d	Flaring	B521, B923 and B926	NI	NI	NI	NI
	1B2biii	1B2e	1B2e	Other	B521 and B561	NO	NO	NO	NO
	1B3	**1B3**	**1B3**	**Other Emissions from Energy Production**	B570	NI	NI	NI	NI
1C CO_2 Transport, and Storage	1C			**Emissions from CO_2 transport injection and storage**					
2 INDUSTRIAL PROCESSES AND PRODUCT USE									
2A Mineral Industry	2A1	2A1	2A1	Cement (decarbonizing)	B3311	(A = fuel rated)	(A = fuel rated)	(A = fuel rated)	(A = fuel rated, process rated depends on the process)
	2A2	2A2	2A2	Lime (decarbonizing)	B3312 (fuel rated and diffuse) and B461	(A = fuel rated)	(A = fuel rated)	(A = fuel rated)	(A = fuel rated)
	2A4	2A3	2A3	Other uses of carbonites/Limestone and Dolomite Use	B4618	B	B	B	B
	2A4b	2A4	2A4	Other uses of Soda Ash/Soda Ash Production and use	B4619	B	B	B	B
	2A3	2A7	2A7	**Other including Non Fuel Mining & Construction**: Glass (decarbonizing)	B3314	(A) depending on the process	(NS) depending on the process	(NS) depending on the process	(A) depending on the process
	2A5 Other	2A7	2A7	Batteries Manufacturing	B461	NS/B	NS /B	NS/B	NS/B
		2A7	2A7	Extraction of Mineral Ores	B461	NS/B	NS/B	NS/B	NS/B
		2A7	2A7	Other (including asbestos products manufacturing)	B461	NS	NS	NS	NS
2 B CHEMICAL INDUSTRY	2B1	2B1	2B1	Ammonia Production	B443	NS/B	NS/B	NS/B	NS/B
	2B2	2B2	2B2	Nitric Acid Production	B442	A	NS	NS	NO
	2B3	2B3	2B3	Adipic Acid Production	B4521	NS/B	NO	NO	NO
	2B5	2B4	2B4	Carbide Production/Calcium Carbide Production	B443	NS/B	NS/B	NS/B	NS/B
	2B4	2B5	2B5	Caprolactam Production	-	NS/B	NS/B	NS/B	NS/B
	2B4	2B5	2B5	Glyoxylic Acid Production	B453	NS	NS	B	NS
	2B6	2B5	2B5	Titanium Dioxide Production	B443	NS/B	NS/B	NS/B	NS/B
	2B7	2A4	2A4	Soda Ash Production	B4619	B	B	B	B
	2B8	Petrochemical and Carbon Black Production							
	2B8a	2B5	2B5	Methanol Production		NS	NS	A	NS

TABLE 7.1 (CONTINUED)
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category: IPCC category		CRF	NFR	Source Sector	EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
						Relevance of emissions from the category (see codes above the table)			
	2B8b	2B5	2B5	Ethylene Production	B451	NS	NS	A	NS
	2B8c	2B5	2B5	Vinylchloride (except 1,2 dichloroethane+vinylchloride) Production	B454	NO	NS	NS	NO
	2B8d	2B5	2B5	Ethylene Oxide Production	B453	NS	NS	NS	NS
	2B8e	2B5	2B5	Acrylonitrile Producton	B4520	NO	NO	A	NO
	2B8f	2B5	2B5	Carbon Black Producton	B443	NS	NS	NS	NS
	2B9			Fluorochemical Production					
	2B10 Other	2B5	2B5	Sulphuric Acid Production	B441	NS	NS	NS	A
		2B5	2B5	Ammonium Sulphate Manufacturing	B443	NS	NS	NS	NS
		2B5	2B5	Ammonium Nitrate Production	B443	NS	NS	NS	NS
		2B5	2B5	Ammonium Phosphate Production	B443	NS	NS	NS	NS
		2B5	2B5	NPK fertilizers	B443	NS	NS	NS	NS
		2B5	2B5	Urea	B443	NS	NS	NS	NS
		2B5	2B5	Graphite	B443	NS	NS	NS	NS
		2B5	2B5	Chlorine Production	B443	NS	NS	NS	NS
		2B5	2B5	Phosphate Fertilisers Production	B443	NS	NS	NS	NS
		2B5	2B5	Storage and Handling of Inorganic Chemical Products	B443	NS	NS	B	NS
		2B5	2B5	Other	B443	NS	NS	NS	NS
		2B5	2B5	Propylene Production	B452	NO	NO	A	NO
		2B5	2B5	1,2 dichoroethane (except 1,2 dichloroethane+vinylchloride) Production	B453	NS	NS	NS	NS
		2B5	2B5	1,2 dichloroethane + vinylchloride (balanced process)	B455	NO	NO	A	NO
		2B5	2B5	Polyethylene (low density) Production	B456	NO	NO	A	NO
		2B5	2B5	Polyethylene (high density) Production	B456	NO	NO	A	NO
		2B5	2B5	Polyvinylchloride Production	B458	NO	NO	A	NO
		2B5	2B5	Polypropylene Production	B459	NO	NO	A	NO
		2B5	2B5	Styrene Production	B4510	NO	NO	A	NO
		2B5	2B5	Polystyrene Production	B4511	NO	NO	A	NO
		2B5	2B5	Styrene Butadiene Production	B4512	NO	NO	A	NO
		2B5	2B5	Styrene-butadiene Latex Production	B4512	NO	NO	A	NO
		2B5	2B5	Styrene-butadiene Rubber (SBR) Production	B4512	NO	NO	A	NO
		2B5	2B5	Acrylonitrile Butadiene Styrene (ABS) Resins Production	B4512	NO	NO	A	NO
		2B5	2B5	Formaldehyde Production	B453	NS	NS	NS	NS
		2B5	2B5	Ethylbenzene Production	B4518	NO	NO	NS	NO
		2B5	2B5	Phtalic Anhydride Production	B4519	NO	NS	A	NS
		2B5	2B5	Storage & Handling of Organic Chemical Products	B453	NS	NS	B	NS
		2B5	2B5	Halogenated Hydrocarbons Production	B453	NS	NS	B	NS
		2B5	2B5	Pesticide Production	B453	NS	NS	B	NS
		2B5	2B5	Production of Persistent Organic Compounds	B453	NS	NS	B	NS
		2B5	2B5	Other (phytosanitary)	B453	NS	NS	B	NS

TABLE 7.1 (CONTINUED)
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category				Source Sector	EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
	IPCC category	CRF	NFR			Relevance of emissions from the category (see codes above the table)			
2 C METAL INDUSTRY	2C1 Processes in Iron and Steel Industries and Colliers			Blast Furnace Charging	B422	NS	A	NS	NS
				Pig Iron Tapping	B423	NS	NS	NO	NS
				Open Hearth Furnace Steel Plant	B425	A	NS	NS	NS
				Basic Oxygen Furnace Steel Plant	B426	NS	A	NS	A
				Electric Furnace Steel Plant	B427	A	A	NS	NS
				Rolling Mills	B428	NS	NS	NS	NS
				Sinter and Pelletizing Plants (except combustion)	B331	A	A	A	A
				Other	B4210	NS	NS	NS	NS
	2C2	2C2	2C2	Ferroalloys Production	NS	NS	NS	NS	NS
	2C3	2C3	2C3	Aluminium Production (electrolysis)	B431	NS	A	NS	A
	2C6	2C5	2C5	Zinc Production		NO	NO	NO	NI
	2C5	2C5	2C5	Lead Production		NO	NO	NO	NI
	2C4	2C5	2C5	Magnesium Production (except combustion)	B432	NS	NS	NS	NS
	2C7 Other	2C5	2C5	Silicium Production	B432	NS	NS	NS	NS
		2C5	2C5	Nickel Production (except combustion)	B432	NS	NS	NS	NS
		2C5	2C5	Allied Metal Manufacturing	B432	NS	NS	NS	NS
		2C5	2C5	Galvanising	B432	NS	NS	NS	NS
		2C5	2C5	Electroplating	B432	NS	NS	NS	NS
		2C5	2C5	Other	B432	NS	NS	NS	NS
2D NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE	2D1	3D	3D	Lubricant Use		NO	NO	NI	NO
	2D2	3D	3D	Paraffin Waxes Use		NO	NO	NI	NO
	2D4	2A5	2A5	Asphalt Roofing	B4610	NS	A	A	NS
		2A6	2A6	Road Paving with Asphalt	B4611	A	A	A	A
	2D3	See **"SOLVENT USE"** below		Solvent Use					
2D3 SOLVENT USE		CRF/NFR 3A PAINT APPLICATION							
		3A	3A	Manufacture of Automobiles	B610	NO	NS	A/B	NO
		3A	3A	Car Repairing	B610	NO	NO	A/B	NO
		3A	3A	Construction and Buildings (except wood painting)	B610	NO	NO	A/B	NO
		3A	3A	Domestic Use (except wood painting)	B610	NO	NO	A/B	NO
		3A	3A	Coil Coating	B610	NO	NO	A/B	NO
		3A	3A	Boat Building	B610	NO	NO	A/B	NO
		3A	3A	Wood Painting/Coating	B610	NO	NO	A/B	NO
		3A	3A	Other Industrial Paint Application	B610	NO	NO	A/B	NO
		3A	3A	Other Non-industrial Paint Application	B610	NO	NO	A/B	NO
		CRF/NFR 3B DEGREASING AND DRY CLEANING							
		3B	3B	Metal Degreasing	B621	NS	NS	A	NS
		3B	3B	Dry Cleaning	B622	NO	NO	A	NO
		3B	3B	Electronic Components Manufacturing	B623	NS	NS	NS	NS
		3B	3B	Other Industrial Cleaning	B623	NS	NS	NS	NS

TABLE 7.1 (CONTINUED)
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category				Source Sector	EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
IPCC category		CRF	NFR			Relevance of emissions from the category (see codes above the table)			
	CRF/NFR 3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING								
2D4 OTHER		3C	3C	Polyester Processing	B631	NS	NS	A/B	NS
		3C	3C	Polyvinylchloride Processing	B631	NS	NS	A/B	NS
		3C	3C	Polyurethane Foam Processing	B633	NS	NS	A	NS
		3C	3C	Polystyrene Foam Processing	B633	NS	NS	A	NS
		3C	3C	Rubber Processing	B631	NS	NS	A/B	NS
		3C	3C	Pharmaceutical Products Manufacturing	B631	NS	NS	A/B	NS
		3C	3C	Paints Manufacturing	B631	NS	NS	A/B	NS
		3C	3C	Inks Manufacturing	B631	NS	NS	A/B	NS
		3C	3C	Glues Manufacturing	B631	NS	NS	A/B	NS
		3C	3C	Asphalt Blowing	B6310	NS	A	A	NS
		3C	3C	Adhesive, Magnetic Tapes, Films & Photographs Manufacturing	B631	NS	NS	A/B	NS
		3C	3C	Textile Finishing	B631	NS	NS	A/B	NS
		3C	3C	Leather Tanning	B631	NS	NS	A/B	NS
		3C	3C	Other	B631	NS	NS	A/B	NS
	CRF/NFR 3 D OTHER including products containing HMs and POPs								
2D4 OTHER		3D	3D	Glass Wool Enduction	B641	NS	NS	B	NS
		3D	3D	Mineral Wool Enduction	B641	NS	NS	B	NS
		3D	3D	Printing Industry	B643	NO	NO	A/B	NO
		3D	3D	Fat, Edible and Not Edible Oil Extraction	B644	NS	NS	A	NS
		3D	3D	Application of Glues and Adhesives	B641	NS	NS	B	NS
		3D	3D	Preservation of Wood	B646	NO	NO	A	NO
		3D	3D	Underseal Treatment and Conservation of Vehicles	B647	NO	NO	IE 3A (car manufacturing & repairing)	NO
		3D	3D	Domestic Solvent Use (other than paint application)	B648	NO	NO	A/B	NO
		3D	3D	Vehicles Dewaxing	B647	NO	NO	A	NO
		3D	3D	Domestic Use of Pharmaceutical Products	B641	NS	NS	B	NS
		3D	3D	Other (preservation of seeds, etc.)	B641	NS	NS	B	NS
		3D	3D	Other (anaesthesia, refrigeration and air conditioning, electrical equipment, etc.)	B651	NS	NS	B	NS
2 E ELECTRONICS INDUSTRY		2F							
2 F PRODUCT USES AS SUBSTITUTES FOR OZONE DEPLETING SUBSTANCES		2F							
2G OTHER PRODUCT USES		**2F, 3D**	**3D**	**See for relevant subcategories under NFR 3D**	-	NS	NS	NS	NS

TABLE 7.1 (CONTINUED)
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category: IPCC category		CRF	NFR	Source Sector		EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
							Relevance of emissions from the category (see codes above the table)			
2 H OTHER	2H1	2D1	2D1	Pulp and Paper						
		2D1	2D1	Processes in wood, paper pulp, food, drink and other industries	Pulp and Paper - Chipboard	B461	NS	NS	NS	NS
		2D1	2D1		Pulp and Paper - Paper pulp (kraft process)	B462	A	NS	A	A
		2D1	2D1		Pulp and Paper - Paper pulp (acid sulphite process)	B463	A	NO	A	A
		2D1	2D1		Pulp and Paper - Paper pulp (neutral sulphite semi-chemical process.)	B464	A	NO	A	A
	2H2	2D2	2D2	Food and Drink						
		2D2	2D2	Processes in wood, paper pulp, food, drink and other industries	Food and Drink - Bread	B465	NS	NS	A	NS
		2D2	2D2		Food and Drink - Wine	B466	NS	NS	A	NS
		2D2	2D2		Food and Drink - Beer	B466	NS	NS	A	NS
		2D2	2D2		Food and Drink - Spirits	B466	NS	NS	A	NS
	2H3				Other					
		3D	3D	Mineral Wool Enduction		B641	NS	NS	B	NS
		3D	3D	Printing Industry		B643	NO	NO	A/B	NO
		3D	3D	Fat, Edible and Not Edible Oil Extraction		B644	NS	NS	A	NS
		3D	3D	Application of Glues and Adhesives		B641	NS	NS	B	NS
		3D	3D	Preservation of Wood		B646	NO	NO	A	NO
		3D	3D	Underseal Treatment and Conservation of Vehicles		B647	NO	NO	IE 3A (car manufacturing & repairing)	NO
		3D	3D	Domestic Solvent Use (other than paint application)		B648	NO	NO	A/B	NO
		3D	3D	Vehicles Dewaxing		B647	NO	NO	A	NO
		3D	3D	Domestic Use of Pharmaceutical Products		B641	NS	NS	B	NS
		3D	3D	Other (preservation of seeds,....)		B641	NS	NS	B	NS
		3D	3D	Other (anaesthesia, refrigeration and air conditioning, electrical equipment, etc.)		B651	NS	NS	B	NS
3 AGRICULTURE, FORESTRY, AND OTHER LAND USE (AFOLU)										
3A Livestock	3A1	4A	4A	Enteric Fermentation		B1040	NO	NO	NO	NO
	3A2	4 B	4B	Manure Management		B1050, B100511, N1090	NO	NO	B	NO
3B Land	3B1 Forest Land	5A	5A	Changes in Forest and Other Woody Biomass Stocks		B112100	B	B	A	B
		5B	5B	Forest and Grassland Conversion (tropical, temperate, boreal forests, grassland, other)		B112200	A	B	NS	B
		5C	5C	Abandonment of Managed Land (tropical, temperate, boreal forests, grassland, other)		B112300	A	B	NS	B
		5E	5E	Managed Forests (broadleaf and coniferous)		B1101, B110117	NI	NI	A	NI
				Non-managed Forests (broadleaf and coniferous)		B1101, B110117	NI	NI	A	NI
				Other		B112500	NS	NS	NS	NS
	3B2 Crop-land						NS	NS	NS	NS

TABLE 7.1 (CONTINUED)
LINK BETWEEN THE IPCC CATEGORIES AND THE CORRESPONDING METHODOLOGY CHAPTERS IN EMEP/CORINAIR GUIDEBOOK [1]

Reporting category				Source Sector	EMEP/CORINAIR Inventory Guidebook Chapter	NO_x	CO	NM-VOC	SO_x
IPCC category		CRF	NFR			Relevance of emissions from the category (see codes above the table)			
3B Land	3B3 Grass-land	4D	4D	Natural Grassland and Other Vegetation (grassland, tundra, other low vegetation, other vegetation (Mediterranean, scrub…)), Soils	B1104 B110117	A	NI	A	NI
	3B4 Wetland	4D	4D	Wetlands (marshes - swamps)	B1105	NI	NI	NI	A
	3B5 Settlem ents	4G	4G	Other	B1060	NO	NO	NO	NO
3B6 Other land									
3C AGGREGATED SOURCES AND NON-CO_2 EMISSION SOURCES ON LAND	3C1a	5B	5B	Forest and vegetation fires (man-induced, other)	B1103	A	A	A	A
	3C1b	4F	4F	Field burning of agricultural wastes	B1030	A	A	A	A
	3C1c	4D	4D	Prescribed burning of savannas		B	B	B	B
	3C4	4D	4D1	Agricultural soils, direct soil emissions	B1010, B1020 and B1105	A	NO	A	NO
	3C7	4C	4C	Rice Cultivation	B1010, B1020	A	NO	A	NO
3D OTHER	3D1	NA	NA	Harvested Wood Products		NO	NO	B	NO
	3D2	NA	NA	Volcanoes	B1108	NO	NO	NO	A
		NA	NA	Gas Seeps	B110900	NO	NO	NO	NO
		NA	NA	Lightning	B111000	A	NO	NO	NO
		NA	NA	Wildlife animals	B1107	NO	NO	NS	NO
		4D	4D	Waters	B1106	NO	NO	B	B
4 WASTE									
4D WASTE	4A and 4B	6A	6A	Solid Waste Treatment and Disposal and Biological treatment of solid waste	B940	NO	NO	A/B	NO
	4C	6C	6C	Incineration and Open Burning of Waste/Waste Incineration	B921, B922, B924, B925, B927, B970, B991, B992	A	A	NI/B	A
	4D	6B	6B	Wastewater Treatment and Discharge/Wastewater Handling	B9101 and B9107	NO	NO	A	NO
	4E	6D	6D	Other waste	B9101, B9203, B9105, B9106	A	A	A	NO
5 OTHER	5A Indirect N_2O emissions								
	5B Other	**7**	**7**	**Geothermal energy extraction**	**B570**	**NO**	**NO**	**NI**	**NO/B**

*) Chapter Small Combustion Installations is available from website http://tfeip-secretariat.org/unece.htm > Expert Panels > Expert Panel on Combustion and Industry

[1] Current references are to the version of the EMEP/CORINAIR Guidebook available when these guidelines are published.

7.3 INDIRECT N_2O EMISSIONS FROM THE ATMOSPHERIC DEPOSITION OF NITROGEN IN NO_X AND NH_3

In this Guidance, direct nitrous oxide emissions are estimated on the basis of human-induced net nitrogen input to managed soils (e.g., synthetic or organic fertilizers, deposited manure, crop residues, sewage sludge), or of other changes in inorganic nitrogen in the soil as a result of interventions by management practices in nitrogen cycling, e.g., mineralization of nitrogen in soil organic matter, following drainage/management of organic soils, or cultivation/land use change on mineral soils.

In addition to these direct emissions of N_2O, indirect emissions also take place as a result of two different nitrogen loss pathways. These pathways are (1) the volatilization/emission of nitrogen as NH_3 and NO_x and the subsequent deposition of these forms of nitrogen as ammonium (NH_4^+) and oxidised nitrogen (NO_x) on soils and waters, and (2) the leaching and runoff of nitrogen from synthetic and organic nitrogen fertilizer inputs, crop residues, mineralization of nitrogen through land use change or management practices, and urine and dung deposition from grazing animals, into groundwater, riparian areas and wetlands, rivers and eventually the coastal ocean.

The volatilization of nitrogen as NH_3 and NO_x results both from agricultural fertilizer applied to land and from manure management, as well as from fossil fuel and biomass combustion, and industrial processes. Before being redeposited, NO_x and NH_3 are typically transformed to other nitrogen containing compounds. Oxides of nitrogen are commonly hydrolysed in the atmosphere or upon deposition to form nitric acid (HNO_3), while NH_3 gas generally combines with atmospheric nitric acid or sulphuric acid (H_2SO_4) to form ammonium nitrate and ammonium sulphate aerosols, which are then transformed to a particulate ammonium (NH_4^+) form. The deposition of these reactive nitrogen compounds from non-agricultural sources onto soils and waters causes N_2O emissions in an exactly analogous way to those resulting from their deposition from agricultural sources. Therefore the indirect N_2O emissions resulting from these various sources are included in these Guidelines using the assumption that same emission factor applies to soil and water deposition.

7.3.1 Methodology

All anthropogenic NH_3 or NO_x emissions are potential sources of N_2O emissions[4]. Specific guidance on estimating N_2O emissions from that portion of nitrogen compounds associated with the volatilisation of NO_x and NH_3 from (1) manure management systems and applied sewage sludge and (2) synthetic and organic nitrogen input to managed soils, and urine and dung nitrogen deposited by grazing animals, are provided in Section 10.5 of Chapter 10, Emissions from livestock and manure management, and Section 11.2.2 of Chapter 11, N_2O and CO_2 emissions from soil amendment, of Volume 4 of AFOLU.

This section provides guidance on estimating N_2O emissions from the atmospheric deposition of nitrogen compounds from all other sources of NO_x and NH_3 emissions, such as fuel combustion, industrial processes, and burning of crop residues and agricultural wastes. The method needs only to be applied where data on NO_x and NH_3 emissions from these sources are available, e.g., from the inventories identified Section 7.2.

Equation 7.1 and EF_4 from Equation 11.9 in Section 11.2.2.1 of Volume 4 can be used to estimate N_2O emissions from the atmospheric deposition of nitrogen resulting from NO_x and NH_3.

EQUATION 7.1
N_2O EMISSIONS FROM ATMOSPHERIC DEPOSITION OF NO_X AND NH_3

$$N_2O_{(i)} = \left[\left(NO_x\text{-}N_{(i)}\right) + \left(NH_3\text{-}N_{(i)}\right)\right] \bullet EF_4 \bullet 44/28$$

[4] In addition to being redeposited on soils and surface waters, NH_3 can also lead to the formation of N_2O from atmospheric chemical reactions. However, there is currently no method available for estimating conversion of NH_3 to N_2O in the atmosphere.

Where:

$N_2O_{(i)}$ = N_2O produced from atmospheric deposition of N from NO_x and NH_3 emissions from source *i*, in Gg

NO_x-$N_{(i)}$ = Nitrogen content of NO_x emissions from source *i* assuming that NO_x is reported in NO_2 equivalents (Gg NO_x-N or Gg NO_2 • 14/46)

NH_3-$N_{(i)}$ = Nitrogen content of NH_3 emissions from source *i* (Gg NH_3-N or Gg NH_3 • 14/17)

EF_4 = Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces (kg N_2O-N/kg NH_3-N or NO_x-N emitted).

The activity data NO_x-$N_{(i)}$ and NH_3 –$N_{(i)}$ are taken from the inventories as identified in Section 7.2, if available.

This method assumes that N_2O emissions from atmospheric deposition are reported by the country that produced the original NO_x and NH_3 emissions. In reality the ultimate formation of N_2O may occur in another country due to atmospheric transport of emissions. The method also does not account for the probable lag time between NO_x and NH_3 emissions and subsequent production of N_2O in soils and surface waters. This time lag is expected to be small relative to an annual reporting cycle.

7.3.2 Quality Assurance/Quality Control, Reporting and Documentation

It is *good practice* to estimate and report N_2O emissions from atmospheric deposition of NO_x and NH_3 where a country already has an inventory of these gases. For the purposes of calculation, it is assumed that N_2O is emitted in the same year that the original NO_x and NH_3 were emitted.

It is *good practice* to estimate emissions ensuring consistency with the emissions estimated for agriculture sources and avoiding double-counting. Because N_2O emissions may occur outside the country emitting NH_3 or NO_x, use of country- or region-specific emission factors should be thoroughly documented.

N_2O emissions from atmospheric deposition of NH_3 and NO_x are reported in Table 5A of reporting tables in Annex 8A.2 for all sectors, and the AFOLU Sector is also reported in Table 3.8 in Annex 8A.2.

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CHAPTER 8

REPORTING GUIDANCE AND TABLES

Authors

María José Sanz Sánchez (Spain),

Sumana Bhattacharya (India), and Katarina Mareckova (Slovakia)

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8 REPORTING GUIDANCE AND TABLES

8.1 INTRODUCTION

This chapter provides guidance for reporting complete, consistent and transparent national greenhouse gas inventories, regardless the method used to produce the data. The framework for reporting emissions and removals provided in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (*1996 Guidelines*, IPCC, 1997)has been further elaborated for the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 Guidelines*) without introducing substantial changes. Most of the changes from the *1996 Guidelines* are motivated by the need to report emissions and removals from additional categories of sources and sinks in a transparent way. Other changes are introduced to increase the consistency in reporting, or as a result of methodology development over the last 10 years. The categories of agriculture and land-use change and forestry have been restructured resulting in increased completeness and consistency. Since many countries will have prepared inventories for more than one year, tables to report trends in emissions and removals have been included as reporting tables. Reporting tables for general inventory issues, such as uncertainties, *key category* identification are also provided.

8.2 REPORTING GUIDANCE

8.2.1 Coverage

Anthropogenic emissions and removals

The *2006 Guidelines* are designed to estimate and report on national inventories of anthropogenic greenhouse gas emissions and removals. Anthropogenic emissions and removals means that greenhouse gas emissions and removals included in national inventories are a result of human activities.

