LOW EMISSION CAPACITY BUILDING PROGRAMME

UNDP

GREEN HOUSE GAS INVENTORY MANUAL FOR UGANDA

VERSION 1

MINISTRY OF WATER AND ENVIRONMENT

CLIMATE CHANGE DEPARTMENT

FOR GOD AND MY COUNTRY

THE REPUBLIC OF UGANDA

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EXECUTIVE SUMMARY

A global response to greenhouse gas (GHG) emission and global warming was resulted into formation of the United Nations Framework Convention on Climate Change (UNFCCC) (March 1994) and there after the Kyoto Protocol (in February 2005). The UNFCCC sets an overall framework for intergovernmental efforts to tackle the challenge posed by global climate change.

The first commitment period of this protocol started in 2008 and ended in 2012. Amendment to the Kyoto protocol took place on 8 December 2012 in Doha, Qatar with Annex I Parties to the Kyoto Protocol agreeing to take on commitments in a second commitment period from 1 January 2013 to 31 December 2020. The level of commitment to the reduction of GHG emissions was set to least 18 percent below 1990 levels plus amendments to several articles that were specifically addressing issues limited to the first commitment period.

Non-Annex I Parties that are signatory to the protocol are not obligated to emission reductions but are required to submit information on emissions and removals of greenhouse gases (GHGs) and details of the activities a Party has undertaken to implement the Convention on a regular basis through National communications and biannual reports to UNFCCC .

Being a party to the UNFCCC, Uganda is required to develop, periodically update and publish its inventory of the country's GHG emissions. These reports in addition serve as a blueprint of the plans and strategies for Uganda in addressing the impacts of climate change. Like many developing countries, Uganda's national inventory system is not yet well developed. However, a number of approaches are being initiated to address this challenge and one of them is the implementation of the Low Emission Capacity Building Project (LEB).

One of the activities that the LEB project has undertaken is the establishment and institutionalizing of the national GHG inventory system. This system incorporates all of the elements needed to estimate report and archive GHG emissions and sinks, including the institutional, legal, communication and procedural arrangements. Having a system in place means that the country can develop a high quality inventory at regular intervals; annually or every three to four years. The institutional arrangements within the country are established and

made known, legal support is also put in place and all the sources of data (activity data, emission factors, and background information) for compiling the national GHG inventories identified, documented, appropriately archived and made accessible through agreed upon procedures.

This manual is part of the process to make Uganda GHG team develop capacity for sustainable GHG inventory management system that will adequately meet country's commitments as party to the UNFCCC. The manual addresses various inventory process steps including background to requirements to key elements that have to be addressed so as to conform with an acceptable GHG reporting.

One of the objectives of the manual is help users appreciate the approach to GHG inventory as presented in the 2006 guidelines. In the same vein, the manual is intended enable the users realize the functionality of the IPCC (2006) Inventory Software and in context of the 2006 guidelines.

ACKNOWOLEDGEMENT

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Special thanks go to all those who provided valuable comments especially members of the climate change technical committee. The comments and suggestions that were provided by the reviewer of this document, Dr. Carlos López, were so valuable and we extend our most sincere appreciation to him.

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List of Acrynoms

Acronym	Full Name
AB	Above Ground
AD	Activity Data
AFOLU	Agriculture Forestry and Other Land Use
BEF	Biomass Expansion Factor
BEST	Biomass Energy Strategy
BG	Below Ground
C	Carbon
CH_4	Methane
CO_2	Carbon Dioxide
CSCF	Carbon Stock Change Factor
DOM	Dead Organic Matter
EF	Emission Factor
ESD	Energy for Sustainable Development
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agricultural Organisation of the United Nations
FIEFCO	Farm Income Enhancement and Forestry Conservation Project
FOLU	Forestry and Other Land Use
FSSD	Forestry Sector Support Division
GFC	Global Forest Change (University of Maryland Department of Geographical Science)
GHG	Green House Gases
GIS	Geographical Information System
GPG	Good Practice Guidelines
GPP	Gross Primary Production
LAC	Low Activity Clay
LULUCF	Land Use Land Use change and Forestry
MAAIF	Ministry of Agriculture Animal Industry and Fisheries

MEMD	Ministry of Energy and Mineral Development
MODIS	Moderate Resolution Imaging Spectroradiometer
MWE	Ministry of Water and Environment
N2O	Nitrous Oxide
NaFORRI	National Forestry Resources Research Institute
NASA	National Aeronautics and Space Administration
NBP	Net Biome Production
NBS	National Biomass Study
NFA	National Forestry Authority
NOX	Nitrogen Oxides
NPP	Net Primary Production
QA	Quality Assurance
QC	Quality Control
RS	Remote sensing
SPGS	Saw Low Production Grant Scheme
UBOS	Uganda Bureau of Statistics
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

The definitions presented hereafter are derived from several UNFCCC documents mainly the 1996 and 2006 IPCC guidelines.

Activity Data: Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on energy use, metal production, land areas, management systems, lime and fertilizer use and waste arising are examples of activity data

Anthropogenic: -The term "anthropogenic", in the context of greenhouse gas inventories, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities

Emissions: -The release of a substance (usually a gas when referring to the subject of climate change) into the atmosphere.

Emission Factor: -A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions.

Emission Rate: -The weight of a pollutant emitted per unit of time (e.g., tons / year). (CARB)

Estimation: -is the assessment of the value of an un-measurable quantity using available data and knowledge within stated computational formulas or mathematical models.

Expert peer review - consists of a review of calculations or assumptions by experts in relevant technical fields. The objective of the expert peer review is to ensure that the inventory's results, assumptions, and methods are reasonable as judged by those knowledgeable in the specific field. Expert review processes may involve technical experts and, where a country has formal stakeholder and public review mechanism in place, these reviews can supplement but not replace expert peer review.

Global Warming Potential (GWP): -An index, based upon radiative properties of well-mixed greenhouse gases, measuring the radiative forcing of a unit mass of a given well-mixed greenhouse gas in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide. The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation. The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame.

Good practice – is a set of procedures intended to ensure that GHG inventories are accurate in the sense that they are systematically neither over- nor underestimated as far as can be judged, and that uncertainties are reduced as far as possible. Good practice covers choice of estimation methods appropriate to national circumstances, quality assurance and quality control at the national level, quantification of uncertainties and data archiving and reporting to promote transparency.

Greenhouse Gas: -Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Key source category - is one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct GHG in terms of the absolute level of emissions, the trend in emissions, or both.

National system - includes all institutional, legal and procedural arrangements made within a Party for estimating anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol, and for reporting and archiving inventory information.

Q/QC Audits - For the purpose of good practice in inventory preparation, audits will be used to evaluate how effectively the national inventory team complies with the minimum QC specifications outlined in the QC plan. It was explained that the auditor should be independent of the inventory agency as much as possible as to be able to provide an objective assessment of the processes and data evaluated. Audits may be conducted during the preparation of an inventory, following inventory preparation, or on a previous inventory.

QA/QC plan – is an internal document to organize, plan and implement QA/QC activities. The plan should, in general, outline QA/QC activities that will be implemented, and include a scheduled time frame that follows inventory preparation from its initial development through to final reporting in any year.

QA/QC system - the major elements of a QA/QC system are:

i) An inventory agency responsible for coordinating QA/QC activities;
ii) A QA/QC Plan;
iii) General QC procedures (Tier1);
iv) QA review procedures;
v) Reporting, documentation and archiving procedures.

Quality assurance (QA) - activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process to verify that data quality objectives were met, ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the quality control (QC) programme. QA activities include audits and expert peer reviews. It is good practice for inventory agencies to conduct a basic expert peer review (Tier 1 QA) prior to inventory submission in order to identify potential problems and make corrections where possible. Inventory agencies may also choose to perform more extensive peer reviews or audits or both as additional (Tier 2 QA) procedures within the available resources.

Quality control (QC) – is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to:

i) Provide routine and consistent checks to ensure data integrity, correctness, and completeness;
ii) Identify and address errors and omissions;
iii) Document and archive inventory material and record all QC activities.

QC activities - include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Higher tier QC activities include technical reviews of source categories, activity data and emissions factors, and methods of estimation.

Tier

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

Transparency

'Transparency' means that the data sources, assumptions and methodologies used for an inventory should be clearly explained, in order to facilitate the replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of the information

Trend:

The trend of a quantity measures its change over a time period, with a positive trend value indicating growth in the quantity, and a negative value indicating a decrease. It is defined as the ratio of the change in the quantity over the time period, divided by the initial value of the quantity, and is usually expressed either as a percentage or a fraction.

Verification

Verification refers to the collection of activities and procedures conducted during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of the inventory. In line with the guidelines, verification refers specifically to those methods that are external to the inventory and apply independent data, including comparisons with inventory estimates made by other bodies or through alternative methods.

1 Background and Introduction to GHG Inventory

A global response to greenhouse gas (GHG) emission and global warming was the international agreement, the Kyoto Protocol, which is an international treaty that extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) committing State Parties to reduce GHG emissions. This agreement was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The first commitment period of this protocol started in 2008 and ended in 2012.

Amendment to the Kyoto protocol took place on 8 December 2012 in Doha, Qatar with Annex I Parties to the Kyoto Protocol agreeing to take on commitments in a second commitment period from 1 January 2013 to 31 December 2020. The composition of Annex I countries changed with some new ones coming on board and others opting out. The level of commitment to the reduction of GHG emissions was set to least 18 percent below 1990 levels instead of 5 percent as was in the first commitment period. In addition, there was a revision of a list of greenhouse gases (GHG) to be reported on by the Parties plus amendments to several articles that were specifically addressing issues limited to the first commitment period.

The above changes notwithstanding, parties to the Convention must submit national reports on implementation of the Convention to the Conference of the Parties. Uganda being a party to the UNFCCC is required to develop, periodically update and publish its inventory of the country's greenhouse gas emissions which also serves as a blueprint of the plans and strategies for Uganda in addressing the impacts of climate change. Like many developing countries, Uganda's national inventory system is not yet well developed. However, a number of approaches are being initiated to address this challenge and one of them is the implementation of the Low Emission Capacity Building Project (LEB).

The Climate Change Department in the Ministry of Water and Environment is implementing LEB with financial support from the UNDP. Through LEB, UNDP is facilitating the development a GHG inventory manual as part of the strategy to help Uganda to gradually build a functional GHG inventory system. The Ministry of Water and Environment (MWE) as the lead agency is collaborating with other key ministries such as Ministry of Energy and Mineral Development (MEMD) and Ministry of Agriculture and Animal husbandry and Fisheries (MAAIF).

This manual is identified as GHG Inventory Manual for Uganda Version 1 considering it may gradually be improved and updated as the National Inventory System develops and the capacity of key institutions improves. The manual provides a guide towards estimation of GHG emissions from human activities in four broad sectors of: 1) Energy 2); Industry 3); Waste and 4) Land activities which include direct emissions from livestock and manure management systems, emissions due to carbon stock changes in living biomass, dead organic matter and soils plus missions from aggregate sources and non-CO_2 emissions like emissions that are related to rice cultivation, lime application and burning of biomass.

As much as possible, the manual tries to follow the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* because the improvements especially in the Agriculture Forestry and Other Land use (AFOLU). The manual presents a couple of methodological approaches (depending on national circumstances) and systematic steps that inventory compiler may follow while estimating carbon pools. Institutional arrangement and general operational environment such as database administration, Quality Control, and Quality Assurance are also discussed. Guidance is also provided to both the data providers and inventory compilers, explaining the importance of documenting error margins and quality control measures that are of great use importance in assessing uncertainties.

Cognizant of the limited resources available, the manual suggests appropriate methodologies and procedures to guide both inventory compilers and key data providers. In accordance with the guidelines (*good practice)*, the manual recommends performance of quantitative analysis of the relationships between the level and the trend of each category's emissions and removals such that limited resources can be focused on those areas that are most in need of improvement to produce the best practical inventory. Since the principles cut across all sectors, the aforementioned are represented in the subsequent section under "Building Sustainable National Inventory Management Systems'.

1.1 Building Sustainable National Inventory Management System

This manual in many ways follows what is proposed in the Developing a National Greenhouse Inventory System Template Workbook (US-EPA-USAID 2011). As identified in US-EPA-USAID 2011, a high level of technical expertise on the source and sink categories (forests, crops, livestock, energy, etc.) already exists in most developing countries. The challenge is to put this expertise to use in applying the IPCC methodologies to develop a high quality, well-documented inventory, and a sustainable inventory management system.

1.2 Methods and Data Documentation

Methods and Data Documentation (MDD) assists inventory teams in documenting and reporting the origin of methodologies, activity datasets, and emission factors used to estimate emissions or removals. Future inventory teams can refer to the completed template for each source and sink category to determine what information was collected, how the data were obtained, and what methods were used, as well as to reproduce estimates.

1.2.1 Providing source/sink category information

The inventory compiler is required to provide information about each category, including the sector it belongs to, a description of the category, and details about emissions and removals from this category including GHGs are emitted. A standard description from existing documents is normally sufficient to describe the category, describe the importance of emissions/removals from the category. Provide the contribution to total net emissions and the historical context for emissions/removals in your country from this category (e.g., relative importance and trends). Table 1-1 below should be completed to document Category Information.

Table 1-1 Category information

Sector	Energy
Category	Transport
Key Category? [Yes or No]	
Category Description/Definition	e.g., CO_2 from Road Transport
Country Detail	National circumstances

1.2.2 Identifying method choice and description

The inventory compiler is required to provide information about the method used to estimate emissions/removals from each category. List the equation used and the reference (e.g., 2006 IPCC Guidelines), equation page number, etc. for the equation. Describe the reason(s) for the methodology chosen. Table 1-2 below should be completed to document methodology choice.

Table 1-2. Category Methodology

Equation (Describe variables for method used.)	e.g., Emissions = (EF x AD)
Reference	e.g., 2006 IPCC Guideline Page x , EQ xx
Describe How and Why this Method Was Chosen	e.g., Tier 1 was used lack of detailed data on xx

1.2.2.1 Listing activity data

The inventory compiler are required to list the activity data used to estimate emissions and removals from each category, including the value, units, and year and provide a reference for the data and other relevant information, such as when the data were obtained, and the contact name (if the data were supplied by a person) or a full citation (if the data were collected from a published source) while describing the full detail of the data used. Table 1-3 below should be completed to document activity data for each category.

Table 1-3. Example of table listing Activity Data

Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Reference	Other Information (e.g., date obtained and data source or contact information)	Category QA/QC Procedure Adequate / Inadequate / Unknown	Are all data entered correctly into models, spreadsheets, etc.? Yes / No (List Corrective Action)	Checks with Comparable Data (e.g., At international level, IPCC defaults). Explain and show results.
e.g., Amount and type of fuel.		TOE		e.g., MEMD			Yes	

1.2.2.2 Listing emission factors

The inventory compiler lists emission factors and carbon-stock change factors (mainly applicable to biomass) used to estimate emissions and removals from each category, including the value and units and provide a reference for the data and other relevant information, such as the date the factor was obtained, and either the contact name (if the data were supplied by a person) or a full citation (if the data were collected from a published source). Table 1-4 below should be completed to document Emission/carbon-stock change factors for each category.

Table 1-4: Emission/carbon-stock change factors for each category

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Other Information (e.g., Date obtained and data source or contact information)	Category QA/QC Procedure Adequate / Inadequate / Unknown	Are all data entered correctly into models, spreadsheets, etc.? Yes / No (List Corrective Action)	Explain how this factor is appropriate to national circumstances. Provide sources.

1.2.2.3 Listing uncertainty estimates (optional for Tier 1)

The inventory compiler lists the current year's emissions for each category for which an uncertainty estimate has been assigned and the assigns lower bound and upper bound uncertainty estimate and the resulting lower and upper bound estimate when the uncertainty bounds are applied to the current estimate. Table 1-5 should be completed to document uncertainty Estimates Calculated for each category. Section 2.6.1 gives steps and examples of how to estimate uncertainty for each subcategory and how to aggregate to at category, sector and overall National inventory.

Table 1-5: Uncertainty Estimates Calculated for Categories

Category	Key Category? [Yes or No]	Emissions Estimate (Gg CO_2 Eq.)	Relative Lower Bound Uncertainty (%)	Relative Upper Bound Uncertainty (%)	Lower Bound Emissions Estimate (Gg CO_2 Eq.)	Upper Bound Emissions Estimate (Gg CO_2 Eq.)

Key concepts and terminology

Definitions associated with conducting an uncertainty analysis include *uncertainty*, *accuracy*, *precision* and *variability*. Clear statistical definitions as provided in 1996 and 2006 IPCC guideline in alphabetical order are presented here:

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

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

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

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

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

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

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

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

Variability**:** Heterogeneity of a variable over time, space or members of a population (Morgan and Henrion, 1990;Cullen and Frey, 1999).

1.2.2.3.1 Causes of Uncertainty and how they can be addressed

Emissions/removals estimates are based on: (1) conceptualisation; (2) models; and (3) input data and assumptions (e.g., emission factor and activity data) and each of these may differ from the true underlying value for many reasons. Quantitative uncertainty analysis tends to deal primarily with random errors based on the inherent variability of a system and the finite sample size of available data, random components of measurement error, or inferences regarding the random component of uncertainty obtained from expert judgement. In contrast, systematic errors that may arise because of imperfections in conceptualisation, models, measurement techniques, or other systems for recording or making inferences from data, can be much more difficult to quantify (IPCC 2006).

It is thus important that an uncertainty analysis be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice. The methods used to attribute uncertainty values must be practical, scientifically defensible, robust enough to be applicable to a range of categories of emissions by source and removals by sinks, methods and national circumstances, and presented in ways comprehensible to inventory users.

Uncertainties should be reduced as far as is practicable during the process of compiling an inventory, and it is particularly important to ensure that the model and the data collected are fair representations of the real world. Table 1-6 provides causes of uncertainties and strategies to reduce them.

Table 1-6, Causes and Strategies to reduce uncertainties, Source: IPCC 2006 Table 3.1

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

1.2.2.3.2 Quantifying uncertainties

After identifying the causes of uncertainties associated with inventory estimates, the inventory compiler needs to collect the appropriate information to develop national and category-specific estimates of uncertainty at the 95 percent confidence interval. Ideally, emission and removal estimates and uncertainty ranges would be derived from category-specific measured data. Since it may not be practical to measure every emission source or sink category in this way, other methods for quantifying uncertainty may be required. The pragmatic approach for producing quantitative uncertainty estimates is to use the best available estimates, which are often a combination of measured data, published information, model outputs, and expert judgement. The sectoral guidance in Volumes 2 to 5 of 2006 IPCCC Guidelines provide default uncertainty estimates for use with the methods to use for the each sector.

Although uncertainties determined from measured data are often perceived to be more rigorous than uncertainty estimates based on models, and similarly, model-based estimates are often perceived as more rigorous than those based on expert judgement, the actual hierarchy depends on the category and/or country-specific circumstances. In particular it is good practice to ensure that uncertainties are representative for the application in the inventory and national circumstances and includes all causes of uncertainty listed in Table 1-6.

1.2.2.3.2.1 Estimation of Population Parameters

Sample statistics (e.g., sample mean, sample standard deviation) are used to estimate chosen population parameter e.g., estimation of Activity data or Emission Factor. The sample AD or EF mean ($\bar{x}$) is calculated as the sum of data values divided by the sample size (n) as shown in Equation 1-1.

Equation 1-1. Sample Mean

$$\bar{x} = \frac{\sum x}{n}$$

Sample standard deviation (Equation 1-2), is calculated as square root of the sample variance or the square root of the average of the squared differences from the mean.

Equation 1-2. Standard Deviation

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

The margin of error (equation 1-3) is calculated using the following formula:

Equation 1-3. Margin of Error

$Z\propto/2 * \sigma/\sqrt{(n)}$

Where

- $Z\,\alpha_{/2}$ = the confidence coefficient, Note that the recommended confidence level is 95 percent
- α = confidence level,
- σ = standard deviation
- n = sample size.

The confidence interval (equation 1-4) is based on the mean, or the average and the margin of error i.e., ± from the mean. The formula is used to determine the confidence interval. Where $\overline{x}$ represents the mean.

Equation 1-4. Confidence Interval

$$\overline{x} \mp z_{\propto/2} \times \frac{\sigma}{\sqrt{(n)}}$$

This may also be expressed as a percentage of the central estimate. Where the PDF is symmetrical (Figure 1-1) the confidence interval can be conveniently expressed as plus or minus half the confidence interval width divided by the estimated value of the variable (e.g., ± 30%).

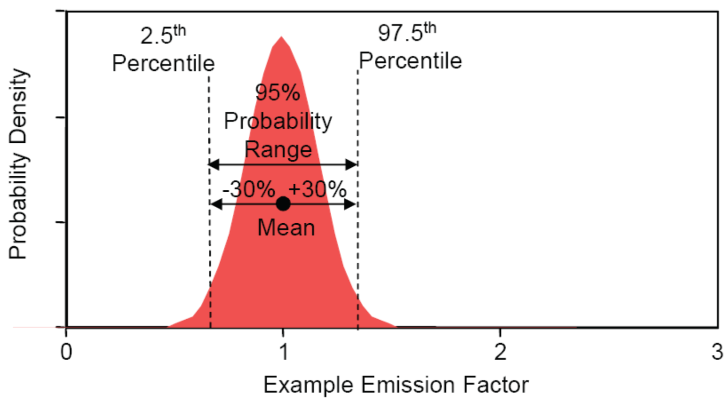

Figure 1-1. Example of a symmetric uncertainty of ±30% relative to the mean

Where the PDF is not symmetrical upper and lower limits of the confidence interval need to be specified separately (e.g., -30%,+60%). In this particular example, the lower end of the 95 percent probability range is a half the mean, and the upper end is a multiplier of 2 larger than the mean. Such a range is commonly summarised as a "factor of 2." An uncertainty of a "factor of n" refers to a range bounded at the low end by (mean/n) and at the high end by (mean × n). Thus, a factor of 10 uncertainty would have a range of 0.1×mean to 10×mean. The factor 10 uncertainty is also often called "an order of magnitude". Higher powers of 10 are referred to as "orders of magnitude;" for example, a factor of 10^3 would be referred to as three orders-of-magnitude.

1.2.2.3.2.2 Combining uncertainties

Once the uncertainties in the source categories have been determined, they may be combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time.

The error propagation equation, yields two convenient rules for combining uncorrelated uncertainties under addition and multiplication (refer to Uncertainties Chapter of the General Guidance Volume of the 2006 IPCC Guidelines,):

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

Using this interpretation, the combined uncertainty can be defined as the square root of the sum of the product of category emissions and the uncertainty divided by the quantity (sum of uncertainties) itself as shown in Equation 1-5.

Equation 1-5. Combining uncertain Approach 1.

$$U_E = \frac{\sqrt{(U_1 \bullet E_1)^2 + (U_2 \bullet E_2)^2 + \cdots + (U_n \bullet E_n)^2}}{E_1 + E_2 + \cdots E_n}$$

where:

- U_E = percentage uncertainty of the sum
- Ui = percentage uncertainty associated with source/sink i
- Ei = emission/removal estimate for source/sink i

The above equation assumes that there is no significant correlation among emission and removal estimates and that uncertainties are relatively small. However, it still can be used to give approximate results where uncertainties are relatively large.

Rule B: where uncertain quantities are to be combined by multiplication (e.g. AD multiplied by EF), the same rule applies except that the standard deviations must all be expressed as fractions of the appropriate mean values (this rule is approximate for all random variables). As in rule A; the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added, with the standard deviations all expressed as coefficients of variation, which are the ratios of the standard deviations to the appropriate mean values. This rule is approximate for all random variables. Under typical circumstances this rule is reasonably applies where there is no significant correlation[1] among data and where uncertainties are relatively small (standard deviation less than about 30% of the mean). Where correlation exist, one approach is to aggregate the source/sink categories to a level where they are eliminated. A simple equation (Equation 1-6) can also be derived for the uncertainty of the product, again expressed in percentage terms:

Equation 1-6. Combining uncertain Approach 2

$$U_{Total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

Where

- U_{Total}= Percentage uncertainty in the product quantities (half of the 95% confidence interval divided by the total and expressed as a percentange)
- U_n^2= Percentage uncertainties associated with each of the quantities

1.3 QA / QC and Verification

A Quality Assurance / Quality Control (QA/QC) and verification system contributes to the objectives of *good practice* in inventory development, namely to improve transparency, consistency, comparability, completeness, and accuracy of national greenhouse gas inventories.

The outcomes of QA/QC and verification may point to particular variables within the estimation methodology which may call for a reassessment and to subsequent improvements in the estimates of emissions or removals.

1.3.1 QA/QC plan

QC activities include general methods such as accuracy checks on data acquisition and calculations, and the use of approved standardised procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting.

[1] Correlation among input data to the uncertainty analysis often exists. Examples are cases where the same activity data or emission factors are used in several estimates that are to be added in a later step

QC activities also include technical reviews of categories, activity data[2], emission factors[3], other estimation parameters and methods.

The QA/QC plan is an internal document to organise and implement QA/QC and verification activities that ensure the inventory is fit for purpose and allow for improvement. A key component of a QA/QC plan is the list of *data quality objectives*, against which an inventory can be measured in a review. Data quality objectives are concrete targets to be achieved in the inventory preparation. They should be appropriate, realistic (taking national circumstances into account) and allow for an improvement of the inventory. Where possible, data quality objectives should be measurable. The following inventory principles may be put into consideration:

- Timeliness
- Completeness
- Consistency (internal consistency as well as time series consistency)
- Comparability
- Accuracy
- Transparency
- Improvement

Any specific details of a QA/QC and verification system should be defined in the QA/QC plan so that national circumstances can be taken into account.

General QC procedures include generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source and sink categories and are summarized in

Table 1-7.

[2] Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on energy use, lime and fertilizer use and waste arising are examples of activity data

[3] A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions.

Table 1-7: General QC procedures; source 2006 IPCC

QC Activity	Procedures
Check that assumptions and criteria for the selection of activity data, emission factors, and other estimation parameters are documented. Check for transcription errors in data input and references.	• Cross-check descriptions of activity data, emission factors and other estimation parameters with information on categories and ensure that these are properly recorded and archived. Check for transcription errors in data input and references. • Confirm that bibliographical data references are properly cited in the internal documentation. • Cross-check a sample of input data from each category (either measurements or parameters used in calculations) for transcription errors.
Check that emissions and removals are calculated correctly.	• Reproduce a set of emissions and removals calculations.
Check that parameters and units are correctly recorded and that appropriate conversion factors are used.	• Use a simple approximation method that gives similar results to the original and more complex calculation to ensure that there is no data input error or calculation error. • Check that units are properly labelled in calculation sheets. • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • Check that temporal and spatial adjustment factors are used correctly.
Check the integrity of database files.	• Examine the included intrinsic documentation to: - confirm that the appropriate data processing steps are correctly represented in the database. - confirm that data relationships are correctly represented in the database. - ensure that data fields are properly labelled and have the correct design specifications. - ensure that adequate documentation of database and model structure and operation are archived
Check for consistency in data between categories.	• Identify parameters (e.g., activity data, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emission/removal calculations.
Check that the movement of inventory data among processing steps is correct.	• Check that emissions and removals data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries.

	• Check that emissions and removals data are correctly transcribed between different intermediate products.
Check that uncertainties in emissions and removals are estimated and calculated correctly.	• Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate. • Check that qualifications, assumptions and expert judgements are recorded. • Check that calculated uncertainties are complete and calculated correctly. • If necessary, duplicate uncertainty calculations on a small sample of the probability distributions used by Monte Carlo analyses (for example, using uncertainty calculations according to Approach 1).
Check time series consistency.	• Check for temporal consistency in time series input data for each category. • Check for consistency in the algorithm/method used for calculations throughout the time series. • Check methodological and data changes resulting in recalculations. • Check that the effects of mitigation activities have been appropriately reflected in time series calculations.

Although the general QC procedures are designed to be implemented for all categories and on a routine basis, it may not be necessary or even possible to check all aspects of inventory input data, parameters and calculations. Checks may be performed on selected sets of data and processes. It is *good practice* for the inventory compiler to plan to undertake QC checks on samples of all parts of the inventory over an appropriate period of time as determined in the QA/QC plan.

Due to the quantity of data that needs to be checked for some categories, automated checks may be used. For example, a QC procedure could be set up to use an automated range check based on the range of expected values of the input data from the original reference (Winiwarter and Schimak, 2005). A combination of manual and automated checks may constitute the most effective procedures in checking large quantities of input data.

1.3.2 **Category-specific QC**

Category-specific QC complements general inventory QC procedures and is applied on a case-by-case basis focusing on *key categories* and on categories where significant methodological and data revisions have taken place. These procedures require knowledge of the specific category, the types of data available and the parameters associated with emissions or removals, and are performed in addition to the general QC checks listed in

Table 1-7. Apart from the Forestry Sector, most GHG categories in Uganda lack detailed Activity data and do not have locally generated Emission factors. For this reason most QC examples will be based on forestry.

1.3.2.1 IPCC Default EF QC

When using IPCC default emission factors, it is *good practice* for the inventory compiler to assess the applicability of these factors to national circumstances. This assessment may include an evaluation of national conditions compared to the context of the studies upon which the IPCC default emission factors were based. If there is insufficient information on the context of the IPCC default emission factors, the inventory compiler should take account of this in assessing the uncertainty of the national emissions estimates based on the IPCC default emission factors.

If possible, a supplemental activity is to compare IPCC default emission factors with site or plant-level factors to determine their representativeness relative to actual sources in the country. This supplementary check is *good practice* even if data are only available for a small percentage of sites or plants.

Many parts of Uganda of central and northern Uganda are set up on fire during the December to March dry season. Estimating emissions from these fires is based on available biomass, the fraction of biomass that is burnt and the emission factor. Some of the areas are considered fire climax vegetation types meaning that only certain age groups and certain species are burnt while other are only partially burnt. An example of QC in this regard would be for Uganda to assess the appropriateness of fraction of biomass burnt IPCC default factors.

1.3.2.2 Country specific EF QC

It is important to assess the adequacy of the emission factors and the QA/QC performed during their development. Where EFs were based on secondary data sources, such as published studies or other literature, the inventory compiler should reassess the uncertainty of any emissions estimates derived from the secondary data. The inventory compiler may also want to consider if any alternative data, including IPCC default values, may provide a better estimate of emission.

Uganda heavily relies on biomass for its energy requirements both for domestic and industrial use yet there are no locally developed biomass expansion factors. One of the QC measures would be to check the appropriateness of the fuelwood to total Tree Biomass Expansion Factors.

Since emissions and from deforestation and forest degradation is a key category in Uganda, an example of category specific QC would be to check the appropriateness of the Allometric equations developed by the National Biomass Study by subjecting them to a number of Expert Peer Reviews.

1.3.2.3 Activity data QC

The estimation methods for many categories rely on the use of activity data and associated input variables that are not directly prepared by the inventory compiler and in many instances activity data are originally prepared for purposes other than as input to estimates of greenhouse gas emissions.

Activity data at a national level are normally drawn from secondary data sources or site-specific data prepared by site or plant personnel from their own measurements.

The inventory compiler needs to determine if the level of QC associated with secondary activity data includes, at a minimum, those QC procedures listed in Table 1-6. In addition, the inventory compiler may check for any peer review of the secondary data and document the scope of this review. If the QA/QC associated with the secondary data is adequate, then the inventory compiler can simply reference the data source and document the applicability of the data for use in its estimates.

