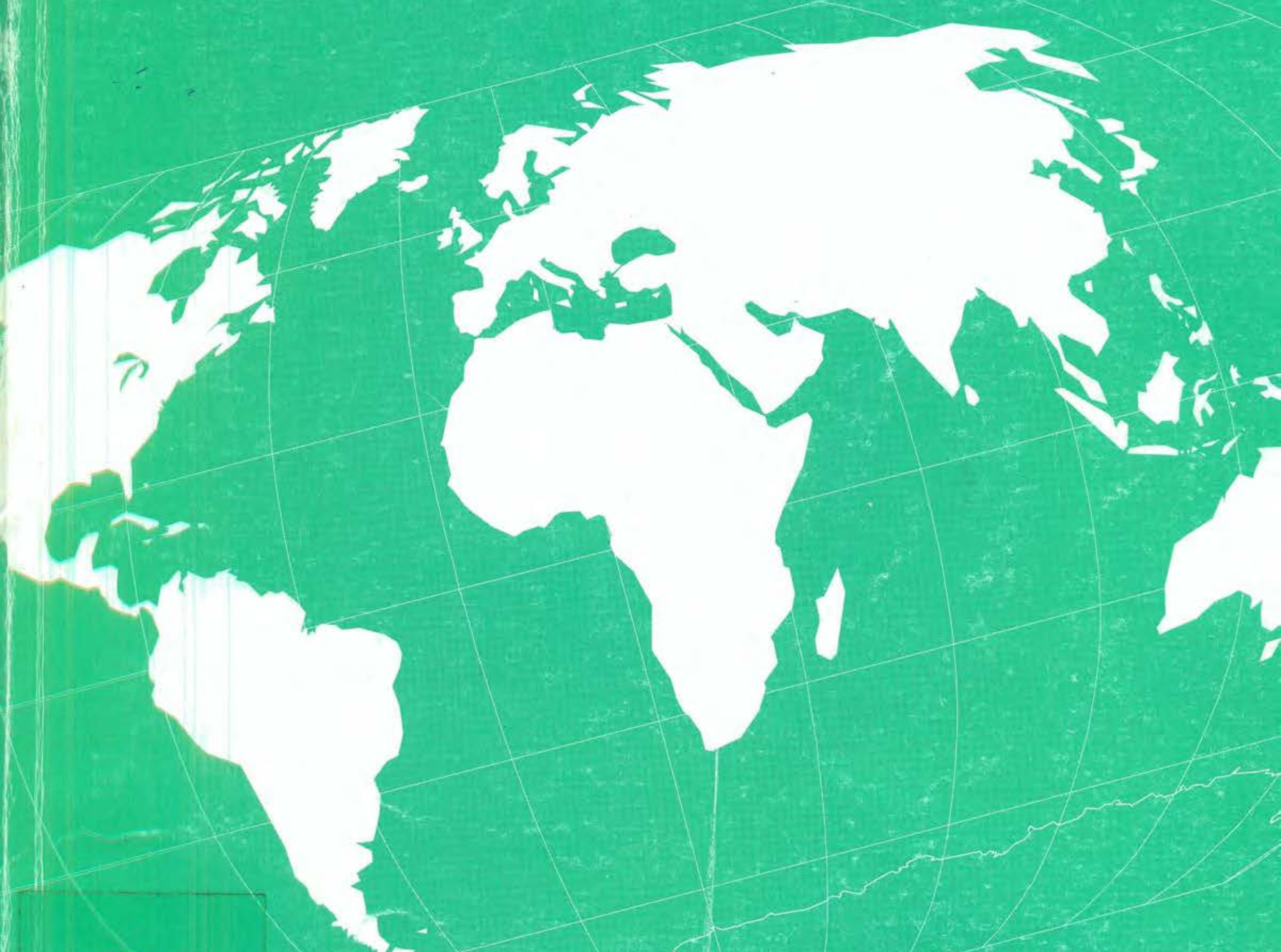
Country/Region-Specific Emmission Factors in National Greenhouse Gas Inventories



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PREFACE

In accordance with Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), all Parties are required to prepare and submit national inventories of anthropogenic sources and removals by sinks of all greenhouse gases not controlled by the Montreal protocol using comparable methodologies to be agreed upon by the conference of the Parties.

A methodology for conducting such inventories was developed by the OECD Environment Directorate, the International Energy Agency (IEA), and the IPCC Working Group I Technical Support Unit. This joint programme received direct support from UNEP through a GEF funded project "Country Case Studies on Sources and Sinks of Greenhouse Gases". This international effort resulted in a methodology that was adopted by the IPCC at its Tenth Plenary Session in November 1994 and by the Conference of the Parties to the UNFCCC in April 1995. It is now the recommended standard methodology and is general use around the world.

This publication, which was completed in collaboration with the Institute of Environmental Studies at the Vrije University in Amsterdam, presents the results of an extensive review of a number of national reports prepared using these approved "IPCC Guidelines for National Greenhouse Gas Inventories". It is a compilation of original work related to the emission factors needed to complete national greenhouse gas inventories and suggests areas of future research.

It is hoped that this publication will serve as a valuable reference for national study teams currently developing greenhouse gas inventories as part of their National Communications and provides some guidance to organizations considering research on new emission factors.

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COUNTRY/REGION-SPECIFIC EMMISSION FACTORS IN NATIONAL GREENHOUSE GAS INVENTORIES

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ACKNOWLEDGEMENTS

This study "Country/region-specific emission factors in national greenhouse gas inventories" was funded by the United Nations Environment Programme/Global Environment Facility. We thank Michael Short (UNEP) for initiating this study.

The study has been carried out in consultation with the Environment Directorate of the Organisation for Economic Cooperation and Development (OECD) and the International Energy Agency (IEA). The contribution of the OECD consisted of the review of the non-energy sections of the inventories from Australia, Austria, Canada, Denmark, the Netherlands, Norway, the United Kingdom and the United States. The IEA reviewed the energy sections of the inventories of Canada, the United Kingdom and the United States. In particular, we would like to thank Bo Lim, Isabelle Mamaty and Caitlin Allen from the OECD, and Jeroen Meijer from the IEA.

Further, we would like to thank everyone who contributed to this project. We would like to thank the UNFCCC Secretariat, which provided us with valuable contact points, and reports/documentation. We would also like to thank the US Country Studies Program, which made available preliminary reports of national GHG inventories carried out under their programme. Without their help, the available information from developing countries would have been very limited. Further, we would like to thank all members from the IPCC/OECD Liaison Group (IOLG) for their input.

Finally, we would like to express our gratitude to all national contact points, who provided us with additional information in reply to our questions. This project summarizes the results from national GHG inventories from a large number of countries. This project would not have been feasible without the results of national research. We wish to thank all the country study teams for their valuable input.

1. INTRODUCTION

This report presents the results of the UNEP/GEF study: "Review of Emission Factors Used in Greenhouse Gas Emission Inventories". (GF/0103-92-44). This study is a sub-project of the UNEP/GEF project "Country Case Studies on Sources and Sinks of Greenhouse Gases" (GF/0103-92-01).

The study has been carried out by the Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam, in consultation with the OECD Environment Directorate and IEA. The report was written by IVM in close consultation with OECD and IEA.

Originally, it was planned to incorporate the identified emission factors into a database currently undergoing development by the US Country Study Program. This database will be transferred to the United Nations' Framework Convention on Climate Change (UNFCCC) Secretariat. However, due to imcompatible timeframes the results of this study are not yet incorporated in an integral database.

1.1. Background

Parties to the UNFCCC are required to carry out an inventory of GHG emissions using comparable methodologies under Article 4.1 of the UNFCCC. The "IPCC Guidelines for National Greenhouse Gas Inventories" have been accepted by the Conference of Parties (COP) to the UNFCCC held in Berlin in March 1995.

The COP I, in considering methodological issues, decided "that the Guidelines for National Greenhouse Gas Inventories .... adopted by the Intergovernmental Panel on Climate Change (IPCC) should be used by Annex I Parties in preparing their National Communications pursuant to the Convention" ... and .... "should be used by non-Annex I Parties, as appropriate and to the extent possible, in the fulfilment of their commitments under the Convention". Approximately 80 countries worldwide are now using these IPCC Guidelines to develop national inventories.

Through the development of the national GHG inventories (in nine developing countries) sponsored under the UNEP/GEF project "Country Case Studies on Sources and Sinks of Greenhouse Gases", national scientists and administrators have actively contributed to the further refinement of the inventory methods. As part of this UNEP project, a series of UNEP/IPCC/OECD/IEA sponsored workshops were held in Bracknell (UK, 92), Sao Jose dos Campos (Brazil, 93), Dakar (Senegal, 93), Nairobi (Kenya, 93, 94), Bratislava (Slovak Republic, 93), and Chaingmai (Thailand, 94). Together these workshops involved scientists and technicians from more than 80 countries.

The "IPCC Guidelines for National Greenhouse Gas Inventories" provide a common format and methodology for estimating and reporting anthropogenic GHG emissions, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOC). The guidelines consist of default calculation methods for the major economic sectors, activity data for some sources, and default emission factors. The methodologies provided include several levels of complexity depending on the availability of national statistics. Where necessary and to the extent possible, default emission factors provided by the IPCC Guidelines are country/region specific, thus taking into account national/regional circumstances. However, country/region specific emission factors are lacking for many economic sectors and/or countries/regions. In these cases, the IPCC Guidelines provide general default emission factors, leading to a larger uncertainty in the emission estimates. Therefore, the IPCC Guidelines strongly encourage countries to use, if available, country specific emission factors and include the sources and references of these factors in their publications.

In the final technical reports prepared by the participating countries, and at each of the above mentioned workshops, technical representatives highlighted the need to develop and disseminate the additional national/regional/ecosystem specific emission factors in order to improve the applicability of the IPCC methodology to local circumstances. Many of the inventories developed for the UNEP project, by other country study programmes supporting studies in developing countries, by countries with economies in transition, and by a number of the Annex I countries contain "new" emission factors stemming from original research.

1.2. Aim and objectives of study

The objective of this study is to identify and collect new emission factors which have not yet been taken into account in the IPCC Guidelines. The aim of the study is to make these emission factors more readily available, especially to scientists in developing countries working in this field. These emission factors may be used by country study teams preparing national inventories and could eventually be incorporated into the revision of the IPCC Guidelines, currently undergoing methodological development (in a Phase II programme). **However, one has to be aware of the fact that in most cases the reliability of these factors could not be assessed, due to the lack of references provided by national reports and background literature.**

THE EMISSION FACTORS INCLUDED IN THIS REPORT SHOULD BE USED WITH CAUTION (SEE CHAPTER 9).

It is recommended that these factors will be evaluated by the IPCC/ OECD/IEA expert groups and after that process may or may not be incorporated into the IPCC Guidelines.

This report includes:

- A detailed presentation of original emission factors developed by country study teams using the IPCC Guidelines;
- Recommendations regarding the potential application of these original emission factors in other countries/regions/ecosystems;
- Recommendations on areas of future targeted research to develop national/regional/ ecosystem specific emission factors.

1.3. Scope of the study

This study includes all national GHG inventories following the IPCC Guidelines that have been completed to date (either the IPCC Guidelines adopted in 1995 or the draft version published in 1994). Various categories of national emission inventories can be distinguished:

- First, emission inventories carried out by Parties listed in Annex I of the UNFCCC. Annex I Parties (i.e. developed country Parties) have already submitted reports on the implementation of their obligations to the UNFCCC. National GHG inventories were included in their "National Communications". Some of the "National Communications" refer to background documents containing more detailed information regarding the emission inventory. If available, background documents have also been reviewed for this study.

- Second, emission inventories carried out by developing countries. Many developing countries are currently in the process of developing emission inventories. Within the scope of two major country study programmes, funded by the US and UNEP/GEF, several emission inventories have already been finalized, or are available in a final draft version. These and some other preliminary reports submitted to the IPCC have been taken into account.

In total, 23 national inventories by Annex I countries have been reviewed, nine inventories by countries in Central and Eastern Europe, 11 inventories by African countries, four inventories by Asian countries, and six inventories by countries in Latin America. Not all reports reviewed provided new information on emission factors. Several National Communications submitted by Annex I countries provided only total emission estimates or aggregated emission factors. Table 1 gives an overview of the national GHG inventories reviewed for this study.

Table 1. National GHG inventories reviewed in this study.

Annex I Countries	**Eastern and Central Europe**	**Africa**	**Asia**	**Latin America**
Australia	Bulgaria	Ethiopia	Bangladesh	Bolivia
Austria	Czech Republic	The Gambia	Micronesia	Costa Rica
Belgium	Hungary	Malawi	Mongolia	Equador
Canada	Kazakhstan	Mauritius	Sri Lanka	Mexico
Denmark	Latvia	Morocco		Peru
Finland	Poland	Mozambique		Venezuela
France	Romania	Senegal		
Germany	Russian Federation	Tanzania		
Greece	Slovenia	Uganda		
Ireland		Zambia		
Italy		Zimbabwe		
Japan				
Liechtenstein				
Luxembourg				
Netherlands				
New Zealand				
Norway				
Portugal				
Spain				
Sweden				
Switzerland				
United Kingdom				
United States				

The emission factors given in the next chapters originate from the national inventories and supplementory reports as listed in Annex I.

2. METHODOLOGY

2.1. IPCC reporting instructions

The "IPCC Guidelines for National Greenhouse Gas Inventories" consist of the following volumes:

- Vol. 1: Reporting Instructions. This contains instructions on how to report inventories;
- Vol. 2: Workbook. This provides default methods and worksheets to calculate emissions;
- Vol. 3: Reference Manual. This contains background information on the methodolgy and literature references.

The IPCC Guidelines distinguish six economic sectors for which methods are provided:

1. Energy;
2. Industrial Processes;
3. Solvent Use;
4. Agriculture;
5. Land Use Change and Forestry; and
6. Waste.

Most of these categories are subdivided into subsectors. For each of the economic sectors, Parties are obliged to report *activity data*, aggregated *emission factors* and the resulting *GHG-emission estimates,* using so-called minimum data tables provided by the IPCC Guidelines.

Activity data are quantitative data of (economic) activities (e.g., total quantity of fuel consumed, the total number of livestock and deforestation rate). The activity data multiplied by an aggregated emission factor results in the emission estimate. The aggregated emission factor often consists of several parameters or more specific emission factors. The resulting analytical complexity gives rise to difficulties in the interpretation of the inventory data in two ways:

- First, the aggregated emission factor can be an average of two or more underlying emission factors. For instance, in the calculation of emissions due to the burning of a certain fuel, emissions can differ due to the kind of process used. Each process will have its own specific emission factor. The aggregated emission factor reported will be the weighted average of specific emission factors used. It will be clear that this aggregated emission factor will not be applicable to other countries since the shares of each process in the total will differ in other countries. Therefore, differences in aggregated emission factors do not necessary imply differences in the underlying specific emission factors for each specific source of GHG emissions.

- Second, the aggregated emission factor may consist of a combination of several parameters. For example, the calculation of methane emissions from waste is based on the amount of waste landfilled (activity data), and the fraction of degradable organic carbon, the fraction which actually degrades and the fraction of methane in landfill gas (parameters included in the emission factor). In this case, it is not clear if the parameter "fraction of degradable organic carbon" should be considered to be an activity data or an (part of) emission factor. Consequently, the distinction between activity data and emission factor is not always as clear as one would like.

In this study, all emission factors have been considered including those parameters in the grey area between emission factors and activity data that have a strong influence on the (aggregated) emission factor used.

The IPCC Guidelines allow countries to use national inventory methods and encourage countries to use national activity data as opposed to internationally reported activity data, and to use country specific emission factors (rather than default values provided). If countries use national methods and/or data, the reporting instructions require that countries clearly communicate these methods/data and give clear references to written sources.

This study focuses on country specific emission factors reported and the corresponding references and background literature. The aim of the study, as mentioned earlier, is to make these emission factors available to scientists in developing countries currently working in this field. Therefore, the emphasis of this study is on the factors that are of importance to developing countries. Consequently, the energy sections of the inventories of Annex 1 Parties received less attention than the non-energy sections of developing countries inventories. This is because the difference in circumstances between Annex 1 Parties and developing countries, which is the largest in the energy section, reduces the applicability of emission factors provided by Annex 1 Parties in developing countries.

2.2. Activities undertaken/communication with countries

In 1993, the IPCC/OECD/IEA, in cooperation with IVM, published an "In-depth review of national greenhouse gas emission inventories". The results of that study have been used in further development of the IPCC Guidelines. In this study, only emission inventories published after this in-depth review have been taken into consideration.

The Institute for Environmental Studies undertook several activities to ensure a complete, as possible, coverage of relevant national inventories GHG emissions. Besides national GHG emission inventories already available at the IVM (collected during the years from various sources), emission inventories available at the following sources were included in the survey:

- UNFCCC Secretariat: All National Communications submitted to the UNFCCC, and corresponding technical background reports where available.
- IPCC/OECD/IEA: All national GHG emission inventories submitted to IPCC/OECD/IEA.
- Country Study Programmes: All national GHG emission inventories carried out under country study programmes. At the time of the study only the US Country Study Program and the UNEP country study programme already resulted in completed inventories. Country study programmes by Germany (GTZ), the Asian Development Bank and the Netherlands either focused on other climate change studies and/or had started recently, and emission inventory reports were not yet available.

National GHG emission inventories included in National Communications often did not provide sufficient information regarding the application of emission factors. Most National Communications provided either total emission estimates, or, as a technical annex, the IPCC minimum data Tables, containing aggregated emission factors. Only in some cases were background documents provided, containing sufficient information regarding emission factors.

The IVM requested all Annex I Parties for detailed information on emission factors. Only in a few cases did this result in additional information. Some other countries replied that it was not feasible to make the requested information available. Those emission inventories were not documented in detail and it would require substantial additional work to collect the emission factors applied. Most countries, however, regardless of subsequent letters and faxes did not reply.

The national GHG emission inventories carried out under the US Country Study Programme were in most cases draft reports. Most of these reports, however, had already been reviewed by the US Country Study Team and were sufficient for use in this study.

3. ENERGY

3.1. Introduction

This chapter deals with emission factors relevant to IPCC emission category I, Energy. The emissions of greenhouse gases from energy activities (fuel combustion as well as fugitive emissions from fuels). The aim is to identify emission factors in the National Communications which are useful for updating the IPCC Guidelines and making these guidelines more appropriate to local circumstances. For energy sources, that is emissions from the production, processing, distribution and combustion of fossil fuels, the target is to search for technologies (and associated emission data) which are not dealt with in the IPCC Guidelines and which are expected to be relevant for emission inventories in other countries.

The chapter is structured according to the IPCC's source categories and by gas, as discussed below.