National inventory

National inventories should include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction. There are, however, some specific issues to be taken into account:

- Emissions from fuel for use on ships or aircraft engaged in international transport should not be included in national totals. To ensure global completeness, these emissions should be reported separately.
- CO_2 emissions from road vehicles should be attributed to the country where the fuel is sold to the end user. The same allocation principle can be applied to other gases depending on the tier used to estimate emissions.
- Fishing includes emissions from fuel used in inland, coastal and deep sea fishing. Emissions resulting from fuel used in coastal and deep sea fishing should be allocated to the country delivering the fuel.
- Military fuel use is reported under “1A5 Non-specified”, and this category includes fuel deliveries for all mobile and stationary consumption (e.g., ships, aircraft, road and energy used in living quarters) of the country. Emissions from multilateral operations pursuant to the Charter of the United Nations are not included in national totals. It is *good practice* to document clearly which activities have been included under the category multilateral operations and report as memo item in the reporting tables.
- Fugitive emissions from pipelines transporting, e.g., oil, gas, or CO_2, should be allocated according to the national territory of the pipeline, including offshore areas. This implies that emissions from one pipeline may be distributed between two or more countries.
- Emissions associated with the injection and possible subsequent leakage of CO_2 stored in geological formations should be linked to the country in whose national jurisdiction or by whose international right the point of injection is located. This includes any emissions arising from leakage of CO_2 from a geological formation that crosses a national boundary.

- The IPCC methodology for carbon stored in non fuel products manufactured from fossil fuels or other non-biogenic sources of carbon takes into account emissions released from their production, use and destruction. Emissions are estimated at each stage when and where they occur, for example in waste incineration.
- Where CO_2 emissions are captured from industrial processes or large combustion sources, emissions should be allocated to the sector generating the CO_2 unless it can be shown that the CO_2 is stored in properly monitored geological storage sites as set out in Chapter 5 of Volume 2. Emissions from CO_2 captured for use, for example in greenhouses and soft drinks, and transported offsite should be allocated to the sector where the CO_2 was captured.
- CO_2 emissions from biomass combustion for energy are estimated and reported in AFOLU Sector as part of net changes in carbon stocks.
- When reporting harvested wood products (HWP), countries can select any of the approaches reflected in Chapter 12 of Volume 4 for the AFOLU Sector when estimating their emissions/removals from HWP.
- N_2O resulting from atmospheric nitrogen deposition is allocated to the country emitting nitrogen oxides and ammonia and it is assumed that N_2O is emitted in the same year.

8.2.2 Gases included

The *2006 Guidelines* can be applied for the following two groups of greenhouse gases[1]:

Greenhouse gases with a GWP in the TAR and not covered by the Montreal Protocol

In addition to the greenhouse gases included in the *1996 Guidelines*, gases for which global warming potential (GWP) values are given in the IPCC Third Assessment Report (TAR) are included in the *2006 Guidelines*[2] unless they are covered by the Montreal Protocol.

The greenhouse gases included are:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)
- hydroflurocarbons (HFCs: e.g., HFC-23 (CHF_3), HFC-134a (CH_2FCF_3), HFC-152a (CH_3CHF_2))
- perfluorocarbons (PFCs: CF_4, C_2F_6, C_3F_8, C_4F_{10}, c-C_4F_8, C_5F_{12}, C_6F_{14})
- sulphur hexafluoride (SF_6)
- nitrogen trifluoride (NF_3)
- trifluoromethyl sulphur pentafluoride (SF_5CF_3)
- halogenated ethers (e.g., $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$)
- other halocarbons not covered by the Montreal Protocol including CF_3I, CH_2Br_2, $CHCl_3$, CH_3Cl, CH_2Cl_2.

Other halogenated greenhouse gases not covered by the Montreal Protocol

The *2006 Guidelines* also provide estimation methods for halogenated greenhouse gases which are not covered by the Montreal Protocol and for which a GWP values are not available from the TAR, inter alia:

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1 In a few cases, although methods are available, the *2006 Guidelines* do not provide default emission factors for all category-gas combinations due to limited research or literature. If a country expects that emissions of these gases occur in a category for which no default emission factors are provided, it is *good practice* to explore the feasibility of developing country-specific data in order to include these emissions in the inventory. If it is not possible to develop country-specific data, countries should provide documentation that these emissions occur but were not estimated.

2 See the IPCC Third Assessment Report "Climate Change 2001: The Scientific Basis" by Working Group I:
Table 6.7 (http://www.grida.no/climate/ipcc_tar/wg1/248.htm#tab67), and
Table 6.8 (http://www.grida.no/climate/ipcc_tar/wg1/249.htm#tab68).

- $C_3F_7C(O)C_2F_5$ [3]
- C_7F_{16}
- C_4F_6
- C_5F_8
- c- C_4F_8O

Some of the methods can be used for other halocarbons not controlled by the Montreal Protocol (including e.g., several fluids and blends e.g., traded under the commercial labels of the Fluorinert™, and Galden® product families)[4].

These and other greenhouse gases can only be considered in *key category* analysis or included in national total emissions using GWP values from sub-sequent Assessment Reports of the IPCC. If these GWP values are not yet available countries are encouraged to provide estimates for them in mass units using the methods provided in the *2006 Guidelines*. Reporting tables are provided for this purpose.

Other gases

Emissions of the ozone precursors nitrogen oxide (NO_x) non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) and the aerosol precursors sulphur dioxide (SO_2) and ammonia (NH_3) should be reported in the appropriate tables if the country has prepared an inventory of these gases. Box 8.1 gives brief explanation of these gases.

BOX 8.1
REPORTING EMISSIONS OF PRECURSORS[5]

NO_x includes NO and NO_2 reported in NO_2 mass equivalents.

SO_2 includes all sulphur compounds expressed in SO_2 mass equivalents.

NMVOC means any non-methane organic compound having at 293.15 K a vapour pressure of 0.01 kP or more, or having a corresponding volatility under the particular conditions of use.

NH_3 is reported in NH_3 mass units.

8.2.3 Time frame of reporting

It is *good practice* to use a calendar year for reporting emissions and removals. Chapter 2, Approaches to Data Collection, provide guidance how to proceed when data for the calendar year reporting are not available or not considered suitable.

8.2.4 Sectors and categories

The *2006 Guidelines* group emissions and removals categories into five main sectors.

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste
- Other

---

3 This gas is traded as Novec™612 which is a fluorinated ketone produced by 3M (Milbrath, 2002).

4 The Fluorinert™ materials are selected from fully fluorinated alkanes, ethers, tertiary amines and aminoethers and mixtures thereof to obtain the desired properties. The Galden® fluids span a range of fully fluorinated polyethers, called perfluoropolyethers (PFPEs).

5 Guidance on reporting and definitions are consistent with the 2002 reporting guidelines of the Convention on Long-Range Transboundary Air Pollution, available in Air Pollution Studies series, No.15, 2003. (http://www.emep.int/index.html)

Compared to the *1996 Guidelines* grouping the sector “Solvent and Other product Use” has been combined with Industrial Processes, and Agriculture has been combined with Land-Use Change and Forestry. Additional subcategories or further disaggregation have been added to increase the completeness and transparency. Table 8.2 in Section 8.5 shows the classification and definition of categories and subcategories of emissions and removals for all 5 sectors.

8.2.5 Notation keys and completeness information

In all tables used by countries to summarise their inventory data, it is *good practice* to fill in information for all entries. If actual emission and removal quantities have not been estimated or can not otherwise be reported in the tables, the inventory compiler should use qualitative notation keys in Table 8.1 and provide supporting documentation. Notation keys are appropriate if emission estimates or removal are incomplete, or representative of only a part of the total activity, or require clarification when specific greenhouse gas emissions were not reported, for any particular source or sink category. In this way it is *good practice* to report on the completeness of each individual emission estimate.

Completeness means that inventory estimates have been prepared for all categories and gases. A country may consider that a disproportionate amount of effort would be required to collect data for a category or a gas from a specific category that would be insignificant in terms of the overall level and trend in national emissions. In these circumstances a country should list all categories and gases from categories excluded on these grounds, together with a justification for exclusion in terms of the likely level of emissions or removals and identify the category as 'Not Estimated' using the notation key 'NE' in the reporting tables.

TABLE 8.1
NOTATION KEYS

Notation Key	Definition	Explanation
NE	Not estimated	Emissions and/or removals occur but have not been estimated or reported.
IE	Included elsewhere	Emissions and/or removals for this activity or category are estimated and included in the inventory but not presented separately for this category. The category where these emissions and removals are included should be indicated (for example in the documentation box in the correspondent table).
C	Confidential information	Emissions and/or removals are aggregated and included elsewhere in the inventory because reporting at a disaggregated level could lead to the disclosure of confidential information.
NA	Not applicable	The activity or category exists but relevant emissions and removals are considered never to occur. Such cells are normally shaded in the reporting tables.
NO	Not occurring	An activity or process does not exist within a country.

8.2.6 Units and digits

SI units (International System of Units) should be used in the worksheets, sectoral and summary tables and other documentation. Emissions and removals should be expressed in mass units and units have to be used consistently within the sector. Emissions in summary and sectoral tables are generally expressed in gigagram (Gg). Other SI mass units may be used to increase the transparency. The number of significant digits of values reported should be appropriate to their magnitude (precision 0.1 percent of national total is adequate for each gas). For some gases, as specified in individual sector tables, emissions and removals should be reported as CO_2 equivalents.

All conversion factors used to convert from original units should be reported in a transparent way.

8.2.7 Time series

It is *good practice* to complete all the reporting tables (summary, sectoral, cross-sectoral) for each year in which an inventory is available.

It is *good practice* to summarise the aggregated inventory data from different years in the trend tables (Table 6A to 6G).

8.2.8 Indirect N_2O

N_2O emissions from atmospheric deposition of NH_3 and NO_x are reported in Table 5.2 for all sectors.

An overview and general description of methodologies to estimate indirect emissions of N_2O are given in Chapter 7 of Volume 1.

8.3 INTRODUCTION TO REPORTING TABLES

The reporting tables in Annex 8A.2 are designed to ensure that inventory compilers can report quantitative data in a standard format and to facilitate consistency between countries, categories, gases and years.

The set of inventory reporting tables consist of:

Summary and short summary tables

Summary and short summary tables allow the inventory compiler to report all emissions and removals at aggregated level for an overview of national totals for the actual year.

The summary tables also allow reporting of memo items including international bunkers and multilateral operations. These emissions are not included in national total emissions of greenhouse gases.

Two tables are included:

Table A	Summary table
Table B	Short summary table

Sectoral and background tables

Sectoral tables enable reporting of emissions and removals, for all relevant categories and subcategories listed in Table 8.2. Background tables allow reporting of activity data and related emissions at the subcategory level to facilitate transparency and consistency of information. Information items that are usually not themselves emissions, for example carbon dioxide stored long-term in the storage sites, are reported separately as additional information under respective sectors for increased transparency.

The following tables are included.

Table 1	Energy Sectoral Table
Table 1.1 – 1.5	Energy Background Tables
Table 2	IPPU Sectoral Table
Table 2.1 – 2.12	IPPU Background Tables
Table 3	AFOLU Sectoral Table
Table 3.1 – 3.10	AFOLU Background Tables
Table 4	Waste Sectoral Table
Table 4.1 – 4.3	Waste Background Tables

Cross-sectoral table

Cross-sectoral tables enable inventory compilers to report indirect emissions of N_2O. Indirect missions are reported in separate columns of Cross-sectoral Table 5A.

Table 5A	Cross-sectoral Table: Indirect emissions of N_2O

Emission trend tables by gas

Trend tables enable inventory compilers to report all greenhouse gas emissions and removals at an aggregated level for entire inventory period. It is *good practice* to complete trend tables if an inventory is available, even if the information is not complete. Reporting of emission trends can help inventory compilers to track time series consistency of the estimates.

Table 6A – 6C   Trends of CO_2, CH_4 and N_2O

Emissions of fluorinated gases are aggregated in three groups and expressed in Gg of CO_2 equivalent.

Table 6D – 6F   Trends of HFC, PFC and SF_6

Emissions of other greenhouse gases are aggregated and expressed in Gg of CO_2 equivalent, if they are reported and included in national totals.

Table 6G   Trends of Other Gases

Uncertainty and key categories tables

Table 7A   Uncertainties

Table 7B   Summary of key category analysis

8.4 OTHER REPORTING

In addition to reporting tables listed in Section 8.3, it is *good practice* to report tabular information on recalculations (see Table 5.2 in Chapter 5, Time Series Consistency, of this Volume).

Additional documentation is needed to ensure the transparency of inventories as part of an inventory report document. An inventory report should clearly explain the assumptions and methodologies used to facilitate replication and assessment of the inventory by users and third parties. Transparency can be ensured through following the guidance on documentation of each category described in the sectoral Volumes 2-5, and for Tier 1 methods by completing the worksheets. Countries using higher tier methods should provide additional documentation in addition to, or instead of the worksheets. Such explanatory information should include cross-references to the tables.

The documentation should include a description of the basis for methodological choice, emission factors, activity data and other estimation parameters, including appropriate references and documentation of expert judgements. The inventory report should also include information on the implementation of a QA/QC plan, verification, splicing of methodologies, recalculations and uncertainty assessment as well as other qualitative information relative to data collection, uncertainty, identification of *key categories* and recalculation mentioned in the correspondent documentation section of the sectoral volumes.

8.5 CLASSIFICATION AND DEFINITION OF CATEGORIES

Table 8.2 introduces the classification and definition of categories and subcategories[6] of emissions and removals (consistent with the sectoral, sectoral background and cross-sectoral tables provided in Annex 8A.2). The correspondence with the reporting categories of the *1996 Guidelines* is also provided in the third column of Table 8.2. A fourth column identifies gases that may be relevant to each category. Additional guidance on gases is provided in Volumes 2-5 and in Table 7.1 of Chapter 7 of this Volume for indirect gases. [7]

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[6] The nomenclature for the levels within the category list is: category, subcategory - 1st order, subcategory - 2nd order, subcategory – 3rd order, etc.

[7] In order to facilitate transparent reporting of emissions of non-CO_2 gases and CO_2 emissions from liming in the AFOLU Sector, reporting is based on aggregated categories (3C) taking into account that data may not be available to report those emissions by land.

TABLE 8.2
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 ENRGY		This category includes all GHG emissions arising from combustion and fugitive releases of fuels. Emissions from the non-energy uses of fuels are generally not included here, but reported under Industrial Processes and Product Use Sector.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A	**Fuel Combustion Activities**	Emissions from the intentional oxidation of materials within an apparatus that is designed to raise heat and provide it either as heat or as mechanical work to a process or for use away from the apparatus.	**1A**	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1	*Energy Industries*	Comprises emissions from fuels combusted by the fuel extraction or energy-producing industries.	1A1	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1 a	Main Activity Electricity and Heat Production	Sum of emissions from main activity producers of electricity generation, combined heat and power generation, and heat plants. Main activity producers (formerly known as public utilities) are defined as those undertakings whose primary activity is to supply the public. They may be in public or private ownership. Emissions from own on-site use of fuel should be included. Emissions from autoproducers (undertakings which generate electricity/heat wholly or partly for their own use, as an activity that supports their primary activity) should be assigned to the sector where they were generated and not under 1 A 1 a. Autoproducers may be in public or private ownership.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1 a i	*Electricity Generation*	Comprises emissions from all fuel use for electricity generation from main activity producers except those from combined heat and power plants.	1A1a i	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1 a ii	*Combined Heat and Power Generation (CHP)*	Emissions from production of both heat and electrical power from main activity producers for sale to the public, at a single CHP facility.	1A1a ii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1 a iii	*Heat Plants*	Production of heat from main activity producers for sale by pipe network.	1A1a iii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1 b	Petroleum Refining	All combustion activities supporting the refining of petroleum products including on-site combustion for the generation of electricity and heat for own use. Does not include evaporative emissions occurring at the refinery. These emissions should be reported separately under 1 B 2 a.	1A1b	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1 c	Manufacture of Solid Fuels and Other Energy Industries	Combustion emissions from fuel use during the manufacture of secondary and tertiary products from solid fuels including production of charcoal. Emissions from own on-site fuel use should be included. Also includes combustion for the generation of electricity and heat for own use in these industries.	1A1c	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 1 c i	*Manufacture of Solid Fuels*	Emissions arising from fuel combustion for the production of coke, brown coal briquettes and patent fuel.	1A1c i	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 A 1 c ii	*Other Energy Industries*	Combustion emissions arising from the energy-producing industries own (on-site) energy use not mentioned above or for which separate data are not available. This includes the emissions from own-energy use for the production of charcoal, bagasse, saw dust, cotton stalks and carbonizing of biofuels as well as fuel used for coal mining, oil and gas extraction and the processing and upgrading of natural gas. This category also includes emissions from pre-combustion processing for CO_2 capture and storage. Combustion emissions from pipeline transport should be reported under 1 A 3 e.	1A1c ii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2	*Manufacturing Industries and Construction*	Emissions from combustion of fuels in industry. Also includes combustion for the generation of electricity and heat for own use in these industries. Emissions from fuel combustion in coke ovens within the iron and steel industry should be reported under 1 A 1 c and not within manufacturing industry. Emissions from the industry sector should be specified by sub-categories that correspond to the International Standard Industrial Classification of all Economic Activities (ISIC). Energy used for transport by industry should not be reported here but under Transport (1 A 3). Emissions arising from off-road and other mobile machinery in industry should, if possible, be broken out as a separate subcategory. For each country, the emissions from the largest fuel-consuming industrial categories ISIC should be reported, as well as those from significant emitters of pollutants. A suggested list of categories is outlined below.	1A2	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 a	Iron and Steel	ISIC Group 271 and Class 2731.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 b	Non-Ferrous Metals	ISIC Group 272 and Class 2732.	1A2b	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 c	Chemicals	ISIC Division 24.	1A2c	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 d	Pulp, Paper and Print	ISIC Divisions 21 and 22.	1A2d	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 e	Food Processing, Beverages and Tobacco	ISIC Divisions 15 and 16.	1A2e	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 f	Non-Metallic Minerals	Includes products such as glass ceramic, cement, etc. ISIC Division 26.	1A2f	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 g	Transport Equipment	ISIC Divisions 34 and 35.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 A 2 h	Machinery	Includes fabricated metal products, machinery and equipment other than transport equipment. ISIC Divisions 28, 29, 30, 31 and 32.	1A2f	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 i	Mining (excluding fuels) and Quarrying	ISIC Divisions 13 and 14.	NA	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 j	Wood and Wood Products	ISIC Division 20.	NA	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 k	Construction	ISIC Division 45.	1A2f	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 l	Textile and Leather	ISIC Divisions 17, 18 and 19.	NA	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 2 m	Non-specified Industry:	Any manufacturing industry/construction not included above or for which separate data are not available. Includes ISIC Divisions 25, 33, 36 and 37.	NA	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3	*Transport*	Emissions from the combustion and evaporation of fuel for all transport activity (excluding military transport), regardless of the sector, specified by sub-categories below. Emissions from fuel sold to any air or marine vessel engaged in international transport (1 A 3 a i and 1 A 3 d i) should as far as possible be excluded from the totals and subtotals in this category and should be reported separately.	1A3	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 a	Civil Aviation	Emissions from international and domestic civil aviation, including take-offs and landings. Comprises civil commercial use of airplanes, including: scheduled and charter traffic for passengers and freight, air taxiing, and general aviation. The international/domestic split should be determined on the basis of departure and landing locations for each flight stage and not by the nationality of the airline. Exclude use of fuel at airports for ground transport which is reported under 1 A 3 e Other Transportation. Also exclude fuel for stationary combustion at airports; report this information under the appropriate stationary combustion category.	1A3a	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 a i	*International Aviation (International Bunkers)*	Emissions from flights that depart in one country and arrive in a different country. Include take-offs and landings for these flight stages. Emissions from international military aviation can be included as a separate sub-category of international aviation provided that the same definitional distinction is applied and data are available to support the definition.	1A3a i	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 a ii	*Domestic Aviation*	Emissions from civil domestic passenger and freight traffic that departs and arrives in the same country (commercial, private, agriculture, etc.), including take-offs and landings for these flight stages. Note that this may include journeys of considerable length between two airports in a country (e.g. San Francisco to Honolulu). Exclude military, which should be reported under 1 A 5 b.	1A3a ii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 A 3 b	Road Transportation	All combustion and evaporative emissions arising from fuel use in road vehicles, including the use of agricultural vehicles on paved roads.	1A3b	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b i	*Cars*	Emissions from automobiles so designated in the vehicle registering country primarily for transport of persons and normally having a capacity of 12 persons or fewer.	1A3b i	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b i 1	Passenger Cars With 3-way Catalysts	Emissions from passenger car vehicles with 3-way catalysts.	1A3b i	CO_2, CH_4, N_2O, NOx, CO, NMVOC, SO_2
1 A 3 b i 2	Passenger Cars Without 3-way Catalysts	Passenger car emissions from vehicles without 3-way catalysts.	1A3b i	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b ii	*Light-duty Trucks*	Emissions from vehicles so designated in the vehicle registering country primarily for transportation of light-weight cargo or which are equipped with special features such as four-wheel drive for off-road operation. The gross vehicle weight normally ranges up to 3500-3900 kg or less.	1A3b ii, 1A3b i	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b ii 1	Light-duty Trucks With 3-way Catalysts	Emissions from light duty trucks with 3-way catalysts.	1A3b ii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b ii 2	Light-duty Trucks Without 3-way Catalysts	Emissions from light duty trucks without 3-way catalysts.	1A3b ii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b iii	*Heavy-duty Trucks and Buses*	Emissions from any vehicles so designated in the vehicle registering country. Normally the gross vehicle weight ranges from 3500-3900 kg or more for heavy duty trucks and the buses are rated to carry more than 12 persons.	1A3b iii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b iv	*Motorcycles*	Emissions from any motor vehicle designed to travel with not more than three wheels in contact with the ground and weighing less than 680 kg.	1A3b iv	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b v	*Evaporative Emissions from Vehicles*	Evaporative emissions from vehicles (e.g. hot soak, running losses) are included here. Emissions from loading fuel into vehicles are excluded.	1A3b v	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 b vi	*Urea-based Catalysts*	CO_2 emissions from use of urea-based additives in catalytic converters (non-combustive emissions).		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 c	Railways	Emissions from railway transport for both freight and passenger traffic routes.	1A3c	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 A 3 d	Water-borne Navigation	Emissions from fuels used to propel water-borne vessels, including hovercraft and hydrofoils, but excluding fishing vessels. The international/domestic split should be determined on the basis of port of departure and port of arrival, and not by the flag or nationality of the ship.	1A3d	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 d i	*International Water-borne Navigation (International Bunkers)*	Emissions from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. Includes emissions from journeys that depart in one country and arrive in a different country. Exclude consumption by fishing vessels (see Other Sector - Fishing). Emissions from international military water-borne navigation can be included as a separate sub-category of international water-borne navigation provided that the same definitional distinction is applied and data are available to support the definition.	1A3d i	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 d ii	*Domestic Water-borne Navigation*	Emissions from fuels used by vessels of all flags that depart and arrive in the same country (exclude fishing, which should be reported under 1 A 4 c iii, and military, which should be reported under 1 A 5 b). Note that this may include journeys of considerable length between two ports in a country (e.g. San Francisco to Honolulu).	1A3d ii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 e	Other Transportation	Combustion emissions from all remaining transport activities including pipeline transportation, ground activities in airports and harbours, and off-road activities not otherwise reported under 1 A 4 c Agriculture or 1 A 2. Manufacturing Industries and Construction. Military transport should be reported under 1 A 5 (see 1 A 5 Non-specified).	1A3de	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 e i	*Pipeline Transport*	Combustion related emissions from the operation of pump stations and maintenance of pipelines. Transport via pipelines includes transport of gases, liquids, slurry and other commodities via pipelines. Distribution of natural or manufactured gas, water or steam from the distributor to final users is excluded and should be reported in 1 A 1 c ii or 1 A 4 a.	1A3e	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 3 e ii	*Off-road*	Combustion emissions from Other Transportation excluding Pipeline Transport.	1A3e	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 4	*Other Sectors*	Emissions from combustion activities as described below, including combustion for the generation of electricity and heat for own use in these sectors.	1A4	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 4 a	Commercial/Institutional	Emissions from fuel combustion in commercial and institutional buildings; all activities included in ISIC Divisions 41,50, 51, 52, 55, 63-67, 70-75, 80, 85, 90-93 and 99.	1A 4 a	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 4 b	Residential	All emissions from fuel combustion in households.	1A4b	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 4 c	Agriculture/Forestry/Fishing/Fish Farms	Emissions from fuel combustion in agriculture, forestry, fishing and fishing industries such as fish farms. Activities included in ISIC Divisions 01, 02 and 05. Highway agricultural transportation is excluded.	1A4c	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 A 4 c i	*Stationary*	Emissions from fuels combusted in pumps, grain drying, horticultural greenhouses and other agriculture, forestry or stationary combustion in the fishing industry.	1A4ci	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 4 c ii	*Off-road Vehicles and Other Machinery*	Emissions from fuels combusted in traction vehicles on farm land and in forests.	1A3e	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 4 c iii	*Fishing (mobile combustion)*	Emissions from fuels combusted for inland, coastal and deep-sea fishing. Fishing should cover vessels of all flags that have refuelled in the country (include international fishing).	1A4ciii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 5	*Non-Specified*	All remaining emissions from fuel combustion that are not specified elsewhere. Include emissions from fuel delivered to the military in the country and delivered to the military of other countries that are not engaged in multilateral operations Emissions from fuel sold to any air or marine vessel engaged in multilateral operation pursuant to the Charter of the United Nations should be excluded from the totals and subtotals of the military transport, and should be reported separately.	1A5	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 5 a	Stationary	Emissions from fuel combustion in stationary sources that are not specified elsewhere.	1A5a	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 5 b	Mobile	Emissions from vehicles and other machinery, marine and aviation (not included in 1 A 4 c ii or elsewhere).	1A5b	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 5 b i	*Mobile (Aviation Component)*	All remaining aviation emissions from fuel combustion that are not specified elsewhere. Include emissions from fuel delivered to the country's military not otherwise included separately in 1 A3 a i as well as fuel delivered within that country but used by militaries of other countries that are not engaged in multilateral operation pursuant to the Charter of the United Nations.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 5 b ii	*Mobile (Water-borne Component)*	All remaining water-borne emissions from fuel combustion that are not specified elsewhere. Include emissions from fuel delivered to the country's military not otherwise included separately in 1 A3 d i as well as fuel delivered within that country but used by militaries of other countries that are not engaged in multilateral operation pursuant to the Charter of the United Nations.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 5 b iii	*Mobile (Other)*	All remaining emissions from mobile sources not included elsewhere.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 A 5 c	Multilateral Operations	Emissions from fuel sold to any air or marine vessel engaged in multilateral operations pursuant to the Charter of the United Nations should be excluded from the totals and subtotals of the military transport, and should be reported separately.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 B	**Fugitive Emissions from Fuels**	Includes all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel to the point of final use.	1B	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
1 B 1	*Solid Fuels*	Includes all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel to the point of final use.	1B1	CO_2, CH_4,
1 B 1 a	Coal Mining and Handling	Includes all fugitive emissions from coal.	1B1a	CO_2, CH_4,
1 B 1 a i	*Underground Mines*	Includes all emissions arising from mining, post-mining, abandoned mines and flaring of drained methane.	1B1a i	CO_2, CH_4,
1 B 1 a i 1	Mining	Includes all seam gas emissions vented to atmosphere from coal mine ventilation air and degasification systems.	1B1a i	CO_2, CH_4,
1 B 1 a i 2	Post-mining Seam Gas Emissions	Includes methane and CO_2 emitted after coal has been mined, brought to the surface and subsequently processed, stored and transported.	1B1a i	CO_2, CH_4,
1 B 1 a i 3	Abandoned Underground Mines	Includes methane emissions from abandoned underground mines.	1B1a i	CO_2, CH_4,
1 B 1 a i 4	Flaring of Drained Methane or Conversion of Methane to CO_2	Methane drained and flared, or ventilation gas converted to CO_2 by an oxidation process should be included here. Methane used for energy production should be included in Volume 2, Energy, Chapter 2 'Stationary Combustion'.	1B1a i	CO_2, CH_4,
1 B 1 a ii	*Surface Mines*	Includes all seam gas emissions arising from surface coal mining.	1B1a ii	CO_2, CH_4,
1 B 1 a ii 1	Mining	Includes methane and CO_2 emitted during mining from breakage of coal and associated strata and leakage from the pit floor and high wall.		CO_2, CH_4,
1 B 1 a ii 2	Post-mining Seam Gas Emissions	Includes methane and CO_2 emitted after coal has been mined, subsequently processed, stored and transported.	1B1a ii	CO_2, CH_4,
1 B 1 b	Uncontrolled Combustion, and Burning Coal Dumps	Includes fugitive emissions of CO_2 from uncontrolled combustion in coal.	1B1c	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 B 1 c	Solid Fuel Transformation	Fugitive emissions arising during the manufacture of secondary and tertiary products from solid fuels.	1B1b	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
1 B 2	*Oil and Natural Gas*	Comprises fugitive emissions from all oil and natural gas activities. The primary sources of these emissions may include fugitive equipment leaks, evaporation losses, venting, flaring and accidental releases.	1B2	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
1 B 2 a	Oil	Comprises emissions from venting, flaring and all other fugitive sources associated with the exploration, production, transmission, upgrading, and refining of crude oil and distribution of crude oil products.	1B2a	CO_2, CH_4, NMVOC,
1 B 2 a i	*Venting*	Emissions from venting of associated gas and waste gas/vapour streams at oil facilities.		CO_2, CH_4, NMVOC,
1 B 2 a ii	*Flaring*	Emissions from flaring of natural gas and waste gas/vapour streams at oil facilities.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
1 B 2 a iii	*All Other*	Fugitive emissions at oil facilities from equipment leaks, storage losses, pipeline breaks, well blowouts, land farms, gas migration to the surface around the outside of wellhead casing, surface casing vent bows, biogenic gas formation from tailings ponds and any other gas or vapour releases not specifically accounted for as venting or flaring.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC,