If the QC associated with the secondary data is inadequate or if the data have been collected using standards/definitions that deviate from this guidance, then the inventory compiler should establish QA/QC checks on the secondary data. The uncertainty of estimates should be reassessed in the light of the findings. The inventory compiler should also reconsider how the data are used and whether any alternative data and international data sets may provide a better estimate of emissions or removals.

The inventory compiler should establish whether individual sites carried out measurements using recognised national or international standards. Comparisons of activity data from different reference sources and geographic scales can play a role in confirming activity data.

In Uganda, data on quantities of harvested forest products e.g., firewood and timber volumes are based international publications e.g., FAO's forest assessment studies. It would be an important QC measure to subject these data sets to special tests by means of special studies and or surveys.

Even where activity data is generated locally such as the land use land cover data generated by the Uganda National Forestry Authority, it is important that the inventory compiler critically assesses the QC measures of data providers with the aim of making improvements.

1.3.2.4 Calculation-related QC

Checks of the calculation algorithm safeguard against duplication of inputs, unit conversion errors, or similar calculation errors. These checks can be independent 'back-of-the-envelope' calculations, which simplify the algorithms to arrive at an approximate method. If the original calculation and the simple approximate method disagree, it is *good practice* to examine both approaches to find the reason for discrepancy.

1.3.3 **Quality assurance**

Quality assurance comprises activities outside the actual inventory compilation and includes reviews and audits to assess the quality of the inventory, to determine the conformity of the procedures taken and to identify areas where improvements could be made. QA procedures may be taken at different levels (internal/external), and they are used in addition to the general and category-specific QC procedures described in section 1.3.2.

Quality assurance procedures may be taken at different levels (internal/external), and they are used in addition to the general and category-specific QC procedures. It is *good practice* for inventory compilers to conduct a basic expert peer review of all categories before completing the inventory in order to identify potential problems and make corrections where possible. Reviews verify that measurable objectives (data quality objectives), were met, ensure that the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability, and support the effectiveness of the QC programme.

1.3.4 Verification

Verification activities include comparisons with emission or removal estimates prepared by other bodies and comparisons with estimates derived from fully independent assessments. Verification activities may be constituents of both QA and QC, depending on the methods used and the stage at which independent information is used.

Verification may involve use of alternative estimation methodologies for the same category or set of categories and or use of both national and international data sets. While national data are normally considered more reliable as they are able to accommodate more detailed country-specific information, and international data are normally compiled at a lower tier, these international data sets provide a good basis for comparison as they are consistent between countries.

An example of verification exercise would be to compare Uganda’s land cover data with data provided by internationally organisations involved in land resource assessments e.g., FAO, Global Forest Assessment of Maryland University, GEOCOVER, etc.

Correspondence between the national inventory and independent estimates is essential in that it increases the confidence and reliability of the inventory estimates by confirming the results. Significant differences may indicate weaknesses in either or both of the datasets.

1.3.4.1.1 Scientific advances

Recent scientific advances may take verification to a new level of measurements of atmospheric concentrations and complex modelling. These techniques will require specialised modelling skills and resources in order to appropriately correlate the atmospheric data back to the inventory for comparison, and be cost- and labour intensive.

There will be possibilities of national inventory compilers joining forces with neighbouring countries to estimate emissions for larger entities than countries. Fluorinated gases and methane (CH4) are potentially good candidates for inverse model[4] verification (Rypdal *et al.*, 2005, Bergamaschi *et al.*, 2004) because they have virtually no natural source interference in the atmospheric measurements. Methane is considered a favourable candidate because of the generally high uncertainty in emission estimates resulting from inventory.

[4] models that calculate emission fluxes from concentration measurements and atmospheric transport

1.4 Data Archiving and Institutional Arrangements

"An Archiving System helps make a national inventory transparent and reproducible, and facilitates development of subsequent inventories by future inventory staff and category leads (individuals responsible for developing estimates within a particular sector). Each new inventory cycle will benefit from effective data and document management during development of the previous inventory" (Okure M.A.E, 2013). Currently, Uganda data lacks a data management system and there are no mechanisms to ensure that subsequent inventories build on previous works.

It is thus recommended the CCD makes a formal request to all key data producers of required data and data formats. To ensure completeness, CCD should develop template tables which data providers will populate. The quality control measured, however, remains the responsibility of the agencies that compile the data.

Data used to create the inventory should be archived in a single location in both electronic and/or hard copy (paper). The data structure should be in a format that can easily be imported or copied and transferred into existing IPCC inventory software and spreadsheets. The information stored at CCD should include internal documentation on QA/QC procedures, external and internal reviews, documentation of annual key categories and key category identification, and planned inventory improvements. If possible, a copy of all archive documents should be kept in multiple locations to reduce the risk of losing all records due to theft or disaster (e.g., fire, earthquake, or flooding) (Okure M.A.E., 2013).

1.4.1 Uganda's GHG Data and Key Institutions

A well planned Institutional Arrangement assists inventory teams in assessing and documenting the strengths and weaknesses of existing institutional arrangements for inventory development to ensure continuity and integrity of the inventory, promote institutionalization of the inventory process, and facilitate prioritization of future improvements. Key institutions responsible for Uganda's GHG inventory are mentioned below.

1.4.1.1 The Climate Change Department

The Climate Change Department (CCD) is the UNFCCC focal point and coordinates all climate change related activities in the country. It is thus supposed to identify organisations, entities or individuals that can carry out GHG inventories and peer reviews. CCD is supposed to ensure that data providers have established quality control and quality assurance mechanisms and procedures. However, the role of quality control will initially be played by the inventory team until the required capacity is acquired by the data providing institutions.

The Climate Change Department needs to establish a system with controls and validation protocols that will ensure that quality is maintained as the inventory system is being developed. Mainly due to limited resources, quality control requirements need to be balanced against requirements for timeliness and cost effectiveness. There is thus need to prioritize QC efforts for certain categories based on criteria like uncertainty, significant changes in category, methodology, technology or management practices. The CDD should have a deliberate effort to build QC systems in data collecting (providing) institutions e.g., National Forestry Authority (NFA), Uganda Revenue Authority (URA), Uganda Bureaux of Statistics (UBOS), MWE, MAAIF and is performed by personnel compiling the inventory. The system should be robust yet flexible enough accommodate changes in data requirement details, changes in methodology as need arises.

1.4.1.2 Data on Energy Sector

MEMD and UBOS are key data providers of energy statistics. The Ministry of Works and Transport and UBOS provides data for the number of vehicles. Biomass data can be obtained from the Ministry of Energy and Mineral Development and NFA. However, big inadequacies in data still exist. For example, there is lack of data of the vehicle fleet. Data on rail and marine transport are not captured in the energy statistics. The Ministry of Agriculture, Animal Industry and Fisheries have some data on fishing boats but it is not captured by UBOS.

It is envisaged that all the data providers of energy will be given support to collect the missing data and also build their QC mechanisms. CCD is expected to provide Q\A through external reviewers of the data.

1.4.1.3 Data on Industrial Processes

The Ministry of Industries, Tourism and Cooperative is the lead Ministry in providing the data on manufacturing in Ugandan industries. Some of this data is available at UBOS but a lot more is needed. The Uganda Manufacturers Association and Private Sector Foundation may also provide some important information. Generally, data on Uganda's industrial sector is not well developed, with a lot small scale or cottage industries data is scanty. All the key data providers need technical and financial support in data collection and in building Q\C mechanisms. The role of Q\A should remain with CCD through peer reviews.

1.4.1.4 Data on AFOLU

UBOS and MAAIF are the key providers of agriculture statistics. Compared to other countries in the region, Uganda has got a relatively advanced Land Cover mapping and biomass stock inventory and monitoring system. NFA is almost the sole provider this data and it is getting overstretched. It is hoped that the CCD will coordinate and bring other entities on board when developing the Third National Communication and Bi-Annual Report that may commence by March 2015.

FAO is providing technical support to NFA in data collection and in the development of a National Forestry Monitoring System (NFMS) under the UN- REDD[5] QC measures will be part of that system. In addition, detailed quality control measures and estimation of uncertainty for AFOLU are discussed in Appendix 4-2.

1.4.1.5 Data on Waste

There is great need to improve data quality and collection mechanisms on waste generation and treatment in Uganda. A well-coordinated system of data collection and quality control is required mainly because waste is generated in a wide range of sources ranging from households, offices, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction and demolition sites, and agricultural activities.

National Environmental Authority (NEMA) has keen interest on waste disposal because waste generation and disposal is associated with serious environmental concerns. It is thus suggested the NEMA be supported to improve on data collection. In the meantime, the inventory could help on Q\C measures as improvements are made in key data providing entities. Q\A will remain the responsibility of the CCD.

[5] REDD stands for Reduced Emissions through Deforestation and forest Degradation

1.5 Key category analysis

A key category is one that is prioritised within the national inventory system because it is significantly important for one or a number of air pollutants in a country's national inventory of air pollutants in terms of the absolute level, the trend, or the uncertainty in emissions.
The concept of "key categories" was created by the IPCC as a way to help countries prioritize resources for improving national greenhouse gas inventories.[6] Key categories have the greatest contribution to the overall level of national emissions. When an entire time series of emission estimates is prepared, key categories can also be identified as those categories that have the largest influence on the trend of emissions over time.[7] In addition, when uncertainty estimates are incorporated into emission estimates, additional key categories are identified.
The results of the key category analysis provide a country with a list of their most important inventory categories. This list is a starting point from which a country can begin the process of improving their greenhouse gas inventory. To improve the national greenhouse gas inventory, it may be necessary to consider applying more accurate or higher tier methodologies, collect more detailed activity data, or develop country-specific emission factors. These activities all require additional resources, and it is not possible to make improvements for every inventory category. The inventory category list resulting from this analysis can provide a quantitative framework for the national greenhouse gas inventory team to develop an inventory improvement plan. The key category analysis also provides more complete and transparent information for the National Communication.
Both Approach 1 and Approach 2 methodologies (as per IPCC guidelines) for determining key categories are explained (referred to as Tier 1 and Tier 2 hereafter). In the Tier 1 methodology, *key* categories are identified using a pre-determined cumulative emissions threshold, where *key categories* are those that, when summed together in descending order of magnitude, add up to 95% of the total level. The Tier 2 methodology to identify *key* categories can be used if category uncertainties or parameter uncertainties are available.
Under the Tier 2 key category methodology, source or sink categories are sorted or ranked

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[6] The 1996 IPCC Guidelines refer to "key source categories" which has been revised in subsequent IPCC Guidelines to "key categories" since sinks are also included in the analysis.

[7] The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) defines a key category as a "category that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Whenever the term key category is used, it includes both source and sink categories." See Chapter 4, "Methodological Choice and Identification of Key Categories," in IPCC 2006 for more information, < http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>.

according to their contribution to uncertainty, and emissions are weighted by their combined uncertainty, in addition to contribution to total emissions.

It is good practice for a country to identify its national key categories in a systematic and objective manner. This can be achieved by a quantitative analysis of the relationship between the magnitude of emission in any one year (level) and the change in emission year to year (trend) of each category's emissions compared to the total national emissions.
It is also good practice to focus the available resources for improvement in data and methods on categories identified as key. The identification of key categories in national inventories enables the limited resources available for preparing inventories to be prioritised; more detailed, higher tier methods can then be selected for key categories. Inventory need to use the category-specific methods presented in sectoral decision trees in the sectoral volumes.

1.5.1.1 Approach;

The inventory compiler identifies key categories in a basic single-year inventory in terms of their contribution to the absolute level of national emissions. For those inventory compilers who have prepared a time series, the quantitative determination of key categories should also include an evaluation of both the absolute level and the trend of emissions. Some key categories may be identified only when their influence on the trend of the national inventory is taken into account.

Tier 1 Current Year Level Analysis

When inventory categories are sorted in order of decreasing GHG magnitude, those that fall at the top of the list and cumulatively account for 95% of emissions are considered key categories. They are those inventory categories that contribute the most to overall national total emissions. This information is filled in a table (template provided in Table 1-8).

Table 1-8. Template of Key Category Based on Contribution to Total National Emissions in current year

IPCC Category Code	IPCC Category	Gas	Current Year Emissions (Gg CO_2 Eq.)	Contribution to National Emissions	Cumulative Percent of National Emissions

The methodologies and equations used to generate information used to fill in the Table 1-8 is adopted from *IPCC Good Practice* (2000) and 2006 *IPCC Guidelines for National Greenhouse Gas Inventories.* Equation 1-7 is used to make calculations for the assessment of Current Year Level Key categories.

Equation 1-7. Key Category Level Assessment

Key Category Level Assessment = |Source or Sink Category Estimate| / Total Contribution

$$L_{x,t} = {|E_{x,t}|}/{\sum_y |E_{y,t}|}$$

where:

$L_{x,t}$ = the level assessment for source or sink category *x* in year *t*

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

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

This equation determines the contribution of each inventory category's GHG emissions to the national total. Key categories are those that, when added together in descending order of magnitude, constitute at least 95% of the total emissions for a given year

Tier 1 Base Year Level and Trend Analyses

Countries like Uganda that have GHG inventories for more than one year like are required to a trend analysis. Key category level analysis for the base year e.g., 1995 is done followed by key category trend analysis for the years e.g. 1995-2000. The key categories are listed in order of decreasing contribution to the overall trend. Together they account for at least 95% of the overall trend in national total emissions. A total number of key categories based on the trend analysis are listed.

Table 1-9.Key Categories Based on Contribution to Overall Trend in National Net Emissions Template

IPCC Category Code	IPCC Category	Gas	Base Year Emissions (Gg CO_2 Eq.)	Current Year Emissions (Gg CO_2 Eq.)	Contribution to Trend	Cumulative Contribution to Trend

The contribution of each category's emission trend to the trend in the total inventory can be assessed if more than one year of inventory data are available, according to Equation 1-8:

Equation 1-8. Source or Sink Trend Assessment

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

where:

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

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

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

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

The trend assessment for an individual source or sink category is the change in the category emission/removal over time, computed by subtracting the base year (year 0) estimate for source or sink category *x* from the current year (year *t*) estimate, and dividing by the current year estimate. The total trend is the change in the total inventory emissions over time, computed by subtracting the base year (year 0) estimate for the total inventory from the current year (year *t*) estimate, and dividing by the current year estimate.

The trend assessment will identify inventory categories that have a trend different from the trend of the overall inventory. As differences in trend are more significant to the overall inventory level for larger inventory categories, the result of the trend difference (i.e., the inventory category trend minus the total trend) is multiplied by the result of the level assessment from the base year ($L_{x,t}$ from Equation 1-7) to provide appropriate weighting. Thus, key categories will be those where the inventory category trend diverges significantly from the total trend, weighted by the emission level of the inventory category.

This type of key category analysis is only applicable to those countries that have emission inventories for more than one year. Thus, key categories are those whose trend diverges significantly from the total trend, weighted by the level of emissions or removals of the category in the base year. Key categories are those that, when summed together in descending order of magnitude, add up to more than 95% of the total trend.

Tier 2 Current Year Level Analysis

Tier2 Key category analysis is done where uncertainty associated with national emissions and sequestration have been estimated. Uganda should look into going in this direction especially for the land use category where Tier 2 level of assessment is already being applied.

Assessment of key categories incorporates each source and sink category's associated uncertainty estimates. Inventory categories are then sorted in order of decreasing GHG magnitude (with the incorporated uncertainty) and those that fall at the top of the list and cumulatively account for 90% of emissions are considered key categories.

Table 1-10 presents the results of the IPCC Tier 2 key category level analysis for a given year.

Table 1-10, Key Category with Incorporated Uncertainty for current year (Tier2)

IPCC Category Code	IPCC Category	Gas	Level Assessment with Uncertainty	Relative Level Assessment with Uncertainty	Cumulative Percent of National Emissions

The key category analysis is enhanced by incorporating the national source or sink category uncertainty estimates. The contribution of each source or sink category to the total national inventory level as weighted by their respective category percent uncertainty is calculated according to Equation 1-9:

Equation 1-9. Key category incorporating uncertainty

$$LU_{x,t} = {(L_{x,t} \times U_{x,t})}/{\sum_y[(L_{y,t} \times U_{y,t})]}$$

where:

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

$L_{x,t}$ = the Tier 1 level assessment as computed in Equation 1-7

$U_{x,t}$ = category percentage uncertainty in year *t* calculated according to the 2006 IPCC Guidelines Chapter 3. If the reported uncertainty is asymmetrical, the larger uncertainty should be used. The relative uncertainty will always have a positive sign.

This equation determines the contribution of each source or sink category's GHG contribution to the national total as weighted by their respective uncertainty estimates. Key categories are those that, when added together in descending order of magnitude, constitute at least 90% of the total emissions for a given year.

Tier 2 Base Year and Trend Analyses with Incorporated Uncertainty

Base year and trend analyses with incorporated uncertainty can be done for those countries that have estimated the uncertainty associated with national emissions and sequestration estimates, and the same time have GHG inventories for more than one year.

Table 1-11 presents the results of Base year and trend analyses with incorporated uncertainty. Like in any Key category analysis, it is important identify and document base year and current year and the number key categories.

Table 1-11 presents the results of the IPCC Tier 2 key category trend analysis for base year and current year. The key categories are listed in order of decreasing contribution to the overall trend when uncertainty in incorporated. Together they account for at least 90% of the overall trend in national total emissions. Like in any Key category analysis, it is important to identify and document the number key categories.

Table 1-11. Incorporated Trend and Uncertainty in Key Category Analysis

IPCC Category Code	IPCC Category	Gas	Trend Assessment with Uncertainty	Relative Trend Assessment with Uncertainty	Cumulative Percent of National Emissions

The contribution of each source or sink category to the trend in the total inventory as weighted by their respective category percent uncertainty can be assessed if more than one year of inventory data is available, according to Equation 1-10.

Equation 1-10. Incorporating Trend and Key category analysis

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

where:

$TU_{x,t}$	= the trend assessment for category *x* in latest inventory year (year *t*) with uncertainty
$T_{x,t}$	= the Tier 1 trend assessment as computed in Equation 1-8
$U_{x,t}$	= the category percent uncertainty in year *t* calculated according to the 2006 IPCC Guidelines Chapter 3. If the reported uncertainty is asymmetrical, the larger uncertainty should be used. The relative uncertainty will always have a positive sign.

This type of key category analysis is only applicable to those countries that have emission inventories for more than one year and uncertainty estimates for individual source and sink categories. Thus, key categories are those whose trend diverges significantly from the total trend, weighted by the uncertainty. Key categories are those that, when summed together in descending order of magnitude, add up at least 90% of the total trend. When all the required data is well arranged, software like EPA KCA Tool may be down loaded and used. All the above steps and processes have been incorporated in the Tool.

1.6 IPCCC 2006 Inventory Software

The IPCC inventory software was launched in May 2012. This software implements the IPCC 2006 greenhouse gas inventories. This allows countries to use improved methodologies for emission estimation and better default values. The software should be used together with the 2006 IPCC Guidelines.

The 2006 IPCC Guidelines contains: Methods, Default data, Good practice guidance and Reporting instructions.

The inventory software can assist in the use of the IPCC Guidelines and it is database based. The software is free and latest version (Ver. 2.12), released in April 2013, can be downloaded from: http://www.ipcc-nggip.iges.or.jp/software/index.html. When downloading, follow instructions and answer questions regarding the regions of the world (Uganda is in Africa); and register username and password. When these are all done, the software is ready to use.

The software is designed to accommodate multiple users that can feed data to a central management centre controlled by a manager as illustrated by Figure 1-2.

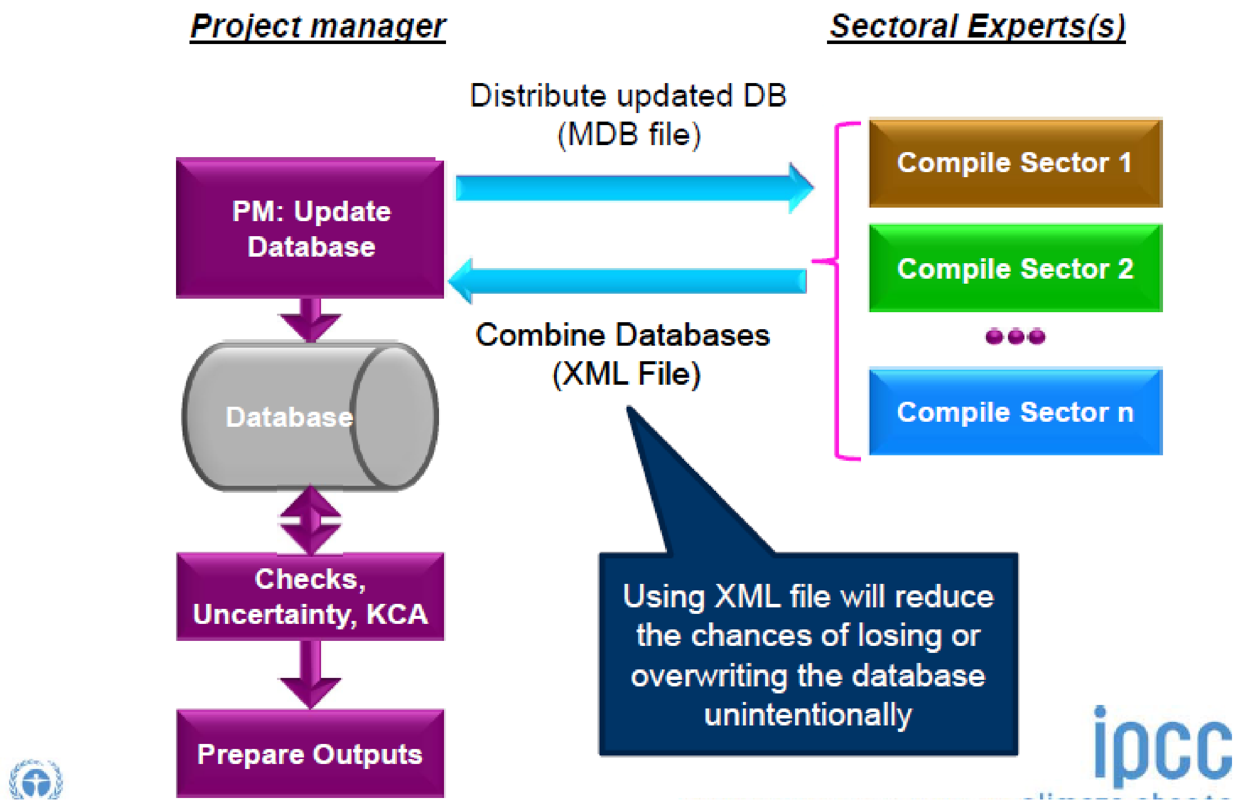


Figure 1-2. GHG national inventory data generation and database management

There are several IPCC guidelines and application that can be used to carry out a National GHG inventory. The 2006 IPCC is considered appropriate for this manual especially the improvements in AFULO sector in terms of completeness and flexibility. It is still possible to report under the 1996 guidelines. As of version (ver2.12.5080.17129) the software is limited to the 5 main GHG (compulsory gases) of CO_2, CH_4, N_2O, CO and NMVOCs. Where it is critically needed, other GHG emissions e.g., of SO_2, HFCs, PFCs, SF_6, NOx may calculated using other software or excel.

1.7 2006 IPCC Software structure

The IPCC Inventory software allows data input for all categories, sectors and sub sectors. All the 2006 IPCC main sectors are shown in the left navigation pane by default. If checked, the tree will be expanded automatically to show the whole hierarchy (Figure 1-3). The basic approach of the software is to enable filling out the *2006 IPCC Guidelines* category worksheets with the activity and emission factor data.

Data capture worksheets are arranged in rows and columns that resemble MS Excel worksheets. Country specific default values may be used. Where not available, IPCC default values are provided. In addition, reference is made to the relevant tables (in the IPCC guidelines) where default values can be found. This helps the inventory compiler to check that appropriate default values are used. It is important that note that reference to default value tables are category specific. The 2006 IPCC is arranged in the following volumes and these are volume 2, volume 3, and volume 4 for Energy, Industry, Agriculture and other lands and Waste respectively.

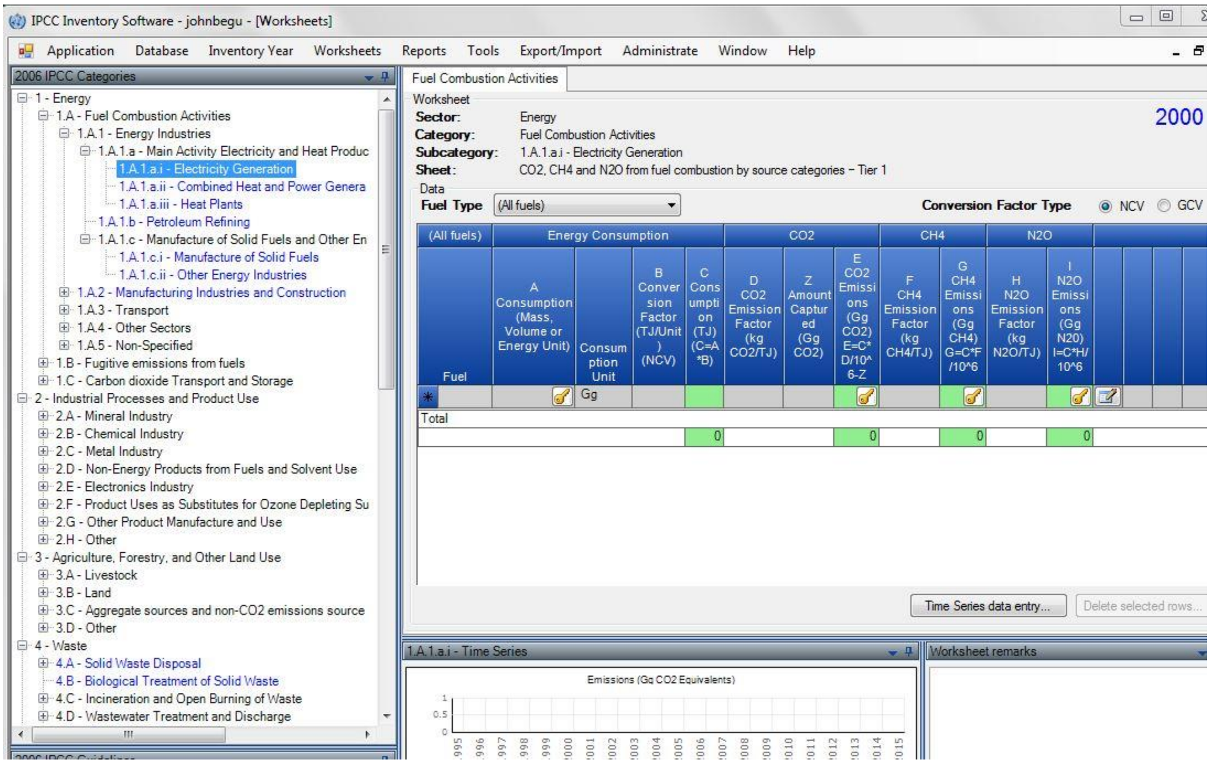


Figure 1-3. Example of IPCC software structure

In addition it also supports many other functions related to database administration, Quality Control, data export / import as well as data reporting. For illustration purposes, examples of data capture worksheets are provided in several topics within this manual and there are hereafter referred to as software worksheets.

1.8 IPCC Software Uncertainty and KCA Tool

The previous sections provided the background and step by step uncertainty KCA analysis plus examples of tools that can be used. This was intended to provide the user of this manual with knowledge and background of these critical components of the GHG inventory. The 2006 IPCC software has inbuilt capacity to provide the same assessments so long as the inventory compiler has internalized these concepts.

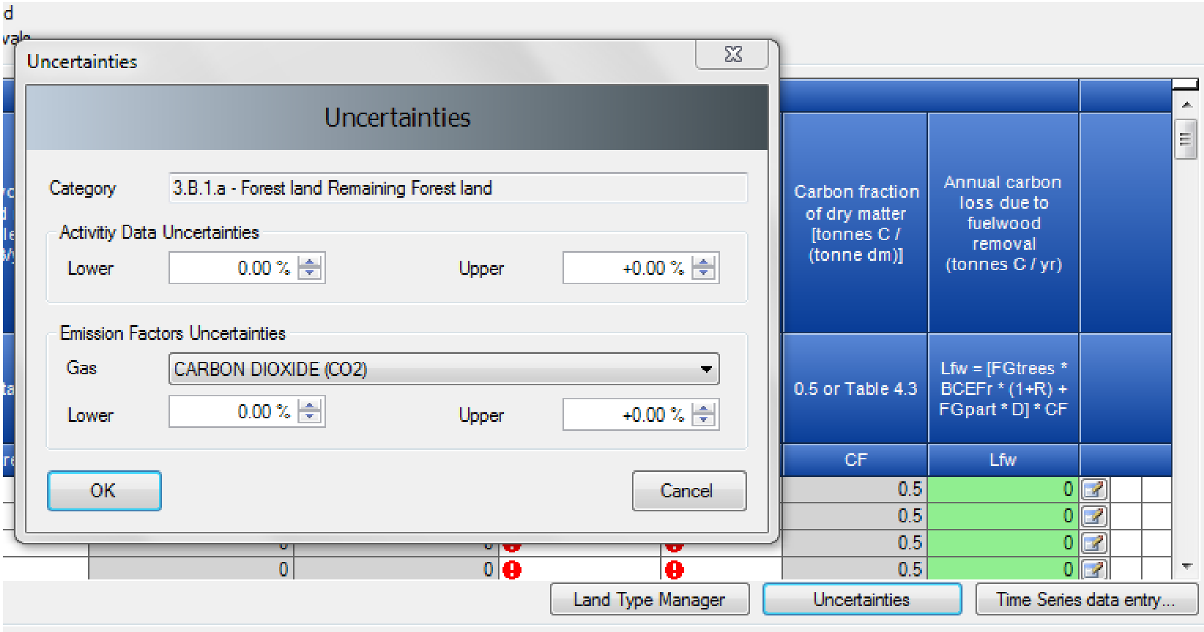


Figure 1-4. Uncertainty and KCA Tools within 2006 IPCC

The 2006 IPCC tools require one to enter the lower and upper limit uncertainty (Figure 1-4). There after one may have an overview of sectoral uncertainties and perform Key Category Analysis (KCA) using the reports menu (Figure 1-5).