3.2. Carbon dioxide emissions from combustion (IPCC category I)

Carbon dioxide (CO_2) emissions are estimated by establishing a national balance for carbon embodied in fuels: which is referred to as the **top-down method**. The basic data used are statistics of annual imports of fuels and endogenous production, statistics related to the export of fuels, the carbon content of the various fuels and correction factors accounting for unburnt fuels and data for the non-energy use of fuels (e.g. Liquified Petroleum Gas (LPG) used for the production of ethene and eventually polythene). For most countries, the reliability of the estimates of these emission hinges on the quality of figures and on the level of detail of the statistics of the trade and production of coal and hydrocarbons. In most of the National Communications, the uncertainties in the data on the carbon content of fuels appear to be relatively low (e.g. $< 1\%$).

3.3. Emissions of carbon monoxide, nitrogen oxides and non-methane volatile organic compounds from combustion in stationary sources (IPCC categories I A 1 and I A 2)

The reports reviewed do not present information about original research which might be useful for preparing inventories in other countries. In many cases no inventory was made of the emissions of CO, NO_x and NMVOCs. Some countries (e.g. the Czech Republic, Japan, the Netherlands) used aggregated plant-specific data to establish an inventory in their National Communications. Reports with these plant-specific data, which might be useful, were not available for the review.

3.4. Methane emissions from combustion in stationary sources (IPCC categories I.A.1 and I.A.2)

The Tables 3.1, 3.2 and 3.3 present emission factors which differ markedly from default values presented in the IPCC Guidelines for National Greenhouse Gas Inventories (Tables I-7 through I-11 of the reference manual). The IPCC data are presented in the first two columns. The source/technology/fuel categories used in the reviewed inventories often do not correspond with the IPCC categories (column 1). Detailed data with respect to the statistical definitions of fuels and combustion technologies were not available, therefore the comparisons in the tables are tentative.

Table 3.1. Energy; fuel combustion activities; energy and transformation industries (I A 1): CH_4 emission factors (g/GJ).

Source (1)	**IPCC (1995)**	**Japan (2)**	**Finland (3)**	**Australia**	**Canada (4)**	**Source/technology (5)**
	g CH_4/GJ	g CH_4/GJ	g CH_4/GJ	g CH_4/GJ	g CH_4/GJ	
Coal in utility boilers	**0.6**	0.54				Coal & briquettes
Residual oil in utility boilers	**0.7**	0.115				Crude oil
Distillate oil boilers	**0.03**	0.17				Petrol/naphta and NGL
		0.057				Kerosene & light oil
		1.057				Fuel oil & petrol. coke
Natural gas in utility boilers	**0.1**	0.152				LNG (6
		0.027				LPG (7)
		0.28				Town gas (8)
Industrial boiler. Wood	**15**			25		Wood (boiler)
					77	Wood waste
					0.01-0.03	Fuel wood
Industrial boiler	**2.4**		8 (9)	2		Boiler coal
Industrial boiler	**2.9**			2.76		Boiler residual oil
Industrial boiler	**1.4**		3	1.25		Boiler natural gas
Cement kilns	**1.1**			1		Kilns natural gas
	1			0.95		Kilns coal/oil
			2-7			Peat fired boilers (9)

(1) IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual, Chapter 1.
(2) Government of Japan (1994).
(3) Boström, S.R., Backman and M. Hupa (1992).
(4) Jaques (1992).
(5) Description of source/technology in reviewed reports.
(6) Liquified Natural Gas.
(7) Liquified Petroleum Gas.
(8) Probably from coal gasifying.
(9) Thermal capacity over 1 MW.

Table 3.2. Energy; fuel combustion activities; industry I A 2): CH_4 emission factors (g/GJ).

Source (1)	IPCC (1995)	Japan (2)	Finland (3)	UK	Canada (4)	Source/technology (5)
	g CH_4/GJ	g CH_4/GJ	g CH_4/GJ	g CH_4/GJ	g CH_4/GJ	
Industrial boilers (coal)	**2.4**	0.54	50 (6)			Coal & briquettes
		0.121 Cokes		0.02 Municipal waste	77 Wood waste	Other
Residual oil	**2.9**	0.115				Crude oil
		0.17		0.99 Naphta refineries		Petrol/naphta and NGL
		0.023				Kerosene & light oil
		1-0.057	10 (6)	1.1 Petrocoke		Fuel oil & petrol. coke
Natural gas in industrial boilers	**1.4.**	0.152				LNG
		0.027				LPG
		0.28 Town gas (5)		3.98 Blast furnace gas 4.42 Other gases		Other gas
			1			Black liquor recovery boilers
			200			Wood/bark fired boilers (6)

(1) IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual, Chapter 1.
(2) Government of Japan (1994).
(3) Boström, S.R., Backman and M. Hupa (1992).
(4) Jaques (1992).
(5) Description of source/technology in reviewed reports.
(6) Thermal capacity over 1 MW.

Table 3.3. Energy; fuel combustion activities; commercial/institutional/residential (I A 4); CH_4 emission factors (g/GJ).

Source (1)	**IPCC (1995)**	**Japan (2)**	**UK**	**Source/technology (3)**
	g CH_4/GJ	g CH_4/GJ	g CH_4/GJ	
Coal boilers commercial sources	**10**	16.16	229 Anthracite	Coal & briquettes
		1	269	Other
			244	Patent fuel (6)
Residual oil commercial sources	**1.6**			Crude oil
				Petrol/naphta and NGL
Distillate boilers	**0.6**		244 Patent fuel	Kerosene & light oil
		0.15		Fuel oil & petroleum coke
Gas boiler/commercial sources	**1.2**			LNG (4)
		1		LPG (5)
		0.28		Other gas

(1) IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual, Chapter 1.
(2) Government of Japan (1994).
(3) Description of source/technology in reviewed reports.
(4) Liquified Natural Gas.
(5) Liquified Petroleum Gas.
(6) Not defined.

The methane emission factors used appear to differ across different countries and IPCC Guidelines up to a factor of 30. However, these differences may be explained by differences in definitions of sources and technologies. The IPCC Guidelines do not provide methane emission factors for combustion of peat and black liquor. The Finnish data (Boström et al., 1992) may be useful to develop such factors for the Guidelines.

3.5. Nitrous oxide emissions from combustion in stationary sources (IPCC I A 1 and I A 2)

The IPCC Guidelines (Tables I-7 through I-11 of the reference manual) contain few N_2O emission factors for all combustion categories. This paucity of data is apparent in the reviewed inventories, which are highly uncertain and variable. Some countries have used simple rule of thumb to estimate N_2O emissions from NO_x emissions. For instance, in the New Zealand inventory, N_2O is assumed to be 5% of the NO_x emissions.

Japan has presented greater detail, which appears to be based on measurements of N_2O in flue gases. Table 3.4 presents data extracted from Japan's action programme (Government of Japan, 1994). However, background reports giving in-depth information about these data could not be acquired. Table 3.4 presents data for the energy and transformation industries in Finland (Boström et al., 1992) and Austria (FME, 1994; Bonelli, 1993). These data are based on actual measurements in these countries. Tables 3.5 and 3.6 present data found in these reports for the source categories "Industry" and "Commercial/ institutional/ residential".

Table 3.4. Energy; fuel combustion activities; energy and transformation industries (I A 1): N_2O emission factors (g/GJ).

	Japan	**Austria**	**Finland**
	g N_2O/GJ	g N_2O/GJ	g N_2O/GJ
Solid fuel (boiler)	0.83		2 (1)
Solid fuel (FBC) (2)	53.1		
Liquid fuel	0.19		
Gaseous fuel	0.4		
Bituminous coal		02 (3)	
Bituminous coal SCR-high dust deNOx (4)		0.21 (3)	
Lignite		0.5 (3)	
Lignite SCR-high dust deNO_x (4)		0.23 (3)	
Lignite (FBC) (2)		13.6	
Waste		6.0	

(1) Coal fired boilers/burners.
(2) Fluid Bed Combustion.
(3) Pulverized firing in plants which have a thermal capacity of over 100 MW.
(4) In case of removal of No_x from flue gases by Selective Catalytic Reduction.

Table 3.5. Energy; fuel combustion activities; industry I A 2): N_2O emission factors (g/GJ).

Source	Japan	Austria	Finland
	g N_2O/GJ	g N_2O/GJ	g N_2O/GJ
Solid fuel (boiler)	0.83		
Bituminous coal, grate firing 2-100 MW		0.5	
Bituminous coal (FBC) (1)		36.7	50
Lignite, grate firing 2-100 MW		0.3	
Peat (FBC)			30
Solid fuel, direct heating	1.93		
Coal fired/grate			4
Liquid fuel, boiler	0.19		2 (2)
Oil type S (3) 2-100 MW		2.4	
Oil type S (3) 2-100 MW		0.8	
Oil type S, deNO_x SCR/ammonia (4)		3.25	
Liquid fuel, direct heating	2.48		
Liquid fuel, other	1.45		
Gaseous fuel, boiler	0.4		
Natural gas, 2-200 MW		0.1	
Natural gas, <200 kW		0.4	
Hydrogen, 2-200 MW		0.1	
Gaseous fuel, direct heating	0.07		
Gaseous fuel, other	0.4		

(1) Fluidized Bed Combustion.
(2) Boiler capacity <1 MW.
(3) Presumably heavy fuel oil.
(4) In case of removal of Selective Catalytic Reduction of No_x in flue gases with ammonia.

Table 3.6. Energy; fuel combustion activities; commercial/institutional/residential (I A 4); N_2O emission factors (g/GJ).

Source	Japan	Austria	Finland
	g N_2O/GJ	g N_2O/GJ	g N_2O/GJ
Bituminous coal/grate firing/ <200 kW		1.0	
Lignite/grade firing/200 kW		0.5	
Oil type L/< 200 kW		0.7	
Natural gas/< 200 kW		0.4	
Wood/grade firing/< 200 kW		0.5	2 (1)
Liquid fuel	0.19		

(1) Boiler capacity <1 MW.

The IPCC Guidelines (Table 1-18 of the reference manual) present default emission factors and uncertainty ranges. The N_2O emission factors presented in tables 3.4, 3.5 and 3.6 are all within these ranges.

3.6. Non-carbon dioxide transport emissions (IPCC I A 3)

To generate a reliable estimate of GHG emissions from vehicles, ships and aeroplanes many "technology" and "activity" factors are required. Elaborate models, such as the COPERT model (European Commission) and MOBIL (US-EPA), which are used for calculating emissions of road vehicles (in many countries the largest source among all mobile sources) take into account specific technologies (type of motor - gasoline-diesel), car vintages, technologies for emission abatement, number of trips (starts), type of driving cycle (urban/rural/motorway), and other factors. In these models, emission factors relate emission to distances driven by a vehicle and are expressed in units of mass GHG per unit distance (e.g. g/km). The use of such models is well documented depending on the availability of statistics of car sales and driving patterns. For the inventories reviewed, such methodology was used for inventorying vehicle emissions in several countries: the United Kingdom, the Netherlands, Norway, Germany.

The IPCC methodology takes a somewhat simpler approach by neglecting driving patterns. Emission factors for most of the pollutants are ultimately derived from measurements of cumulative emissions occurring in a standard trip (e.g. a simulated trip in congested town traffic or a simulated highway trip). The IPCC emission factors presented in the Guidelines are based on European and United States emission data. The Australian inventory appears to be based specifically upon Australian information (Carnovale et al., 1991; Weeks et al., (1993). The Australian data, which cover the common pollutants, are presented in Table 3.7 together with European and United States data (as presented in the IPCC Guidelines) for comparison.

Other inventories present only CH_4 or N_2O information. The specific emission factors cited for N_2O are presented in Table 3.8, while those for methane are shown in Table 3.9. Austrian data were found in Bonelli et al. (1993), Japanese in Japan's action report (Japan, 1994), while the data for New Zealand are derived from Warings and Richards (1994). The Polish data were found in the Polish inventory (NEFP, 1995). The Netherlands also presented an elaborate inventory (Van Amstel et al., 1994), while Berge et al. (1994), Rypdal (1993) and Bang et al. (1993) present Norwegian data. The factors presented could be useful for the IPCC Guidelines.

Table 3.7. Energy; fuel combustion; road transport (I A 3); CH_4, N_2O NO_x, CO and NMVOC emission factors (g/km): Australia, Europe, US.

	CH_4	**N_2O**	**NO_x**	**CO**	**NMVOCs**	**Evaporation loss**	**Running loss**	**Total NMVOC**
	g CH_4/km	g N_2O/km	g NO_x/km	g CO/km	g NMVOC/km	g NMVOC/km	g NMVOC/km	g NMVOC/km
Australian data								
Cars. Petrol > 85 km	0.10	0.025	1.23	7.81	0.50	0.33	0.14	0.97
Cars. Petrol 80-85 km	0.15	0.0037	1.70	28.93	2.38	1.04	0.25	3.67
Cars. Petrol 76-80 km	0.18	0.0037	1.87	37.15	2.88	1.13	0.25	4.26
Cars. Petrol < 76 km	0.21	0.0037	2.15	37.84	3.33	2.48	0.29	6.1
European data								
3-way catalyst	0.02	0.05	0.52	2.86	0.32 g VOC/km			0.38
Non-catalytic control - advanced	0.071	0.005	2.34	19.39	2.02 g VOC/km			3.26
Non-catalytic control	0.082	0.005	2.05	28.57	2.49 g VOC/km			3.86
Uncontrolled	0.08	0.005	2.19	49.97	3.54 g VOC/km			4.63
US data								
Early three way catalyst	0.04	0.046	0.52	3.12	0.25	0.12	0.14	0.51
Non. catalytic control	0.174	0.005	1.97	23.8	2.14	0.45	0.29	2.88
Uncontrolled	0.174	0.005	2.14	40.62	4.36	1.37	0.32	6.05

Table 3.8. Energy; fuel combustion; road transport (I A 3) CH_4 emission factors (g/km).

Methane source category	**Austria (1)**	**Poland**	**Australia**	**Norway**
	g CH_4/km	g CH_4/km	g CH_4/km	g CH_4/km
Passenger cars (gasoline)	0.04 (early three way catalytic control)		00.155-0.21	0.096 (urban driving) 0.054 (other driving modes)
Passenger cars (no catalytic control)	0.21	1.7		
Passenger cars. Gasoline. Three-way catalyst. Electronic control. EC-93.	Average (five cars) 0.0183 (0.028-0.0057)		0.10 (types > 1985)	0.014 (urban driving) 0.007 (rural driving) 0.005 (motorway)
Passenger cars (diesel)		0.1 (incl. light trucks)		0.006
Trucks/buses (gasoline)		2.5		
Trucks/buses (diesel)		0.3		0.007-0.011 (light duty vehicles)

(1) Measured emissions for the US FTP-f5 driving cycle.
(2) Unit g/GJ.

Table 3.9. Energy; fuel combustion; road transport (I A 3) N_2O emission factors (g/km).

	Austria (1)	Japan	Poland	Australia	Norway	The Netherlands
	g N_2O/km	g N_2O/km	g N_2O/km	g N_2O/km	g N_2O/km	g N_2O/km
Passenger cars (gasoline)		0.0168 (0-0.0579)	0.10			
Passenger cars (no catalytic control)	0.0007			0.0037	0.005 (urban) 0.009 (>50 km/h)	0.015
Passenger cars. Gasoline. Three way catalyst. Electronic control. EC-93.	0.028 - 0.0057 < 20.000 km). 0.029 for an "old" car (3)			0.025	0.05 - 0.02	0.107 (car fleet average), 80% 0.004 and 20% 0.030 "old" cars") (3)
Passenger cars (diesel)	0.0012-0.0019 (two cars)	0.00651	0.13		0.005 - 0.009	0.031
Trucks/buses (gasoline)		0.024	0.10			
Trucks buses (diesel)		0.025	0.20			0.200
Shipping		2 (2)				

(1) Measured emissions for the US FTP-f5 driving cycle.
(2) Unit g/GJ.
(3) "Old" refers to mileage. In Austria "old" means a mileage of over 120.000 km.

3.7. Fugitive emissions from fuels (IPCC 1 B)

Solid fuels (I.B.1)

The IPCC Guidelines present three methods for estimating methane emissions from mining: the global average method (tier 1), the country or coal basin method (tier 2) and the mine specific method (tier 3). The choice of the method depends on the availability of information in a country. Poland applied a mine specific approach and the results of that study indicate that there are large differences in emissions between mines. Although the results are not shown here, as they are specific to the Polish mines and cannot be used for mines in other countries, the methodology used may be applicable in other countries.

The IPCC Guidelines state that emission measurements are unavailable for methane emissions from coal waste piles. Therefore, it is interesting to note that the Polish emissions inventory (NFEPP, 1995) provides an estimate of these methane emissions and cites the country average emissions from "spoil heaps" as being about 10 per cent of the total emissions (p. 155 of NFEPP, 1995).

Oil and natural gas activities (I B 2)

The IPCC Guidelines mention that the estimation of methane emissions of oil and gas activities is weak for most of the regions of the world. An area of particular interest is the former USSR and Central and Eastern Europe, as these countries may account for a disproportionate share in the global methane emissions from oil and gas production activities (IPCC Guidelines, Table I-8 of the workbook). With regard to this sector, the Polish inventory is particularly relevant (NEFPP, 1955). The Polish inventory refers to another study (Stezcko et al., 1994) concerning fugitive emissions. Unfortunately, however, this study was not available to the authors. The national report also mentions that a detailed study has been made of gas losses from the Pomerial District Gas Supply Plant. Unfortunately, gas losses from gas distribution were not actually measured. The Polish inventory of the emissions from processing oil and oil products also uses results from a more detailed study (Zebrofski et al., 1994). It appears that this Polish report presents data of recorded emissions of NMVOCs in individual refineries.

Emissions from gas distribution

Bonelli (1993) has summarized the Austrian studies of methane leakage, while the Danish data are presented by Fenhamm and Kilde (1994). The latter cite results from Cristansen (1990) which were also not available to the authors. Table 3.10 summarizes the relevant information in both reports and data from the Netherlands (Van Amstel et al., 1994).

Table 3.10. Energy; Fugitive emissions from natural gas; transmission and distribution (I B 2 bii) CH_4 emission factors (% volume los of low).

Source category/ circumstances/ origin of leakage	Austria	Denmark	The Netherlands
	% volume loss of flow	% volume loss of flow	% volume loss of flow
Modern piping	welded steel tubing: > 4 bar 0.005 - 02 < 4 bar 0.01 - 05 Plastic tubing < 4 bar 0.01 - 0.1	0.01	0.015-0.020 in gas transport. 0.5-0.7 gas distribution (11% grey cast iron)
Old (town gas) piping	grey cast iron: < 4 bar: 1.0 - 3.0 spheric cast iron: < 4 bar 0.01 - 1.0	1.0	

A key factor is the type of material used for tubing. Grey cast iron pipes are cited as having the highest leakage rates.