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
1 B 2 a iii I	Exploration	Fugitive emissions (excluding venting and flaring) from oil well drilling, drill stem testing, and well completions.	1B2a i	CO_2, CH_4, NMVOC,
1 B 2 a iii 2	Production and Upgrading	Fugitive emissions from oil production (excluding venting and flaring) occur at the oil wellhead or at the oil sands or shale oil mine through to the start of the oil transmission system. This includes fugitive emissions related to well servicing, oil sands or shale oil mining, transport of untreated production (i.e , well effluent, emulsion, oil shale and oilsands) to treating or extraction facilities, activities at extraction and upgrading facilities, associated gas re-injection systems and produced water disposal systems. Fugitive emission from upgraders are grouped with those from production rather than those from refining since the upgraders are often integrated with extraction facilities and their relative emission contributions are difficult to establish. However, upgraders may also be integrated with refineries, co-generation plants or other industrial facilities and their relative emission contributions can be difficult to establish in these cases.	1B2a ii	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
1 B 2 a iii 3	Transport	Fugitive emissions (excluding venting and flaring) related to the transport of marketable crude oil (including conventional, heavy and synthetic crude oil and bitumen) to upgraders and refineries. The transportation systems may comprise pipelines, marine tankers, tank trucks and rail cars. Evaporation losses from storage, filling and unloading activities and fugitive equipment leaks are the primary sources of these emissions.	1B2a iii	CO_2, CH_4, NMVOC,
1 B 2 a iii 4	Refining	Fugitive emissions (excluding venting and flaring) at petroleum refineries. Refineries process crude oils, natural gas liquids and synthetic crude oils to produce final refined products (e.g., primarily fuels and lubricants). Where refineries are integrated with other facilities (for example, upgraders or co-generation plants) their relative emission contributions can be difficult to establish.	1B2a iv	CO_2, CH_4, NMVOC,
1 B 2 a iii 5	Distribution of Oil Products	This comprises fugitive emissions (excluding venting and flaring) from the transport and distribution of refined products, including those at bulk terminals and retail facilities. Evaporation losses from storage, filling and unloading activities and fugitive equipment leaks are the primary sources of these emissions.	1B2a v	CO_2, CH_4, NMVOC,
1 B 2 a iii 6	Other	Fugitive emissions from oil systems (excluding venting and flaring) not otherwise accounted for in the above categories. This includes fugitive emissions from spills and other accidental releases, waste oil treatment facilities and oilfield waste disposal facilities.	1B2a vi	CO_2, CH_4, NMVOC,
1 B 2 b	Natural Gas	Comprises emissions from venting, flaring and all other fugitive sources associated with the exploration, production, processing, transmission, storage and distribution of natural gas (including both associated and non-associated gas).	1B2b	CO_2, CH_4, NMVOC,
1 B 2 b i	*Venting*	Emissions from venting of natural gas and waste gas/vapour streams at gas facilities.		CO_2, CH_4, NMVOC,
1 B 2 b ii	*Flaring*	Emissions from flaring of natural gas and waste gas/vapour streams at gas facilities.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
1 B 2 b iii	*All Other*	Fugitive emissions at natural gas facilities from equipment leaks, storage losses, pipeline breaks, well blowouts, gas migration to the surface around the outside of wellhead casing, surface casing vent bows and any other gas or vapour releases not specifically accounted for as venting or flaring.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
1 B 2 b iii 1	Exploration	Fugitive emissions (excluding venting and flaring) from gas well drilling, drill stem testing and well completions.	1Bb i	CO_2, CH_4, NMVOC,

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name	Definition	96 GLs Category Code	Gases
1 B 2 b iii 2 Production	Fugitive emissions (excluding venting and flaring) from the gas wellhead through to the inlet of gas processing plants, or, where processing is not required, to the tie-in points on gas transmission systems. This includes fugitive emissions related to well servicing, gas gathering, processing and associated waste water and acid gas disposal activities.	1Bb ii	CO_2, CH_4, NMVOC,
1 B 2 b iii 3 Processing	Fugitive emissions (excluding venting and flaring) from gas processing facilities.	1Bb iii	CO_2, CH_4, NMVOC,
1 B 2 b iii 4 Transmission and Storage	Fugitive emissions from systems used to transport processed natural gas to market (i.e., to industrial consumers and natural gas distribution systems). Fugitive emissions from natural gas storage systems should also be included in this category. Emissions from natural gas liquids extraction plants on gas transmission systems should be reported as part of natural gas processing (Sector 1.B.2.b.iii.3). Fugitive emissions related to the transmission of natural gas liquids should be reported under Category 1.B.2.a.iii.3.	1B2b ii	CO_2, CH_4, NMVOC,
1 B 2 b iii 5 Distribution	Fugitive emissions (excluding venting and flaring) from the distribution of natural gas to end users.	NA	CO_2, CH_4, NMVOC,
1 B 2 b iii 6 Other	Fugitive emissions from natural gas systems (excluding venting and flaring) not otherwise accounted for in the above categories. This may include emissions from well blowouts and pipeline ruptures or dig-ins.	1B2 c	CO_2, CH_4, NMVOC,
1 B 3 *Other Emissions from Energy Production*	Other fugitive emissions for example, from geo thermal energy production, peat and other energy production not included in 1.B.2.		CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
1 C **Carbon Dioxide Transport and Storage**	Carbon dioxide (CO_2) capture and storage (CCS) involves the capture of CO_2 from anthropogenic sources, its transport to a storage location and its long-term isolation from the atmosphere. Emissions associated with CO_2 transport, injection and storage are covered under category 1C. Emissions (and reductions) associated with CO_2 capture should be reported under the IPCC Sector in which capture takes place (e.g. Fuel Combustion or Industrial Activities).		CO_2,
1 C 1 *Transport of CO_2*	This comprises fugitive emissions from the systems used to transport captured CO_2 from the source to the injection site. These emissions may comprise losses due to fugitive equipment leaks, venting and releases due to pipeline ruptures or other accidental releases (e.g., temporary storage).		CO_2,
1 C 1 a Pipelines	Fugitive emissions from the pipeline system used to transport CO_2 to the injection site.		CO_2,
1 C 1 b Ships	Fugitive emissions from the ships used to transport CO_2 to the injection site.		CO_2,
1 C 1 c Other (please specify)	Fugitive emissions from other systems used to transport CO_2 to the injection site and temporary storage		CO_2,
1 C 2 *Injection and Storage*	Fugitive emissions from activities and equipment at the injection site and those from the end containment once the CO_2 is placed in storage.		CO_2,
1 C 2 a Injection	Fugitive emissions from activities and equipment at the injection site.		CO_2,
1 C 2 b Storage	Fugitive emissions from the end equipment once the CO_2 is placed in storage.		CO_2,
1 C 3 *Other*	Any other emissions from CCS not reported elsewhere.		CO_2,

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name					Definition	96 GLs Category Code	Gases
2	**INDUSTRIAL PROCESSES AND PRODUCT USE**				Emissions from industrial processes and product use, excluding those related to energy combustion (reported under 1A), extraction, processing and transport of fuels (reported under 1B) and CO_2 transport, injection and storage (reported under 1C).		CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, other halogenated gases, NO_x, CO, NMVOC, SO_2
2	A			**Mineral Industry**		2A	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2	A	1		*Cement Production*	Process-related emissions from the production of various types of cement (ISIC: D2694).	2A1	CO_2, CH_4,
2	A	2		*Lime Production*	Process-related emissions from the production of various types of lime (ISIC: D2694).	2A2	CO_2, CH_4
2	A	3		*Glass Production*	Process-related emissions from the production of various types of glass (ISIC: D2610).	2A3, 2A4	CO_2, CH_4
2	A	4		*Other Process Uses of Carbonates*	Includes limestone, dolomite and other carbonates etc. Emissions from the use of limestone, dolomite and other carbonates should be included in the industrial source category where they are emitted. Therefore, for example, where a carbonate is used as a flux for iron and steel production, resultant emissions should be reported under 2C1 "Iron and Steel Production" rather than this subcategory.	2A3, 2A4	CO_2, CH_4, NO_x, CO, NMVOC, SO_2
2	A	4	a	Ceramics	Process-related emissions from the production of bricks and roof tiles, vitrified clay pipes, refractory products, expanded clay products, wall and floor tiles, table and ornamental ware (household ceramics), sanitary ware, technical ceramics, and inorganic bonded abrasives (ISIC: D2691, D2692 and D2693).	2A3	CO_2, CH_4
2	A	4	b	Other Uses of Soda Ash	This should include emissions from soda ash use that are not included elsewhere. For example, soda ash used for glass should be reported in 2A3.	2A4	CO_2, CH_4, NO_x, CO, NMVOC, SO_2
2	A	4	c	Non Metallurgical Magnesia Production	This source category should include emissions from magnesia production that are not included elsewhere. For example, where magnesia production is used for primary and secondary magnesium production, emissions should be reported in relevant source category in Metals.	2A3	CO_2, CH_4
2	A	4	d	Other (please specify)	Process-related emissions reported under this sub-category should include all other miscellaneous uses of limestone, dolomite and other carbonates, except from uses already listed in the sub-categories above, and uses as fluxes or slagging agents in the Metals and Chemicals industries, or for the liming of soils and wetlands in Agriculture, Forestry and Other Land Uses (ISIC D269).	2A3	CO_2, CH_4, NO_x, CO, NMVOC, SO_2
2	A	5		*Other (please specify)*		2A7	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
2 B	**Chemical Industry**		2B, 2A4, 3C	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, other halogen ated gases, NO_x, CO, NMVOC, SO_2
2 B 1	*Ammonia Production*	Ammonia (NH_3) is a major industrial chemical and the most important nitrogenous material produced. Ammonia gas is used directly as a fertilizer, in heat treating, paper pulping, nitric acid and nitrates manufacture, nitric acid ester and nitro compound manufacture, explosives of various types, and as a refrigerant. Amines, amides, and miscellaneous other organic compounds, such as urea, are made from ammonia. The main greenhouse gas emitted from NH_3 production is CO_2. CO_2 used in the production of urea, a downstream process, should be subtracted from the CO_2 generated and accounted for in the AFOLU Sector.	2B1	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 B 2	*Nitric Acid Production*	Nitric acid is used as a raw material mainly in the manufacture of nitrogenous-based fertiliser. Nitric acid may also be used in the production of adipic acid and explosives (e.g., dynamite), for metal etching and in the processing of ferrous metals. The main greenhouse gas emitted from HNO_3 production is nitrous oxide.	2B2	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
2 B 3	*Adipic Acid Production*	Adipic acid is used in the manufacture of a large number of products including synthetic fibres, coatings, plastics, urethane foams, elastomers and synthetic lubricants. The production of Nylon 6.6 accounts for the bulk of adipic acid use. The main greenhouse gas emitted from adipic acid production is nitrous oxide.	2B3	N_2O, CO_2, CH_4 , NO_x,
2 B 4	*Caprolactam, Glyoxal and Glyoxylic Acid Production*	Most of the annual production of caprolactam ($NH(CH_2)_5CO$) is consumed as the monomer for nylon-6 fibres and plastics, with a substantial proportion of the fibre used in carpet manufacturing. All commercial processes for the manufacture of caprolactam are based on either toluene or benzene. This subcategory also covers production of glyoxal (ethanedial) and glyoxylic acid production. The main greenhouse gas emitted from this subcategory is nitrous oxide.	2B5	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
2 B 5	*Carbide Production*	The production of carbide can result in emissions of CO_2, CH_4, CO and SO_2. Silicon carbide is a significant artificial abrasive. It is produced from silica sand or quartz and petroleum coke. Calcium carbide is used in the production of acetylene, in the manufacture of cyanamide (a minor historical use), and as a reductant in electric arc steel furnaces. It is made from calcium carbonate (limestone) and carbon-containing reductant (petroleum coke).	2B4	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
2 B 6	*Titanium Dioxide Production*	Titanium dioxide (TiO_2) is the most important white pigment. The main use is in paint manufacture followed by paper, plastics, rubber, ceramics, fabrics, floor covering, printing ink, and other miscellaneous uses. The main production process is the chloride route, giving rise to CO_2 emissions that are likely to be significant. This category also includes synthetic rutile production using the Becher process, and titanium slag production, both of which are reduction processes using fossil fuels and resulting in CO_2 emissions. Synthetic rutile is the major input to TiO_2 production using the chloride route.	2B5	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
2 B 7	*Soda Ash Production*	Soda ash (sodium carbonate, Na_2CO_3) is a white crystalline solid that is used as a raw material in a large number of industries including glass manufacture, soap and detergents, pulp and paper production and water treatment. Emissions of CO_2 from the production of soda ash vary dependent on the manufacturing process. Four different processes may be used to produce soda ash. Three of these processes, monohydrate, sodium sesquicarbonate (trona) and direct carbonation, are referred to as natural processes. The fourth, the Solvay process, is classified as a synthetic process.	2A4	CO_2, CH_4, N_2O, NO_x, CO, NMVOC,
2 B 8	*Petrochemical and Carbon Black Production*		2B5	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 B 8 a	Methanol	Methanol production covers production of methanol from fossil fuel feedstocks [natural gas, petroleum, coal] using steam reforming or partial oxidation processes. Production of methanol from biogenic feedstocks (e.g., by fermentation) is not included in this source category.	2B5	CO_2, CH_4, N_2O, NMVOC
2 B 8 b	Ethylene	Ethylene production covers production of ethylene from fossil fuel-derived feedstocks at petrochemical plants by the steam cracking process. Production of ethylene from processes situation within the boundaries of petroleum refineries is not included in this source category. The greenhouse gases produced from ethylene production are carbon dioxide and methane.	2B5	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 B 8 c	Ethylene Dichloride and Vinyl Chloride Monomer	Ethylene dichloride and vinyl chloride monomer production covers production of ethylene dichloride by direct oxidation or oxychloination of ethylene, and the production of vinyl chloride monomer from ethylene dichloride. The greenhouse gases produced from production of ethylene dichloride production and vinyl chloride monomer production are carbon dioxide and methane.	2B5	CO_2, CH_4, N_2O, CO, NMVOC
2 B 8 d	Ethylene Oxide	Ethylene oxide production covers production of ethylene oxide by reaction of ethylene and oxygen by catalytic oxidation. The greenhouse gases produced from ethylene oxide production are carbon dioxide and methane.	2B5	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 B 8 e	Acrylonitrile	Acrylonitrile production covers production of acrylonitrile from ammoxidation of propylene, and associated production of acetonitrile and hydrogen cyanide from the ammoxidation process. The greenhouse gases produced from production of acrylonitrile are carbon dioxide and methane.	2B5	CO_2, CH_4, N_2O, NMVOC
2 B 8 f	Carbon Black	Carbon black production covers production of carbon black from fossil fuel-derived feedstocks (petroleum or coal-derived carbon black feedstock, natural gas, acetylene). Production of carbon black from biogenic feedstocks is not included in this source category.	2B5, 3C	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 B 9	*Fluorochemical Production*		2E	HFCs, PFCs, SF_6, other halogen ated gases,
2 B 9 a	By-product Emissions	Fluorochemical Production covers the complete range of fluorochemicals, whether or not the principal products are greenhouse gases. Emissions encompass HFCs, PFCs, SF_6 and all other halogenated gases with global warming potential listed in IPCC assessment reports. The most significant by-product emission is that of HFC-23 from the manufacture of HCFC-22 and this is described separately.	2E1	HFCs, PFCs, SF_6, other halogen ated gases

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
2 B 9 b	Fugitive Emissions	These are emissions of the principal product from the process to manufacture it and so fluorochemical production in this context is limited to HFCs, PFCs, SF_6 and other halogenated gases with global warming potential listed in IPCC assessment reports.	2E2	HFCs, PFCs, SF_6, other halogenated gases
2 B 10	*Other (Please specify)*	For example, gases with global warming potential listed in IPCC assessment reports that do not fall within any categories above could be reported here, if they are estimated.	2B5	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, other halogenated gases, NO_x, CO, NMVOC, SO_2
2 C	**Metal Industry**		2C	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, other halogenated gases, NO_x, CO, NMVOC, SO_2
2 C 1	*Iron and Steel Production*	Carbon dioxide is the predominant gas emitted from the production of iron and steel. The sources of the carbon dioxide emissions include that from carbon-containing reducing agents such as coke and pulverized coal, and, from minerals such as limestone and dolomite added.	2C1	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 C 2	*Ferroalloys Production*	Ferroalloys production covers emissions from primary metallurgical reduction production of the most common ferroalloys, i.e. ferro-silicon, silicon metal, ferro-manganese, silicon manganese, and ferro-chromium, excluding those emissions relating to fuel use. From the production of these alloys, carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) originating from ore- and reductant raw materials, is emitted.	2C2	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 C 3	*Aluminium Production*	Aluminium Production covers primary production of aluminium, except the emissions related to the use of fuel. Carbon dioxide emissions result from the electrochemical reduction reaction of alumina with a carbon-based anode. Tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) are also produced intermittently. No greenhouse gases are produced in recycling of aluminium other than from the fuels uses for metal remelting. Sulphur hexafluoride (SF_6) emissions are not associated with primary aluminium production; however, casting of some high magnesium containing alloys does result in SF_6 emissions and these emissions are accounted for in Section 2C4, Magnesium Production.	2C3	CO_2, CH_4, PFCs, NO_x, CO, NMVOC, SO_2
2 C 4	*Magnesium Production*	Magnesium production covers GHG emissions related to both primary magnesium production as well as oxidation protection of magnesium metal during processing (recycling and casting), excluding those emissions relating to fuel use. In the primary production of magnesium, carbon dioxide (CO_2) is emitted during calcination of dolomite and magnesite raw materials. Primary production of magnesium from non-carbonate raw materials does not emit carbon dioxide. In the processing of liquid magnesium, cover gases containing carbon dioxide (CO_2), sulphur hexafluoride (SF_6), the hydrofluorocarbon HFC 134a or the fluorinated ketone FK 5-1-12 ($C_3F_7C(O)C_2F_5$) may be used. Partial thermal decomposition and/or reaction between these compounds and liquid magnesium generates secondary compounds such as perfluorocarbons (PFCs), which are emitted in addition to unreacted cover gas constituents.	2C4	CO_2, HFCs, PFCs, SF_6, other halogenated gases, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED) CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS				
Category Code and Name		**Definition**	**96 GLs Category Code**	**Gases**
2 C 5	*Lead Production*	Lead production covers production by the sintering/smelting process as well as direct smelting. Carbon dioxide emissions result as a product of the use of a variety of carbon-based reducing agents in both production processes.	2C5	CO_2
2 C 6	*Zinc Production*	Zinc production covers emissions from both primary production of zinc from ore as well as recovery of zinc from scrap metals, excluding emissions related to fuel use. Following calcination, zinc metal is produced through one of three methods; 1-electro-thermic distillation, 2-pyro-metallurgical smelting or 3-electrolysis. If method 1 or 2 is used, carbon dioxide (CO_2) is emitted. Method 3 does not result in carbon dioxide emissions. Recovery of zinc from metal scrap often uses the same methods as primary production and may thus produce carbon dioxide emissions, which is included in this section.	2C5	CO_2
2 C 7	*Other (please specify)*		2C5	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, other halogen ated gases, NO_x, CO, NMVOC, SO_2
2 D	**Non-Energy Products from Fuels and Solvent Use**	The use of oil products and coal-derived oils primarily intended for purposes other than combustion.	1, 2A5, 2A6, 3	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 D 1	*Lubricant Use*	Lubricating oils, heat transfer oils, cutting oils and greases.	1, 3	CO_2
2 D 2	*Paraffin Wax Use*	Oil-derived waxes such as petroleum jelly, paraffin waxes and other waxes.	1, 3	CO_2, CH_4, N_2O
2 D 3	*Solvent Use*	NMVOC emissions from solvent use e.g. in paint application, degreasing and dry cleaning should be contained here. Emissions from the use of HFCs and PFCs as solvents should be reported under 2F5.	3A, 3B	NMVOC
2 D 4	*Other (please specify)*	For example, CH_4, CO and NMVOC emissions from asphalt production and use (including asphalt blowing), as well as NMVOC emissions from the use of other chemical products than solvents should be contained here, if relevant.	2A5, 2A6, 3D	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 E	**Electronics Industry**		2F6	CO_2, CH_4, N_2O, PFCs, HFCs, SF_6, other halogen ated gases
2 E 1	*Integrated Circuit or Semiconductor*	Emissions of CF4, C_2F_6, C_3F_8, c-C_4F_8, C_4F_6, C_4F_8O, C_5F_8, CHF_3, CH_2F_2, NF_3 and SF_6 from uses of these gases in Integrated Circuit (IC) manufacturing in rapidly evolving ways and in varying amounts, which depend on product (e.g., memory or logic devices) and equipment manufacturer.	2F6	CO_2, N_2O, PFCs, HFCs, SF_6, other halogen ated gases
2 E 2	*TFT Flat Panel Display*	Uses and emissions of predominantly CF_4, CHF_3, NF_3 and SF_6 during the fabrication of thin-film transistors (TFTs) on glass substrates for flat panel display manufacture. In addition to these gases, C_2F_6, C_3F_8 and c-C_4F_8 may also be used and emitted during the manufacture of thin and smart displays.	2F6	PFCs, HFCs, SF_6, other halogen ated gases

TABLE 8.2 (CONTINUED) CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS			
Category Code and Name	**Definition**	**96 GLs Category Code**	**Gases**
2 E 3 *Photovoltaics*	Photovoltaic cell manufacture may use and emit CF_4 and C_2F_6 among others.	2F6	PFCs, HFCs, SF_6, other halogenated gases
2 E 4 *Heat Transfer Fluid*	Heat transfer fluids, which include several fully fluorinated carbon compounds (either in pure form or in mixtures) with six or more carbon atoms, used and emitted during IC manufacture, testing and assembly. They are used in chillers, temperature shock testers and vapour phase reflow soldering.	2F6	other halogenated gases
2 E 5 *Other (please specify)*		2F6	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, other halogenated gases
2 F **Product Uses as Substitutes for Ozone Depleting Substances**		2F	CO_2, HFCs, PFCs, other halogenated gases
2 F 1 *Refrigeration and Air Conditioning*	Refrigeration and air-conditioning systems are usually classified in six application domains or categories. These categories utilise different technologies such as heat exchangers, expansion devices, pipings and compressors. The six application domains are domestic refrigeration, commercial refrigeration, industrial processes, transport refrigeration, stationary air conditioning, mobile air-conditioning systems. For all these applications, various HFCs are selectively replacing CFCs and HCFCs. For example, in developed countries, HFC-134a has replaced CFC-12 in domestic refrigeration and mobile air conditioning systems, and blends of HFCs such as R-407C (HFC-32/HFC-125/HFC-134a) and R-410A (HFC-32/HFC-125) are replacing HCFC-22 mainly in stationary air conditioning. Other, non HFC substances are used to replace CFCs and HCFCs such as iso-butane in domestic refrigeration or ammonia in industrial refrigeration. HFC-152a is also being considered for mobile air conditioning in several regions.	2F1	CO_2, HFCs, PFCs, other halogenated gases
2 F 1 a Refrigeration and Stationary Air Conditioning	The application domains are domestic refrigeration, commercial refrigeration, industrial processes, stationary air conditioning.	2F1	CO_2, HFCs, PFCs, other halogenated gases
2 F 1 b Mobile Air Conditioning	The application domains are transport refrigeration, mobile air-conditioning systems.	2F1	CO_2, HFCs, PFCs, other halogenated gases