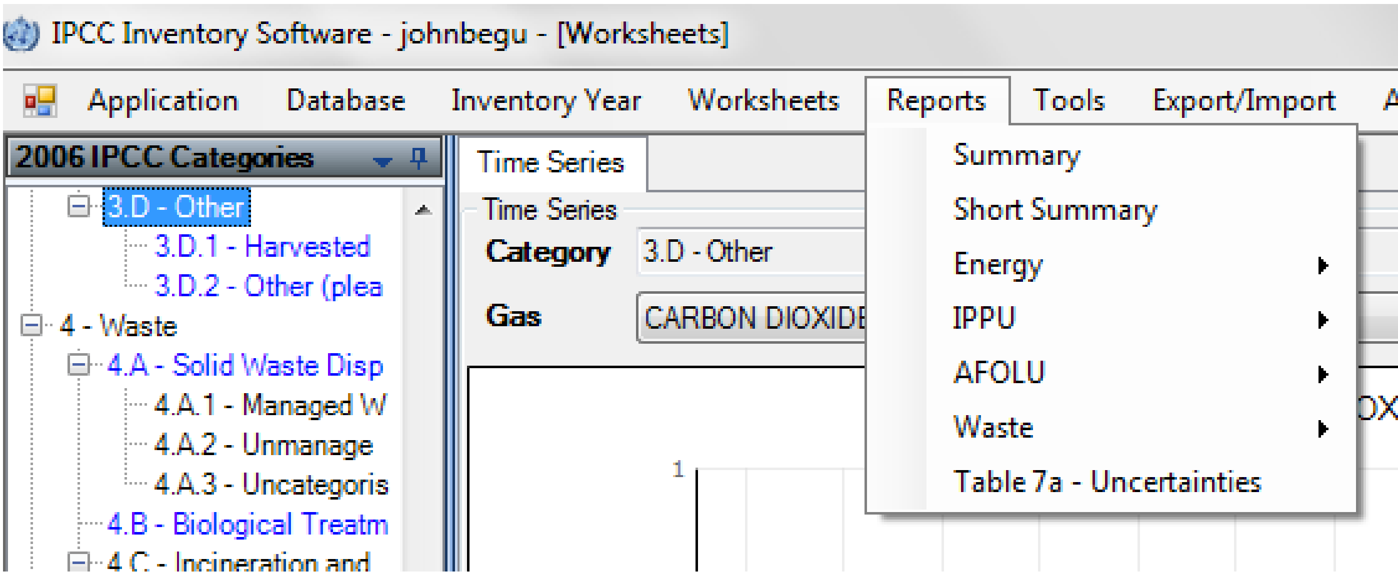


Figure 1-5. Key Category Analysis (KCA) Using the 1006 Software

2 Energy Sector

Energy sector is the engine of the economy. There is a strong linkage between the economic development and energy consumption. In most countries modern energy is driven by fossil fuels. It is for this reason is that in most countries the energy sector is a major source of anthropogenic GHG emissions. As the country is set to increase development mostly in the petroleum sector, it is envisaged the landscape of emission in the energy sector will change drastically in the foreseeable future. The government is planning to build refineries and pipelines for petroleum products. These will be among the main sources of GHG emissions in the near future. The energy sector in Uganda is currently dominated by use of biomass in form of fuel wood, charcoal and agricultural residues. The biomass use finds applications in the residential, commercial and industrial subsector. Fossil fuels find applications in all subsectors. Most of the fossil fuel is used in the transport subsector. It is for this reason most of the anthropogenic GHG is from the transport sector.

Generally the emissions in the energy sector comes from different sources, thus from generation, transformation, transportation and its use at the end use level. There are basically two source categories of combustion-related activities, namely stationary combustion and mobile combustion. The combustion of fuel is used to produce energy e.g. motive power, heat and electricity. As the result of combustion, the following GHG are emitted: Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The other gases are Nitrogen Oxides (NO_X), Sulphur dioxide (SO_2) and Non-Methane Volatile Organic Compounds (NMVOC). There are two types of approaches which can be used to calculate emissions in the energy sector. These are reference approach and sectoral approach.

There two approaches of estimating emissions from the energy sector; the reference approach and the sectoral approach.

2.1 Reference Approach

The method used in reference approach is based on the primary fuels supply and distribution. This approach is top down. The calculation of apparent consumption is based on the fuel imports, exports to the neighbouring countries, the amount of primary and secondary fuel exported, the amount of fuel used for international aviation and marine transport and the variations in the quantity of fuel in stock.

2.1.1 Category information under Reference Approach

The data on production will be considered when Uganda starts to produce petroleum based fuels. The calculation of CO_2 emissions is based on the fuel imported. It should ideally give a higher CO_2 emission than sectoral approach. The fuels in the international bunkers and exports are not distributed in the country. This method is theoretically an upper bound to sectoral approach. This can be described as a straightforward top-down methodology where emissions of CO_2 from combustion of mainly fossil fuels may be estimated relatively easily from available energy supply statistics.

The Reference Approach methodology breaks the calculation of carbon dioxide (CO_2) emissions from fuel combustion into 5 steps:

- Step 1: Estimate Apparent Fuel Consumption in Original Units
- Step 2: Convert to a Common Energy Unit
- Step 3: Multiply by Carbon Content to Compute the Total Carbon
- Step 4: Compute the Excluded Carbon
- Step 5: Correct for Carbon Unoxidised and Convert to CO_2 Emissions

Under the reference approach, data is organized under fuel five types of Liquid fuels, Solid fuels, gaseous fuels, Other fossil fuels and Peat (Figure 2-1).

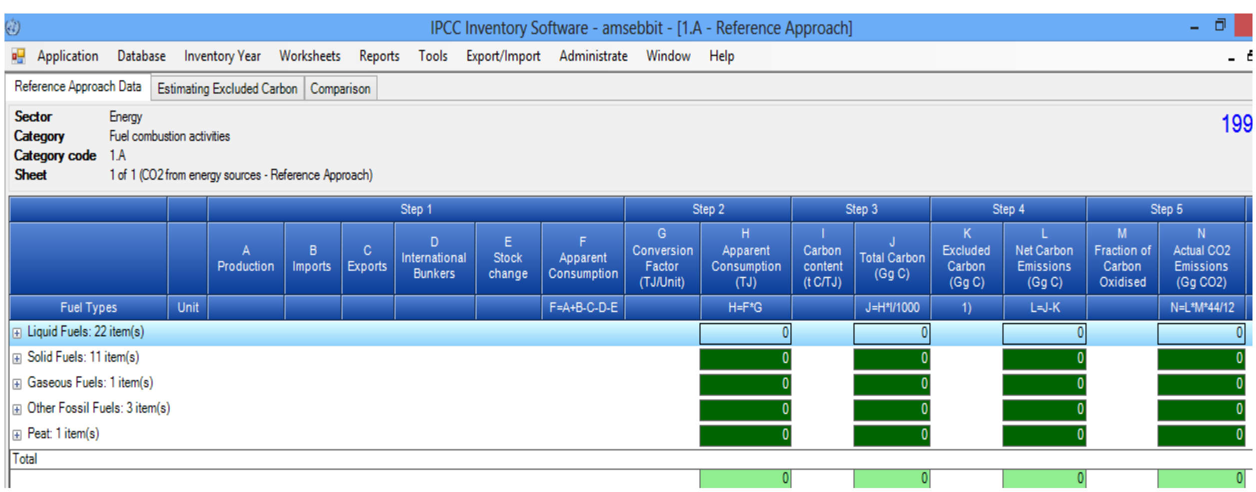


Figure 2-1. IPCC Inventory software Reference Approach

2.1.2 Methodology approach

2.1.2.1 Estimation of CO_2 Emission

Estimation of annual CO_2 emissions is made by use of the Table 1A1 and 1A2 in the Annex 1 worksheet, page A1.10 of volume 2, 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Using the 2006 IPCC software, fraction of carbon oxidized when burning the fuels is captured. This corresponds to Column M in Table 1A in Annex 1 volume 2, 2006 IPCC Guidelines and the software Figure 2-1). The figures for the actual carbon emissions and the actual CO_2 emissions are calculated automatically by the software.

The Reference Approach can be accessed through the pull down menu of the inventory software. It has columns from A-N . Appropriate parameter should be entered in the columns. Typical use of the 2006 IPCC Software for National GHG Inventory is as shown in Figure 2-1.

2.1.2.2 Estimation of Carbon content in fuels

Generally, there is considerable variation in the energy and carbon content by weight and volume of fuels. The inventory compiler has to select the carbon content factors for each fossil fuel type and the estimation of the total carbon content of fuels consumed. There could be considerable variation in carbon content factors both among and within primary fuel types, it is for this reason they are given in ranges.

The inventory compilers are required to input the carbon emission factors (kg CO_2/TJ) for each fuel type. The carbon content is provided on the drop down menu in the inventory software. However default values of carbon content (lower and upper values) can be obtained from Table 1.3, Chapter 1, page 1.21, Volume 2, 2006 IPCC. Default carbon content, carbon oxidation and CO_2 emission factors for each fuel type are listed in Table 1.4, Chapter 1, Volume 2, page 1.23, 2006 IPCC Guidelines for National Greenhouse Gas Inventories. For quick references for default carbon content and default CO_2 emission factor are as shown Appendix A, Table A-1and Table A-2 respectively.

2.1.2.3 Estimation of Non Energy use of Fuels

In some cases fuels such as kerosene is used for non-energy purposes such as a feed stock. It is important to account for the carbon that is stored in non-energy uses of fossil fuels. To compute the amount of fuel using the table in the Annex 1 worksheet page A1.10 in 2006 IPCC Guidelines for National Greenhouse Gas Inventories is used. It is estimated that 10% of the total kerosene is used in manufacturing processes which are non-energy. It is used as feedstock.

2.1.2.4 Net Carbon Emissions

The computation of net carbon emissions can be done using Table 1A in Annex 1 volume 2, 2006 IPCC Guidelines. In the column K (sheet 3 of 3 Table 1A) the inventory compiler should enter the relevant information for calculating the carbon stored in products. Since fossil fuels are used for non-energy purposes to some degree, it is also important to account for the carbon that is stored in non-energy uses of fossil fuels.

2.1.3 Activity data Reference Approach

Under reference approach activity is the apparent consumption of various fuel types as listed in first column in Figure 2-1.

2.1.3.1 Apparent Consumption

Uganda currently imports all fossil fuels. The apparent consumption is calculated based on imports of primary and secondary fuels, the amounts of primary fuels produced the amounts of primary and secondary fuels exported, the amount of fuel used for international bunkers and the net increase or decrease in stocks of the fuels. At least two of these components (exports and international bunkers) are not distributed within the country. The CO_2 emission computed based on the apparent fuel consumption gives overall national inventory of fuel supply. Since Uganda is net importer of fossil fuels the importation data can be obtained from Uganda Revenue Authority and Ministry of Energy and Mineral Development. However the fuel exported and used for international bunkers such as international aviation and marines are not included in the national inventory, but presented as a separate item as per recommendation by the IPCC guidelines . At national level the fuel used in the domestic aviation and marines should be reported in the nation inventory.

2.1.3.2 The Computation of Apparent Consumption

The estimation of CO_2 emission respective of the tier used, in this case Reference Approach was considered for calculation by using equation 2-1:

Equation 2-1. Estimating Apparent Consumption

$$Apparent\ comsuption = Primary\ fuel\ produced + import - export - international\ bunkers - net\ change\ in\ stocks \quad (2.1).$$

All the required data such as imports, exports and the stocks can be obtained from national statistics, energy statistics and national energy balance. The data sources are mostly from Ministry of Energy and Mineral Development and Uganda Revenue Authority. The inventory compiler enters type data either in TJ or Gg. In Uganda the national energy balance unit used is kTOE. The data has to be converted from kTOE to TJ. The conversion factor is 41.868 TJ /kTOE. There also an option of entering data Gg as a unit in the IPCCC Inventory software.

2.1.4 Emission Factors under Reference Approach

Emission factor is a product of net carbon emission and fraction of carbon oxidized. Estimation of net carbon emission is explained section 2.1.2.4 above.

2.2 Sectoral Approach

Under Energy Sector, denoted as (1) in the inventory software, there are three major categories based on 2006 IPCC guidelines. These are A.1 Fuel Combustion Activities, 1.B Fugitive Emissions from Fuels and I.C Carbon dioxide Storage and Transport. 1.B Fugitive Emissions from Fuels and I.C Carbon dioxide Storage and Transport is not applicable to Uganda. For this matter, only one key category (A.1 Fuel Combustion Activities) is considered in Uganda.

This approach involves looking at the actual consumption of the specific subcategory. It is also referred to as bottom up approach. This approach is similar in methodology to reference approach in steps of calculations, but there are important conceptual differences. The reference approach is based on the estimate of an apparent consumption by type of fuels derived not from fuel consumption data but from high level energy supply data by types of fuels at country level.
Contrary to the Reference method, the Sectoral methodology (bottom-up approach) is based on real fuel consumption data (by types of fuels) reported for the subsectors (subcategories) considered in the category. Fuel Combustion is subdivided further into five sectors of Energy Industries (1.A.1), Manufacturing Industries and Construction (1.A.2), Transport (1.A.3), Other Sectors (1.A.4), and None Specified (1.A.5).

2.2.1 **Category Information of Stationary combustion**

The equipment used in stationary combustion are not movable. Examples of stationary combustions are diesel generators used to generate electricity in industries, heavy fuel oil electric generators and steam boilers. There are private companies which generate electricity from fossil fuels and bagasse to meet the growing energy demand. Currently Uganda has few auto producers they are undertakings which generate electricity/heat wholly or partly for their own use an activity that support their primary activity of electricity or heat, as an example there are cogeneration plants that produce electricity and heat by the private sector. Cogeneration is common in sugar factories. Some of the sugar factories generate electricity for their internal needs and excess is sold to the national grid. Auto production is sometimes also called auto generation, self-generation or self-production.

2.2.1.1 Energy Industries (1.A.1)

Energy industries comprises of emissions from fuels combusted by energy-producing industries. This sub category includes emissions from generation of electricity (1.A.1.a.i) and combined heat and power generation (1.A.1.a.ii) for own use in these industries. Petroleum fuels are used by Independent Power Producers to generate electricity and sell to the national grid. There are also several companies with generators which are used whenever there is load shedding.

Manufacture of solid fuel (1.A.1.c.i) (charcoal) is mostly done using traditional method with low efficiency. The efficiency of traditional kiln is estimated at 12%. Charcoal is mostly used in the urban households.

2.2.1.2 Manufacturing Industries and Construction (1.A.2)

Manufacturing Industries and Construction sector is still developing. The major industries are 1.A.1.2.a Iron and Steel most of the activities it involves recycling of steel scraps, 1.A.1.2.e Food Processing and Beverages, 1.A.1.2.d Pulp Paper and Printing; and 1.A.1.2.k Construction. The energy consumption is this subcategory is aggregated in the national energy statistics.

2.2.2 **Methodology**

The Tier 1 is used because it is simplest calculation method and it requires the least data. Although it is likely to provide the least accurate estimates of emissions, higher Tiers can be used when there is sufficient data. Applying a Tier 1 emission estimate requires the following information for each source category and fuel: Data on the amount of fuel combusted in the source category. This data can be obtained from national statistics. Emission factor can be obtained from the default values provided in the either IPCCC Tables or EMEP/EEA Air Pollutant Emission Inventory guidebook 2013, together with associated uncertainty range.

2.2.2.1 Computation of CO_2, CH_4 and NO_2 Emission

Under the sectoral approach, the general formula used for computation of emissions using Tier 1 which applies to both direct and indirect emissions. The inventory compiler needs to identify applicable activity data and emission factor. The equations from volume 2, chapter 2, and page 2.11, 2006 IPCC Guidelines for National Greenhouse Gas Inventories are presented in Equation 2.2 and Equation 2.3.

The same Equations 2.2 and 2.3 can be used to calculate CO_2 and non-CO_2 emissions. Fuel consumption can be obtained from national statistics as illustrated in the activity data in section 2.2.3 of this document.

Equation 2-2. General Equation for estimating emissions under sectoral approach

$$Emissions_{GHG,\ fuel,} = Fuel\ Consumption_{\ fuel,} \bullet Emission\ Factor_{GHG,\ fuel,}\ (2.2)$$

Where

Emissions$_{GHG\ ,fuel}$ = emissions of a given GHG by type of fuel (kg GHG)

Fuel Consumption$_{fuel}$= amount of fuel combusted (TJ)

Emission FactorGHG,$_{fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ).

The total emission from different types of fuels can be calculated using equation 2-3

Equation 2-3. Estimating Total emission

$$Emissions_{GHG} \sum_{Fuels} Emissions_{GHG,fuel}$$

2.2.2.2 The Computation of Emissions for Non CO_2 gases

When fuels such as gasoline, diesel, wood/wood-waste, charcoal, and other biomass fuels are combusted apart from CO_2, the following non- CO_2 gases are emitted: Nitrogen oxides (NOx), Carbon monoxide (CO), and Non-methane volatile organic compounds (NMVOC). Emission factors for CH_4 and N_2O for different source categories differ due to differences in combustion technologies applied in the different source categories.

The subcategories considered are Energy industries (1.A.1); Manufacturing Industries and Construction (1.A.2) and Other Sectors (1.A.4). The use EMEP/CORINAIR Emission Inventory Guide is applicable in this section because it has updated data. The general equation derived from EMEP/EEA emission inventory NFR Energy Industry (1.A.1), page 13 Guidebook 2013 was used for non CO_2 gases are as shown in Equations 2-4 and 2-5.

Equation 2-4. General Equation for precursor gases

$$E_{pollutant} = AR_{fuel,pollutant} * EF_{pollutant}$$

where: $E_{Pollutant}$ = emissions of pollutant (kg),

$AR_{fuel\ consumption}$ = fuel used in the industrial combustion (TJ) for each fuel,

$EF_{fuel,pollutant}$ = an average emission factor (EF) for each pollutant for each unit of fuel type used (kg/TJ

The total emission from different types of fuels is calculated using Equation 2-5.

Equation 2-5. Summation of precursor gas emissions

$$Emissions_{GHG} \sum_{Fuels} Emissions_{GHG,fuel}$$

2.2.2.2.1 Methane

Biomass based fuels such as fuelwood; charcoal, agricultural residues and municipal waste combustion are the major contributors to CH_4 emissions. The contribution of fuel combustion to global emissions of methane is minor and the uncertainty is high. Methane is produced in small quantities from fuel combustion due to incomplete combustion of hydrocarbons in fuel.

2.2.2.2.2 N_2O

Nitrous oxide is emitted when transportation fuels are burned. Motor vehicles, including passenger cars and trucks, are the primary source of N_2O emissions from transportation. The amount of N_2O

emitted from transportation depends on the type of fuel and vehicle technology, maintenance, and operating practices. Reducing mobile fuel consumption in motor vehicles can reduce transportation emissions and the introduction of pollution control technologies, such as catalytic converters to reduce exhaust pollutants from passenger cars can also reduce emissions of N_2O.

2.2.2.3 Precursor gases

The inventory compiler is reminded that 2006 IPCCC inventory software does not offer direct calculation of the four precursor gases. However emission can be calculated using other software and later added to the summary sheet. The use EMEP/CORINAIR Emission Inventory Guide is applicable in this section because it has updated emission data. The general equation used for non CO_2 gases is as shown in Equation 2-2. .

2.2.2.3.1 Nitrogen Oxides NOx

Nitrogen oxides are indirect greenhouse gases. They have effect on the environment for their role in forming ozone (O_3), as well for their direct acidification effects. Fuel combustion activities form a significant anthropogenic source of NOx. Within fuel combustion, the most important sources are the energy industries and mobile sources.

2.2.2.3.2 Carbon Monoxide (CO)

Carbon monoxide is one of the indirect greenhouse gases. Most of CO emissions from fuel combustion come from motor vehicles. It is an intermediate product of the combustion process and in particular under stoichiometric combustion conditions. The emissions from mobile sources are a function of the efficiency of combustion and post combustion emission controls.

2.2.2.3.3 Non-Methane Volatile Organic Compounds (NMVOC)

These products of combustion are indirect greenhouse gases. The major sources are from fuel combustion activities are mobile and residential combustion. They are products of incomplete combustion. The emission of NMVOC decreases in large combustion plants and increasing plant efficiency.

2.2.2.3.4 Sulphur dioxide (SO_2)

Although SO_2 is not a greenhouse gas but its presence in the atmosphere may influence climate. Sulphur dioxide can react with a variety of photochemically produced oxidants to form sulphate aerosols. Burning of fossil fuels which contain sulphur is harmful to the environment. The emissions of sulphur oxides (SO_x) are directly related to the sulphur content of the fuel.

2.2.3 **Activity Data**

In most cases the activity data in Uganda is aggregated. There are limited specific data on energy at end use levels. It is for the reason aggregated data are used in most cases. The activity data is used to estimate emissions for the each category. The data required includes, values, units and years. The detailed reference should be provided. Most of information about activity data can be obtained from the UBOS. Energy Industries (1.A.1), the amount and types of fuels consumed in this sector. The units should be either in TJ or Gg. The sources of data are from UBOS and Ministry of Energy and Mineral Development Statistics, Uganda Electricity Transmission Company and other energy service providers. Manufacturing Industries and Construction (1.A.2) category the data is mostly from UBOS and National Energy Balance.

The data for Other Sectors (1.A.4) can be obtained from UBOS. These data are useful in computation of emission as illustrated in Section 2.4 of this document. The Type of Activity data requires the entry of the type of fuel. As an example the activity data for energy industry can be filled as shown in Table 2-1. The Manufacturing Industries and Construction (1.A.2) is as shown in Table 2-2

Table 2-1. Energy industries (1.A.1) Activity Data

Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Reference	Other Information (e.g., date obtained and data source or contact information)	Category QA/QC Procedure Adequate / Inadequate / Unknown	Are all data entered correctly into models, spreadsheets, etc.? Yes / No (List Corrective Action)	Checks with Comparable Data (e.g., At international level, IPCC defaults). Explain and show results.
Diesel	15677	TOE	2000	NEB 2000	December 2001 MEMD	Inadequate.	It will have to be the by quality controller	The data was comparable to UBOS.
Charcoal	333442	TOE	2000	NEB 2000	December December 2001 MEMD	Inadequate.	It will have to be the by quality controller	The data was comparable to UBOS.

Table 2-2. Manufacturing Industries and Construction (1.A.2) Activity Data

Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Reference	Other Information (e.g., date obtained and data source or contact information)	Category QA/QC Procedure Adequate / Inadequate / Unknown	Are all data entered correctly into models, spreadsheets, etc.? Yes / No (List Corrective Action)	Checks with Comparable Data (e.g., At international level, IPCC defaults). Explain and show results.
Heavy Fuel Oil	31600	TOE	2000	National Energy Balance 2000	June 2001 Ministry of Energy and Mineral Development	Inadequate	Not sure . The data has to be cross checked by quality controller	The data was comparable to UBOS
Fuel wood	314865	TOE	2000	NEB 2000	June 2001	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS

Other energy uses like LPG can be got from energy statistics e.g., energy balance

2.2.4 **Emission Factors Fuel Combustion (CO_2, N_2O and CH_4)**

There are two types of emission factors. The emissions which must be reported these include CO_2, CH_4 and N_2O. These data can be obtained 2006 IPCC Guidelines for National Greenhouse Gas Inventories. These emission factors can be obtained from section 2.2.4 and 2.2.5 of this document. The units should be converted to either Gg or TJ if 2006 IPCC Inventory software is used. The CO_2, emission factors mainly depend upon the carbon content of the fuel. Emission factors for CO_2 are in units of kg CO_2/TJ on a net calorific value basis and reflect the carbon content of the fuel and the assumption that the carbon oxidation factor is 1.

Examples of default emission factors for CO_2 and N_2O are given in Table 2-3 and Table 2-4 respectively. Default Emission of other gases e.g. CH_4 can be found in IPCC guidelines.

Table 2-3. Energy industries (1.A.1) CO_2 Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Diesel	74100	Kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.16	It is adequate for Tier 1 default emission factor.
Residual Fuel oil	74400	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.16	It is adequate for Tier 1 default emission factor

Table 2-4. Manufacturing Industries and Construction (1.A.2) N_2O Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Diesel	0.6	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy	It is adequate for Tier 1 default emission factor.

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
			Page 1.14,	
Residual Fuel oil	0.6	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.14,	It is adequate for Tier 1 default emission factor
Biomass	4	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.14,	It is adequate for Tier 1 default emission factor.
LPG	0.1	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.14,	It is adequate for Tier 1 default emission factor

2.2.4.1 Emission Factors for Precursor Gases in Energy Industry

Some of the heavy fuel oil is used to generate electricity. Default emission factors for Nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC) and sulphur oxides (SO_2) can be obtained from Table 2-5. The inventory compile is reminded to take note that the energy units here are g/ GJ.

Table 2-5. Energy Industry (1.A.1) Default Emission factor heavy fuel oil (g/GJ).

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.1.a	Public electricity and heat production			
Fuel	Heavy Fuel Oil				
Not applicable					
Not estimated	NH3, PCBs, Benzo(a)pyrene, HCB				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	142	g/GJ	70	300	US EPA (2010), chapter 1.3
CO	15.1	g/GJ	9.06	21.1	US EPA (2010), chapter 1.3
NMVOC	2.3	g/GJ	1.4	3.2	US EPA (2010), chapter 1.3
SOx	495	g/GJ	146	1700	See Note

Ref: Table 3-5 Tier 1 emission factors for source category 1.A.1.a using heavy fuel oil. EMEP/EEA Air Pollutant Emission Inventory guidebook 2013.

Grid electricity may not be available due to load shedding or electric energy system fialure. Under such circumstances, gas oil is used to generate electricity. Default emission factors of precursors gases can be obtained from Table 2-6. Note that currently data in Uganda is aggreagated. The uncernity is high but is optional for Tier 1

Table 2-6. Energy Industry (1.A.1) Emission factor for gas oil (g/GJ).

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.1.a	Public electricity and heat production			
Fuel	Gas oil				
Not applicable					
Not estimated	NH3, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, HCB				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	65	g/GJ	22	195	US EPA (1998), chapter 1.3
CO	16.2	g/GJ	4	65	US EPA (1998), chapter 1.3
NMVOC	0.8	g/GJ	0.48	1.28	US EPA (1998), chapter 1.3
SOx	46.5	g/GJ	4.65	465	See Note

Ref : Table 3-6 Tier 1 emission factors for source category 1.A.1.a using gas oil**,** EMEP/EEA Air Pollutant Emission Inventory guidebook 2013.

Hint: The inventory compiler has to note the units of g/GJ

Biomass is commonly in sugar factories to generate steam which is used for heating process and electricity to run equiment and lighting. Default emission factors for precursor gases can be obtained from Table 2-7 .

Table 2-7. Energy Industry (1.A.1) Emission factor for Biomass

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.1.a	Public electricity and heat production			
Fuel	Biomass				
Not applicable					
Not estimated	NH3				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	81	g/GJ	40	160	Nielsen et al., 2010
CO	90	g/GJ	45	180	Nielsen et al., 2010
NMVOC	7.31	g/GJ	2.44	21.9	US EPA (2003), chapter 1.6
SOx	10.8	g/GJ	6.45	15.1	US EPA (2003), chapter 1.6

Table 3-7 Tier 1 emission factors for source category 1.A.1.a using biomass, EMEP/EEA Air Pollutant Emission Inventory guidebook 2013.

Charcoal production emission and emission factors are considered under the energy industries subcategory 1.A.1. Most of the charcoal is produced using traditional kilns. The efficiency is low. The emission factor for Non-CO2 emission factors for charcoal production is given in Table 2-8. The inventory complier has to take choose one method either wood input or charcoal produced.

Table 2-8. Non-CO_2 emission factors for charcoal production (in kg/TJ).

Compound	Default Emission Factor (kg/TJ of Wood Input)(a)	Default Emission Factor (kg/TJ of Charcoal Produced)
CH_4	300	1000
N_2O	NAV	NAV
NO_x	5	10
CO	2000	7000
NMVOC	600	1700
SO_2	NAV	NAV
(a) Assuming 1 kg charcoal is produced from 6 kg wood and the energy content for wood and charcoal is 15 and 30 MJ/kg respectively. 1 TJ charcoal produced is equivalent to 3 TJ wood input.		

Ref: Vol 2,Chap1, page 1.46 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

The Manufacturing Industries and Construction (1.A.2), categories, the Default Emission Factors for CO_2 and N_2O are as shown in and Table 2-9 and Table 2-10 respectively, while emission for CH_4 is as presented in Table 2-11. For quick references see Appendix A, Table A-4.

Table 2-9. Manufacturing Industries and Construction: (1.A.2) CO_2 Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Residual Fuel oil	74400	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.16	It is adequate for Tier 1 default emission factor
LPG	63100	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.16	It is adequate for Tier 1 default emission factor
Biomass	112000	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.16	It is adequate for Tier 1 default emission factor

Table 2-10. Manufacturing Industries and Construction: (1.A.2) N_2O Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Residual Fuel oil	0.6	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.18-1.19	It is adequate for Tier 1 default emission factor
LPG	0.1	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.18-1.19	It is adequate for Tier 1 default emission factor
Biomass	1.5	kg/TJ	2006 IPCC. Table 2.4 . Volume 2 Energy Page 1.17	It is adequate for Tier 1 default emission factor

Table 2-11. Manufacturing Industries and Construction: (1.A.2) CH_4 Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Residual Fuel oil	3	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.18-1.19	It is adequate for Tier 1 default emission factor
LPG	1	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.18-1.19	It is adequate for Tier 1 default emission factor
Biomass	100	kg/TJ	2006 IPCC. Table 2.2 . Volume 2 Energy Page 1.18-1.19	It is adequate for Tier 1 default emission factor

2.2.4.2 Emission Factors for Precursor Gases manufacturing and Construction category (1.A.2)

There are basically four main types of fuels used in this category to generate heat required in the indusrties. These fuels are liquids, gaseous, solid(coal) and biomass.

The use of gasous fuels in Uganda’s manufacturing and Construction sector is still very limited. One of the tiles and brick factories uses LPG as the main source of energy. Of recent one of the cement factories has started importing coal. The default emission factors for the relevant precursor gases for the four fuels gaseous, Solid, Liqud and biomass are given in Table 2-12, Table 2-13, Table 2-14and Table 2-15 respectively.

Table 2-12. Default emissions factors for gaseous fuels in manufacturing industries and construction

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.2	Manufacturing industries and construction			
Fuel	Gaseous Fuels				
Not applicable					
Not estimated	NH3, PCBs, HCB				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NO_x	74	g/GJ	46	103	See note
CO	29	g/GJ	21	48	See note
NMVOC	23	g/GJ	14	33	See note
SO_x	0.67	g/GJ	0.40	0.94	See note

Ref: Table 3-3 Tier 1 emission factors for 1.A.2 combustion in industry using gaseous fuels. EMEP/EEA Air Pollutant Emission Inventory guidebook 2013.

Table 2-13. Tier 1 emission factors for 1.A.2 combustion in industry using solid fuels

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.2	Manufacturing industries and construction			
Fuel	Solid Fuels				
Not applicable					
Not estimated	NH3				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	173	g/GJ	150	200	Guidebook (2006) chapter B216
CO	931	g/GJ	150	2000	Guidebook (2006) chapter B216
NMVOC	88.8	g/GJ	10	300	Guidebook (2006) chapter B216
SOx	900	g/GJ	450	1000	Guidebook (2006) chapter B216
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Page 15, Table 3-2 Tier, 1 EMEP/EEA Air Pollutant Emission Inventory guidebook 2013.

Table 2-14. Tier 1 emission factors for 1.A.2 combustion in industry using liquid fuels

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.2	Manufacturing industries and construction			
Fuel	Liquid Fuels				
Not applicable					
Not estimated	NH3, PCBs, HCB				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NO_x	513	g/GJ	308	718	See note
CO	66	g/GJ	40	93	See note
NMVOC	25	g/GJ	15	35	See note
SO_x	47	g/GJ	28	66	See note

Ref: Page 17, Table 3-4Tier, 1 EMEP/EEA Air Pollutant Emission Inventory guidebook 2013

Table 2-15. Tier 1 emission factors for 1.A.2 combustion in industry using biomass fuels

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.2	Manufacturing industries and construction			
Fuel	Biomass				
Not applicable					
Not estimated	NH3				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NO_x	91	g/GJ	20	120	Lundgren et al. (2004) [1)]
CO	570	g/GJ	50	4000	EN 303 class 5 boilers, 150-300 kW
NMVOC	300	g/GJ	5	500	Naturvårdsverket, Sweden
SO_2	11	g/GJ	8	40	US EPA (1996) AP-42, Chapter 1.9

Ref: Page 18, Table 3-5 Tier, 1 EMEP/EEA Air Pollutant Emission Inventory guidebook 2013

The Default Emission Factors CO_2, CH_4 and N_2O in Other Sectors (1.A.4) category are as shown in Table 2-16, Table 2-17 and Table 2-18.