Venting and flaring (I B 3)

For estimating emissions from venting and flaring the IPCC Guidelines provide a three tier method. No reference to research concerning emissions other than those already mentioned in the IPCC Guidelines were identified, except for the Polish report (Zebrofski et al., 1994) mentioned previously. This Polish study appears to refer only to NMVOCs, not to methane.

4. INDUSTRIAL PROCESSES

At this time, cement production is the only process for which the IPCC Guidelines proposes a detailed methodology for emissions estimation. In these guidelines, it is recommended that all processes generating GHG emissions be identified. By some national reports, preliminary information is provided for emission estimates from other industrial sources.

4.1. Carbon dioxide emissions

The tables below present the emission factors for carbon dioxide used in the inventories under consideration. To facilitate comparison, the countries are grouped per region: Central and Eastern Europe (including for comparison reasons the former GDR), Western Europe and other OECD countries. From the developing countries, only Peru presented new emission factors in this category.

It should be noted that the factors presented here are not the only ones available. International literature sources can provide additional information (CORINAIR, RAND, etc). However, listing these factors is beyond the scope of this study.

The presented emission factors will be discussed per region and per sector.

Table 4.1. Industrial Processes: CO_2-emission factors per industry and process. Latin America.

IPCC categories		Peru
		CO_2
		kg/ton product
B	**Non-ferrous metals**	
	Aluminium production	1222.2
	Magnesium production	1810.0
C	**Inorganic chemicals**	
	Calcium nitrate Ammonia	203.7
	White phosphorus	3551.8
	Sodium sulphate	310.0
	Sodium sulphide	2256.0
	Sodium bisulphite	140.9
	Sodium thiosulphite	92.8
	Sodium nitrate	318.8
D	**Organic chemical**	
	Tetryl	153.3
	Cyclonite	594.3
	Phthalic acid anhydrate	594.6
E	**Non-metallic mineral products**	
	Glass ($Na_2CO_2 + SiO_2$)	
	Window	295.3
	Laminated	291.5
	Polished plate	288.0
	Bottles	287.2
	Glass ($CaCo_3 + SiO_2$)	
	Window	303.6
	Laminated	310.0
	Polished plate	314.0
	Bottles	309.9

Table 4.2. Industrial Processes: CO_2 - Emission factors per industry and process. Central and Eastern Europe.

IPCC Categories		IPCC	Bulgaria	Czech Republic	Germany Former GDR	Kazakhstan	Poland (1)
		CO_2	CO_2	CO_2	CO_2	CO_2	CO_2
		kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.
A	**Iron and Steel**						
	Steel		60				
	Coke production			397.9 (2)			
	Sinter production						8.10
	Steel production; hearth furnaces						52.00
	Steel casting						62.00
	Iron casting						61.00
	Charging of blast furnaces						0.22
	Converter steel production						11.26
	Electric steel production						4.30
	Ferroalloys production						541.90
B	**Non-ferrous metals**						
	Aluminium production				1222		804.34
C	**Inorganic chemicals**						
	Ammonia synthesis		862		690		
	Soda production				430		
	Soda ash cons.		415				
	Soda ash prod.		97				
2D	**Organic chemicals**						
	Ethylene						0.3 (3)
E	**Non-metallic mineral products**						
	Cement	**498.5**			565		
	Lime	**785**			760		
	Glass		800		200		
	Calcium Carbide					686 (4)	

(1) Based on measurements and research in Polish industries.

(2) Jilek, P. (1991).

(3) Emission factor developed by the Institute of the Ecology of Industrialised Areas; Katowice.

(4) Based on chemical formula.

Table 4.3. Industrial Processes: CO_2 - emission factors per industry and process. Western Europe.

IPCC Categories		IPCC	Denmark	Netherlands	Sweden	United Kingdom	Germany (West)
		CO_2	CO_2	CO_2	CO_2	CO_2	CO_2
		kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.
A	**Iron and Steel**				330		
B	**Non-ferrous metals**						
	Aluminium production				1660		1222
	Other				1050		
C	**Inorganic chemicals**						
	Ammonia synthesis						690
	Soda production						380
	Urea						
E	**Non-metallic mineral prod.**						
	Cement	**498.5**	616 (1)		900	503 (4)	565
	Masonry Cement						
	Brick		158 (2)				
	Lime	**785**	786 (2)	800 (3,4)	840		760
	Glass						200
	Other				500		

(1) Fenger, J. et al. (1990).
(2) Strategisk Miljoforningsprogram (AMOR). DMU. To be published.
(3) Smit, J.R.K. (1993).
(4) Loos, B. (1992).
(5) DOE (1994).

Table 4.4. Industrial Processes: CO_2 - emission factors per industry and process. Oceania and North America.

IPCC Categories		**IPCC**	**Australia**	**Canada**	**United States** (1)
Cat.		CO_2	CO_2	CO_2	CO_2
		kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.
A	**Iron and Steel**				
B	**Non-ferrous metals**				
	Aluminium production		1750		1500-2200 (2,6)
C	**Inorganic chemicals**				
	Ammonia synthesis			1560 (3)	
	Urea			730	
E	**Non-metallic mineral prod.**				
	Cement	**498.5**	450	500 (4)	507
	Masonry Cement				224
	Lime	**785**	790	790 (5)	

(1) U.S. EPA (1985).
(2) Abrahamson (1992).
(3) Canadian Fertilizer Institute (CCFI) (1992)
(4) Energy, Mines and Resources, "Cement Production" (1990).
(5) Energy, Mines and Resources , " Lime Production " (1990).
(6) US used mid point of 1850.

4.1.1. Category A: Iron and Steel industry

Sweden provides an aggregated emission factor of 330 kg CO_2 per ton of product for the total Iron and Steel category. Bulgaria provides an emission factor for steel production of 60 kg CO_2 per ton of steel produced. However, the production processes in both cases are not specified and hamper the applicability of this emission factor for other countries. The Czech Republic reports an emission factor for coke production. However, it is debatable as to whether this process should be reported under the Industrial Processes category rather than the Energy category. Poland provides a set of emission factors for several processes in the Iron and Steel category based on measurements and research in Polish industrial enterprises. Unfortunately, the underlying report is only available in Polish and no further information can be given here.

Conclusion

Only Poland provided emission factors in this category that could be useful to other countries, especially Central and Eastern European countries. The applicability and reliability of these factors, however, could not be assessed, since insufficient information was available for a thorough review.

4.1.2. Category B: Non -ferrous metals

Aluminium production:

Six countries (four OECD and two Central and Eastern European countries) provided emission factors for aluminium production.

The U.S. uses a range of 1550 - 2200 kg CO_2/ton aluminium. The emission factors used by Sweden and Australia (1660 and 1750 kg CO_2/ton aluminium) fall within this range. Germany uses the same factor for West Germany and the former GDR (1222 kg CO_2/ton aluminium). This factor is also used by Peru. Poland provides a factor substantially lower than all others; 804 kg CO_2/ton aluminium.

Conclusion

The range of 1550 - 2200 kg CO_2/ton aluminium seems a reliable default for at least the OECD countries. The range between the Polish and German emission factors (800 - 1220 kg CO_2/ton aluminium) might be useful to other Central and Eastern European countries. The applicability and reliability of these factors, however, could not be assessed due to a lack of background information.

4.1.3. Category C: Inorganic chemicals

Ammonia synthesis:

Three countries provide emission factors for ammonia synthesis. The emission factors used by Bulgaria and Germany are similar, while the factor provided by Canada is twice as high. This could be due to differences in the production processes used, but no further information could be obtained.

Soda production:
Germany provides a slightly different emission factor for West Germany and the former GDR. Bulgaria makes a distinction between emission factors for soda ash consumption and soda ash production. The emission factor for soda ash consumption is in the same range as the German factors for soda production, while the Bulgarian factor for soda ash production is approximately four times lower.

Urea production:
Only Canada provides an emission factor.

Other
Peru provides emission factors for a wider range of inorganic chemicals.

4.1.4. Category D: Organic chemicals

Only Poland provides an emission factor in this category (i.e. for ethylene production).

4.1.5. Category E: Nonmetallic mineral products

Cement:
Six countries provide an emission factor for cement production that all vary between 450 - 900 kg/ton of product. This is a rather broad range that could be due to differences in the average CaO content of the cement. The United States makes a distinction between cement and masonry cement.

Lime:
Seven countries provide emission factors for lime production, of which four countries provide slightly higher figures compared to the IPCC default values. This can be explained by rounding. Two countries (West Germany and former GDR) provided slightly lower factors most likely due to assumptions regarding the purity of the product. Only Sweden provides a substantially higher emission factor.

Glass:
Germany and Bulgaria provide emission factors for glass production. Surprisingly, the figures provided by Germany (identical for West Germany and the former GDR) are four times lower than the factor provided by Bulgaria.

Calcium carbide:
Only Kazakhstan provided an emission factor for the production of Calcium carbide.

4.2. Methane emissions

The table below presents the emission factors for methane applied in the inventories reviewed. Inventories from developing countries did not present any new factors in this category. Following Table 4.5 the emission factors presented will be discussed.

Table 4.5. Industrial Processes: CH_4 - emission factors per industry and process.

IPCC Categories		IPCC	Czech Republic	Germany (West)	Germany (Former GDR)	Poland (1)
		CH_4	CH_4	CH_4	CH_4	CH_4
		kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.	kg/ton prod.
A	**Iron and Steel**	**<3.0**				
	Coke production	**0.5**	0.14 (2,3)			
	Sinter production	**0.5**				
	Pig iron production	**0.9**				
	Cast iron and steel,			0.04	0.04	
	malleable cast iron					
	Coking of hard coal			0.31	0.31	
	Electric steel production					0.12
F	**Others**					
	Refining (crude oil)			0.03	0.03	
	Coking of lignite				0.31	

(1) Based on measurements and research in Polish industries.
(2) Neuzil et al. (1992).
(3) Macak, J. (1992).

Country specific emission factors for CH_4 from industrial processes were provided by Germany, the Czech Republic and Poland. A comparison between these factors could not be made, because the factors provided were for different categories.

Germany: The factors provided by Germany are in general equal for both West Germany and the former GDR. For coking of lignite, Germany provides only a factor for the former GDR.

Czech Republic: The emission factor for coke production provided by the Czech Republic is lower by more than a factor of 3 when compared with the IPCC default. A review of the local studies underlying this emission factor is recommended in order to more fully understand the variance.

Poland: Poland provides an emission factor for electric steel production based on measurements and research in industries.

4.3. Nitrous oxide emissions

The table below presents the emission factors for nitrous oxide used in the inventories reviewed. Inventories from developing countries did not present any new factors in this category. It should be noted that the factors presented here are not the only ones available. International literature sources can provide additional information (CORINAIR, RAND, etc). However, listing these factors is beyond the scope of this study.

Table 4.6. Industrial Processes: N_2O - emission factors per industry and process.

IPCC Categories		IPCC	Canada	Germany (West)	Germany (Former GDR)	Netherlands (1)	United Kingdom
		N_2O	N_2O	N_2O	N_2O	N_20	N_2O
		kg /t prod	kg /t prod	kg /t prod	kg /t prod	kg/t prod	kg /t prod
C	**Organic chemicals**						
	Nitric acid	2 - 9	3.4 (2)	5.5	5.5	5.9	5.5
	Laughing gas			3	3		
D	**Organic chemicals**						
	Adipic acid	300	303 (3)	333	333		

(1) Amstel, A. van (1995).
(2) Corpus information Services (1990).
(3) Thiemens, M.H. and U.C. Trogler (1991).

Country specific emission factors for N_2O from industrial processes were provided by Canada, Germany and the United Kingdom.

Nitric Acid:
All emission factors provided are within the range of the IPCC default. Germany and the United Kingdom apply the average default factor, the Netherlands a slightly higher factor, while Canada uses a somewhat lower factor based on product information from the industrial sector.

Laughing gas (N_2O):
Germany provides an emission factor for the production of laughing gas.

Adipic acid:
All emission factors provided are similar to the IPCC default.

4.4. Carbon monoxide emissions

The table below presents the emission factors for carbon monoxide used in the inventories reviewed. Inventories from developing countries did not present any new factors in this category. The emission factors presented will be discussed per country and per sector.

Country specific emission factors for CO from industrial processes were provided by Germany, Kazakhstan, Poland and Sweden. A comparison between the factors provided could not be made, because they are for different source categories.

Sweden provides an emission factor for cement production and an aggregate emission factor for the Iron and Steel category. However, aggregated emission factors like this one are not applicable in other countries.

Germany provides emission factors for several categories and no distinction is made between West Germany and the former GDR. Poland provides a large number of emission factors for detailed subcategories based on measurement and research in Polish industries. Kazakhstan provides an emission factor for the production of calcium carbide based on the chemical formula.

Table 4.7. Industrial Processes: CO - emission factors per industry and process.

IPCC Categories		Germany (West)	Germany (Former GDR)	Kazakhstan	Peru	Poland (1)	Sweden
		CO	CO	CO	CO	CO	CO
		kg/t prod	kg/t prod.	kg/t prod.	kg/t prod.	kg/t prod.	kg/t prod
A	**Iron and Steel**						0.46
	Coking of hard coal	1.00	1.00				
	Steel (electric and blown steel)	11.50	11.50				
	Pig iron	1.18	1.18				
	Sinter production					0.14	
	Steel production in open hearth furnaces					1.27	
	Steel casting					2.5 (2)	
	Iron casting					2.5 (2)	
	Charging of blast furnaces					0.17	
	Converter steel production					5.73	
	Electric steel production					0.03	
	Ferroalloys production					2.18	
C	**Non Ferrous metals**						
	Primary aluminium pig	150.00	150.00				
	Aluminium production					76.09	
	Magnesium production				1151.7		
	Lead production				135		
	Zinc production				428		
	Electrolitic copper					70.05	
	Zinc and lead refined					9.50	
	Electrolitic zinc					20.20	
D	**Inorganic chemicals**						
	Soot	4.80	4.80				
E	**Non-metallic mineral products**						
	Cement						7.3
	Calcium Carbide			437 (3)	437.5		

(1) Based on measurements and research in Polish industries. (2) Jangbski, J., Kapata J. (1976). (3) Based on chemical formula.

4.5. Nitrogen oxide emissions

Country specific emission factors for NO_x from industrial processes were provided by Germany, Poland, Sweden and the United Kingdom. For most of the categories, country specific emission factors were provided by only one country. Therefore, a comparison between factors was not possible in most cases.

Table 4.8 Industrial Processes: NO_x - emission factors per industry and process.

IPCC Categories		Germany (West)	Germany (Former GDR)	Poland (1)	Sweden	United Kingdom
		NO_x	NO_x	NO_x	NO_x	NO_x
		kg/t prod	kg/t prod.	kg/t prod	kg/t prod	kg/t prod
A	**Iron and Steel**				0.2	
	Steel (electric and blown steel)	0.08	0.08			
B	**Non Ferrous metals**					
	Other				2.4	
	Aluminium production			0.85		
	Steel production in open			3.90		
	hearth furnaces					
	Electric steel production			0.70		
	Ferroalloys production			2.66		
C	**Inorganic chemicals**					
	Nitric acid	5.00	5.00			3.8
E	**Non-metallic mineral products**					
	Cement				2.5	
	Lime				1.3	
	Glass	0.80	0.80			
	Other				4.3	

(1) Based on measurements and research in Polish industries.

Nitric acid production:
Only the United Kingdom and Germany provide emission factors for nitric acid production.

Poland provides emission factors for several detailed categories, based on measurements and research in Polish industries.

4.6. Non-methane volatile organic compounds (NMVOC) emissions

Country specific emission factors for NMVOCs from industrial processes were provided by the Czech Republic, Germany, Poland and the United Kingdom.

Table 4.9. Industrial Processes: NMVOC - emission factors per industry and process.

IPCC Categories		Czech Republic	Germany (West)	Germany (Former GDR)	Poland (1)	United Kingdom
		NMVOC	NMVOC	NMVOC	NMVOC	NMVOC
		kg/ton prod.	kg/t prod.	kg/t prod.	kg/ton prod.	kg/t prod.
2A	**Iron and Steel**					0.0026 (2)
	Cast iron and steel,		0.36	0.36		
	malleable cast iron					
	Coking of hard coal		0.31	0.31		
	Rolled steel		0.04	0.04		
	Coke production	1.18 (3,4)				
	Steel prod. open hearth furnaces				0.02	
	Charging of blast furnaces				0.40	
	Electric steel production				0.12	
	Hot rolling				0.02 (5)	
	Cold rolling				0.15 (5)	
B	**Non-ferrous metals**					
	Aluminium production				0.0036	
2D	**Organic chemicals**					
	Ethene		5.0	5.0		
	Propene		2.5	2.5		
	1,2 dichloroethene		2.5	2.5		
	Vinyl chloride		0.02	2.5	14 (5)	
	Vinyl chloride bal.proc.			2.5		
	Ethylene				11 (5)	
	Polyethylene (low density)		8.0	8.0	26 (5)	
	Polyethylene (high density)		6.0	6.0	63.0 (5)	
	PVC		0.25	1.5	8.0 (5)	
	Polypropylene		8.0			
	Styrene		0.25	0.25		
	Polystyrene		1.0	1.0		
	Styrene butadiene latex		5.0			
	Styrene butadiene SBR		5.0	5.0		
	Acrylonitrile butadiene styrene			5.0		
	Ethylene oxide		5.0	5.0		
	Formaldehyde		5.0	5.0		
	Ethylbenzene		0.6		1.85 (5)	
	Phthalic anhydride		5.0	5.0		
	Acrylonitrile		5.0	5.0		
2F	**Others**					
	Refining (crude oil)		0.288	0.288		
	Bitumen-coated materials		0.07	0.07		
	Bread		3.00	3.00		
	Beer		0.20	0.20		
	Wine		0.50	0.50		
	Sugar		1.00	1.00		
	Particle board		0.90	0.90		

(1) Based on measurements and research in Polish industries. (2) Passant, N.R. (1995).
(3) Neuzil et al. (1992). (4) Macak, J. (1992)
(5) Emission factor developed by the Institute of the Ecology of Industrialised Areas; Katawice.

The United Kingdom provided an aggregate emission factor for the Iron and Steel category. However, it is not clear what industrial processes are taken into account.

Germany provides emission factors for a large number of categories. For most categories, no distinction is made between West Germany and the former GDR. Different factors are provided for the categories:

- Vinylcloride (a difference of a factor of 100), and
- PVC (a difference of a factor of 6).