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
2 F 2	*Foam Blowing Agents*	HFCs are being used as replacements for CFCs and HCFCs in foams, particularly in closed-cell insulation applications. Compounds that are being used include HFC-245fa, HFC-365mfc, HFC-227ea, HFC-134a, and HFC-152a. The processes and applications for which these various HFCs are being used include insulation boards and panels, pipe sections, sprayed systems and one-component gap filling foams. For open-cell foams, such as integral skin products for automotive steering wheels and facias, emissions of HFCs used as blowing agents are likely to occur during the manufacturing process. In closed-cell foam, emissions not only occur during the manufacturing phase, but usually extend into the in-use phase and often the majority of emission occurs at the end-of-life (de-commissioning losses). Accordingly, emissions can occur over a period of up to 50 years or even longer.	2F2	CO_2, HFCs, PFCs, other halogenated gases
2 F 3	*Fire Protection*	There are two general types of fire protection (fire suppression) equipment that use greenhouse gases as partial replacements for halons: portable (streaming) equipment, and fixed (flooding) equipment. The non-ozone depleting, industrial gases HFCs, PFCs and more recently a fluoroketone are mainly used as substitutes for halons, typically halon 1301, in flooding equipment. PFCs played an early role in halon 1301 replacement but current use is limited to replenishment of previously installed systems. HFCs in portable equipment, typically replacing halon 1211, are available but have achieved very limited market acceptance due primarily to their high cost. PFC use in new portable extinguishers is currently limited to a small amount (few percent) in an HCFC blend.	2F3	CO_2, HFCs, PFCs, other halogenated gases
2 F 4	*Aerosols*	Most aerosol packages now contain hydrocarbon (HC) as propellants but, in a small fraction of the total, HFCs and PFCs may be used as propellants or solvents. Emissions from aerosols usually occur shortly after production, on average six months after sale. During the use of aerosols, 100% of the chemical is emitted. The 5 main sources are metered dose inhalers (MDIs), personal care products (e.g. hair care, deodorant, shaving cream), household products (e.g. air-fresheners, oven and fabric cleaners), industrial products (e.g. special cleaning sprays such as those for operating electrical contact, lubricants, pipe-freezers) and other general products (e.g. silly string, tire inflators, claxons), although in some regions the use of such general products is restricted. The HFCs currently used as propellants are HFC 134a, HFC 227ea, and HFC 152a. The substance HFC 43 10mee and a PFC, perfluorohexane, are used as solvents in industrial aerosol products.	2F4	HFCs, PFCs, other halogenated gases
2 F 5	*Solvents*	HFCs and, to a much lesser extent PFCs, are being used as substitutes for ozone depleting substances (most notably CFC-113). Typical HFCs used are HFC-365mfc and HFC-43-10mee. Use of these fluorinated replacements is much less widespread than the ozone depleting substances they replace. Re-capture and re-use is also much more widely practiced The primary areas of use are precision cleaning, electronics cleaning, metal cleaning and deposition applications. Emissions from aerosols containing solvents should be reported undercategory 2F4 "Aerosols" rather than under this category.	2F5	HFCs, PFCs, other halogenated gases
2 F 6	*Other Applications (please specify)*	The properties of ozone depleting substances have made them attractive for a variety of niche applications not covered in other sub-source categories. These include electronics testing, heat transfer, dielectric fluid and medical applications. The properties of HFCs and PFCs are equally attractive in some of these sectors and they have been adopted as substitutes. There are also some historical uses of PFCs, as well as emerging use of HFCs, in these applications. These applications have leakage rates ranging from 100% emissive in year of application to around 1% per annum.	2F6	CO_2, CH_4, N_2O, HFCs, PFCs, other halogenated gases

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
2 G	**OTHER PRODUCT MANUFACTURE AND USE**		2F6, 3D	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, other halogenated gases
2 G 1	*Electrical Equipment*	Electrical equipment is used in the transmission and distribution of electricity above 1 kV. SF_6 is used in gas-insulated switchgear (GIS), gas circuit breakers (GCB), gas-insulated transformers (GIT), gas-insulated lines (GIL), outdoor gas-insulated instrument transformers, reclosers, switches, ring main units and other equipment.	2F6	SF_6, PFCs, other halogenated gases
2 G 1 a	Manufacture of Electrical Equipment		2F6	SF_6, PFCs, other halogenated gases
2 G 1 b	Use of Electrical Equipment		2F6	SF_6, PFCs, other halogenated gases
2 G 1 c	Disposal of Electrical Equipment		2F6	SF_6, PFCs, other halogenated gases
2 G 2	*SF_6 and PFCs from Other Product Uses*		2F6	SF_6, PFCs, other halogenated gases
2 G 2 a	Military Applications	Military applications include AWACS, which are military reconnaissance planes of the Boeing E-3A type. In AWACS (and possibly other reconnaissance planes), the SF6 is used as an insulating gas in the radar system.	2F6	SF_6, PFCs, other halogenated gases
2 G 2 b	Accelerators	Particle accelerators are used for research purposes (at universities and research institutions), for industrial applications (in cross-linking polymers for cable insulation and for rubber parts and hoses), and in medical (radiotherapy) applications.	2F6	SF_6, PFCs, other halogenated gases
2 G 2 c	Other *(please specify)*	This source includes adiabatic uses, sound-proof glazing, PFCs used as heat transfer fluids in consumer and commercial applications, PFCs used in cosmetic and medical applications, and PFCs and SF_6 used as tracers.	2F6	SF_6, PFCs, other halogenated gases
2 G 3	*N_2O from Product Uses*		3D	N_2O
2 G 3 a	Medical Applications	This source covers evaporative emissions of nitrous oxide (N_2O) that arise from medical applications (anaesthetic use, analgesic use and veterinary use). N_2O is used during anaesthesia for two reasons: a) as an anaesthetic and analgesic and as b) a carrier gas for volatile fluorinated hydrocarbon anaesthetics such as isoflurane, sevoflurane and desflurane.	3D	N_2O
2 G 3 b	Propellant for Pressure and Aerosol Products	This source covers evaporative emissions of nitrous oxide (N_2O) that arise from use as a propellant in aerosol products primarily in food industry. Typical usage is to make whipped cream, where cartridges filled with N_2O are used to blow the cream into foam.	3D	N_2O
2 G 3 c	Other (Please specify)		3D	N_2O
2 G 4	*Other (Please specify)*		2F6, 3D	CO_2, CH_4, HFCs, other halogenated gases

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
2 H	**Other**		2D1, 2D2, 2G	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
2 H 1	*Pulp and Paper Industry*		2D1	CO_2, CH_4, NO_x, CO, NMVOC, SO_2
2 H 2	*Food and Beverages Industry*		2D2	CO_2, CH_4, NO_x, CO, NMVOC, SO_2
2 H 3	*Other (please specify)*		2G	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
3	**AGRICULTURE, FORESTRY, AND OTHER LAND USE**	Emissions and removals from forest land, cropland, grassland, wetlands, settlements, and other land. Also includes emissions from livestock and manure management, emissions from managed soils, and emissions from liming and urea application. Methods to estimate annual harvested wood product (HWP) variables are also covered in this category.	4,5	CH_4, N_2O, CO_2
3 A	**Livestock**	Methane emissions from enteric fermentation, and methane and nitrous oxide emissions from manure management.	4	CH_4
3 A 1	*Enteric Fermentation*	Methane emissions from herbivores as a by-product of enteric fermentation (a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream). Ruminant animals (e.g., cattle, sheep) are major sources with moderate amounts produced from non-ruminant animals (e.g., pigs, horses).	4A	CH_4
3 A 1 a	Cattle	Methane emissions from dairy cows and other cattle.	4A1	CH_4
3 A 1 a i	*Dairy Cows*	Methane emissions from cattle producing milk for commercial exchange and from calves and heifers being grown for dairy purposes.	4A1a	CH_4
3 A 1 a ii	*Other Cattle*	Methane emissions from all non-dairy cattle including: cattle kept or grown for meat production, draft animals, and breeding animals.	4A1b	CH_4
3 A 1 b	Buffalo	Methane emissions from buffalo.	4A2	CH_4
3 A 1 c	Sheep	Methane emissions from sheep.	4A3	CH_4
3 A 1 d	Goats	Methane emissions from goats.	$4A_4$	CH_4
3 A 1 e	Camels	Methane emissions from camels.	4A5	CH_4
3 A 1 f	Horses	Methane emissions from horses.	4A6	CH_4
3 A 1 g	Mules and Asses	Methane emissions from mules and asses.	4A7	CH_4
3 A 1 h	Swine	Methane emissions from swine.	4A8	CH_4
3 A 1 j	Other (please specify)	Methane emissions from other livestock (e.g. alpacas, llamas, deer, reindeer, etc.).	4A10	CH_4
3 A 2	*Manure Management*	Methane and nitrous oxide emissions from the decomposition of manure under low oxygen or anaerobic conditions. These conditions often occur when large numbers of animals are managed in a confined area (e.g. dairy farms, beef feedlots, and swine and poultry farms), where manure is typically stored in large piles or disposed of in lagoons and other types of manure management systems.	4B	CH_4, N_2O
3 A 2 a	Cattle	Methane and nitrous oxide emissions from the decomposition of manure from cattle.	4B1	CH_4, N_2O

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
3 A 2 a i	*Dairy Cows*	Methane and nitrous oxide emissions from the decomposition of manure from dairy cows.	4B1a	CH_4, N_2O
3 A 2 a ii	*Other Cattle*	Methane and nitrous oxide emissions from the decomposition of manure from other cattle.		CH_4, N_2O
3 A 2 b	Buffalo	Methane and nitrous oxide emissions from the decomposition of manure from buffalo.	4B2	CH_4, N_2O
3 A 2 c	Sheep	Methane and nitrous oxide emissions from the decomposition of manure from sheep.	4B3	CH_4, N_2O
3 A 2 d	Goats	Methane and nitrous oxide emissions from the decomposition of manure from goats.	4B4	CH_4, N_2O
3 A 2 e	Camels	Methane and nitrous oxide emissions from the decomposition of manure from camels.	4B5	CH_4, N_2O
3 A 2 f	Horses	Methane and nitrous oxide emissions from the decomposition of manure from horses.	4B6	CH_4, N_2O
3 A 2 g	Mules and Asses	Methane and nitrous oxide emissions from the decomposition of manure from mules and assess.	4B7	CH_4, N_2O
3 A 2 h	Swine	Methane and nitrous oxide emissions from the decomposition of manure from swine.	4B8	CH_4, N_2O
3 A 2 i	Poultry	Methane and nitrous oxide emissions from the decomposition of manure from poultry including chicken, broilers, turkeys, and ducks.	4B9	CH_4, N_2O
3 A 2 j	Other (please specify)	Methane and nitrous oxide emissions from the decomposition of manure from other livestock (e.g. alpacas, llamas, deer, reindeer, fur-bearing animals, ostriches, etc.)	4B13	CH_4, N_2O
3 B	**Land**	Emissions and removals from five land use categories (Forest land, Cropland, Grasslands, Settlements, and Other land) except for sources listed under 3C (Aggregate sources and non-CO2 emissions sources on land) . Except for Wetlands, the greenhouse gas inventory involves estimation of changes in carbon stock from five carbon pools (i.e. aboveground biomass, belowground biomass, dead wood, litter, and soil organic matter), as appropriate.	5	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 1	*Forest Land*	Emissions and removals from lands with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, sub-divided into managed and unmanaged, and possibly also by climatic region, soil type and vegetation type as appropriate. It also includes systems with vegetation that currently fall below, but are expected to later exceed, the threshold values used by a country to define the forest land category.	5A,5B,5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 1 a	Forest land Remaining Forest Land	Emissions and removals from managed forests and plantations which have always been under forest land use or other land categories converted to forest over 20 years ago (default assumption).	5A	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 1 b	Land Converted to Forest Land	Emissions and removals from lands converted to forest land. Includes conversion of cropland, grassland, wetlands, settlements, and other land to forest land. Even abandoned lands which are regenerating to forest due to human activities are also included.	5A,5C,5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 1 b i	*Cropland Converted to Forest Land*	Emissions and removals from cropland converted to forest land.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 1 b ii	*Grassland Converted to Forest Land*	Emissions and removals from grassland converted to forest land.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
3 B 1 b iii	*Wetlands Converted to Forest Land*	Emissions and removals from wetlands converted to forest land.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 1 b iv	*Settlements Converted to Forest Land*	Emissions and removals from settlements converted to forest land.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 1 b v	*Other Land Converted to Forest Land*	Emissions and removals from other land converted to forest land.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2	*Cropland*	Emissions and removals from arable and tillage land, rice fields, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category.	4C, 4D, 4F, 5A, 5B, 5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2 a	Cropland Remaining Cropland	Emissions and removals from cropland that has not undergone any land use change during the inventory period.	4C, 4D, 4F, 5A, 5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2 b	Land Converted to Cropland	Emissions and removals from lands converted to cropland. Includes conversion of forest land, grassland, wetlands, settlements, and other land to cropland.	5B, 5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2 b i	*Forest Land Converted to Cropland*	Emissions and removals from forest land converted to cropland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2 b ii	*Grassland Converted to Cropland*	Emissions and removals from grassland converted to cropland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2 b iii	*Wetlands Converted to Cropland*	Emissions and removals from wetlands converted to cropland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2 b iv	*Settlements Converted to Cropland*	Emissions and removals from settlements converted to cropland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 2 b v	*Other Land Converted to Cropland*	Emissions and removals from other land converted to cropland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED) CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS			
Category Code and Name	**Definition**	**96 GLs Category Code**	**Gases**
3 B 3 *Grassland*	Emissions and removals from rangelands and pasture land that is not considered cropland. It also includes systems with woody vegetation that fall below the threshold values used in the forest land category and are not expected to exceed them, without human intervention. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, subdivided into managed and unmanaged, consistent with national definitions.	4D, 4E, 5A,5B,5C 5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 3 a Grassland Remaining Grassland	Emissions and removals from grassland remaining grassland.	4D, 4E, 5A,5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 3 b Land Converted to Grassland	Emissions and removals from land converted to grassland.	5B, 5C, 5D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 3 b i *Forest Land Converted to Grassland*	Emissions and removals from forest land converted to grassland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 3 b ii *Cropland Converted to Grassland*	Emissions and removals from cropland converted to grassland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 3 b iii *Wetlands Converted to Grassland*	Emissions and removals from wetlands converted to grassland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 3 b iv *Settlements Converted to Grassland*	Emissions and removals from settlements converted to grassland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 3 b v *Other Land Converted to Grassland*	Emissions and removals from other land converted to grassland.		CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 4 *Wetlands*	Emissions from land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, grassland or settlements categories. The category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.	5A, 5B, 5E, 4D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 4 a Wetlands Remaining Wetlands	Emissions from peatland undergoing peat extraction and from flooded land remaining flooded land.	5A, 5D, 5E, 4D	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 4 a i *Peatlands Remaining peatlands*	Includes (1) on-site emissions from peat deposits during the extraction phase and (2) off-site emissions from horticultural use of peat. The off-site emissions from the energy use of peat are reported in the Energy Sector and are therefore not included in this category.	5A, 5E, 4D	CO_2, CH_4 N_2O, NOx, CO, NMVOC, SO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
3 B 4 a ii	*Flooded Land Remaining Flooded Land*	Emissions from flooded land remaining flooded land. Flooded lands are defined as water bodies where human activities have caused changes in the amount of surface area covered by water, typically through water level regulation. Examples of flooded lands include reservoirs for the production of hydroelectricity, irrigation, navigation, etc. Regulated lakes and rivers that have not experienced substantial changes in water area in comparison with the pre-flooded ecosystem are not considered as flooded lands. Some rice paddies are cultivated through flooding of land, but because of the unique characteristics of rice cultivation, rice paddies are addressed in 3C7.	5A, 5E	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 4 b	Land Converted to Wetlands	Emissions from land being converted for peat extraction from land converted to wetland.	5B, 5E	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 4 b i	*Land Converted for Peat Extraction*	Emissions from land being converted for peat extraction	5B, 5E	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 4 b ii	*Land Converted to Flooded Land*	Emissions from land converted to flooded land	5B, 5E	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 4 b iii	*Land Converted to Other Wetlands*	Emissions from land converted to other wetlands than flooded land and land for peat extraction.	5E	CO_2, CH_4 N_2O, NO_x, CO, NMVOC, SO_2
3 B 5	*Settlements*	Emissions and removals from all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with national definitions.	5A, 5D, 5E, 5B	CO_2
3 B 5 a	Settlements Remaining Settlements	Emissions and removals from settlements that have not undergone any land use change during the inventory period.		CO_2
3 B 5 b	Land Converted to Settlements	Emissions and removals from lands converted to settlements. Includes conversion of forest land, cropland, grassland, wetlands, and other land to settlements.		CO_2
3 B 5 b i	*Forest Land Converted to Settlements*	Emissions and removals from forest land converted to settlements.		CO_2
3 B 5 b ii	*Cropland Converted to Settlements*	Emissions and removals from cropland converted to settlements.		CO_2
3 B 5 b iii	*Grassland Converted to Settlements*	Emissions and removals from grassland converted to settlements.		CO_2
3 B 5 b iv	*Wetlands Converted to Settlements*	Emissions and removals from wetlands converted to settlements.		CO_2
3 B 5 b v	*Other Land Converted to Settlements*	Emissions and removals from other land converted to settlements.		CO_2
3 B 6	*Other Land*	Emissions and removals from bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.		CO_2
3 B 6 a	Other Land Remaining Other Land	Emissions and removals from other land that has not undergone any land use change during the inventory period.		CO_2

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
3 B 6 b	Land Converted to Other Land	Emissions and removals from lands converted to other land. Includes conversion of forest land, cropland, grassland, wetlands, and settlements to other land.		CO_2
3 B 6 b i	*Forest Land Converted to Other Land*	Emissions and removals from forest land converted to other land.		CO_2
3 B 6 b ii	*Cropland Converted to Other Land*	Emissions and removals from cropland converted to other land.		CO_2
3 B 6 b iii	*Grassland Converted to Other Land*	Emissions and removals from grassland converted to other land.		CO_2
3 B 6 b iv	*Wetlands Converted to Other Land*	Emissions and removals from wetlands converted to other land.		CO_2
3 B 6 b v	*Settlements Converted to Other Land*	Emissions and removals from settlements converted to other land.		CO_2
3 C	**Aggregate Sources and Non-CO_2 Emissions Sources on Land**	Includes emissions from activities that are likely to be reported at very high aggregation land level or even country level.		
3 C 1	*Emissions from Biomass Burning*	Emissions from biomass burning that include N_2O and CH_4. CO_2 emissions are included here only if emissions are not included in 3B categories as carbon stock changes.		N_2O, CH_4, CO_2*
3 C 1 a	Biomass Burning in Forest Lands	Emissions from biomass burning that include N_2O and CH_4 in forest lands. CO_2 emissions are included here only if emissions are not included in 3B1 categories as carbon stock changes.		N_2O, CH_4, CO_2*
3 C 1 b	Biomass Burning in Croplands	Emissions from biomass burning that include N_2O and CH_4 in croplands. CO_2 emissions are included here only if emissions are not included in 3B2 categories as carbon stock changes.		N_2O, CH_4, CO_2*
3 C 1 c	Biomass Burning in Grasslands	Emissions from biomass burning that include N_2O and CH_4 in grasslands. CO_2 emissions are included here only if emissions are not included in 3B3 categories as carbon stock changes.		N_2O, CH_4, CO_2*
3 C 1 d	Biomass Burning in All Other Land	Emissions from biomass burning that include N_2O and CH_4 in settlements~~,~~ and all other land. CO_2 emissions are included here only if emissions are not included in 3B6 categories as carbon stock changes.		N_2O, CH_4, CO_2*
3 C 2	*Liming*	CO_2 emissions from the use of lime in agricultural soils, managed forest soils or lakes.		CO_2
3 C 3	*Urea Application*	CO_2 emissions from urea application		CO_2
3 C 4	*Direct N_2O Emissions from Managed Soils*	Direct N_2O emissions from managed soils from the synthetic N fertilizers application; organic N applied as fertilizer (e.g. animal manure, compost, sewage sludge, rendering waste); urine and dung N deposited on pasture, range and paddock by grazing animals; N in crop residues (above and below ground), including from N-fixing crops and from forages during pasture renewal; N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils; and drainage/management of organic soils (i.e., histosols).	4D	N_2O
3 C 5	*Indirect N_2O Emissions from Managed Soils*	Indirect N_2O emissions from: (1) the volatilization of N (as NH_3 and NO_x) following the application of synthetic and organic N fertilizers and /or urine and dung deposition from grazing animals, and the subsequent deposition of the N as ammonium (NH_4+) and oxides of N (NO_x) on soils and waters, and (2) the leaching and runoff of N from synthetic and organic N fertilizer additions, crop residues, mineralization /immobilization of N associated with loss/gain of soil C in mineral soils through land use change or management practices, and urine and dung deposition from grazing animals, into groundwater, riparian areas and wetlands, rivers and eventually the coastal ocean.	4D	N_2O

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
3 C 6	*Indirect N_2O Emissions from Manure Management*	Indirect N_2O emissions from manure management (activity data amount of nitrogen in the manure excreted).		N_2O
3 C 7	*Rice Cultivations*	Methane (CH_4) emissions from anaerobic decomposition of organic material in flooded rice fields. Any N_2O emissions from the use of nitrogen-based fertilizers in rice cultivation should be reported under N_2O emissions from managed soils.	4C	CH_4
3 C 8	*Other (please specify)*	Other sources of CH_4 and N_2O emissions on land.		N_2O, CH_4
3 D	**Other**			
3 D 1	*Harvested Wood Products*	CO_2 net emissions or removals resulting from Harvest Wood Products.		CO_2
3 D 2	*Other (please specify)*			
4 WASTE				CO_2, CH_4, N_2O, NO_x, CO, NMVOC SO_2
4 A	**Solid Waste Disposal**	Methane is produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites. Carbon dioxide (CO_2) is also produced but CO_2 from biogenic or organic waste sources is covered by the AFOLU Sector. Emissions of halogenated gases should be accounted in IPPU. Long-term storage of carbon in SWDS is reported as an information item.	6A	CH_4 N_2O, NO_x, CO, NMVOC
4 A 1	*Managed Waste Disposal Sites*	A managed solid waste disposal site must have controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and fires) and will include at least one of the following: cover material; mechanical compaction; or leveling of the waste. This category can be subdivided into aerobic and anaerobic.	6A 1	CH_4 N_2O, NO_x, CO, NMVOC
4 A 2	*Unmanaged Waste Disposal Sites*	These are all other solid waste disposal sites that do not fall into the above category. This category can be subdivided into deep and shallow.	6A2	CH_4 N_2O, NO_x, NMVOC
4 A 3	*Uncategorised Waste Disposal Sites*	Mixture of above 4 A1 and 4 A2. Countries that do not have data on division of managed/unmanaged may use this category.	NA	CH_4 N_2O, NO_x, NMVOC
4 B	**Biological Treatment of Solid Waste**	Solid waste composting and other biological treatment. Emissions from biogas facilities (anaerobic digestion) with energy production are reported in the Energy Sector (1A4).	6A3	CH_4, N_2O NO_x, CO, NMVOC
4 C	**Incineration and Open Burning of Waste**	Incineration of waste and open burning waste, not including waste-to-energy facilities. Emissions from waste burnt for energy are reported under the Energy Sector, 1A. Emissions from burning of agricultural wastes should be reported under AFOLU (3C1). All non-CO_2 greenhouse gases as well as CO_2 from fossil waste should be reported here for incineration and open burning.	6C	CO_2, CH_4, N_2O, NO_x, CO, NMVOC
4 C 1	*Waste Incineration*	Combustion of solid wastes in controlled incineration facilities.	6C	CO_2, CH_4, N_2O, NO_x, CO, NMVOC
4 C 2	*Open Burning of Waste*	Combustion of waste in the open-air or in an open dump.	NA	CO_2, CH_4, N_2O, NO_x, CO, NMVOC

TABLE 8.2 (CONTINUED)
CLASSIFICATION AND DEFINITION OF CATEGORIES OF EMISSIONS AND REMOVALS

Category Code and Name		Definition	96 GLs Category Code	Gases
4 D	**Wastewater Treatment and Discharge**	Methane is produced from anaerobic decomposition of organic matter by bacteria in sewage facilities and from food processing and other industrial facilities during wastewater treatment. N_2O is also produced by bacteria (denitrification and nitrification) in wastewater treatment and discharge.	6B	CH_4, N_2O NO_x, CO, NMVOC
4 D 1	*Domestic Wastewater Treatment and Discharge*	Treatment and discharge of liquid wastes and sludge from housing and commercial sources (including human waste) through: wastewater sewage systems collection and treatment systems, open pits / latrines, anaerobic lagoons, anaerobic reactors and discharge into surface waters. Emissions from sludge disposed at SWDS are reported under category 4A.	6B2	CH_4, N_2O NO_x, CO, NMVOC
4 D 2	*Industrial Wastewater Treatment and Discharge*	Treatment and discharge of liquid wastes and sludge from industrial processes such as: food processing, textiles, or pulp and paper production. This includes anaerobic lagoons, anaerobic reactors, and discharge into surface waters. Industrial wastewater released into domestic wastewater sewage should be included under 4D1.	6B1	CH_4, N_2O NO_x, CO, NMVOC
4 E	**Other (please specify)**	Release of GHGs from other waste handling activities than listed in categories 4A to 4D.	6D	CO_2, CH_4, N_2O, NO_x, CO, NMVOC
5	**Other**		7	
5 A	Indirect N_2O Emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3	Excluding indirect emissions from NO_x and NH_3 in agriculture which are reported in 3C5 & 3C6.	NA	N_2O
5 B	Other (please specify)	Only use this category exceptionally, for any categories than cannot be accommodated in the categories described above. Include a reference to where a detailed explanation of the category can be found.	7	

(1) Under the *2006 IPCC Guidelines*, emissions from the use of carbonates should be reported in the subcategories (industries) where they occur. Therefore, part of emissions that were reported in 2A3 or 2A4 under the *1996 Guidelines* should be reported in various relevant subcategories (for example 2C1) under the *2006 Guidelines*. In this column of this table, however, the 96GLs Category Code 2A3 and 2A4 are entered not everywhere possibly relevant, for the sake of simplicity.

