# PROMITHEAS – 4

# "Overview of international procedures and standards in collecting and reporting data and information"

**(Draft Final)**

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**PROMITHEAS-4:** "*Knowledge transfer and research needs for preparing mitigation/adaptation policy portfolios*"

This report has been read, commented and approved by all members of the PROMITHEAS-4 Scientific Committee.

It was also disseminated for comments, through BSEC – PERMIS and BSEC – BC, to all relevant governmental and business authorities and partners before its finalization.

Partners from the beneficiary countries* of the consortium were encouraged to contact direct national authorities, agencies, institutions and market stakeholder for comments before the finalization of this report.

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CONTENTS

# 1. Introduction

## 1.1. *The climate-change issue*

The term *climate* refers to an ensemble of average values of the main meteorological parameters that characterize weather at a place, e.g., temperature, humidity, barometric pressure, sunshine duration, rain intensity, and wind speed and direction. These averages are calculated from the readings of the above parameters recorded at a place over a long period of, say, 10 or more years (typically 30 years). The term *climate change* refers to the trends in the above parameters established over a long period. Climate change has been reported to have occurred in the past due to natural phenomena and has sometimes had catastrophic effects, as the extinction of various species during the ice ages. However, in the past two decades there is growing scientific evidence that the earth's climate has been undergoing changes due to human activities, the so-called *anthropogenic effects*.

These effects mainly come from human-induced greenhouse-gas (GHG) emissions, which began at the start of the industrial revolution as a result of utilisation of fossil fuels for electricity generation, industrial processes and transportation. Apart from the electricity and transportation sectors changes in the level of GHG emissions also occur due to deforestation.

To combat human activity that is responsible for the increased levels of GHG emissions, a large number of countries have begun making efforts to reduce these levels. These efforts are focused on the following sectors: land use, agriculture, energy, business (including industry and services), transportation and wastes.

## 1.2. *The GHGs*

The GHGs constitute part of the composition of the atmosphere of the earth with less than 0.1 % of the total gases in it. The GHGs nowadays (natural and synthetic) are carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), sulphur hexafluoride ($SF_6$), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) primarily, and water vapour ($H_2O$), ozone ($O_3$) and hydrochlorofluorocarbons (HCFCs) secondarily.

## 1.3. *The GH effect*

Solar energy from the sun enters the earth's atmosphere as short-wavelength radiation. Part of it is reflected by the earth's surface and atmosphere back to space; however, the vast majority is absorbed, warming the planet. On the other hand, as the earth's surface gains heat, it starts emitting long-wavelength (infra-red, IR) radiation back into the atmosphere.

Despite their relative scarcity, GHGs prevent IR from escaping into space because they act like a blanket, trapping part of this IR radiation; without this phenomenon the temperature on the earth's surface would be a lot colder. The concentration of GHGs in the atmosphere has grown as a result of human activities; this process may prove to be disturbing the natural balance between incoming and outgoing energy.

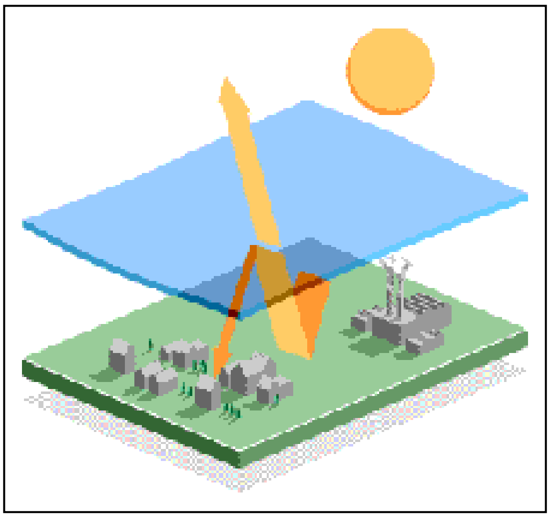

**Figure 1.3.1.** The principle of the GH effect; part of the IR radiation from the earth's surface is trapped by the GHG (blue) layer. Source: http://news.bbc.co.uk/hi/english/static/in_depth/sci_tech/2000/climate_change/greenhouse/ghouse_3.stm.

## 1.4. International organisations involved in the assessment of GHG emissions

### 1.4.1. The IPCC

Just 23 years ago, a number of governments decided that the issue of climate change needs to be addressed by an independent body. So the *Intergovernmental Panel for Climate Change* (IPCC) is the leading international body for the assessment of climate change. Therefore, in 1988 the IPCC was established by the *United Nations Environmental Programme*[1] (UNEP) and the *World Meteorological Organisation*[2] (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. It is open to all member countries of WMO and UNEP. The work of the IPCC is driven by scientific literature that is relevant to the understanding of the risk of human-induced climate change. Thousands of scientists all over the world contribute to the work of the IPCC on voluntary basis. Review is an essential part of the IPCC process to ensure an objective and complete assessment of current information.

The IPCC presented its *1st Assessment Report on Climate Change* in 1990; thereafter, other such reports have been published at regular five-year intervals. The findings of the 1st Assessment Report paved the way for the establishment of the *United Nations Framework Convention on Climate Change*[3] (UNFCCC), while the 2nd Assessment Report (1995) was the key for the negotiations of the *Kyoto Protocol* in 1997 and still remains the basis for collecting and disseminating GHG-emission data.

[1] http://www.unep.org/
[2] http://www.wmo.int/pages/index_en.html
[3] http://unfccc.int/2860.php

### 1.4.2. The UNFCCC

The UNFCCC is committed to:

- Making a contribution to sustainable development through support the action to mitigate and adapt to climate change at the global, regional and national level;
- Providing high-quality support to the intergovernmental process in the context of the Convention and the Kyoto Protocol; and
- Creating and maintaining necessary conditions for an early, effective and efficient implementation of the Kyoto Protocol.

The Convention was signed on 9 May 1992. Its ultimate objective is to stabilise the GHG concentrations in the atmosphere 'at a level that would prevent dangerous, human-induced interference with the earth's climatic system'. In the end of 2009, one hundred and ninety four (194) individual countries ratified the UNFCCC. All participating countries are divided into three (3) main groups according to their commitments. The Annex-I Parties include the industrialised countries that were members of the *Organisation for Economic Cooperation and Development* (OECD) in 1992 plus the countries with economies in transition (the EIT parties), including the Russian Federation, the Baltic States and several central and eastern European States. The Annex-II Parties are those of OECD membership of Annex I, but not the EIT parties. The Non-Annex I Parties are mostly developing economies.

### 1.4.3. The Kyoto Protocol

This is an international agreement linked to the UNFCCC: while the latter encouraged industrialised countries to stabilise their emission levels, the Kyoto Protocol committed them to limit or reduce their GHG emissions. The protocol was signed in 1997, setting commitments for reducing GHG emissions in the developed countries during the period 2008 - 2012. The protocol entered into force on 16 February 2005 with the Russian Federation having ratified it on 18 November 2004. It addresses six main GHGs ($CO_2$, $NH_4$, $N_2O$, $SF_6$, HFCs and perfluorocarbons - PFCs); emission reductions are generally measured against a base year (normally 1990).

The Kyoto Protocol established different commitments for the associated countries according to their economic development. In general, the developed countries were required to reduce their emissions from the 1990-base-year levels by at least 5 % during the period 2008 - 2012. Nevertheless, political negotiations resulted in different national targets.

Among the EU-15 there was a specific agreement to meet an 8 % reduction. This, of course, varied among the countries: -28 % for Luxembourg, -21 % for Denmark and Germany, and +25 % and +27 % for Greece and Portugal, respectively. Out of the twelve (12) Member States (MS) that joined EU in 2004, Cyprus and Malta are not a Parties to the Kyoto Protocol; the remaining ten (10) countries have their own reduction targets, generally set at -8 %, although the target is -6 % for Hungary and Poland.

In an attempt to find alternative ways to reduce emissions, a trading mechanism was established using the so-called *Assigned Amount Units* (AAUs). This initiative enable developed countries to acquire AAUs from other countries that are able to reduce their emissions. This form of trading allows countries that have achieved emission reductions beyond those required by the Kyoto Protocol to sell their excess reductions to other countries that are finding it more difficult or expensive to meet their commitments.

### 1.4.4. COP15 and COP16

The Kyoto-Protocol agreement expires in 2012. In view of this fact, international negotiations have begun for a post-2012 climate regime under the auspices of the UNFCCC; more specifically, the action is concentrated on the annual progress meetings of the *Conferences of the Parties* (COP), which monitor climate change. COP15 took place in Copenhagen, Denmark, in December 2009 without any legally-binding agreement. Details of the mitigation actions were left for the next COP16 in Cancun, Mexico, in November 2010, which failed the same way as COP15.

## *1.5. European organisations involved in the assessment of GHG emissions*

### 1.5.1. The EEA

The *European Environment Agency* (EEA) has now thirty two (32) member countries of EEA: the 27 EU MS, together with Iceland, Liechtenstein, Norway, Switzerland and Turkey. EEA aims at:

(i) supporting sustainable development and helping achieve significant and measurable improvement in Europe's environment, through the provision of information to policy-making agents and the public;

(ii) supporting the information requirements of EU and international environmental legislation;

(iii) making assessments of the European environment;

(iv) evaluating policy effectiveness; and

(v) improving the coordination and dissemination of environmental data and information about Europe.

Regarding GHG emissions, the EEA is responsible for the preparation and submission of the EU's GHG inventory to the UNFCCC; this action includes the implementation of the quality control/quality assurance (QA/QC) procedures to ensure compliance with UNFCCC and IPCC guidelines. The website of EEA[4] hosts the environmental data centre for climate change[5].

[4] http://www.eea.europa.eu

### 1.5.2. The DG-Environment

The *DG for the Environment*[6] is part of the *European Commission* (EC), with the aim of 'protecting and preserving the environment for present and future generations'. Its 6th *Environment Action Programme* (6th EAP) set out the framework for environmental policy-making within the EU during the period 2002 - 2012, based on four (4) avenues:

(i) climate change;

(ii) nature and biodiversity;

(iii) environment, health and the quality of life; and

(iv) natural resources and wastes.

In December 2008, the European Parliament adopted three (3) ambitious targets for combating GHG emissions and mitigating climate changes until 2020: cutting EU GHG emissions by 20 %, reducing EU energy consumption by 20 %, and meeting 20 % of Europe's energy needs from renewable-energy sources (EC, 2008).

### 1.5.3. The Eurostat

*Eurostat*[7] is the official EU statistics office. It is responsible for collecting, analysing and disseminating EU statistics about socio-economic, and environmental topics, so that they are useful in relevant EC policies. Many calculations concerning GHG emissions are based on these statistics, though Eurostat data is not specifically collected for this purpose.

### 1.5.4. The IES

The institute[8] was established in Ispra, Italy, in 2001 as part of the *Joint Research Centre* (JRC). Its mission is to provide scientific support to the EU's policies for the protection of the European environment as well as the global one.

## *1.6. GHG-emission inventories*

All countries having signed the Kyoto Protocol are obliged to compile an annual inventory of their GHG emissions and submit a report on their actions to control them. The inventories are based on a set of standard guidelines to ensure consistency and comparability.

These inventories consist of standardised tables based on a *common reporting format* (CRF) followed by a report on the methodologies and data sources used, the so-called *National Inventory Report* (NIR). The NIR from each developed country must be submitted by 15 April each year (Y), providing estimates of its net GHG emissions for the period from 1990 up to the year Y-2. In particular, the EU MS are also obliged to submit their individual inventories

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[5] http://www.eea.europa.eu/themes/climate
[6] http://ec.europa.eu/dgs/environment/index_en.htm
[7] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home
[8] http://ies.jrc.ec.europa.eu/index.php?page=welcome-message

to the EEA. All NIRs contain standardised QA/QC methodologies, following UNFCCC and IPCC guidelines[9], to ensure accuracy, consistency, comparability and transparency of reporting. One of the obligations of the reporting countries in their NIRs is the ability of reconstructing their inventory by expert teams to improve the quality of the GHG estimates. The GHGs included in the NIRs are the primary ones mentioned in §1.2.

## 1.7. Sectors and categories of GHG emissions

The sectors associated with NIRs are energy (fuel combustion), industry (processes, solvents and other product uses), agriculture, and wastes. Each of these sectors may be comprised of individual categories. The total estimation of the GHG emissions is a bottom-up approach, i.e., starting from the data at the sub-category level and summing up to obtain categories, sectors and eventually total emissions. Among those, land use, land-use change and forestry (LULUCF) activities also have the potential to reduce emissions. Nevertheless, net emissions from LULUCF activities are excluded from the total emissions in relation to the Kyoto-Protocol targets. Apart from LULUCFs, the use of fuel in ships or aircrafts is also excluded from NIRs of GHG emissions within the Kyoto Protocol.

## 1.8. Estimation of GHG emissions

The emissions inventories do not measure, but estimate the GHG emissions by applying the 1996-IPCC methods. The simplest methodology involves information about a human activity with an *emissions factor* (EF), a coefficient that quantifies the emissions from that activity. Therefore, emissions are estimated as follows:

$$\text{emissions} = \text{activity data} \times \text{EF} \qquad (1.8.1)$$

As an example for eq (1.8.1), consider a set of activity data for fuel consumption; the corresponding EF is the mass of $CO_2$ emitted per unit of fuel consumed. Nevertheless, such basic equations may include other parameters. The degree of calculation complexity is known as *tier*. The basic calculation methods constitute tier 1, intermediate ones are grouped under tier 2, and the most complex and demanding calculations are defined as tier 3.

Each country is free to decide upon the most appropriate data and calculation methods. However, a review of these activities is needed on a regular basis in order to secure a continuous improvement of the inventory. After such changes take place, the entire inventories should be revised accordingly from 1990 onwards.

## 1.9. Air-emission accounts

*Air-emission accounts* refer to annual data on emissions of GHGs and other air pollutants. They are collected every second year by Eurostat. In these accounts, emissions of GHGs are

[9] http://unfccc.int/resource/docs/2004/sbsta/08.pdf

classified according to economic activities (NACE coding[10]). In contrast to Eurostat accounts, GHG inventories are classified according to the technology used.

An example for the difference between the Eurostat accounts and the inventories in NIRs is the emissions from transport. In the latter, transport emissions are recorded altogether under the same technology category (e.g., fuel combustion under road, air, and water transport). In contrast, air-emission accounts contain emissions according to the economic activity (e.g., private cars-households, ambulances-health services, tractors-agriculture, trucks-road freight transport).

Another difference between the two types of inventories lies in the fact that the GHG inventory contains data from the national territory only, while the Eurostat one may include regional data, e.g., emissions from ships regardless of their travel.

## *1.10. GHG emissions by sector*

The most important source of GHG emissions across the EU-27 for 2008 was energy (Figure 1.10.1; EEA, 2010a). This category has been the principal source of emissions in the whole period of 1990 - 2008 (see Figure 1.10.2 for 1990). The latest available data shows energy (excluding transport) with a 59.6 % share in total emissions (or more than 3000 Mtons of $CO_2$ equivalents).

The transport sector (a sub-sector of the IPCC energy sector) is the next largest contributor (19.5 % of EU's GHG emissions in 2008). Agriculture accounted for 9.6 % of all GHG emissions in EU-27 in 2008; contrary to other areas, where $CO_2$ was the principal GHG emitted, agricultural emissions are largely composed of $N_2O$ and $CH_4$. Emissions from industrial processes, solvents and product use accounted for a slightly lower share (8.5 %), while emissions from wastes (including disposal, landfill sites and water treatment) accounted for the remaining 2.8 % of EU's GHG emissions in 2008.