Table 2-16. Table Other Sectors (1.A.4) CO2 Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Wood fuel	112000	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 .	It is adequate for Tier 1 default emission factor

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
			2006 PICC guidelines	
Kerosene	71900	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
Charcoal	112000	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
Agric Waste	100000	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
LPG	63100	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor

Table 2-17. Other Sectors (1.A.4) CH4 Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Wood fuel	300	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Kerosene	10	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
Charcoal	200	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
Agric Waste	300	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
LPG	5	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor

Table 2-18. . Other Sectors (1.A.4) NO2 Default Emission Factors

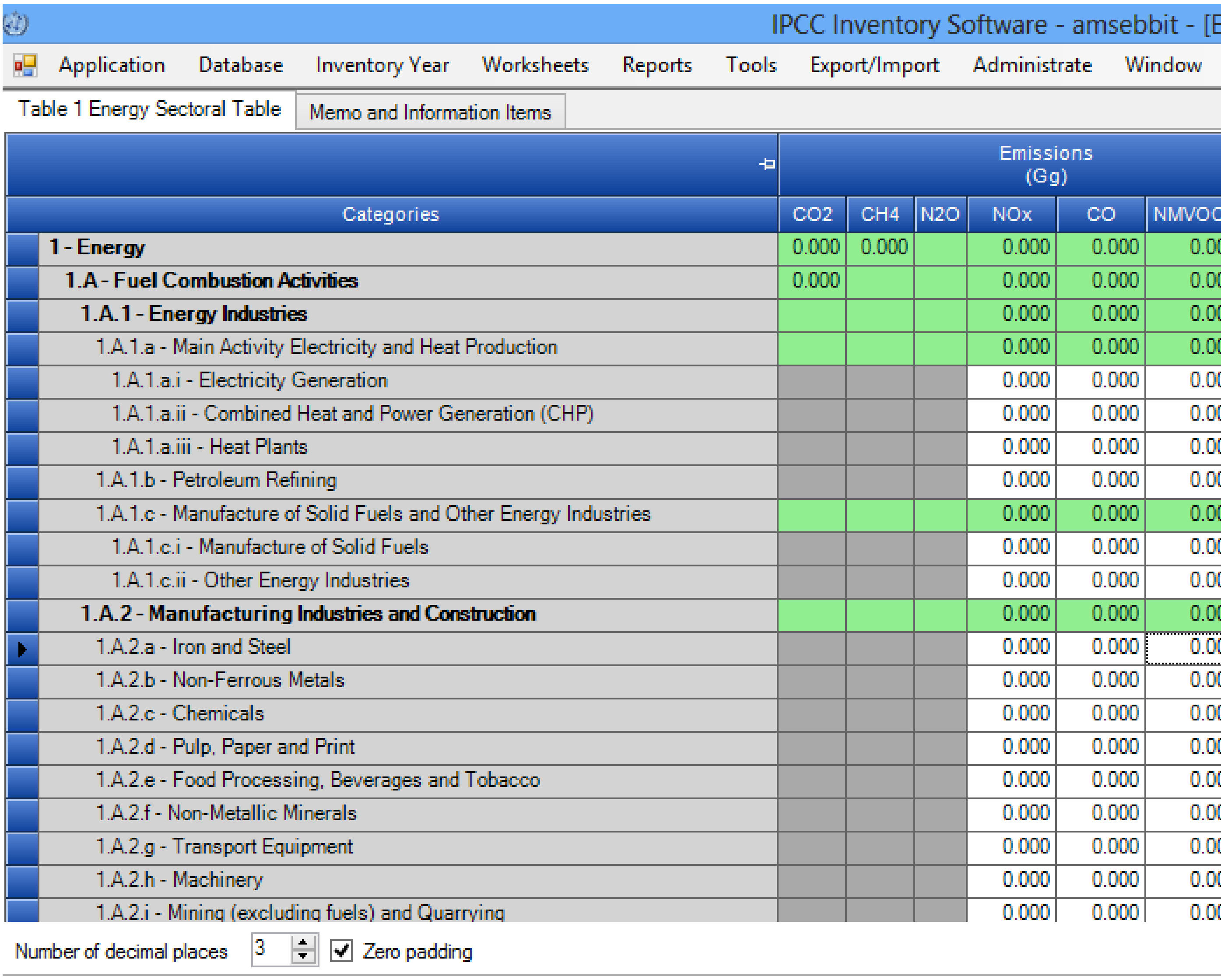
Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Wood fuel	4	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
Kerosene	0.6	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 .	It is adequate for Tier 1 default emission factor

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
			2006 PICC guidelines	
Charcoal	1	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
Agric Waste	4	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.20 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor
LPG	0.1	kg/TJ	Volume 2, Chapter 2, Table 2.4, page 2.19 . 2006 PICC guidelines	It is adequate for Tier 1 default emission factor

2.2.4.2.1 Reporting on Precursor gases using the 2006 IPCC Software

Precursor gases are manually captured into the software unlike emissions of other gases that calculated by the software based on activity data and emissions factor. Precursor gases emissions may be calculated using spread sheets or other software.

These gases are included by selecting report form the main menu bar followed by a pull down menu select energy. Figure 2-2 represents that the inventory compile would manually fill in the precursor emission. This process applies to all subcategories such as Manufacturing Industries and Construction (1.A.2) and Other Sectors (1.A.4).



IPCC Inventory Software - amsebbit - [E

Application | Database | Inventory Year | Worksheets | Reports | Tools | Export/Import | Administrate | Window

Table 1 Energy Sectoral Table | Memo and Information Items

Categories	Emissions (Gg)					
	CO2	CH4	N2O	NOx	CO	NMVOC
1 - Energy	0.000	0.000		0.000	0.000	0.0
1.A - Fuel Combustion Activities	0.000			0.000	0.000	0.0
1.A.1 - Energy Industries				0.000	0.000	0.0
1.A.1.a - Main Activity Electricity and Heat Production				0.000	0.000	0.0
1.A.1.a.i - Electricity Generation				0.000	0.000	0.0
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				0.000	0.000	0.0
1.A.1.a.iii - Heat Plants				0.000	0.000	0.0
1.A.1.b - Petroleum Refining				0.000	0.000	0.0
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries				0.000	0.000	0.0
1.A.1.c.i - Manufacture of Solid Fuels				0.000	0.000	0.0
1.A.1.c.ii - Other Energy Industries				0.000	0.000	0.0
1.A.2 - Manufacturing Industries and Construction				0.000	0.000	0.0
1.A.2.a - Iron and Steel				0.000	0.000	0.0
1.A.2.b - Non-Ferrous Metals				0.000	0.000	0.0
1.A.2.c - Chemicals				0.000	0.000	0.0
1.A.2.d - Pulp, Paper and Print				0.000	0.000	0.0
1.A.2.e - Food Processing, Beverages and Tobacco				0.000	0.000	0.0
1.A.2.f - Non-Metallic Minerals				0.000	0.000	0.0
1.A.2.g - Transport Equipment				0.000	0.000	0.0
1.A.2.h - Machinery				0.000	0.000	0.0
1.A.2.i - Mining (excluding fuels) and Quarrying				0.000	0.000	0.0

Number of decimal places 3 ☑ Zero padding

Figure 2-2. Emissions from the energy sector

The default factors presented for Tier 1 apply to technologies without emission controls; the emission factors for non CO_2 combustion can be obtained from 1996 IPCCC reference guidelines volume 3. The other improved methods such as by EMEP/EEA Air Pollutant Emission Inventory guidebook 2013, but at times it need more data from subcategories than the 1996 IPCC reference manual.

2.2.4.3 List Uncertainty Estimates (optional)

Uganda like most of the developing countries, data collection remains a challenge. UBOS is leading institution in data collection. They however do not publish data on uncertainty. In the national census the level of confidence is 95%. The increase in population is used to project future energy consumption in the household sector. In most cases the energy data is aggregated. The aggregate data related to energy consumption by fossil fuel type are generally, unlike in developed countries not estimated accurately. The data comes from oil companies and there could also be fuel smuggling. The estimated uncertainty is estimated be about 15%. There is more uncertainty for biomass and traditional fuels that is because results from survey can be used for projection for a period of more than ten years.

The activity data uncertainty ranges shown in Table 2-19. Level of Uncertainty Associated with Stationary Combustion Activity Data, may be used when reporting uncertainties. It is good practice for inventory compiler to check also with the national statistics.

Table 2-19. Level of uncertainty associated with stationary combustion activity data

Sector	Well developed statistical systems		Less developed statistical systems	
	Surveys	Extrapolation	Surveys	Extrapolation
Main activity electricity and heat production	Less than 1%	3-5%	1-2%	5-10%
Commercial, institutional, residential combustion	3-5%	5-10%	10-15%	15-25%
Industrial combustion (Energy intensive industries)	2-3%	3-5%	2-3%	5-10%
Industrial combustion (others)	3-5%	5-10%	10-15%	15-20%
Biomass in small sources	10-30%	20-40%	30-60%	60-100%

The inventory compiler should judge which type of statistical system best describes their national circumstances.
Source: IPCC *Good Practice Guidance* and Uncertainty Management in National Greenhouse Gas Inventories (2000)

The emission factors for CO, NOx, NMVOC and SO_2 in different categories and sub categories are given in EMEP/EEA Air Pollutant Emission Inventory guidebook 2013. The confidence interval is 95%, the upper and lower limits are given in Table 2-19.

Emission factors According to expert judgment, CO_2 emission factors for fuels are generally well determined as they are primarily dependent on the carbon content of the fuel (EPA, 2004). For example, the default uncertainty value for diesel fuel is about ± -1.5 percent and for residual fuel oil ± -3 percent. The uncertainty for non-CO_2 emissions, however, is much greater. The uncertainty of the CH_4 emission factor may range as high as 50 percent. The uncertainty of the N_2O emission factor may range from about 40 percent below to about 140 percent above the default value (Watterson, 2004).

2.2.4.4 Additional Information

There is need to improve on data collection in all subsectors. It is important to have quality controllers at all levels, data collection, data entry and archiving.

2.2.5 **Transport (1.A.3)/ Mobile Combustion**

The mobile combustion emissions are generated from transportation of the energy carriers by road, ship, rail and air. Transport by land is the dominant means of transport in Uganda. The examples of land transportation are roads and railways, while civil aviation and marine navigation are transport by air and water respectively. The emission from fuels used in the international transport activities is reported separately and excluded from the national inventory total.

Transport subcategory (1.A.3), the emissions are from the combustion and evaporation of fuel for all transport activities. Transport subcategory is very important in the national economy. Civil Aviation (1.A.3.a)is growing over the last decades. International Aviation (International Bunkers) (1. A. 3. a.i) is the major consumer of aviation fuels imported in the country while Domestic Aviation (1. A. 3.a ii) Emissions from civil domestic passenger and freight traffic in Uganda is negligible.

2.2.5.1 Aviation (1.A.3.a)

The level of civil aviation development is still low. Uganda has only one international air and few airfields which are operational. Nearly all the flights from Entebbe international airport are international. Domestic aviation industry is not well developed.

2.2.5.2 Category Information

The Emissions from aviation come from the combustion of jet fuel and aviation gasoline. Aircraft engine emissions are roughly composed of about 70 percent CO_2, and less than 1 percent each of NOx, CO, SOx, and NMVOC. Emissions depend on the number and type of aircraft operations; the types and efficiency of the aircraft engines; the fuel used; the length of flight; the power setting; the time spent at each stage of flight; and, to a lesser degree, the altitude at which exhaust gases are emitted

2.2.5.2.1 Methodology

The Tier 1 method is based on an aggregate quantity of fuel consumption data for aviation (LTO and cruise) multiplied by average emission factors. The methane emission factors have been averaged over all flying phases based on the assumption that 10 percent of the fuel is used in the LTO phase of the flight. Emissions are calculated according to Vol.2 Chap 3 page 3.59 Equation 3.6.1, 2006 IPCC. The aviation equation can be expressed using the general equation 2-2.

Domestic and international emissions are to be estimated separately using the above equation 2. 14, Tier 1 method is also used for jet-fuelled aviation activities when aircraft operational use data are not available. Domestic and international emissions are to be estimated separately using equation 2-2.

2.2.5.2.2 Activity Data

The aviation fuel consumption is available in national energy statistics and the energy balance which is prepared by the Ministry of Energy and Mineral Development. Although the domestic fuel consumption is small, the data can also be obtained from the Civil Aviation Authority. The energy consumption in form of aviation gas in the aviation sub category was 32,253 TOE in 2000. The data was o obtained from the National Energy balance for 2000 published by the Ministry of Energy and Mineral Development. The Q/A &Q/C could not be ascertained. The data is comparable to the UBOS.

2.2.5.2.3 Emission Factors

The CO_2 emission factor for aviation is as shown in Table 2-20

Table 2-20. Civil Aviation Emission Factors for CO2

Fuel	Default (kg/TJ)	Lower	Upper
Aviation Gasoline	70 000	67 500	73 000
Jet Kerosene	71 500	69 800	74 400

Default values for CH_4 and N_2O from aircraft are given in (Ref: Table 3.6.5, Page 3.64). Different types of aircraft/engine combinations have specific emission factors and these factors may also vary according to distance flown.

Tier 1 assumes that all aircraft have the same emission factors for CH_4 and N_2O based on the rate of fuel consumption. This assumption has been made because more disaggregated emission factors are not available at this level of aggregation. Non CO_2 emission factors are as shown in Table 2-21.

Table 2-21. Civil Aviation Non CO_2 emission Factors

Fuel	CH_4 Default (Uncontrolled) Factors (in kg/TJ)	N_2O Default (Uncontrolled) Factors (in kg/TJ)	NO_x Default (Uncontrolled) Factors (in kg/TJ)
All fuels	0.5[a] (-57%/+100%)[b]	2 (-70%/+150%)[b]	250 ±25%[c]

[a] In the cruise mode CH_4 emissions are assumed to be negligible (Wiesen *et al.*, 1994). For LTO cycles only (i.e., below an altitude of 914 metres (3000 ft.)) the emission factor is 5 kg/TJ (10% of total VOC factor) (Olivier, 1991). Since globally about 10% of the total fuel is consumed in LTO cycles (Olivier, 1995), the resulting fleet averaged factor is 0.5 kg/TJ.

[b] IPCC, 1999.

[c] Expert Judgement.

Emission factors for other gases (CO and NMVOC) and sulphur content which were included in the 1996 IPCC Guidelines can be found in the EFDB.

2.2.5.2.4 Uncertainty

Activity data much of the uncertainty in water-borne navigation emission estimates is related to the difficulty of distinguishing between domestic and international fuel consumption. With complete survey data, the uncertainty may be low (say ± -5 percent), while for estimations or incomplete surveys the uncertainties may be considerable (say ± -50 percent). The uncertainty will vary widely from country to country and is difficult to generalise. Global data sets may be helpful in this area, and it is expected that reporting will improve for this category in the future.

2.2.6 Road Transport subcategory (1.A.3.b)

Road transport is the dominant means of transport in Uganda. There is some improvement in the infrastructure. The number of motor vehicles imported in on increase of the last decades.

2.2.6.1 Category Information

Most of the anthropogenic GHG emission is from the road sector. That is because most of the vehicles imported were previously owned. In general the maintenance practice and culture in Uganda is not adequate. There is very limited public transport and most of them ply upcountry, but the Kampala City there is hardly and public transport apart from the 14 passenger minibuses.

2.2.6.2 Methodology

Emissions of CO_2 are calculated on the basis of the amount and type of fuel combusted and its carbon content. The Tier 1 approach calculates CO_2 emissions by multiplying estimated fuel sold with a default CO_2 emission factor. The approach is represented in Equation 2-2 or 3.2.1 from Volume 2: Energy page 3.12, 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The general equation 2-2 can be also be used to compute emissions for CO_2, CH_4 and N_2O. Equation 2-.6 provides units of energy and emission factor of the general equation (Equation 2-2).Note that NMVOC and SO_2 use different equations which are explained later in the section and section 2.2.6.2.4

Equation 2-6. General Equation Details

$$Emission = \sum_a [Fuel_a \bullet EF_a]$$

Where:

- Emission = Emissions of CO_2 (kg)
- $Fuel_a$ = fuel sold (TJ)
- EF_a = emission factor (kg/TJ). This is equal to the carbon content of the fuel multiplied by 44/12.
- a = type of fuel (e.g. petrol, diesel, natural gas, LPG etc)

2.2.6.2.1 CO_2 Emissions

The estimated emissions of CO_2 are computed on the basis of the amount and type of fuel combusted and its carbon content. Due to limited availability of data the Tier 1 approach is used to calculate CO_2 emissions. The equation used for calculation is from Vol.2, chap 3, page 3.13, equation 3.2.1 IPCC 2006 Guidelines.

2.2.6.2.2 Emission of CH_4 and N_2O

The emissions of CH_4 and N_2O depend on vehicle technology, fuel and operating characteristics. The calculation is based on the fuel sold since it is not possible to estimate fuel consumption by vehicle type. It is assumed that there is no control of the emission. The calculation of the emission is adapted; Vol.2 Chap 3, page 3.13 equation 3.2.3 is from IPCC 2006 Guideline.

2.2.6.2.3 The Emission of Precursor Gases in Transport sub category

The emission factors of precursor gases are not available in 2006 IPCC Guidelines. However, the emission factors for Nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC) may be obtained from 1996 IPCCC reference guidelines volume. The use EMEP/CORINAIR Emission Inventory Guide is not appropriate because it requires more data than 1996 IPCCC Guidelines. The general equation for calculation of CO, NOx, SO_2 and NMVOC is provided in Chapter 1 page 1.42, Volume 3, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual**.**

2.2.6.2.4 Sulphur Dioxide Emission from Fuel Combustion)

The emission factor for SO_2 is not available in tabular form in 2006 IPCCC Guidelines. However the equation and approach for estimation is provided for completeness and possible future use (Equation 2-7). Emission factor in the transport sector are provided in Chapter 1, page 1.43, Volume 3, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual. The improved emission factor by EMEP/EEA Air Pollutant Emission Inventory guidebook 2013, but it needs more data than the 1996 IPCCC, which is not readily available.

Equation 2-7. Estimating SO_2 Emissions

$$EF\left[\frac{kg}{TJ}\right] = 2 * \frac{s}{100} * \frac{1}{Q} * 10^6 * \left(\frac{100-r}{100}\right) * \left(\frac{100-n}{100}\right) \qquad 2.10$$

Where:

EF = Emission Factor (kg/TJ);

2 = SO_2 /S [kg/kg];

s = Sulphur content in fuel [%];

r = Retention of sulphur in ash [%];

Q = Net calorific value [TJ/kt];

10^6 = (Unit) conversion factor; and

n = Efficiency of abatement technology and/or reduction efficiency [%].

The sulphur content of fuel and the net caloric value is as shown in Table 2-22 and Table 2-23 respectively.

Table 2-22. . The Sulphur content in fuel

Type of fuel	Default	CORINAIR 90
Diesel Road	0.3	0.1-1.0
Gasoline	0.1	0.012-0.15
Jet kerosene	0.05	0.0001-0.3

Reference: Chapter 1, Table 1-12, Page, 1.44, Volume 3, sample and default values of sulphur content in fuel, 1996 PCCC Inventory guideline

Table 2-23. Net Calorific Value of Fuels

Type of fuel (Refined)	Net Calorific Value (TJ/10^3 tonnes)
Diesel Road	43.33
Gasoline	44.80
Jet kerosene	44.59

Reference: Chapter 1, Table 1.3, page 1.23Volumes 3 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual 1.23

2.2.6.3 The Activity Data

The most commonly used fuels in the transport sector are diesel, gasoline and aviation fuel. In road transport, diesel is most popular fuel followed by gasoline. The inventory compiler can add more fuels in the Table 2-24 below.

Table 2-24. Emission Factors: Road Transport (1.A.3) Activity Data

Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Reference	Other Information (e.g., date obtained and data source or contact information)	Category QA/QC Procedure Adequate / Inadequate / Unknown	Are all data entered correctly into models, spreadsheets, etc.? Yes / No (List Corrective Action)	Checks with Comparable Data (e.g., At international level, IPCC defaults). Explain and show results.
Gasoline	147322	TOE	2000	National Energy Balance 2000	June 2001 MEMD	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS
Aviation Fuel	32253	TOE	2000	N EB 2000	June 2001 = MEMD t	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS
Kerosene	9298	TOE	2000	NEB 2000	June 2001 MEMD	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS
Diesel	125416	TOE	2000	NEB 2000	June 2001 MEMD	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS

2.2.6.4 Emission Factor s CO_2

The emission from Road Transport (1.A.3) subcategory is as shown in Table 2-25,

Table 2-.28 and Table 2-.29, for quick reference for other types of fuels can be found in Appendix A, Table A-6, Table A-7 and Table A-8.

Table 2-25. Transport (1.A.3) CO_2 Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Gasoline	69,3000	kg/TJ	Volume 2, Chapter 2, Table 2.2, Page 1.14, 2006 IPCC Guidelines	It is adequate for Tier 1 default emission factor
Diesel	74,100	kg/TJ	1.14, 2006 IPCC Volume 2, Chapter 2, Table 2.2, Page Guidelines	It is adequate for Tier 1 default emission factor
Gasoline	69300	kg/TJ	1.14, 2006 IPCC Volume 2, Chapter 2, Table 2.2, Page Guidelines	It is adequate for Tier 1 default emission factor
Aviation gas	70,000	kg/TJ	1.14, 2006 IPCC Volume 2, Chapter 2, Table 2.2, Page Guidelines	It is adequate for Tier 1 default emission factor
Kerosene	71500	kg/TJ	1.14, 2006 IPCC Volume 2, Chapter 2, Table 2.2, Page Guidelines	It is adequate for Tier 1 default emission factor

Table 2-26. Transport (1.A.3) N_2O Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Gasoline	3.2	kg/TJ	Volume 2, Chapter 3, Table 3.3.2, Page 3.21, 2006 IPCC Guidelines	It is adequate for Tier 1 default emission factor
Diesel	3.9	kg/TJ	Volume 2, Chapter 3, Table 3.3.2, Page 3.21, 2006 IPCC Guidelines	It is adequate for Tier 1 default emission factor

Table 2-27. Table 2 29. Transport (1.A.3) CH_4 Default Emission Factors

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Gasoline	33	kg/TJ	Volume 2, Chapter 3, Table 3.3.2, Page 3.21, 2006 IPCC Guidelines	It is adequate for Tier 1 default emission factor
Diesel	3.9	kg/TJ	Volume 2, Chapter 3, Table 3.3.2, Page 3.21, 2006 IPCC Guidelines	It is adequate for Tier 1 default emission factor

2.2.6.5 The Emission Factor for Precursor Gases

Unlike other sectors, it was not possible to use the CEMP/CONAIR because more data is required before the given tables can be used by inventory complier. In this case IPCC 1996 reference was used as shown in Table 2-28

Table 2-28. Emission factor for precursor gases in Transport Category (1.A.3) (kg/TJ)

Transport Mode	NOx[a]		CO[b]		NMVOC[c]		SO_2[d]	
Aviation	300		100		50		1.1	
Road	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
	600	800	8000	1000	1500	200	2.2	6.9

References :

[a] page 1.42 , Table1-11, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

[b] page 1.40 Table 1-10, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

[c] page 1.38 Table 1-9 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

[d] SO_2 is calculated

2.2.6.6 Uncertainty

At international level, CO_2 is usually responsible for about 97% of the CO_2 equivalent. The expert judgements suggest that uncertainty is about ± 5% based on studies with reliable fuel statistics. The primary source of uncertainties is based on the activity data rather that the emission factors. The uncertainty in Uganda can be about 20 % with error margin of ± 5%.

2.2.6.7 Improvement

There is need to carry national vehicle inventory so that the fleet and capacities of will be determined. It is not only good for improvement of emission data but also for urban planning.

2.2.7 Railways (1.A.3.c)

Rail transport is one of the mobile sources and concerns the movement of freight or people by rail, but in Uganda it is currently limited to movement of freight. Generally the railway transport is under developed.

2.2.7.1 Category Information

At present railway locomotives uses diesel and in future electric will be used. .

There is low use of railway system in Uganda. Diesel locomotives generally use diesel engines. The contribution of emissions from railways originates from the combustion of fuel to propel trains. Exhaust emissions from railways arise from the combustion of liquid fuels in diesel engines to provide propulsion..

2.2.7.2 Methodology Emission in Railways

The pollutants for which rail are SO_2, NO_x, CO_2 ,CO, NMVOCs (non- methane volatile organic compounds) and some metals. The calculation of emission can be done using equations from IPCCC and MEP/CONAIR 2013.

2.2.7.2.1 CO_2 Emissions

Tier 1 is used to calculate emissions in the railway. The general equation can be found in Vol.2 Chapter 3, Equation 3.4.1 is from IPCC 2006. Similarly equation 2-2 can be used to calculate emissions in this subcategory.

The Tier 1 default emission factors should be considered applicable both to diesel and gas oil fuels.

2.2.7.2.2 CH_4 and N_2O Emissions

The equations weighing of CH_4 and N_2O Emissions Factors for specific Technologies. The general equation (Equation 2-2) is applicable.

2.2.7.2.3 SO_2 Emissions

Emissions of SO_2 of the railway transport may be calculated by use of equation 2-8:

Equation 2-8. SO_2 Railway transport

$$E_{SO2} = 2 \times \sum_{m} k_{S,m} \times FC_m$$

Where:

E_{SO2} = emissions of sulphur dioxide for the period concerned in the inventory [kg],

$k_{S,m}$ = the sulphur content in the fuel (% by mass).

Typical sulphur content in gas oil is 0.1 % by mass and for diesel is 0.005 % by mass. Exact values may be provided by the railways operators in each country. Table 2-29 : Non- CO_2 Emission Factor

2.2.7.3 Activity Data

The Tier 1 approach uses fuel sales as the measure of activity .There is only one railway track which is operational in Uganda. The distance is about 200 km. That is from Kenya boarder in Malaba to Kampala. There is currently no data of the fuel use in the sector. At times there is data on tonne-kilometres in the national statistics.

The data can be obtained from depots. It also assumed that the quantity of fuel sold in a year is the quantity of fuel used in that year.

2.2.7.4 The Emissions

The emission for the CO_2, CH_4 and N_2O can be abstained from the Vol.2, Chap 3, Page 3.43 Table 3.4.1, 2006 IPCC. Table 2-29 show the emission of major GHG gases.

Table 2-29. Default emission factor for most common fuel used for rail transport

Gas	Diesel (kg/TJ)			Sub-bituminous Coal (kg/TJ)		
	Default	Lower	Upper	Default	Lower	Upper
CO_2	74 100	72 600	74 800	96 100	72 800	100 000
CH_4 [1]	4.15	1.67	10.4	2	0.6	6
N_2O [1]	28.6	14.3	85.8	1.5	0.5	5

Notes:

[1] For an average fuel consumption of 0.35 litres per bhp-hr (break horse power-hour) for a 4000 HP locomotive, (0.47 litres per kWh for a 2983 kW locomotive).(Dunn, 2001).

[2] The emission factors for diesel are derived from (EEA, 2005) (Table 8-1), while for coal from Table 2.2 of the Stationary Combustion chapter.

These default emission factors may, for non-CO2 gases, be modified depending on the engine design parameters in accordance with Equation 2.13 using pollutant weighing factors in Table 2-30.

Table 2-30. Pollutant weighing Factors as Function of an Engine Design Parameters for uncontrolled Engine

Engine type	CH_4	N_2O
Naturally Aspirated Direct Injection	0.8	1.0
Turbo-Charged Direct Injection / Inter-cooled Turbo-Charged Direct Injection	0.8	1.0
Naturally Aspirated Pre-chamber Injection	1.0	1.0
Turbo-Charged Pre-chamber Injection	0.95	1.0
Inter-cooled Turbo-Charged Pre-chamber Injection	0.9	1.0

Source: EEA 2005 (Table 8-9);

Source: Vol.2 Chap 3, Table 3.4.2, 2006 IPCC

The emissions for other precursor gases are as shown in Table 2-33.

Table 2-31. Default Precursor Emission Factors for Railway

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.c	Railways			
Fuel	Gas Oil/Diesel				
Not estimated	SO_x, Pb, Hg, As, PCDD/F, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NO_x	52.4	kg/tonne fuel	25	93	Aggregated Tier 2 method
CO	10.7	kg/tonne fuel	6	19	EMEP CORINAIR Gdbk 3.2/2006
NMVOC	4.65	kg/tonne fuel	2	8	EMEP CORINAIR Gdbk 3.2/2006
NH_3	0.007	kg/tonne fuel	0.004	0.012	EMEP CORINAIR Gdbk 3.2/2006
TSP	1.52	kg/tonne fuel	3	23	Aggregated Tier 2 method
PM_{10}	1.44	kg/tonne fuel	2	16	Aggregated Tier 2 method
$PM_{2.5}$	1.37	kg/tonne fuel	2	14	Aggregated Tier 2 method
Cd	0.01	g/tonne fuel	0.003	0.025	EMEP CORINAIR Gdbk 3.2/2006
Cr	0.05	g/tonne fuel	0.02	0.2	EMEP CORINAIR Gdbk 3.2/2006
Cu	1.7	g/tonne fuel	0.5	4.9	EMEP CORINAIR Gdbk 3.2/2006
Ni	0.07	g/tonne fuel	0.02	0.2	EMEP CORINAIR Gdbk 3.2/2006
Se	0.01	g/tonne fuel	0.003	0.025	EMEP CORINAIR Gdbk 3.2/2006
Zn	1	g/tonne fuel	0.3	2.5	EMEP CORINAIR Gdbk 3.2/2006
Benzo(a)pyrene	0.03	g/tonne fuel	0.01	0.1	EMEP CORINAIR Gdbk 3.2/2006
Benzo(b)fluoranthene	0.05	g/tonne fuel	0.02	0.2	EMEP CORINAIR Gdbk 3.2/2006
(*) CO_2	3140	kg/tonne fuel	3120	3160	EMEP CORINAIR Gdbk 3.2/2006
Benz(a)anthracene	0.08	g/tonne fuel	0.03	0.2	EMEP CORINAIR Gdbk 3.2/2006
Dibenzo(a,h)anthracene	0.01	g/tonne fuel	0.004	0.03	EMEP CORINAIR Gdbk 3.2/2006

2.2.7.5 Uncertainty Assessment

Greenhouse gas emissions from railways are typically much smaller than those from road transportation because the amounts of fuel consumed are less, and also because operations. The use of representative locally estimated data is likely to improve accuracy although uncertainties may remain large.

2.2.7.6 Activity data uncertainty

The uncertainty in top-down activity data (fuel use) is likely to be of the order 5 percent. The uncertainty in disaggregated data for bottom-up estimates (usage or fuel use by type of train) is unlikely to be less than 10 percent and could be several times higher

2.2.7.6.1 Uncertainty

Since there was no activity data, there is no uncertainty assessment.

2.2.7.6.2 Improvement

There is a need to collect data regularly on the tonne –kilometre and fuel consumption. The types of engines used in traction. When railway transport system is fully operational additional data such as person-kilometre and shutting should be collected.