Note: NA or blank cells under the column '96 GLs category code': categories that are not defined in 1996 Guidelines.

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ANNEX 8A.1

PREFIXES,
UNITS AND ABBREVIATIONS,
STANDARD EQUIVALENTS

Annex 8A.1 Prefixes, units and abbreviations, standard equivalents

Prefixes and multiplication factors

Multiplication Factor	Abbreviation	Prefix	Symbol
1 000 000 000 000 000	10^{15}	peta	P
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^{9}	giga	G
1 000 000	10^{6}	mega	M
1 000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ

Units and abbreviations

cubic metre	m^3
hectare	ha
gram	g
tonne	t
Joule	J
degree Celsius	℃
calorie	cal
year	yr
capita	cap
gallon	gal
dry matter	d.m.
kilogram	kg
pound	lb
atmosphere	atm
Pascal	Pa
hour	h
Watt	W

Units and abbreviations, and standard equivalents

1 tonne of oil equivalent (toe)	1 toe	1 x 10^{10} calories	1 x 10^{10} cal
1 ktoe		41.868 terajoules	41.868 TJ
1 short ton	1 sh t	0.9072 tonne	0.9072 t
1 tonne	1 t	1.1023 short tons	1.1023 sh t
1 tonne	1 t	1 megagram	1 Mg
1 kilotonne	1 kt	1 gigagram	1 Gg
1 megatonne	1 Mt	1 teragram	1 Tg
1 gigatonne	1 Gt	1 petagram	1 Pg
1 kilogram	1 kg	2.2046 pounds	2.2046 lb
1 hectare	1 ha	10^4 squire meters	10^4 m^2
1 $calorie_{IT}$	1 cal_{IT}	4.1868 Joules	4.1868 J
1 atmosphere	1 atm	101.325 kilopascal	101.325 kPa
1 gram	1 g	0.002205 pounds	0.00205 lb
1 pound	1 lb	453.6 gram	453.6 g
1 terajoule	1 TJ	2.78 x 10^5 kiloWatt hour	2.78 x 10^5 kWh
1 kilowatt hour	1 kWh	3.6 x 10^6 Joules	3.6 x 10^6 J

Formulae for chemical compounds

Chemical formula	Gas
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SF_6	Sulphur hexafluoride
NF_3	Nitrogen trifluoride
SF_5CF_3	Trifluoromethyl sulphur pentafluoride
CFCs	Chlorofluorocarbons
CHF_3	HFC-23
CH_2F_2	HFC-32
CH_3F	HFC-41
CHF_2CF_3	HFC-125
CHF_2CHF_2	HFC-134
CH_2FCF_3	HFC-134a
CHF_2CH_2F	HFC-143
CF_3CH_3	HFC-143a
CH_2FCH_2F	HFC-152
CH_3CHF_2	HFC-152a
CH_3CH_2F	HFC-161
CF_3CHFCF_3	HFC-227ea
$CH_2FCF_2CF_3$	HFC-236cb
CHF_2CHFCF_3	HFC-236ea

Formulae for chemical compounds (Continued)

Chemical formula	Gas
$CF_3CH_2CF_3$	HFC-236fa
$CH_2FCF_2CHF_2$	HFC-245ca
$CHF_2CH_2CF_3$	HFC-245fa
$CF_3CH_2CF_2CH_3$	HFC-365mfc
$CF_3CHFCHFCF_2CF_3$	HFC-43-10mee
CF_3OCHF_2	HFE-125
CHF_2OCHF_2	HFE-134
CH_3OCF_3	HFE-143a
$CF_3CHClOCHF_2$	HCFE-235da2
$CF_3CF_2OCH_3$	HFE-245cb2
$CF_3CH_2OCHF_2$	HFE-245fa2
$CHF_2CF_2OCH_3$	HFE-254cb2
$CF_3CF_2CF_2OCH_3$	HFE-347mcc3
$CHF_2CF_2CH_2OCHF_2$	HFE-356pcf3
$CHF_2CF_2OCH_2CH_3$	HFE-374pc2
$C_4F_9OCH_3$	HFE-7100
$C_4F_9OC_2H_5$	HFE-7200
$CHF_2OCF_2OC_2F_4OCHF_2$	H-Galden 1040x
$CHF_2OCF_2OCHF_2$	HG-10
$CHF_2OCF_2CF_2OCHF_2$	HG-01
CF_4	Perfluoromethane
C_2F_6	Perfluoroethane
C_3F_8	Perfluoropropane
C_4F_{10}	Perfluorobutane
$c\text{-}C_4F_8$	Perfluorocyclobutane
C_5F_{12}	Perfluourpentane
C_6F_{14}	Perfluorohexane
$c\text{-}C_3F_6$	Perfluorocyclopropane
$CF_3CHFOCF_3$	HFE-227ea
$CF_3CHFOCHF_2$	HFE-236ea2
$CF_3CH_2OCF_3$	HFE-236fa
$CHF_2CH_2OCF_3$	HFE-245fa1
$CF_3CH_2OCH_3$	HFE-263fb2
$CF_3CF_2OCF_2CHF_2$	HFE-329mcc2
$CF_3CF_2OCH_2CF_3$	HFE-338mcf2
$CF_3CF_2OCH_2CHF_2$	HFE-347mcf2
$CF_3CHFCF_2OCH_3$	HFE-356mec3
$CHF_2CF_2CF_2OCH_3$	HFE-356pcc3
$CHF_2CF_2OCH_2CHF_2$	HFE-356pcf2
$CF_3CF_2CH_2OCH_3$	HFE-365mcf3
CO	Carbon monoxide
NO_X	Nitrogen oxides
NMVOC	Non-methane volatile organic compound
SO_2	Sulphur dioxide
NH_3	Ammonia

ANNEX 8A.2

REPORTING TABLES

Year of the Inventory	
Contact Name	
Country	
Organisation	
Address	
Phone	
Fax	
e-mail	

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Categories	Net CO_2 (1) (2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
	(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
Total National Emissions and Removals												
1 ENERGY												
1A Fuel Combustion Activities												
1A1 Energy Industries												
1A2 Manufacturing Industries and Construction												
1A3 Transport												
1A4 Other Sectors												
1A5 Non-Specified												
1B Fugitive Emissions from Fuels												
1B1 Solid Fuels												
1B2 Oil and Natural Gas												
1B3 Other Emissions from Energy Production												
1C Carbon Dioxide Transport and Storage												
1C1 Transport of CO_2												
1C2 Injection and Storage												

Table A Summary Table (2 of 6)

Categories	Net CO_2 (1) (2)	CH4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
	(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
2 INDUSTRIAL PROCESSES AND PRODUCT USE												
2A Mineral Industry												
2A1 Cement Production												
2A2 Lime Production												
2A3 Glass Production												
2A4 Other Process Uses of Carbonates												
2A5 Other (please specify)												
2B Chemical Industry												
2B1 Ammonia Production												
2B2 Nitric Acid Production												
2B3 Adipic Acid Production												
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production												
2B5 Carbide Production												
2B6 Titanium Dioxide Production												
2B7 Soda Ash Production												
2B8 Petrochemical and Carbon Black Production												
2B9 Fluorochemical Production												
2B10 Other (please specify)												

Table A Summary Table (3 of 6)

Categories		Net CO_2 (1) (2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
		(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
2C	**Metal Industry**												
2C1	Iron and Steel Production												
2C2	Ferroalloys Production												
2C3	Aluminium Production												
2C4	Magnesium Production												
2C5	Lead Production												
2C6	Zinc Production												
2C7	Other (please specify)												
2D	**Non-Energy Products from Fuels and Solvent Use**												
2D1	Lubricant Use												
2D2	Paraffin Wax Use												
2D3	Solvent Use												
2D4	Other (please specify)												
2E	**Electronics Industry**												
2E1	Integrated Circuit or Semiconductor												
2E2	TFT Flat Panel Display												
2E3	Photovoltaics												
2E4	Heat Transfer Fluid												
2E5	Other (please specify)												

Table A Summary Table (4 of 6)

Categories		Net CO_2 (1) (2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
		(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
2F	**Product Uses as Substitutes for Ozone Depleting Substances**												
2F1	Refrigeration and Air Conditioning												
2F2	Foam Blowing Agents												
2F3	Fire Protection												
2F4	Aerosols												
2F5	Solvents												
2F6	Other Applications												
2G	**Other Product Manufacture and Use**												
2G1	Electrical Equipment												
2G2	SF_6 and PFCs from Other Product Uses												
2G3	N_2O from Product Uses												
2G4	Other (please specify)												
2H	**Other (please specify)**												
2H1	Pulp and Paper Industry												
2H2	Food and Beverages Industry												
2H3	Other (please specify)												

Table A Summary Table (5 of 6)

Categories	Net CO_2 (1) (2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
	(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
3 AGRICULTURE, FORESTRY AND OTHER LAND USE												
3A Livestock												
3A1 Enteric Fermentation												
3A2 Manure Management												
3B Land												
3B1 Forest Land												
3B2 Cropland												
3B3 Grassland												
3B4 Wetlands												
3B5 Settlements												
3B6 Other Land												
3C Aggregate Sources and Non-CO_2 Emissions Sources on Land												
3C1 Biomass Burning												
3C2 Liming												
3C3 Urea Application												
3C4 Direct N_2O Emissions from Managed Soils												
3C5 Indirect N_2O Emissions from Managed Soils												
3C6 Indirect N_2O Emissions from Manure Management												
3C7 Rice Cultivations												
3C8 Other (please specify)												
3D Other												
3D1 Harvested Wood Products												
3D2 Other (please specify)												

Table A Summary Table (6 of 6)

Categories	Net CO_2 (1) (2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
	(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
4 WASTE												
4A Solid Waste Disposal												
4B Biological Treatment of Solid Waste												
4C Incineration and Open Burning of Waste												
4D Wastewater Treatment and Discharge												
4E Other (please specify)												
5 OTHER												
5A Indirect N_2O Emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3												
5B Other (please specify)												
Memo items (5)												
International Bunkers												
International Aviation (International Bunkers)												
International Water-borne Transport (International Bunkers)												
Multilateral Operations												

(1) CO_2 net emissions (emissions minus removals)

(2) Total amount of CO_2 captured for long-term storage is to be reported separately for domestic storage and for export in the documentation box.

(3) The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this column. Such gases should be reported in the column 'Other halogenated gases without CO_2 equivalent conversion factors'.

(4) When this column is used, gases should be listed separately (in IPPU Background Tables and Table 2.11) and the name of the gas should be given in the documentation box.

(5) Emissions that are not included in the national total should be reported as memo items.

* Cells to report emissions of NO_x, CO, NMVOC and SO_2 have not been shaded although the physical potential for emissions is lacking for some categories.

Documentation box:

Table B Short Summary Table (1 of 2)

Categories	Net CO_2 (1) (2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
	(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
Total National Emissions and Removals												
1 ENERGY												
1A Fuel Combustion Activities												
1B Fugitive Emissions from Fuels												
1C Carbon Dioxide Transport and Storage												
2 INDUSTRIAL PROCESSES AND PRODUCT USE												
2A Mineral Industry												
2B Chemical Industry												
2C Metal Industry												
2D Non-Energy Products from Fuels and Solvent Use												
2E Electronics Industry												
2F Product Uses as Substitutes for Ozone Depleting Substances												
2G Other Product Manufacture and Use												
2H Other												
3 AGRICULTURE, FORESTRY AND OTHER LAND USE												
3A Livestock												
3B Land												
3C Aggregate Sources and Non-CO_2 Emissions Sources on Land												
3D Other												
4 WASTE												
4A Solid Waste Disposal												
4B Biological Treatment of Solid Waste												

Table B Short Summary Table (2 of 2)

Categories		Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
		(Gg)			CO_2 equivalents (Gg)				(Gg)	(Gg)			
4C	Incineration and Open Burning of Waste												
4D	Wastewater Treatment and Discharge												
4E	Other (please specify)												
5 OTHER													
5A	Indirect N_2O emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3												
5B	Other (please specify)												
Memo items (5)													
International Bunkers													
	International Aviation (International Bunkers)												
	International Water-borne Transport (International Bunkers)												
	Multilateral Operations												

(1) CO_2 net emissions (emissions minus removals)

(2) Total amount of CO_2 captured for long-term storage is to be reported separately for domestic storage and for export in the documentation box.

(3) The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this column. Such gases should be reported in the column 'Other halogenated gases without CO_2 equivalent conversion factors'.

(4) When this column is used, gases should be listed separately in IPPU Background Tables and Table 2.11 and the name of the gas should be given in the documentation box.

(5) Emissions that are not included in the national total should be reported as memo items.

* Cells to report emissions of NO_x, CO, NMVOC and SO_2 have not been shaded although the physical potential for emissions is lacking for some categories.

Documentation box:

Table 1 Energy Sectoral Table (1 of 3)

Categories		CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
		(Gg)						
1 ENERGY								
1A	**Fuel Combustion Activities**							
1A1	**Energy Industries**							
1A1 a	Main Activity Electricity and Heat Production							
1A1 ai	Electricity Generation							
1A1 aii	Combined Heat and Power Generation (CHP)							
1A1 aiii	Heat Plants							
1A1 b	Petroleum Refining							
1A1 c	Manufacture of Solid Fuels and Other Energy Industries							
1A1 ci	Manufacture of Solid Fuels							
1A1 cii	Other Energy Industries							
1A2	**Manufacturing Industries and Construction**							
1A2 a	Iron and Steel							
1A2 b	Non-Ferrous Metals							
1A2 c	Chemicals							
1A2 d	Pulp, Paper and Print							
1A2 e	Food Processing, Beverages and Tobacco							
1A2 f	Non-Metallic Minerals							
1A2 g	Transport Equipment							
1A2 h	Machinery							
1A2 i	Mining (excluding fuels) and Quarrying							
1A2 j	Wood and Wood Products							
1A2 k	Construction							
1A2 l	Textile and Leather							
1A2 m	Non-specified Industry							
1A3	**Transport**							
1A3 a	Civil Aviation							
1A3 ai	International Aviation (International Bunkers) [1]							
1A3 aii	Domestic Aviation							
1A3 b	Road Transportation							
1A3 bi	Cars							
1A3 bi	Passenger Cars with 3-way Catalysts							
1A3 bi2	Passenger Cars without 3-way Catalysts							
1A3 bii	Light-duty Trucks							
1A3 bii1	Light-duty Trucks with 3-way Catalysts							
1A3 bii2	Light-duty Trucks without 3-way Catalysts							
1A3 biii	Heavy-duty Trucks and Buses							
1A3 biv	Motorcycles							
1A3 bv	Evaporative Emissions from Vehicles							
1A3 bvi	Urea-based Catalysts							
1A3 c	Railways							
1A3 d	Water-borne Navigation							
1A3 di	International Water-borne Navigation (International Bunkers) [1]							
1A3 dii	Domestic Water-borne Navigation							
1A3 e	Other Transportation							
1A3 ei	Pipeline Transport							
1A3 eii	Off-road							
1A4	**Other Sectors**							
1A4 a	Commercial/Institutional							
1A4 b	Residential							

Table 1 Energy Sectoral Table (2 of 3)

Categories		CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
		(Gg)						
1A4 c	Agriculture/Forestry/Fishing/Fish Farms							
1A4 ci	Stationary							
1A4 cii	Off-road Vehicles and Other Machinery							
1A4 ciii	Fishing (mobile combustion)							
1A5	**Non-Specified**							
1A5 a	Stationary							
1A5 b	Mobile							
1A5 bi	Mobile (aviation component)							
1A5 bii	Mobile (water-borne component)							
1A5 biii	Mobile (other)							
1A5 c	Multilateral Operations (1) (2)							
1B	**Fugitive Emissions from Fuels**							
1B1	**Solid Fuel**							
1B1 a	Coal Mining and Handling							
1B1 ai	Underground Mines							
1B1 ai1	Mining							
1B1 ai2	Post-mining Seam Gas Emissions							
1B1 ai3	Abandoned Underground Mines							
1B1 ai4	Flaring of Drained Methane or Conversion of Methane to CO_2							
1B1 aii	Surface Mines							
1B1 aii1	Mining							
1B1 aii2	Post-mining Seam Gas Emissions							
1B1 b	Uncontrolled Combustion, and Burning Coal Dumps							
1B1 c	Solid Fuel Transformation							
1B2	**Oil and Natural Gas**							
1B2 a	Oil							
1B2 ai	Venting							
1B2 aii	Flaring							
1B2 aiii	All Other							
1B2 aiii1	Exploration							
1B2 aiii2	Production and Upgrading							
1B2 aiii3	Transport							
1B2 aiii4	Refining							
1B2 aiii5	Distribution of Oil Products							
1B2 aiii6	Others							
1B2 b	Natural Gas							
1B2 bi	Venting							
1B2 bii	Flaring							
1B2 biii	All Other							
1B2 biii1	Exploration							
1B2 biii2	Production							
1B2 biii3	Processing							
1B2 biii4	Transmission and Storage							
1B2 biii5	Distribution							
1B2 biii6	Others							
1B3	**Other Emissions from Energy Production**							
1C	**Carbon Dioxide Transport and Storage**							
1C1	**Transport of CO_2**							
1C1 a	Pipelines							
1C1 b	Ships							
1C1 c	Other (Please specify)							
1C2	**Injection and Storage**							
1C2 a	Injection							
1C2 b	Storage							

Table1 Energy Sectoral Table (3 of 3)

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
	(Gg)						
Memo items [(3)]							
International Bunkers							
International Aviation (International Bunkers)							
International Water-borne Transport (International Bunkers)							
Multilateral Operations							
Information items							
CO_2 from Biomass Combustion for Energy Production							

(1) To be reported as a memo item, and not part of the national inventory.

(2) Multilateral operations pursuant to the Charter of the United Nations: including emissions from fuel delivered to the military in the country and delivered to the military of other countries.

(3) Emissions that are not included in the national total should be reported as memos.

* Cells to report emissions of NO_x, CO, NMVOC and SO_2 have not been shaded although the physical potential for emissions is lacking for some categories

Documentation box:

Table 1.1 Energy Background Table: 1A1-1A2 (1 of 2)

Categories	Activity (TJ)						Emissions (Gg)																				Information item[2] (Gg)	
							Solid			Liquid			Gas			Other fossil fuel			Peat[1]			Biomass		Total			CO_2 amount captured[3]	Biomass
	Solid	Liquid	Gas	Other fossil fuel	Peat	Bio-mass	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CO_2 emitted
1A Fuel Combustion Activities																												
1A1 Energy Industries																												
1A1a Main Activity Electricity and Heat Production																												
1A1ai Electricity Generation																												
1A1aii Combined Heat and Power Generation (CHP)																												
1A1aiii Heat Plants																												
1A1b Petroleum Refining																												
1A1c Manufacture of Solid Fuels and Other Energy Industries																												
1A1ci Manufacture of Solid Fuels																												
1A1cii Other Energy Industries																												
1A2 Manufacturing Industries and Construction																												
1A2a Iron and Steel																												
1A2b Non-Ferrous Metals																												
1A2c Chemicals																												
1A2d Pulp, Paper and Print																												
1A2e Food Processing, Beverages and Tobacco																												
1A2f Non-Metallic Minerals																												
1A2g Transport Equipment																												

Table 1.1 Energy Background Table: 1A1-1A2 (2 of 2)

Categories	Activity (TJ)						Emissions (Gg)																				Information item[2] (Gg)	
							Solid			Liquid			Gas			Other fossil fuel			Peat[1]			Biomass		Total			CO_2 Amount captured[3]	Biomass
	Solid	Liquid	Gas	Other fossil fuel	Peat	Bio-mass	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CO_2 emitted
1A2h Machinery																												
1A2i Mining and Quarrying																												
1A2j Wood and Wood Products																												
1A2k Construction																												
1A2l Textile and Leather																												
1A2m Non-specified Industry																												

(1) Although peat is not strictly speaking a fossil fuel, the CO_2 emissions from combustion of peat are included in the national emissions as for fossil fuels. See Chapter 1 of Energy Volume, page 1.15.

(2) Information items that are not themselves emissions, therefore not included in the national total. The carbon should be converted to carbon dioxide. It is subtracted in the CO_2 emission columns (net emissions). Only CO_2 captured for permanent storage in geological reservoirs should be subtracted.

(3) Enter the amount of CO_2 captured as a negative number since this amount is subtracted from total CO_2 produced.

Documentation box:

Table 1.2 Energy Background Table: 1A3-1A5 (1 of 2)

Category	Activity (TJ)						Emissions (Gg)																	Total emissions (Gg)		
							Solid			Liquid			Gas			Other fossil fuel			Peat[1]			Biomass				
	Solid	Liquid	Gas	Other fossil fuel	Peat	Bio-mass	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CH_4	N_2O	CO_2	CH_4	N_2O
1A3 Transport																										
1A3a Civil Aviation																										
1A3ai International Aviation (International Bunkers) [2]																										
1A3aii Domestic Aviation																										
1A3b Road Transportation																										
1A3bi Cars																										
1A3bi1 Passenger Cars with 3-way catalysts																										
1A3bi2 Passenger Cars without 3-way Catalysts																										
1A3bii Light-duty Trucks																										
1A3bii1 Light-duty Trucks with 3-way Catalysts																										
1A3bii2 Light-duty Trucks without 3-way Catalysts																										
1A3biii Heavy-duty Trucks and Buses																										
1A3biv Motorcycles																										
1A3bv Evaporative Emissions from Vehicles																										
1A3bvi Urea based Catalyst [3]																										
1A3c Railways																										
1A3d Water-borne Navigation																										
1A3di International Water-borne Navigation (International Bunkers) [2]																										
1A3dii Domestic Water-borne Transport																										
1A3e Other Transportation																										
1A3ei Pipeline Transport																										
1A3eii Off-road																										
1A4 Other Sectors																										
1A4a Commercial/Institutional																										
1A4b Residential																										
14Ac Agriculture/Forestry/Fishing/Fish Farms																										
1A4ci Stationary																										
1A4cii Off-road Vehicles and Other Machinery																										
1A4ciii Fishing (mobile combustion)																										

Table 1.2 Energy Background Table: 1A3-1A5 (2 of 2)

Category	Activity (TJ)						Emissions (Gg)																	Total emissions (Gg)		
							Solid			Liquid			Gas			Other fossil fuel			Peat[1]			Biomass				
	Solid	Liquid	Gas	Other fossil fuel	Peat	Bio-mass	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CH_4	N_2O	CO_2	CH_4	N_2O
1A5 Non-Specified																										
1A5a Stationary																										
1A5b Mobile																										
1A5bi Mobile (aviation component)																										
1A5bii Mobile (water-borne component)																										
1A5biii Mobile (other)																										
1A5c Multilateral Operation																										
Memo items [4]																										
International Bunkers																										
International Aviation (International Bunkers)																										
International Water-borne Transport (International Bunkers)																										
Multilateral Operations [5]																										

(1) Although peat is not strictly speaking a fossil fuel, the CO_2 emissions from combustion of peat are included in the national emissions as for fossil fuels. See Chapter 1 of Energy Volume, page 1.15.

(2) To be reported as a memo item, and not part of the national inventory.

(3) Report the amount of urea-based additive used and its purity in the documentation box.

(4) Emissions that are not included in the national total should be reported as memo items.

(5) Multilateral operations pursuant to the Charter of the United Nations: including emissions from fuel delivered to the military in the country and delivered to the military of other countries.

Documentation box:

Table 1.3 Energy Background Table: 1B

Category		Activity Data			Emissions (Gg)			Information item: Amount captured (2) (Gg)
		Description	Unit (1)	Value	CO_2	CH_4	N_2O	CO_2
1B Fugitive Emissions from Fuels								
1B1 Solid Fuel								
1B1a	Coal Mining and Handling							
1B1ai	Underground Mines	coal produced	ktonnes					
1B1ai1	Mining	coal produced	ktonnes					
1B1ai2	Post mining Seam Gas Emissions	coal produced	ktonnes					
1B1ai3	Abandoned Underground Mines	number of mines	number					
1B1ai4	Flaring of Drained Methane or Conversion of CH_4 to CO_2	gas flared	10^6 Sm^3					
1B1aii	Surface Mines							
1B1aii1	Mining	coal produced	ktonnes					
1B1aii2	Post-mining Seam Gas Emissions	coal produced	ktonnes					
1B1b	Uncontrolled Combustion, and Burning Coal Dumps	solid fuel combusted	ktonnes					
1B1c	Solid fuel Transformation	solid fuel transformed	ktonnes					
1B2 Oil and Natural Gas								
1B2a	Oil							
1B2ai	Venting	total gas vented from oil production	10^6 Sm^3					
1B2aii	Flaring	gas flared from oil production	10^6 Sm^3					
1B2aiii	All other							
1B2aiii1	Exploration	wells drilled	number					
1B2aiii2	Production and Upgrading	oil produced	10^3 m^3					
1B2aiii3	Transport	crude oil transported	10^3 m^3					
1B2aiii4	Refining	refinery crude oil throughput	10^3 m^3					
1B2aiii5	Distribution of Oil Products	amount distributed	10^3 m^3					
1B2biii6	Others							
1B2b	Natural Gas							
1B2bi	Venting	Total gas vented from natural gas production	10^6 Sm^3					
1B2bii	Flaring	gas flared from natural gas production	10^6 Sm^3					
1B2biii	All Other							
1B2biii1	Exploration	number wells drilled	number					
1B2biii2	Production	Gas produced	10^6 Sm^3					
1B2biii3	Processing	Amount of gas processed at facilities	10^6 Sm^3					
1B2biii4	Transmission and Storage	Amount transported and stored	10^6 Sm^3					
1B2biii5	Distribution	Amount of gas distributed	10^3 m^3					
1B2biii6	Others							
1B3 Other Emissions from Energy Production								

(1) The units given here are the most commonly used for respective activity data. For convenience and/or consistency, they can be converted into appropriate energy units.

(2) The amount of CO_2 captured is given for information purposes; it is subtracted in the CO_2 emission columns (net emissions).