[10] http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

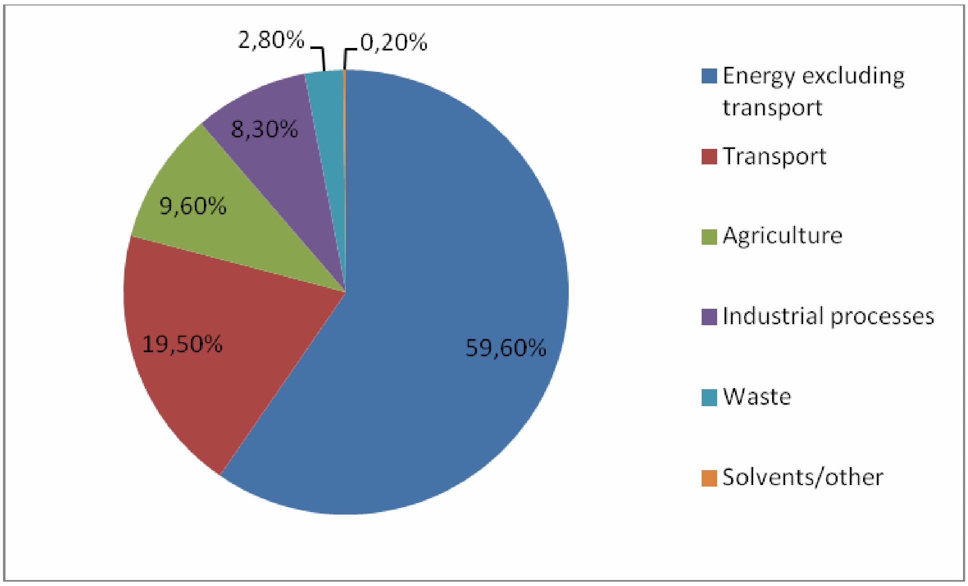


**Figure 1.10.1.** GHG emission totals from EU-27 per sector for 2008 excluding LULUCFs. Note that the energy sector includes energy production, households/services, manufacturing/construction and fugitive emissions. Data from EEA (2010a).

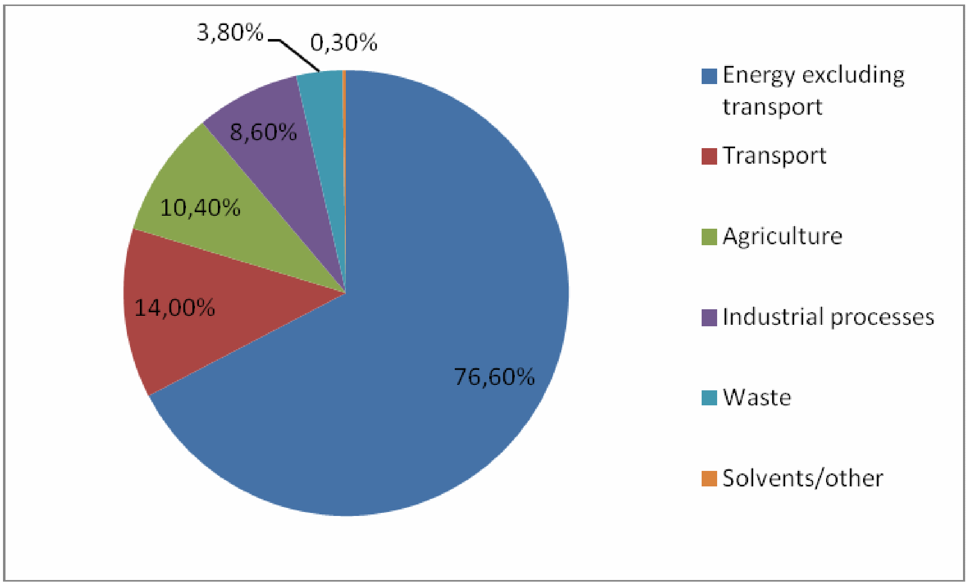


**Figure 1.10.2.** As in Fig. 1.10.1, but for 1990. Data from EEA (2010a).

Figure 1.10.2 shows the distribution of the GHGs per sector in EU-27 for 1990 excluding LULUCFs. It is seen that the GHGs coming from the energy sector were higher in 1990 than in 2008 by 17 %; they occupied 76.6 % in the total 1990-distribution pie. To the contrary, the transport sector gave 14 %, i.e., 5.5 % less than its counterpart of 2008. The rest of the sectors provided comparable percentages with those of 2008.

Figure 1.10.3 shows the change in the GHG levels coming from the aforementioned sectors between the base year of 1990 and 2007, including LULUCFs. It is seen that positive change has happened in the transport, international bunker and LULUCF sectors.

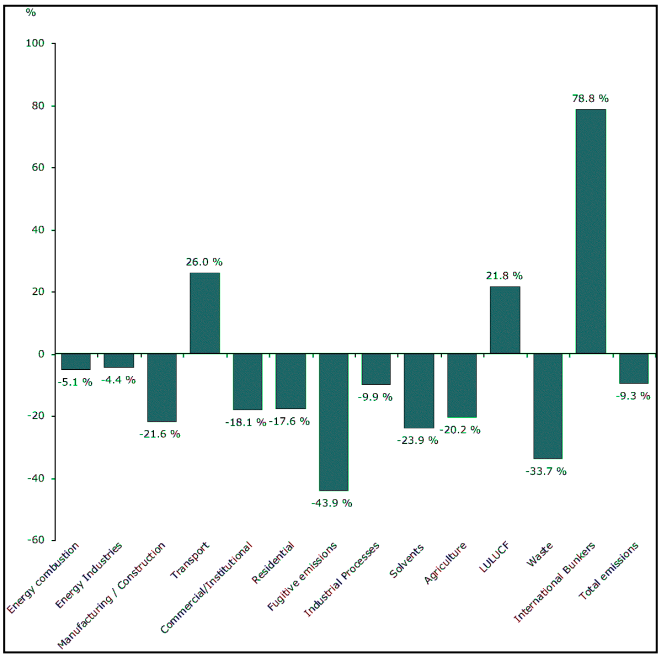


**Figure 1.10.3.** Change (%) in GHG emission totals per source for EU-27 in the period 1990-2007. Source: EEA (http://www.eea.europa.eu/data-and-maps/figures/greenhouse-gas-emissions-kyoto-gases.

## *1.11. GHG emissions by type*

As in §1.10 Figure 1.11.1 shows the distribution of emissions per type of GHG for 1990 (base year) and Figure 1.11.2 for 2008. The $CO_2$ contribution does not include LULUCFs. The comparison of both Figures shows that the production of $CO_2$ and $CH_4$ increased, while those of the rest GHGs decreased.

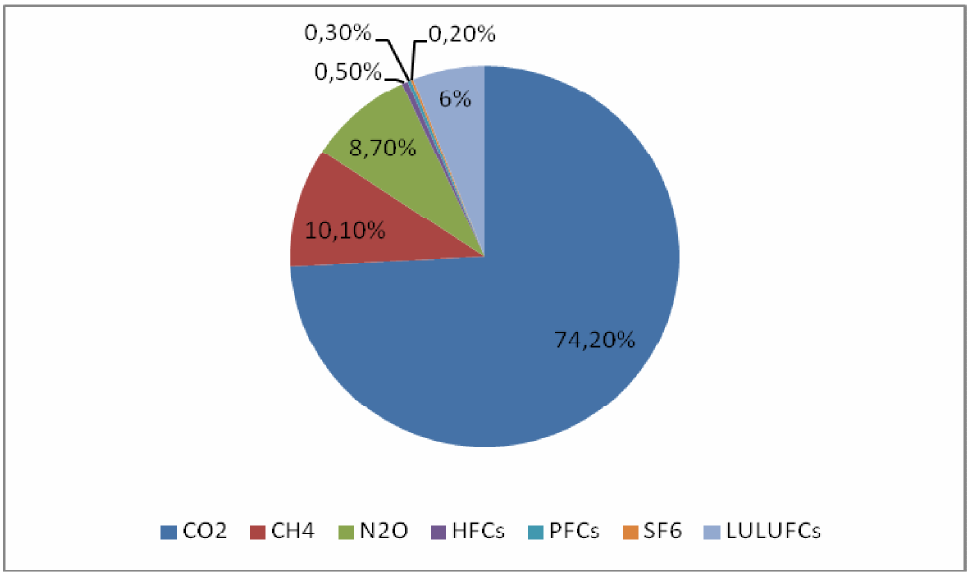


**Figure 1.11.1.** Emission totals per type of GHG from EU-27 for 1990 excluding LULUCFs. Data from EEA (2010a).

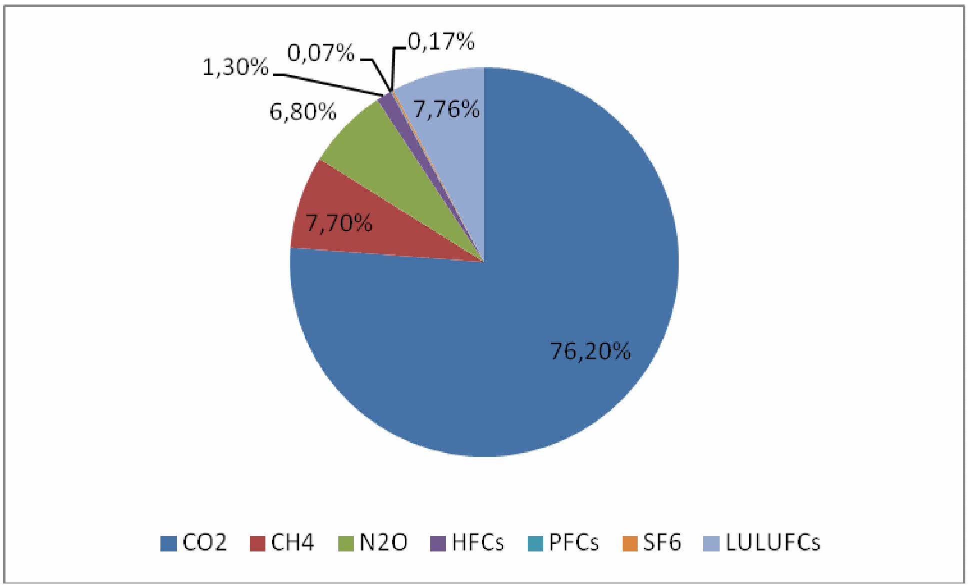


**Figure 1.11.2.** As in Fig. 1.11.1 but for 2008. Data from EEA (2010a).

## *1.12. GHG emissions by EU MS's*

The reduction in GHG emissions in 2008 in comparison to the base year of 1990 is estimated at 11.3 % (this figure excludes LULUCFs; EEA, 2010a). In terms of $CO_2$ equivalent this is 627 Mtoe. Figure 1.12.1 gives the variation of GHG emissions from EU-27 standardised to those of 1990.

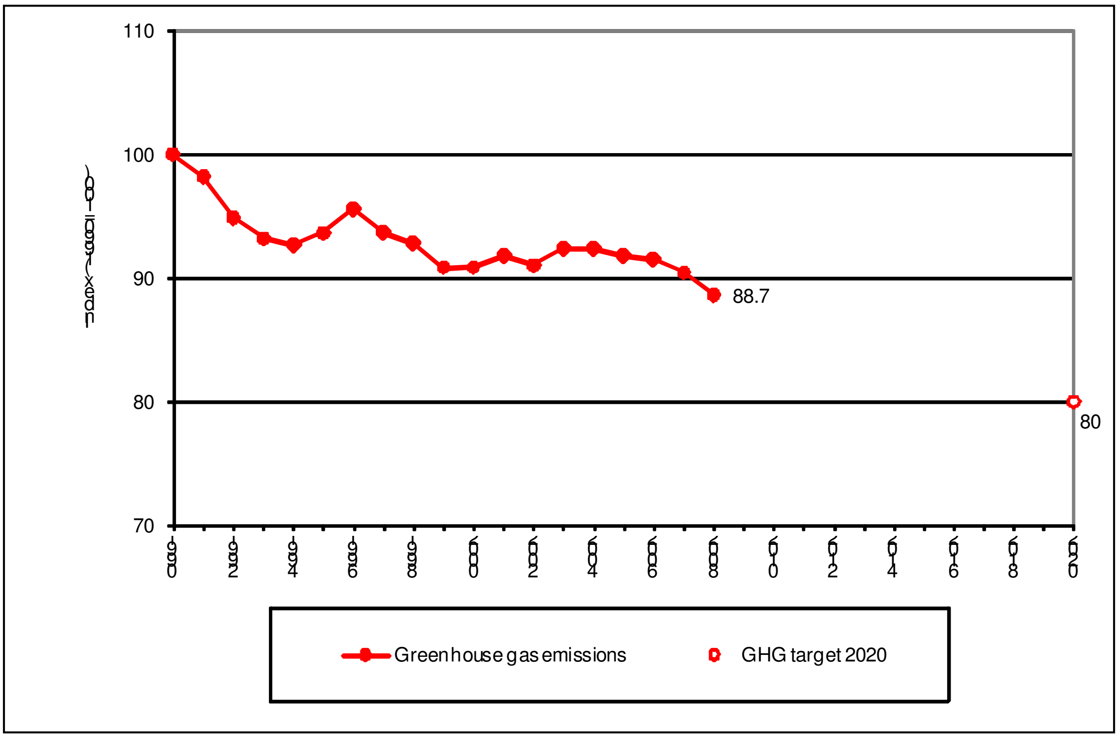


**Figure 1.12.1.** GHG emission totals from EU-27 between 1990 and 2008 (1990=100) excluding LULUCFs. Source: EEA (2010a).

Among the MS's, GHG emissions were dominated by the largest emitter, namely Germany (19.4 % of EU-27 total or 958.1 Mtoe of $CO_2$ equivalents in 2008), while the UK (12.7 %), Italy (11.0 %) and France (10.7 %) were the only other countries to have double-digit shares. The EU-15 MS accounted for 80.4 % in total GHG emissions within EU-27 in 2008, just 4.2 % higher than their corresponding share of 1990 (EEA, 2010a).

Table 1.12.1 gives an account of the GHG emissions distribution in $CO_2$ equivalents for 1990 and 2008 as well as the change (%) for the in-between period.