2.2.8 **Water Borne Navigation (1.A.3.d)**

This source subcategory covers all types of water-borne transport. Water-borne navigation causes emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), as well as carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrogen (NOx). The activities included in this chapter are outlined in Table 1-1 (IPCC, 2006)

International water-borne navigation (1.A.3.d.i) (International bunkers), these are emissions from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation takes place on inland lakes and Includes emissions from journeys that depart in one country and arrive in a different country. That applies to ship which ply in Lake Victoria. Excludes consumption by fishing vessels.

Domestic water- borne navigation (1.A.3.d.ii); Emissions from fuels used by local vessels such boats that depart and arrive in the same country (excludes fishing). In Uganda it is the water borne navigation within national lakes, water ways and rivers.

2.2.8.1 Category Information

The emission is sector is very low. There is very limited activity in the areas of water transport in Uganda. The total emission is very low.

2.2.8.2 Methodology

The Tier 1 method is the simplest and can be applied with either default values or country-specific information. The fuel consumption data and emission factors in the Tier 1 method are fuel-type-specific and should be applied to the corresponding activity data.

2.2.8.2.1 CO_2, CH_4, and N_2O. Emissions

The calculation is based on the amount of fuel combusted and on emission factors for CO_2, CH_4, and N_2O. The calculation is shown in Vol.2. Chap 3, page 3.41 Equation 3.5.1 2006 IPCC. The emission factors are provided in Vol. 2 Chap 3. Page3.41, Table 3.5.2 and Table 3.5.3, 2006 IPCC Guidelines. For quick reference these tables are in Appendix A, Tables A-12 and Table A-13 Equations 2-9 and 2-10 show the application of water borne emission to the general equation (Equation 2-2).

Equation 2-9. Water borne Emissions

$$Emissions = \sum (Fuel\ Consumed_{ab} \bullet Emission\ Factor_{ab})$$

Where:

a = fuel type (diesel, gasoline, LPG, bunker, etc.)

b = water-borne navigation type (i.e., ship or boat, and possibly engine type.)

Equation 2-10. Summing up water borne emissions

$$E_i = \sum_m (FC_m \times EF_{i,m})$$

where:

E_i = emission of pollutant i in kilograms;

F_{Cm} = mass of fuel type m sold in the country for navigation (tonnes);

$EF_{i,m}$ = fuel consumption-specific emission factor of pollutant i and fuel type m [kg/tonne];

m = fuel type (bunker fuel oil, marine diesel oil, marine gas oil, gasoline).

2.2.8.3 Activity Data

There is no data on the boats used for transport in Uganda. Efforts should be made to collect data.

2.2.8.3.1 Default emission factors Precursor gases

The Tier 1 approach uses emission factors for each pollutant for each type of fuel used. Some factors (e.g. SO_2) depend on the fuel quality, which may change from batch to batch, and from year to year, and consequently these emission factors include a 'Sulphur content of fuel' factor. Table 2-32, Table 2-33 and Table 2-34 provide emission factors for ships using bunker fuel oil, marine diesel oil/marine gas oil and gasoline.

Table 2-32. Tier 1 emission factors for ships using bunker fuel oil

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.d.i	International navigation			
Fuel	Bunker Fuel Oil				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex,				
Not estimated	NH3, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	79.3	kg/tonne fuel	0	0	Entec (2007). See also note (2)
CO	7.4	kg/tonne fuel	0	0	Lloyd's Register (1995)
NMVOC	2.7	kg/tonne fuel	0	0	Entec (2007). See also note (2)
SOx	20	kg/tonne fuel	0	0	Note value of 20 should read
TSP	8.2	kg/tonne fuel	0	0	Entec (2007)

Reference: SNAP 080402 page 13,EMEP/EEA emission inventory guidebook 2013

Table 2-33. Tier 1 emission factors for ships using marine diesel oil/marine gas oil

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.d.i	International navigation			
Fuel	Marine diesel oil/marine gas oil (MDO/MGO)				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex,				
Not estimated	NH3, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	78.5	kg/tonne fuel	0	0	Entec (2007). See also note (2)
CO	7.4	kg/tonne fuel	0	0	Lloyd's Register (1995)
NMVOC	2.8	kg/tonne fuel	0	0	Entec (2007). See also note (2)
SOx	20	kg/tonne fuel	0	0	Note value of 20 should read

Reference: SNAP 080402 page 15 EMEP/EEA emission inventory guidebook 2013

Ref Table 3-2 page 14.

Table 2-34. Tier 1 emission factors for ships using gasoline

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.d.ii	National navigation			
Fuel	Gasoline				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	9.4	kg/tonne fuel	0	0	Winther & Nielsen (2006)
CO	573.9	kg/tonne fuel	0	0	Winther & Nielsen (2006)
NMVOC	181.5	kg/tonne fuel	0	0	Winther & Nielsen (2006)
SOx	20	kg/tonne fuel	0	0	Winther & Nielsen (2006)

Reference. SNAP 080304, page 15,EMEP/EEA emission inventory guidebook 2013

2.2.8.4 Uncertainty

There no data, so the uncertainty cannot be determined.

2.2.8.5 Improvement

Effort should be made to collect data in this subcategory.

2.2.9 **Other Sectors (1.A.4)**

2.2.9.1 Category Information

This encompasses a mix of mobile, stationary, off road emissions. It includes emissions from commercial institutions (1.A.4.a), residential (1.A. 4.b), and Agriculture, Forestry, Fish farms etc (1.A.4.c). The emission from Other Sectors (1.A.4), which include emission from 1.A.4.a commercial / institutional from combustion of fuels such as kerosene, LPG and biomass. The commercial sector and institutions includes hotels, schools and restaurants. The combustion of 1.A.4.b Residential, this includes all emissions from fuel combustion in households. The most common fuels are fuelwood, charcoal and agriculture waste. There also emissions from

1.A.4.c Agriculture / Forestry / Fishing / Fish farms the source of emission is the fuel combustion in agriculture, forestry, fishing and fishing industries such as fish farms.

2.2.9.2 Methodology

Tie1 is used to calculate the CO_2, CH_4 and N_2O Emissions. The general formula (Equation 2-2) is applicable.

2.2.9.3 Activity Data

Activity may be found scattered in different institutions. Table 2-35 provides examples on data households energy use. The inventory compiler may find other information e.g., on institutions, energy used in fishing, agriculture form MAAIF, UBOS and Uganda's energy balance.

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Table 2-35. Other Sectors (Residential) (1.A.4.a) Activity Data

Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Reference	Other Information (e.g., date obtained and data source or contact information)	Category QA/QC Procedure Adequate / Inadequate / Unknown	Are all data entered correctly into models, spreadsheets, etc.? Yes / No (List Corrective Action)	Checks with Comparable Data (e.g., At international level, IPCC defaults). Explain and show results.
Fuelwood	4684651	TOE	2000	National Energy Balance 2000	June 2001 Ministry of Energy and Mineral Development	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS
Charcoal	254566	TOE	2000	National Energy Balance 2000	June 2001 MEMD	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS
Kerosene	37190	TOE	2000	National Energy Balance 2000	June 2001 MEMD	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS
LGP	1350	TOE	2000	National Energy Balance 2000	June 2001 MEMD	Inadequate	The data has to be cross checked by quality controller	The data was comparable to UBOS

2.2.9.4 Emission Factors (others)

The emission factor for CO_2 in Other Sectors (1.A.4) which includes institutions, commercial and households are as shown in Table 2-36 and for fishing Table 2-37 while for other fuels is as illustrated in Appendix A, Table A-5. For other sector the inventory have to get relevant information from 2006 IPCC guidelines and EMEP/EEA 2013 Guidebook.

Table 2-36. Other Sectors (1.A.4) Fuel combustion CH_4

Type of Factor	Emission or carbon-stock change Factor Value	Emission or carbon-stock change Factor Units	Reference	Explain how this factor is appropriate to national circumstances. Provide sources.
Kerosene	10	kg/TJ	Revised 2006, IPCC Guidelines, Reference Manual Vol 2.Cap.2 Table 2.4 page 2.20	Limited data
Firewood	300	kg/TJ	Reference Manual Revised 2006, IPCC Guidelines, Reference Manual Vol 2.Cap.2 Table 2.4 page 2.21	Limited data
Charcoal	200	kg/TJ	Reference Manual Revised 2006, IPCC Guidelines, Reference Manual Vol 2.Cap.2 Table 2.4 page 2.21	Limited data
Agricultural waste	300	kg/TJ	Reference Manual Revised 2006, IPCC Guidelines, Reference Manual Vol 2.Cap.2 Table 2.4 page 2.21	Limited data
LPG	5	kg/TJ	Reference Manual Revised 2006, IPCC Guidelines, Reference Manual Vol 2.Cap.2 Table 2.4 page 2.21	Limited data

Table 2-37. Emissions factor of precursor gases from the fishing boats

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.3.d.ii	National navigation			
Fuel	Gasoline				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	9.4	kg/tonne fuel	0	0	Winther & Nielsen (2006)
CO	573.9	kg/tonne fuel	0	0	Winther & Nielsen (2006)
NMVOC	181.5	kg/tonne fuel	0	0	Winther & Nielsen (2006)
SOx	20	kg/tonne fuel	0	0	Winther & Nielsen (2006)

2.2.9.4.1 Emission Factors for Precursor Gases for Other Sectors (1.A.4)

Due to low level of electrification, most of the rural households use kerosene for lighting and to limited extent for cooking. The default emission factors for the precursor gases from liquid fuels used in household is as given in Table 2-38. The inventory complier should note the unit g/GJ.

Table 2-38. Precursor Emission Factors of liquid fuels in Residential Sector (1.A.4)

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	'Other' Liquid Fuels				
Not applicable	HCH				
Not estimated	NH_3, HCB, PCB				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	51	g/GJ	31	72	*
CO	57	g/GJ	34	80	*
NMVOC	0.69	g/GJ	0.4	1.0	*
SOx	70	g/GJ	42	97	*

Reference: Table 3-5 Tier 1 emission factors for NFR source category 1.A.4.b, using liquid fuels

Biomass is the dominant fuel used for cooking in the household. In rural area they rely on fire wood while in urban areas the use of charcoal is very common. The emission of precursor gases in the households is shown in Table 2-39.

Table 2-39. Precursor Emission Factors of biomass fuels in Residential Sector (1.A.4)

Tier 1 default emission factors					
	Code	Name			
NFR source category	1.A.4.b.i	Residential plants			
Fuel	Biomass				
Not applicable	HCH				
Not estimated					
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NOx	80	g/GJ	30	150	Pettersson et al. (2011) [1)]
CO	4000	g/GJ	1000	10000	Pettersson et al. (2011) and Goncalves et al. (2012) [2)]
NMVOC	600	g/GJ	20	3000	Pettersson et al. (2011) [2)]
SO2	11	g/GJ	8	40	US EPA (1996) AP-42, Chapter 1.9

Reference: Table 3-6 Tier 1 emission factors for NFR source category 1.A.4.b, using biomass

2.2.9.5 Uncertainty

Uncertainty in this sector is very high. For example, there is no information about number of boats used in the fishing sector. Information generated form household surveys by UBOS is considered inadequate to estimate energy use by households. The same applies to institutions. Documentation of energy by the agriculture and forestry is assumed to be 10% but there is not empirical data to support this.

2.2.9.6 Improvement

Data should be collected Department of Fisheries, Ministry of Animals Industry and Fisheries. The data should include the number of boats and their engine capacities, and the fuel consumption for the boats. In cases where there are no data on fuel consumption a sample survey can be made. It can be done at selected major landing sites with users of the motor boat. It is most likely that not all the boats are registered allowance can be made for the unregistered boats mostly on the islands in the lakes and other water ways.

3 INDUSTRIAL PRODUCTS AND PRODUCT USE

Industrial Processes and Product Use (IPPU) is a sector that covers greenhouse gas emissions occurring from industrial processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel carbon. Due to low level of industrialisation, the emission in this sector is not significant. The related emissions in Ugandan industries are mainly from cement and lime industries and to some extent food and beverages processing. The Government is planning to make large investment in infrastructure development including hydropower dams and roads. There will be increasing emissions in the road sector.

The main Uganda emission sources are from industrial processes that chemically or physically transform materials. During these processes, many different greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Non methane Volatile Organic Compounds ((NMVOC), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) can be produced.

In addition, greenhouse gases often are used in products such as refrigerators, foams or aerosol cans. Similarly, sulphur hexafluoride (SF_6) and N_2O are used in a number of products used in industry (e.g., SF_6 used in electrical equipment, N_2O used as a propellant in aerosol products primarily in food industry) or by end-consumers (e.g., SF_6 used in running-shoes, N_2O used during anaesthesia). The emissions associated with the energy input are not regarded as IPPU emissions and therefore not included in the emission factor estimation. They are accounted for under source category 1.A.2 – Manufacturing industries and construction in the energy sector.

There are two major cement factories in Uganda, namely Tororo Cement and Hima Cement factories .Emissions of CO_2 occur during the production of *clinker* that is an intermediate component in the cement manufacturing process. During the production of clinker, limestone, which is mainly (95%) calcium carbonate ($CaCO_3$), is heated (calcined) to produce lime (CaO) and CO_2 as a by-product. NMVOCs are produced during the processing of cereals and fruits in preparation for the fermentation processes. The beverages in this category include wine, beer and spirits. Emissions also occur in the process of bread making and other food processing.

3.1 Category Information

Industrial Processes and Product use (2) is a key category. Under Mineral Industry (2.A) The cement production (2.A.1), Lime Production (2.A.2) are the main subcategories and 2.H.2 Food and Beverages industries (EMEP/EEA emission inventory guidebook 2013).

2.D Non Energy Products from Fuels and Solvent use (2.D.3) Solvent Use (EMEP/EEA emission inventory guidebook 2013) which includes, asphalt application in road works. Emissions of CO_2 occur during the production of *clinker* that is an intermediate component in the cement manufacturing process. During the production of clinker, limestone, which is mainly (95%) calcium carbonate ($CaCO_3$), is heated (calcined) to produce lime (CaO) and CO_2 as a by-product.

The food processing and beverage (2.H.2) production are among the growing industrial activities in Uganda. This section addresses NMVOC emissions from food and beverages manufacturing, except emissions from vegetable oil extraction Emissions from food manufacturing include all processes in the food production chain which occur after the slaughtering of animals and the harvesting of crops. Emissions from drink manufacturing include the production of alcoholic beverages, especially wine, beer and spirits. Emissions occur in all the stages of food processing and beverage chains.

Asphalt is commonly referred to as bitumen is mainly produced in petroleum refineries. Asphalt surfaces and pavements are composed of compacted aggregate and an asphalt binder. This section covers emissions from asphalt paving operations as well as subsequent releases from the paved surfaces Liquefied asphalts may be used as a pavement sealant in priming roadbeds for hot mix application and for operations. Liquefied asphalts are considered to be significant sources of NMVOCs during the mixing and subsequent paving operations.

3.2 Methodology

There are several sub categories under IPPC category.

3.2.1 Emission based on the Cement Production

Portland cement is used in Uganda. There is lack of data on clinker imports, it is for this reasons the CO_2beemissions is based on cement production. Tier 1 is used for calculation CO_2 emissions using equation 3-1 (Reference Vol.3 Chap2, page 2.8, equation 2.1, 2006 IPCC)

Equation 3-1. Emissions from Related to Cement Production

$$CO_2\ Emissions = \left[\sum_i (M_{ci} \bullet C_{cl_i}) - Im + Ex\right] \bullet EF_{clc}$$

Where:

CO_2 Emissions = emissions of CO_2 from cement production, tonnes

M_{ci} = weight (mass) of cement produced of type i, tonnes

C_{cli} = clinker fraction of cement of type i, fraction

Im = imports for consumption of clinker, tonnes

Ex = exports of clinker, tonnes

EF_{clc} = emission factor for clinker in the particular cement, tonnes CO2/tonne clinker. The default clinker emission factor (EF_{clc}) is corrected for CKD.

3.2.2 Emission based on the Clinker Production

Data on clinker import and export can be obtained from Uganda Revenue Authority. If is done, then Tier 2 can be used to calculate CO_2 emission from equation 3-2 (Reference Vol.3 Chap2, page 2.9, equation 2.1, 2006 IPCC) can be used

Equation 3-2. Estimating Clinker Usage Emissions

$$CO_2\ Emissions = M_{cl} \bullet EF_{cl} \bullet CF_{ckd}$$

Where

CO_2 Emissions = emissions of CO2 from cement production, tonnes

M_{cl} = weight (mass) of clinker produced, tonnes

EF_{cl} = emission factor for clinker, tonnes CO2/tonne clinker.

CF_{ckd} = emissions correction factor for CKD, dimensionless (see Equation 2-5)

3.2.3 Lime Production

Tier 1 : Emission Factor for Lime Production can be calculated using equation 3-3 below (Reference: Vol.3, Chap.2, page 2.22 equation 2.8 , 2006 IPCC)

Equation 3-3. Lime Production Emissions

$$\begin{aligned} EF_{Lime} &= 0.85 \bullet EF_{high\ calcium\ lime} + 0.15 \bullet EF_{dolomitic\ lime} \\ &= 0.85 \bullet 0.75 + 0.15 \bullet 0.77^{a} \\ &= 0.6375 + 0.1155 \\ &= 0.75 \text{tonnes } CO_2 \text{ / tonne lime produced} \end{aligned}$$

3.2.4 Road Pavement

There is emission of NMVOCs during paving of roads. This equation is applied at the national level, using annual national road paving with asphalt. The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all sub-processes in the road paving process.

The Tier 1 approach for process emissions from road paving with asphalt uses the general equation (Equation 3-4):

Equation 3-4 Road Pavement Emissions

$$E_{pollutant} = AR_{production} . EF_{pollutant}$$

Where:

$E_{pollutant}$ = the emission of the specified pollutant

$AR_{production}$ = the activity rate for the road paving with asphalt

$EF_{pollutant}$ = the emission factor for this pollutant

3.2.5 **Food and Beverages**

The algorithm for the Tier 1 approach for process emissions from the food and beverages industry uses the general equation 3-3 above. This equation is applied at the national level, using annual national total food and beverages production. The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes in the food and beverages production.

3.2.6 **Refrigeration and Air Conditioner**

The emission of ODS substances is calculated using Tier 1 method. Tier 1 relies on the availability of basic activity data at the application level. It is a bottom approach. Net Consumption values for each HFC or PFC are then used to calculate annual emissions (references Vol.3 Chap 7, page 7.14 2006 IPCC) for applications exhibiting prompt emissions (Equation 3-5) as follows:

Equation 3-5 ODS emissions from Refrigeration

$$Annual\ Emissions = Net\ Consumption \bullet Composite\ EF$$

Where:

Net Consumption = net consumption for the application Composite

EF = composite emission factor for the application

3.3 Activity Data

Activity data sources include:

(a) Plant-level measurements or direct emissions reports with documented methodologies

(b) Where direct measurements are not available, estimations are based on calculation with plant-specific data

(c) International data set (United Nations data sets and industry associations)

(d) National databases where available from appropriate government ministries (e.g., statistics services, environmental protection agencies)

(e) Standard production statistics from national statistical publications.

Most of the activity data can be obtained from national statistics, UBOS. The data can cross checked with international data such as World Bank data.

3.3.1 **Cement**

Uganda has only two cement factories. The cement production data can be obtained from these two factories, the national statics or Uganda Manufacturers Association or Ministry of

Industries, Tourism and Cooperatives. Data is also available from United Nations statistical yearbooks.

3.3.2 Lime

Lime is widely used in production of cement. There are numerous small scale industries producing lime for other applications such road construction, agriculture and bricks as stabilizers. The data can be obtained from the Small Scale Industry Associations.

3.3.3 Food and Beverages

There are several beer and wine manufacturers in Uganda. The data on production can be obtained from national statistics and or Uganda Manufacturers Association or Ministry of Industries, Tourism and Cooperatives.

3.3.4 Road Pavement.

The data on road pavement can be accessed from the Ministry of Works and Transport or Uganda National Roads Authority. The number of kilometre paved per annum can be used to estimate NMVOCs emissions .The tonnage on imports can be obtained from Uganda Revenue Authority for quality assurance..

3.3.5 Refrigeration and Air Conditioning

All the refrigerants used in the refrigeration and air conditioning are imported. There are no organised refrigeration associations in Uganda. There is wide use of second hand refrigerators in Uganda. They came when charged with refrigerant. The data on imports of refrigerants and refrigerators can be obtained from Uganda Revenue authority.

3.4 Emission Factors

3.4.1 Lime

The emission factor the lime depends on the type of lime to be produced as show in Table 3-1 (Reference: Vol.3, Chap.2, page 2.22, Table 2.4, 2006 IPCC.

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Table 3-1. Emission from lime subcategory

Lime Type	Stoichiometric Ratio [tonnes CO_2 per tonne CaO or CaO·MgO] (1)	Range of CaO Content [%]	Range of MgO Content[d] [%]	Default Value for CaO or CaO·MgO Content [fraction] (2)	Default Emission Factor [tonnes CO_2 per tonne lime] (1) • (2)
High-calcium lime[a]	0.785	93-98	0.3-2.5	0.95	0.75
Dolomitic lime [b]	0.913	55-57	38-41	0.95 or 0.85[c]	0.86 or 0.77[c]
Hydraulic lime [b]	0.785	65-92[e]	NA	0.75[e]	0.59

Source:
[a] Miller (1999b) based on ASTM (1996) and Schwarzkopf (1995).
[b] Miller (1999a) based on Boynton (1980).
[c] This value depends on technology used for lime production. The higher value is suggested for developed countries, the lower for developing ones.
[d] There is no exact chemical formula for each type of lime because the chemistry of the lime product is determined by the chemistry of the limestone or dolomite used to manufacture the lime.
[e] Total CaO content (including that in silicate phases).

3.4.2 **Food and Beverages**

The default emission factor for NMVOC emissions from food and beverages production is as given in Table 3-2 below. It is calculated based on kg/Mg product produced. A very large 95% confidence interval has been applied to this factor, because of the variety in the emission factors for the food and beverage processes that are included in this source category.

Table 3-2. Tier 1 emission factors for source category 2.H.2 Food and beverages industry

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	2.H.2	Food and beverages industry			
Fuel	NA				
Not applicable	NOx, CO, SOx, NH3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane, Chlordecone, Dieldrin,				
Not estimated	TSP, PM10, PM2.5				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NMVOC	2	kg/Mg product produced	0.3	150	Guidebook (2006)

Reference: NFR 2.H.2 Table 1-3 Page 7 EMEP/EEA emission inventory guidebook 2013

3.4.3 **Road Pavement**

The emission factor from the road pavement is adapted from EMEP/EEA emission inventory guidebook 2013. The emission factor Road paving is as shown in Table 3-3

Table 3-3. Tier 1 emission factors for source category 2.D.3.b Road paving with asphalt

Tier 1 default emission factors					
	Code	Name			
NFR source category	2.D.3.b	Road paving with asphalt			
Fuel	NA				
Not applicable	NH_3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, HCH, PCBs				
Not estimated	NO_x, CO, SO_2, PCDD/F, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	16	g/Mg asphalt	3	100	US EPA (2004)

Reference: NFR 2.D.3.b Table 1-3, Page 8 EMEP/EEA emission inventory guidebook 2013

3.5 Uncertainty Estimates

3.5.1 Cement

The clinker data is important estimating cement production emissions. If clinker data are available, the uncertainty of the emission factor is equal to the uncertainty of the CaO fraction and the assumption that it was all derived from $CaCO_3$ uncertainty of 1-2%, uncertainty of the emission factor. The uncertainty in clinker production data is about 1-2%. The component uncertainties in Table 3-4 below have been combined as though they were symmetric maximum- minimum errors.

Table 3-4. Default uncertainty Cement Production

Step	Error[a]	Comment	Method
(1)	1-2%	Uncertainty of plant-level production data. Plants generally do not weigh clinker better than this. Assumes complete reporting.	Tier 2
(2)	1-3%	Error associated with assuming that all CaO in clinker is from calcium carbonate.	Tier 2
(3)	1-2%	Uncertainty of plant-level data on CaO content of clinker. This is the best case error of chemical analysis on a production basis.	Tier 2
(4)	4-8%	Error in assuming an average CaO in clinker of 65% (CaO usually 60-67%).	Tier 1, 2
(5)	5%	The best case error assuming that weight and composition of cement kiln dust (CKD) are known.	Tier 2
(6)	1-2%	Plants generally do not weigh cement production better than this. Assumes complete reporting.	Tier 1
(7)	20%	Error due to miss-reporting or non-unique blended cement formulations.	Tier 1
(8)	35%	'Worst case' assumes overall 70% blended cement of 50% non-clinker recipe.	Tier 1
(9)	5%	Reporting error, but more accurate than for cement (clinker tariff number is less encompassing).	Tier 1
Summary of resulting error estimates in emissions (see Chapter 6, Quantifying Uncertainties in Practice)			
	20-40%	**Tier 1 error** assuming that clinker production data were derived from cement production data (excluding additional errors for correction of international clinker trade stemming from any need to estimate national clinker production level from cement production).	
	5-10%	**Tier 2 error** assuming derivation from clinker production data.	

[a] Numbers refer to Figure 3.1 and are the 'maximum' error – i.e. the most likely rectangular distribution function is assumed. The estimated error at each step, and certain summations thereof, are based on experience in collecting and calculating data.

Source: van Oss (1998).

References Chapter 3 Table 3.2, Page 3.15, 2006 IPCC Guideline

3.5.2 **Lime**

The stoichiometric ratio is an exact number and therefore the uncertainty of the emission factor is the uncertainty of lime composition, in particular of the share of hydraulic lime that has 15% uncertainty in the emission factor (2% uncertainty in the other types). Therefore, the total uncertainty is 15% at most (see Table 3-4, Basic Parameters for the Calculation of Emission Factors for Lime Production).

The uncertainty for the activity data is likely to be much higher than for the emission factors, based on experience in gathering lime data (see completeness section above). Omission of non-marketed lime production may lead to an error of +100% or more. The correction for hydrated lime typically adds about ±5% to the former uncertainty.

3.5.3 **Food and Beverages**

Uncertainties in the emissions from the production of food and beverages are generally expected to be greater than a factor of 2 in Tier 1 emission factor provided in the EMEP/EEA emission inventory guidebook 2013 have a 95% confidence interval with them. The uncertainty in emissions from spirits will also be greater than a factor of 2 unless the type of spirit produced is identified. If this is the case, then the uncertainty in emissions from spirits will be less than a factor of 2.

3.5.4 Road Pavement

The largest source of uncertainty in these estimates will be the level of detail available in terms of the relative breakdown of asphalt into asphalt cement, cutback asphalt and emulsified asphalt. As an example, in the USA in 1991, 86 % of total asphalt sales were asphalt cement for hot mix use. If this was assumed to be RC cutback at an average of 45 %, total emissions would be 6 448 174 tonnes VOC. In comparison, total organic emissions (interpreted as NMVOC) from hot mix plants would be 8 815 Mg for an equivalent amount of asphalt cement, assuming that asphalt cement is 8 % of hot mix. Therefore, the simpler estimation can greatly overestimate emissions of NMVOCs.

Situation Uganda will be different. More information can be obtained from Ministry of Works and Transport and Uganda National Road Authority.

3.6 Improvements

Refrigeration and air conditioning are the largest users HFC or PFC. The information about the consumption of the HFC or PFC can be obtained though surveys. The key industries will be fish processing industries, beverage industries and refrigeration system service providers. The import data from the Uganda Revenue Authority will also good source of information.

4 AGRICULTURE FORESTRY AND OTHER LAND USE

4.1 Introduction

Under the 2006 IPCC guidelines, Agriculture has been integrated with what was previously referred to as Land Use Land Use Change and Forestry (LULUCF) and is now called Agriculture, Forestry and Other Land use, AFOLU in short. In AFOLU, anthropogenic GHG emissions by source and removals by sinks are defined as those occurring on *managed land*. Managed land is defined as where human interventions and practices have been applied to perform production, ecological or social functions (2006 IPCC). Though emissions / removals of greenhouse gases do not need to be reported for unmanaged land, it is *good practice* to quantify, and track over time, the area of unmanaged land so that consistency in area accounting is maintained as land-use change occurs.

In line with the notion of managed land, emissions and removals associated with all fires on managed land are now estimated, removing the previous optional distinction between wildfires and prescribed burning. Emissions due to “wildfires and other disturbances on unmanaged land are not included in the estimates, unless the disturbance causes a land-use change”.

In this manual, emissions from fires and land management activities such as rice cultivation, lime, urea and fertilizer application are discussed under aggregate sources and non-CO_2 emissions sources as arranged in the 2006 IPCC software.

4.2 AFOLU Overview Category Information

This sector is the widest because it deals with anything that involves land management that is not considered under energy, industries and waste treatment. The key greenhouse gases of concern are CO_2, N_2O and CH_4. Plant biomass is the main conduit for CO_2 removal from the atmosphere. The uptake of CO_2 through photosynthesis is referred to as gross primary production (GPP). About half of the GPP is respired by plants, and returned to the atmosphere, with the remainder constituting net primary production (NPP), which is the total production of biomass and dead organic matter in a year (2006 IPCC).

NPP minus losses from heterotrophic respiration (decomposition of organic matter in litter, dead wood and soils) and biomass removals (land clearing, timber harvesting, fuelwood harvesting and other disturbances, e.g., fires) is referred to as net biome production (NBP). The carbon stock change that is reported in national greenhouse gas inventories for land-use categories is equal to NBP (2006 IPCC).