Documentation box:

Table 1.4a Energy Background Table: 1C CO_2 Transport, Injection and Storage

Category	Activity (Gg)		Annual mass of fugitive CO_2 emissions to the atmosphere or sea bed (Gg) (2)
	Annual mass of CO_2 transported	Annual mass of CO_2 injected (1)	
1C1 Transport of CO_2			
1C1a Pipelines			
1C1b Ships			
1C1c Other (please specify)			
1C2 Injection and Storage (3)			
1C2a Injection			
1C2b Storage			
1C3 Other			

(1) Excluding recycled CO_2 for enhanced recovery.

(2) Corrected for baseline background fluxes.

(3) Fugitive emissions during above ground operations such as processing and CO_2 recycling during enhanced oil and gas recovery operations should be reported as fugitive emissions from oil and natural gas and reported under the appropriate categories for that sector.

Documentation box:

Table 1.4b Energy Background Table: 1C CO_2 Transport, Injection and Storage - Overview

Category (1)	CO_2 (Gg)
Total amount captured for storage (A)	
Total amount of import for storage (B)	
Total amount of export for storage (C)	
Total amount of CO_2 injected at storage sites (D)	
Total amount of leakage during transport (E1) category 1C1	
Total amount of leakage during injection (E2) category 1C2a	
Total amount of leakage from storage sites (E3) category 1C2b	
Total leakage (E4 = E1 + E2 + E3))	
Capture + imports (F = A + B)	
Injection + leakage + exports (G = D + E4 + C)	
Discrepancy (F – G)	

(1) Once captured, there is no differentiated treatment between biogenic carbon and fossil carbon. Emissions and storage of both biogenic and fossil carbons will be estimated and reported.

Documentation box:

Table 1.5 Energy Background Table: Reference Approach (1 of 1)

Fuel Types			Production	Import	Export	International bunkers	Stock change	Apparent consumption	Conversion factor	Apparent consumption	Carbon emission factor	Carbon content	Carbon content	Excluded carbon	Net carbon emission	Fraction of carbon oxidised	Actual carbon emission	CO_2 emission
			(Unit)	(Unit)	(Unit)	(Unit)	(Unit)	(Unit)	(TJ/Unit)	(TJ)	(tC/TJ)	(t C)	(Gg C)	(Gg C)	(Gg C)		(Gg C)	(Gg CO_2)
Liquid Fossil	Primary Fuels	Crude Oil																
		Orimulsion																
		Natural Gas Liquids																
	Secondary Fuels	Gasoline																
		Jet Kerosene																
		Other Kerosene																
		Shale Oil																
		Gas / Diesel Oil																
		Residual Fuel Oil																
		LPG																
		Ethane																
		Naphtha																
		Bitumen																
		Lubricants																
		Petroleum Coke																
		Refinery Feedstocks																
		Other Oil																
Liquid Fossil Totals																		
Solid Fossil	Primary Fuels	Anthracite(1)																
		Coking Coal																
		Other Bit. Coal																
		Sub-bit. Coal																
		Lignite																
		Oil Shale and Tar Sands																
	Secondary Fuels	BKB & Patent Fuel																
		Coke Oven/Gas Coke																
		Coal Tar																
Solid Fossil Totals																		
Gaseous Fossil	Natural Gas (Dry)																	
Other Fossil Fuels																		
Peat(2)																		
Total																		

(1) If anthracite is not separately available, include with Other Bituminous Coal.

(2) Although peat is not strictly speaking a fossil fuel, the CO_2 emissions from combustion of peat are included in the national emissions as for fossil fuels. See Chapter 1 of Energy Volume, page 1.15.

Documentation box:

Table 2 IPPU Sectoral Table (1 of 2) (See Volume 3, Chapter 1, Table 1.1.)

Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (1)	Other halogenated gases without CO_2 equivalent conversion factors (2)	NO_x	CO	NMVOCs	SO_2
	(Gg)			CO_2 equivalents (Gg)				(Gg)				
2 INDUSTRIAL PROCESSES AND PRODUCT USE												
2A Mineral Industry												
2A1 Cement Production												
2A2 Lime Production												
2A3 Glass Production												
2A4 Other Process Uses of Carbonates												
2A4a Ceramics												
2A4b Other Uses of Soda Ash												
2A4c Non Metallurgical Magnesia Production												
2A4d Other (please specify) (3)												
2A5 Other (please specify) (3)												
2B Chemical Industry												
2B1 Ammonia Production												
2B2 Nitric Acid Production												
2B3 Adipic Acid Production												
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production												
2B5 Carbide Production												
2B6 Titanium Dioxide Production												
2B7 Soda Ash Production												
2B8 Petrochemical and Carbon Black Production												
2B8a Methanol												
2B8b Ethylene												
2B8c Ethylene Dichloride and Vinyl Chloride Monomer												
2B8d Ethylene Oxide												
2B8e Acrylonitrile												
2B8f Carbon Black												
2B9 Fluorochemical Production												
2B9a By-product Emissions (4)												
2B9b Fugitive Emissions (4)												
2B10 Other (please specify) (3)												
2C Metal Industry												
2C1 Iron and Steel Production												
2C2 Ferroalloys Production												
2C3 Aluminium Production												
2C4 Magnesium Production (5)												
2C5 Lead Production												
2C6 Zinc Production												
2C7 Other (please specify) (3)												
2D Non-Energy Products from Fuels and Solvent Use (6)												
2D1 Lubricant Use												
2D2 Paraffin Wax Use												
2D3 Solvent Use (7)												
2D4 Other (please specify) (3), (8)												
2E Electronics Industry												
2E1 Integrated Circuit or Semiconductor (9)												
2E2 TFT Flat Panel Display (9)												
2E3 Photovoltaics (9)												
2E4 Heat Transfer Fluid (10)												
2E5 Other (please specify) (3)												
2F Product Uses as Substitutes for Ozone Depleting Substances												
2F1 Refrigeration and Air Conditioning												
2F1a Refrigeration and Stationary Air Conditioning												

Table 2 IPPU Sectoral Table (2 of 2)

Category	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (1)	Other halogenated gases without CO_2 equivalent conversion factors (2)	NO_x	CO	NMVOCs	SO_2
	(Gg)			CO_2 equivalents (Gg)				(Gg)				
2F1b Mobile Air Conditioning												
2F2 Foam Blowing Agents												
2F3 Fire Protection												
2F4 Aerosols												
2F5 Solvents												
2F6 Other Applications (3)												
2G Other Product Manufacture and Use												
2G1 Electrical Equipment												
2G1a Manufacture of Electrical Equipment												
2G1b Use of Electrical Equipment												
2G1c Disposal of Electrical Equipment												
2G2 SF_6 and PFCs from Other Product Uses												
2G2a Military Applications												
2G2b Accelerators												
2G2c Other (please specify)(3)												
2G3 N_2O from Product Uses												
2G3a Medical Applications												
2G3b Propellant for Pressure and Aerosol Products												
2G3c Other (please specify)(3)												
2G4 Other (please specify)(3)												
2H Other												
2H1 Pulp and Paper Industry												
2H2 Food and Beverages Industry												
2H3 Other (please specify) (3)												

(1) The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this column. Such gases should be reported in the column "Other halogenated gases without CO_2 equivalent conversion factors".

(2) When this column is used, gases should be listed separately (in IPPU background tables and Table 2.11) and the name of the gas should be given in the documentation box. Insert additional columns if necessary.

(3) Insert additional rows if needed

(4) The "Other halogenated gases" are fluorinated alcohols, fluorinated ethers, NF_3, SF_5CF_3.

(5) Small amounts of CO_2 used as a diluent for SF_6 and emitted during magnesium processing is considered insignificant and is usually counted elsewhere. The "Other halogenated gases" here mainly comprise fluorinated ketones.

(6) Emissions from feedstock uses in petrochemical industry should be addressed in 2B8 (Petrochemical and Carbon Black Production). Emissions from some product uses should be allocated to each industry source category (e.g., CO_2 from carbon anodes and electrodes → 2C (Metal Industry)).

(7) Only NMVOC emissions and no direct GHGs are relevant to this category.

(8) Emissions from asphalt production, and paving of roads and roofing are included here.

(9) "Other halogenated gases" are NF_3, c-C_4F_8O, etc.

(10) The "Other halogenated gases" here include $C_4F_9OC_2H_5$ (HFE-7200), $CHF_2OCF_2OC_2F_4OCHF_2$ (H-Galden 1040x), $CHF_2OCF_2OCHF_2$ (HG-10), etc.

* Cells to report emissions of NO_x, CO, NMVOC and SO_2 have not been shaded although the physical potential for emissions is lacking for some categories.

Documentation box:

Table 2.1 IPPU Background Table: 2A Mineral Industry, 2B (2B1-2B8, 2B10) Chemical Industry - CO_2, CH_4 and N_2O

Categories	Activity data			Emissions						
	Production/Consumption quantity			CO_2 (Gg)			CH_4 (Gg)		N_2O (Gg)	
	Description (1)	Quantity	Unit (2)	Emissions (3)	Information item Captured and Stored (4)	(memo) Other Reduction (5)	Emissions (3)	Information item Reduction (6)	Emissions (3)	Information item Reduction (6)
2A Mineral Industry										
2A1 Cement production										
2A2 Lime production										
2A3 Glass Production										
2A4 Other Process Uses of Carbonates (7)										
2A4a Ceramics										
2A4b Other Uses of Soda Ash										
2A4c Non Metallurgical Magnesia Production										
2A4d Other										
2A5 Other (please specify) (8)										
2B Chemical Industry										
2B1 Ammonia Production										
2B2 Nitric Acid Production										
2B3 Adipic Acid Production										
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production										
2B5 Carbide Production										
2B6 Titanium Dioxide Production										
2B7 Soda Ash Production										
2B8 Petrochemical and Carbon Black Production										
2B8a Methanol										
2B8b Ethylene										
2B8c Ethylene Dichloride and Vinyl Chloride Monomer										
2B8d Ethylene Oxide										
2B8e Acrylonitrile										
2B8f Carbon Black										
2B10 Other (please specify) (8)										

(1) Where the options for activity data, e.g., cement or clinker or carbonates for estimating the emissions from Cement Production, specify the activity data used in order to make the choice of emission factor more transparent.

(2) Unit of activity data should be specified.

(3) Enter the reported emissions (adjusted with captured and/or reduced amount).

(4) Where generated CO_2 is captured for injection into a storage, the captured amount should be reported here. These data are provided as the additional information. They are not emissions, therefore should not be included in the national total.

(5) Where reduction of generated CO_2 except for capture and storage occurs (e.g., re-conversion to carbonates) and its amount is available, it should be reported here.

(6) Enter the quantities of reduction of generated gas (emission recovery, destruction, etc.)

(7) Report here only the emissions from carbonate uses not covered in other categories.

(8) Insert additional rows if necessary.

Note: Where information is confidential the entries should provide notation key "C" but there should be a note indicating this in the documentation box below. Also, More specific information could be provided in the documentation box.

Documentation box:

Table 2.2 IPPU Background Table: 2B (2B9 - 2B10) Chemical Industry
HFCs, PFCs, SF_6 and other halogenated gases

Categories	HFC-23	HFC-32	HFC-41	HFC-125	HFC-134	HFC-134a	HFC-143	HFC-143a	HFC-152	HFC-152a	HFC-161	HFC-227ea	HFC-236cb	HFC-236ea	HFC-236fa	HFC-245ca	HFC-245fa	HFC-365mfc	HFC-43-10mee	Other HFCs [(2)] (please specify)	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	$c\text{-}C_4F_8$	C_5F_{12}	C_6F_{14}	Other PFCs [(2)] (please specify)	Total PFCs	SF_6	Other halogenated gases [(2)] (please specify)
CO_2 equivalent conversion factors[(1)] [Source of the factor:]																															
Emissions in original mass unit (tonne)																															
2B9 Fluorochemical Production																															
2B9a By-product Emissions [(3)]																															
(information) Reduced amount [(4)]																															
2B9b Fugitive Emissions [(3)]																															
(information) Reduced amount [(4)]																															
2B10 Other (please specify) [(5)]																															
Emissions in CO_2 equivalent unit ($Gg\text{-}CO_2$)																															
2B9 Fluorochemical Production																															
2B9a By-product Emissions																															
2B9b Fugitive Emissions																															
2B10 Other (please specify) [(5)]																															

(1) Typically, global warming potential (100 year time horizon) identified in the IPCC Assessment Report can be used. The source of the factors must be specified in the bracket.

(2) Insert additional columns if necessary. The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this table. Such gases should be reported in Table 2.11 IPPU background table: Greenhouse Gases without CO_2 equivalent conversion factors.

(3) Enter the reported emissions (adjusted with captured and/or reduced amount).

(4) Enter the quantities of reduction of generated gas (emission recovery, destruction, etc.).

(5) Insert additional rows if necessary.

Note: Where information is confidential the entries should provide aggregate figures but there should be a note indicating this in the documentation box below.

Documentation box:

Table 2.3 IPPU Background Table: 2C Metal Industry CO_2, CH_4 and N_2O

Categories	Activity Data			Emissions						
	Production/Consumption quantity			CO_2 (Gg)			CH_4 (Gg)		N_2O (Gg)	
	Description [(1)]	Quantity	Unit [(2)]	Emissions [(3)]	(information) Captured and Stored [(4)]	(information) Other Reduction [(5)]	Emissions [(3)]	(information) Reduction [(6)]	Emissions [(3)]	(information) Reduction [(6)]
2C Metal Industry										
2C1 Iron and Steel Production										
2C2 Ferroalloys Production										
2C3 Aluminium Production										
2C4 Magnesium Production										
2C5 Lead Production										
2C6 Zinc Production										
2C7 Other (please specify) [(7)]										

(1) Where the options for activity data, e.g. steel production or process materials consumption for estimating the emissions from Iron and Steel Production, specify the activity data used in order to make the choice of emission factor more transparent.

(2) Unit of activity data should be specified.

(3) Enter the reported emissions (adjusted with captured and/or reduced amount).

(4) Where generated CO_2 is captured for injection into a storage, the captured amount should be reported here. These data are provided as the additional information. They are not emissions, therefore should not be included in the national total.

(5) Where reduction of generated CO_2 except for capture and storage occurs and its amount is available, it should be reported here.

(6) Enter the quantities of reduction of generated gas (emission recovery, destruction, etc.).

(7) Insert additional rows if necessary.

Note: Where information is confidential the entries should provide notation key “C” but there should be a note indicating this in the documentation box below. Also, More specific information (e.g. data on virgin and recycled steel production) could be provided in the documentation box.

Documentation box:

Table 2.4 IPPU Background Table: 2C (2C3, 2C4, 2C7) Metal Industry HFCs, PFCs, SF_6 and other halogenated gases

Categories	HFC-134a	Other HFCs (2) (please specify)	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	$c\text{-}C_4F_8$	C_5F_{12}	C_6F_{14}	Other PFCs (2) (please specify)	Total PFCs	SF_6	Other halogenated gases (2) (please specify)
CO_2 equivalent conversion factors (1) [Source of the factor:]														
Emissions in original mass unit (tonne)														
2C3 Aluminium Production (3)														
(information) Reduced amount (4)														
2C4 Magnesium Production (3)														
(information) Reduced amount (4)														
2C7 Other Metals (please specify) (5)														
(information) Reduced amount (4)														
Emissions in CO_2 equivalent unit (Gg-CO_2)														
2C3 Aluminium Production														
2C4 Magnesium Production														
2C7 Other (please specify) (5)														

(1) Typically, global warming potential (100 year time horizon) identified in the IPCC Assessment Report can be used. The source of the factors must be specified in the bracket.

(2) Insert additional columns if necessary. The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this table. Such gases should be reported in Table 2.11 IPPU background table: Greenhouse Gases without CO_2 equivalent conversion factors.

(3) Enter the reported emissions (adjusted with captured and/or reduced amount).

(4) Enter the quantities of reduction of generated gas (emission recovery, destruction, etc.).

(5) Insert additional rows if necessary.

Note: Where information is confidential the entries should provide aggregate figures but there should be a note indicating this in the documentation box below.

Documentation box:

Table 2.5 IPPU Background Table: 2D Non-Energy Products from Fuels and Solvent Use
CO_2, CH_4 and N_2O

Categories	Activity Data			Emissions		
	Production/Consumption quantity			CO_2	CH_4	N_2O
	Description	Quantity	Unit	(Gg)	(Gg)	(Gg)
2D Non-Energy Products from Fuels and Solvent Use						
2D1 Lubricant Use	Lubricant consumption		tonne			
2D2 Paraffin Wax Use	Wax consumption		tonne			
2D3 Solvent Use						
2D4 Other						
Product (please specify)						
Product (please specify)						
Product (please specify) (1)						

(1) Insert additional rows if necessary.

Documentation box:

Table 2.6 IPPU Background Table: 2E Electronics Industry HFCs, PFCs, SF_6 NF_3 and other halogenated gases

Categories	CO_2 (2)	N_2O (2)	HFC-23	HFC-32	Other HFCs (3) (please specify)	Total HFCs	CF_4	C_2F_6	C_3F_8	$c\text{-}C_4F_8$	Other PFCs (3) (please specify)	Total PFCs	SF_6	NF_3	Other halogenated gases (3) (please specify)
CO_2 equivalent conversion factors (1) **[Source of the factor:]**															
Emissions in original mass unit (tonne)															
2E Electronics Industry															
2E1 Integrated Circuit or Semiconductor															
2E2 TFT Flat Panel Display															
2E3 Photovoltaics															
2E4 Heat Transfer Fluid															
2E5 Other (please specify) (4)															
Emissions in CO_2 equivalent unit (Gg-CO_2)															
2E Electronics Industry															
2E1 Integrated Circuit or Semiconductor															
2E2 TFT Flat Panel Display															
2E3 Photovoltaics															
2E4 Heat Transfer Fluid															
2E5 Other (please specify) (3)															

(1) Typically, global warming potential (100 year time horizon) identified in the IPCC Assessment Report can be used. The source of the factors must be specified in the bracket.

(2) Emissions may occur but no methodological guidance is provided in these Guidelines.

(3) Insert additional columns if necessary. The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this table. Such gases should be reported in Table 2.11 IPPU background table: Greenhouse gases without CO_2 equivalent conversion factors.

(4) Insert additional rows if necessary.

Note: Where information is confidential the entries should provide aggregate figures but there should be a note indicating this in the documentation box below.

Documentation box:

Table 2.7 IPPU Background Table: 2F Product Uses as Substitutes for Ozone Depleting Substances HFCs, PFCs and other halogenated gases

Categories	CO_2 (2)	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea	HFC-236fa	HFC-245fa	HFC-365mfc	HFC-43-10mee	Other HFCs (3) (please specify)	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	Other PFCs (3) (please specify)	Total PFCs	Other halogenated gases (3) (please specify)
CO_2 equivalent conversion factors(1) [Source of the factor:]																					
Emissions in original mass unit (tonne)																					
2F Product Uses as Substitutes for Ozone Depleting Substances																					
2F1 Refrigeration and Air Conditioning																					
2F1a Refrigeration and Stationary Air Conditioning																					
2F1b Mobile Air Conditioning																					
2F2 Foam Blowing Agents																					
2F3 Fire Protection																					
2F4 Aerosols																					
2F5 Solvents																					
2F6 Other Applications(4)																					
Emissions in CO_2 equivalent unit (Gg-CO_2)																					
2F Product Uses as Substitutes for Ozone Depleting Substances																					
2F1 Refrigeration and Air Conditioning																					
2F1a Refrigeration and Stationary Air Conditioning																					
2F1b Mobile Air Conditioning																					
2F2 Foam Blowing Agents																					
2F3 Fire Protection																					
2F4 Aerosol																					
2F5 Solvents																					
2F6 Other Applications(4)																					

(1) Typically, global warming potential (100 year time horizon) identified in the IPCC Assessment Report can be used. The source of the factors must be specified in the bracket.

(2) Emissions may occur but no methodological guidance is provided in these Guidelines.

(3) Insert additional columns if necessary. The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this table. Such gases should be reported in Table 2.11 IPPU background table: Greenhouse gases without CO_2 equivalent conversion factors.

(4) Insert additional rows if necessary.

Note: Where information is confidential the entries should provide aggregate figures but there should be a note indicating this in the documentation box below.

Documentation box:

Table 2.8 IPPU Background Table: 2G (2G1, 2G2, 2G4) Other Product Manufacture and Use – PFCs, SF_6 and other halogenated gases

Categories	CF_4	C_2F_6	C_3F_8	C_4F_{10}	$c\text{-}C_4F_8$	C_5F_{12}	C_6F_{14}	Other PFCs [2] (please specify)	Total PFCs	SF_6	Other halogenated gases [2] (please specify)
CO_2 equivalent conversion factors[1] **[Source of the factor:]**											
Emissions in original mass unit (tonne)											
2G Other Product Manufacture and Use											
2G1 Electrical Equipment											
2G1a Manufacture of Electrical Equipment [3]											
(information) Reduced amount [4]											
2G1b Use of Electrical Equipment [3]											
(information) Reduced amount [4]											
2G1c. Disposal of Electrical Equipment [3]											
(information) Reduced amount [4]											
2G2 SF_6 and PFCs from Other Product Uses											
2G2a Military Applications [3]											
(information) Reduced amount [4]											
2G2b Accelerators [3]											
University and Research Particle Accelerators [3]											
(information) Reduced amount [4]											
Industrial and Medical Particle Accelerators [3]											
(information) Reduced amount [4]											
2G2c Other (please specify) [3], [5]											
(information) Reduced amount [4], [5]											
2G4 Other (please specify) [3], [5], [6]											
(information) Reduced amount [4], [5], [6]											
Emissions in CO_2 equivalent unit (Gg-CO_2)											
2G Other Product Manufacture and Use											
2G1 Electrical Equipment											
2G1a Manufacture of Electrical Equipment											
2G1b Use of Electrical Equipment											
2G1c Disposal of Electrical Equipment											
2G2 SF_6 and PFCs from Other Product Uses											
2G2a Military Applications (AWACS)											
2G2b Accelerators											
University and Research Particle Accelerators											
Industrial and Medical Particle Accelerators											
2G2c Other (please specify) [5]											
2G4 Other (please specify) [5], [6]											

(1) Typically, global warming potential (100 year time horizon) identified in the IPCC Assessment Report can be used. The source of the factors must be specified in the bracket.

(2) Insert additional columns if necessary. The other halogenated gases for which the CO_2 equivalent conversion factor is not available should not be included in this table. Such gases should be reported in Table 2.11 IPPU background table: Greenhouse gases without CO_2 equivalent conversion factors.

(3) Enter the reported emissions (adjusted with captured and/or reduced amount).

(4) Enter the quantities of reduction of generated gas (emission recovery, destruction, etc.)

(5) Insert additional rows if necessary.

(6) If HFCs with CO_2 equivalent conversion factor are estimated, include them in the column for "Other halogenated gases".

Note: Where information is confidential the entries should provide aggregate figures but there should be a note indicating this in the documentation box below.

Documentation box:

Table 2.9 IPPU Background Table: 2G (2G3, 2G4) Other Product Manufacture and Use - N_2O, CO_2, CH_4,

Categories	Activity Data			Emissions					
				N_2O (Gg)		CO_2 (Gg)		CH_4 (Gg)	
	Description	Quantity	Unit	Emissions (1)	(information) Reduction (2)	Emissions (1)	(information) Reduction (2)	Emissions (1)	(information) Reduction (2)
2G3 N_2O from Product Uses									
2G3a Medical Applications	N_2O supplied		tonne						
2G3b Propellant for Pressure and Aerosol Products	N_2O supplied		tonne						
2G3c Other (please specify) (3)	N_2O supplied		tonne						
2G4 Other (please specify) (3)									

(1) Enter the reported emissions (adjusted with captured and/or reduced amount).

(2) Enter the quantities of reduction of generated gas (emission recovery, destruction, etc.)

(3) Insert additional rows if necessary.

Documentation box:

Table 2.10 IPPU Background Table: 2H Other

Categories	Activity Data		Emissions					
			CO_2 (Gg)		CH_4 (Gg)		N_2O (Gg)	
	Quantity	Unit	Emissions [1]	(information) Reduction [2]	Emissions [1]	(information) Reduction [2]	Emissions [1]	(information) Reduction [2]
2H Other								
2H1 Pulp and Paper Industry								
2H2 Food and Beverages Industry								
2H3 Other (please specify) [3]								

(1) Enter the reported emissions (adjusted with captured and/or reduced amount).

(2) Enter the quantities of reduction of generated gas (emission recovery, destruction, etc.).

(3) Insert additional rows if necessary.

Documentation box:

Table 2.11 IPPU Background Table: Greenhouse gases without CO_2 equivalent conversion factors

Categories		(please specify)	(please specify)	(please specify)	(please specify)	(please specify) [1]
Emissions in original mass unit (tonne)						
Total						
2B Chemical Industry						
2B9	Fluorochemical Production					
2B9a	By-product Emissions					
2B9b	Fugitive Emissions					
2B10	Other (please specify) [2]					
2C Metal Industry						
2C4	Magnesium Production					
2C7	Other (please specify) [2]					
2E Electronics Industry						
2E1	Integrated Circuit or Semiconductor					
2E2	TFT Flat Panel Display					
2E3	Photovoltaics					
2E4	Heat Transfer Fluid					
2E5	Other (please specify) [2]					
2F Product Uses as Substitutes for Ozone Depleting Substances						
2F1	Refrigeration and Air Conditioning					
2F1a	Refrigeration and Stationary Air Conditioning					
2F1b	Mobile Air Conditioning					
2F2	Foam Blowing Agents					
2F3	Fire Protection					
2F4	Aerosols					
2F5	Solvents					
2F6	Other Applications (please specify) [2]					
2G. Other Product Uses						
2G1	Electrical Equipment					
2G1a	Manufacture of Electrical Equipment					
2G1b	Use of Electrical Equipment					
2G1c	Disposal of Electrical Equipment					
2G2	SF_6 and PFCs from Other Product Uses					
2G2a	Military Applications (AWACS)					
2G2b	Accelerators					
2G2c	Other (please specify)[2]					
2G4	Other (please specify)[2]					

(1) Insert additional columns if necessary. The gases for which the CO_2 equivalent conversion factor is available should not be included in this table. Such gases should be reported in the respective sectoral background tables and included in national totals.