The former GDR emission factors are more or less in line with the CORINAIR factors. The factors provided by Poland for vinylchloride and PVC are five times higher than the factors provided for the former GDR. Also, the emission factors provided by Poland for Polyethylene (low and high density) and ethylbenzene are significantly higher than the factors provided by Germany.

Polish emission factors are based on measurements and research in Polish industries. Polish experts stated that the Polish emission factors for NMVOCs are significantly higher than CORINAIR values (pers. comm.). They "assume that CORINAIR emission factors relate to more up-to-date technologies and industrial installations which are in a better technical state". If this is the case, then the Polish emission factors would be more applicable to Central and Eastern European Countries than the factors supplied by CORINAIR. Further research is recommended.

Table 4.10 provides a comparison between the Polish NMVOC emission factors and COR-INAIR emission factors.

Table 4.10. A comparison between the Polish NMVOC emission factors and CORINAIR.

Categories	**Poland**	**CORINAIR**
Ethylene	11.0	5.0
Vinyl chloride	14.0	2.5
PVC	8.0	3.0
Polyethylene (low density)	26.0	10.0
Polyethylene (high density	63.0	10.0
Ethylbenzene	1.85	0.6

4.7. Conclusions and recommendations

Poland, a country with an economy in transition, provides a large number of country specific emission factors, for all GHG and for detailed subcategories of industrial processes. These GHG emission factors are based mainly on measurements and research in Polish industries. Unfortunately, because the background literature was only available in the Polish language, no further review/evaluation of these emission factors took place. However, the Polish emission factors could be highly useful for broader application in Central and Eastern European countries, and it is therefore recommended that a detailed review study of the Polish emission factors be considered.

As far as OECD countries are concerned, only Germany provided several emission factors (for West Germany as well as for the former GDR). For most categories, these emission factors were identical and indicate that Germany did not assume a major difference between production processes/circumstances in West Germany and the former GDR. Only a few emission factors from OECD countries and Central and Eastern European Countries could be compared. In these cases, the emission factors differed substantially. These categories are:

- soda production (CO_2 emissions),
- vinyl chloride (NMVOC emissions), and
- PVC (NMVOC emissions).

As stated by the Polish researchers, this could be due to a difference in technology and maintenance between Western and Central and Eastern Europe.

Developing countries inventories did not provide any new emission factors in this section.

In general, it can be concluded that national emission inventories provide a large number of emission factors for sources for which no IPCC default factors were provided. A review of the underlying studies is needed to evaluate these emission factors in order to decide on possible inclusion in the IPCC methodology.

In the IPCC Guidelines the sector on Industrial Processes is not addressed in detail and further development of the methodology is on-going. Since not all literature sources and data from other emission inventory programmes (CORINAIR/EMEP, US EPA, TNO) have been provided, it is not possible to give specific recommendations for targeted research in this field.

However, seeing the differences in comparable emission factors between OECD and Central and Eastern European Countries, further research on GHG emissions from major industries in developing countries is recommended.

5. SOLVENT AND OTHER PRODUCT USE

The IPCC methodology only provides general guidance for estimating emissions from the Solvent and Other Product Use category. The IPCC/OECD/IEA programme on emission inventory methodology has produced no original work on estimation of NMVOC emissions from the use of these products and gives two reasons for this: first, NMVOCs are greenhouse gases assigned a lower priority for national experts initiating GHG inventory work. Second, NMVOCs are among the gases already under heavy scrutiny in national and international inventory programmes because of their role as local and regional air pollutants. Hence, there is a large and growing body of literature containing guidance on estimation procedures and emission factors for NMVOCs (see references in the IPCC Guidelines).

This chapter only presents the factors reported in National Communications/inventories.
It should be clear that the emission factors presented here are only a part of the emission factors internationally available.

Table 5.1. presents the emission factors for NMVOCs used in the national emission inventories reviewed. Only five countries provided emission factors to calculate NMVOC emissions from solvent use.

Table 5.1. Solvent and Other Product Use: NMVOCs - emission factors per category and use.

IPCC Categories		Bulgaria (1)	Czech Republic (2,3)	Poland (4)	Denmark (5)	Germany (West)	Germany (Former GDR)
		NMVOC	NMVOC	NMVOC	NMVOC	NMVOC	NMVOC
		kg/t paint	kg/t prod.	kg/t paint	kg/t solvent	kg/t prod.	kt/t prod.
A	**Paint application**		560	500	301.3	802	901
	Use of water based paints	30					
	Use of other paints	500					
	Lithography	350					
	Rotogravure	100					
B	**Degreasing and dry cleaning**	900	935			663	n.a.
C	**Chemical products manufacture/processing**					976	1000
	Edible oil extraction				4.4		
	Glue production		6	5	8.9		
	Glue use		600		750		
	Medicines production	14					
	Paint production	15	4		8.6		
	Pharmaceuticals production			550			
	Plastics production		6				
	Polyester processing				50		
	Polystyrene foam processing				61.3		
	Polyurethane processing				25		
	Printing industry		800		441.7		
	Underseal car treatment				1000		
	Vegetable oil production	18					
D	**Others**						
	Residential solvent use	2 kg/cap.					
	Solvents in households, printing ink, glues					832	n.a.

(1) CORINAIR. (2) Neuzil et al. (1992).
(3) Macak, J. (1992). (4) Based on research in Polish industries.
(5) Kjems Hove, E. (1993).

NMVOCs

Original emission factors are cited in the inventories of Bulgaria, Czech Republic, Denmark, Germany (different factors for West Germany and the former GDR) and Poland. The factors provided by Bulgaria are based on CORINAIR and are presented here to compare with the emission factors from the other countries.

The emission factors presented in the national emission inventories are expressed in different units. Denmark presents the emission factors in kg/ton of solvent, while Bulgaria and Poland present the factors in kg/ton of paint. The Czech Republic and Germany provide emission factors in kg/ton of product (it is assumed that 'product' means 'paint'). The emission factors provided by Denmark are based on data from the Danish industry. However, this research is not documented.

Bulgaria bases its emission factors on CORINAIR, while the emission factors from the Czech Republic are based on local studies. The Czech Republic states in its emission inventory report that these should be regarded as preliminary figures. No further information is available on the emission factors provided by Germany. The Polish factors are based on specific research in Polish industries.

The emission factors provided for paint application by the Czech Republic, Poland, Denmark and Germany are difficult to compare. First, because of the unit differences mentioned previously. Second, and more important because of the use of the units "kg/t paint or product". It is assumed here that "paint or product" refers to all kinds of paints: water-based paints, as well as, organic solvent-based paints. If this assumption is correct, the share of water-based paints in the total amount of paint used will determine, to a large extent, the value of the emission factor (see also the related emission factors presented by Bulgaria in Table 5.1).

Due to the substantial difference between countries in the ratios of water-based and organic solvent-based paints used, such emission factors cannot be compared. However, it is rather surprising that the emission factors provided by the Czech Republic (although preliminary), Bulgaria (CORINAIR) and Poland are relatively low compared to the emission factor provided by Germany, especially considering the fact that Germany has an ambitious programme to increase the use of water-based paints.

The Danish emission factor for paint application expressed as kg/ton of solvent does not have the above problems. However, the data needed to use this factor might be more difficult to obtain. It seems that a distinction between emissions due to the use of different kinds of paints as practised by Bulgaria (CORINAIR) best ensures comparability. Assuming a similar ratio of water- and organic solvent-based paints is used in Bulgaria, Poland and the Czech Republic the emission factors are in the same range. The same goes for the emission factors for degreasing and dry cleaning in Bulgaria and the Czech Republic. The Czech emission factor for NMVOCs emitted by the printing industry is twice as high as the Danish factor, which may be explained by the difference in technology used. Germany gives a combined emission factor (832 kg/t product) for solvents in households, the printing industry, and glues.

The emission factors available for the former GDR are only slightly higher than the emission factors provided for Western Germany. These differences could well be within the range of uncertainty.

Nitrous oxide
Germany provides an emission factor for N_2O emissions from the use of laughing gas (N_2O) (Table 5.2.). No distinction is made between the emission factor provided for West Germany and the former GDR.

Table 5.2. Solvent and Other Product Use: N_2O - emission factors per category and use.

IPCC Categories	Product use	Germany (West)	Germany (Former GDR)
		N_2O	N_2O
		kg/t prod.	kg/t prod.
3D	Others		
	Laughing gas	1000	1000

Conclusion and Recommendations
Developing countries inventories did not provide any new emission factors in this section. In general it seems likely that the emission factors for (industrial) use of solvents will be higher in Central and Eastern Europe than in OECD countries due to the application of recycling technologies in the OECD.

Emission factors provided by CORINAIR, Poland and the Czech Republic are more or less comparable. A tentative conclusion would be that these factors are applicable in other countries in Central and Eastern Europe. In general it can be concluded that a number of emission factors have been provided in national emission inventories for sources for which no IPCC default factors were provided.

Since background studies were not available or only available in other languages, and/or literature references were not provided, it has not been possible to review these factors on their scientific value and/or the application possibilities in other regions. In the IPCC Guidelines, the section on Solvent and Other Product Use is not addressed in detail. Several studies which could contribute to the development of the guidelines for this section include:

- Bräutigam and Kruse (1992) (a detailed study on VOC emissions in Germany);
- SFT (1995) (a detailed study on solvent and NMVOC emissions in Norway); and
- Baars et al. (1993) (Proceedings of a workshop on the reliability of VOC data bases).

Taking the above into consideration, it is not possible to give specific recommendations for targeted research in this field. However, due to the differences in comparable emission factors between OECD and Central and Eastern European countries research on emissions from major categories in this section in developing countries is recommended. Furthermore, to ensure comparability, clear guidance in the IPCC Guidelines on the preferred units of the emission factors and the definition of categories is needed.

6. AGRICULTURE

6.1. Methane emissions from enteric fermentation in domestic livestock

The IPCC Guidelines provide a simple Tier 1 and a more detailed Tier 2 approach. The Tier 1 approach is based on a methane emission factor per animal. The Tier 2 approach calculates a country specific emission factor using country specific data on milk production, feed intake, energy content, etc. Most emission factors in the national GHG inventories were calculated using the Tier 2 approach as given in the IPCC Guidelines. These factors may be used to evaluate the IPCC default values and can be useful to countries in the same regions with comparable livestock, feeding and grazing circumstances.

6.1.1. Africa

Tanzania used the Tier 2 approach as given in the IPCC Guidelines, while Uganda used an older version of this approach (OECD, 1991).

Table 6.1. Enteric Fermentation - Africa: CH_4 emission factors (kg/head/year).

	IPPC Africa kg CH_4/hd/y	**Tanzania** kg CH_4/hd/y	**Uganda** kg CH_4/hd/y
Dairy Cattle	**36**		
Males		37.23	
Females-not pregnant		63.40	
Females-pregnant		66.58	
Young		38.26	
Beef Cattle	**32**		
Males		59.89	
Females-not pregnant		67.45	
Females-pregnant		71.66	
Young		53.93	
Indigenous Cattle	**32-36**		33.2
Males	**55**	48.01	
Females-not pregnant	**46**	53.15	
Females-pregnant		56.76	
Young	**14**	44.91	
Oxen		95.36	

The emission factor used in the Uganda inventory is comparable with the IPCC default. The factors from the Tanzanian inventory are much higher than the IPCC defaults. This is partly due to the differences in cattle categories used. In the Tanzanian inventory, emission factors are calculated for dairy, non-dairy and indigenous cattle, while the IPCC defaults (assumed to be for indigeneous cattle) distinguish between dairy and non-dairy cattle.

Even if the IPCC categories (dairy and non-dairy cattle) are assumed to be the same as the Tanzanian category "indigenous cattle", the Tanzanian factors are substantially higher than the IPCC defaults. The average milk production for this group of cattle in Tanzania, as well as in Uganda, is, according to local sources, 2 kg/hd/yr, while the IPCC default uses a milk production factor of 1.3 kg/hd/yr.

For non-indigenous cattle, the Tanzanian emission factors are significantly higher than the IPCC defaults for Western Europe. However, the number of non-indigenous cattle is relatively low compared with indigenous cattle (1.2 million - 11.5 million) and therefore the impact on national GHG emissions.

The above supports the statement in the IPCC Guidelines that for countries with a substantial cattle population, it is advisable to use the Tier 2 approach with the use of local data (milk production, weight etc.). Considering the differences between the Tanzanian factors and the IPCC defaults it is probably not advisable for other countries in that region to use the Tanzanian figures as a replacement of the IPCC value without a systematic evaluation of local circumstances and available data.

6.1.2. Asia and Latin America

Only one country in each region reported emission factors for enteric fermentation. The factors used in the emission inventory of Bangladesh are not well documented and therefore the reliability of these factors could not be assessed. The Venezuelan factors are based on the Tier 2 approach from the IPCC Guidelines.

Table 6.2. Enteric Fermentation - Asia and Latin America: CH_4 emission factors kg/head.year).

	IPCC - Asia (1)	Bangladesh (2)	IPCC-Latin America	Venezuela (3)
	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Dairy Cattle	**56**	17.8	**57**	69
Non-Dairy Cattle	**44**	16.2	**49**	
Beef cattle				
Mature females	**41-48**			74
Mature males	**44-58**			68
Young/Calves	**31**			48
Buffalo	**55**	18.6		
Sheep	**5**	2.0		
Goats	**5**	1.8		

(1) Cattle:based on estimates for China.
(2) Emission factors based on "some current studies" and Indian Report (ABD, 1994).
No further details available.
(3) Based on Tier 2.

Almost all factors used in the Bangladesh emission inventory are three times lower than the IPCC defaults, but no further information could be obtained. For Venezuela the emission factors are significantly higher than the IPCC defaults. The differences compared with the default values are caused by differences between the default and country specific data in the parameters (milk yield, weight etc.) used in the Tier 2 approach. This strengthens the recommendation in the IPCC Guidelines that emission inventory calculations should be carried out as a detailed a level as possible (i.e. Tier 2).

6.1.3. North America

Emission factors are provided by the United States and Canada.

Table 6.3. Enteric Fermentation - North America: CH_4 emission factors (kg/head/year).

	IPCC (1) North America	U.S.	Canada (2,3,4,5,6)
	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Dairy Cattle	**118**	80.4	
Lactating			
Dry			
Dairy cows		114.6	120
Heifer (under 2 years)			72
Replacements 0-12 months (7)		19.6	
Replacements 12-24 months (7)		58.8	
Feedlot			
Non-Dairy Cattle	**47**	47.5	
Beef cattle			
Mature females	**69**	66.7	48
Mature males	**75**	100.0	120
Young/Calves	**42**		24
Heifer			36
Heifer for meat			36
Steer			48
Replacements 0-12 months (7)		22.3	
Replacements 12-24 months (7)	**56**	65.0	
Weanling system Steers/Heifers (8)		23.1	
Yearling system Steers/Heifers (9)		47.3	
Buffalo	**55**		
Sheep	**8**		10
Lamb			6
Goats	**5**		
Camels	**46**		
Horses	**18**		
Mules and Asses	**10**		
Swine	**1.5**		
Boars			5
Sows			5
Pigs (<20 kg)			1
Pigs (20-60kg)			2
Pigs (>60kg)			3
Poultry			
Chickens			0
Hens			0.02
Turkeys			0.01

(1) Cattle: based on estimates for the US.

(2) Crutzen et al. (1986).

(3) Blaxter and Clapperton (1965).

(4) Baldwin and Allison (1983).

(5) Kirchgessner et al., (1991).

(6) Kinsman (1992).

(7) A portion of the offspring are retained to replace mature cows that die or are removed from the herd each year. Those that are retained are called "replacements".

(8) In "weanling systems", calves are moved directly from weaning to confined feeding programs.This system represents a very fast movement of cattle through to marketing. Weanling system cattle are marketed at about 420 days of age (14 months).

(9) "Yearling systems" represent a relatively slow movement to cattle through to marketing. These systems include a wintering over, followed by a summer of grazing on pasture. Yearling system cattle are marketed at 565 days of age (18.8 months).

Although the IPCC default emission factors are based on estimates from the US, there are some significant differences between these IPCC emisson factors and the emission factors used in the US inventory. This may be due (in part) to differences in livestock composition. The Canadian emission factors for non-dairy cattle show significant differences with the IPCC defaults. Canada provides emission factors for several categories of swine, e.g. boars, sows, pigs. The Canadian factors for swine and to a lesser extent for sheep show substantial differences compared with the IPCC defaults.

6.1.4. Central and Eastern Europe

Emission factors are provided by Germany (for former GDR), Czech Republic and Poland.

Table 6.4. Enteric Fermentation - Central and Eastern Europe: CH_4 emission factors (kg/head/year).

	IPCC E- Europe (1)	**Former GDR**	**Czech Rep.(2)**	**Poland**
	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Dairy Cattle	**86.4**	95	87.16	94.3
Non-Dairy Cattle	**56.0**			48.6
Beef cattle	**74.0**		54.57	
Mature males	**65.0**	65	49.58	
Young/Calves	**40.0**	51	6.25	
Heifer			11.02	
Heifer for meat			23.81	
Sheep	**8.0**		7.87	8.9
Goats			4.59	
Horses	**18.0**		47.22	
Swine	**1.5**		3.41	
Poultry		0.13	0.07	

(1) Cattle: based on estimates for the former USSR.

(2) Tier 2.

Notable differences occur between the emission factors calculated for young non-dairy and horses in the Czech inventory and the IPCC defaults (6.25-40; 47.22-18 resp). No explanation for these differences is given.

6.1.5. Western Europe

Emission factors are provided by Denmark, the United Kingdom, the Netherlands, Germany and Sweden.

Table 6.5. Enteric Fermentation - Western Europe: CH_4 emission factors (kg/head/year)

	IPPC W-Europe	**Denmark (1,2)**	**U. K.**	**Netherlands (3,4)**	**Germany (West)**	**Sweden**
	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Dairy Cattle	**100**		109		95	154
Young ,1 yr				49.25		
Young female >1yr				62.80		
Dairy cows				102.13		
Dairy male >1 yr				93.22		
Non-Dairy Cattle	**48**	57 (5)				
Beef cattle	**84**					80
Mature males	**60**			87.01	65	
Young/Calves	**0-33**			17.65	51	
Bulls and steer calves < 6 months		0				
Bull and steer calves 1/2-1 year		35				
Bulls and bullocks, 1-2 yr		55				
Bulls and bullocks, +2 yr		48				
Heifer calves - 6 months		0				
Heifer calves 1/2 - 1 yr		22				
Heifers, 1-2 yr		38				
Heifers, - 2 yr		57				
Cows and heifers having calved		110		102.13		
Buffalo	**55**					
Sheep	**8**	11				16
Breeding ewes		14				
Rams		9				
Lambs		9				
Goats	**5**					21
Camels	**46**					
Horses	**18**	19				

Table 6.5. (cont.) Enteric Fermentation - Western Europe: CH_4 emission factors (kg/head/year).