Net Biome Production (NBP) = Net Primary Production (NPP) – Heterotrophic respiration – Carbon Losses from Disturbance/Land-Clearing/Harvest

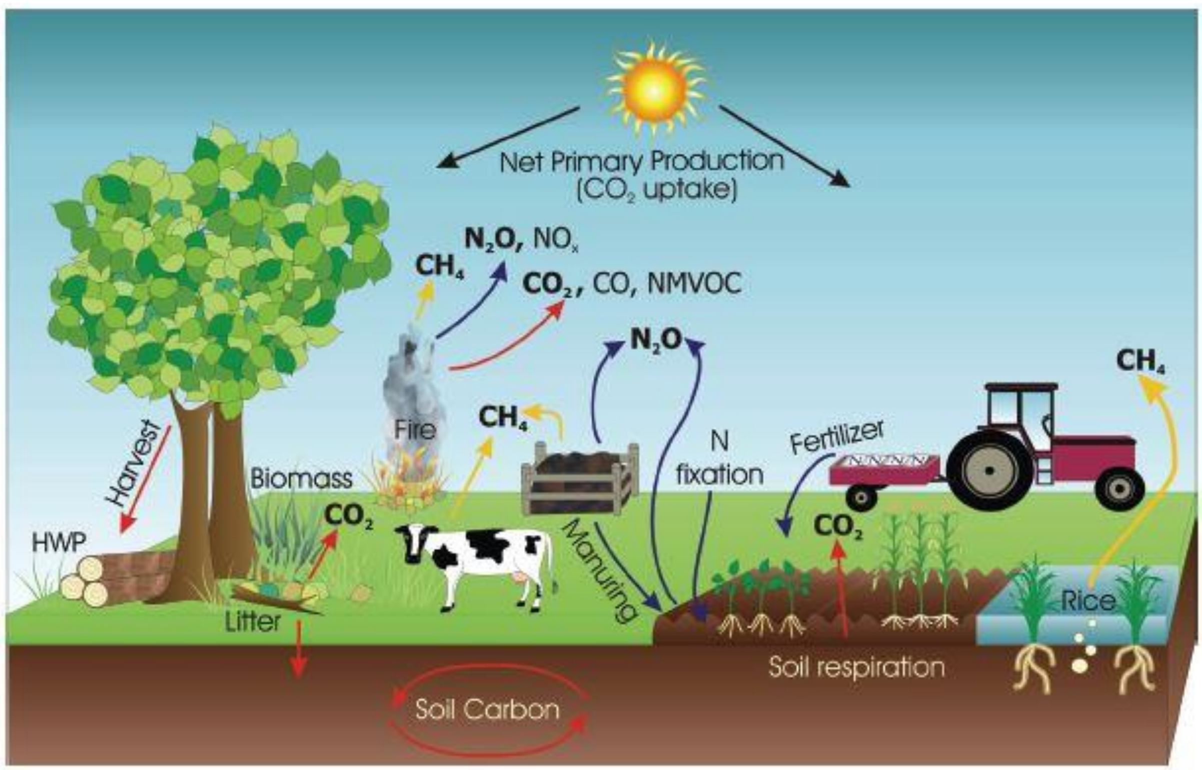


Figure 4-1. GHG emission / removals (sinks) in managed land. Source: 2006 IPCC guidelines

CO_2 fluxes between the atmosphere and ecosystems are primarily controlled by uptake through plant photosynthesis and releases via respiration, decomposition and combustion of organic matter (Figure 4-1). N_2O is primarily emitted from ecosystems as a by-product of nitrification and denitrification, while CH_4 is emitted through methanogenesis under anaerobic conditions in soils and manure storage, through enteric fermentation, and during incomplete combustion while burning organic matter. Other gases of interest (from combustion and from soils) are NOx, NH_3, NMVOC and CO, because they are precursors for the formation of greenhouse gases in the atmosphere. Formation of greenhouse gases from precursor gases is considered an indirect emission.

It is important to note that NPP is influenced by land use and a variety of anthropogenic actions such as deforestation, afforestation, fertilizer application, and irrigation. Other issues to consider are carbon stock transformations. For example, as trees die and otherwise deposit litter and debris on the forest floor, carbon (C) is released to the atmosphere or transferred to the soil by organisms that facilitate decomposition. The net change in forest C is not equivalent to the net flux between forests and the atmosphere because timber harvests do not cause an immediate flux of C of all vegetation C to the atmosphere. Instead, harvesting transfers a portion of the C stored in wood to a "product pool." Once in a product pool, the C is emitted over a long time as CO_2 when the wood product combusts or decays. The rate of emission thus varies considerably among different product pools.

To be consistent with the 2006 IPCC software, the sector is discussed under three main subsectors namely; Livestock (denoted as 3.A), Land Biomass (denotes as 3.B) and Aggregate Sources and non-CO_2 Emission Sources on land (denotes as 3.C). A forth subcategory called Other (denotes as 3.D) may added to discuss harvested wood products for those countries that have data on harvested forest products that many years to decompose such as furniture.

4.2.1 **Livestock (3.A)**

4.2.2 **Livestock Key Category Information**

Emissions from Livestock production are considered in two broad sections of methane (CH_4) emissions from enteric fermentation (denoted as 3.A.1) and CH_4 and nitrous oxide (N_2O) emissions from livestock manure management systems (denoted as 3.A.2).

Enteric fermentation, CH_4 is produced in animals as a by-product of a digestive process by which carbohydrates are broken down into simple molecules for absorption into the bloodstream. Ruminant animals (e.g. cattle, buffalo) are the largest source of methane emission from enteric fermentation with moderate amount of methane produced from non-ruminant animals (e.g. swine, horses). The amount of CH_4 emitted from the animal depends on the type, age, and weight of the animal; the quality and quantity of feed; and the energy expenditure of the animal.

Methane emitted from the manure management is as a result of manure decomposition under anaerobic conditions, which usually occur in manure stored in large piles. During storage of manure, some nitrogen in manure are oxidized and converted into N_2O. Under livestock, the methodological approach and most of the equations, emission factors and examples are based on Chapter 10, Volume 4 of 2006 IPCC guidelines unless stated otherwise.

4.2.2.1 Methodological choice and description

When using the IPCC 2006 Software, livestock population is first defined under Enteric Fermentation sub category (. Livestock population for specific manure management systems is defined later under the manure management sub category. This number has got to be less than the total livestock defined above. Poultry is the only expectation and all poultry population is defined once under the under the manure management sub category.

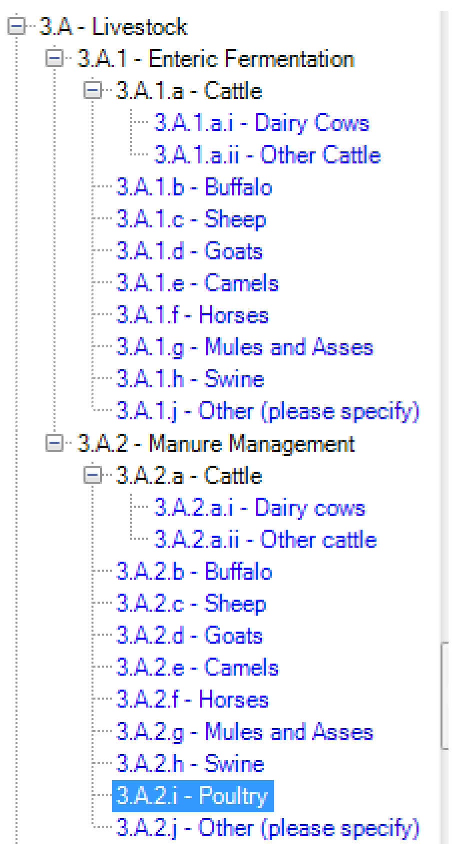


Figure 4-2. Defining Enteric Fermentation Population and Manure Management

4.2.2.1.1 CH_4 from enteric Fermentation (3.A.1)

In the absence of any country-specific methane emission factors from enteric fermentation and due to lack of activity data to perform enhanced characterization of livestock population, Tier 1 approach which is simply based on livestock population and default emission factor is used. Figure 4-2 and Figure 4-3 are an illustration of how the population data and emissions factors are captured. The software uses this data to calculate both enteric fermentation and manure management emissions per livestock category and total annual emissions of livestock.

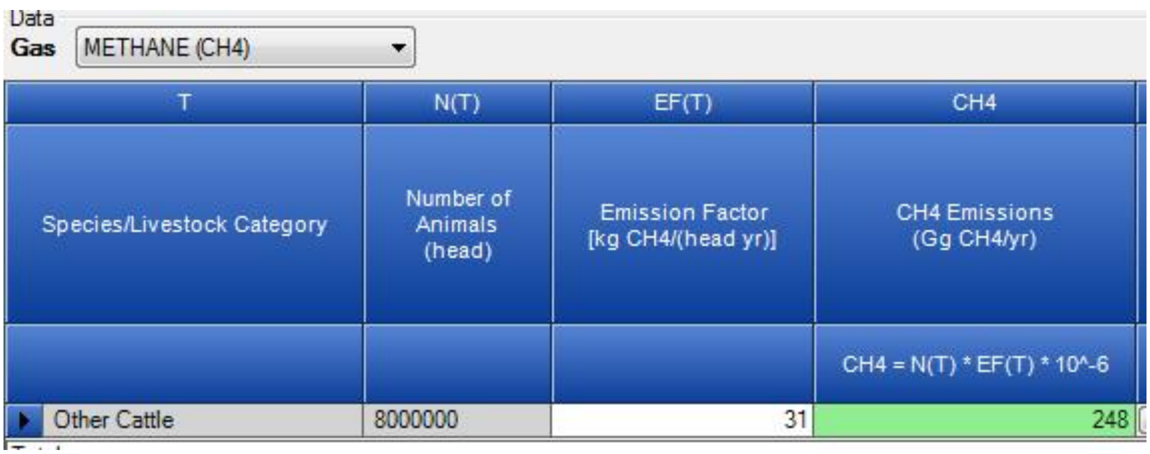
The calculations are based equation 10.19, Vol 4 of 2006 IPCC here represented as (Equation 4-1):

Equation 4-1. CH4 Emissions from Enteric Fermentation

$$\textbf{Emissions} = EF_T \ (N_T / 10^6)$$

Where:

- Emissions = Methane (CH_4)emissions from Enteric Fermentation for a defined population Gg/yr)
- EF_T = Emission factor for the defined livestock population, kg CH_4 / head/yr. Default factors are listed in tables 10.10 and 10.11 Vol.4 2006 IPCC. Sample of these tables are provided in 0
- N(T) = the number of head of livestock species / category T in the country
- 10^6 = Conversion factor (to Gg)



Data

Gas: METHANE (CH4)

T	N(T)	EF(T)	CH4
Species/Livestock Category	Number of Animals (head)	Emission Factor [kg CH4/(head yr)]	CH4 Emissions (Gg CH4/yr)
			CH4 = N(T) * EF(T) * 10^-6
Other Cattle	8000000	31	248

Figure 4-3. Example of 2006 software worksheet data capture for CH4 from enteric fermentation

4.2.2.1.2 Emissions from manure management Systems (3.A.2)

The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock. Where data is available, countries are encouraged to use Tier 2, where manure characteristics and management systems are describe. Figure 4-4 is an example of some of the systems at is provided by the software.

	System	Definition
☑	Pasture/Range/Paddock	The manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed.
☐	Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion.
☐	Solid storage	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
☑	Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically.
☐	Liquid/Slurry	Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year.
☑	Uncovered anaerobic lagoon	A type of liquid storage system designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the volatile solids loading rate, and other operational factors. The water from the lagoon may be recycled as flush water or used to irrigate and fertilise fields.
☑	Pit storage below animal confinements	Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.

Figure 4-4. An example of software inbuilt manure management systems

After defining all possible manure management systems in the country, the IPCC 2006 software can then be used to estimate CH_4 and N_2O emissions that are attributable to all livestock listed on the left hand size tree in Figure 4-5. Most of the emission factors are in built in the software. A list of tables for with relevant livestock emission factors as provided in the IPCC guidelines is available in Appendix C.

Figure 4-5. Defining CH_4 and N_2O emission parameters for manure management

4.2.2.1.3 CH4 from enteric Manure Management

The method used to estimate methane emission from manure management is similar in form with that used in estimating methane emission from enteric fermentation and is based on equation 10.22 of Vol4, 2006 IPCC presented in Equation 4-2:

Equation 4-2 CH4 Emissions from Manure Management

$$CH_{4manure} = \mathbf{EF_T \; (N_T / 10^6)}$$

Where:

- Emissions = Methane (CH_4)emissions from manure management for a defined population Gg/yr)
- EF_T = Emission factor for the defined livestock population, kg CH_4 / head/yr. Temperature is factor to consider while choosing default factors as provided in table 10.14 , 10.15 and table 10.16 of chapter 10, volume 4, 2006 IPCC. Sample of these tables are provided in 0of this manual.
- N(T) = the number of head of livestock species / category T in the country
- 10^6 = Conversion factor (to Gg)

4.2.2.1.4 Direct N_2O emissions from Manure Management

The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock. N_2O is produced, directly and indirectly, during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes.

***Note**: N_2O emissions that occur directly and indirectly from the soil e.g., generated in 'pasture, range, and paddock' is reported under in 'N_2O Emissions from Managed Soils' (in Chapter 11 Vol4. 2006 IPCC). This information is captured under Aggregate sources and non-CO_2 emissions sources in the 2006 Inventory software. The emissions associated with the burning of dung for fuel are to be reported under 'Energy -Fuel Combustion' (see Vol 2, 2006 IPCC), or under 'Waste Combustion' (Vol 5, 2006 IPCC) if burned without energy recovery.*

Under manure management systems, direct N2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NOx.

Tier 1 method entails multiplying the total amount of N excretion from all livestock species/categories in each type of manure management system by an emission factor for that type of manure management system. Default N excretion values are listed in table 10.19, Vol 4. 2006 IPCC. Corresponding default emission factor are listed in table 10.21, vol4 2006 IPCC. For quick reference, these tables are provided in 0.

Category
Dairy Cows
Other Cattle

T	N(T)	TAM(T)	ER	Nex(T)	
Livestock Subcategory	Annual Average Population (head)	Typical Animal Mass (kg)	Excretion Rate per mass per day [kg N/(1000kg animal mass day)]	Excretion Rate per animal per year [kg N/(animal yr)]	Remark
				Nex(T) = TAM(T) / 1000 * 365 * ER	
Other Cattle	33333	173	0.63	39.78135	Cattle Mix
*					

Figure 4-6. An illustration of How $Nex_{(T)}$ is calculated in the software

Figure 4-6 illustrated how the default values of typical animal mass per region and emission rate per mass per day are used to estimate average N excretion per head of species/category *T* in the country within the software. Annual average N excretion per head of species can then be used to estimate direct N_2O emissions from Manure Management in the country using equation 10.25 of Vol 4 IPPC guidelines presented here as Equation 4-3:

Equation 4-3. N2O from Manure Management

$$N_2O_{D(mm)} = \left[\sum_S \left[\sum_T \left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)} \right) \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28}$$

Where:

- $N_2OD_{(mm)}$ = direct N2O emissions from Manure Management in the country, kg N_2O / yr
- $N_{(T)}$ = number of head of livestock species/category *T* in the country
- $Nex_{(T)}$ = Annual average N excretion per head of species/category *T* in the country, kg N animal-1 yr-1. (this is derived as
- $MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless
- $EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system *S* in the country, kg
- S = manure management system
- T = species/category of livestock
- 44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

4.2.2.1.5 Indirect N_2O emissions from Manure Management

There may be losses of nitrogen in other forms (e.g., ammonia and NOx) as manure is managed on site. The approach for the estimation of Indirect N_2O emissions for manure management is similar to that of estimating direct emissions. As per equation 20.27 (Vol4., 2006 IPCC), fractions of N losses is used instead of the emission factor. Default fractions of N losses from manure management systems due to volatilisation are provided in Table 10.22 Vol 4, 2006 IPCC. A quick reference provided in Appendix C**Error! Reference source not found.** of this anual. Equation 20.27 is here present as Equation 4-4:

Equation 4-4. Indirect N_2O from Manure Management

$$N_{volatilization-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)}\right) \bullet \left(\frac{Frac_{GasMS}}{100}\right)_{(T,S)}\right]\right]$$

Where:

- $N_{volatilization\text{-}MMS}$ = amount of manure nitrogen that is lost due to volatilisation of NH_3 and NOx, kg N yr-1
- $N_{(T)}$ = number of head of livestock species/category *T* in the country
- $Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N animal-1 yr-1
- $MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless
- $Frac_{GasMS}$ = percent of managed manure nitrogen for livestock category *T* that volatilises as NH_3 and NOx in the manure management system *S*, %

*Note that the software has been designed such that indirect N_2O emissions in manure management systems is handled with indirect N_2O emissions soil management under aggregate sources and non CO_2 sources on land (*Figure 4-7*).*

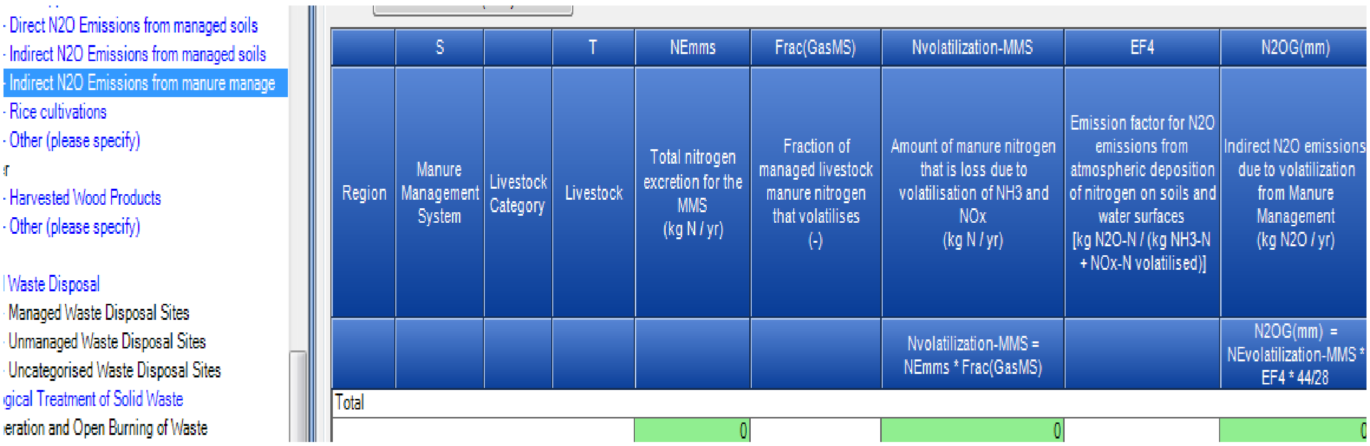


Figure 4-7. Compile should take note of location of Indirect N_2O emissions worksheet within the software

4.2.2.1.6 Livestock Activity data

If possible, inventory compilers should use population data from official national statistics or industry sources. Food and Agriculture Organisation (FAO) data can be used if national data are unavailable. Seasonal births or slaughters may cause the population size to expand or contract at different times of the year, which will require the population numbers to be adjusted accordingly. It is important to fully document the method used to estimate the annual population, including any adjustments to the original form of the population data as it was received from national statistical agencies or from other sources.

Annual average populations are estimated in various ways, depending on the available data and the nature of the animal population. In the case of static animal populations (e.g., dairy cows, breeding swine, layers), annual average population may be used.

However, estimating annual average populations for a growing population (e.g., meat animals, such as broilers, turkeys, beef cattle, and market swine) requires more evaluation. Most animals in these growing populations are alive for only part of a complete year. Estimating the average annual population as the number of birds grown and slaughtered over the course of a year would greatly overestimate the population, as it would assume each bird lived the equivalent of 365 days. Instead, one should estimate the average annual population as the number of animals grown divided by the number of growing cycles per year. For example, if broiler chickens are typically grown in flocks for 60 days, an operation could turn over approximately 6 flocks of chickens over the period of one year. Therefore, if the operation grew 61,000 chickens in a year, their average annual population would be 10,027 chickens. For this example the equation would be:

Annual average population = 60 days ● 60,000 / 365 days / yr = 10,027 chickens

Uganda needs to build an agricultural statistical system that will collect more detailed data on livestock and crop production. Current data is based on projections from previous studies. The last set of livestock census was carried out by UBOS in 2007/ 2008 (Table 4-1). The uncertainties associated with current projections need to be documented.

Table 4-1. Livestock Activity Data Sources

Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Reference	Other Information (e.g., date obtained and data source or contact information)	Category QA/QC Procedure Adequate / Inadequate / Unknown	Are all data entered correctly into models, spreadsheets, etc.? Yes / No (List Corrective Action)	Checks with Comparable Data (e.g., At international level, IPCC defaults). Explain and show results.
Livestock Type and Manure management System (Dairy Cows – by AVG Kg)	Annual Average Population)	Avg Number and Avg KG		UBOS	MAAIF Agric Statistics	Inadequate Data is Projection of 2007/8 Livestock census	The data has to be cross checked by quality controller	
Livestock Type and Manure management System (Other Cattle by AVG Kg)	Annual Average Population)	Avg Number and Avg KG		UBOS	MAAIF Agric Statistics	Inadequate Data is Projection of 2007/8 Livestock census	The data has to be cross checked by quality controller	
Sheep and Manure management System	Annual Average Population)	Avg Number and Avg KG		UBOS	MAAIF Agric Statistics	Inadequate Data is Projection of 2007/8 Livestock census	The data has to be cross checked by quality controller	
Goats and Manure management System	Annual Average Population)	Avg Number and Avg KG		UBOS	MAAIF Agric Statistics	Inadequate Data is Projection of 2007/8 Livestock census	The data has to be cross checked by quality controller	
Swine and Manure management System	Annual Average Population)	Avg Number and Avg KG		UBOS	MAAIF Agric Statistics	Inadequate Data is Projection of 2007/8 Livestock census	The data has to be cross checked by quality controller	
Poultry and Manure management System	Annual Average Population)	Avg Number and Avg KG		UBOS	MAAIF Agric Statistics	Inadequate Data is Projection of 2007/8 Livestock census	The data has to be cross checked by quality controller	

4.2.2.2 `Emission Factors

Uganda does not have its own emission factors thus default EF (Table 4-2) are used as provided in the 2006 IPCC guidelines. EF Tables relevant to Uganda's situation are listed in Appendix C. Calculation of emissions from each source categories involves use of equations as outlined in section 4.2.2.1 above. Unless otherwise stated, references for the livestock and manure management refer to chapter 10 and 11 volume 4 (Agriculture, Forestry and other land use) of 2006 IPCC guidelines.

Table 4-2. Livestock Emission factors Sources

Type of Factor	Emission Factor Value	Emission Factor Units	Reference	Uncertainty
Enteric Fermentation Methane Emission Factor	kg CH_4 / Head / Year	kg	Default factors IPCC 2006	+- 10 -30%
Excretion rate of Nitrogen per animal type mass per day	kg N/ 1,000 KG Animal mass per day	kg	Default factors IPCC 2006	
Manure management system CH_4 Emission	kg CH_4 / Animal / Manure Mgt System	kg	Default factors IPCC 2006	
Manure management system N_2O Emission	kg N_2O / Kg N in MMS	kg	Default factors IPCC 2006	
N loss per Manure Mgt System	Fraction Loss MS %	%	Default factors IPCC 2006	
Fraction Manure Mgt Syst (MS T,S)	Fraction (0 to 1)	Dimensionless	Default factors IPCC 2006	
Animal Excretion per Head Next (T)	Kg N / Mass Animal (1000 Kg) /day	kg	Default factors IPCC 2006	
Beddings Emissions	N KG in Organic bedding / Animal/ Year	kg	Default factors IPCC 2006	

Table 4-3. Livestock Emission Factors

4.2.2.3 Uncertainty

Uncertainty of livestock data is not discussed because of paucity of data. General guidance on how uncertainties may be estimated is provided in section 1.2 of this manual.

4.2.2.4 Improvements

It is recommended that the old system where agriculture extension workers would collect data at lower administration levels (parish and sub county) and forward it up to district be reestablished. For GHG purposes, the system should include livestock characterisation by age, sex, breed, and manure management.

Uganda livestock population could also be categorized into two different zones based on annual average temperature e.g. Cool (<=20°C), and warm (>20°C)**.** The system could be developed such that in future it can easily capture ‘enhanced’ livestock characterisation information on: Average annual population per year by livestock sub-category, Feed intake by sub-category (e.g. Mega Joules (MJ) per day) or dry matter (e.g. kilograms (kg) per day), Seasonal births and slaughters. In addition, where possible, livestock categories may be characterised by manure management systems.

4.2.3 Land 3.B. Carbon stock changes in Forest and non – forest stands

In Uganda, Forest and non- forest stands are key component of the GHG inventory, mainly because of high rates of deforestation and forest degradation.

The net carbon uptake or emission of the Land sub-sector is dependent on two basic biophysical processes:

i) Changes in forest/woody carbon stocks due to the net annual biomass growth and removals from existing forest and non-forest stands, and possible biomass regrowth in abandoned lands;
ii) Land use and forest conversion practices which affect the carbon chemistry of the atmosphere via biomass burning, decay, and soil carbon release or uptake.

4.2.3.1 Forest and Other Land Key Category Information

It is also important to note that carbon stock changes are categorised into five pools of; Aboveground biomass, Belowground biomass, Dead wood, Litter and Soil organic matter. These pools are commonly aggregated further into three carbon pools of: living biomass, Dead Organic Matter (DOM) and soils as shown in Table 4-4. Changes in these pools may result in net emission and or net removals.

Table 4-4. Carbon Pools, Source: 2006 IPCC guidelines

Pool		Description
Living Biomass	Aboveground Biomass	All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage.
	Belowground biomass	All biomass of live roots. Fine roots of less than 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.
Dead Organic Matter (DOM)	Dead wood	All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter
	Litter	All non-living biomass with a size greater than the limit for soil organic matter (2 mm) and less than the minimum diameter chosen for dead wood (e.g. 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil.
Soils	Soil organic matter	Includes organic carbon in mineral soils to a specified depth (suggest 1 m) and applied consistently through the time series2. Live and dead fine roots and DOM within the soil, that are less than the minimum diameter limits (2mm) for roots and DOM, are included with soil organic matter where they cannot be distinguished from it empirically.

Emissions and removals related to carbon stock changes in Forest Land and other land on forestry land and other lands is discussed under six land categories divided into two sub categories of a) land remaining the same land and b) land converted into other land (Table 4-5).

Table 4-5. Land remaining the same and land converted

a)Land remaining the same land	b) Land converted from other land categories
1.FF = forest land remaining forest land	1.LF = lands converted to forest land
2.CC = cropland remaining cropland	2.LC = lands converted to cropland
3.GG = grassland remaining grassland	3.LG = lands converted to grassland
4.WW = wetlands remaining wetlands	4.LW = lands converted to wetlands
5.SS = settlements remaining settlements	5.LS = lands converted to settlements
6.OO = other land remaining other land	6.LO = lands converted to other land

Every land conversion (land subcategory b in Table 4-5) theoretically has five possibilities of land conversions. For example land converted into cropland could be from forest land (3.B.2.b.i), grass land (3.B.2.b.ii), wetland (3.B.2.b.iii), settlements (3.B.2.b.iv) or other land ((3.B.2.b.v). An example of the IPCC 2006 software naming convention for forest and other land is shown in Figure 4-8.

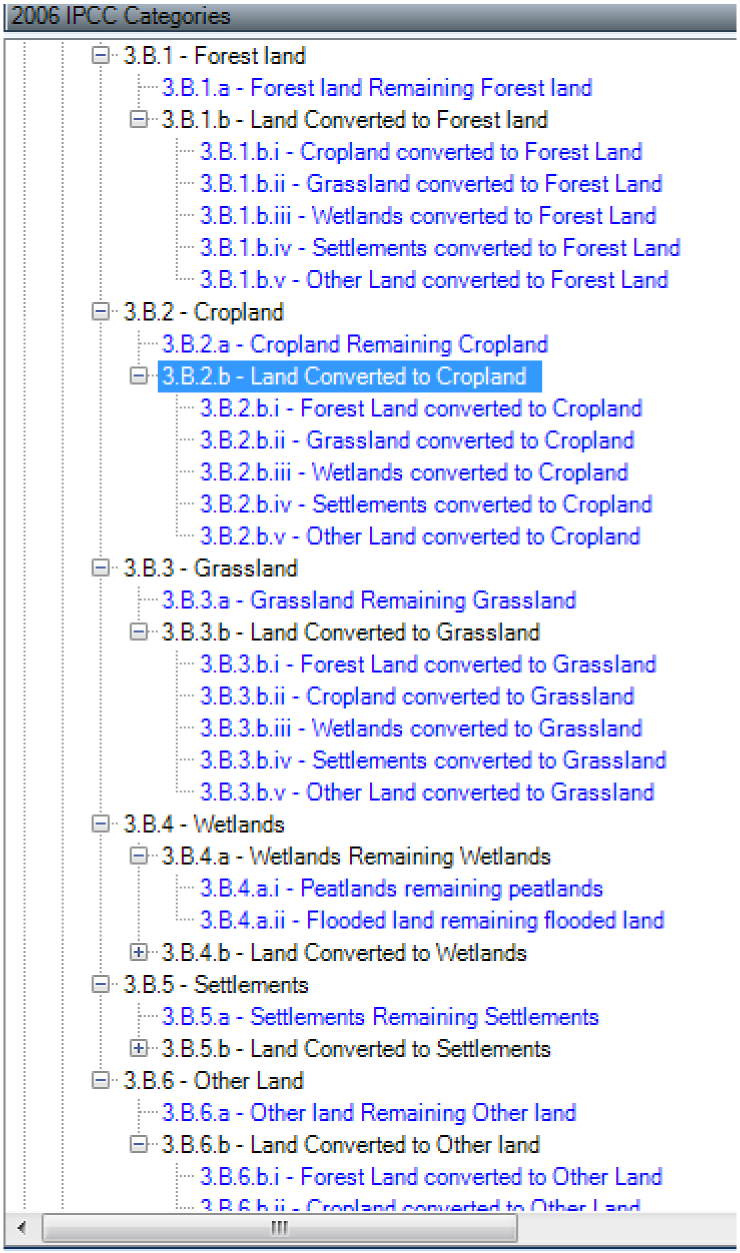


Figure 4-8. Category and Main Activity Tree

For each of the land category remaining the same (Table 4-5) and all the possible land conversions, (Figure 4-8), carbon stock changes may occur in living biomass, DOM and Soils. However, depending on availability of data and depending on local circumstances, some of these changes are so minimal such that there may be no value gained in trying to assess all carbon stock changes and activity data. For example, it might be of much value (in terms of estimating emissions) to estimate carbon stock changes in mineral soils for land that has been deforested and not in land that has remained forest. A combination of carbon pools and land changes that may be of high significance in the estimation of GHG emissions is presented below:

- Carbon stock changes in Living biomass in land that has remained 1); forestland 2); cropland and 3) grassland.
- Carbon stock changes in Living biomass in land that has been converted into 1);Forest land 2); Cropland 3); Grassland 4); Settlements and 4) Other land.
- Carbon stock changes in organic soils may be considered in drained organic soils (mainly in land remaining forestland and land converted to forest). The same applies to cultivated organic soils in land remaining cropland, grassland and or settlement plus land converted to grassland, cropland, settlement and other land.
- Carbon stock changes in mineral soils may be considered in land converted to forestland, Land that has remained cropland or converted to cropland, Land that has remained grassland or converted to grassland and Land converted to settlements or converted to other land

Carbon stock changes in DOM in countries like Uganda may be ignored or considered to be zero due to paucity of data. *However for completeness, assessment of Carbon stock changes in DOM may be considered in land that has been converted to forest land, crop land, grassland and or settlements.*

4.2.3.2 Methodology and Approach

There are two approaches of assessing GHG emissions under forestry and other land use. The first approach is based on information on carbon gain, less carbon losses (*Gain-Loss Method*). This method requires information on annual biomass stock increments, biomass losses (land clearance, extraction of firewood, timber and other wood products), losses due to disturbance (fire, disease and pests), and carbon loss in soils. The Gain-Loss Method is flexible in that it can use both detailed data (Tier2 and 3) and coarse data (Tier1) where country specific detailed data is not available. Since many countries lack detailed data on land use and biomass stocks, the Gain-Loss Method is the default methodology.

The second approach is known as *Stock-Difference Method* where carbon stock changes at time *t2* are compare with the stock at *t1* and the difference divided by the years between the two inventories gives the annual stock change. The Stock-Difference Method requires detailed time series data of area statistics of land categories, land conversions and associated biomass stock changes. This kind of assessment is considered to be appropriate for Tier2 and Tier3 analysis. A mix of different Tiers is also acceptable. Uganda is already using this approach.

The following are general guidelines of how carbon pools are estimated regardless of the methodological approach:

The IPCC (2006) Inventory software is designed such a land use change matrix is automatically generated once a user enters initial area and final area by land category and sub categories (Figure 4-9). Land categories may be subdivided sub categories. For example, forest land may be subdivided into forest on private land and forest under protection. Protect forests may further be subdivided according to type of protection or level of accessibility of biomass e.g. national parks, forest reserve nature reserve, forest reserve for production, forest reserve plantations. The subdivision may consider factors like differences in rate of deforestation, biomass stock, biomass increment and level of wood extraction.