(2) Insert additional rows if necessary.

Note: Where information is confidential the entries should provide aggregate figures but there should be a note indicating this in the documentation box below.

Documentation box:

Table 2.12 IPPU Background Table: Allocation of CO_2 emissions from Non-Energy Use of fossil fuels: IPPU and other sectors [See also section 1.4 of Volume 3.]

Category	Reported in year: ……..				Notes
	Primary NEU fuel [(1)]	Other NEU fuel(s) [(1)]	Emissions Amount Reported in IPPU Sector CO_2 [(2)] (Gg)	In case reported elsewhere: Sub-category in 1A where these emissions are (partly) reported	
2 Industrial Processes and Product Use					
2A Mineral Industry					
(Please specify the sub-category)	(coal, ..)				4
2B Chemical Industry					
2B1 Ammonia Production	natural gas	oil, coal			
2B5 Carbide Production	pet coke	oil			
2B6 Titanium Dioxide Production	coal				
2B8 Petrochemical and Carbon Black Production					
2B8a Methanol	natural gas	coal, oil			5
2B8b Ethylene	naphtha	gas oil; butane, ethane, propane, LPG			5
2B8f Carbon Black	natural gas	oil, coke oven gas			
2B10 Other					
2C Metal Industry					
2C1 Iron and Steel Production	coke	coal, pet coke (carbon electrode)			6
2C2 Ferroalloys Production	(carbon electrode)	coke, coal			7
2C3 Aluminium Production	(carbon electrode)	coke, coal			7
2C5 Lead Production	coke				
2C6 Zinc Production	coke				
2C7 Other	(carbon electrode)	coke, coal			
2D Non-Energy Products from Fuels and Solvent Use					
2D1 Lubricant Use	lubricants	greases			
2D2 Paraffin Wax Use	waxes				
2D3 Solvent Use	(mineral turpentine)	coal tars and oils			8
2D4 Other					9
2H Other					
2H1 Pulp and Paper Industry					
2H2 Food and Beverages Industry	coke				
2H3 Other					
1 ENERGY					
1A Fuel Combustion Activities			**Reported in Sector 1A [(3)]**		
1A1a Main Activity Electricity and Heat Production	(BF gas)	(chemical off-gases)			10
1A1b Petroleum Refining					
1A1c Manufacture of Solid Fuels and Other Energy Industries	BF gas				
1A2 Manufacturing Industries and Construction	(BF gas)	(lubricants, chemical off-gases))			

(1) The columns 'Primary NEU fuel' and 'Other NEU fuel' should be completed with the actual fuel types used.

(2) These are the same emissions reported in the sectoral background table (also the same emissions notation keys NE, NO, IE, where applicable). If (partly) reported elsewhere, a reference to that other source category should be added in the next column.

(3) Report here only the CO_2 emissions from combustion of waste gases produced from industrial processes but used for fuel combustion in other economic sectors and reported in the Energy sector.(e.g. from combustion of blast furnace gas or chemical off-gases transferred offsite to another source category).

(4) For example powdered anthracite coal may be used in Glass Production (2A3).

(5) In cases where the production of off-gases (i.e. byproduct gases) is fully accounted for in the energy statistics, the combustion of these gases may be used to calculate and report CO_2 emissions from the feedstock losses. Part of these off-gases may be combusted off-site (i.e. in a sector other than the petrochemical industry) and should thus be accounted for separately as fuel combustion in the Energy Sector.

(6) Part of the blast furnace gas produced from coke used in blast furnaces may be combusted off-site (i.e. in a sector other than the iron and steel industry) and should thus be accounted for separately as fuel combustion in the Energy Sector.

(7) Carbon electrodes are generally manufactured from coke, coal or tar either on-site by the users themselves or separately by anode production plants and then sold to users domestically and/or exported. If anodes are also imported and/or exported, there is no direct correspondence between fuels used for anode production and the amounts of anodes used in the country.

(8) Mineral turpentines are often used as solvent, possibly blended with other liquids. Aromatics derived from coal oils may also be used as solvents.

(9) Emissions from asphalt production, paving of roads and roofing should be reported under 2D4. However, bitumen - and other oil as diluent or 'road oil' - used for this activity does not result in CO_2 emissions.

(10) CO_2 from blast furnace gas and chemical off-gases should be reported here only when utilised in public power or heat production.

Documentation box:

Table 3 AFOLU Sectoral Table (1 of 2)

Categories	Net CO_2 emissions/ removals	Emissions				
		CH_4	N_2O	NO_x	CO	NMVOCs
	(Gg)					
3 AFOLU						
3A Livestock						
3A1 Enteric Fermentation						
3A1a Cattle						
3A1ai Dairy Cows						
3A1aii Other Cattle						
3A1b Buffalo						
3A1c Sheep						
3A1d Goats						
3A1e Camels						
3A1f Horses						
3A1g Mules and Asses						
3A1h Swine						
3A1j Other (please specify)						
3A2 Manure Management [1]						
3A2a Cattle						
3A2ai Dairy Cows						
3A2aii Other Cattle						
3A2b Buffalo						
3A2c Sheep						
3A2d Goats						
3A2e Camels						
3A2f Horses						
3A2g Mules and Asses						
3A2h Swine						
3A2i Poultry						
3A2j Other (please specify)						
3B Land						
3B1 Forest Land						
3B1a Forest Land Remaining Forest Land						
3B1b Land Converted to Forest Land						
3B1bi Cropland Converted to Forest Land						
3B1bii Grassland Converted to Forest Land						
3B1biii Wetlands Converted to Forest Land						
3B1biv Settlements Converted to Forest Land						
3B1bv Other Land Converted to Forest Land						
3B2 Cropland						
3B2a Cropland Remaining Cropland						
3B2b Land Converted to Cropland						
3B2bi Forest Land Converted to Cropland						
3B2bii Grassland Converted to Cropland						
3B2biii Wetlands Converted to Cropland						
3B2biv Settlements Converted to Cropland						
3B2bv Other Land Converted to Cropland						
3B3 Grassland						
3B3a Grassland Remaining Grassland						
3B3b Land Converted to Grassland						
3B3bi Forest Land Converted to Grassland						
3B3bii Cropland Converted to Grassland						
3B3biii Wetlands Converted to Grassland						
3B3biv Settlements Converted to Grassland						
3B3bv Other Land Converted to Grassland						

Table 3 AFOLU Sectoral Table (2 of 2)

Categories		Net CO_2 emissions/ removals	Emissions				
			CH_4	N_2O	NO_x	CO	NMVOCs
		(Gg)					
3B4	**Wetlands**						
3B4a	Wetlands Remaining Wetlands						
3B4ai	Peatlands Remaining Peatlands						
3B4aii	Flooded Land Remaining Flooded Land						
3B4b	Land Converted to Wetlands						
3B4bi	Land Converted for Peat Extraction						
3B4bii	Land Converted to Flooded Land						
3B4biii	Land Converted to Other Wetlands						
3B5	**3B5 Settlements**						
3B5a	Settlements Remaining Settlements						
3B5b	Land Converted to Settlements						
3B5bi	Forest Land Converted to Settlements						
3B5bii	Cropland Converted to Settlements						
3B5biii	Grassland Converted to Settlements						
3B5biv	Wetlands Converted to Settlements						
3B5bv	Other Land Converted to Settlements						
3B6	**3B6 Other Land**						
3B6a	Other Land Remaining Other Land						
3B6b	Land Converted to Other Land						
3B6bi	Forest Land Converted to Other Land						
3B6bii	Cropland Converted to Other Land						
3B6biii	Grassland Converted to Other Land						
3B6biv	Wetlands Converted to Other Land						
3B6bv	Settlements Converted to Other Land						
3C Aggregate Sources and Non-CO_2 Emissions Sources on Land (2)							
3C1	**Biomass Burning**						
3C1a	Biomass Burning in Forest Land						
3C1b	Biomass Burning in Cropland						
3C1c	Biomass Burnings in Grassland						
3C1d	Biomass Burnings in All Other Land						
3C2	**Liming**						
3C3	**Urea Fertilization**						
3C4	**Direct N_2O Emissions from Managed Soils** (3)						
3C5	**Indirect N_2O Emissions from Managed Soils**						
3C6	**Indirect N_2O Emissions from Manure Management**						
3C7	**Rice Cultivations**						
3C8	**Other (please specify)**						
3D Other							
3D1	**Harvested Wood Products**						
3D2	**Other (please specify)**						

(1) Indirect N_2O emissions are not included here (see category 3C6).

(2) If CO_2 emissions from Biomass Burning are not already included in Table 3.2 (Carbon stock changes background table), they should be reported here.

(3) Countries may report by land categories if they have the information.

* Cells to report emissions of NO_x, CO, and NMVOC have not been shaded although the physical potential for emissions is lacking for some categories.

Documentation box:

Table 3.1 AFOLU Background Table: 3A1 - 3A2 Agriculture/Livestock

Categories		Activity data	Emissions	
			CH_4	N_2O
		(number of animals)	(Gg)	
3A Livestock				
3A1	**Enteric Fermentation**			
3A1a	Cattle			
3A1ai	Dairy Cows			
3A1aii	Other Cattle			
3A1b	Buffalo			
3A1c	Sheep			
3A1d	Goats			
3A1e	Camels			
3A1f	Horses			
3A1g	Mules and Asses			
3A1h	Swine			
3A1j	Other (please specify)			
3A2	**Manure Management** (1)			
3A2a	Cattle			
3A2ai	Dairy Cows			
3A2aii	Other Cattle			
3A2b	Buffalo			
3A2c	Sheep			
3A2d	Goats			
3A2e	Camels			
3A2f	Horses			
3A2g	Mules and Asses			
3A2h	Swine			
3A2i	Poultry			
3A2j	Other (please specify)			

(1) Indirect N_2O emissions are not included here.

Documentation box:

Table 3.2 AFOLU Background Table: 3B Carbon stock changes in FOLU (1 of 2)

Categories	Activity data		Net carbon stock change and CO_2 emissions									Net CO_2 emissions
			Biomass				Dead organic matter			Soils		
	Total area	Thereof: Area of organic soils	Increase	Decrease	Carbon emitted as CH_4 and CO from fires (1)	Net carbon stock change	Net carbon stock change	Carbon emitted as CH_4 and CO from fires (1)	Net carbon stock change	Net carbon stock change in mineral soils (2)	Carbon loss from drained organic soils	
	(ha)		(Gg C)									(Gg CO_2)
3B Land												
3B1 Forest Land												
3B1a Forest Land Remaining Forest Land												
3B1b Land Converted to Forest Land												
3B1bi Cropland Converted to Forest Land												
3B1bii Grassland Converted to Forest Land												
3B1biii Wetlands Converted to Forest Land												
3B1biv Settlements Converted to Forest Land												
3B1bv Other Land Converted to Forest Land												
3B2 Cropland												
3B2a Cropland Remaining Cropland												
3B2b Land Converted to Cropland												
3B2bi Forest Land Converted to Cropland												
3B2bii Grassland Converted to Cropland												
3B2biii Wetlands Converted to Cropland												
3B2biv Settlements Converted to Cropland												
3B2bv Other Land Converted to Cropland												
3B3 Grassland												
3B3a Grassland Remaining Grassland												
3B3b Land Converted to Grassland												
3B3bi Forest Land Converted to Grassland												
3B3bii Cropland Converted to Grassland												
3B3biii Wetlands Converted to Grassland												
3B3biv Settlements Converted to Grassland												
3B3bv Other Land Converted to Grassland												
3B4 Wetlands (3)												
3B5 Settlements												

Table 3.2 AFOLU Background Table: 3B Carbon stock changes in FOLU (2of 2)

Categories		Activity data		Net carbon stock change and CO_2 emissions										Net CO_2 emissions
				Biomass				Dead organic matter			Soils			
		Total area	Thereof: Area of organic soils	Increase	Decrease	Carbon emitted as CH_4 and CO from fires (1)	Net carbon stock change	Net carbon stock change	Carbon emitted as CH_4 and CO from fires (1)	Net carbon stock change	Net carbon stock change in mineral soils (2)	Carbon loss from drained organic soils		
		(ha)		(Gg C)										(Gg CO_2)
3B5a	Settlements Remaining Settlements													
3B5b	Land Converted to Settlements													
3B5bi	Forest Land Converted to Settlements													
3B5bii	Cropland Converted to Settlements													
3B5biii	Grassland Converted to Settlements													
3B5biv	Wetlands Converted to Settlements													
3B5bv	Other Land Converted to Settlements													
3B6	**Other Land**													
3B6a	Other Land Remaining Other Land													
3B6b	Land Converted to Other Land													
3B6bi	Forest Land Converted to Other Land													
3B6bii	Cropland Converted to Other Land													
3B6biii	Grassland Converted to Other Land													
3B6biv	Wetlands Converted to Other Land													
3B6bv	Settlements Converted to Other Land													

(1) Where the carbon contained in the emissions of CH_4 and CO is significant part of the sectoral emissions, this should be copied from the corresponding columns in the Sectoral Background Table 3.4. This amount of carbon emitted as CH_4 and CO is then subtracted from carbon stock change to avoid double counting (see Volume 4, Section 2.2.3).

(2) The activity data used for this column correspond to the difference between the column Area and the Area of organic soils.

(3) CO_2 Emissions from Wetlands are reported in a separate background table (Table 3.3) that includes all gases emitted from Wetlands.

Documentation box:

Table 3.3 AFOLU Background Table: Emissions in Wetlands (3B4)

Categories	Activity data	Emissions		
	Area	CO_2	CH_4	N_2O
	(ha)	(Gg)		
3B4 Wetlands				
3B4a Wetlands Remaining Wetlands				
3B4ai Peatlands Remaining Peatlands				
3B4aii Flooded Land Remaining Flooded Land				
3B4b Land Converted to Wetlands				
3B4bi Land Converted for Peat Extraction				
3B4bii Land Converted to Flooded Land				
3B4biii Land Converted to Other Wetlands				

Documentation box:

Table 3.4 AFOLU Background Table: Biomass Burning (3C1) (1 of 2)

Categories (1)	Activity data			Emissions							Information item: Carbon emitted as CH_4 and CO (5)	
	Description(2)	Unit	Values	CO_2(3)	CH_4(4)		N_2O	CO(4)		NO_x	Biomass	DOM
					Biomass	DOM		Biomass	DOM			
		(ha or kg dm)		(Gg)							(C Gg)	
3C1 Biomass Burning												
3C1a Biomass Burning in Forest Land												
Controlled Burning												
Wildfires												
3C1b Biomass Burning in Cropland												
Biomass Burning in Cropland Remaining Cropland												
Controlled Burning												
Wildfires												
Biomass burning in Forest Land Converted to Cropland												
Controlled Burning												
Wildfires												
Biomass Burning in Non Forest Land Converted to Cropland												
Controlled Burning												
Wildfires												
3C1c Biomass Burning in Grassland												
Burning in Grassland Remaining Grassland												
Controlled Burning												
Wildfires												
Burning in Forest Land Converted to Grassland												
Controlled Burning												
Wildfires												
Burning in Non Forest Land Converted to Grassland												
Controlled Burning												
Wildfires												
3C1d Biomass Burning in All Other Land												
Biomass Burning in Other Land Remaining All Other Land												
Controlled Burning												
Wildfires												

Table 3.4 AFOLU Background Table: Biomass Burning (3C1) (2 of 2)

Categories [1]	Activity data			Emissions							Information item: Carbon emitted as CH_4 and CO [5]	
	Description[2]	Unit	Values	CO_2 [3]	CH_4 [4]		N_2O	CO [4]		NO_x	Biomass	DOM
					Biomass	DOM		Biomass	DOM			
		(ha or kg dm)		(Gg)							(C Gg)	
Biomass Burning in Forest Land Converted to All Other Land												
Controlled Burning												
Wildfires												
Biomass Burning in Non Forest Land Converted to All Other Land												
Controlled Burning												
Wildfires												

(1) Parties should report both Controlled/Prescribed Burning and Wildfires emissions, where appropriate, in a separate manner.

(2) For each land type data should be selected between area burned or biomass burned. Units for area will be in hectare (ha) and for biomass burned in kilogram dry matter (kg dm).

(3) If CO_2 emissions from biomass burning are not already included in Table 3.2 (Carbon stock changes background table), they should be reported here. Carbon stock changes associated with biomass burning should not also be reported in Table 3.2 to avoid double counting.

(4) CH_4 and CO emissions from biomass burning and DOM are reported separately.

(5) Where the carbon contained in the emissions of CH_4 and CO is a significant part of the sectoral emissions this should be transferred to the corresponding columns in the Sectoral Background Table 3.2. This amount of carbon emitted as CH_4 and CO is then subtracted from carbon stock change to avoid double counting. The conversion factors to convert CH_4 and CO to C (as input to Table 3.2) are 12/16 for CH_4 and 12/28 for CO. (see Volume 4, Section 2.2.3).

Documentation box:

Table 3.5 AFOLU Background Table: CO_2 emissions from Liming (3C2)

Categories	Activity data			Emissions
	Limestone $CaCO_3$	Dolomite $CaMg(CO_3)_2$	Total amount of lime applied [2]	CO_2
	(Mg/yr)		(Mg/yr)	(Gg)
3C2 Liming [1]				
Forest Land				
Cropland				
Grassland				
Wetland				
Other Land				
Other				

(1) If countries are not able to separate liming application for different land use categories, they should use the main category “Liming”. Also, if a country has data broken down to limestone and dolomite at national level, it can be reported under this category.

(2) A country may report aggregate estimates for total lime applications when data are not available for limestone and dolomite.

Documentation box:

Table 3.6 AFOLU Background Table: CO_2 emissions from Urea Fertilization (3C3)

Categories	Activity data	Emissions
	Total amount of urea applied	CO_2
	(Mg/yr)	(Gg)
3C3 Urea applied [(1)]		
Forest Land		
Cropland		
Grassland		
Settlements		
Other Land		

(1) If countries are not able to separate urea application for different land use categories, they should use the main category “Urea applied”.

Documentation box:

Table 3.7 AFOLU Background Table: Direct N_2O emissions from Managed Soils (3C4)

Categories [(1)]	Activity data	Emissions
	Total amount of nitrogen applied	N_2O
	(Gg N/yr)	(Gg)
3C4 Direct N_2O Emissions from Managed Soils		
Inorganic N fertilizer application		
Forest Land		
Cropland		
Grassland		
Settlements		
Other Land		
Organic N applied as fertilizer (manure and sewage sludge)		
Forest Land		
Cropland		
Grassland		
Settlements		
Other Land		
Urine and dung N deposited on pasture, range and paddock by grazing animals [(2)]		
N in crop residues		
	Area	
	(ha)	
N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils		
Drainage/management of organic soils (i.e., Histosols)		

(1) Countries will report at the aggregation level if their activity data allows them within each category. If country has disaggregated data by land use, reporting is also possible using this table.

(2) Only for Grassland.

(3) Only for Cropland.

Documentation box:

Table 3.8 AFOLU Background Table: Indirect N_2O emissions from Managed Soils and Manure Management (3C5 and 3C6)

Categories [1]	Activity data	Emissions
	Total amount of nitrogen applied / excreted	N_2O
	(Gg N/yr)	(Gg)
3C5 Indirect N_2O emissions from Managed Soils		
From atmospheric deposition of N volatilized from managed soils from agricultural inputs of N (synthetic N fertilizers; organic N applied as fertilizer; urine and dung N deposited on pasture, range and paddock by grazing animals [2]; N in crop residues [3]; and N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils [3])		
Forest Land		
Cropland		
Grasslands		
Settlements		
Other Land		
From N leaching/runoff from managed soils (i.e. from synthetic N fertilizers; organic N applied as fertilizer; urine and dung N deposited on pasture, range and paddock by grazing animals [2]; N in crop residues [3]; and N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils [3])		
Forest Land		
Cropland		
Grasslands		
Settlements		
Other Land		
3C6 Indirect N_2O emissions from Manure Management		

(1) Countries will report at the aggregation level if their activity data allows them within each category. If country has disaggregated data by land use, reporting is also possible using this table.

(2) Only for Grassland.

(3) Only for Cropland.

Documentation box:

Table 3.9 AFOLU Background Table: Non-CO_2 GHG emissions not included elsewhere (3C7 and 3C8)

Categories	Activity data	Emissions	
		CH_4	N_2O
	(ha)	(Gg)	
3C7 Rice Cultivations [(1)]			
3C8 Other (please specify)			

(1) If a country wishes to report direct N_2O emissions from N fertilizer application to rice field, it should be reported here. Otherwise, in Table 3.7.

Documentation box:

Table 3.10 AFOLU Background Table: Harvested Wood Products (3D1) - Annual carbon HWP contribution to total AFOLU CO_2 removals and emissions and background information

	Variable number										
	1A	1B	2A	2B	3	4	5	6	7	8	9
Inventory year	Annual Change in stock of HWP in use from consumption	Annual Change in stock of HWP in SWDS from consumption	Annual Change in stock of HWP in use produced from domestic harvest	Annual Change in stock of HWP in SWDS produced from domestic harvest	Annual Imports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/ chips	Annual Exports of wood, and paper products + wood fuel, pulp, recovered paper, roundwood/ chips	Annual Domestic Harvest	Annual release of carbon to the atmosphere from HWP consumption (from fuelwood & products in use and products in SWDS)	Annual release of carbon to the atmosphere from HWP (including fuelwoood) where wood came from domestic harvest (from products in use and products in SWDS)	HWP Contribution to AFOLU CO_2 emissions/ removals	Approach used to estimate HWP Contribution
	$\Delta C_{HWP\ IU\ DC}$	$\Delta C_{HWP\ SWDS\ DC}$	$\Delta C_{HWP\ IU\ DH}$	$\Delta C_{HWP\ SWDS\ DH}$	P_{IM}	P_{EX}	H	$\uparrow C_{HWP\ DC}$	$\uparrow C_{HWP\ DH}$		
	Gg C /yr									Gg CO_2 /yr	
1990											
…..											

Report Col 6 or 7 as needed for the approach used. Col 6 or 7 may be computed using Cols 1 through 5 or by a Tier 3 method. Always report Cols 3, 4, and 5. Report Cols 1A, 1B, 2A, 2B if they are used.

The HWP contribution and approach should be reported in Columns 8 and 9 together with a description of the approach chosen and main assumptions in the Documentation Box

Additional Variables calculated and used should be reported to enhance the transparency of the results. (e.g., CH_4 from SWDS if this was used) Add additional columns if needed.

Note: $\uparrow C_{HWP\ DC} = H + P_{IM} - P_{EX} - \Delta C_{HWP\ IU\ DC} - \Delta C_{HWP\ SWDS\ DC}$ AND $\uparrow C_{HWP\ DH} = H - \Delta C_{HWP\ IU\ DH} - \Delta C_{HWP\ SWDS\ DH}$

Documentation box:

Table 4 Waste Sectoral Table

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOC [1]	SO_2
	(Gg)						
4 WASTE							
4A Solid Waste Disposal							
4A1 Managed Waste Disposal Sites							
4A2 Unmanaged Waste Disposal Sites							
4A3 Uncategorised Waste Disposal Sites							
4B Biological Treatment of Solid Waste							
4C Incineration and Open Burning of Waste							
4C1 Waste Incineration							
4C2 Open Burning of Waste							
4D Wastewater Treatment and Discharge							
4D1 Domestic Wastewater Treatment and Discharge							
4D2 Industrial Wastewater Treatment and Discharge							
4E Other (please specify) [2]							

(1) Countries may wish to report emissions of NMVOCs from waste disposal sites and waste water treatment.

(2) Insert additional rows if necessary.

* Cells to report emissions of NO_x, CO, NMVOC and SO_2 have not been shaded although the physical potential for emissions is lacking for some categories.

Documentation box:

Table 4.1 Waste Background Table: CO_2, CH_4, N_2O emissions

Categories	Type of activity data	unit	Emission factor			Emissions		
			CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
			(Gg/unit activity data)			(Gg)		
4A Solid Waste Disposal [(1)]								
4A1 Managed Waste Disposal Sites								
4A2 Unmanaged Waste Disposal Sites								
4A3 Uncategorised Waste Disposal Sites								
4B Biological Treatment of Solid Waste								
4C Incineration and Open Burning of Waste [(2)]								
4C1 Waste Incineration								
4C2 Open Burning of Waste								
4D Wastewater Treatment and Discharge								
4D1 Domestic Wastewater Treatment and Discharge								
CH_4 emissions [(3)]								
N_2O emissions [(4)]								
4D2 Industrial Wastewater Treatment and Discharge								
CH_4 emissions [(3)]								
N_2O emissions [(4)]								
4E Other (please specify) [(5)]								

(1) Amount of waste deposited in the SWDS in the inventory year. [mil. tonnes of wet waste/yr] Specification by waste type is encouraged. Emission factor data (parameters used in the calculations) should be reported in FOD parameter sheet or reported separately, when other methods are used.

(2) Waste burned for energy is reported in the Energy Sector under 1A. Information on reporting of waste combustion in the Energy Sector should be given in the documentation box.

(3) Activity data for estimation of CH_4 emissions is total amount of organically degradable material in the wastewater (TOW) [Gg BOD/yr or Gg COD/yr].

(4) Activity data for estimation of N_2O emissions is total amount of nitrogen in effluent [Gg N/yr].

(5) Insert additional rows if necessary.

Documentation box:

Table 4.2 Waste Background Table: CH_4 recovery [1] [2]

Categories	Unit	CH_4	
	Gg CH_4	Flared [3]	Energy recovery [4]
4A Solid Waste Disposal			
4B Biological Treatment of Solid Waste			
4D Wastewater Treatment and Discharge			
4D1 Domestic Wastewater Treatment and Discharge			
4D2 Industrial Wastewater Treatment and Discharge			
4E Other (please specify) [5]			

(1) The amount of CH_4 recovery should be reported in this table even if the gas is used for energy.

(2) Flaring and energy recovery should be reported separately, if possible.

(3) Default EF for CH_4 and N_2O from flaring is zero. The CO_2 emissions are not reported as the gas is of biogenic origin.

(4) When CH_4 recovered is used for energy, the emissions from the combustion of the gas should be reported in the Energy sector (under 1A). Default EF for CH_4 and N_2O from the combustion of the gas is zero.

(5) Insert additional rows if necessary.