**Table 12.1.** GHG emissions in $CO_2$ equivalents (excluding LULUCF) and Kyoto-Protocol targets for 2008-2012. *Cyprus and Lithuania do not have targets under the Kyoto Protocol and, therefore, they do not provide base years. Source: EEA (2010a).

| MEMBER STATE | 1990 (million tonnes) | Kyoto Protocol base year [(a)] (million tonnes) | 2008 (million tonnes) | Change 2007–2008 (million tonnes) | Change 2007–2008 (%) | Change 1990-2008 (%) | Change base year–2008 (%) | Targets 2008–12 under Kyoto Protocol and "EU burden sharing" (%) |
|---|---|---|---|---|---|---|---|---|
| Austria | 78.2 | 79.0 | 86.6 | -0.3 | -0.4% | 10.8% | 9.6% | -13.0% |
| Belgium | 143.4 | 145.7 | 133.3 | 3.0 | 2.3% | -7.1% | -8.6% | -7.5% |
| Denmark | 68.9 | 69.3 | 63.8 | -3.0 | -4.5% | -7.4% | -7.9% | -21.0% |
| Finland | 70.4 | 71.0 | 70.1 | -7.9 | -10.2% | -0.3% | -1.2% | 0.0% |
| France | 563.2 | 563.9 | 527.0 | -3.2 | -0.6% | -6.4% | -6.5% | 0.0% |
| Germany | 1231.8 | 1232.4 | 958.1 | 0.7 | 0.1% | -22.2% | -22.3% | -21.0% |
| Greece | 103.3 | 107.0 | 126.9 | -5.0 | -3.8% | 22.8% | 18.6% | 25.0% |
| Ireland | 54.8 | 55.6 | 67.4 | -0.2 | -0.3% | 23.0% | 21.3% | 13.0% |
| Italy | 517.0 | 516.9 | 541.5 | -11.1 | -2.0% | 4.7% | 4.8% | -6.5% |
| Luxembourg | 13.1 | 13.2 | 12.5 | -0.30 | -2.3% | -4.8% | -5.1% | -28.0% |
| Netherlands | 212.0 | 213.0 | 206.9 | 0.0 | 0.0% | -2.4% | -2.9% | -6.0% |
| Portugal | 59.3 | 60.1 | 78.4 | -1.5 | -1.9% | 32.2% | 30.3% | 27.0% |
| Spain | 285.1 | 289.8 | 405.7 | -32.9 | -7.5% | 42.3% | 40.0% | 15.0% |
| Sweden | 72.4 | 72.2 | 64.0 | -2.2 | -3.3% | -11.7% | -11.3% | 4.0% |
| United Kingdom | 771.7 | 776.3 | 628.2 | -11.8 | -1.8% | -18.6% | -19.1% | -12.5% |
| **EU-15** | **4244.7** | **4265.5** | **3970.5** | **-75.7** | **-1.9%** | **-6.5%** | **-6.9%** | **-8.0%** |
| Bulgaria | 117.4 | 132.6 | 73.5 | -2.4 | -3.2% | -37.4% | -44.6% | -8.0% |
| Cyprus | 5.3 | Not applicable | 10.2 | 0.4 | 3.7% | 93.9% | Not applicable | Not applicable |
| Czech Republic | 195.2 | 194.2 | 141.4 | -6.1 | -4.1% | -27.5% | -27.2% | -8.0% |
| Estonia | 40.8 | 42.6 | 20.3 | -1.8 | -8.2% | -50.4% | -52.5% | -8.0% |
| Hungary | 97.4 | 115.4 | 73.1 | -2.6 | -3.4% | -24.9% | -36.6% | -6.0% |
| Latvia | 26.8 | 25.9 | 11.9 | -0.4 | -3.1% | -55.6% | -54.1% | -8.0% |
| Lithuania | 49.7 | 49.4 | 24.3 | -1.1 | -4.5% | -51.1% | -50.8% | -8.0% |
| Malta | 2.0 | Not applicable | 3.0 | -0.05 | -1.8% | 44.2% | Not applicable | Not applicable |
| Poland | 453.3 | 563.4 | 395.6 | -4.3 | -1.1% | -12.7% | -29.8% | -6.0% |
| Romania | 242.1 | 278.2 | 145.9 | -6.7 | -4.4% | -39.7% | -47.6% | -8.0% |
| Slovakia | 73.9 | 72.1 | 48.8 | 1.1 | 2.3% | -33.9% | -32.2% | -8.0% |
| Slovenia | 18.5 | 20.4 | 21.3 | 0.7 | 3.5% | 15.2% | 4.6% | -8.0% |
| **EU-27** | **5567.0** | **Not applicable** | **4939.7** | **-99.0** | **-2.0%** | **-11.3%** | **Not applicable** | **Not applicable** |

## 1.13. Carbon-intensity indicators

*Emission intensity* is the average emission rate of a given pollutant (in this case the GHGs) from a given source relative to the intensity of a specific activity; it is expressed as tonnes of $CO_2$ released per unit of energy produced, or the ratio of GHG emissions produced to the *Gross Domestic Product* (GDP). Emission intensities are used to derive estimates of GHG emissions based on the amount of fuel combusted, the number of animals in animal husbandry, on industrial production levels, distances travelled or similar activity data. Emission intensities may also be used to compare the environmental impact of different fuels or activities.

The related terms *emissions factor* (eq 1.8.1) or *carbon intensity* are often used interchangeably, but "factors" exclude aggregate activities such as GDP, and "carbon" excludes other pollutants. Intensities are also used in projecting possible future scenarios such as those used in the IPCC Assessment Reports, along with projected future changes in population, economic activity and energy technologies. The interrelations of these variables are treated under the so-called *Kaya identity*[11]. An economy that is dominated by “heavy”, traditional industries is more likely to have higher energy intensity than an economy based

[11] A simple model for forecasting future $CO_2$ emissions, based on trends in population, income, efficiency, and energy sources.

on services. Likewise, a country that relies on imports of goods (say, iron and steel products) will, a priori, have a lower level of energy intensity than a country that manufactures these goods itself.

The use of fuels with low-carbon content or carbon-neutral fuels clearly has an impact on the level of GHG emissions per capita. Emission levels per capita also reflect inherent differences between countries for other GHGs. For example, $CH_4$ and $N_2O$ emissions are strongly related to agricultural activities. Therefore, if an economy is characterised by a relatively low population density and has the necessary climatic and soil conditions to encourage farming, it is likely to have higher levels of $CH_4$ and $N_2O$ emissions per capita than a country with arid or arctic conditions.

The emission intensity is generally measured as the level of GHG emissions per unit of GDP. The GDP data is presented in terms of *purchasing power standards* (PPS), thus removing distortions that result from differences in price levels between countries. There is particular interest in this relationship from a sustainable development point of view, in order to show whether GHG emissions can be decoupled from economic growth; in other words, to investigate the way environmental pressures are linked to economic growth.

## *1.14. Public information related to climate change*

The climate-change issue is a common talk worldwide. Because of the wide public interest blogs, websites, leaflets, brochures, electronic documents as well as ordinary books have been devoted to explaining the cause of climate change and how its impact can be mitigated. At European level official documents have appeared several times. Since such publications are numerous, they cannot be deployed here. For brevity it is said that almost all Ministries of Environment devote part of their website to climate change and particularly the measures taken at national level to combat its effects. Examples are the Department of Energy and Climate Change of UK[12], the Ministry of Environment, Energy and Climate Change of Greece[13], the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany[14], the Ministry of Environment, Rural and Marine Affairs of Spain[15], the EEA[16]. On the other hand, various videos have been produced by the National Geographic[17], the Discovery News[18], in YouTube[19], or The Guardian[20] covering various topics of climate change.

[12] www.decc.gov.uk
[13] http://www.ypeka.gr/Default.aspx?tabid=226&locale=en-US&language=el-GR
[14] http://www.bmu.de/english/climate_energy/doc/41327.php
[15] http://www.mma.es/portal/secciones/cambio_climatico/
[16] http://www.eea.europa.eu/themes/climate
[17] e.g. http://video.nationalgeographic.com/video/player/environment/global-warming-environment/way-forward-climate.html
[18] e.g. http://news.discovery.com/videos/animals-tigers-threatened-by-climate-change.html
[19] e.g. http://www.youtube.com/watch?v=zzjOcOcQ90U
[20] e.g. http://www.guardian.co.uk/environment/video/2010/jan/15/climate-change-nile

## 1.15. *Energy-related GHG emissions*

Energy production and consumption are the largest sources of GHG emissions in EU-27, amounting to 80 % of the total. Energy-related GHG emissions in EU-27 decreased by 17 % between 1990 and 2008 (see Figs 1.10.1 and 1.10.2). This was coincidentally equal to the 17 % reduction observed for the non-energy (agriculture, industrial processes, solvents/other, transport, waste) related emissions (see also Figs 1.10.1 and 1.10.2). Between 2003 and 2005 energy-related GHG emissions in EU-27 decreased by 0.8 %, while they increased by 4.2 % between 1999 and 2003, mainly due to increases in thermal power production (EEA, 2007a).

The decrease in 2003 - 2005 is partly due to higher electricity generation from hydropower in northern European countries and lower thermal power production. Warmer winters were also partly responsible for lower emissions from households and services in Germany and the Netherlands.

Concerning energy-related $CO_2$, $CH_4$, and $N_2O$ emissions marked differences in their shares are shown:

- $CO_2$ is by the most significant energy-related GHG, with a share of 96.4 %. In EU-27, energy-related $CO_2$ emissions decreased by 3.3 % in the period 1990 - 2005; most EU-15 MS had a rise, but that was offset by a decrease in emissions from most new MS; and
- $CH_4$ and $N_2O$ emissions constitute only a small fraction in total energy-related emissions (2.1 % and 1.5 %, respectively). $N_2O$ emissions increased by 31.9 %, while $CH_4$ ones decreased by 44.4 %. More than 80 % of $CH_4$ emissions come from fugitive emissions in the extraction, production and distribution of fossil fuels.

The above reductions in energy-related emissions in the period 1990 - 2005 were supported by structural changes in the economies of the new MS in central and eastern Europe in the early 1990s; these were combined with reductions within Germany due to economic restructuring and in the UK due to a switch from coal to gas (EEA, 2007a) accompanied by specific policies and measures from other EU MS. However, the reductions achieved by the UK, Germany and Sweden were partly offset by increased emissions in other MS, like Austria, Greece, Ireland, Portugal and Spain.

## 1.16. *GHG-mitigation/adaptation policies within EU*

### 1.16.1. GHG-mitigation policy

As known, UNFCCC has set an ultimate goal of stabilising the GHG concentrations 'at a level that would prevent dangerous anthropogenic interference with the climate system.' The Convention also requires precise and regularly updated inventories of the GHG emissions from industrialised countries. The reference or base year for calculations is 1990, with few exceptions.

The Kyoto Protocol has set binding targets for the industrialised countries and EC for reducing the GHG emissions. These emissions amount to an average of 5 % against the 1990 levels over the period 2008 - 2012.

EC sends annual reports to UNFCCC on the GHG emissions for its MS's. These reports are called "Annual European Community GHG inventory and inventory report" (EAA, 2010b) and are officially submitted to UNFCCC on behalf of EC DG-Environment by EEA's ETC/ACC supported by JRC and Eurostat. The legal basis for the preparation of these reports is *280/2004/EC decision* (EC, 2004). The directive has set the following rules for the MS's:

- to monitor all anthropogenic GHG emissions covered by the Kyoto Protocol;
- to evaluate progress towards meeting GHG-reduction commitments under UNFCCC and Kyoto Protocol;
- to implement UNFCCC and Kyoto Protocol in the national programmes, GHG inventories, national systems and registries of the EC and its MS's, and the relevant procedures under the Kyoto Protocol; and
- to ensure the timeliness, completeness, accuracy, consistency, comparability and transparency of reporting by the EC and its MS's to UNFCCC Secretariat.

The Kyoto Protocol has enforced EU-15 to take on common commitment to reduce GHG emissions by 8 % on average between 2008 and 1012. Hungary and Poland have reduction targets of 6 %. Of the new EEA member countries, Norway and Iceland have emission-reduction targets under the Kyoto Protocol of 1 % and 10 %, respectively, from their base-year emissions. Switzerland and Liechtenstein have targets of 8%. Turkey, a Party to UNFCCC, but not to Kyoto Protocol, has no reduction target. Croatia, an EU candidate, ratified the Protocol in May 2007 with a reduction target of 5 %.

In March 2007 the EU leaders endorsed an integrated approach to climate and energy policy to combat climate change and increase EU-energy security, while strengthening its competitiveness. They committed Europe to transforming itself into a highly energy-efficient, low-carbon economy. This is known as the "20-20-20" target[21]. In more detail the target concerns:

- a reduction in EU GHG emissions of at least 20 % below the 1990 levels;
- 20 % of EU-energy consumption to come from renewable resources; and
- a 20 % reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

The EU leaders also offered to increase the EU-emission reduction target to 30 %, provided that other major emitting countries in the developed and developing worlds would commit to take their share under a global climate agreement. UN negotiations on such an agreement are ongoing.

The *DG for Climate Action* (DG-Clima) was established in February 2010; this issue was previously addressed by the DG-Environment. The DG-Clima leads international negotiations

[21] http://www.energyefficiencynews.com/i/1693/

on climate, helps EU to deal with the consequences of climate change and to meet its targets for 2020, as well as develops and implements EU ETS.

In view of the goal to keep global average temperature increase below 2$^{o}$ C (that is 1.2$^{o}$ C above today's level) compared to the pre-industrial levels, the DG-Clima develops and implements cost-effective international and domestic climate-change policies and strategies in order for the EU to meet its targets for 2020 and beyond, especially with regard to reducing its GHG emissions. Its policies also aim at protecting the ozone layer.

### 1.16.2. GHG-adaptation policy

EU is working hard to cut its GHG emissions substantially, while encouraging other nations and regions to do so. At the same time, EU is developing a strategy for adapting to the impacts of climate change (EC, 2008). It tries to invest in green technologies that cut emissions, but also create jobs and boost national and European economies. Along these lines EC services are exploring options for preparing future proposals. The initiatives undertaken for cutting climate emissions refer to the following measures:

- continual improvement of the energy efficiency in a wide variety of equipment and household appliances;
- increased use of RES, such as wind, solar, hydro and biomass, and of renewable transport fuels, such as biofuels;
- support to the development of CCS technologies to trap and store $CO_2$ emitted by power stations and other large installations;
- launch of ECCP in 2000, which has led to the adoption of a wide range of new policies and measures, including ETS(EC, 2009); and
- development of a comprehensive EU-adaptation strategy that strengthens Europe's resilience to climate change.

In April 2009 EC publicized a policy paper known as "White Paper", which presents the framework for adaptation measures and policies to reduce EU's vulnerability to the impacts of climate change. The framework focuses on the following key areas:

- building a stronger knowledge base since sound data is vital in the development of climate policy;
- taking climate-change impacts into consideration in key EU policies;
- financing climate-change policy measures; and
- supporting wider international efforts on adaptation by helping, for example, non-EU countries to improve their resilience and capacity to adapt to climate change.

# 2. Overview of procedures and standards in data collection

## *2.1. EC Decision 280/2004/EC*

This Decision was published in the *Official Journal of the European Union* on February 19, 2004, under the distinct title *"Decision 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community GHG emissions and for implementing the Kyoto Protocol"*. It concerns the establishment of a mechanism for monitoring all anthropogenic emissions, evaluating the progress towards meeting commitments in respect of these emissions, implementing the UNFCCC and the Kyoto Protocol, and ensuring the timeliness, completeness, accuracy, consistency, comparability and transparency of reporting (Article 1). In Article 2, EU lays the base in the MS's for implementing national and Community programmes to meet the above requirements. Article 3 talks about the obligation of each MS to report to UNFCCC and Kyoto Protocol. Article 4 refers to the necessity of the creation of a GHG inventory in each MS, while Article 5 refers to the obligation of EC to assess the progress of MS's towards fulfilling their commitments under UNFCCC and Kyoto Protocol.

## *2.2. EC FP7 model grant*

The FP7 Grant Agreement (2009) describes the rules that data in an FP7 project should be handled and disseminated. This model is also related to GHG-inventory data and statistics released through such projects, as PROMITHEAS-4. Clause 21 talks about classified data or information or dangerous materials specific to a security-related project (SAL). Clause 22 refers to the treatment of confidential, classified data or information or dangerous materials specific to a SAL. These two Clauses are not applicable to PROMITHEAS-4 project. Clause 28 refers to the right to access and to use data for the purposes of EU specific to SAL, i.e., "the Union shall enjoy access rights to information specifically acquired for the project and to foreground for the purpose of developing, implementing and monitoring Union policies related to environment and security. Such access rights shall be granted on a royalty-free basis". Clause 33 refers to confidential, classified data or information or dangerous materials, where specific mention is made about the preservation of the data gathered through a project, such as PROMITHEAS-4, by the beneficiaries for a period of five (5) years after its completion. The two last Clauses apply to PROMITHEAS-4.

## *2.3. EMEP/CORINAIR good practice for CLRTAP-emission monitoring*

The core of any air-quality management is an emissions inventory. The emissions inventories do not measure, but estimate the GHG emissions by applying the 1996-IPCC methods. The simplest methodology involves information about a human activity with an EF, as described in §1.8 (eq 1.8.1).