	Initial	Forest Land										
	Final	Bush	Bush gaz	DTHF	DTHF gaz	Plantation Euc	Plantation Pine	THF	THF gaz	Woodland	Wood	Final Area
Forest Land	Bush	711181		1254.6		56.3	105.3	345.4		73588		855862.5
	Bush gaz		177795		313.64				614		1(	189718.64
	DTHF			92052				1737.7				93789.7
	DTHF gaz				84971				3089.3			88060.3
	Plantation Euc	47	11.8	20.2	18.6	5003				127		6168.6
	Plantation Pine	9.7	2.4	100	92.4		10099			179	2	10919.1
	THF							220521				220521
	THF gaz								392038			392038
	Woodland									2756006		2756006
	Woodland gaz										41	411817
	Unmanaged											0
Cropland	Larg Scale Com Farms	371		148		135	5	296		551		61276
	SubsFarm Annual	24563		9986		1070	324	6964		75337		5745623
	SubsFarm Perennial											1382643
	Initial Area	736402.6	177809.2	104123.5	85395.64	6405.3	10651.3	230527.2	395741.3	2906296.2	422	16860223.34
	Net Change	119459.9	11909.44	-10333.8	2664.66	-236.7	267.8	-10006.2	-3703.3	-150290.2	-11	0

Figure 4-9. Land use Change Matrix as generated by the IPCC 2006 Software

The Gain and Loss Approach:

- The gain loss approach is relevant on land remaining in the relevant category at the end of the year for which the inventory is being estimated.
- The land that was converted (under transition) is treated separately from the land category that was not converted (remained the same category) when estimating emissions. Area of land converted into a land category whose emissions are being estimated is regarded to be under transition until 20 years have elapsed (the default number of years). Country specific transition years may be used. Where land has been converted, biomass after and biomass before approach is considered.
- The CSCF, EF and AD used may vary depending on the carbon pools being considered as shown the equations in the proceeding subsections.

4.2.3.2.1 Steps for estimating carbon pools in living biomass

The gain and loss approach, which is the default approach, is presented here. Overall carbon stock changes are estimated as biomass gains less biomass losses (Equation 4-5) as noted below:

Equation 4-5. Carbon stock Gain Loss General Equation

$$\Delta C = \Delta CG - \Delta CL$$

Where:

- ΔC = annual carbon stock change in the pool, tonnes C yr-1
- ΔCG = annual gain of carbon, tonnes C yr-1
- ΔCL = annual loss of carbon, tonnes C yr-1

The gain and loss approach is mainly applicable to all land categories where increment can be determined (default values or even better locally generated coefficients) and are a source of biomass (main forest products being Timber and Fuel wood). Key land categories considered are Land remaining forestland (denoted as 3.B.1.a) and Land converted from other land categories to forest land (denoted as 3.B.1.b. from i to v). However, the above approach may be applied to cropland in Uganda since it is an important source fuel wood.

Gains are estimated as a product of area and biomass increment (Equation 4-6) as shown below:

Equation 4-6. Estimating Biomass Increment

$$\Delta CG = A * G_{TOTAL} * CF$$

Where:

- A = area of land remaining same category
- G_{TOTAL} = average annual biomass growth above- and below-ground.
- CF = carbon fraction of dry matter (default value = 0.5). This is used to convert biomass to carbon

Note that G_{TOTAL} is growth of above-ground biomass adjusted to cater for below-ground biomass as noted in the Equation 4-7 and Figure 4-10.

Equation 4-7. Factoring in below ground biomass growth

$$G_{TOTAL} = GW * (1+R)$$

Where

- GW = Average annual above-ground biomass growth
- R = Ratio of below-ground biomass to above-ground biomass

Land Use Category		Equation 2.9	Equation 2.10			Equation 2.9	
		Area of Forest Land Remaining Forest Land (ha)	Average annual above-ground biomass growth (tonnes dm / (ha * yr))	Ratio of below-ground biomass to above-ground biomass [tonnes bg dm / (tonne ag dm)]	Average annual biomass growth above- and below-ground (tonnes dm / (ha * yr))	Carbon fraction of dry matter [tonnes C / (tonne dm)]	Annual increase in biomass carbon stocks due to biomass growth (tonnes C / yr)
Initial land use	Land use during reporting year	National statistics or international data sources	Tables 4.9, 4.10, 4.12	Zero (0) or Table 4.4	Gtotal = Gw * (1+R)	0.5 or Table 4.3	ΔCG = A * Gtotal * CF
		A	Gw	R	Gtotal	CF	ΔCG
Woodla...	Plantation Pine	26.7	10	0.2	12	0.5	160.2
Plantati...	Plantation Pine	10099	10	0.2	12	0.5	60594
THF	THF	220521	15	0.24	18.6	0.5	2050845.3

Figure 4-10. Capturing growth data IPCC 2006 software worksheet

Losses are normally estimated from national statistics using this formula:

$$\Delta CL = Lwood\text{-}removals + Lfuelwood + Ldisturbance$$

Where:

- ΔCL = annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category, tonnes C yr-1
- Lwood-removals = annual carbon loss due to wood removals, tonnes C yr-1
- Lfuelwood = annual biomass carbon loss due to fuelwood removals, tonnes C yr-1
- Ldisturbance = annual biomass carbon losses due to disturbances, tonnes C yr-1

Note that fuelwood removal will often be comprised of two components. 1) removal of fuelwood from living trees and parts of trees such as tops and branches, where the tree itself remains in the forest and 2), gathering of dead wood and logging slash which reduces the dead organic matter carbon pool. If possible, it is *good practice* to estimate the two components separately.

Land Use Category		Equation 2.12				
		Annual wood removal (m3/yr)	Biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark) (tonnes of biomass removals / m3 of removals)	Ratio of below-ground biomass to above-ground biomass [tonnes bg dm / (tonne ag dm)]	Carbon fraction of dry matter [tonnes C / (tonne dm)]	Annual carbon loss due to biomass removals (tonnes C / yr)
Initial land use	Land use during reporting year	National statistics or international data sources	Table 4.5	Zero (0) or Table 4.4	0.5 or Table 4.3	Lwr = H * BCEFr * (1+R) * CF
		H	BCEFr	R	CF	Lwr
Plantation Euc	Plantation Euc	2000000	2.28	0.2	0.5	2736000
Plantation Pine	Plantation Euc		2.28	0.2	0.5	0

Figure 4-11. Capturing loss of carbon from wood (timber) removals in the worksheet

Data on biomass extraction may be available as tonnes of biomass (dry matter per year) or as round wood (cubic metres per year). Where data on wood extraction is available in m^3 (of merchantable volumes), round wood has to be converted to total tree biomass (estimate non-merchantable parts of branches and twigs and the part below-ground) by use of a Biomass Expansion Factors (BEF) and a root to shoot ratio (Figure 4-11, Figure 4-12 and Figure 4-13).

Land Use Category		Equation 2.13						
		Annual volume of fuelwood removal of whole trees (m3/yr)	Biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark) (tonnes of biomass removals / m3 of removals)	Ratio of below-ground biomass to above-ground biomass [tonnes bg dm / (tonne ag dm)]	Annual volume of fuelwood removal as tree parts (m3/yr)	Basic wood density tonnes / m3	Carbon fraction of dry matter [tonnes C / (tonne dm)]	Annual carbon loss due to fuelwood removal (tonnes C / yr)
Initial land use	Land use during reporting year	FAO Statistics	Table 4.5	Zero (0) or Table 4.4	FAO Statistics	Tables 4.13,4.14	0.5 or Table 4.3	Lfw = [FGtrees * BCEFr * (1+R) + FGpart * D] * CF
		FGtrees	BCEFr	R	FGpart	D	CF	Lfw
Woodland	Woodland	2000000	2.28	0.2			0.5	2736000

Figure 4-12. Capturing loss of carbon from fuelwood removals (charcoal inclusive) in the worksheet

The Equation 4-8 below explains the process of making carbon estimates that are related to fuel extraction (including usage of expansion factor and root to shoot ratio).

Equation 4-8. Application of BEF in estimating biomass related to fuelwood extraction

$$Lfuelwood = [\{FGtrees \bullet BCEFR \bullet (1+R)\} + FGpart \bullet D] \bullet CF$$

Where:

- Lfuelwood = annual carbon loss due to fuelwood removals, tonnes C yr^{-1}
- FGtrees = annual volume of fuelwood removal of whole trees, m^3 yr^{-1}
- FGpart = annual volume of fuelwood removal as tree parts, m^3 yr^{-1}
- R = ratio of below-ground biomass to above-ground biomass, in tonne dry matter d.m. below-ground biomass (tonnes d.m. above-ground biomass)$^{-1}$; R must be set to zero if assuming no changes of below-ground biomass allocation patterns.
- CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$). The default value is 0.5.
- D = basic wood density, tonnes d.m. m^3
- BCEFR = biomass conversion and expansion factor for conversion of removals in merchantable volume to biomass removals (including bark), tonnes biomass removal (m^3 of removals)-1, or calculated as: BCEFR = BEFR * D, where Biomass Expansion Factors (BEFR) expand the consideration of merchantable wood removals to total above-ground biomass volume to account for non-merchantable components of the tree, stand and forest. BEFR is dimensionless.

Land Use Category			Equation 2.14							Equation 2.11
			Available area (ha)	Area affected by disturbances (ha / yr)	Average above-ground biomass of areas affected (tonnes dm / ha)	Ratio of below-ground biomass to above-ground biomass [tonnes bg dm / (tonne ag dm)]	Carbon fraction of dry matter [tonnes C / (tonne dm)]	Fraction of biomass lost in disturbance	Annual other losses of carbon (tonnes C / yr)	Annual decrease in carbon stocks due to biomass loss (tonnes C / yr)
Initial land use		Land use during reporting year		National statistics or international data sources	Table 4.9	Zero (0) or Table 4.4	0.5 or Table 4.3		Ldisturb = A * Bw * (1+R) * CF * fd	ΔCl = Lwr + Lfw + Ldisturb
				Adisturb	Bw	R	CF	fd	Ldisturb	ΔCl
est Land	DTHF	Bush	1254.6	1254	13	2	0.5	1	24453	24453.09
	THF	Bush	345.4	345	13	2	0.5	1	6727.5	6727.5

Figure 4-13. Capturing loss of carbon loss due to disturbance

4.2.3.2.2 Estimating, Changes in living biomass in converted land category

Loss in carbon stocks may also be as result of land being converted from a land category of a higher biomass stock to a land category of a lower biomass category. Under such circumstance, the methodology includes defining biomass stock before conversion and biomass stock after conversion (Figure 4-14). Biomass gain and losses of convert land is estimated based on Equation 4-9:

Equation 4-9. Carbon stock changes in living biomass on converted land

$$C_B = \Delta C_G + ((B_{After} - B_{BEFORE}) * \Delta A_{TO\_OTHER}) * CF - \Delta C_L$$

Where:

C_B = Annual change in carbon stocks in biomass

ΔC_G = Annual biomass carbon growth

B_{BEFORE} = Biomass stocks before the conversion

B_{After} = Biomass stocks after the conversion

ΔA_{TO_OTHER} = Annual area of Land Converted

CF = Carbon fraction of dry matter (0.5 default)

ΔC_L = Annual loss of biomass carbon

Note that under Tier 1, B_{After} is normally equated to be 0. Where information is available (especially Tier 2 and Tier2) it is good practice to use the actual value if biomass stock after is significantly greater than zero and can be estimated or is known.

Main land categories where this approach is applicable is land converted into cropland (3.B.2.b) from forest land to cropland (3.B.2.b.i), grassland land to cropland (3.B.2.b.ii) wetland to cropland (3.B.2.b.iii) wetland land to cropland (3.B.2.b.iii) settlement to cropland (3.B.2.b.iv) other land to cropland (3.B.2.b.v).

Land Use Category					Equation 2.16			Equation 2.15,2.16		
					Annual area of Land Converted to Cropland (ha)	Biomass stocks before the conversion (tonnes dm / ha)	Carbon fraction of dry matter [tonnes C / (tonne dm)]	Annual biomass carbon growth (tonnes C / yr) (1)	Annual loss of biomass carbon (tonnes C / yr) (2)	Annual change in carbon stocks in biomass (tonnes C / yr)
Initial land use		Land use during reporting year		Vegetation type		Table 5.8	0.5	Table 5.9	National estimates, or Table 5.1	ΔCb = ΔCg + ((0 - Bb) * ΔA) * CF - ΔCl
					ΔA	Bb	CF	ΔCg	ΔCl	ΔCb
Grassland	Grassla...	Cropland	SubsFa...	Herbaceous		8	0.5	0.5	0.8	-0.3
	Grassla...		SubsFa...	Woody		8	0.5	1	1.2	-0.2
				Subtotal						-0.5
Grassland	Grassla...	Cropland	Larg Sc...	Herbaceous	1317	8	0.5	0.4	0.6	-5268.2
	Grassla...		Larg Sc...	Woody	1317	8	0.5	0.5	1.2	-5268.7
				Subtotal						-10536.9
Grassland	Grassla...	Cropland	SubsFa...	Herbaceous	96806	8	0.47	1	1	-363990.56

Figure 4-14. Example of data capture biomass changed due to land conversion

4.2.3.2.3 Estimation of C Pools in dead organic matter (DOM)

Annual change in carbon stocks in dead organic matter due to land conversion takes the following factors into consideration: Area undergoing conversion, Dead wood/litter stock, under the new land-use category, Dead wood/litter stock under the old land-use category, and the time period of the transition from old to new land-use. Due to paucity of data (even no default values) these pools may not estimated in developing countries. However, annual change in carbon stocks in dead wood and litter may be estimated using Equation 4-10:

Equation 4-10. Estimating Carbon Stock changes in DOM

$$\Delta C_{DOM} = A * (C_n - C_o) / T$$

Where ;

- ΔC_{DOM} = Annual change in carbon stocks in dead wood/litter
- A = Area undergoing conversion from old to new land-use category
- C_n = Dead wood/litter stock, under the new land-use category (tonnes C ha^{-1})
- C_o = Dead wood/litter stock, under the old land-use category (tonnes C ha^{-1})
- T = Time period of the transition from old to new land-use category (default 20 years)

4.2.3.2.4 Estimation of C Pools in Wetlands (general)

Wetlands include any land that is covered or saturated by water for all or part of the year, and that does not fall into the Forest Land, Cropland, or Grassland categories. Managed wetlands are restricted to wetlands where the water table is artificially changed (e.g., drained or raised) or those created through human activity (e.g., damming a river). Emissions from unmanaged wetlands are not estimated.

Methodologies are provided for:

- Peatlands cleared and drained for production of peat for energy, horticultural and other uses.
- Reservoirs or impoundments, for energy production, irrigation, navigation, or recreation

Some uses of wetlands are not covered because adequate methodologies are not available. These include manure management ponds, industrial effluent ponds, aquaculture ponds, and rewetting of previously drained wetlands or wetland restoration. If any of these activities are considered significant, Uganda should consider research to assess their contribution to greenhouse gas emissions or removals.

Total emissions from wetlands are estimated as a combination of land conversion (flooding, or drainage) and peat extraction (Equation 4-11).

Equation 4-11. Estimating CO_2 emissions related to peat extraction

$$CO_2\_W = CO_{2\_Wpeat} + CO_{2\_Wflood}$$

Where:

- CO_2_W = CO_2 emissions from wetlands, Gg CO_2 yr-1
- CO_2_Wpeat = CO_2 emissions from peatlands managed for peat production, Gg CO_2 yr-1
- CO_2_Wflood = CO_2 emissions from (lands converted to) Flooded Land, Gg CO_2 yr-1

Note that estimating CO_2 emissions from lands undergoing peat extraction has two basic elements: on-site emissions from peat deposits during the extraction phase, and off-site emissions from the horticultural (non-energy) use of peat. Peat extraction starts with vegetation clearing, which prevents further carbon sequestration, so only CO_2 emissions are considered.

$$CO_2\text{-}C_{WW\ peat} = CO_2\text{-}C_{WW\ peaton\text{-}site} + CO_2\text{-}C_{WW\ peatoff\text{-}site},$$

Later, converted to CO_2-equivalent (CO_2- WW peat = CO2-CWW peat * 44/12)

Where:

- CO_2 WW_{peat} = CO_2 emissions from land undergoing peat extraction, Gg CO2 yr-1
- CO_2–$CWW_{peatoff\text{-}site}$ = off-site CO_2–C emissions from peat removed for horticultural use, Gg C yr-1
- CO_2–$CWW_{peaton\text{-}site}$ = on-site CO_2–C emissions from drained peat deposits, Gg C yr-

Off-site emissions from peat removed for horticultural use (Gg C yr^{-1}) are estimated as:

$$CO_2\text{-}C_{WW\ peatoff\text{-}site} = (Wt_{dry\ peat} * Cfraction_{wt\ peat})/1000$$

Where

- $Wt_{dry\ peat}$ = air-dry weight of extracted peat, tonnes yr-1

On-site CO_2–C emissions from drained peat deposits are estimates as:

$$CO_2\text{-}C_{WW\ Peat\text{-}on\text{-}site} = CO_2\text{-}C_{WW\ PeatSoil} + \Delta C_{WWpeatB}$$

Where

- $\Delta C_{WWpeatB}$ = CO_2–C emissions from change in carbon stocks in biomass due to vegetation clearing, Gg C yr-1
- $CO_2\text{-}C_{WW\ PeatSoil}$ = CO_2-C emissions from managed peatlands

Note that emissions from change in C stocks in biomass that are due to vegetation clearing (Gg C yr^{-1}) are calculated as in the carbon stock changes in living biomass discussed before: ($DC_{WWpeatB} = \{\Delta A_{TO\_OTHERS} * (B_{AFTER} - B_{BEFORE}) * CF\}/1000$)

CO_2-C emissions from managed peatlands is calculated as:

$$CO_2\text{-}C_{WW\ PeatSoil} = (A_{PeatRich} * EF_{PeatRich} + A_{PeatPoor} * EF_{PeatPoor}) * 10^{-3}$$

Where:

- $CO_2\text{-}C_{WW\ PeatSoil}$ = CO_2-C emissions from managed peatlands
- $A_{PeatRich}$ = area of nutrient-rich peat soils managed for peat extraction (all production phases), ha
- $A_{PeatPoor}$ = area of nutrient-poor peat soils managed for peat extraction (all production phases), ha

- $EF_{PeatRich}$ = CO_2 emission factors for nutrient-rich peat soils managed for peat extraction or abandoned after peat extraction, tonnes C ha-1 yr-1
- $EF_{PeatPoor}$ = CO_2 emission factors for nutrient-poor peat soils managed for peat extraction or abandoned after peat extraction, tonnes C ha-1 yr-1

4.2.3.2.5 Carbon Stock changes in Flooded Land

Flooded Lands are defined as water bodies where human activities have caused changes in the amount of surface area covered by water, typically through water level regulation. Examples of Flooded Land include reservoirs for the production of hydroelectricity, irrigation, and navigation. Regulated lakes and rivers that do not have substantial changes in water area in comparison with the pre-flooded ecosystem are not considered as Flooded Lands. Rice paddies are addressed under Aggregate sources and non CO_2 emissions. Temporal and spatial variability of CH_4 emissions has so far precluded the development of default emissions for flooded areas. Country specific CH_4 emission factors may be developed where they are considered significant . Nitrous oxide emissions from Flooded Lands are typically very low, unless there is a significant input of organic or inorganic nitrogen from the watershed.

For the above reasons, only CO_2 emissions from Land Converted to Flooded Land are considered.

Equation 4-9 of estimating annual change in carbon stocks in biomass on Land Converted to Flooded Land tonnes C yr^{-1} (tonnes C yr^{-1}) is applicable while estimating annual change in carbon stocks in biomass on *Land Converted to Flooded Land*, tonnes.

4.2.3.2.6 Carbon Emissions from organic soils

4.2.3.2.7 Drained Land

CO2 emissions from organic soils are due to enhanced microbial decomposition caused by drainage and associated management activity. Emissions are estimated as a factor of land area affected and Emission factor: see Figure 4-15 and Equation 4-12

Equation 4-12. Estimating Emissions from drained organic soils

$$L_{Organic} = A * EF$$

Where:

- A = Land area of drained organic soil (or cultivated)
- EF = Table 5 provides C Emission factor of organic soils based on climate type. This referenced as Table 4.6 of the 2006 IPCC guidelines. Also provided in Appendix 6 under reference tables for land.

Land Use Category		Equation 2.26			
		Available area (ha)	Land area of drained organic soil (ha)	Emission factor for climate type (tonnes C/ha/yr)	Annual carbon loss from drained organic soils (tonnes C / yr)
Initial land use	Land use during reporting year			Table 4.6	Lorganic = A * EF
			A	EF	Lorganic
Total					

Figure 4-15. Capturing carbon loss from drained organic soils

4.2.3.2.7.1 Non-CO2 Emissions from Peatland

When peatlands are drained in preparation for peat extraction, the natural production of CH_4 is largely reduced, but not entirely shut down (Strack *et al*., 2004), as the methanogen bacteria thrive only in anaerobic conditions. Under Tier 1, methane emissions are thus assumed to be insignificant.

Depending on site fertility, peat deposits may contain significant amounts of organic nitrogen in inactive form. Drainage allows bacteria to convert the nitrogen into nitrates, which then leach into the surface where they are reduced to N_2O. In drained peatlands, the potential quantity of N_2O emitted depends on the nitrogen content of the peat. At C:N ratios exceeding 25, the N_2O emissions may be considered insignificant (Klemedtsson et al., 2005).

Land Use Category		Equation 7.7			
		Available area (ha)	Area of nutrient rich peat soils managed for peat extraction, including abandoned areas in which drainage is still present (ha)	Emission factor for drained nutrient-rich Wetlands organic soils (kg N2O / (ha yr))	Direct N2O emissions from peatlands managed for peat extraction (Gg N2O / yr)
Initial land use	Land use during reporting year			Table 7.6	N2O = (Arich * EFrich) * 44/28 * 10^-6
			Arich	EFrich	N2O

Figure 4-16. Capturing data on N_2O emissions from drained organic soils

Nitrogen fertilizers are commonly added to horticultural peat before use, and this source would likely dominate N_2O emission patterns. Though there could be N_2O emissions from organic matter decay during the off-site use of horticultural peat these emissions are handled in the under aggregate sources in the section of fertilizer applications to avoid double counting. Thus only direct N_2O emissions due to peat extraction are estimated using Equation 4-13.

Equation 4-13. Direct N2O emissions related to Peat Extraction

Direct N_2O emissions from peatlands managed for peat extraction (Gg N_2O yr^{-1}):

$$N_2O_{WW\ peatExtraction} = (A_{PeatRich} * EF_{N2O\text{-}NPeatRich}) * 44/28 * 10^{-6}$$

Where:

- $N_2O_{WW\ peatExtraction}$ = direct N_2O emissions from peatlands managed for peat extraction, Gg N_2O/ yr
- $A_{PeatRich}$ = area of nutrient-rich peat soils managed for peat extraction, including abandoned areas in which drainage is still present, ha
- $EF_{N2O\text{-}NPeatRich}$ = emission factor for drained nutrient-rich wetlands organic soils, kg N_2O–N /ha/yr. Software illustration given in Figure 4-16).

4.2.3.2.7.2 Estimation of Carbon stock changes in Mineral soils

For mineral soils, the default method is based on changes in soil C stocks over a finite period of time. The change is computed based on C stock after the management change relative to the carbon stock in a reference condition (i.e., native vegetation that is not degraded or improved).

Equation 2.25, Formulation B in Box 2.1 of Section 2.3.3.1								
Area for land-use change by climate and soil comb -ination (ha)	Reference carbon stock for the climate and soil combination (tonnes C / ha)	Time dependence of stock change factors (D) or number of years over a single inventory time period (T) (yr)	Stock change factor for land -use system in the last year of an inventory time period (-)	Stock change factor for management regime in last year of an inventory period (-)	Stock change factor for C input in the last year of the inventory period (-)	Stock change factor for land-use system at the beginning of the inventory time period (-)	Stock change factor for management regime at the beginning of the inventory time period (-)	Stock change factor for C input at the beginning of the inventory time period (-)
	Table 2.3; Section 2.3.3.1	Default value is 20	Table 5.5	Table 5.5	Table 5.5	Table 5.10	Table 5.10	Table 5.10
A(0)	SOCref	D	Flu(0)	Fmr(0)	Fi(0)	Flu(0-T)	Fmr(0-T)	Fi(0-T)
	47	20	0.48	1	0.92	1	1	1
	47	20	0.48	1	0.92	1	1	1
	47	20	0.48	1	0.92	1	1	1

Figure 4-17. Capturing data on annual change in carbon stocks in mineral soils

It is assumed that soil organic C (SOC) stock changes during the transition to a new equilibrium SOC occurs in a linear fashion. Using the default method, changes in soil C stocks are computed over an inventory time period. Inventory time periods will likely be established based on the years in which activity data are collected, such as 1990, 1995, 2000, 2005 and 2010. For each inventory time period, the SOC stocks are estimated for the first (SOC(0-T)) and last year (SOC(0)) based on multiplying the reference C stocks by stock change factors (Figure 4-17). Annual rates of carbon stock change are estimated as the difference in stocks at two points in time divided by the time dependence of the stock change factors as shown in the equation 2.25 of Vol 4 of IPCC 2006 presented here as Equation 4-14.

Equation 4-14. Estimating Emissions from Mineral Soils:

ANNUAL CHANGE IN ORGANIC CARBON STOCKS IN MINERAL SOILS

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

$$SOC = \sum_{c,s,i} \left(SOC_{REF_{c,s,i}} \bullet F_{LU_{c,s,i}} \bullet F_{MG_{c,s,i}} \bullet F_{I_{c,s,i}} \bullet A_{c,s,i} \right)$$

(Note: T is used in place of D in this equation if T is ≥ 20 years, see note below)

Where:

- ΔC Mineral = annual change in carbon stocks in mineral soils, tonnes C yr-1
- SOC(0) = soil organic carbon stock in the last year of an inventory time period, tonnes C
- SOC(0-T) = soil organic carbon stock at the beginning of the inventory time period, tonnes C
- SOC(0) and SOC(0-T) are calculated using the SOC equation in Equation 2.25 where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)
- T = number of years over a single inventory time period, year
- D = Time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, year. Commonly 20 years, but depends on assumptions made in computing the factors FLU, FMG and FI. If T exceeds D, use the value for T to obtain an annual rate of change over the inventory time period (0-T years).
- *c* = represents the climate zones, *s* the soil types, and *i* the set of management systems that are present in a country.
- SOCREF = the reference carbon stock, tonnes C ha-1.
- FLU = stock change factor for land-use systems or sub-system for a particular land-use, dimensionless .
- FMG = stock change factor for management regime, dimensionless.
- FI = stock change factor for input of organic matter, dimensionless.
- A = land area of the stratum being estimated, ha. All land in the stratum should have common biophysical conditions (i.e., climate and soil type) and management history over the inventory time period to be treated together for analytical purposes. Inventory calculations are based on land areas that are stratified by climate regions , and default soils types as shown in Table 2.3 Vol4 of IPCC 2006 guidelines.

4.2.3.3 ActivitY Data on Land

Within the region, Uganda has got a relatively detailed Activity Data (AD) for forestry and other land use. Regarding to area statistics, biomass stock and biomass increment, Uganda can Tier2 activity data. A summary of AD, units measure, key data providers and year of collection are provided in for Table 4-6 quick reference. Data collection for this subsector is very wide.

Table 4-6. Forestry and other Land use Activity data

A_id	Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Key data providers
1	Managed and unmanaged land area remaining unchanged	Area land categories managed and unmanaged	ha	1995 and 2005	NBS1995 NFA, 2005- 2012 GFC, GEOCOVER
2	Land category converted into land category being considered	Area of land category converted	ha yr-1	1995 and 2005	NBS1995 NFA, 2005- 2012 GFC, GEOCOVER
3	Standing Biomass	Biomass (above ground and below ground)	Dry Matter (dm) Tones / ha	1995 and 2005	NBS 1995 or default values 2006 IPCC
4	Amount of fuelwood harvested	Sum of fire wood and wood used for charcoal in a year	M^3 or Dry Matter (dm) Tones	1995, estimated / projected	ESD study, ESMAP, BEST, UBOS, MEMD, MWE, FAO
5	Amount of wood harvested	Sum of timber harvested in a year	M^3 or Dry Matter (dm) Tones	1995, estimated / projected	ESD study, ESMAP, BEST, UBOS, MEMD, MWE, FAO
6	Loss due to disturbance	Biomass loss due to fire, pest and disease	Dm /yr	2000- 2012	FSSD, NFA, Global fire monitoring agencies
7	Area of organic soils drained or cultivated	Area organic soils drained or cultivated annually	ha yr-1	1995 and 2005	NBS 1995, NFA2005 or MAAIF
8	Area of flooded	Area flooded annually	ha yr-1	1995 and 2005	NBS1995, NFA, NFA 2005
9	Area of peat extraction	Area of peat extraction and stockpiling	ha yr-1		
10	Liming	Amount of lime applied	Tons yr-1		NFA, SPGS, MAAIF
11	Fertilizer (N) input on managed soils	N in synthetic fertilizers, animal manure, compost, sewage sludge, crop residues, changes in land use / management	Kg N yr-1		NFA, SPGS, MAAIF
12	Burnt area of savannah annually	Area of managed land burnt	ha yr-1	2000 to Present	NASA- MODIS, UNEP

4.2.3.4 Emission Factors (Carbon Stock Change Factors)

Approach and methodological choice are determined by data availability, level of accuracy and spatial resolution. In addition the activity data, Emission Factors (or commonly known as Carbon Stock Change (CSC) in Forest and Other land) are listed in Table 4-7 as quick reference guide. Tables with default values are referenced such that they are applied where country specific data is insufficient or is not available. Unless otherwise stated, most references are from volume 4 2006 IPCC guidelines. Chapters vary from 4 up to 9 depending on the land category. For quick reference most of the tables have been listed in Appendix C under Forest and other land reference tables.

Table 4-7. Country Specific and Default Carbon Stock Change Factors (Ref; 2006 IPCC,2003 LULUCF GPG).