Documentation box:

Table 4.3 Waste Background Table: Long-term storage of carbon Information items

Categories	C [1] (Gg)
Information items[2]	
Long-term storage of carbon in waste disposal sites	
Annual change in total long-term storage of carbon stored	
Annual change in long-term storage of carbon in HWP waste [3]	

(1) Report in mass carbon.

(2) These items are listed for information only and will not be added to the totals. The carbon should be converted to carbon dioxide.

(3) Carbon stored in wood, paper, cardboard, garden (yard) and park (equal to the annual change in stock of HWP in SWDS from consumption, reported in Table 3.10, Column 1B).

Documentation box:

Table 5A Cross-sectoral Table: Indirect emissions of N_2O (1)(2)

Categories	Activity data / source emissions		Emissions
	Emissions NH_3	Emissions NO_x	N_2O
	($Gg\ NH_3$)	($Gg\ NO_2$-equivalents)	($Gg\ N_2O$)
1 Energy			
2 Industrial Processes and Product Use			
3 Agriculture, Forestry and Other Land Use			
3C5 Indirect N_2O Emissions from managed soils			
3C6 Indirect N_2O Emissions from manure management			
Other (3) (Please specify)			
4 Waste			
5 Other (Please specify) (4)			

(1) 90 to 99 percent of ammonia emissions originate in the Agriculture Sector. Other emission sources for ammonia are in the Energy Sector (such as combustion, petroleum refining, catalyst cars in the transport sector), in the Industrial processes sector in particular from production of ammonia, nitric acid, ammonium nitrate and phosphate, urea, and fertilizers), and from metal industry (coke ovens battery operations), and also in the Waste Sector (solid waste disposal and waste incineration).

(2) Indirect N_2O emissions from nitrogen leaching /runoff from managed soils in AFOLU categories are included in Table 3.8.

(3) Any other sources not included in 3C5 and 3C6.

(4) Insert additional rows if necessary.

Documentation box:

Table 6A Trends of CO_2 (1 of 3)

(Gg)

Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
Total National Emissions and Removals																				
1 ENERGY																				
1A Fuel Combustion Activities																				
1A1 Energy Industries																				
1A2 Manufacturing Industries and Construction																				
1A3 Transport																				
1A4 Other Sectors																				
1A5 Non-Specified																				
1B Fugitive Emissions from Fuels																				
1B1 Solid Fuels																				
1B2 Oil and Natural Gas																				
1B3 Other Emissions from Energy Production																				
1C Carbon Dioxide Transport and Storage																				
2 INDUSTRIAL PROCESSES AND PRODUCT USE																				
2A Mineral Industry																				
2A1 Cement Production																				
2A2 Lime Production																				
2A3 Glass Production																				
2A4 Other Process Uses of Carbonates																				
2A5 Other (please specify)																				
2B Chemical Industry																				
2B1 Ammonia Production																				
2B2 Nitric Acid Production																				
2B3 Adipic Acid Production																				
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production																				
2B5 Carbide Production																				
2B6 Titanium Dioxide Production																				
2B7 Soda Ash Production																				
2B8 Petrochemical and Carbon Black Production																				
2B9 Fluorochemical Production																				
2B10 Other (please specify)																				
2C Metal Industry																				
2C1 Iron and Steel Production																				
2C2 Ferroalloys Production																				
2C3 Aluminium Production																				
2C4 Magnesium Production																				
2C5 Lead Production																				
2C6 Zinc Production																				
2C7 Other (please specify)																				
2D Non-Energy Products from Fuels and Solvent Use																				
2D1 Lubricant Use																				
2D2 Paraffin Wax Use																				
2D3 Solvent Use																				
2D4 Other (please specify)																				
2E Electronics Industry																				
2E1 Integrated Circuit or Semiconductor																				
2E2 TFT Flat Panel Display																				
2E3 Photovoltaics																				
2E4 Heat Transfer Fluid																				
2E5 Other (please specify)																				

Table 6A Trends of CO_2 (2of 3)

(Gg)

Categories		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
2F	**Product Uses as Substitutes for Ozone Depleting Substances**																				
2F1	Refrigeration and Air Conditioning																				
2F2	Foam Blowing Agents																				
2F3	Fire Protection																				
2F4	Aerosols																				
2F5	Solvents																				
2F6	Other Applications																				
2G	**Other Product Manufacture and Use**																				
2G1	Electrical Equipment																				
2G2	SF_6 and PFCs from Other Product Uses																				
2G3	N_2O from Product Uses																				
2G4	Other (please specify)																				
2H	**Other**																				
2H1	Pulp and Paper Industry																				
2H2	Food and Beverages Industry																				
2H3	Other (please specify)																				
3 AGROCULTURE, FORESTRY AND OTHER LAND USE																					
3A	**Livestock**																				
3A1	Enteric Fermentation																				
3A2	Manure Management																				
3B	**Land**																				
3B1	Forest Land																				
3B2	Cropland																				
3B3	Grassland																				
3B4	Wetlands																				
3B5	Settlements																				
3B6	Other Land																				
3C	**Aggregate Sources and Non-CO_2 Emissions Sources on Land**																				
3C1	Biomass Burning																				
3C2	Liming																				
3C3	Urea Application																				
3C4	Direct N_2O Emissions from Managed Soils																				
3C5	Indirect N_2O Emissions from Managed Soils																				
3C6	Indirect N_2O Emissions from Manure Management																				
3C7	Rice Cultivations																				
3C8	Other (please specify)																				
3D	**Other**																				
3D1	Harvested Wood Products																				
3D2	Other (please specify)																				
4 WASTE																					
4A	**Solid Waste Disposal**																				
4A1	Managed Waste Disposal Sites																				
4A2	Unmanaged Waste Disposal Sites																				
4A3	4A3 Uncategorised Waste Disposal Sites																				
4B	**Biological Treatment of Solid Waste**																				
4C	**Incineration and Open Burning of Waste**																				
4C1	Waste Incineration																				
4C2	Open Burning of Waste																				

Table 6A Trends of CO_2 (3 of 3)

(Gg)

Categories		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
4D	**Wastewater Treatment and Discharge**																				
4D1	Domestic Wastewater Treatment and Discharge																				
4D2	Industrial Wastewater Treatment and Discharge																				
4E	**Other (please specify)**																				
5 OTHER																					
5A	**Indirect N_2O emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3**																				
5B	**Other (please specify)**																				
Memo items																					
International Bunkers																					
	International Aviation (International Bunkers)																				
	International Water-borne Transport (International Bunkers)																				
	Multilateral Operations																				
Information items (1)																					
CO_2 from Biomass Burning for Energy Production																					
CO_2 captured																					
	For domestic storage																				
	For storage in other countries																				
Long-term storage of carbon in waste disposal sites																					
	Annual change in total long-term storage of carbon stored																				
	Annual change in long-term storage of carbon in HWP waste																				
Other (please specify)																					

(1) Here, both emissions and removals can be listed.

Table 6B Trends of CH_4 (1 of 3)

(Gg)

Categories		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
Total National Emissions and Removals																					
1 ENERGY																					
1A	**Fuel Combustion Activities**																				
1A1	Energy Industries																				
1A2	Manufacturing Industries and Construction																				
1A3	Transport																				
1A4	Other Sectors																				
1A5	Non-Specified																				
1B	**Fugitive Emissions from Fuels**																				
1B1	Solid Fuels																				
1B2	Oil and Natural Gas																				
1B3	Other Emissions from Energy Production																				
1C	**Carbon Dioxide Transport and Storage**																				
2 INDUSTRIAL PROCESSES AND PRODUCT USE																					
2A	**Mineral Industry**																				
2A1	Cement Production																				
2A2	Lime Production																				
2A3	Glass Production																				
2A4	Other Process Uses of Carbonates																				
2A5	Other (please specify)																				
2B	**Chemical Industry**																				
2B1	Ammonia Production																				
2B2	Nitric Acid Production																				
2B3	Adipic Acid Production																				
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production																				
2B5	Carbide Production																				
2B6	Titanium Dioxide Production																				
2B7	Soda Ash Production																				
2B8	Petrochemical and Carbon Black Production																				
2B9	Fluorochemical Production																				
2B10	Other (please specify)																				
2C	**Metal Industry**																				
2C1	Iron and Steel Production																				
2C2	Ferroalloys Production																				
2C3	Aluminium Production																				
2C4	Magnesium Production																				
2C5	Lead Production																				
2C6	Zinc Production																				
2C7	Other (please specify)																				
2D	**Non-Energy Products from Fuels and Solvent Use**																				
2D1	Lubricant Use																				
2D2	Paraffin Wax Use																				
2D3	Solvent Use																				
2D4	Other (please specify)																				
2E	**Electronics Industry**																				
2E1	Integrated Circuit or Semiconductor																				
2E2	TFT Flat Panel Display																				
2E3	Photovoltaics																				
2E4	Heat Transfer Fluid																				
2E5	Other (please specify)																				

Table 6B Trends of CH_4 (2 of 3)

(Gg)

Categories		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
2F	**Product Uses as Substitutes for Ozone Depleting Substances**																				
2F1	Refrigeration and Air Conditioning																				
2F2	Foam Blowing Agents																				
2F3	Fire Protection																				
2F4	Aerosols																				
2F5	Solvents																				
2F6	Other Applications																				
2G	**Other Product Manufacture and Use**																				
2G1	Electrical Equipment																				
2G2	SF_6 and PFCs from Other Product Uses																				
2G3	N_2O from Other Product Uses																				
2G4	Other (please specify)																				
2H	**Other**																				
2H1	Pulp and Paper Industry																				
2H2	Food and Beverages Industry																				
2H3	Other (please specify)																				
3 AGROCULTURE, FORESTRY AND OTHER LAND USE																					
3A	**Livestock**																				
3A1	Enteric Fermentation																				
3A2	Manure Management																				
3B	**Land**																				
3B1	Forest Land																				
3B2	Cropland																				
3B3	Grassland																				
3B4	Wetlands																				
3B5	Settlements																				
3B6	Other Land																				
3C	**Aggregate Sources and Non-CO_2 Emissions Sources on Land**																				
3C1	Biomass Burning																				
3C2	Liming																				
3C3	Urea Application																				
3C4	Direct N_2O Emissions from Managed Soils																				
3C5	Indirect N_2O Emissions from Managed Soils																				
3C6	Indirect N_2O Emissions from Manure Management																				
3C7	Rice Cultivations																				
3C8	Other (please specify)																				
3D	**Other**																				
3D1	Harvested Wood Products																				
3D2	Other (please specify)																				
4 WASTE																					
4A	**Solid Waste Disposal**																				
4A1	Managed Waste Disposal Sites																				
4A2	Unmanaged Waste Disposal Sites																				
4A3	Uncategorised Waste Disposal Sites																				
4B	**Biological Treatment of Solid Waste**																				
4C	**Incineration and Open Burning of Waste**																				
4C1	**Waste Incineration**																				
4C2	**Open Burning of Waste**																				

Table 6BTrends of CH_4 (3 of 3)

(Gg)

Categories		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
4D	**Wastewater Treatment and Discharge**																				
4D1	Domestic Wastewater Treatment and Discharge																				
4D2	Industrial Wastewater Treatment and Discharge																				
4E	**Other (please specify)**																				
5 OTHER																					
5A	**Indirect N_2O emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3**																				
5B	**Other (please specify)**																				
Memo items																					
International Bunkers																					
	International Aviation (International Bunkers)																				
	International Water-borne Transport (International Bunkers)																				
	Multilateral Operations																				
Information items (1)																					
CO_2 from Biomass Burning for Energy Production																					
CO_2 captured																					
	For domestic storage																				
	For storage in other countries																				
Long-term storage carbon in waste disposal sites																					
	Annual change in total long-term storage of carbon stored																				
	Annual change in long-term storage of carbon in HWP waste																				
Other (please specify)																					

(1) Here, both emissions and removals can be listed.

Table 6C Trends of N_2O (1 of 3)

(Gg)

Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
Total National Emissions and Removals																				
1 ENERGY																				
1A Fuel Combustion Activities																				
1A1 Energy Industries																				
1A2 Manufacturing Industries and Construction																				
1A3 Transport																				
1A4 Other Sectors																				
1A5 Non-Specified																				
1B Fugitive Emissions from Fuels																				
1B1 Solid Fuels																				
1B2 Oil and Natural Gas																				
1B3 Other Emissions from Energy Production																				
1C Carbon Dioxide Transport and Storage																				
2 INDUSTRIAL PROCESSES AND PRODUCT USE																				
2A Mineral Industry																				
2A1 Cement Production																				
2A2 Lime Production																				
2A3 Glass Production																				
2A4 Other Process Uses of Carbonates																				
2A5 Other (please specify)																				
2B Chemical Industry																				
2B1 Ammonia Production																				
2B2 Nitric Acid Production																				
2B3 Adipic Acid Production																				
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production																				
2B5 Carbide Production																				
2B6 Titanium Dioxide Production																				
2B7 Soda Ash Production																				
2B8 Petrochemical and Carbon Black Production																				
2B9 Fluorochemical Production																				
2B10 Other (please specify)																				
2C Metal Industry																				
2C1 Iron and Steel Production																				
2C2 Ferroalloys Production																				
2C3 Aluminium Production																				
2C4 Magnesium Production																				
2C5 Lead Production																				
2C6 Zinc Production																				
2C7 Other (please specify)																				
2D Non-Energy Products from Fuels and Solvent Use																				
2D1 Lubricant Use																				
2D2 Paraffin Wax Use																				
2D3 Solvent Use																				
2D4 Other (please specify)																				
2E Electronics Industry																				
2E1 Integrated Circuit or Semiconductor																				
2E2 TFT Flat Panel Display																				
2E3 Photovoltaics																				
2E4 Heat Transfer Fluid																				
2E5 Other (please specify)																				

Table 6C Trends of N_2O (2of 3)

(Gg)

Categories		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
2F	**Product Uses as Substitutes for Ozone Depleting Substances**																				
2F1	Refrigeration and Air Conditioning																				
2F2	Foam Blowing Agents																				
2F3	Fire Protection																				
2F4	Aerosols																				
2F5	Solvents																				
2F6	Other Applications																				
2G	**Other Product Manufacture and Use**																				
2G1	Electrical Equipment																				
2G2	SF_6 and PFCs from Other Product Uses																				
2G3	N_2O from Other Product Uses																				
2G4	Other (please specify)																				
2H	**Other**																				
2H1	Pulp and Paper Industry																				
2H2	Food and Beverage Industry																				
2H3	Other (please specify)																				
3 AGROCULTURE, FORESTRY AND OTHER LAND USE																					
3A	**Livestock**																				
3A1	Enteric Fermentation																				
3A2	Manure Management																				
3B	**Land**																				
3B1	Forest land																				
3B2	Cropland																				
3B3	Grassland																				
3B4	Wetlands																				
3B5	Settlements																				
3B6	Other land																				
3C	**Aggregate Sources and non-CO_2 Emissions Sources on Land**																				
3C1	Biomass Burning																				
3C2	Liming																				
3C3	Urea Application																				
3C4	Direct N_2O Emissions from Managed Soils																				
3C5	Indirect N_2O Emissions from Managed Soils																				
3C6	Indirect N_2O Emissions from Manure Management																				
3C7	Rice Cultivations																				
3C8	Other (please specify)																				
3D	**Other**																				
3D1	Harvested Wood Products																				
3D2	Other (please specify)																				
4 WASTE																					
4A	**Solid Waste Disposal**																				
4A1	Managed Waste Disposal Sites																				
4A2	Unmanaged Waste Disposal Sites																				
4A3	Uncategorised Waste Disposal Sites																				
4B	**Biological Treatment of Solid Waste**																				
4C	**Incineration and Open Burning of Waste**																				
4C1	Waste Incineration																				
4C2	Open Burning of Waste																				

Table 6C Trends of N_2O (3 of 3)

(Gg)

Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
4D Wastewater Treatment and Discharge																				
4D1 Domestic Wastewater Treatment and Discharge																				
4D2 Industrial Wastewater Treatment and Discharge																				
4E Other (please specify)																				
5 OTHER																				
5A Indirect N_2O emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3																				
5B Other (please specify)																				
Memo items																				
International Bunkers																				
International Aviation (International Bunkers)																				
International Water-borne Transport (International Bunkers)																				
Multilateral Operations																				
Information items (1)																				
CO_2 from Biomass Burning for Energy Production																				
CO_2 captured																				
For domestic storage																				
For storage in other countries																				
Long-term storage of carbon in waste disposal sites																				
Annual change in total long-term storage of carbon stored																				
Annual change in long-term storage of carbon in HWP waste																				
Other (please specify)																				

(1) Here, both emissions and removals can be listed.

Table 6D Trends of HFCs (CO$_2$ equivalents (Gg))

Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
Total National Emissions and Removals																				
2 INDUSTRIAL PROCESSES AND PRODUCT USE																				
2A Mineral Industry																				
2A1 Cement Production																				
2A2 Lime Production																				
2A3 Glass Production																				
2A4 Other Process Uses of Carbonates																				
2A5 Other (please specify)																				
2B Chemical Industry																				
2B1 Ammonia Production																				
2B2 Nitric Acid Production																				
2B3 Adipic Acid Production																				
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production																				
2B5 Carbide Production																				
2B6 Titanium Dioxide Production																				
2B7 Soda Ash Production																				
2B8 Petrochemical and Carbon Black Production																				
2B9 Fluorochemical Production																				
2B10 Other (please specify)																				
2C Metal Industry																				
2C1 Iron and Steel Production																				
2C2 Ferroalloys Production																				
2C3 Aluminium Production																				
2C4 Magnesium Production																				
2C5 Lead Production																				
2C6 Zinc Production																				
2C7 Other (please specify)																				
2D Non-Energy Products from Fuels and Solvent Use																				
2D1 Lubricant Use																				
2D2 Paraffin Wax Use																				
2D3 Solvents Use																				
2D4 Other (please specify)																				
2E Electronics Industry																				
2E1 Integrated Circuit or Semiconductor																				
2E2 TFT Flat Panel Display																				
2E3 Photovoltaics																				
2E4 Heat Transfer Fluid																				
2E5 Other (please specify)																				
2F Product Uses as Substitutes for Ozone Depleting Substances																				
2F1 Refrigeration and Air Conditioning																				
2F2 Foam Blowing Agents																				
2F3 Fire Protection																				
2F4 Aerosols																				
2F5 Solvents																				
2F6 Other Applications																				
2G Other Product Manufacture and Use																				
2G1 Electrical Equipment																				
2G2 SF$_6$ and PFCs from Other Product Uses																				
2G3 N$_2$O from Other Product Uses																				
2G4 Other (please specify)																				
2H Other																				
2H1 Pulp and Paper Industry																				
2H2 Food and Beverages Industry																				
2H3 Other (please specify)																				

Table 6E Trends of PFCs (CO$_2$ equivalents (Gg))

Categories		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
Total National Emissions and Removals																					
2 INDUSTRIAL PROCESSES and PRODUCT USE																					
2A	**Mineral Industry**																				
2A1	Cement Production																				
2A2	Lime Production																				
2A3	Glass Production																				
2A4	Other Process Uses of Carbonates																				
2A5	Other (please specify)																				
2B	**Chemical Industry**																				
2B1	Ammonia Production																				
2B2	Nitric Acid Production																				
2B3	Adipic Acid Production																				
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production																				
2B5	Carbide Production																				
2B6	Titanium Dioxide Production																				
2B7	Soda Ash Production																				
2B8	Petrochemical and Carbon Black Production																				
2B9	Fluorochemical Production																				
2B10	Other (please specify)																				
2C	**Metal Industry**																				
2C1	Iron and Steel Production																				
2C2	Ferroalloys Production																				
2C3	Aluminium Production																				
2C4	Magnesium Production																				
2C5	Lead Production																				
2C6	Zinc Production																				
2C7	Other (please specify)																				
2D	**Non-Energy Products from Fuels and Solvent Use**																				
2D1	Lubricant Use																				
2D2	Paraffin Wax Use																				
2D3	Solvent Use																				
2D4	Other (please specify)																				
2E	**Electronics Industry**																				
2E1	Integrated Circuit or Semiconductor																				
2E2	TFT Flat Panel Display																				
2E3	Photovoltaics																				
2E4	Heat Transfer Fluid																				
2E5	Other (please specify)																				
2F	**Product Uses as Substitutes for Ozone Depleting Substances**																				
2F1	Refrigeration and Air Conditioning																				
2F2	Foam Blowing Agents																				
2F3	Fire Protection																				
2F4	Aerosols																				
2F5	Solvents																				
2F6	Other Applications																				
2G	**Other Product Manufacture and Use**																				
2G1	Electrical Equipment																				
2G2	SF$_6$ and PFCs from Other Product Uses																				
2G3	N2O from Other Product Uses																				
2G4	Other (please specify)																				
2H	**Other**																				
2H1	Pulp and Paper Industry																				
2H2	Food and Beverages Industry																				
2H3	Other (please specify)																				

Table 6F Trends of SF_6 (CO_2 equivalents (Gg))

Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
Total National Emissions and Removals																				
2 INDUSTRIAL PROCESSES AND PRODUCT USE																				
2A Mineral Industry																				
2A1 Cement Production																				
2A2 Lime Production																				
2A3 Glass Production																				
2A4 Other Process Uses of Carbonates																				
2A5 Other (please specify)																				
2B Chemical Industry																				
2B1 Ammonia Production																				
2B2 Nitric Acid Production																				
2B3 Adipic Acid Production																				
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production																				
2B5 Carbide Production																				
2B6 Titanium Dioxide Production																				
2B7 Soda Ash Production																				
2B8 Petrochemical and Carbon Black Production																				
2B9 Fluorochemical Production																				
2B10 Other (please specify)																				
2C Metal Industry																				
2C1 Iron and Steel Production																				
2C2 Ferroalloys Production																				
2C3 Aluminium Production																				
2C4 Magnesium Production																				
2C5 Lead Production																				
2C6 Zinc Production																				
2C7 Other (please specify)																				
2D Non-Energy Products from Fuels and Solvent Use																				
2D1 Lubricant Use																				
2D2 Paraffin Wax Use																				
2D3 Solvent Use																				
2D4 Other (please specify)																				
2E Electronics Industry																				
2E1 Integrated Circuit or Semiconductor																				
2E2 TFT Flat Panel Display																				
2E3 Photovoltaics																				
2E4 Heat Transfer Fluid																				
2E5 Other (please specify)																				
2F Product Uses as Substitutes for Ozone Depleting Substances																				
2F1 Refrigeration and Air Conditioning																				
2F2 Foam Blowing Agents																				
2F3 Fire Protection																				
2F4 Aerosols																				
2F5 Solvents																				
2F6 Other Applications																				
2G Other Product Manufacture and Use																				
2G1 Electrical Equipment																				
2G2 SF_6 and PFCs from Other Product Uses																				
2G3 N_2O from Other Product Uses																				
2G4 Other (please specify)																				
2H Other																				
2H1 Pulp and Paper Industry																				
2H2 Food and Beverages Industry																				
2H3 2H3 Other (please specify)																				

Table 6G Trends of other gases [1] (Gg)

Categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	…
Total National Emissions and Removals																				
2 INDUSTRIAL PROCESSES AND PRODUCT USE																				
2A Mineral Industry																				
2A1 Cement Production																				
2A2 Lime Production																				
2A3 Glass Production																				
2A4 Other Process Uses of Carbonates																				
2A5 Other (please specify)																				
2B Chemical Industry																				
2B1 Ammonia Production																				
2B2 Nitric Acid Production																				
2B3 Adipic Acid Production																				
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production																				
2B5 Carbide Production																				
2B6 Titanium Dioxide Production																				
2B7 Soda Ash Production																				
2B8 Petrochemical and Carbon Black Production																				
2B9 Fluorochemical Production																				
2B10 Other (please specify)																				
2C Metal Industry																				
2C1 Iron and Steel Production																				
2C2 Ferroalloys Production																				
2C3 Aluminium Production																				
2C4 Magnesium Production																				
2C5 Lead Production																				
2C6 Zinc Production																				
2C7 Other (please specify)																				
2D Non-Energy Products from Fuels and Solvent Use																				
2D1 Lubricant Use																				
2D2 Paraffin Wax Use																				
2D3 Solvent Use																				
2D4 Other (please specify)																				
2E Electronics Industry																				
2E1 Integrated Circuit or Semiconductor																				
2E2 TFT Flat Panel Display																				
2E3 Photovoltaics																				
2E4 Heat Transfer Fluid																				
2E5 Other (please specify)																				
2F Product Uses as Substitutes for Ozone Depleting Substances																				
2F1 Refrigeration and Air Conditioning																				
2F2 Foam Blowing Agents																				
2F3 Fire Protection																				
2F4 Aerosols																				
2F5 Solvents																				
2F6 Other Applications (please specify)																				
2G Other Product Manufacture and Use																				
2G1 Electrical Equipment																				
2G2 SF_6 and PFCs from Other Product Uses																				
2G3 N_2O from Other Product Uses																				
2G4 Other (please specify)																				
2H Other																				
2H1 Pulp and Paper Industry																				
2H2 Food and Beverages Industry																				
2H3 Other (please specify)																				

(1) This includes all other GHGs including fluorinated gases.

Table 7A Uncertainties

IPCC category	Gas	Base year emissions /removals	Year *t* emissions /removals	Activity data uncertainty		Emission factor /estimation parameter uncertainty (combined if more than one estimation parameter is used)		Combined uncertainty		Contribution to variance in Year *t*	Inventory trend in national emissions for year *t* increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to Base Year		Approach and Comments
		Gg CO_2 equivalent	Gg CO_2 equivalent	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(fraction)	(% of base year)	(-) %	(+) %	
E.g. 1.A.1. Energy Industries Fuel 1	CO_2													
E.g. 1.A.1. Energy Industries Fuel 2	CO_2													
Etc...	…													
Total														

Table 7B Summary of Key Category analysis

Quantitative method used: Approach 1/Approach 1 and Approach 2

IPCC Category Code	IPCC Category	Greenhouse Gas	Identification criteria (1)	Comments (2)

(1) The notation keys to be used for this column:
L1 = key category according to Approach 1 Level Assessment
L2 = key category according to Approach 2 Level Assessment
T1 = key category according to Approach 1 Trend Assessment
T2 = key category according to Approach 2 Trend Assessment
Q = key category according to qualitative criteria

(2) In the column for comments, reasons for a qualitative assessment can be provided.