	IPPC W-Europe	Denmark (1,2)	U. K.	Netherlands (3,4)	Germany (West)	Sweden
	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Mules and Asses	**10**					
Swine	**1.5**	0.8				
Boars		1				
Sows		1				
Breeding sows		2.2				
Pigs for slaughter		0.7				
Poultry					0.13	

(1) NERI , Technical Report No 19, 1991.

(2) De Reydellet, A. (1990).

(3) Amstel, A. Van, (1995).

(4) Casada and Safley (1990).

(5) No distinction is made between dairy and non-dairy cattle.

The emission factors in the Danish, German, English and Dutch inventories show only slight differences with the IPCC defaults. Most Swedish factors, however, are substantially higher. No explanation for these differences are given.

6.1.6. Oceania

Emission factors are provided by Australia and Japan.

Table 6.6. Enteric Fermentation - Oceania and Australia: CH_4 emission factors (kg/head/year).

	IPCC (1) Oceania	Australia	Japan (2)
	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Cattle		65.9	
Dairy Cattle	**68**	101.2	
Lactating		101.2	110
Dry			62
Heifer (under 2 years)			66
Feedlot		87.5	
Non-Dairy Cattle	**53**		
Beef cattle	**55-63**	61.8	
Dairy breed			77
Fattening (+ 1year)			62
Fattening (- 1 year)	**39**		44
Breeding cows			51
Buffalo	**55**	46.0	
Sheep	**8**	7.1	4
Goats	**5**		4
Horses	**18**		17
Swine	**1.5**		1
Poultry			
Deer		10.7	
Ostriches/Emus		5.0	
Alpacas		10.0	

(1) Cattle: based on estimates for Australia.

(2) National Institute of Animal Industry, Ministry of Agriculture, Forestry and Fisheries (1993). Values based on respiration trials.

The above table does not show remarkable differences except for the factor for sheep used in the Japanese inventory, and the Australian emission factor for dairy cattle. Australia provides emission factors for deer, ostriches and alpacas.

6.1.7. Conclusions and recommendations

New emission factors are provided for alpacas, deer, goats, ostriches, poultry and turkeys. As far as the emission factors for cattle are concerned, it is shown that in many cases the country specific emission factors differ substantially from the corresponding IPCC default values. As stated above, countries with a significant number of cattle should use the Tier 2 approach using country specific data (milk production, weight, feed intake etc.). If these data are not available research is advised strongly. Countries using the Tier 2 approach distinguish a large number of subcategories. IPCC default emission factors are only provided for the main categories.

Considering the differences in emission factors calculated in the Tier 2 approach and taking into consideration that this Tier 2 approach originates mainly from scientific studies in the US, it is recommended to scientifically test the approach in the other regions. From the point of view of the differences in emission factors provided for swine and horses, research might be useful. However, considering the total emissions from these animals, this research certainly has no priority

6.2. Emissions from manure management

6.2.1. Methane

Like the emission factors for enteric fermentation most of the factors for manure management presented below are based on the Tier 2 approach as provided in the IPCC Guidelines.

Africa

Three countries, Ethiopia, Tanzania and Uganda, calculated country specific emission factors based on the Tier 2 approach.

Table 6.7. Manure Management: Africa: CH_4 emission factors (kg/head/year).

		IPCC Africa	**Ethiopia (1)**	**Tanzania (2)**	**Uganda (2)**
		kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Cattle					
Dairy Cattle				0.63	
	Cool	**1**	1.51		
	Temperate	**1**	1.81		
	Warm	**1**	2.05		
Non-Dairy Cattle				0.37	0.82
	Cool	**0**	0.99		
	Temperate	**1**	1.14		
	Warm	**1**	1.32		
Buffalo					
Sheep		**0.10-0.21**		0.17	0.23
Goats		**0.11-0.22**		0.17	0.30
Camels		**1.3-2.6**			
Horses		**1.1-2.2**			
Mules and Asses		**0.6-1.2**		0.59	
Swine				0.03	0.14
Pigs breeding					
Pigs market					
Poultry		**0.012-0.023**		0.02	0.02
Alpacas					
Llamas					

(1) Based on IPCC tier 2 method, using default parameters.
(2) Based on Tier 2 method.

The emission factors used in the inventories from African countries differ from the IPCC defaults, although this difference is not consistent. In the Ethiopian inventory it is indicated that the climate classification system used differs from the IPCC system. The Ethiopian emission factors are significantly higher while the Tanzanian and Ugandan emission factors are lower. Differences are due to the use of national data for the underlying parameters.

Latin America

Three countries, Costa Rica, Peru and Mexico, provide emission factors based on the Tier 2 approach. Mexico calculated emission factors for a great number of subcategories.

Table 6.8. Manure Management:Latin America: CH_4 emission factors (kg/head.year).

		IPCC Latin America	**Costa Rica**	**Peru**	**Mexico (1,2,3,4)**
		kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Cattle					
Dairy Cattle			1.00	0.66	
	Cool	**0**			
	Temperate	**1**			
	Warm	**2**			
age 0-1 year	cool/arid region				0.285
age 1-2 year	cool/arid region				0.454
age 2-3 year	cool/arid region				0.56
age +3 year	cool/arid region				0.781
cows	cool/arid region				0.461
age 0-1 year	temperate region				0.6
age 1-2 year	temperate region				0.843
age 2-3 year	temperate region				0.989
age +3 year	temperate region				1.299
cows	temperate region				1.024
age 0-1 year	warm region				0.905
age 1-2 year	warm region				1.218
age 2-3 year	warm region				1.424
age +3 year	warm region				1.817
cows	warm region				1.568

Table 6.8. (cont.) Manure Management:Latin America: CH_4 emission factors (kg/head.year).

		IPCC Latin America	**Costa Rica**	**Peru**	**Mexico (1,2,3,4)**
		kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Non-Dairy Cattle			1.00		
	Cool	**1**			
	Temperate	**2**			
	Warm	**1**			
age 0-1 year	cool/arid region				0.287
age 1-2 year	cool/arid region				0.414
age 2-3 year	cool/arid region				1.025
age +3 year	cool/arid region				0.621
cows	cool/arid region				0.529
age 0-1 year	temperate region				0.479
age 1-2 year	temperate region				0.684
age 2-3 year	temperate region				0.832
age +3 year	temperate region				1.001
cows	temperate region				0.889
age 0-1 year	warm region				0.670
age 1-2 year	warm region				0.940
age 2-3 year	warm region				1.148
age +3 year	warm region				1.353
cows	warm region				1.246
Buffalo			2.00		
Sheep		**0.10-0.21**	0.16	0.12	
Goats		**0.11-0.22**	0.17	0.15	
Camels		**1.3-2.6**			
Horses		**1.1-2.2**	1.60	1.60	
Mules and Asses		**0.6-1.2**			
Swine			2	1.82	
Pigs breeding					
Pigs market					
Poultry		**0.012-0.023**	0.02	0.02	
Alpacas				0.70	
Llamas				0.80	

(1) Anastasi, C. and V.J. Simpson (1993).
(2) González, E. (1994).
(3) Safley, L.M. et al. (1992).
(4) Steed, J. Jr. and A. Hashimoto (1993).

The country specific emission factors, as given in Table 6.8 are comparable with the IPCC default emission factors. New factors are provided for buffalo, swine, alpaca and lama manure.

Central and Eastern Europe

Country specific emission factors are provided by Bulgaria, the Czech Republic, Germany (former GDR) and Poland.

Table 6.9. Manure Management: Central and Eastern Europe: CH_4 emission factors (kg/head/year).

Manure Management		IPCC E-Europe	Bulgaria(1)	Czech Rep.	Germany (Former GDR)	Poland
		kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y	kg CH_4/hd./y
Cattle					24.46	
Dairy Cattle				3.29		
	Cool	**6**				2.9
	Temperate	**19**	28			
	Warm	**33**				
Non-Dairy Cattle				1.6		1.22
	Cool	**4**				
	Temperate	**13**				
	Warm	**23**				
Sheep			0.28	0.33	0.2	
	Cool	**0.1**				
	Temperate	**0.16**				
	Warm	**0.21**				
Goats			0.18			
	Cool	**0.11**				
	Temperate	**0.17**				
	Warm	**0.22**				
Horses			2.1	3.63	2	
	Cool	**1.09**				
	Temperate	**1.64**				
	Warm	**2.18**				
Mules and Asses			1.14		2	
	Cool	**0.6**				
	Temperate	**0.9**				
	Warm	**1.19**				
Swine			15	8.8	5.12	1.43
	Cool	**4**				
	Temperate	**7**				
	Warm	**11**				
Poultry			0.12	0.02	0.13	
	Cool	**0.012**				
	Temperate	**0.018**				
	Warm	**0.023**				

(1) Based on Tier 2 method, applying IPCC default values for Central and Eastern Europe.

Substantial differences occur between the IPCC default emission factors and the emission factors for cattle manure in the Czech Republic and Poland and for poultry manure in Bulgaria and the former GDR. However, no information could be obtained to explain these differences.

Western Europe

Denmark, the Netherlands, Sweden, United Kingdom and Germany (West) provide country specific emission factors. The emission factor provided by the Netherlands is expressed in a different unit and based on manure from cattle in stables.

Table 6.10. Manure Management: Western Europe: CH_4 emission factors (kg/head/year).

		IPCC W-Europe (1)	Denmark	Netherlands(2,3)	Sweden (4)	U K (5)	Germany (West)
		kg/hd/y	kg/hd/y	kg/m³/y (5)	kg/hd/y	kg/hd/y	kg/hd/y
Cattle							23.5
Dairy Cattle				0.698			
	Cool	**14**			8	11.3	
	Temperate	**44**					
	Warm	**81**					
Non-Dairy Cattle				2.534			
	Cool	**6**			2		
	Temperate	**20**					
	Warm	**38**					
Sheep		**0.19-0.37**		2.979	2		0.2
Goats		**0.12-0.23**		2.979	2		
Camels		**1.59-3.17**					
Horses		**1.39-2.77**			2		2.0
Mules and Asses		**0.76-1.51**			2		2.0
Swine		**3-17**	11(6)	3.009	2		4.6
Poultry				4.11			0.1
Fowls, Turkeys, Geese and Ducks						0.078	

(1) Casada and Safley, Jr (1990).

(2) Amstel, A van(1995).

(3) Based on manure from animals in stables which is 70% of the total amount of manure.

(4) Katscher (1995) stated that emission factors were based on expert judgement, in most cases no references were provided.

(5) Based on Tier 2 method.

(6) De Reydellet, A. (1990).

The emission factors for cattle used in the Swedish emission inventory are substantially lower than the IPCC defaults. In the Netherlands report, the emission factors are expressed in another unit than the IPCC Guidelines. The Netherlands emission factors are based on the emissions from manure from animals in stables and are expressed as the amount of methane emitted per cubic metres of manure.

It must be possible to convert the Netherlands emission factor to the commonly used unit. It is recommended that the Netherlands reports the emissions from manure management in future in kg/hd./y, so comparison is possible.

Oceania and North America

In these two regions emission factors are provided by Australia, United States and Canada.

Table 6.11. Manure Management: Oceania and North America: CH_4 emission factors (kg/head.year).

		IPCC Oceania	**Australia**	**IPCC North America**	**Canada (1)**
		kg CH_4/hd/y	kg CH_4/hd/y	kg CH_4/hd/y	kg CH_4/hd/y
Cattle			0.8		
Dairy Cattle			7.75		42.94
	Cool	**31**		**36**	
	Temperate	**32**		**54**	
	Warm	**33**		**76**	
Non-Dairy Cattle			0.0		12.14
	Cool	**5**		**1**	
	Temperate	**6**		**2**	
	Warm	**7**		**3**	
Feedlot			1.4		
Sheep		**0.19-0.37**		**0.19-0.37**	6.44
Lambs					6.44
Swine		**20**	12.9	**10-18**	
Pigs breeding					24.14
Pigs market					6.17
Poultry			0.13		
Chickens					0.14
Hens					0.14
Turkeys					0.43

(1) Casada and Safley (1990).

The countries in these regions i.e. Australia and Canada use significantly different emission factors than the IPCC defaults. In the Australian inventory the emission factor for dairy cattle is four times lower then the default while the emissions from manure from non-dairy cattle are assumed to be zero. In the Canadian inventory the emission factors for non-dairy cattle and sheep manure are 12 and 20 times lower respectively. It seems that local circumstances (climate and stables/free range) are the causes of these differences.

Conclusions and recommendations

As already stated in the section on enteric fermentation local circumstances/practices may cause considerable differences with the IPCC default emission factors. Those countries for which emissions from this sector are relatively substantial should use a detailed method where possible with local data. Targeted research in this field could be useful for some regions but only in cooperation with the recommended research for enteric fermentation, since the latter is a far more important source of methane emissions.

6.2.2. Nitrous oxide

Two countries provide emission factors for nitrous oxide from manure management systems. This category of emissions has not been dealt with in the IPCC Guidelines. Considering the global warming potential of nitrous oxide this can be considered as a valuable addition. It should be noted that if manure is applied on agricultural soils the nitrous oxide emissions are taken into account in section 6.6, N_2O and NMVOC emissions from agricultural soils.

Table 6.12. Manure Management: N_2O emission factors (kg/head.year).

	UK (1)	**Germany**
	kg/hd/yr	kg/hd/yr
Cattle	0.17(2)	0.38 (3)
Goats	0.017	
Sheep	0.026	0.03
Pigs		0.09
Horses	0.11	0.19
Swine	0.032	
Poultry		0.004
Fowls, Turkeys, Geese and Ducks	0.003	

(1) MAFF (1995).
(2) Aggregate for all cattle.
(3) including calves < 6.

No information on the provided emission factors is given. It is advised that the IPCC expert groups develop a method for estimating the nitrous oxide emissions from manure management. Information from the above countries would be a good start.

6.3. Methane emissions from rice cultivation

Almost all countries with rice cultivation report emissions estimated by the IPCC methodology using default values. Japan and Australia report emission estimates based on country experiments.

Table 6.13. Rice cultivation: CH_4 emission factors (g/m^2/year).

Japan (1)	IPCC	
	kg/ha.days	g CH4/m2/year
Soil type		
Alluvial soil		13.4 (8.0-27.0)
Volcanic ash soil		5.9 (3.6-9.8)
Peaty soil		22.3 (13.3-44.8)
Other		9.6 (5.9-18.4)
Australia		kg/ha.days
Continuously flooded	**3.91 (2)**	0.67 (3,4,5,6)
Mexico		0.269
U.S. (7,8,9,10)		1.065-5,639

(1) National Institute of Agro-Environmental Sciences, Ministry of Agriculture, Forestry and Fisheries (1993). Values are based on field measurements by closed chamber method.
(2) for a growing season average temperature of 20 degrees Celsius.
(3) This figure is based on three sets of investigations conducted in Australia in 1987, 1990 and 1991.
(4) Denmead and Freney, J.R. (1991).
(5) Williams, D.J. (1994).
(6) Keerthisinge et al. (1993).
(7) The endpoints of the emission rates measured in the studies.
(8) Cicerone, R.J.et al. (1983).
(9) Lindau, C.W. and P.K. Bollich (1993).
(10) Lindau, C.W. et al. (1991).

As will be clear from the above table there is a very big difference between the Australian emission factor and the IPCC default.

Conclusions and recommendations

The IPCC methodology and default factors are mainly based on (extensive) research in Asian countries. This together with the above observation that all other countries use the IPCC default and the significantly different emission factor based on Australian research leads to the conclusion that research on methane emission factors for rice cultivation is highly advised for those countries with a substantial rice production. (Preliminary results from research in Thailand and the Philippines give emission factors significantly lower than the IPCC defaults (Watdipong, 1996; Francisco, 1996)).

6.4. Methane, carbon monoxide, nitrous oxide and nitrogen oxide emissions from prescribed burning of savannas

The methodology for estimating emissions from savanna burning is based on a set of data, which in combination, form the base for the calculation of the emissions. The most important parameters are:

- Fraction of total savanna burned annually;
- Aboveground biomass density;
- Fraction of biomass actually burned;
- Fraction of aboveground biomass that is living;
- Carbon fraction of biomass.

The IPCC Guidelines state that, if possible, locally available data should be used. If local data is not available, a crude default approach can be used by using the regional defaults given. It is also mentioned that savannas should be divided into woody savannas and grasslands, where possible. Inventories from countries where savanna burning takes place show that it seems advisable to divide into more than the suggested two categories.

The next tables present the country specific values for the regions Africa, Latin America and Oceania respectively.

Table 6.14. Savanna burning: Africa: parameters determining emissions.

Country	Region/Category	Area burned (%)	Aboveground biomass density (t dm/ha)	Fraction burned	Fraction of living biomass	Carbon content living biomass	Carbon content dead biomass
IPCC	**Tropical Africa**	**80.0**	**6.6**			**0.45**	**0.40**
	Sahel Zone	**5.0-15**	**0.5-2.5**	**0.95**	**0.20**		
	North Sudan Zone	**25-50**	**2.0-4.0**	**0.85**	**0.45**		
	South Sudan Zone	**25-50**	**3.0-6.0**	**0.85**	**0.45**		
	Guinea Zone	**60-80**	**4.0-8.0**	**0.9-1.0**	**0.55**		
Gambia			2.126				
Malawi			3	0.8	0.8		
Senegal	Savanna grassland		0.724		0.03		
	Savanna thicket		1.661		0.03		
	Transition Zone		1.660		0.03		
	Woody savanna		4.660		0.05		
	Agro-Forestry Zone		3.739		0.05		
Tanzania	Humid savanna	32	6.6	0.85	0.85		
	Semi arid savanna	32	4.5	0.90	0.65		
Uganda	Permanent swamp	5	200.0		1.00	0.102	
	Seasonal swamp	44	54.0		0.05	0.020	0.770
	Savanna woodland	48	26.0		0.10	0.026	0.306
	Savanna grassland	5	36.0		0.05	0.026	0.306
	Dry thicket	56	4.0		0.00		0.306

Table 6.15. Savanna burning: Latin America and Oceania: parameters determining emissions.

Country	Region/Category	Area burned (%)	Aboveground biomass density (t dm/ha)	Fraction of living biomass	Carbon content living biomass
IPCC	**Tropical America**	**50.0**	**6.6**		
Bolivia			8.4	0.4	
Costa Rica			5	0.55	
Peru				0.4	
Venezuela (1)	Andes	11.2	5.08		
	Zulia	11.2	5.34		
	Centro-Occidente	49.8	4.30		
	Llanos	17.1	6.07		
	Nor-Oriente	0.6	3.31		
	Guyana	11.2	6.20		
IPCC	**Australia**	**5.0-70**	**2.1-6.0**		**0.45**
Micronesia		20 - 40			
Australia					0.46 (2,3)

(1) Preliminary figures, based on local studies using satellite images.