The emissions inventory is needed by environmental policy makers in order to assess the contribution of individual air pollutants to the integrated air-pollution problem of an area and to know about the possible interactions among them. Also, such data is used as input to air-quality models. In view of these the EMEP/CORINAIR programme (EEA, 2007b) issued a good-practice guidance aiming at supporting Parties to CLRTAP in preparing inventories that allow for:

- the process of considering Parties' reports on emission inventories and projections, including their technical analysis and compilation; and
- the process of verification and technical assessment, including expert review.

This guidance is fully compatible with that developed by IPCC for climate change (Penman et al., 2000), known as IPCCC GPGAUM. The correspondence between sections of that Guidance and IPCCC GPGAUM is as follows:

- *Introduction and application of data* corresponds to *Chapter 1*, *Annexes 1 and 3*
- *Documentation of data and procedures* corresponds to *Chapter 8*
- *Good practice in inventory preparation – Methodological choice* corresponds to *Chapter 7*
- *Uncertainty estimates* corresponds to *Chapter 6* and sectors in *Chapter 2, 3, 4 and 5*
- *Verification* corresponds to *Annex 2*.

All above descriptions fall into three (3) main categories as far as inventory quality is concerned: (i) verification and validation, (ii) uncertainties, and (iii) good practice. A brief description of these three core issues is given below.

### 2.3.1. Verification and validation

The purpose of verification/validation is to ensure that Parties report accurate and reliable emissions data. The verification process refers to the collection of activities and procedures, which have to be followed in planning and development of the data base. The validation process refers to the establishment of a checking procedure to ensure that the inventory has been compiled correctly.

### 2.3.2. Uncertainties

The estimate of uncertainties in the measurement of the elements comprising the data base is essential. Given the uncertainties in the inventory, verification and validation of an inventory are aspects of the quality of the inventory. Tools that support these activities include quality assurance (QA) and quality control (QC) and verification.

### 2.3.3. Good practice

According to IPCCCGPGAUM, Good Practice is "a set of procedures intended to ensure that inventories are accurate in the sense that they are systematically neither over- nor under-estimated so far as can be judged and that underestimates are reduced as possible". This definition covers (i) the choice of estimation methods appropriate to national peculiarities,

(ii) the QA/QC at the national level, (iii) the quantification of uncertainties, and (iv) the data archiving and reporting to promote transparency.

## *2.4. EMEP/EEA definitions*

The EMEP/EEA guide for data collection (EEA, 2009) has been adopted by IPCC (IPCC, 2006). The data collection is defined as "an integral part of developing and updating an inventory". The basic principles for data collection are the following:

- collection of data needed to improve estimates of the largest key categories;
- selection of data-collection procedures that improve the quality of the inventory;
- selection of data-collection activities that result in continuous improvement of the data in the inventory;
- collection of data/information at such a detail that is appropriate for the method used;
- regular review of data-collection activities and methods to ensure improvement of the inventory, and
- agreement with data suppliers for a smooth and continuous flow of information.

The data in an inventory can refer to the following categories: (i) existing data; (ii) new data; (iii) data adaptation; (iv) emission factors and measured emissions; and (v) activity data.

### 2.4.1. Existing data

Sources for existing data can be the national or international statistics agencies (Eurostat, UN, OECD, IMF, IEA), sectoral, national and international experts, stakeholder organisations, emission-factor data bases (including the US EPA), national libraries, academia (e.g., universities, research centres, academies of sciences), and web pages. The main effort in obtaining data is the detailed information of its source (what to ask for, from whom and when) and then the application of QA/QC procedures to ensure that the data is reliable. The data details should include:

- definition of the data set (e.g., time series, sectors and sub-sectors, national coverage, requirements for uncertainty of the data, emission factors and/or activity-data units);
- data format (e.g., Microsoft Excel) and structure (e.g., tables needed and their structure);
- description of national coverage, sectors included, representative (base) year, technology/management level, uncertainty parameters;
- identification of routines and time scales for the data-collection activity (e.g., how often and what elements are updated);
- QA/QC procedures;
- contact person; and
- date of availability.

In case that there are some gaps in the collection of the data sets, then *surrogate data* can be used for this purpose. This data should be physically and statistically related to the emissions of the set of facilities for which information is not available. Such 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 from the information obtained from a representative subset of facilities whose emissions are known. To do that, it is good practice for the countries to:

(i) confirm and document the physical relationship between emissions and surrogate-activity data;
(ii) confirm and document a statistically-significant correlation between emissions and surrogate-activity data; and
(iii) develop a country-specific factor relating emissions with surrogate data, using regression analysis.

It is good practice to engage data suppliers in the inventory compilation process by involving them in activities such as: (i) initial estimate for the data category, (ii) scientific or statistical workshops on inventory inputs and outputs, (iii) contracts or agreements for regular data supply, (iv) regular update on the methods that use their data, (v) ToR or MoU for government and/or trade organisations providing data.

It should be mentioned that some data providers may pose restrictions or confidentiality. It is advisable, though, to cooperate with data suppliers to find solutions to overcome their concerns.

### 2.4.2. New data

The generation of new data may be necessary if representative emission factors, activity data or other estimation parameters do not exist or cannot be estimated from existing sources. This generation should be undertaken by experts (e.g., organisations with calibrated equipment, surveys and censuses). Upon generating data by measurements it is good practice to check whether this data comprises a representative sample, i.e., it is typical of a representative proportion of the whole sector. The best measurement methods are those conformed to international standards, e.g., ISO, EN. Reliable and comparable results can be achieved via a well-designed measurement programme with specific objectives, appropriate methods, clear instructions to the measurement staff, and clear data processing and reporting procedures and adequate documentation.

### 2.4.3. Data adaptation

In using existing data, making new measurements or combining the two for inventory use, some approaches in filling gaps in the data sets should be considered. Some examples of data gaps are the following:

(i) filling gaps in periodic data (gaps in time series when data is available less frequently than annual supply);
(ii) time-series revision (use of modelling and assumptions to complete most recent year of emission estimates);

(iii) improved data (availability of better-quality data from countries that generally improve data collection and data quality);
(iv) compensation for deteriorated data (use of splicing techniques); and
(v) incomplete coverage (for data not representative of the whole country time-series consistency techniques must be applied).

In combining data sets of various uncertainties the overall inaccuracy may increase due to, say, data inhomogeneity. This inhomogeneity can come from (i) multi-year averaging (for calculating single-year statistics), and (ii) use of non-calendar-year data (data collection for a period of the year, e.g., animal population during the summer).

In certain circumstances regional-activity statistics and emission-data sets are more detailed than national ones. In these cases, the good practice is to compile the entire or partial inventory on regional basis provided that QA/QC is applied, data gaps are filled, and the final inventory meets the requirements of completeness, consistency, comparability, timeliness, accuracy and transparency.

The advice of experts in selecting the appropriate methodology and appropriate data for the development of the inventory should always be sought. Some statisticians may be experts in data-gap filling. Others may be valuable in judging the uncertainty ranges of the data to be included in the inventory.

### 2.4.4. Emission factors and measured emissions

It is good practice in developing emission or abatement factors, which will reflect the quality of the data collected, to set priorities, to develop a strategy for accessing, collecting and processing the data. Available literature on emission sources can be used in this case (e.g., the EMEP/CORINAIR emission-inventory guidebook, the international emission-factor data bases of US EPA, the international emission-factor data bases from OECD, the country-specific data from international or national peer-review journals, the national-testing facilities, the emission regulating-authority records and papers or pollution releases and transfer registries, the industry technical and trade papers, other studies, censuses, surveys, and emission factors from other countries).

In performing an emission-measurements programme it is good practice to use instruments of known quality, calibrated, regularly maintained and inspected and to include a monitoring protocol, e.g., if there are contaminants that could harm the measurement process.

### 2.4.5. Activity data

The activity data in an inventory contains information on specialised data sources, surveys censuses, and the use of the measurement-related data, where appropriate.

## *2.5. Eurostat definitions*

The air-emission accounts are a statistical information system that consists of conventional national accounts and environmental accounts. The national accounts (called SNA) represent all economic activities of a country with a prominent indicator, the GDP. The environmental accounts consist of environmental variables, which are organised in a format compatible with the standardised system of the national accounting. It allows for environment-pressure data to be directly related to economic production and consumption activities. The Eurostat air-emission accounts contain information about emissions of GHGs and air pollutants.

As mentioned in §1.9, air-emission accounts are based on residence principle, while national emission inventories on territory principle. For example, Eurostat's air-emission accounts are related to emissions of entities registered in the country (e.g., ships, residents) and the $CO_2$ from biomass. To the contrary, UNFCCC's national emission inventories include emissions from international bunkers allocated to country where the fuel is sold and not to the nationality of the purchasing unit; also, emissions/removals induced by land-use change and forestry are accounted for. Air-emission accounts include $CO_2$, $CH_4$, $N_2O$ as GHGs, excluding HFCs, PFCs, $SF_6$, $NO_x$, CO, NMVOCs, and $SO_2$ (Eurostat, 2010).

## 2.6. IPCC guidelines for national GHG inventories

These guidelines are those adopted by EMEP/EEA and described in §2.4. Therefore, there is no need for repetition in this section. The revised 1996-IPCC guidelines (IPCC, 1996) set out the GHG sectors to be included in the national inventory. This revision resulted from the requirement of United Nations Economic Commission for Europe[22] (UNECE) to establish a much more detailed understanding of the physical source and geographic distribution of emissions and was based on the correspondence between EMEP/CORINAIR (EEA, 2007b) and IPCC source categories. These same categories are found in the latest IPCC (2006b) guidelines for national GHG inventories and are the following:

(1) energy, including transport (fuel combustion activities and fugitive emissions from fuels),
(2) industrial processes,
(3) solvent and other product use,
(4) agriculture,
(5) LULUCF, and
(6) waste,

with memo items: international aviation bunkers, international marine bunkers, $CO_2$ emissions from biomass.

Every NIR, and therefore each national GHG Inventory, should include data for the 6 categories described here.

## 2.7. IPCC GPGAUM national GHG inventory

The IPCC good practice guidance and uncertainty management in GHG inventories was published in 2000 (IPCC, 2000) with a corrigendum (IPCC, 2001). This report was the

[22] http://www.unece.org/

response to the request from UNFCCC for IPCC to complete its work on uncertainty and prepare a report on good practice in inventory management. The report provides *good practice guidance* to assist countries in producing inventories that are neither over- nor under-estimated so far as can be judged, and in which uncertainties are reduced as far as practicable. To this end, it supports the development of inventories that are transparent, documented, consistent over time, complete, comparable, assessed for uncertainties, subject to quality control and quality assurance, and efficient in the use of resources.

# 3. Choice and identification of key-emission categories

## 3.1. Introduction

In an inventory it is essential to choose the appropriate sources/sinks and determine their associated uncertainties. It is, therefore, good practice to identify those *key categories* that have the greatest contribution to the overall inventory uncertainty, in order to make use of the available resources. Thus, it is good practice for each country to identify its national key categories in a systematic and objective manner (IPCC, 2006b). A key category is a sector that has significant influence on a country's GHG inventory in terms of absolute terms, trends and uncertainty in emissions and removals. Therefore, the term "key category" includes sources and sinks.

## 3.2. General rules

Table 3.2.1 gives an account of the suggested aggregation level of analysis for Approach 1 (for Approaches see §3.3). For each key category, the inventory compiler should determine the sub-categories that are significant. The sub-categories must then be ranked according to their contribution to the *aggregate key category*. If the sub-category contributes more than 60 % to the key category, it must be included.

**Table 3.2.1.** Source and sink categories for key-category analysis (IPCC, 2006b).

| Category code | Category title | GHGs | Remarks |
|---|---|---|---|
| **Energy** | | | |
| 1A1 | Fuel combustion, energy industries | $CO_2$, $N_2O$, $CH_4$ | Disaggregate to main fuel types |
| 1A2 | Fuel combustion, manufacturing industries & construction | $CO_2$, $N_2O$, $CH_4$ | Disaggregate to main fuel types |
| 1A3a | Fuel combustion, transport, civil transport | $CO_2$, $N_2O$, $CH_4$ | Domestic aviation only |
| 1A3b | Fuel combustion, transport, road transport | $CO_2$, $N_2O$, $CH_4$ | |
| 1A3c | Fuel combustion, transport, railways | $CO_2$, $N_2O$, $CH_4$ | |
| 1A3d | Fuel combustion, transport, water-borne navigation | $CO_2$, $N_2O$, $CH_4$ | Disaggregate to main fuel types, domestic water-borne navigation only |
| 1A3e | Fuel combustion, transport, other transportation | $CO_2$, $N_2O$, $CH_4$ | Determine which sub-categories are significant, if this category is key |
| 1A4 | Fuel combustion, other sectors | $CO_2$, $N_2O$, $CH_4$ | Disaggregate to main fuel types |
| 1A5 | Fuel combustion, unspecified | $CO_2$, $N_2O$, $CH_4$ | Disaggregate to main fuel types |
| 1B1 | Fugitive emissions from fuels, solid fuels | $CO_2$, $CH_4$ | |
| 1B2a | Fugitive emissions from fuels, oil & natural gas, oil | $CO_2$, $CH_4$ | Determine which sub-categories are |

| | | | |
|---|---|---|---|
| | | | significant, if this category is key |
| 1B2b | Fugitive emissions from fuels, oil & natural gas, natural gas | $CO_2$, $CH_4$ | Determine which sub-categories are significant, if this category is key |
| 1C | $CO_2$ transport & storage | $CO_2$ | Determine which sub-categories are significant, if this category is key |
| 1 | Miscellaneous | $CO_2$, $N_2O$, $CH_4$ | Assess whether other sources in the energy sector not listed above should be included |
| **Industrial processes & product use** | | | |
| 2A1 | Mineral industry, cement production | $CO_2$ | |
| 2A2 | Mineral industry, lime production | $CO_2$ | |
| 2A3 | Mineral industry, glass production | $CO_2$ | |
| 2A4 | Mineral industry, other process uses of carbonates | $CO_2$ | Determine which sub-categories are significant, if this category is key |
| 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- & glyoxylic-acid production | $N_2O$ | Determine which sub-categories are significant, if this category is key |
| 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 & black-carbon production | $CO_2$, $CH_4$ | Determine which sub-categories are significant, if this category is key |
| 2B9 | Chemical industry, flurochemical production | HFCs, PFCs, $SF_6$ & other halogenated gases | All gases should assessed jointly |
| 2C1 | Metal industry, iron & steel production | $CO_2$, $CH_4$ | |
| 2C2 | Metal industry, ferroally production | $CO_2$, $CH_4$ | |
| 2C3 | Metal industry, aluminium production | PFCs, $CO_2$ | PFCs should be assessed jointly and $CO_2$ separately |
| 2C4 | Metal industry, magnesium production | $CO_2$, HFCs, PFCs, $SF_6$ & other | If HFCs and PFCs are not included in the |

| | | | |
|---|---|---|---|
| | | halogenated gases | inventory it is good practice to use qualitative estimates |
| 2C5 | Metal industry, lead production | $CO_2$ | |
| 2C6 | Metal industry, zinc production | $CO_2$ | |
| 2D | Non-energy products from fuels & solvent use | $CO_2$ | Determine which sub-categories are significant, if this category is key |
| 2E | Electronics industry | HFCs, PFCs, $SF_6$ & other halogenated gases | All gases should be included jointly |
| 2F1 | Product uses as substitutes for $O_3$ depleting substances, refrigeration & air conditioning | HFCs, PFCs | All HFCs and PFCs should be assessed jointly |
| 2F2 | Product uses as substitutes for $O_3$ depleting substances, foam-blowing agents | HFCs | All HFCs should be assessed jointly |
| 2F3 | Product uses as substitutes for $O_3$ depleting substances, fire protection | HFCs, PFCs | All HFCs and PFCs should be assessed jointly |
| 2F4 | Product uses as substitutes for $O_3$ depleting substances, aerosols | HFCs, PFCs | All HFCs and PFCs should be assessed jointly |
| 2F5 | Product uses as substitutes for $O_3$ depleting substances, solvents | HFCs, PFCs | All HFCs and PFCs should be assessed jointly |
| 2F6 | Product uses as substitutes for $O_3$ depleting substances, other applications | HFCs, PFCs | All HFCs and PFCs should be assessed jointly |
| 2G | Other product manufacture & use | $SF_6$, PFCs, $N_2O$ | All PFCs and $SF_6$ should be assessed jointly |
| 2 | Miscellaneous | $CO_2$, HFCs, PFCs, $SF_6$ & other halogenated gases | Assess whether other sources in the industrial processes & product use sector not listed above should be included |
| **Agriculture, forestry & other land use (AFOLU)** | | | |
| 3A1 | Enteric fermentation | $CH_4$ | Determine which animal categories are significant, if this category is key |
| 3A2 | Manure management | $CH_4$, $N_2O$ | Determine which animal categories are significant, if this category is key |
| 3B1a | Forest land remaining forest land | $CO_2$ | Determine which pools are significant, if this category is key |
| 3B1b | Land converted to forest land | $CO_2$ | Determine which pools & sub-categories are significant, if this |

| | | | |
|---|---|---|---|
| | | | category is key |
| 3B2a | Cropland remaining cropland | $CO_2$ | Determine which pools are significant, if this category is key |
| 3B2b | Land converted to cropland | $CO_2$ | Assess impact of forest land converted to cropland in a separate category |
| 3B3a | Grassland remaining grassland | $CO_2$ | Determine which sub-categories are significant, if this category is key |
| 3B3b | Land converted to grassland | $CO_2$ | Assess impact of forest land converted to grassland in a separate category |
| 3B4ai | Peatlands remaining peatlands | $CO_2$, $N_2O$ | |
| 3B4aii | Flooded land remaining flooded land | $CO_2$ | |
| 3B4b | Land converted to weatlands | $CO_2$ | Assess impact of forest land converted to wetland in a separate category |
| 3B5a | Settlements remaining settlements | $CO_2$ | Determine which sub-categories are significant, if this category is key |
| 3B5b | Land converted to settlements | $CO_2$ | Assess impact of forest land converted to settlements in a separate category |
| 3C1 | Biomass burning | $CH_4$, $N_2O$ | |
| 3C2 | Liming | $CO_2$ | |
| 3C3 | Urea application | $CO_2$ | |
| 3C4 | Direct $N_2O$ emissions from managed soils | $N_2O$ | Determine which sub-categories are significant, if this category is key |
| 3C5 | Indirect $N_2O$ emissions from managed soils | Indirect $N_2O$ | Determine which sub-categories are significant, if this category is key |
| 3C6 | Indirect $N_2O$ emissions from manure management | Indirect $N_2O$ | |
| 3C7 | Rice cultivation | $CH_4$ | |
| 2D1 | Harvested wood products | $CO_2$ | Optional |
| 3 | Miscellaneous | $CO_2$, $N_2O$, $CH_4$ | Assess whether other sources in the AFOLU sector not listed above should be included |
| **Waste** | | | |
| 4A | Solid-waste disposal | $CH_4$ | Determine which sub-categories are significant, if this category is key |

| | | | |
|---|---|---|---|
| 4B | Biological treatment of solid waste | $CH_4$, $N_2O$ | |
| 4C | Incineration & open burning of waste | $CO_2$, $N_2O$, $CH_4$ | |
| 4D | Wastewater treatment & discharge | $N_2O$, $CH_4$ | Assess whether domestic or industrial wasterwater treatment is a significant category |
| 4 | Miscellaneous | $CO_2$, $N_2O$, $CH_4$ | Assess whether other sources in the waste sector not listed above should be included |
| 5A | Indirect $N_2O$ emissions from atmospheric deposition of nitrogen in $NO_x$ & $NH_3$ | Indirect $N_2O$ | |
| 5B | Other | $CO_2$, $N_2O$, $CH_4$, $SF_6$, PFCs, HFCs | Include sources & sinks reported under 5B |

## 3.3. Methodological approaches

As said in the Introduction (§3.1), it is good practice for each country to identify its national key categories in a systematic and objective way. This can be done by working out a quantitative analysis of the relationships that exist between the level and the trend of the emissions/removals in each category to the total national emissions/removals. There are two ways of implementing this approach.

Approach 1.

The key categories are identified using a pre-defined cumulative-emissions threshold. The key categories are those sectors that, when summed up in descending order of magnitude, account for up to 95 % of the total level.

The level assessment for the contribution of each source/sink category to the total national inventory level is given by:

$$L_{x,t} = |E_{x,t}| \;/\; \Sigma|E_{y,t}| \qquad (3.3.1)$$

where $L_{x,t}$ is the level for source/sink x in the latest inventory year t, $|E_{x,t}|$ is the absolute value of emissions/removals estimate of source/sink category x in year t, and $\Sigma|E_{y,t}|$ is the sum of the absolute values of emissions/removals (y variable) in year t calculated using the aggregation level chosen by the country for the key category analysis. There should be noted here that since both emissions/removals are entered as positive (absolute) values, the total contribution can exceed the country's total emissions less the removals. Table 3.3.1 gives a spreadsheet example and by no way it can be considered a complete inventory. Therefore, the sum of all $L_{x,t}$ in column F is not 1 and the final cumulative total in column G is not unity either.

**Table 3.3.1.** Example of level assessment in Approach-1 analysis.

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| **IPCC** | **IPCC** | **GHG** | **Latest year** | **Absolute** | **Level** | **Cumulative** |

| category code | category title | | estimate, $E_{x,t}$ (Mtoe $CO_2$) | value of latest year estimate, $\|E_{x,t}\|$ (Mtoe $CO_2$) | assessment, $L_{x,t}$ | total of column F |
|---|---|---|---|---|---|---|
| 3B1a | Forest land remaining forest land | $CO_2$ | -21354 | 21354 | 0.193 | 0.193 |
| 1A1 | Energy industries, solid | $CO_2$ | 17311 | 17311 | 0.157 | 0.350 |
| 1A1 | Energy industries, peat | $CO_2$ | 9047 | 9047 | 0.082 | 0.432 |
| 1A1 | Energy industries, gas | $CO_2$ | 6580 | 6580 | 0.060 | 0.492 |
| 1A4 | Other sectors, liquid | $CO_2$ | 5651 | 5651 | 0.051 | 0.543 |
| … | … | … | … | … | … | should be 1.000 in a complete inventory |
| **Total** | | | **17235** | **60123** | **should be 1 in a complete inventory** | |

Another statistic is trend. The purpose for the assessment of this parameter is to identify those categories that may not be large enough to be identified by the previous statistic (level assessment), but their trend is significantly different from that of the overall inventory. This statistic is defined as follows:

$T_{x,t} = A\ |B - C|$ (3.3.2a)

$A = |E_{x,0}|\ /\ \Sigma|E_{y,0}|$ (3.3.2b)

$B = (E_{x,t} - E_{x,0})\ /\ |E_{x,0}|$ (3.3.2c)

$C = (\Sigma E_{y,t} - \Sigma E_{y,0})\ /\ |\Sigma E_{y,0}|$ (3.3.2d)

where $T_{x,t}$ is the trend of the source/sink category x in year t compared to the base year 0, $E_{x,t}$ and $E_{x,0}$ are the values of the emission/removal estimates of the source/sink category x in years t and 0, respectively, and $\Sigma E_{y,t}$ (summation in y) and $\Sigma E_{y,0}$ (summation in y) are the total inventory estimates for years t and 0, respectively.

The trend of a category refers to the change in the source/sink category emissions/removals over time; it is computed by subtracting the base year-0 estimate for the source/sink category x from the latest inventory 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/removals over time; it is computed by subtracting the base year-0 estimate for the total inventory from the latest year-t estimate and dividing by the absolute value of the base-year estimate. The relationship for the total trend is given below:

$$T_{x,t} = |E_{x,t} / \Sigma|E_{y,0}|| \quad (3.3.3)$$

where the summation is for all y's. The assessment of the total trend identifies those categories, which have trend different from the trend of the overall inventory, regardless whether the category trend increases or decreases, or is a sink or source. Those categories that have trends diverging most from the total trend should be identified as key, when this difference is weighted by the level of emissions/removals of the category in the base year. Table 3.3.2 gives a spreadsheet example and by no way it can be considered a complete inventory. Therefore, the sum of all contributions to trends in column G is not 1 and the final cumulative total in column H is not unity either.

**Table 3.3.2.** Example of trend assessment in Approach-1 analysis.

| A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| **IPCC category code** | **IPCC category** | **GHG** | **$E_{x,0}$ (MToe $CO_2$)** | **$E_{x,t}$ (MToe $CO_2$)** | **Trend assessment, $T_{x,t}$** | **Contribution to trend (%)** | **Cumulative total of column G** |
| 3B1a | Forest land remaining forest land | $CO_2$ | -23798 | -21354 | 0.078 | 0.147 | 0.147 |
| 1A1 | Energy industries, solid | $CO_2$ | 9279 | 17311 | 0.042 | 0.079 | 0.226 |
| 1A4 | Other sectors, liquid | $CO_2$ | 6714 | 5651 | 0.040 | 0.075 | 0.301 |
| 1A1 | Energy industries, peat | $CO_2$ | 3972 | 9047 | 0.035 | 0.066 | 0.367 |
| 1A1 | Energy industries, gas | $CO_2$ | 2659 | 6580 | 0.029 | 0.054 | 0.421 |
| … | … | … | … | … | … | … | should be 1.000 in a complete inventory |
| **Total** | | | **-1354** | **17235** | **0.224** | **should be 1 in a complete inventory** | |

The IPCC good practice for LULUCF (IPCC, 2003) gives the methodology about how to perform a key-category analysis using a stepwise approach, identifying first the key categories for the inventory excluding LULUCF, and then repeating it for the full inventory including LULUCF categories to identify additional key categories.

Approach 2.

The key categories of sources/sinks are identified on the results of the uncertainty analysis described in Chapter 5. A piece of advice to inventory compilers is to apply Approach 2 in addition to Approach 1, if possible, because this will provide further insight into the reasons that some key categories are keys and will help in prioritising the activities to improve inventory quality and reduce overall uncertainty. As for Approach 1, there are also the level assessment and the trend assessment statistics for Approach 2, which include estimation of the uncertainties.

The relationship for the first statistic is the following:

$$LU_{x,t} = L_{x,t}\ U_{x,t} / \Sigma(L_{y,t}\ U_{y,t}) \qquad (3.3.4)$$

where $LU_{x,t}$ is the level assessment for the category x in the latest year t with uncertainty, $L_{x,t}$ is computed as in eq (3.3.1), and $U_{x,t}$ is the category percentage uncertainty in year t described in Chapter 5. The summation in eq (3.3.4) is for y's. After computing the level assessment with U, results should be sorted in descending order of magnitude, as in Approach 1. The key categories are identified as those that accumulate to 90 % of the total $LU_{x,t}$. This 90 % is the basis for the derivation of the threshold used in Approach 1 (Rypdal and Flugsrud, 2001). The categories that are identified in this analysis with U to be different from the categories found in Approach 1 must be treated as key categories.

The trend assessment evaluation is given below:

$$TU_{x,t} = T_{x,t}\ U_{x,t} \qquad (3.3.5)$$

where $TU_{x,t}$ is the trend assessment for the category x in the latest year t with U, $T_{x,t}$ is the trend assessment from eq (3.3.2a), and $U_{x,t}$ is the category percentage uncertainty in year t described in Chapter 5. After computing the trend assessment with U, results should be sorted in descending order of magnitude. The key categories are identified as those that accumulate to 90 % of the total $LU_{x,t}$. This 90 % is the basis for the derivation of the threshold used in Approach 1 (Rypdal and Flugsrud, 2001). The categories that are identified in this analysis with U to be different from the categories found in Approach 1 must be treated as key categories.

Another analysis tool described in Chapter 5 is the Monte-Carlo analysis. This is particularly applied in Approach 2 for the quantitative uncertainty assessment. The results from the Monte-Carlo analysis in Approach 2 can be used directly in eqs (3.3.4) and (3.3.5).

Though a quantitative analysis for the identification of the key categories is the most secure way, there are cases of incomplete inventories where a qualitative analysis is needed for the same purpose. For this reason, it is good practice to use qualitative criteria to identify those key categories. Such criteria may be the following:

- mitigation techniques and technologies (it is good practice to identify the category as key, if emissions have decreased or removals have increased in this category due to climate-change mitigation techniques);

- expected growth (identification of the categories to show increase of emissions or decrease of removals in the future);
- no quantitative assessment in Approach 2 (in such case identification of the categories as key that contribute most to the overall uncertainty); and
- completeness (in case that the inventory is not complete, it is good practice to examine qualitatively potential key categories that are not yet estimated in a quantitative manner by applying the qualitative criteria referred to here).

### *3.4. Reporting and documentation*

It is good practice that all the key-category results from the above analyses are clearly documented in the NIRs. The method selected for each category must be mentioned here. Also, the criteria (level, trend, qualitative) upon which the identification of the key categories is based should be reported as well as the method used to perform them (Approach 1, Approach 2). Tables 3.3.1 and 3.3.2 should be included to show the results of the key-category analysis. Table 3.4.1 must also be embedded to present a summary of the key-category analysis.

**Table 3.4.1.** Summary of key-category identification for Approach-1 and -2 analyses.

| A | B | C | D | E |
|---|---|---|---|---|
| **IPCC category code** | **IPCC category** | **GHG** | **Identification criteria** | **Comments** |
| … | … | … | … | … |
| … | … | … | … | … |
| … | … | … | … | … |

## 4. Data collection

### *4.1. Introduction*

A good description of the types of data to be collected for a national GHG inventory is given in §2.4. Therefore, here some additional information is deployed.

### *4.2. Existing data*

Before any data analysis, initial screening of available data must be made. A critical question is about the purpose for which the data was collected. Official statistical agencies and regulatory authorities often adopt standard procedures for making accurate measurements.

Though data from official statistical bureaus take long time to become available, preliminary data can be used, if available, because of a secure reliability.

In most cases it is preferable to use national data since its sources are up-to-date and it provides clear indication for its origin. In case of lack of national data, international organisations (e.g., international trade unions, international statistical authorities) may prove data suppliers for a national GHG inventory as they may have country-specific data sets for industries or other economic sectors. Nevertheless, it is strongly encouraged that all countries make efforts in gathering and compiling their own data sets.

## *4.3. New data*

In case that measurements are planned to be made through an appropriate programme, the listed in Table 4.3.1 elements must be followed.

**Table 4.3.1.** Requirements for a measurement programme (IPCC, 2006b).

| **Measurement objectives** | Parameters to be determined (e.g., PHCs) |
|---|---|
| **Methodology protocol** | Components to be measured and associated references<br>Methods to be used<br>Standard techniques to be used<br>Equipment needed<br>Access requirements to sources/sinks<br>Accuracy requirements<br>Data recording requirements<br>QA/QC procedures |
| **Measurement plan** | No of sampling points for each parameter<br>No of individual measurements at each sampling point<br>Experimental period<br>Reporting requirements<br>Additional source/sink information<br>Condition of source/sink during measurements<br>Staff involved |
| **Data processing and reporting procedures and documentation** | Reporting procedures<br>Documentation |

## *4.4. Emission-factor data base*

EFDB is a continuous updated web-based data base for emission factors and other parameters that are relevant for the estimation of emissions/removals of GHGs at national level. It can be reached at http://www.ipcc-nggip.iges.or.jp/efdb/main.php. The criteria for including data in EFDB are: (i) robustness (repeatability of measurements will not change measurement uncertainty), (ii) applicability (an emission factor must be able to be applied securely), and (iii) documentation (information about the original technical reference).