(2) Carbon fraction in dry residue (no distinction between living and dead biomass).

(3) Hurst et al. (1994b).

Table 6.16. Savanna burning: emission ratios Australia.

Trace gases	IPCC Range	IPCC Default	Australia (1,2)
Gas type			
CH_4	0.003-0.007	0.005	0.0035
CO	0.075-0.12	0.1	0.078
NHVOC			0.0091
N_2O	0.005-0.009	0.007	0.0076
NO_x	0.09-0.15	0.12	0.21

(1) Hurst et al. (1994a).

(2) Hurst et al. (1994b).

It will be clear from Tables 6.13 and 6.14 that the IPCC default values are only crude estimates and that the use of locally available data is needed to get a reasonable estimate. Categorising the savanna either by type (Senegal, Uganda, Tanzania) or by location (Venezuela) seems necessary considering the differences in the parameters used. Senegal uses a somewhat different approach so not all parameters can be compared with other countries.

In several national inventories it is stated that the uncertainty of the estimated area burned annually is very high and subsequently the emission estimate is tentative. In addition there is a discussion o how far these emissions should be considered anthropogenic or a naturally occurring phenomena (lightning). Australia states that savanna burning has taken place for thousands of years and is therefore not considered anthropogenic.

The applicability of the country specific values of the above parameters for other countries seems low. Only for areas close to the ones given above the same data might be of value. However, it is advised to use country specific data.

Australia provides figures on emission ratios for savanna burning, based on published research (see Table 6.15). The ratios are within the range provided by the IPCC, except for the emission ratio for No_x, which is substantially higher. Australia also provides the emission ratio for NMVOC (not provided by the IPCC). Australia used the same emission ratios for the savanna burning and the burning of agricultural waste (see 6.5.5).

Conclusions and recommendations

If the emissions from savanna burning are considered to be anthropogenic (distinction between fires due to human activities and natural causes can not be made most of the time) it is certainly an area for targeted research considering the importance of this source in a large number of developing countries. The research should be aimed at determining with greater precision the area burned annually and the biomass density for each savanna type.

6.5. Methane, carbon monoxide, nitrous oxide and nitrogen oxide emissions from the burning of agricultural residues

As was the case for savanna burning, the calculation of the emissions from burning of agricultural residues is based on a set of data rather than a specific emission factor. The important data are:

- Residue to crop ratio;
- Dry matter content;
- Carbon fraction;
- Nitrogen-Carbon ratio.

The following sections give the information from the inventories reviewed. In principle these data, apart from the ones concerning agricultural practices (crops, areas etc.) in the countries, should not show a great difference and the applicability and reliability of default values should be far greater than for savanna burning.

6.5.1. Residue to crop ratio

Although the IPCC Guidelines provide an extensive list of crops for which residue to crop ratios are available, the inventories under consideration provide ratios for another 13 crops.

For its national emission inventory Uganda carried out a specific research project to determine country specific data for this section. It should be mentioned that this research was carried out with a small number of samples and the results should therefore be treated with caution. However, in most cases where the results from the Ugandan study can be compared with the IPCC defaults they are similar. Differences occur with beans and peas.

Comparing the results from all countries the following important differences can be observed:

- Cotton: this crop shows a remarkable difference in the presented ratios, ranging from 1.1 (Malawi) to 50.0 (Tanzania).
- Groundnuts: Malawi reports a ratio twice the default and the Ugandan ratio.
- Maize: Ethiopia uses a ratio 2.5 times higher than other countries and default.
- Millet/sorghum: Senegal uses the same ratios for millet and sorghum due to the lack of specific ratios available. The ratio for sorghum used by the United States and Senegal are 5-6 times higher than the ratios used by other countries and the default.
- Sugar cane: no consistency can be observed in the ratio for this crop. Reported values range from 0.2 (Tanzania) to 8.0 (US).

Table 6.17 Agricultural Residue Burning: residue to crop ratio.

	IPCC	Ethiopia	Malawi(1)	Senegal	Tanzania	Uganda	Zambia	Zimbabwe	Peru(2)	US	Australia
Asparagus									2.8		
Banana						0.4					
Barley	**1.2**	1.5									1.5
Beans	**2.1**					0.7			1.5		
Beans (soya)	**2.1**					0.7					
Cassava			0.5			0.3	0.2				
Coffee						0.8					
Cotton			1.1		50.0	12.5	1.2	3	7.5		
Feedbeet	**0.3**										
Groundnuts	**1.0**		2.0			1.0					
Maize	**1.0**	2.7	1.5	1.5		1.0					1.5
Millet	**1.4**	1.5		7.5		1.1					
Oats	**1.3**										1.5
Peas (cow)						0.6					
Peas (field)	**1.5**					0.6					
Peas (pigeon)						0.7					
Potatoes (Irish)	**0.4**					0.4					
Potatoes (sweet)						0.3					
Rice	**1.4**			1.4	0.3	1.4					1.5
Rye	**1.6**										
Simsim						5.1					
Sorghum	**1.4**	1.5		7.5		1.2				8.0	1.5
Sugar cane					0.2	0.3	1.3			0.8	0.25
Sugar beet	**0.2**									0.3	
Sunflower			1.4				0.7				
Teff		2.2									
Tobacco			1.2					0.5			
Triticale											1.5
Wheat	**1.3**	2.0				1.2					1.5

(1) Technical Report Ministry of Agriculture (1991) (No further details available). (2) Based on local studies.

6.5.2. Dry matter fraction

There is a great deal of agreement in the reported dry matter fraction in most inventories. Differences in the reported ratios exist mainly for millet, sorghum and maize. Furthermore the fractions provided by Bolivia are low for several crops compared to other countries, the US uses high fractions for potatoes and sugar beet compared to defaults and ratios from other countries. All in all, for 23 crops dry matter fractions are reported that are not available in the IPCC Guidelines.

The applicability of these factors for other countries is high, considering the comparability between the fraction reported in the inventories reviewed.

Table 6.18. Agricultural Residue Burning: dry matter fraction.

	IPCC	Ethiopia(1)	Malawi	Senegal	Tanzania	Uganda	Zimbabwe	Bolivia	Peru	Greece	US	Australia
Artichoke											0.90	
Asparagus									0.7 (2)			
Banana						0.45						
Barley	**0.78-0.88**	0.87						0.88			0.90	0.8
Beans		0.85				0.80		0.50			0.89	
Beans (soya)						0.88	0.88	0.50			0.89	
Cassava			0.45			0.50						
Coffee						0.42						
Cotton			0.83		0.88	0.80	0.70		0.6 (3)			
Feedbeet	**0.10-0.20**											
Groundnuts			0.83			0.76	0.88	0.30			0.90	
Lentils											0.89	
Maize	**0.30-0.50**	0.87		0.40		0.75		0.50			0.88	0.8
Millet		0.84		0.40		0.85	0.50					
Oats								0.88		0.83	0.91	0.8
Peas (cow)						0.80						
Peas (field)		0.85				0.80		0.50			0.90	
Peas (pigeon)		0.85				0.80						
Potatoes (Irish)	**0.30-0.60**					0.40		0.60			0.87	
Potatoes (sweet)						0.40						
Rice	**0.78-0.88**			0.70	0.97	0.85		0.88			0.90	0.8
Rye										0.83	0.90	
Simsim						0.73						
Sorghum		0.86		0.40		0.80	0.50	0.50			0.90	0.8
Sugar cane					0.84	0.90		0.90	0.4 (4)		0.90	0.2
Sugar beet	**0.10-0.20**										0.90	
Sunflower			0.83									
Teff												
Tobacco			0.83				0.70					
Triticale												0.8
Wheat	**0.78-0.88**	0.87				0.90		0.88			0.91	0.8

(1) Based on indirect method on moisture context information: CESEN, New and Renewable Energy Technologies, May 1984 (no further details available).

(2) Suárez, M. (1993). (3) Gamarra, L. (1967). (4) Anales Científicos, UNALM, Peru.

6.5.3. Carbon fraction

The reported carbon fractions are highly comparable between countries and IPCC defaults. Only the fractions provided by the Ugandan inventory are significantly lower than the other reported fractions. Since this difference exist for all crops it suggests that a systematic error might have occurred in the determination of these factors. As already mentioned above the Ugandan data are the results from a study with only a few samples, and therefore the results should be treated with caution. In total carbon fractions are presented for 23 crops for which no defaults are given in the IPCC Guidelines.

The applicability of these factors for other countries is high, considering the comparability between the fraction reported by the countries under consideration (with the exception of Uganda).

Table 6.19 . Agricultural Residue Burning: carbon fraction (% dm).

	IPCC	Malawi	Tanzania	Uganda	Zambia	Zimbabwe	Peru	Greece	US	Australia
Artichoke									0.4072	
Asparagus										
Banana				0.3120						
Barley	**0.4567**									0.4
Beans		0.41		0.2970	0.4478		0.4500		0.45	
Beans (soya)		0.41		0.3350	0.4478				0.45	
Cassava		0.42		0.3320	0.4364					
Coffee				0.3810						
Corn							0.4709			
Cotton		0.46	0.36	0.3420	0.4364	0.50				
Feedbeet	**0.4072**									
Groundnuts		0.41		0.2960	0.4478				0.4226	
Lentils									0.45	
Maize	**0.4709**			0.3290						0.4
Millet				0.3260	0.4853	0.4709				
Oats								0.4567	0.4853	0.4
Peas (cow)		0.41		0.2930						
Peas (field)				0.2970					0.45	
Peas (pigeon)		0.41		0.2990						
Potatoes (Irish)	**0.4226**			0.3450						
Potatoes (sweet)				0.3650						
Rice	**0.4144**		0.30	0.2480						0.4
Rye								0.4567	0.4853	
Simsim				0.1890						
Sorghum		0.41		0.2840	0.4853	0.4709			0.4853	0.4
Sugar cane			0.41	0.3470	0.4571				0.4695	0.4
Sugar beet	**0.4072**									
Sunflower		0.41			0.4478					
Teff										

Table 6.19 . (cont.) Agricultural Residue Burning: carbon fraction (% dm).

	IPCC	Malawi	Tanzania	Uganda	Zambia	Zimbabwe	Peru	Greece	US	Australia
Tobacco		0.46				0.50				0.4
Triticale										0.4
Wheat	**0.4853**			0.3140						0.4

6.5.4. Nitrogen carbon ratio

Table 6.20. Agricultural Residue Burning: nitrogen carbon ratio.

	IPCC	Malawi	Tanzania	Uganda	Bolivia	Ecuador	Peru	US	Australia
Artichoke								0.0228	
Asparagus									
Banana				0.0288					
Barley					0.020			0.0060	0.008
Beans		0.02		0.0236	0.012		0.015	0.0230	
Beans (soya)	**0.0500**			0.0627				0.0230	
Cassava		0.05		0.0693					
Coffee				0.0459					
Corn							0.02		
Cotton		0.01	0.015	0.0561					
Feedbeet									
Groundnuts		0.02		0.0473	0.050			0.0110	
Lentils								0.0230	
Maize	**0.0200**			0.0161				0.0081	0.008
Millet	**0.0160**			0.0491					
Oats					0.017			0.0070	0.008
Peas (cow)		0.02		0.0836					
Peas (field)				0.1111	0.012			0.0230	
Peas (pigeon)		0.02		0.1137					
Potatoes (Irish)				0.0507	0.5			0.0110	
Potatoes (sweet)				0.0337					
Rice	**0.0140**		0.015	0.0484				0.0067	0.008
Rye								0.0070	
Simsim				0.1746					
Sorghum	**0.0200**			0.0387				0.0085	0.008
Sugar cane		0.02	0.015	0.0100	0.035			0.0030	0.008
Sugar beet						0.0100		0.0228	
Sunflower		0.02							
Teff									
Tobacco		0.01							
Triticale									0.008
Wheat	**0.0120**			0.0466				0.0040	0.008

There is far less consistency in the nitrogen - carbon ratios provided in the inventories than in the carbon and dry matter fractions. In general the Ugandan ratios are higher than the defaults and ratios presented by the other countries. This is probably due to the relatively low carbon fractions used in the Ugandan inventory (see Table 6.16). There is a remarkable difference between the N/C ratios provided by the United States and the IPCC defaults, the United States ratios are 2-3 times lower. Considering these differences further research is advised.

6.5.5. Emission ratios

Table 6.21. Agricultural Residue Burning: emission ratios.

Trace gases	IPCC Range	IPCC Default	Australia(1,2)	US
gas type				
CH_4	0.003 - 0.007	**0.005**	0.0035	0.003
CO	0.075 - 0.12	**0.1**	0.078	0.06
NMVOC			0.0091	
N_2O	0.005 - 0.009	**0.007**	0.0076	0.007
NOx	0.09 - 0.15	**0.12**	0.21	0.121

(1) Hurst, D.F. et al. (1994a).
(2) Hurst, D.F. et al. (1994b).

Only two countries provide country specific emission ratios. All other countries use the IPCC default ratios. The country specific emission ratios provided by the United States and Australia are well in line with the range presented in the IPCC Guidelines. Only the ratio for NO_x presented by Australia is higher. Australia also presents an emission ratio for NMVOCs, a ratio not given in the IPCC Guidelines.

Conclusions and Recommendations

For a large number of crops for which no default values are given in the IPCC Guidelines, new country specific data are presented in the national inventories reviewed. Most of these data seem applicable to other countries considering the comparability of these data, with the exception of the nitrogen-carbon ratios. For a few crops additional research is advised:

- Residue to crop ratio: cotton, sorghum, millet, sugar cane and less important maize and groundnut.
- Dry matter content: millet, sorghum, maize, potatoes and sugar beet.

Considering the differences in the provided N/C ratios, research in this area will increase the applicability and reliability of the IPCC defaults. Further it is advised to evaluate the research carried out in Uganda to determine if country specific circumstances or a systematic error are due to the observed differences. On the basis of this evaluation it can be decided if more extensive research should be carried out.

6.6. Nitrous oxide and non-methane volatile organic compound missions from agricultural soils

The methodology for estimating GHG emissions from agricultural soils is currently under development. Therefore only in the IPCC Guidelines Reference Manual is this subject addressed and not in the Workbook. Since some countries already reported on these emissions and provided emission factors based on country specific research it is addressed here. It is emphasised that the factors presented below originate from national emission inventories and form only a (small) part of information that is internationally available.

6.6.1. Nitrous oxide emissions due to fertilizer application

Two kinds of emission factors are applied in the national emission inventories i.e.:

1. Factors based on the amount of nitrogen fertilizers/manure applied (kg N_2O/kg N applied);
2. General emission factors per soil type, sometimes related to rainfall and drainage (kg N_2O/ha/yr).

Table 6.22. Nitrous oxide emission factors due to fertilizer application.

	IPCC	Australia (1,2)	Canada (3,4)	Japan (5)	Netherlands (6)	Germany (West- and Former GDR)	US (7)
		(tN_2O/tN applied)	(tN_2O/tN applied)	(tN_2O/tN applied)	(tN_2O-N/tN applied)	(tN_2O-N/tN applied)	(tN_2O-N/tN applied)
Agricultural soils				0.0027 (0.0006-0.0055)		0.032	0.0117
Ammonia	**0.0005 - 0.039**	0.0163	0.042				
Urea	**0.0005 - 0.039**	0.0011	0.048				
Ammonium nitrate	**0.0005 - 0.039**	0.0012					
Ammonium phosphate	**0.0005 - 0.039**	0.0012					
Ammonium sulfate	**0.0005 - 0.039**	0.0012	0.06				
Anhydrous			0.85				
Other N	**0.0005 - 0.039**	0.0003					
Manure		0.018 (2,8,9)					
Fertilizer							
Mineral soils					0.01		
Organic soils					0.02		
Manure							
Mineral soils					0.01		
Organic soils					0.02		
Injection into soils					0.02		

(1) Galbally (1985).
(2) Eichner, M.J. (1990).
(3) Eichner, M.J. (1990a).
(4) Collis (1992).
(5) Katsuyuki Minami (1987).
(6) Amstel, van A. (1995).
(7) CAST (1992).
(8) Bouwman, A.F. (1990).
(9) median value from the range 0.0178-0.0180.

The factors provided by Australia, Japan, the Netherlands, Germany and the United States are within the (broad) range given by IPCC. The Canadian factors are a bit higher. It is obvious that further (literature) research is needed before reliable default values can be given. The IPCC/OECD expert group is developing a methodology.

Table 6.23. Nitrous oxide emission factors per arable land type

Greece (1)	N_20 kg/ha/yr
Fertilizers applied:	
Permanent crops	2.30
Arable land crops	2.30
Market gardening	2.30
No fertlizers applied	
Permanent crops	0.20
Grassland	0.91
Fallows	1.28
Other arable land crops	0.20
New Zealand (2)	
Grasslands, well drained soils:	
N fixation (legume based)	1(3)
N fertilizer (400 kg/ha/year)	6(3)
Grasslands, poorly drained soils	2.0-3.0

(1) Mosier et al. (1991).
(2) R.A. Carren, 1991.
(3) Based on experiments (2 year study; dissertation).

New Zealand (1)	kg N_2O/ha/yr				
	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)
	300-599	600-799	800-999	1000-1049	>1500
Drainage Class					
Excessive ++	[-1.0-0.5]	[-1.0-1.0]	[-1.0-1.0]	[-1.0-1.0]	[-1.0-1.0]
Excessive +	[-1.0-0.5]	[-1.0-1.0]	0-2.0	0-2.0	0-2.0
Moderate	[-1.0-0.5]	0-2.0	0-2.0	1.0-3.0	1.0-3.0
Poor +	[-1.0-0.5]	1.0-3.0	1.0-3.0	1.0-3.0	2.0-4.0
Poor ++	[-1.0-0.5]	1.0-3.0	2.0-4.0	3.0-5.0	5.0-6.5

(1) R.A. Carren et al. (1993).

Greece and New Zealand provided emission factors per arable land type. The most elaborated emission factors are provided by New Zealand. The emission factors applied are related to rainfall and drainage class, which seems a good set up because rainfall and drainage class can act as general parameters for potential anaerobic conditions.

6.6.2. Non-methane volatile organic compound emission factors per soil type

Only Denmark provided emission factors for NMVOC emissions from soil. These emissions have not been taken into account in the IPCC Guidelines. No background information could be obtained.

Table 6.24. NMVOC emission factors per soil type.

	NMVOC
	kg/ha/year
Denmark (1)	
Cultivated land	0.393
Fertilized grassland	2.12
Other grassland	2.12

(1) A. Prieme and S. Christensen (1991).

7. LAND USE CHANGE AND FORESTRY

The estimation of greenhouse gas (GHG) emissions in this sector is rather complicated and requires a range of country specific data not only for the inventory year but also "historical" data. For many countries, certainly for developing countries, the latter is the main reason that emissions from these activities are considered very tentative. In this chapter we do not discuss the IPCC methodology or the IPCC forest classification system. Only the country specific information presented in the various inventories will be given, which simultaniously will give some information on the different classification systems/tree species in plantations used in the countries concerned. The following parameters will be discussed:

Dry matter in aboveground biomass (before and after clearing) (7.1);
Fraction of the biomass burned on-site (7.1);
Annual biomass growth (forests and village and farm trees) (7.2).

7.1. Dry matter in aboveground biomass in forests (before and after clearing) and fraction of biomass burned on-site

The methodology to estimate the GHG emissions due to forest clearing depends largely on country specific data of which the aboveground biomass of the area cleared is one of the most important. It is obvious that different types of forests will have a different amount of aboveground biomass. Although these data cannot be considered emission factors, they are so important for the estimation of GHG emissions in developing countries, that in the opinion of the authors it is worthwhile presenting the available information in this report.

In most countries some information on these variables is available, but is classified according to forests types which differ from country to country in very general terms without the necessary detail. The IPCC Guidelines provide a categorisation of forest types with related default values for the aboveground biomass given. The countries using the draft Guidelines were often under the impression that this categorisation was compulsory. In those inventories it was stated that the IPCC categorisation was too rigid and did not comply with local circumstances and data. In the final version of the IPCC Guidelines it is stated that countries can use their own classification system, but it is emphasized that the definitions of the different forest types should be given to make a comparision between countries possible. This forest classification is currently under review and expert groups are recommending a larger range of biomass default data be included in the IPCC Guidelines update.

Table 7.1 gives the data on dry matter in abovemground biomass and fraction of biomass burned on-site from the various inventories. The definitions of the forest types used are not given here, but are available from the references given. IPCC default data are not included in this table since no comparison is possible due to large differences in the classifications used.

Dry matter in aboveground biomass

No comparison between the data in Table 7.1 and the IPCC default values are given, as due to different classifications of forest types this would only be confusing. Only a few countries in each region report country specific data on biomass density: three in Africa, four in Latin America, and France, Australia and Kazakhstan. The data used in the Zimbabwean inventory are rather general.

Data from Ethiopia and Uganda are based on a national biomass study and give a good idea of the differences per forest type. With regard to the data from Uganda, it should be stressed that in the inventory data for only two forest types are given. The Ugandan National Biomass Study, however, uses a far more elaborate classification system (definitions of forest types are available) , but the results were not fully available at the time of the inventory.

In Latin America, Mexico and Venezuela present data per specific forest types (definitions of forest types available). Mexico uses a very elaborate classification system.

Very little data are provided on aboveground biomass after clearing. Only Uganda and Costa Rica present data. The Costa Rican data are based on expert judgement, while the Ugandan data are results of the National Biomass Study. (More data will be available from the final reports of this study).

The above data provided by Ethiopia, Uganda, and Mexico could be applicable for other countries in the region. This should be done with great caution by local forestry experts by using the same well defined classification systems and by taking differences in local circumstances into consideration.

Fraction of biomass burned on-site

With regard to the fraction of biomass burned on-site very little information is available; most countries use "guestimates". It is clear, however that the IPCC default value of 50% is considered far too high by the experts in most countries. This difference might be due to the different practises in forest clearing between Latin America (Brazil) and other regions.

Table 7.1. Land Use Change and Forestry; dry matter in above ground biomass and fraction of biomass burned on-site: Africa.

Forest category	**Biomass before clearing**	**Biomass after clearing**	**Fraction of biomass burned onsite**
	(t dm/ha)	(t dm/ha)	
AFRICA			
Ethiopia (1,2)			
Dense coniferous forest	243.5		0.23
Dense mixed high forest	243.5		0.23
Disturbed high forest	243.5		0.23
Dense woodland	85.8		0.23
Open woodland	85.8		0.23
Dense bushland	31.5		0.23
Riperian vegetation	65.7		0.23
Lowland bamboo forest	31.5		0.23
Open bushland	31.5		0.23
Afro-Alpine vegetatation	3.9		0.23
Malawi			
Tropical primary forest, moist			0.1
Tropical primary forest, dry			0.1
Uganda (3)			
Tropical high forest	202	59.46	
Tropical open forest	32	10	
Zimbabwe (4)			
Woodland	45		
Bushland	35		
Closed forest	260		
Plantations	150		

(1) National biomass data for leap priliminary report, EEA, march 1992 (no further details available).
(2) based on local calculations.
(3) National Biomass Study.
(4) Southern Centre (1993).

Table 7.2. Land Use Change and Forestry; dry matter in above ground biomass and fraction of biomass burned on-site: Latin America, Eastern and Western Europe, Oceania.

Forest category	Biomass before clearing	Biomass after clearing	Fraction of biomass burned on-site
	(t dm/ha)	(t dm/ha)	
LATIN AMERICA			
Costa Rica (1)			
Tropical rainforest	155.1	15-20	
Mexico (2)			
Temperate broadleaf undisturbed	64		
Temperate broadleaf logged	46		
Temperate conifer undisturbed	90		
Temperate conifer logged	65		
Tropical evergreen undisturbed	240		
Tropical evergreen logged	240		
Tropical deciduous undisturbed	85		
Tropical deciduous logged	85		
Tropical open forest productive	37		
Tropical open forest unproductive	25		
Peru (3)			
Tropical, closed forest			
Broadleaf, undisturbed	275.2		
Venezuela (4,5)			
Closed forest I	400		
Closed forest II	240		
Closed forest III	140		
Open forest	55		
CENTRAL AND EASTERN EUROPE			
Kazakhstan			
Abies Sibirica	147		0.3
Larix Sibirica	178		0.3
Open forest	160		
Woodland and scrub	60		
WESTERN EUROPE			
France			
Forests (6)	47		0.2
OCEANIA			
Australia (7,8)			
Tropical and temperate closed forest	320		
Open forest	160		
Woodland and scrub	60		

(1) Brown, S. and A. Lugo (1984).
(2) Masera et al. (1992) and Forestal (1992).
(3) Local studies.
(4) Brown (1989).
(5) Veillon (1976).
(6) SCEES Enquete TERUTI (1992).
(7) Grierson et al. (1992).
(8) Gifford et al. (1992).

7.2. Annual biomass growth rate

For estimation of the amount of carbon sequestered by forests and village trees etc., the annual biomass growth rate is an important factor. Several countries provide data per forest type or tree species.

Table 7.3. Land Use Change and Forestry; annual biomass growth rate: Africa, Asia.

	Annual biomass growth rate	**Annual biomass growth rate**
	(t dm/ha)	(t dm/1000 trees)
AFRICA		
Zimbabwe (1)		
Woodland	7.5	
Bushland	4.0	
Closed forest	7.5	
Plantations		
Savanna		
Senegal (2)		
Acacia spp	2.75 **(IPCC 15.0)**	
Eucalyptus spp	3.25 **(IPCC 14.5)**	
Tectona grandis	3.25 **(IPCC 8.0)**	
Mixed hardwood	2.75 **(IPCC 6.8)**	
Logged forest-broadleaf	2.75	
Reforestation programmes		2.875
Village trees		2.875
Tanzania		
Mixed softwood plantations	11.0	
Mixed hardwood plantations	4.9	
Managed forest - mangrove	2.0	
Managed forest - seasonal	7.0	
Managed forest - woody savanna	4.0	
Village woodlots	5.0	
Tree planting programmes		4.8
ASIA		
Bangladesh		
Mangrove forest (tropical evergreen)		
Sundarbans	14.0	
Coastal	14.0	
Hill forest (trop. moist evergreen)		
Govt. managed forest	12.5	
Unclassed forest	6.8	
Plainland forest (tropical moist, deciduous)	14.5	
Village forest (Tropical mixed)	10.0	
Mongolia (3,4)		
Boreal	0.50	
Trees in afforestation programmes	0.10	

(1) Southern Centre 1993.

(2) Results of plantations and reforestation programmes.

(3) Institute of Forestry and Wildlife, Ulaanbaatar,Mongolia.

(4) Publication in Russian.

Table 7.4. Land Use Change and Forestry; annual biomass growth rate: Latin America, Central and Eastern Europe.

	Annual biomass growth rate	**Annual biomass growth rate**
	(t dm/ha)	(t dm/1000 trees)
LATIN AMERICA		
Venezuela (1)		
Average	3.30	
Pinus Caribaea	6.40 (IPCC 10.0)	
CENTRAL AND EASTERN EUROPE		
Bulgaria		
Pinus Sylvestris	2.6	
Pinus Nigra	1.4	
Picea Abies	1.5	
Abies Alba	1.7	
Other coniferous	1.9	
Quercus spp.	1.1	
Fagus Sylvatica	1.6	
Carpinus Betulus	2.3	
Robinia Pseudoaccacia	2.5	
Tilia spp.	5.0	
Populus spp.	8.3	
Other deciduous	1.7	
Kazakhstan		
Boreal forests, conifer		
Pinus Silvestris	1.1	
Picea Abovata	1.64	
Abies Sibirica	1.1	
Larix Sibirica	1.45	
Pinus Sibirica	1.1	
Juiperus	0.32	
Boreal forests, hard leafed		
Quercus Robur	0.94	
Ash-tree	0.7	
Aser	0.5	
Ulmus Laevis	0.5	
Haloxylon Aphyilum	0.2	
Boreal forests, soft leafed		
Betula Pendula	1.4	
Populus Tremula	1.32	
Alnus	1.24	
Populus	3.37	
Tree-willow	2.93	
Other tree types	1.0	

(1) Plonczak, M. (1993).

Table 7.5. Land Use Change and Forestry; annual biomass growth rate: Oceania, North America.

	Annual biomass growth rate
	(t dm/ha)
NORTH AMERICA	
Canada (1.2.3.4)	1.50
OCEANIA	
Australia (5.6)	(tC/ha/y)
Rainforest and tropical	2
Eucalypt or paperbark	2
Eucalypt I	1
Eucalypt II	0.5
Eucalypt III	0.75

(1) overall average of range 0.2-5.7.
(2) Kurtz et al. (1991).
(3) Kurtz et al. (1992).
(4) Apps and Kurz (1991).
(5) Grierson et al. (1992).
(6) Gifford et al. (1992).

Most data provided on annual biomass growth in the inventories are for plantations and specific growth rates per species are given. Differences between growth rates of the same species are due to local circumstances (climate, water availability, soil fertility etc). Comparison with the IPCC defaults is possible for the species Acacia spp, Eucalyptus spp and Tectona grandis in Senegal, Pinus caribaea in Venezuela. In all cases, the IPCC defaults are far higher then the country specific growth rates.

Very little information could be found on the growth rates of village and farm trees. More information on these growth rates is necessary together with an inventory of the number of these trees, since they form an important source for local woodfuel.

Growth rates for several species not given in the IPCC Guidelines are provided by a few national inventories, but further evaluation of these data is required for the improvement of the IPCC default data. The data as presented in the above table would potentially be applicable to other countries in the same region with similar climatic and soil circumstances.

7.3. Conclusions and Recommendations

This chapter on Land Use Change and Forestry is short compared to others in this report. This does not imply that this section is less important. It is due to the lack of data and highlights the urgent need for targeted research.

It is clear from the inventories that in most developing countries the data on the aboveground biomass per forest type, before and after clearing, are lacking. The use of the IPCC default data, as emphasized in the Guidelines, can give only tentative estimates of emissions from this source. For countries where emissions from this source are relatively important, i.e. most developing countries, research in this area is essential for a reliable emission inventory. Four categories of longitudinal data are of the utmost importance:

Area per forest type;

Biomass and biomass increment per forest type;

Number of farm and village trees;

Biomass and biomass increment of farm and village trees.

National biomass studies form a very valuable source for this kind of data, as is shown in the inventories by e.g. Ethiopia, Uganda, and Mexico. Since this type of study is in general not initiated by climate studies, it would be advisable to collaborate with the other users of data from national biomass studies (forestry-, energy (woodfuel)-, natural resources- and land use planning departments) in order to stress the importance at national and international level.

8. WASTE

8.1. Methane emissions from landfills and open dumps

The simple Tier 1 methodology for estimating methane emissions from land disposal of solid wastes uses four variables i.e.:

- Amount of municipal solid waste (MSW) generated in total or per capita
- Fraction MSW landfilled or total amount of MSW landfilled
- Fraction degradable organic carbon (DOC)
- Fraction DOC that actually degrades
- Fraction of methane in landfill gas

The IPCC Guidelines provide for a number of OECD countries defaults for waste generation per capita and for fraction MSW landfilled, while regional defaults are given for the use by non-OECD countries. Table 8.1. gives the country specific information from the respective inventories.

Table 8.1. Waste: waste generation, fraction landfilled, fraction DOC, fraction DOC actually degrading, fraction CH_4 in biogas; Africa and Asia.

	Waste Generation rate kg/cap/day	**Fraction MSW Landfilled**	**Fraction DOC**	**Fraction DOC actually degrading**	**Fraction CH_4 in biogas**
Africa					
IPCC	**0.5**	**0.80**	**0.15**	**0.77**	**0.5**
Gambia	0.62(1)				
Malawi		0.15-0.53(2)			
Blantyre		0.53			
Lilongwe		0.21			
Mzuzu		0.39			
Zomba		0.15			
Mauritius	0.6(3)	0.2			
Morocco (4)	0.6(1)	0.8		0.67	
Senegal					
Mun. waste	0.39	0.7		0.582	
Ind. waste	0.24		0.06	0.33	
Tanzania (1)					
Household waste	0.38	0.3-0.13 (5)			
Market waste	0.17				
Other waste	0.1				
Total	0.65				
Uganda (Kampala)					
Domestic waste	0.8	0.25 (6)			
Market waste	0.05				
Industrial waste	0.2				
Street sweepings	0.1				
Zimbabwe			0.3465		
Asia					
IPCC	**0.5**	**0.80**	**0.15**	**0.77**	**0.5**
Bangladesh	0.4 (1)	0.26(7)	0.26(8)		
Sri Lanka	0.25 (9)				

(1) Urban population.
(2) Chilemba and Kazombo (1994).
(3) Scott Wilson Kirkpatrick (1993).
(4) Darley (1994).
(5) Fraction disposed at dumpsites - fraction landfilled.
(6) Fraction collected and dumped at open dumpsites.
(7) Dhaka City Corporation.
(8) Ahmed (1994).
(9) population greater Colombo.

Table 8.2. Waste: waste generation, fraction landfilled, fraction DOC, fraction DOC actually degrading, fraction CH_4 in biogas; Latin America, North America, Central and Eastern Europe, Western Europe and Oceania.

	Waste generation rate kg/cap/day	Fraction MSW landfilled	Fraction DOC	Fraction DOC actually degrading	Fraction CH_4 in biogas
Latin America					
IPCC	**0.5**	**0.80**	**0.15**	**0.77**	**0.5**
Bolivia	0.4	0.25			
Costa Rica	0.55 (1)				
Ecuador			0.18		
Mexico					
Mexico City	0.96	0.65	0.19	0.75	
Rest of Mexico	0.62	0.22	0.15	0.75	
Peru	0.54 (1,2)	0.35-0.71			
Venezuela	0.7 - 1.2	0.5			
North America					
IPCC	**1.8**	**0.91**	**0.22**	**0.77**	**0.5**
Canada (3,4,5)	1.75				
Central & E. Europe					
IPCC	**0.6**	**0.85**	**0.175**	**0.77**	**0.5**
Bulgaria	2.2-2.6				
Czech Republic	1.29 (6)	0.96 (6,7)			0.62 (8)
Russian Fed. (9)					0.55 (10)
Western Europe					
IPCC	**0.8**	**0.71**	**0.19**	**0.77**	**0.5**
Greece	1.0	0.5(11)			
Japan			0.161(12)	0.50(13)	0.55(13)
The Netherlands (14,15,16,17,18,19)			0.17	0.80	
Oceania					
IPCC	**0.8**	**0.71**	**0.19**	**0.77**	**0.5**
New Zealand (20)					0.55

(1) Based on local study: Estudios CEPIS-OPS y/o Estudio Sectorial de Residuos Solidos del Peru. Ditesa/OPS.
(2) Urban population.
(3) Canada has used the Scholl Canyon model to estimate the methane emissions.
(4) Levelton, B.H. and Associates (1991).
(5) McGuinn, Y.C. (1988).
(6) Ministry of the Environment (1993).
(7) Municipal waste. Including industrial waste: 1.21.
(8) Straka (1994).
(9) Figures on MSW landfilled in Russia differed 16% with figures calculated using IPCC defaults.
(10) Research carried out in the late '80s found that 1 ton MSW emitted 200 m3 biogas (in active period 10-20 year) for the area USSR, former GDR, Poland, Bulgaria, and former Czechoslovakia.
(11) Fraction dumped in open sites: 0.35.
(12) Study conducted by the Ministry of Health and Welfare.
(13) Watanabe et al. (1992).
(14) Verschut et al. (1991).

(15) Van den Born et al. (1991).
(16) Scheepers (1991).
(17) RIVM (1992).
(18) Novem (1991).
(19) Oonk (1993).
(20) Royds Consulting Ltd. (1994).

Developing countries

Some of the data in the above tables regarding waste generation rates, fraction collected and fraction landfilled/dumped are calculated on the basis of the amount landfilled or are not used in the actual emission calculations. The calculation of methane emissions from landfills/open dumps in developing countries is very often based on the amount of MSW landfilled/dumped. Consistent data on waste generation rates, fraction collected and fraction landfilled/dumped are rarely available. In most cases only statistics on the amount of waste landfilled/dumped are easily available and more reliable.

Developing countries often make a distinction between (large) urban centres and smaller cities and rural areas. Collection of MSW is only taking place in urban centres. Even in large urban centres only one or a few sanitary landfills, if any, exist. This is shown in the above tables in the country specific data on fraction landfilled. In most cases these data are considerably lower then the rather optimistic IPCC default of 0.8.

The IPCC default waste generation rates for developing countries seem more or less in line with the country specific rates for *urban* areas, but are not applicable for the country as a whole. Modification of the IPCC defaults for waste generation rate and fraction landfilled seems necessary.

Most countries use the IPCC defaults for the fraction DOC and the fraction DOC which actually degrades. Country specific fractions provided by countries in Latin America are mostly consistent with the IPCC default, while factors provided by countries in Africa and Asia differ significantly.