In case of emission measurements, the emissions must be determined directly or calculated. Anyhow, they must be representative of the specific activity. For example stack measurements may exclude losses in the atmosphere through evaporation or purely-burned fuel (emitted as VOCs); these should be reported in the emission totals. Nevertheless, in a measurements programme it is good practice to: (i) distinguish between the different components in a mixed fuel or raw material, (ii) specify the method with which the chemical synthesis of fuels or raw materials must be determined from analyses of samples, (iii) ascertain representative sampling, (iv) use instruments with known characteristics. Sometimes it is necessary to convert GHG emissions to reference conditions (e.g., 273 K and 1013 hPa). Therefore, additional measurements of gas flow, barometric pressure, air temperature and relative humidity (or water vapour) are needed.

In performing a measurements programme standard methods must be used. These are outlined in Table 4.4.1.

**Table 4.4.1.** Standards for measurements methodologies.

| | |
|---|---|
| $CO_2$ | ISO 12308:2001, ISO 10396:2006 |
| $N_2O$ | ISO 11564:1998 |
| Gas flow | ISO 10780:1994, ISO 3966:1977, ISO 14164:1999 |
| General | ISO/IEC 17025:2005, ISO 10012:2003 |

## *4.5. Activity data*

As described in §4.2, it is better to use data from official bodies such as national statistical authorities and national regulatory agencies. Nevertheless, there are occasions when activity data can be available from international bodies (e.g., UN statistics, US Geological Survey). Other sources of information can be surveys and censuses. Surveys contain sample data, while censuses consist of complete records. In order to plan a new survey/census the planning needs to cover budget, staff and project management.

# 5. Data uncertainties

## *5.1. Introduction*

This Chapter provides information about the estimate and reporting of those uncertainties, which are related with annual estimates of emissions/removals and their trends with time. The uncertainty methodology includes:

(i) the determination of the uncertainties in individual variables in an inventory (e.g., emission factors, activity data);
(ii) the aggregation of the component uncertainties to the total inventory;

(iii) the determination of the uncertainty in the trend; and

(iv) the identification of the significant sources of those uncertainties in an inventory that help prioritise data collection and efforts to improve the quality of the inventory by reducing emission-estimation errors in the future.

A quantitative uncertainty analysis is performed by estimating the 95 % confidence interval of the emissions/removals for each emission category as well as the total emission inventory.

The overall uncertainty analysis for the emissions/removals estimates is based on three (3) components: (i) conceptualisation (set of assumptions for the structure of an inventory or a sector, e.g., scope of geographic area, temporal averaging, categories and gases to be included, emissions/removals to be processed), (ii) models (simple arithmetic manipulations or complex processes specific for each category), and (iii) input data and assumptions (e.g., emission factor, activity data).

Technical terms associated with uncertainty analysis are *accuracy* (agreement between the true value and the average of repeated measurements or estimates for a variable), *bias* (systematic trend of the measured values or estimates for a variable to be over or under its average), *confidence interval* (the interval around the true value of a quantity, usually set to 95 %), *precision* (agreement between repeated measurements of the same variable), *PDF* (describing the range and relative likelihood of possible values), *random error* (random variation above/below a mean value), *systematic error* (another name for the *bias*), *uncertainty* (lack of knowledge of the true value of a variable, which can be described as PDF characterising the range and likelihood of possible values), and *variability* (heterogeneity of a variable over time, space or ensemble of a population, Morgan and Henrion, 1990, Cullen and Frey, 1999).

## 5.2. Uncertainty analysis

It is good practice to prevent bias in conceptualisations, models and inputs to models wherever possible, by, say, applying appropriate QA/QC procedures. For the confidence interval a value is normally fixed to 95 %. When the PDF is symmetrical (Fig. 5.2.1), the confidence interval can be expressed as ±half the confidence interval width divided by the estimated value of the variable (e.g., ±10 %). When the PDF is asymmetrical (Fig. 5.2.2), upper and lower limits of the confidence interval have to be specified separately (e.g., -30 %, +50 %).

The sources of uncertainty can be focused on the following issues:

- lack of completeness (lack of measurements or lack of a measurements method);
- models (specially complex processes);
- lack of data (unavailability of data to characterize a particular emission/removal, although proxy or surrogate data can be used in such circumstances; or, data that is not at all representative of emissions/removals or activities);

- sampling error (uncertainty associated with data that constitutes random sample of finite size; this type of error depends upon the variance of the population from which the sample has been taken);
- measurement error (random or systematic error resulting from errors in measuring, recording and transferring information); and
- missing data (this category also includes incomplete, unclear or faulty definition of emissions/removals).

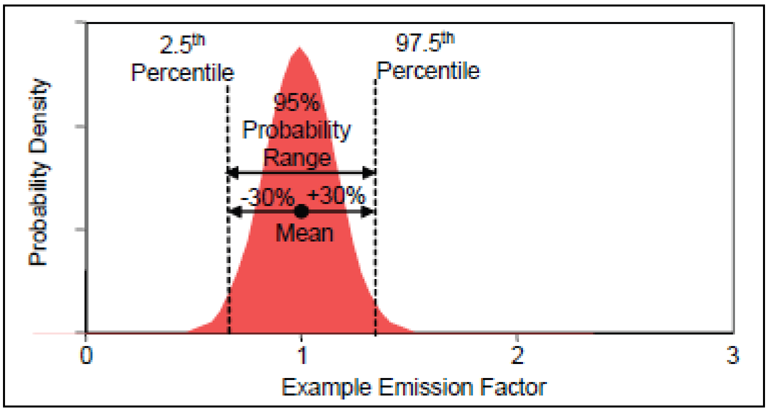


**Figure 5.2.1.** Example of a symmetric uncertainty of ±30 % relative to the mean. Source: IPCC (2006b).

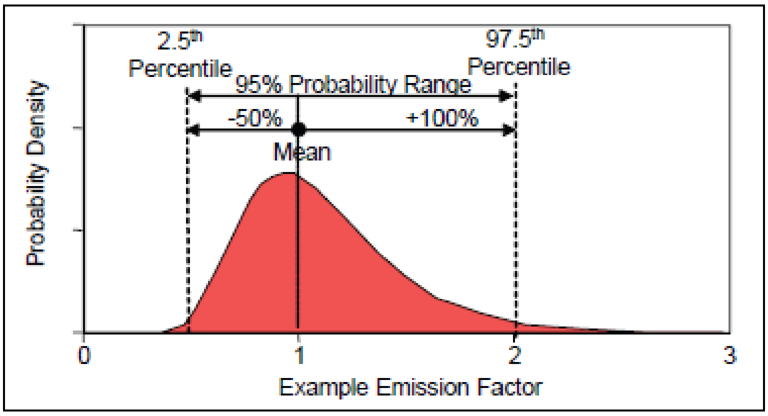


**Figure 5.2.2.** Example of an asymmetric uncertainty of -50 % to +100 % relative to the mean. Source: IPCC (2006b).

To reduce the above sources of error, some actions can be taken as regards:

- the improvement of conceptualisation (by improving the inclusiveness of the structural assumptions chosen, e.g., by a better treatment of the seasonality cycles in emission/removal data in a sector);
- the improvement of models (by improving the structure and parameterisation of the model);
- the improvement of representativeness (by applying other sampling strategies, e.g., a continuous emission-monitoring system may reduce uncertainty for some sources and gases);
- the use of more precise measurement methods (by avoiding simple assumptions and ensuring the measurement technologies used are appropriate);

- the collection of more data (thus the bias is reduced);
- the elimination of known risks of bias (by proper positioning and calibrating the instrumentation); and
- the improvement of the state-of-knowledge (by fully understanding the categories and processes involved in the emission/removal estimation).

## *5.3. Quantification of uncertainty*

After the identification of the causes of uncertainties related to inventory estimates, the inventory compiler should try to collect all information to develop national and category-specific estimates with an uncertainty at 95 % confidence interval. Since it is not always feasible to perform measurements for all emission sources/sinks, other methods are employed. This section consists of three sub-sections, which focus on the identification of the possible sources of data and information and the associated uncertainties, on the methods that attempt to prevent/correct biases, and on the application of two Approaches that combine uncertainties in inputs.

### 5.3.1. Identification of uncertainties

One source of collecting data is from models. There are two types: conceptualisation uncertainties (descriptive errors, errors in professional judgment, incomplete assumptions) and model uncertainties (limitations of available data, imperfections in the conceptualisations to be modelled).

Other sources of error may come from empirical data, data from literature and activity data. In this case the criteria set above (representativeness of the data, precision and accuracy of the measurements, sample size and inter-variability in the measurements, inter-variability in the emissions/removals) must be taken into account. An example to find the uncertainty hidden in measured data is by comparing its PDF with, say, a log-normal distribution. If the sample size is small, then a band in the PDF may be generated to examine whether most of the individual measurements lie within the band.

In the case of continuous monitoring, the average annual value of the parameter over several years can be determined and the distribution of annual values from year to year can be used to assess a 95 % confidence interval in the annual average. It is unlikely to find errors between years if the annual average is based on data from individual categories.

In the case of periodic measurements, the representativeness criterion should be met. To enhance representativeness it may be necessary to stratify the data in order to reflect typical operating conditions.

In the case of a large sample of data, goodness-of-fit tests can be used to assist in finding the most appropriate PDF that describes variability in the data. The uncertainty in the mean can often be estimated as ±1.96 times the standard error (the standard error is the standard deviation divided by the square root of the sample size). On the contrary, if the sample size is small, it is not secure to rely on goodness-of-fit tests; in that case it is better to be based on a judgment to select the most appropriate parametric distribution to fit to the small data set. In this case the uncertainty in the mean is not 1.96 times the standard error, but another value has to be determined from the student's t-distribution. This value may be larger than 1.96 for a 95 % confidence interval and it asymptotically approaches 1.96 for a sample size larger than 30 or so.

When site-specific data is not available, inventories should be based on emission factors, which are derived from published studies specific to the conditions in that country. When this source of information is not available either, other published studies can be used, if these studies reflect the conditions in that country. In the latter case, the associated uncertainties should be determined from within the measurement programme and related guidelines providing default values.

In the case of activity data, there is no typical statistical sample of alternative activity-data estimates readily available to fit distributions and, therefore, determine the uncertainty. There are, though, some approaches that may help in assessing this type of uncertainty. These approaches refer to if the activity data is based on complete samples (censuses), or, on the contrary, on random samples.

If empirical data for sources/sinks or activity inputs is not available, a solution is to obtain information from experts regarding best estimates and uncertainties of inputs to the inventory.

### 5.3.2. Quantification of uncertainties

The judgment in assessing uncertainties of a model used for the inventory development is based on results of the comparison of that model with independent data (or other alternative models). The aim is to reduce bias. The Monte-Carlo analysis may be preferable here.

In the case of empirical data a statistical analysis can be summarised in the following steps (Frey and Zheng, 2002): (i) compilation and evaluation of a data base for emission factors, activity data and other parameters; (ii) visualisation of data; (iii) selection of appropriate PDfs; (iv) characterization of the uncertainty in the mean of the distributions; (v) application of specified uncertainties to a probabilistic analysis for estimating total uncertainty; and (vi) sensitivity analysis.

In the case of lack of empirical data or if the data is not fully representative for all causes of uncertainty, the judgment of an expert may be invoked for estimating uncertainty. This judgment should be based upon methods regarding uncertainty in the form of PDF. Some commonly used methods are: *fixed value* (estimation of the probability being higher/lower than an arbitrary value and its repetition for 3 or more times), *fixed probability* (estimation of a value associated with a certain higher/lower probability), *interval* (choice of a value of a parameter, say of emission factor, with the probability that the true value of the emission factor is higher/lower than the chosen value), *graph* (draw of own distribution). In the last method it is decisive to choose the most appropriate PDF. Such PDFs can be the uniform, triangle, fractile, normal and log-normal ones (Frey and Rubin, 1991). A rule for choosing the most appropriate PDF is to ensure that the inputs to the PDF model are as statistically independent as possible. Monte-Carlo analysis may help in this direction (Ogle et al., 2003).

### 5.3.3. Combination of uncertainties

When individual uncertainties for the emission factors, emissions/removals and activity data have been identified, they must be combined to provide the overall uncertainty of the inventory in any year and the overall uncertainty in the inventory trend in time. In this effort two approaches are proposed. Approach 1 is a simple error propagation methodology, while Approach 2 uses Monte Carlo or other similar technique.

<u>Approach 1.</u>

For the estimation of the combined uncertainty ($U_{tot}$) of quantities to be combined by multiplication, the following relationship is used:

$$U_{tot} = \int(U_1^2 + U_2^2 + \dots + U_n^2) \qquad (5.3.3.1)$$

where $U_{tot}$ is in % and $U_i$ is the uncertainty associated with each individual quantity (in %).

For the estimation of the combined uncertainty ($U_{tot}$) of quantities to be combined by addition or subtraction, the following relationship is used:

$$U_{tot} = \int[(U_1x_1)^2 + (U_2x_2)^2 + \dots + (U_nx_n)^2] \,/\, |x_1 + x_2 + \dots + x_n| \qquad (5.3.3.2)$$

where $x_i$ is the value of the quantity x; $U_{tot}$ and $U_i$ are in %.

The uncertainty associated with the trend in the total emissions from a country ($U_T$) in year y is given by:

$$U_T = \int\Sigma U_i^2 \qquad (5.3.3.3)$$

where $U_i$ is the trend uncertainty from a specific gas of category i. $U_i$ is given by:

$$U_i = \int(U_{E,i}^2 + U_{A,i}^2) \qquad (5.3.3.4)$$

where $U_{E,i}$ and $U_{A,i}$ are the uncertainties introduced into $U_i$ by those associated with the emission factor of the specific gas of category i and the activity data for the specific gas of category i. These quantities can be written as:

$$U_{E,i} = A_i u_{e,i} \text{ and } U_{A,i} = B_i u_{a,i} \qquad (5.3.3.5)$$

where $A_i$ is called *Type-A sensitivity* and $u_{e,i}$ is the uncertainty associated with the emission factor (in %); $B_i$ is called *Type-B sensitivity* and $u_{a,i}$ is the uncertainty associated with the activity data (in %). The formulas for $A_i$ and $B_i$ as well as a worksheet template are given analytically in Chapter 3 of IPCC (2006b).

The error propagation method of Approach 1 works fine if the uncertainties are relatively small for a non-negative quantity meaning that the standard deviation divided by the mean is less than 0.3. For values larger than 0.3 Approach 1 can be used for informative purposes. Approach 2 constitutes an alternative way.

Approach 2.

This approach is mostly dedicated to the application of the Monte-Carlo simulation. For this simulation generation of pseudo-random samples according to the PDFs for each input is needed. These samples are called pseudo-random because they are generated by a *pseudo-random number generator* (PRNG) as described in Barry (1996). If the model has more than two inputs, pseudo-random samples are generated from the PDFs for each of the model input; then one random value is entered into the model to give an estimate in the model output. This process is repeated for a number of iterations in order for the analysis to arrive at multiple estimates in the model output. These multiple estimates are sample values of the PDF in the model output. The mean, standard deviation, 95 % confidence interval and other statistics are generated from the analysis of the samples of the PDF in the model output. The precision of the results is enhanced with increased number of iterations (Hahn and Shapiro, 1967; Ang and Tang, 1984; Morgan and Henrion, 1990). The Monte-Carlo simulation is more appropriate when the uncertainties are large, their distribution is not Gaussian, the algorithms are complex functions, correlations appear between some activity data, and emission factors, or both, and the uncertainties are different for different years of the inventory.