Bangladesh provided a DOC fraction of 0.26, but noted that some literature sources (DCC, 1992) reported a far higher fraction of 70%. This high fraction was explained by the fact that recyclable materials, such as plastics and metals, are picked up by groups of waste scavengers. This especially takes place if a long time gap exists between waste collection and land filling.

Countries in Central and Eastern Europe

Regarding countries in Central and Eastern Europe, the IPCC waste generation default is very low compared with the country specific data of the two countries in this region.

8.2. Methane emissions from waste water treatment

8.2.1. Methane emissions from municipal waste water treatment

The methodology as described in the IPCC Guidelines is still under development. The methodology is based on the amount of organic material in the waste stream. This is indicated by the biochemical oxygen demand (BOD) of the waste water. Very few countries give GHG emission estimates from this source. Most countries applied the IPCC default values and only a few countries provided new data/emission factors.

Table 8.3. Municipal waste water treatment.

	BOD generation rate		**m3 CH_4/m3 sewage**	**Fraction waste water anaerobically treated**
	kg/person/day	**kg CH_4/kg BOD**		
IPCC-Africa	**0.037**			
Ethiopia	0.063			
Morocco	0.036(0.026 - 0.046)			
Tanzania				
Pit latrines		0.023		
Stabilisation ponds		0.077		
Septic tanks		0.086		
Zimbabwe			0.0184	
IPCC Europe				**0.15**
Bulgaria				0.5

As clearly shown in the above table very little new information is provided in the national emission inventories. The BOD generation rate applied by Morocco is comparable with the IPCC default. Ethiopia applies a BOD generation rate almost twice the default.

The emission factors for pit latrines, stabilisation ponds and septic tanks provided by Tanzania are based on actual measurements in a small research project (very few measurements, no full description of the procedures etc.). Evaluation of this research and further research is necessary before these figures can be used by other countries. It is clear that more country specific information, especially from developing countries, and research is needed to improve the default values.

8.2.2. Methane emissions from industrial waste water treatment

Only four countries provide country specific data with regard to the methane emissions from industrial waste water treatment.

The country specific data is only for the BOD generation rates per industrial sector. Default emission factors (kg CH_4/BOD) are applied to estimate the methane emission. Further research into this default emission factor is recommended.

Countries provide BOD generation rates for 16 additional categories not yet taken into account in the IPCC methodology. The IPCC defaults seem to be rather high compared to some country specific factors.

Table 8.4. Industrial waste water treatment

	IPCC	Peru	Mauritius	Senegal (6)	Russian Fed.
Industry	BOD kg/l	BOD kg/l	BOD kg/l	BOD kg/l	BOD kg/l
Beer	**0.085**	0.0018(1)			0.001
Cane factories			0.000074		
Canneries					0.001
Coffee & other industries		0.0015(2)			
Tanneries		0.0024(1)			
Dye houses			0.000139		
Fertilizer	**0.001**			0.002	
Fish processing		0.0027(1)			
Food and beverage - other	**0.035**			0.035	
Fuel production					0.002
Grains		0.0300(3)			
Heat & power production					0.001
Iron & steel	**0.001**			0.001	
Lacteal products		0.0050(4)			
Light industries					0.001
Meat packing	**0.02**	0.0017(5)		0.02	
Oil & grease		0.0190(2)			
Oil refinery					0.001
Rayon		0.0002(4)			
Rubber	**0.001**			0.001	
Slaughterhouses		0.0018(1)			
Soft drinks		0.0016(1)			

(1) Service for drinking water and waste water. Lima, Peru.

(2) Average default.

(3) Expert judgemen.

(4) National Water Regulation.

(5) Air quality Technologies, 1982.

(6) Based on information from industries.

8.3. GHG emissions from waste incineration

In the IPCC Guidelines no methodology is given for the estimation of GHG emissions from waste incineration. A few OECD countries, however, incorporated emissions from this source into the national emission inventories.

Table 8.5. CO_2, CH_4, N_2O, NO_x, CO and NMVOC emissions due to waste incineration.

	kg CO_2/t waste	**g CH_4/t waste**	**g N_2O/t waste**	**g NO_x/t waste**	**g CO/t waste**	**g NMVOC/t waste**
Japan (1)						
Municipal waste						
Facility type						
Continuous		29.7 (2.15 - 114)	144 (28.7-293)			
Semi-continuous		617 (258 - 975)	128 (97.4-145)			
Batch		742 (41 - 2310)	115 (58.5-187)			
Industrial waste		680 (2)	122 (2)			
Netherlands	260 (3,4,5)		12.7 (6)			
Canada						
Municipal refuse	900					
Sewage sludge	660					
Industrial	900					
Wood waste	1500					
United Kingdom (7)						
Domestic	733	9.38		1500	17500	740.6 (8)
Industrial	711	93.75		1000	10000	7406 (9)

(1) Institute of Public Health, Ministry of Health and Welfare (1993). (Emission factors based on measurements at various facilities)
(2) Based on the average emission factor for municipal waste for semi continuous and batch facilities
(3) The estimation of CO_2 is based on analysis of waste streams and the amount of fossil carbon in these waste streams
(4) The Netherlands assumes that 27% of the carbon in municipal waste is of fossil origin.
(5) De Jager and Block (1993).
(6) Spoelstra (1993).
(7) USEPA (1977).
(8) Passant (1993).

The above factors can be useful to the IPCC/OECD expert group in developing a methodology for estimating emissions from this source. As far as the carbon dioxide emissions are concerned, it is stressed that, in the present methodology, only carbon dioxide emissions originating from fossil carbon should be estimated.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. Emission factors in national GHG emission inventories and National Communications

This report presents an overview of original GHG emission factors as provided in national GHG emission inventories and/or National Communications of the UNFCCC. Although a lot of effort has been put into this exercise, it is acknowledged that this review is neither complete nor exhaustive.

It was found that the information on GHG emission factors, given in the national GHG inventories and/or National Communications, is in most cases insufficient. In many cases, it is not specified if the emission factors are IPCC defaults, from international literature, or are original country/region specific emission factors based on national/regional research. Only by comparing these emission factors with the IPCC defaults and other literature sources, could the original emission factors be identified.

National GHG emission inventories included in National Communications often do not provide sufficient information regarding emission factors. Most National Communications provide either total GHG emission estimates, or, as a technical annex, the IPCC minimum data tables. Only in some cases were background documents provided.

Very often literature references are lacking or incomplete.

Although correspondance was sent to the national contact points requesting information, this did not produce any response in most cases. Some national contact points stated that the national GHG emission inventory was compiled based on contributions from several national institutes and that obtaining additional information would require a significant amount of time and effort since the researchers in these institutes would have to be contacted. In some cases, the background literature was in the local language and therefore inaccessible within the timeframe and budget of this study.

The lack of information on emission factors is partly due to the IPCC reporting instructions. The standard reporting tables include **aggregated** emission factors. The underlying specific (non-aggregated) emission factors are not included in the standard reporting tables. The aggregated emission factors reported are not applicable in other inventories since they depend on national circumstances that differ from country to country.

Due to the above reasons it was impossible to evaluate the reliability and applicability of the country/region specific GHG emission factors presented in this study. Therefore, incorporation of original emission factors into the IPCC Guidelines requires additional research and/or verification.

The expert groups currently improving the IPCC Guidelines will have to invest a significant amount of effort into obtaining the necessary background information to be able to review/evaluate these emission factors.

This leads us to the following recommendations regarding reporting of national GHG inventories:

- The standard reporting tables in the IPCC Reporting Instructions should be revised. Instead of aggregated emission factors, all (non-aggregated) emission factors used should be reported.
- All GHG emission factors used in a national GHG inventory should be fully referenced.
- National GHG emission inventories should either contain all background literature as annexes, or, at least, all background literature should be available at the national contact point.
- National GHG emission inventories should contain an additional chapter in which all new country/region specific (non-aggregated) emission factors used are summarized and discussed.

As a matter of priority, these recommendations should be incorporated into the current revisions of the IPCC Guidelines. This will facilitate future technical review of GHG emission inventories in a cost effective manner.

9.2. Energy

For most countries, the reliability of carbon dioxide emission estimates hinges upon data quality and upon the level of detail of the statistics of trade and production of fossil fuels. The uncertainties of carbon contents of fuels appear to be relatively low.

Only a few OECD countries provide new emission factors for non-CO_2 emissions in the energy sector.

Poland is the only non-OECD country that provides new non-CO_2 emission factors in this sector. Unfortunately the background literature is in Polish and therefore it was not possible to evaluate these factors within the timeframe and budget of this study.

Research
The fact that neither developing countries nor countries with economies in transition (except Poland) provide new emission factors highlights the need for country/region specific emission factor research in this area.

For most developing countries the need for country specific emission factors should focus on non-CO_2 emissions from the use of traditional biomass burned for energy, since this is by far the major source in these countries.

9.3. Industrial processes

Developing country inventories did not provide any new emission factors in this section. The exception is Peru, which provided emission factors for aluminium production and for a wide range of inorganic chemicals.

Poland, a country with an economy in transition, provides a large number of country specific emission factors, for all GHG and for detailed subcategories of industrial processes. These GHG emission factors are based mainly on measurements and research in Polish industries. Since the background literature was only available in Polish, no further review/evaluation of these emission factors took place. However, the Polish emission factors may be relevant for other Central and Eastern European countries, and it is therefore recommended that a detailed review study of the Polish emission factors be considered.

With regard to NMVOC emission factors it was shown in the Polish emission inventory that the Polish emission factors (based on measurements in Polish industries) are significantly higher than the CORINAIR emission factors. It is assumed that the CORINAIR emission factors relate to more up-to-date technologies and industrial installations which are in a better technical state. If so, the Polish emission factors would be more applicable to Central and Eastern European Countries than the factors supplied by CORINAIR.

As far as OECD countries are concerned, only Germany provides emission factors (for West Germany as well as for the former GDR). For most categories, these emission factors are identical, indicating that Germany does not assume a major difference between production processes/circumstances in West Germany and the former GDR.

Only for a few categories could emission factors from OECD countries and Central and Eastern European countries be compared. In those cases, the emission factors differed substantially. These categories are: soda production (CO_2 emissions), vinyl chloride (NMVOC emissions) and PVC (NMVOC emissions).

In general, it can be concluded that national emission inventories provide a large number of emission factors for which no IPCC default factors were provided. A review of the underlying studies is needed to evaluate these emission factors by IPCC expert groups for possible inclusion in the IPCC methodology, after IPCC review and approval.

Research
The IPCC Guidelines do not address the sector, Industrial Processes in detail. Further development of the methodology is on-going. Since not all literature sources and data from other emission inventory programmes (CORINAIR/EMEP, US EPA, TNO) have been reviewed in this study, it is not possible to give specific recommendations for targeted research in this field. This review is currently under way in the Phase II inventory programme.

Further research into the applicability of the Polish emission factors in other Central and Eastern European countries and the differences between these and the CORINAIR emission factors is recommended.

The differences observed in comparable emission factors between OECD and Central and Eastern European Countries suggests that differences might also exist between developing countries and OECD countries. Additional research on GHG emission factors for major industries in developing countries is recommended.

9.4. Solvents

Developing country inventories did not provide any new emission factors in this section. In general, it seems likely that the emission factors for (industrial) use of solvents will be higher in Central and Eastern Europe than in OECD countries due to the use of recycling technologies in the OECD countries

Emission factors provided by CORINAIR, Poland and the Czech Republic are more or less comparable. A tentative conclusion would be that these factors are applicable in other countries in Central and Eastern Europe.

In general, it can be concluded that a number of emission factors have been provided in national emission inventories for which no IPCC default factors were provided. Since background studies were not available, only available in non-UN languages, or literature references were not provided, it has not been possible to review these factors for technical merit, scientific value and/or the application possibilities in other regions.

Research
The IPCC Guidelines do not address the section on Solvent and Other Product Use in detail. Literature sources and other emission inventory programmes have still to be reviewed for emission factors.

Considering the above, it is not possible to give specific recommendations for targeted research in this field.

However, a comparison of emission factors between OECD and Central and Eastern European Countries suggests that there is also a significant difference between developing countries and OECD countries. Therefore it is recommended that research on GHG emission factors for major categories in this section in developing countries be conducted.

To ensure comparability, it is recommended that the IPCC Guidelines provide guidance on the units of the emission factors and the definition of categories.

9.5. Agriculture

9.5.1 Enteric fermentation

Many developing countries provide either new emission factors or calculated country specific emission factors using the Tier 2 approach.

Emission factors are provided for categories not involved in the IPCC Guidelines, including alpacas, deer, goats, ostriches, poultry and turkeys.

In many cases, country specific emission factors for cattle differ significantly from the corresponding IPCC default values. This strengthens the recommendation, as stated in the IPCC Guidelines, that countries with a significant number of cattle should use the Tier 2 approach using country specific data (milk production, weight, feed intake etc.).

Research

Given the large differences between emission factors of the Tier 2 methodology, it is recommended that this approach be tested in other regions.

For those countries with a significant number of cattle, which lack data for the Tier 2 approach, it is strongly recommended that additional research be conducted.

9.5.2. Manure

As stated in the section on enteric fermentation, local circumstances/practices may cause considerable deviation from the IPCC default emission factors. Those countries for which emissions from this sector are significant should use a detailed method where possible with local data, as recommended in all areas of the IPCC Guidelines.

Research

Targeted research in this field could be useful for some regions with a focus on enteric fermentation, since the latter is a far more important source of methane emissions.

9.5.3. Rice cultivation

Almost all countries use the IPCC default emission factors to calculate the emissions from rice cultivation. The emission factor provided in the Australian emission inventory differs significantly from the IPCC default.

Research

The IPCC methodology and default factors are mainly based on (extensive) research in Asian countries. Since almost all countries use the IPCC default emission factors and Australian research leads to a significantly different emission factor it is recommended that research on methane emission factors for rice cultivation for those countries with a substantial rice production be conducted. Preliminary results show that the IPCC emission factors are relatively high for some countries.

9.5.4. Savanna burning

Most countries that report emissions from this source state that most of the data (area burned annually, aboveground biomass density, fraction of biomass actually burned and fraction of aboveground biomass that is living) needed to calculate the emissons are not available or highly uncertain. Subsequently, GHG emission estimates from this source can only be considered tentative.

The Australian emission inventory states that savanna burning has taken place for thousands of years and is therefore not anthropogenic. Other countries hold this view noting that a distinction between fires due to human activities and natural causes is often not possible.

Research

If emissions from savanna burning (and other types of burning) are defined as anthropogenic, it is a highly recommended area for targeted research. Emissions from this source form a substantial part of total GHG emissions in a large number of developing countries. The research should aim at determining (with greater precision) the area burned annually and the biomass density for each savanna type.

9.5.5 Agricultural residues

Developing countries provide new, country specific data for a large number of crops for which no default values are given in the IPCC Guidelines. Most of these data seem applicable to other countries considering the comparability of these data, with the exception of the nitrogen-carbon ratios.

Research

For a few crops research is advised:

- Residue to crop ratio:
  cotton, sorghum, millet, sugar cane and of lesser importance maize and groundnuts.

- Dry matter content:
  millet, sorghum, maize, potatoes and sugar beet.

Considering the differences in the provided N/C ratios, research in this area will increase the applicability and reliability of the IPCC defaults. Further it is recommended that an evaluation be carried out in Uganda to determine if country specific circumstances or systematic errors are due to the observed differences with IPCC default values and values provided by other countries. On the basis of this evaluation it can be decided if more extensive research should be carried out.

9.6. Land use change and Forestry

The inventories reviewed indicate that in most developing countries the necessary detail in country specific data on the aboveground biomass (per forest type, before and after clearing) are lacking. As emphasized in the IPCC Guidelines, the use of the IPCC default values can only give tentative estimates of emissions from this source.

Research

For countries where emissions from this source are relatively important, i.e. most developing countries, research in this area is essential for a reliable emission inventory.
Four kinds of longitudinal data are of the utmost importance:

Area per forest type;
Biomass and biomass increment per forest type;
Number of farm and village trees;
Biomass and biomass increment of farm and village trees.

National biomass studies form a very valuable source for this kind of data, as is shown in the inventories by Ethiopia, Uganda, and Mexico. Since these studies are in general not initiated by climate studies, it seems advisable to collaborate with the other users of data from national biomass studies (forestry-, energy (woodfuel)-, natural resources- and land use planning departments).

9.7. Waste

9.7.1. Landfills

In most cases, developing countries base the calculation of emissions from landfills on statistics covering the amount of waste landfilled/dumped. Consistent data on waste generation rates, fraction collected and fraction landfilled/dumped are rarely available.

For developing countries, the IPCC default waste generation rates seem more or less in line with the country specific rates for *urban* areas, but are not applicable for the country as a whole.

Research

Research is recommended on country specific values for the following:

- the waste generation rate in developing countries and Central and Eastern European countries. Values for developing countries should take account of the differences between urban and rural areas;
- the fraction landfilled in developing countries. The IPCC default seems to be rather high;
- the fraction DOC of waste landfilled in developing countries. This fraction depends on e.g. activities from waste scavengers.

9.7.2. Municipal and industrial waste water

Only a few countries provided country/region specific emission factors for these sources. The IPCC default emission factors for industrial waste water seem to be rather high if compared with country specific emission factors. BOD generation rates are provided for 16 industrial categories not yet included in the IPCC methodology.

Research

Research is needed on country specific information especially from developing countries. It is recommended that research carried out by Tanzania on pit latrines, stabilisation ponds and septic tanks be evaluated. The BOD generation rates provided for additional industrial categories should be evaluated.

9.8. Concluding remarks

In the sections above recommendations for research have been given for almost all sectors in the IPCC Guidelines. Within the timeframe and budget of this study it was not possible to prioritize these research needs. Since the recommended research is categorised by source the prioritisation should be based on the relative importance of each source. In general terms the important considerations for such a prioritisation should be:

- Importance of an emission from a source relative to the total emission in a country/region (using global warming potential (GWP));
- Uncertainty of the estimated emission (based on the uncertainty in the underlying data).

An additional consideration could be the applicability of the research results in other studies (mitigation, vulnerability, future emissions).

However, a very rough prioritisation in sectors can be given on the basis of the documents in sectors reviewed. For most developing countries the main sectors in which further research is needed are land use change and agriculture, for countries with economies in transition the main sectors are energy and industry.

Many of the methodological issues discussed above are being addressed under Phase II of the IPCC Inventory Programme. For information, please contact:

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Michael Short
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Re.: **Report 'Contry/Region-specific emission factors in national greenhouse gas inventories'**

Dear Dr. Short,

On behalf of Jan Feenstra I herewith send you the corrected version of the above mentioned report. I also enclose files of the report in Word 6.0 (file E96-08.doc contains the total report, the other files contain the various chapters).

Kind regards,

Dita Smit

UNEP

United Nations
Environment Programme

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Development Programme

World Bank