The starting key in the Monte-Carlo analysis is the choice of the appropriate PDF that reasonably represents each model input for which the uncertainty is sought. The principle of the analysis is the selection of the random values of emission factors, activity data and other parameters from within their individual PDFs and the calculation of the corresponding emission values. The procedure is repeated many times in a PC and the results of each calculation build up the overall emission PDF. The Monte-Carlo simulation can be performed at the category level, for aggregating categories, or at the inventory level as a whole. The Monte-Carlo approach is implemented in four separate successive steps: (1) specify the category uncertainties (i.e., estimate the parameters and activity data and associated means and PDfs and correlations and assess the uncertainties following guidance given in §5.3.1 and 5.3.2), (2) select the random variables (i.e., select the input values, which are the estimates applied in the inventory calculation; this is the start of the iterations), (3) estimate the emissions/removals (i.e., estimate the annual emissions/removals from the variables of step 2 based on the input values), and (4) iterate and monitor the results (i.e., store the calculations from step 3 and repeat step 2; results from the repetitions calculate the mean and the PDF).

The uncertainties in the trend as well as in the absolute emission value in a given year are based on four steps, too. These are: (1) specify the source/sink category uncertainties (i.e., determine the PDFs for the emission factors, activity data and other parameters as done in step 1 above but it needs to be applied for the base year and the current one), (2) select the random variables (i.e., proceed as in step 2 above), (3) estimate emissions (i.e., proceed as in step 3 above), and (4) present the results (i.e., store the emissions calculated in step 3 in a data file; repeat steps 2-3 until a convergence is achieved). A schematic diagram is given in Chapter 3 of IPCC (2006b).

The Monte-Carlo simulation is available in commercial statistical software packages. Many such software tools offer an option of different sampling methods, including random Monte-Carlo simulation. The number of iterations can be set at 10000 in the beginning and allow the simulation to continue until it reaches the set number, or alternatively allow the mean to reach a relatively stable situation before ending the simulation. As an example, when the estimate for the 95 % confidence interval is defined to within ±1 %, then an adequately stable situation has been reached. To check the result, plot a frequency diagram of the estimates of the emission. The plot should be reasonably smooth (Fig. 5.3.3.1).

There are cases where a hybrid combination of Approaches 1 and 2 must be applied. If there are significant correlations among a sub-set of categories, then the sub-set can be treated individually in Approach 2, but as an aggregation of categories in Approach 1. Most of the category uncertainties in an inventory may be estimated through the Approach 2, while very few are estimated through the Approach 1. In general, the Approach 1 deals with the estimation of uncertainties by category using eqs (5.3.3.1) and (5.3.3.2), and a simple combination of uncertainties by category to estimate the overall uncertainty for one year and the uncertainty in the trend. Approach 2 deals with the estimation of uncertainties by category using the Monte-Carlo analysis, followed by the use of Monte-Carlo techniques to estimate the overall uncertainty for one year and the uncertainty in the trend.

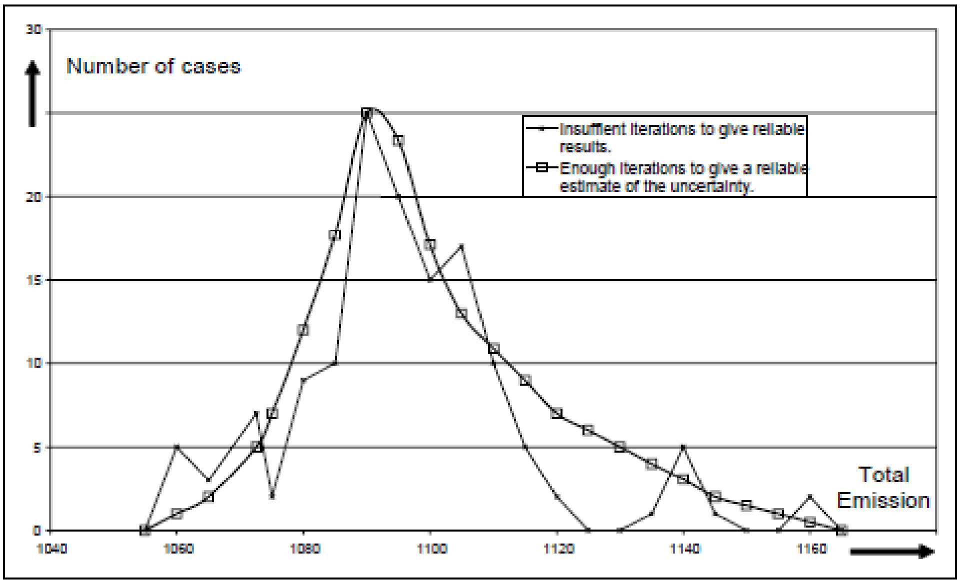


**Figure 5.3.3.1.** Frequency plots of the results of a Monte-Carlo simulation. Source: IPCC (2006b).

When Approach 2 is selected, the inventory compiler is advised to also apply Approach 1 because the latter gives insights and does not require a significant amount of additional work. In the case that Approach 2 is used, the so-derived estimates of the overall uncertainty are preferred in the reporting.

## 5.4. *Reporting and documentation*

As seen above, there are many inputs and assumptions to document an uncertainty analysis; all these elements cannot be reported due to their great quantity. Therefore, only the necessary information has to be included. The documentation should be based on the following issues:

- the causes of the uncertainty;
- the methods used to treat the uncertainty;
- the source of the data or models used to estimate the uncertainty;
- the bias of the estimate;
- a summary of the data used, the mean, the sample standard deviation, the sample size;
- sufficient information about the range in which the estimate of the random error lies (e.g., % variation to the mean);
- the judgment of an expert;
- any correlation or dependence between two or more inputs;
- special techniques applied (use of various statistical techniques, mixture distributions, extrapolation); and
- differences in results between Approach 1 and 2.

Table 5.4.1 gives a report of the uncertainty of an inventory no matter which Approach is applied. It is good practice that the uncertainty ranges shown in columns E, F, G and J be estimated relative to point estimates upon reporting the national inventory in the case that the point estimate and the mean estimate of emissions/removals are not the same value.

| **Table 5.4.1.** Reporting uncertainties. Source: IPCC (2006b). | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | **B** | **C** | **D** | **E (activity data uncertainty)** | | **F (emission factor uncertainty)** | | **G (combined uncertainty)** | | **H** | **J (uncertainty in trend in total national emissions with respect to base year)** | | **K** |
| **IPCC category** | **GHG** | **Base year for emissions/removals** | **Year t for emissions/removals** | **-%** | **+%** | **-%** | **+%** | **-%** | **+%** | **Contribution to variance in year t** | **-%** | **+%** | **Comments** |
| 1A1, energy industries, fuel 1 | $CO_2$ | | | | | | | | | | | | |
| 1A1, energy industries, fuel 2 | $CO_2$ | | | | | | | | | | | | |
| … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| **Total** | | | | | | | | | | **1.000** | | | |

# 6. Data consistency

## *6.1. Introduction*

As said earlier, a great effort in formulating a GHG inventory is to spot the various data sources at national and/or international level and collect the data. Apart from ensuring data homogeneity, the emission time series constructed from this data should be checked for consistency. This means that the time series should be calculated using the same method and data sources in all years. In doing else, a bias may be introduced in the time series because the estimated emission trend will reflect not only real changes in the emissions/removals, but also in the methodological approaches. It is good practice, therefore, to follow certain procedures to ensure the data consistency.

## *6.2. Ensuring time-series consistency*

It was said in the Introduction above that a bias may be introduced in the emissions-data analysis due to various reasons among which the methodological approach is one of them; not to mention that a bias also appears in a change of the methodology used. *Methodological changes* are often driven by the development of new and different data sets. An example may be the use of a higher tier method than Tier 1 for an industrial category if a country has obtained emission data that can be used directly or for the development of national emission factors. Another source of bias is when the inventory compiler uses the same tier to estimate emissions, but he/she applies it using different data setas or a different level of aggregation. This is called *methodological refinement*. An example of a methodological refinement may be if new data permits further disaggregation of a livestock enteric fermentation model, so that the resulting animal categories are more homogeneous. Methodological changes and refinements are essential tools for improving the inventory quality. It is good practice to change or refine methods when:

- the available data has changed;
- the method used is not consistent with the IPCC guidelines for that category;
- a category has become key;
- the method used is insufficient to reflect mitigation activities in a transparent way;
- the capacity for the preparation of the inventory has increased;
- new inventory methods have become available; and
- errors must be corrected.

In the case of adding a new category or sub-category to the inventory of a country, efforts should be made to use the same method and data sets for each year. Reasons for adding new categories to the inventory are the following:

- a new emission/removal activity occurs;
- rapid growth constitutes a small activity;
- new IPCC categories exist; and
- additional resources and/or experts are available.

If changes in the activity level, changes in the emission rates as well as the capture, destruction or combustion of emissions are included in methodologies, they can lead to a significant impact on the time-series consistency.

## *6.3. Resolution of data gaps*

The appearance of data gaps in an inventory for one or more years provides difficulties in re-calculating previous estimates using a higher tier method or developing estimates for a new category. Examples of data missing are the following:

- periodic data (e.g., forest and waste inventories may not cover the entire country on a continuous annual basis, but they are taken at some periods in a year, for instance every second year or region-by-region); and
- changes and gaps in the available data (e.g., change in data availability or gap in data different from periodically available data).

In the case of non-calendar year data it is good practice to use the same collection period all the way for the same time series as described in §4. Splicing techniques are generally used to combine methods to minimise the potential inconsistencies in a time series. Table 6.3.1 gives a summary of the splicing techniques.

**Table 6.3.1.** Summary of splicing techniques.

| Approach | Description | Remarks |
|---|---|---|
| Overlap | Apply overlap on data if the previously used and the new method are available for one or more years. | The approach becomes more reliable when applied to two or more sets of annual estimates and if the trends observed using the previously used and the new methods are inconsistent. The latter does not constitute good approach. |
| Surrogate data | Use this approach if the emission factors, activity data or other emission parameters used in the new method are strongly correlated with other well-known and more readily available data. | This approach is appropriate for multiple data sets to be tested in order to determine the most strongly correlated. This approach is not good for long periods. |
| Interpolation | Apply interpolation to data that needs re-calculation if it is collected for a number of consecutive years without intermission. | The approach is suitable for the linear interpolation of estimates for the periods for which the new method cannot be applied. The interpolation should not be used for large annual fluctuations. |
| Trend extrapolation | Apply this method if the data is not collected annually or in the end of the time series. | The technique becomes more reliable if the trend is constant over time, but it is not suitable for changing trends and for long periods. |

| | | |
|---|---|---|
| Other techniques | Apply other known techniques only if the standard ones above are not valid because technical conditions change. | Comparison with standard techniques is advised. |

The re-calculation of the data using the overlap technique is given in the following relationship:

$$y_0 = x_0 \{[1/(n-m-1)][\Sigma(y_i/x_i)\} \qquad (6.3.1)$$

where $y_0$ is the re-calculated emission/removal estimate, $x_0$ is the estimate developed using the previously used method, $y_i$ and $x_i$ are the estimates using the new and previously-used methods during the period of the overlap for the years m to n; the summation is done from m to n.

In the case of surrogate data, the re-calculation is given by the following relation:

$$y_0 = y_t (s_0 / s_t) \qquad (6.3.2)$$

where y is the emission/removal estimate in years 0 and t, s is the surrogate statistical parameter in years 0 and t.

Figure 6.3.1 shows the linear interpolation technique. It is good practice to compare interpolated data with surrogate one as a QA/QC check.

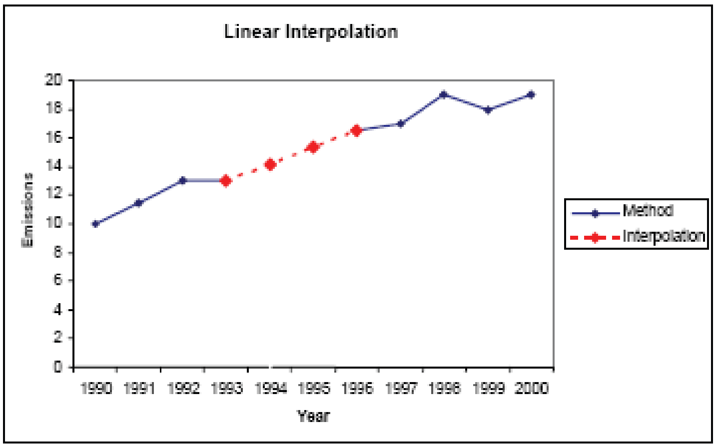


**Figure 6.3.1.** Example of linear interpolation. Source: IPCC (2006b).

Extrapolation can be applied either forward to estimate more recent emissions/removals or backward to estimate a base year.

## *6.4. Reporting and documentation*

The inventory compiler should specifically refer to any re-calculations made. The documentation should explain the reason for the re-calculation and its effect on the time series. Additionally, a graph may be provided to show the relationship between the previous data trend and the new one. Table 6.4.1 provides an example of documented re-calculations to be used for reporting or internal check.

**Table 6.4.1.** Documentation of re-calculations.

| Category | Emissions/removals (ktoe) | | | | | |
|---|---|---|---|---|---|---|
| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| Old data (od) | | | | | | |
| New data (nd) | | | | | | |
| Difference in % = 100(nd-od)/od | | | | | | |
| **Documentation (explain reason for re-calculations)** | | | | | | |

## *6.5. QA/QC for time-series consistency*

To ensure the quality of a time series both general and category-specific checks must be applied to the entire time series as described in §7. As already said, a plot of the results of the splicing techniques for comparison purposes is considered a useful QA/QC practice. A side-by-side comparison of the re-calculated estimates with the previous ones can be taken as a useful assessment of the quality of the re-calculation. If multiple approaches are used, it is good practice to explain the reason for the differences occurred.

There may be cases where an interruption in some activity-data collection has occurred or this data has drastically changed. It is good practice to examine the available documentation of the previous data-collection system in order to comprehend how these changes in the old data have affected the data used in the inventory and any consequences to the inconsistency of the time series.

In the case that a country has been divided into, say, two new countries, it is good practice to compare the inventory data with estimates from regional statistics before the split of the country.

If any inconsistencies are identified, it is good practice to correct them by applying the splicing techniques referred to in the above.

# 7. QA/QC and verification of data

## 7.1. Introduction

According to IPCC (2006b) it is good practice to establish quality assurance / quality control (QA/QC) strategy and a verification procedure for the GHG inventory. These practices aim at improving transparency, consistency, comparability, completeness and accuracy of the national GHG inventories. Such activities must be part of the inventory process. The value of the QA/QC and verification procedures is a re-assessment of the inventory or a category uncertainty and, therefore, an improvement in the estimates of emissions/removals.

The definitions of QA, QC and verification are the following. QA is a review system conducted by staff not directly involved in the inventory compilation or development phases. The review verifies that the data quality objectives are met and that the inventory estimates are the best possible of the emissions/removals. QC is a routine system to assess and maintain the quality of the inventory. It includes checks about the data integrity, correctness and completeness and identifies errors and omissions. Verification refers to the methods external to the inventory that are applied to independent data including comparison with inventory estimates. The aim of the verification process is to establish reliability for the contents of the inventory.

## 7.2. Elements of a QA/QC plan and verification procedure

These elements include a QA/QC plan (QC procedures for all inventory categories, category-specific QC procedures, QA and review procedures, and uncertainty assessment), verification activities and reporting, documentation and archiving procedures.

The QA/QC plan ensures that the inventory is suitable for the purpose it is built and is subject to improvement. A key role of the plan is the list of the *data-quality objectives*, which must be measurable. Such data-quality objectives are the timeliness, completeness, consistency, comparability, accuracy, transparency and improvement of the inventory. Periodic revision of the QA/QC plan is an important element. The QA/QC plan should use relevant standards and guidelines, such as ISO.

## 7.3. QC procedures

These procedures are related to the data processing, completeness and documentation for all inventory-source/sink categories. It is good practice that the inventory compiler undertakes QC checks on all parts of the inventory over an appropriate period of time as shown in the QA/QC plan. It is also good practice that the inventory compiler confirms that the national statistical agencies are implementing QC procedures in accordance to those shown in Table 7.3.1. A common QC procedure refers to checking that the data typed into a data base is correct.

**Table 7.3.1.** General QC procedures for emission/removal inventories. Source: IPCC (2006b).

| QC plan | Procedures |
|---|---|
| Are assumptions and criteria for the selection activity data, emission factors and other parameters 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. |
| Are the transcription errors in data input and references checked? | • Confirm that bibliographical data references are properly cited in the internal documentation.<br>• Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors. |
| Are emissions/removals calculated correctly? | • Reproduce a set of emissions/removals calculations.<br>• 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. |
| Are parameters and units correctly recorded and appropriate conversion factors are used? | • Check that units are properly labelled in calculation sheets.<br>• Check that units are correctly carried through from beginning to end of calculations.<br>• Check that conversion factors are correct.<br>• Check that temporal and spatial adjustment factors are used correctly. |
| Has the integrity of the data base files been secured? | • Examine the included intrinsic documentation to:<br>- confirm that the appropriate data-processing steps are correctly represented in the database.<br>- confirm that data relationships are correctly represented in the data base.<br>- ensure that data fields are properly labelled and have the correct design specifications.<br>- ensure that adequate documentation of data base and model structure and operation are archived. |
| Has consistency in data between categories been secures? | 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. |
| Is the movement of inventory data among processing steps correct? | • Check that emissions/removals data is correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries.<br>• Check that emissions/removals data is correctly transcribed between different intermediate products. |
| Are the uncertainties in emissions/removals estimated and calculated correctly? | • Check that qualifications of individuals providing expert judgment for uncertainty estimates are appropriate.<br>• Check that qualifications, assumptions and expert judgments are recorded.<br>• Check that calculated uncertainties are complete and calculated correctly.<br>• 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). |
| Has there been a check about time-series consistency? | • Check for temporal consistency in time series input data for each category.<br>• Check for consistency in the algorithm/method used for calculations throughout the time series.<br>• Check methodological and data changes resulting in re-calculations.<br>• Check that the effects of mitigation activities have been appropriately reflected in time-series |

| | |
|---|---|
| | calculations. |
| Is there a check about 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.<br>• For sub-categories, confirm that entire category is being covered.<br>• Provide clear definition of 'Other' type categories.<br>• 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., sub-categories classified as 'not estimated'). |
| Is there a check about trend? | • 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/removals from previous years may indicate possible input or calculation errors.<br>• Check value of implied emission factors (aggregate emissions divided by activity data) across time series.<br>- Do any years show outliers that are not explained?<br>- If they remain static across time series, are changes in emissions/removals being captured?<br>• Check if there are any unusual and unexplained trends noticed for activity data or other parameters across the time series. |
| Is there a 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.<br>• Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review.<br>• Check that the archive is closed and retained in secure place following completion of the inventory.<br>• Check integrity of any data archiving arrangements. |

When using the IPCC default emission factors, it is good practice for the inventory compiler to assess the applicability of the factors at national level. A supplementary activity is to compare the IPCC default emission factors with site- or plant-level factors. This supplementary check is good practice.

In order to evaluate the quality of the country-specific factors, QC checks must be used for:

- the background data used to develop the emission factors;
- the models used;
- the comparison with the IPCC default factors;
- the comparison of the emission factors between countries; and
- the comparison to plant-level emission factors.

Data provided through direct-emission measurements should be checked with a QC procedure. For instance, plants and facilities that perform direct measurements as part of an official regulatory programme may apply QC standards.

The activity data and the associated input variables constitute the basis for the estimation methods of many categories. Activity data normally comes from secondary data sources or site-specific data prepared by the staff of a plant or a site from own measurements. In the case of assessing the quality of national level activity data the following fundamental QC checks are necessary.

- QCs of the reference source for the national activity data;
- Comparison with independently-compiled data sets;
- Comparison with sample data; and
- Checks for the trend in activity data.

There other emission methods that rely on site-specific activity data. The following QC procedures try to identify errors in site-specific activity data.

- Check of the measurement protocol;
- Comparison between sites and national data; and
- Production and consumption balance.

If the original calculation and the simple approximate method for assessing the estimate of emissions/removals in an inventory disagree, then it is good practice to examine both approaches for finding the discrepancy. It is also good practice to discriminate between the input data, the conversion algorithm of a calculation and the output.

## 7.4. QA procedures

The QA procedures stand outside the actual inventory. They include reviews and audits to assess the quality of the inventory. The inventory may be reviewed as part of a whole. It is important that these reviewers are irrelevant with the preparation of the inventory and, therefore, unbiased. It is good practice that the inventory compiler performs a basic expert search for all categories of the inventory before completing it.

After identifying the experts, the selected experts may perform a review of the documentation with the methods and results. This procedure does not normally include certification of the data or references as those may be undertaken during an audit. The aim of the experts is to ensure that the results of the inventory, its assumptions and methods used can be justified by their knowledge in the specific field. There are no standard expert peer-review tools or mechanisms for GHG inventories. Therefore, such methodologies should be used on a case-by-case basis. All expert peer-reviews must be well documented including suggestions for improving the inventory.

It is good practice that during the preparation phase of an inventory audits may be used to evaluate the efficiency of the inventory compiler to comply with the QC procedures set out in the QA/QC plan. It is also good practice that the inventory compiler develops a schedule of audits at important points of the inventory. Such audits may verify that the QC steps outlined in Table 7.3.1 have been applied.

## *7.5. QA/QC and uncertainty estimates*

The QA/QC procedures and the uncertainty analysis are inter-related. The staff involved in both can identify those critical parts of the inventory and data sources, which contribute to the inventory quality and uncertainty level and need immediate attention for improvement. In the absence of measured data, many uncertainty estimates may rely on expert judgment. It is good practice to apply the QC procedures to the uncertainty estimation in order to confirm that the calculations performed are correct and that the data used and the calculations having been worked out are well documented. Also the assumptions related to each category for its uncertainty estimation must be documented. The calculations of category-specific and aggregated uncertainty estimates must be examined; the errors derived must be taken into account and handled.

## *7.6. Verification*

The verification system includes comparison with emission/removal estimates prepared by other bodies and comparison with estimates from independent assessments. The verification activities provide information to countries with the aim to improve their inventories as part of the QA/QC and verification system. The criteria for the selection of the verification approach refer to the scale of interest, cost, level of accuracy and precision, and availability of data. The information drawn from the above criteria at national level is referred to as national activities.

For national estimates, discrepancies between inventory data and data compiled using alternative methods do not mean that the inventory data is wrong. This is, though, the case that when analysing discrepancies there are found large uncertainties associated with the alternative calculations. Such cases are identified when:

- applying lower-tier methods (these are IPCC methods typically based upon “top-down” approaches; an inventory compiler may apply a higher-tier approach, i.e., a “bottom-up” one, as a simple verification tool);
- applying higher-tier methods (these are IPCC methods based upon “bottom-up” approaches; an inventory compiler may find that they cannot apply such an approach because of lack of data or resources);
- comparing with independently-compiled estimates (they constitute a quick alternative to the evaluation of completeness, approximate emission/removal levels and correct category allocations); and
- applying comparison of intensity indicators between countries (these indicators, or else emission/removal factors, provide a preliminary check and verification about the order of magnitude of the emissions/removals; such indicators are emissions per capita, industrial emissions per unit of value added, transport emissions per car, emissions from power generators per kWh).

Individual independent measurements, such as those of atmospheric-pollutant concentrations, can be used by the verification system as the basis for emission modelling. This approach is particularly useful as it is independent of standard estimation methods, such as sector-activity data and emission factors. Nevertheless, comparisons with atmospheric measurements cannot be a standard tool for verification for the inventory compiler. Despite the above limitations there are several techniques that can be mentioned here:

- inverse modelling (it can calculate emission fluxes from concentration measurements and atmospheric transport models; nevertheless, this technique is subject to criticism for national inventories because flux assessments from inverse models include the effect of natural sources/sinks and international transport, that cannot be estimated precisely due to the lack of many monitoring stations and the introduction of error in the estimates);
- trans-boundary transport (e.g., CFCs, $CH_4$ and $N_2O$ from continental Europe may be measured in Ireland; these measurements can be used for quantification of the European emission-source strength by inverse modelling, Derwent et al., 1998a, 1998b, Vermeulen et al., 1999);
- proxy emission data (for co-located measurements, the GHG emissions may be estimated from the other “marker” or “tracer” compound); and
- global dynamic approach (can apply to cover a large proportion of global emissions, e.g., $CH_4$, Dlugokencky et al., 1994, $SF_6$, Maiss and Brennikmeijer, 1998, PFCs and $CF_4$, Harnisch and Eisenhauer, 1998).

## *7.7. Reporting and documentation*

It is good practice to document and archive all information relevant to the planning, preparation and management of the inventory activities. These include:

- the procedures, arrangements and responsibilities for the planning, preparation and management of the inventory activities;
- the assumptions and criteria for the selection of the activity data and emission factors;
- the emission factors and other parameters used;
- the activity data;
- the uncertainties related to the activity data and emission factors;
- the reasoning for selecting the methods;
- the methods used;
- the changes in the input data or methods;
- the identification of an individual judgment for the uncertainty estimates;
- the details of the electronic data bases or software used;
- the worksheets and related calculations for category and aggregated estimates;
- the final inventory report;
- the QA/QC plan and procedures; and
- the secure archiving of the whole data base.

It is good practice that inventory compilers maintain and archive this documentation in such a way that every inventory estimate can be reproduced. Also, it is good practice to include all checks/audits/reviews performed during the QA/QC activities.

It is good practice to report a summary of the applied QA/QC activities. In this summary, the inventory compiler should make effort to refer to the following activities:

- the QA/QC plan, its schedule and the responsibilities involved;
- a description of the activities performed internally and the external reviews for each source/sink category;
- a description on the quality of the input data, methods, processing or estimates for each category; and
- an explanation of the significant trends in the time series.

# 8. Conclusions

From what has been described in all above chapters it is seen that for setting up a national GHG inventory the following general steps must be considered.

## 8.1. *Collection of data*

In the case of collecting existing data:

1. Define the data set (e.g., time series, sectors and sub-sectors, national coverage, requirements for uncertainty of the data, emission factors and/or activity-data units);
2. Determine the data format (e.g., Microsoft Excel) and structure (e.g., tables needed and their structure);
3. Describe the national coverage, sectors included, representative (base) year, technology/management level, uncertainty parameters;
4. Identify the routines and time scales for the data-collection activity (e.g., how often and what elements are updated);
5. Define the QA/QC procedures;
6. Find the contact person; and
7. Date of availability.

In the case of collecting new data, the requirements for a measurement programme given in Table 4.3.1 have to be taken into account. In the case of combining new and existing data (i.e., adaptation of data) the approaches in filling gaps and testing for inhomogeneity described in §2.4.3 must be implemented. The activity data must also be identified by the inventory compiler.

## 8.2. *Identification of key-emission categories*

The general guidance given in Table 3.2.1 must be followed in order to create an account of all key categories that have to be included in the inventory. Sub-categories must also be identified by the inventory compiler. The methodological Approach 1 and/or Approach 2 must be applied in this respect. The six GHG-emission categories dictated by IPCC are energy, industrial processes, solvent/other product use, agriculture, waste and LULUCF, with a memo on international aviation bunkers, international marine bunkers and $CO_2$ emissions from biomass.

## 8.3. *Identification of emission factors*

To ascertain the quality of the data collected, emission factors must be established by the inventory compiler. To do this, it is good practice to set priorities, and develop a strategy for accessing, collecting and processing the data. The criteria for including data in the EFDB are given in §4.5.

## 8.4. Data uncertainties

This is an important step in ensuring that the emissions/removals data base is reliable. First, an uncertainty analysis must be applied (see §5.2) to provide the sources of errors in the inventory as well as their quantification. The errors may not only come from measurements, but also from the application of models to create or to combine data. In the former case the PDF methodology is preferred, and in the latter case the Monte-Carlo analysis is often used. In combining uncertainties, the error-propagation method can be applied as described in §5.3.3.

## 8.5. Data consistency

Any time series in the inventory must be checked for consistency due to various reasons deployed in §6.2. The gaps in the time series must be treated properly by using splicing techniques (see Table 6.3.1).

## 8.6. QA/QC and verification of data

The QA/QC procedures and verification of the data in the data base concern the whole of the inventory because these procedures establish the transparency, comparability, consistency, completeness and accuracy of the GHG inventory. A QA/QC plan must be laid by the inventory compiler. This plan contains the QC procedures described in §7.3, the QA activities mentioned in §7.4, and the verification system described in §7.6.

## 8.7. Reporting and documentation

This is an important part of the reliability, reproducibility, transparency, consistency, robustness, comparability, completeness and accuracy of the GHG inventory. It is expressed in certain formats detailed by the IPCC guidelines. These formats are in tabular form and most of them are provided in the present document.

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## A. Units

All units are mentioned in the present report explicitly.

## B. Abbreviations

| | |
|---|---|
| AAUs | - Assigned Amount Units |
| CCS | - Carbon capture and storage |
| CLRTAP | - Convention on long-range trans-boundary air pollution |
| COP | - Conferences of the Parties |
| CRF | - Common Reporting Format |
| DG | - Directorate General |
| EC | - European Community |
| ECCP | - European Climate Change Programme |
| EEA | -European Environment Agency |
| EF | - Emissions Factor |
| EFDB | - Emission-Factor Data Base |
| EIT | - Economies in Transition |
| EMEP | - European Monitoring and Evaluation Programme |
| EN | - European Standards |
| EPA | - Environmental Protection Agency |
| ETC/ACC | - European Topical Centre / Air and Climate Change |
| ETS | - European Trading Scheme |
| EU | - European Union |
| FP7 | - Framework Programme 7 |
| GDP | - Gross Domestic Product |
| GH | - Greenhouse |
| GHG | - Greenhouse Gas |
| IEA | - International Energy Agency |
| IES | - Institute for Environment and Sustainability |
| IMF | - International Monetary Fund |
| IPCC | - Intergovernmental Panel on Climate Change |
| IR | - Infra-Red |
| ISO | - International Standards Organisation |
| JRC | - Joint Research Centre |
| LULUCF | - Land use, land-use change, forestry |
| MoU | - Memorandum of Understanding |
| MS | - Member State |
| NIR | - National Inventory Report |
| NMVOC | - Non-methane volatile organic compound |

| | |
|---|---|
| OECD | - Organisation for Economic Cooperation and Development |
| PC | - Personal Computer |
| PDF | - Probability-density function |
| PFCs | - Perfluorocarbons |
| PPS | - Purchasing power standards |
| PRNG | - Pseudo-random number generator |
| RES | - Renewable Energy Sources |
| UK | - United Kingdom |
| UN | - United Nations |
| UNECE | -United Nations Economic Commission for Europe |
| UNEP | - United Nations Environmental Programme |
| UNFCCC | - United Nations Framework Climate Change Convention |
| QA / QC | quality assurance / quality control |
| SNA | System of National Accounts |
| ToR | Terms of Reference |
| WMO | World Meteorological Organisation |