Type of Factor	Emission Factor (Carbon-Stock Change Factor) Value	Emission Factor (Carbon-Stock Change Factor)Units	Reference
Annual growth rates	$G_{W,}$ Varies per land category and sub category	tonnes dry matter (dm)ha^{-1} yr^{-1}	Country specific studies e.g., National Biomass Study 1995 NFA 2004-200;Where not applicable, use Default values Tables 4.9, 4.10 and 4.12
Annual stock change	Derived from Forest inventories (Varies per land category and location)	tonnes dry matter (dm)ha^{-1} yr^{-1}	Country specific studies e.g., National Biomass Study 1995 NFA 2004-2006
Root to shoot ratio	Varies per land use, management and species (table 4.4)	Dimensionless	Table 4.4
Conversion and expansion factor merchantable volume to total biomass	$BCEF_R$	Ratio	Table 4.5
Carbon fraction (CF) of dry matter	(CF) 0.5 or Table 4.3	Ratio[1]	0.5 or Table 4.3
Fuelwood removed (m^3) as tree parts	FG_{part}	m^3 yr^{-1}	NBS, FAO statistics
Basic wood density	D varies per species	tonnes m^{-3}	Country specific studies e.g., NBS 1992 Comparable to default values in Tables 4.13 and 4.14
Emission factor for drained nutrient-rich Wetlands organic soils	$EF_{N2O-NPeatRich}$	(kg N_2O-N ha^{-1} yr^{-1})	2006 IPCC Table 4.6
Native (mineral soils) Reference carbon stock	SOC_{ref} Varies per climate and soil combination	T C ha^{-1}	Table 2.3; Chap. 2, Sec. 2.3.3.1
Mineral soils relative Stock change factor for land-use system	$F_{LU,}$ Varies per land category, last year of inventory period and first year of inventory period	Denoted as $F_{LU(0)}$ for last year and $F_{LU(0-T)}$ for first year	Forest land (Ref Table 2.3) Cropland Table 5.5 Grassland Table 6.2 Settlement Chap. 8, Sec. 8.3.3 Other land Chap. 9, Sec. 9.3.3
Mineral soils relative Stock change factor for management regime	F_{MG} Varies per land category, last year of inventory period and first year of inventory period	Denoted as $F_{MG(0)}$ for last year and $F_{MG(0-T)}$ for last year	Forest land (Ref Table 2.3) Cropland Table 5.5 Grassland Table 6.2 Settlement Chap. 8, Sec. 8.3.3 Other land Chap. 9, Sec. 9.3.3

Mineral soils relative Stock change factor for C input	F_I Varies per land category, last year of inventory period and first year of inventory period	Denoted as $F_{I(0)}$ for last year and $F_{I(0-T)}$ for first year	Forest land (Ref Table 2.3) Cropland Table 5.5 Grassland Table 6.2 Settlement Chap. 8, Sec. 8.3.3 Other land Chap. 9, Sec. 9.3.3
Emission factor lime calcic limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$	Calcic limestone default is 0.12 Dolomite default is 0.13	Dimensionless	2006 IPCC
Emission factor for CO2-C from nutrient rich managed peat soils for peat extraction	$EF_{PeatRich}$	T C ha^{-1} yr^{-1}	Table 7.4 2006 IPCC
Emission factor for CO2-C from nutrient poor managed peat soils for peat extraction	$EF_{PeatPoor}$	T C ha^{-1} yr^{-1}	Table 7.4 2006 IPCC
CO2 emission factors for nutrient-rich peat soils	$EF_{CO2PeatRrich}$ T C ha^{-1} yr^{-1}	T ha^{-1} yr^{-1}	Table 7.4
Emission factor for drained nutrient-rich Wetlands organic soils	kg N_2O-N ha^{-1} yr^{-1}	Kg ha^{-1} yr^{-1}	Table 7.6

4.2.3.5 Uncertainty

Uganda is using approach 3 on activity data on land i.e., periodic wall to wall mapping of land cover / land use and a mixture of Tier 3, Tier2 and Tier 1 carbon stock changes. Land cover mapping in Uganda was never intended of GHG inventories and document of level of uncertainty is lacking. This applies to forest inventories whose purpose was for quantification of forest product (mainly timber, and fuelwood). As guide, an example of how uncertainties for land use cover may be assessed is provided in Appendix D.

4.2.3.6 Improvements

It is recommended that the old system where agriculture extension workers would collect data at lower administration levels (parish and sub county) and forward it up to district be re-

4.2.4 Aggregate Sources and Non-CO_2 Emission Sources on Land(3.C)

4.2.4.1 Aggregate Sources and Non- CO_2 Category Information

The emissions from this subcategory are divided into emissions from biomass burning, Liming, Urea Application Direct and indirect N_20 emissions from managed soils, Rice cultivation and indirect emissions from manure management.

4.2.4.2 Methodology and Approach

4.2.4.2.1 Emissions from Biomass Burning (3.C.1)

GHG emissions results from the burning of savannas, forest, cropland and all other land burning. The mass of fuel available for combustion is critical for estimating emissions from burning biomass. Data for the area burnt may be downloaded from MODIS (NASA) website on http://wist.echo.nasa.gov. This data may be over layered country specific biomass spatial data sets in a Geographical Information System (GIS) environment. Alternatively, FAO statistics on biomass burning may be used. IPCC default values may be used where country-specific data is unavailable. Tables 2.4 to 2.6 volume 4 of 2006 IPCC provide default values.

The general equation for estimating emissions from fires is presented Equation 4-15:

Equation 4-15. Estimating Emissions for fire burning

$$\boldsymbol{L_{fire}} = A\ x\ \boldsymbol{M_B}\ \ x\ \boldsymbol{C_f\ x\ G_{ef}}\ \ x\ \ 10^{-3}$$

Where:

- Lfire = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc.
- A = area burnt, ha
- M_B = mass of fuel available for combustion, tonnes ha-1. This includes biomass, ground litter and dead wood. When Tier 1 methods are used then litter and dead wood pools are assumed zero, except where there is a land-use change (see Section 2.3.2.2).
- C_f = combustion factor, dimensionless (default values in Table 2.6)
- G_{ef} = emission factor, g kg-1 dry matter burnt (default values in Table 2.5)

Note: Where data for MB and Cf are not available, a default value for the amount of fuel actually burnt (the product of MB and Cf) can be used (Table 2.4) under Tier 1 methodology.

4.2.4.2.2 Estimating emissions from liming and Urea application (3.C.2 and 3.C.3)

Liming is used to reduce soil acidity and improve plant growth in managed systems, particularly agricultural lands and managed forests. Adding carbonates to soils in the form of lime (e.g., calcic limestone ($CaCO_3$), ordolomite ($CaMg(CO_3)_2$) leads to CO_2 emissions as the carbonate limes dissolve and release bicarbonate ($2HCO_{3-}$), which evolves into CO_2 and water (H_2O). Inventories can be developed using Tier 1, 2 or 3 approaches, with each successive Tier requiring more detail and resources than the previous one. It is *good practice* for countries to use higher tiers if CO_2 emissions from liming are a key source category.

Adding urea to soils during fertilisation leads to a loss of CO_2 that was fixed in the industrial production process. Urea ($CO(NH_2)_2$) is converted into ammonium (NH_4+), hydroxyl ion (OH-), and bicarbonate (HCO_3-), in the presence of water and urease enzymes. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO_2 and water.

CO2 Emissions from additions of carbonate limes to soils can be estimated Equation 4-16:

Equation 4-16. Emission From Lime Application

$$CO_2\text{–}C\ Emission = \left(M_{Limestone} \bullet EF_{Limestone}\right) + \left(M_{Dolomite} \bullet EF_{Dolomite}\right)$$

Where:

- CO2–C Emission = annual C emissions from lime application, tonnes C yr-1
- M = annual amount of calcic limestone (CaCO3) or dolomite (CaMg(CO3)2), tonnes yr-1
- EF = emission factor, tonne of C (tonne of limestone or dolomite) -1

CO_2 Emissions from urea fertilization can be estimated with

Equation 4-17 as shown below.

Equation 4-17. General Equation for estimating Emissions from fertilizer

$$CO_2\text{–}C\ Emission = M \bullet EF$$

Where:

- CO_2–C Emission = annual C emissions from urea application, tonnes C yr-1

- M = annual amount of urea fertilisation, tonnes urea yr-1
- EF = emission factor, tonne of C (tonne of urea)-1

4.2.4.2.3 Direct N_2O and Indirect N_2O Emissions from Managed Soils

Managed soils are all soils on land, including Forest Land, which is managed. There are two pathways considered for emissions of N_2O that resulting from anthropogenic N inputs or N mineralization occur;

i) a direct pathway (i.e., directly from the soils to which the N is added/released), and
ii) through two indirect pathways:
   a. following volatilization of NH_3 and NO_x from managed soils and from fossil fuel combustion and biomass burning, and the subsequent redisposition of these gases and their products NH_4+ and NO_3- to soils and waters; and
   b. after leaching and runoff of N, mainly as NO_3-, from managed soils.

Direct emissions of N_2O from managed soils are estimated separately from indirect emissions, though using a common set of activity data. The Tier 1 methodologies do not take into account different land cover, soil type, climatic conditions or management practices (other than specified above). Neither do they take account of any lag time for direct emissions from crop residues N, and allocate these emissions to the year in which the residues are returned to the soil. These factors are not considered for direct or (where appropriate, indirect) emissions because limited data are available to provide appropriate emission factors.

4.2.4.2.4 Estimating Direct N_2O Emissions from Managed Soils (3.C.4)

i) Input the total synthetic N fertilizer (in kg N/yr) used in the country. If this is unavailable 0.1 may be used (2006 IPCC Guidelines).
ii) Enter the amount of manure nitrogen used as fertilizer corrected for NH_3 and NO_x emissions, and excluding manure produced during grazing. To obtain this, use 4-5A (Supplement).
iii) Enter the emission factor or choose default for N2O emission from the N inputs and the software will calculate the required emissions automatically
iv) To calculate the ***emissions from Urine and dung inputs in the grazed soils;*** enter the emission factor for N_2O from the urine and dung deposits on pasture, rangelands and paddocks by grazing animals.
v) The software calculates the emissions automatically.

Figure 4-18 , Figure 4-19 and Figure 4-20 illustrate how data related to direct and indirect N_2O emissions is captured in the 2006 IPCC software.

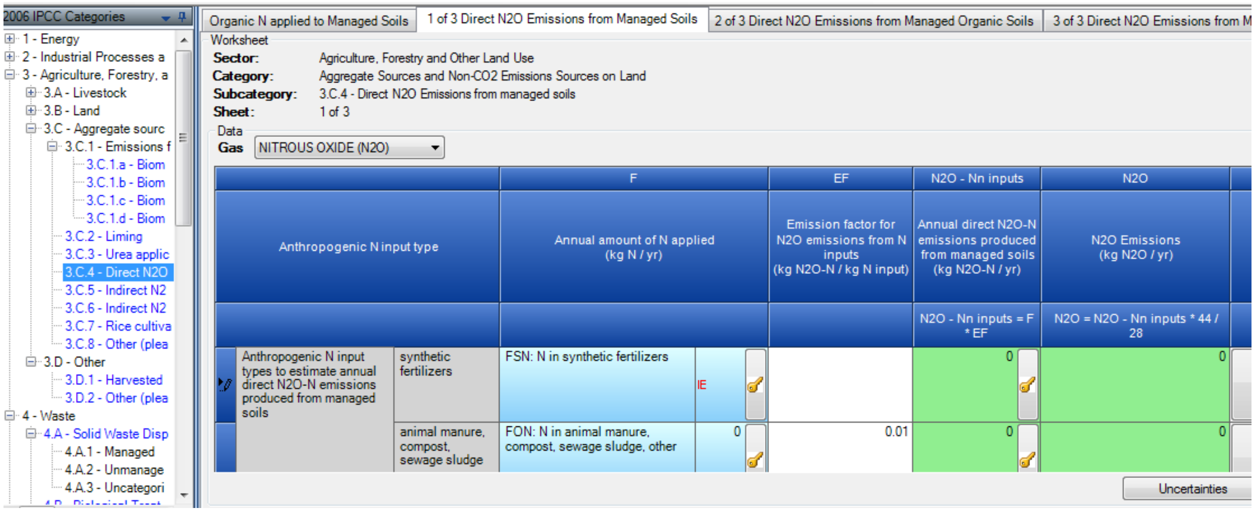


Figure 4-18.Direct N2O Emissions from managed soils worksheet

4.2.4.2.5 Estimating Indirect N_2O Emissions from Managed Soils (3.C.5)

The N2O emissions from atmospheric deposition of N volatilised from managed soil are estimated using Equation 4-18:

Equation 4-18. Indirect N2O Emissions from managed Soils

$$N_2O_{(ATD)}-N = \left[\left(F_{SN} \bullet Frac_{GASF}\right) + \left(\left(F_{ON} + F_{PRP}\right) \bullet Frac_{GASM}\right)\right] \bullet EF_4$$

($N2O_{(ATD)–N}$ = annual amount of N_2O–N produced from atmospheric deposition of N volatilised from managed soils, kg N_2O–N/ yr)

i) Enter the total annual synthetic fertilizer nitrogen applied to the soil FSN (kg N / yr)

ii) Input the fraction of synthetic nitrogen fertilizer ($Frac_{GASF}$) that volatilizes as NH_{3}- and NO_x. The 2006 IPCC default value of 0.10 kg (NH_3-N + NO_x-N)/kg N applied may be used.

iii) Enter annual amount of animal manure, compost, sewerage sludge and other organic N_{on} (kg N / yr)

iv) Enter annual amount of Urine and Dung N deposited by the grazing animals on pasture F_{PRP}(kg N / yr)

v) Enter the fraction $Frac_{GASM}$ of total applied organic N fertilizer material (F_{ON}) and of Urine and Dung N deposited by the grazing animals on pasture (F_{PRP}) that volatilizes. The 2006 IPCC default value of 0.20 kg (NH_3-N + NOx-N)/kg N applied or deposited may be used.

vi) Enter the emission factor (EF_4) for N_2O from atmospheric deposition of N on soils and water surfaces. Use the IPCC 2006 default value of 0.01 kg N_2O -N/kg(NH_3-N+ NOx -N) volatilized if local data is absent.

Conversion of $N_2O_{(ATD)–N}$ emissions to N_2O emissions for reporting purposes is performed by using the following factor:

$$N_2O_{(ATD)} = N_2O_{(ATD)} – N \bullet 44/28$$

The IPCC software worksheet (Figure 4-18) automatically performs these conversions once all the data is captured. For countries that are able to estimate the quantity of N mineralised from organic soils, this should be included as additional input to the equation.

4.2.4.2.5.1 N_2O emissions from N leaching and runoff

The N_2O emissions from leaching and runoff in regions where leaching and runoff occurs are estimated using Equation 4-19 as per explanation in chapter 10, volume 4 2006 IPCC.

Equation 4-19. N_2O from Leaching and runoff

$$N_2O_{(L)}–N = \left(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}\right) \bullet Frac_{LEACH-(H)} \bullet EF_5$$

Where:

- $N2O_{(L)}$–N = annual amount of N2O–N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, kg N2O–N / yr
- F_{SN} = annual amount of synthetic fertiliser N applied to soils in regions where leaching/runoff occurs, kg N / yr
- F_{ON} = annual amount of managed animal manure, compost, sewage sludge and other organic N additions applied to soils in regions where leaching/runoff occurs, kg N / yr
- F_{PRP} = annual amount of urine and dung N deposited by grazing animals in regions where leaching/runoff occurs, kg N / yr-1
- F_{CR} = amount of N in crop residues (above- and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils annually in regions where leaching/runoff occurs, kg N / yr

- F_{SOM} = annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions
- $Frac_{LEACH-(H)}$ = fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N (kg of N additions)-1 (Table 11.3)
- EF_5 = emission factor for N2O emissions from N leaching and runoff, kg N2O–N (kg N leached and runoff)-1 (Table 11.3) For countries that are able to estimate the quantity of N mineralised from organic soils, this should be included as additional input to the equation

As in Equation 4-18, the IPCC software worksheet (Figure 4-19) automatically performs these conversions $N2O_{(L)}$–N into annual amount of N_2O emissions by a factor of 44 /28 once all the data is captured.

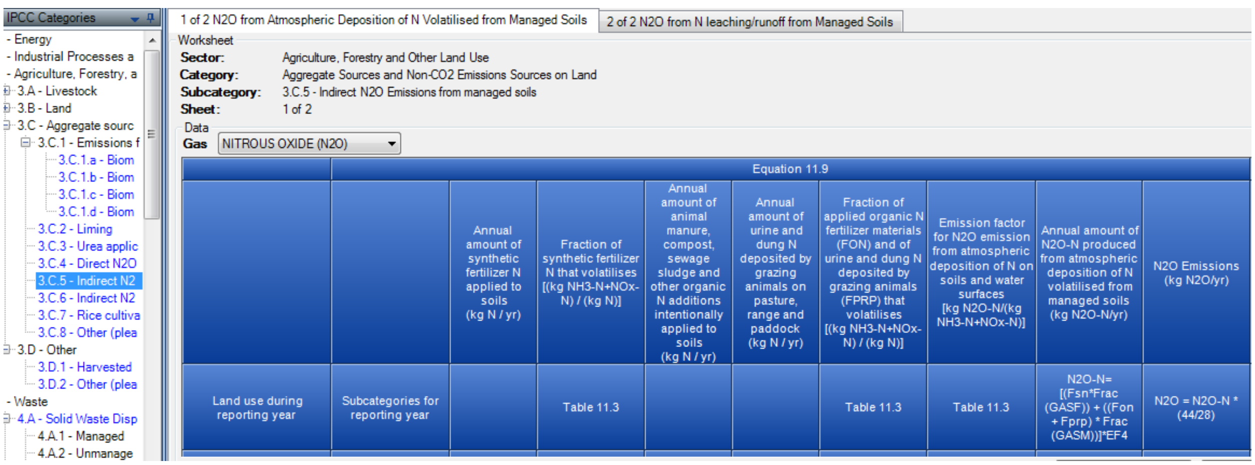


Figure 4-19. Software worksheet to estimate indirect N_2O Emissions from managed soils

4.2.4.2.6 Estimate Indirect N_2O Emissions from Manure Management (3.C.6)

i) Enter the fraction of livestock manure nitrogen that volatilizes. This can be obtained from the default table in the IPCC guidelines in case there are no country specific values. The IPCC inventory software has in built factors for selection. Note that the fraction is species specific.

ii) Enter the emission factor (EF4) for N_2O from atmospheric deposition of N on soils and water surfaces. Use the IPCC 2006 default value of 0.01 kg N_2O -N/kg(NH3-N+ NOx -N) volatilized if local data is absent.

iii) The IPCC inventory software calculates the N_2O emissions from Manure Management automatically

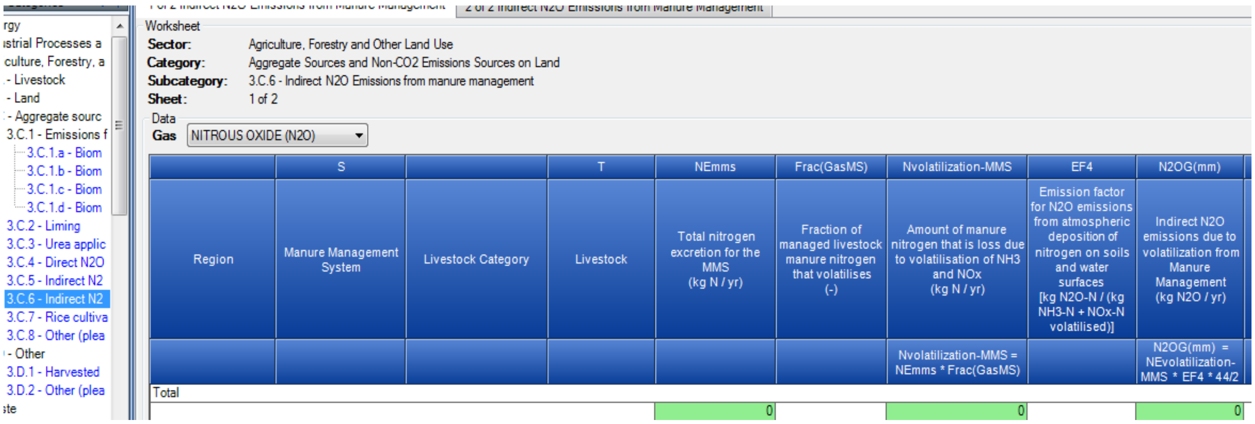


Figure 4-20, Capturing data on Indirect N_2O emissions due to manure management

$$N_{volatilization-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)}\right) \bullet \left(\frac{Frac_{GasMS}}{100}\right)_{(T,S)}\right]\right]$$

Where:

- $N_{volatilization-MMS}$ = amount of manure nitrogen that is lost due to volatilisation of NH_3 and NOx, kg N yr-1
- $N_{(T)}$ = number of head of livestock species/category *T* in the country
- $Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N animal-1 yr-1
- $MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless
- $Frac_{GasMS}$ = percent of managed manure nitrogen for livestock category *T* that volatilises as NH_3 and NOx in the manure management system *S*, %

4.2.4.2.6.1 Emissions from Rice Cultivation (3.C.7)

The calculation of CH_4 rice emissions combines a number of equations depending on available information (Figure 4-21). Calculation of the methane emissions from the rice fields is done by determining the annual harvested area of rice, the cultivation period of rice, and the daily emission factor for methane emission in rice (Equation 4-20). The data on harvested rice can be obtained from the Agricultural agencies and at the International Rice Research Institute (IRRI) at http://beta.irri.org.

Equation 4-20. Emission related to paddy rice

$$CH_{4\ Rice} = \sum_{i,j,k} (EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6})$$

Where:

- CH_4 Rice = annual methane emissions from rice cultivation, Gg CH4 yr-1
- EF*ijk* = a daily emission factor for *i*, *j*, and *k* conditions, kg CH4 ha-1 day-1
- t*ijk* = cultivation period of rice (days in a year) for *i*, *j*, and *k* conditions, day
- A*ijk* = annual harvested area of rice for *i*, *j*, and *k* conditions, ha /yr (harvested rice area according to rice ecosystem and category of land use)

i, *j*, and *k* = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary. The different conditions that should be considered include rice ecosystem type, flooding pattern before and during cultivation period, and type and amount of organic amendments. Other conditions such as soil type, and rice cultivar can be considered for the disaggregation if country-specific information about the relationship between these conditions and CH_4 emissions are available. The rice ecosystem types and water regimes during cultivation period are listed in Table 5.12.

4.2.4.2.6.2 Adjustments in emission factors (Equation 4-21)

Equation 4-21. Applying adjustment to Paddy Rice Emission factors

$$EF_i = EF_c \bullet SF_w \bullet SF_p \bullet SF_o \bullet SF_{s,r}$$

Where:

- EFi = adjusted daily emission factor for a particular harvested area
- EFc = baseline emission factor for continuously flooded fields without organic amendments

- SFw = scaling factor to account for the differences in water regime during the cultivation period (from Table 5.12)
- SFp = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (from Table 5.13)
- SFo = scaling factor should vary for both type and amount of organic amendment applied (from Table 5.14)
- SFs,r = scaling factor for soil type, rice cultivar, etc., if available

4.2.4.2.6.3 Scaling factors for organic amendments

It is *good practice* to develop scaling factors (Equation 4-22) that incorporate information on the type and amount of organic amendment applied (compost, farmyard manure, green manure, and rice straw).

Equation 4-22. Scaling Factors for organic amendments

$$SF_o = \left(1 + \sum_i ROA_i \bullet CFOA_i\right)^{0.59}$$

Where:

- SFo = scaling factor for both type and amount of organic amendment applied
- ROA*i* = application rate of organic amendment *i*, in dry weight for straw and fresh weight for others, tonne ha-1
- CFOA*i* = conversion factor for organic amendment *i* (in terms of its relative effect with respect to straw applied shortly before cultivation) as shown in Table 5.14.

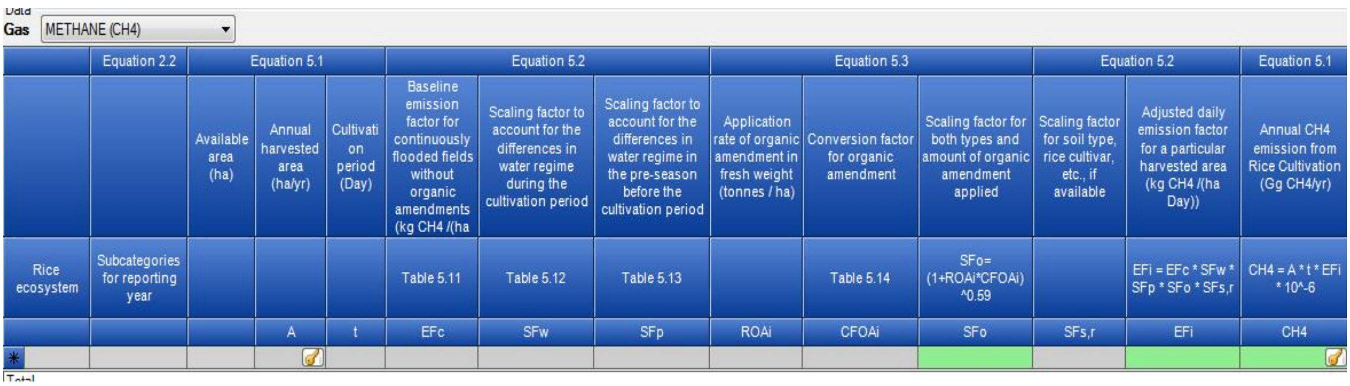


Figure 4-21, Example software data in puts related to rice cultivation

4.2.4.3 Activity Data

Table 4-8 gives an overview of the activity data for aggregate sources and CO_2 emission sources on land and possible data providers.

Table 4-8. Activity data for Aggregate sources and non CO_2 emissions onLand

A_id	Type of Activity Data	Activity Data Value(s)	Activity Data Units	Year (s) of Data	Data Providers
1	Liming	Amount of lime applied	Tons yr-1		NFA, SPGS, MAAIF
2	Rice cultivation area by type	Area (Ha)	HA		MAAIF
3	Fertilizer (N) input on managed soils	N in synthetic fertilizers, animal manure, compost, sewage sludge, crop residues, changes in land use / management	Kg N yr-1		NFA, SPGS, MAAIF, commercial crop and tree plantations
4	Burnt area of savannah annually	Area of managed land burnt	ha yr-1	2000 to Present	NASA- MODIS, UNEP

4.2.4.4 Emission Factors

gives a summary of the emission factors for aggregate sources and lists reference tables as per volume 4 2006 IPCC guidelines. These tables are also available in Appendix C of this manual.

Table 4-9. Emission Factors for aggregate sources and non CO emissions on Land

Type of Factor	Emission or Carbon-Stock Change Factor Value	Emission or Carbon-Stock Change Factor Units	Reference
Emission factor lime calcic limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$	Calcic limestone default is 0.12 Dolomite default is 0.13	Dimensionless	2006 IPCC
Emission factor for N_2O fertilizer application (direct emission)	kg N2O-N (kgN input)$^{-1}$	Kg	Table 11.1
Emission factor for N_2O managed soils (direct emission)	kg N_2O-N (ha^{-1} yr^{-1})	Kg	Table 11.1
Emission factor for N_2O due to leaching managed soils(Indirect emission)	Fraction of N leached kg N (kg of N additions)$^{-1}$	Kg	Table 11.3
Fraction of synthetic fertilizer N that volatilises (indirect emission)	(kg NH_3-N + NO_x-N) (kg of N applied)$^{-1}$	Kg	Table 11.3
Mass of fuel available for combustion	Varies per land category	Kg dry matter (dm /ha	Country specific studies e.g., National Biomass Study 1995 NFA 2004-200, where not applicable use Default values Table 2.4
Combustion factor	Varies per land category	Dimensionless	Table 2.6
CH_4 emission factor	Varies per land category	g GHG (kg dm burnt)$^{-1}$	Table 2.5
CO emission ratio	Varies per land category	g GHG (kg dm burnt)$^{-1}$	Table 2.5
N_2O emission ratio	Varies per land category	g GHG (kg dm burnt)$^{-1}$	Table 2.5
NO_x ratio	Varies per land category	g GHG (kg dm burnt)$^{-1}$	Table 2.5

4.2.5 **Harvested Wood Products (3.D)**

Harvested wood products transfer a portion of carbon into product pool that may take a long time to release CO_2. The rate of emission thus varies considerably among different product pools. Currently there are several different approaches for reporting the storage of carbon in wood products and estimation, reporting and accounting of the *HWP Contribution* is still under consideration by the UNFCCC.

5 WASTE SECTOR

5.1 Introduction

Wastes are generated from the day to day human activities as human population grow the quantities of the different categories of waste generated also increase proportionately. The problems of wastes are more pronounced in urban centres where there is concentration of human population and human activities. Waste management problems are therefore compounded by the rapid urban population growth that overstretches available resources. This is a big challenge to urban authorities and the wastes are impacting on the environment, the social and economic aspect of urban wellbeing. The input requirements for waste management in the form of money and equipment have constraint on all urban centres in Uganda that have failed to cope with the demands.

Municipal, industrial and other wastes produce significant amounts of greenhouse gases. In addition to CH_4, biogenic CO_2 and non-methane volatile organic compounds (NMVOCs) as well as smaller amounts of N_2O, NOx and CO are also produced. When the waste is decomposing NH_3 is also produced.

Solid Waste generation rates from the urban centres of Uganda are on average 0.55kg/capita/day; with the low income locations at 0.3kg/capita/day and high income locations at 0.66kg/capita/day. This amounts to about 200kg/cap/year compared to the African average value of 290kg/cap/year (IPCC 2006). The total amount of solid waste generated by Ugandan municipalities varies dependent on urban population and consumption cultures. The composition of municipal solid waste (MSW) in the different urban centres are however similar. Typical solid waste composition for Uganda is displayed in Figure 5-1. Only about 40% of the solid waste generated is collected and disposed of at dumpsites compared to the African disposal level of 69%. Most of the wastes therefore are discharged to the environment in various forms via burning, burying, etc.

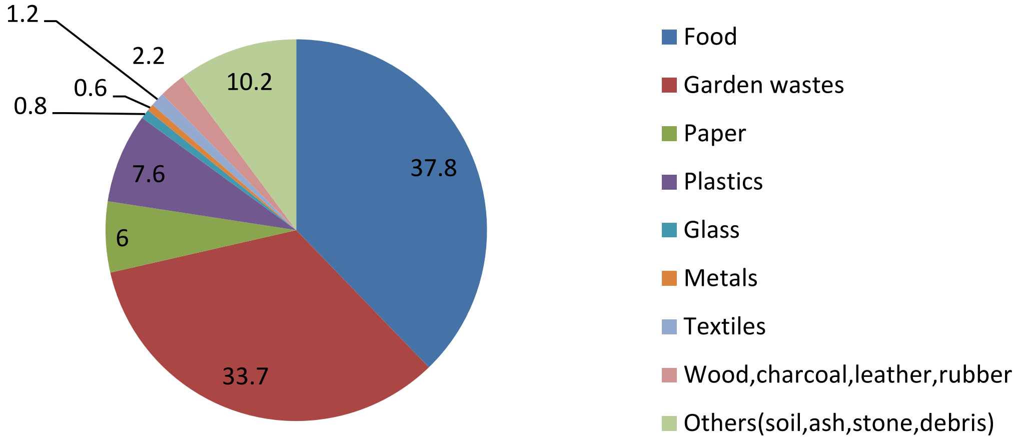


Figure 5-1. Average composition (% wet weight) of MSW for Uganda towns (NEMA 2011)

Waste is key sector for consideration in the GHG inventory. The waste sector covers greenhouse gas emissions occurring from Solid Waste disposal (4.A), Biological Treatment of Solid Waste (4.B) . Incineration and Open Burning of Waste (4.C). Wastewater Treatment and Discharge (4.D) (Figure 5-2).

Solid waste disposal has three subcategories of managed waste disposal (4.A.1), unmanaged waste disposal (4.A.2) and uncategorized waste disposal (4.A.3). Incineration and Open Burning of Waste has two subcategorise of waste incineration (4.C.1) and Open Burning of waste (4.C.2) while Wastewater Treatment has two subcategories of domestic wastewater treatment (4.D.1) and discharge and industrial wastewater treatment and discharge (4.D.2).

The inventory in the waste sector considers solid waste and wastewater from various sources. The different categories are illustrated in (see details in Box 2.1, Vol. 5. Chapter 2,page 2.6 IPCC 2006) and the schematic presentation in Figure 5-2

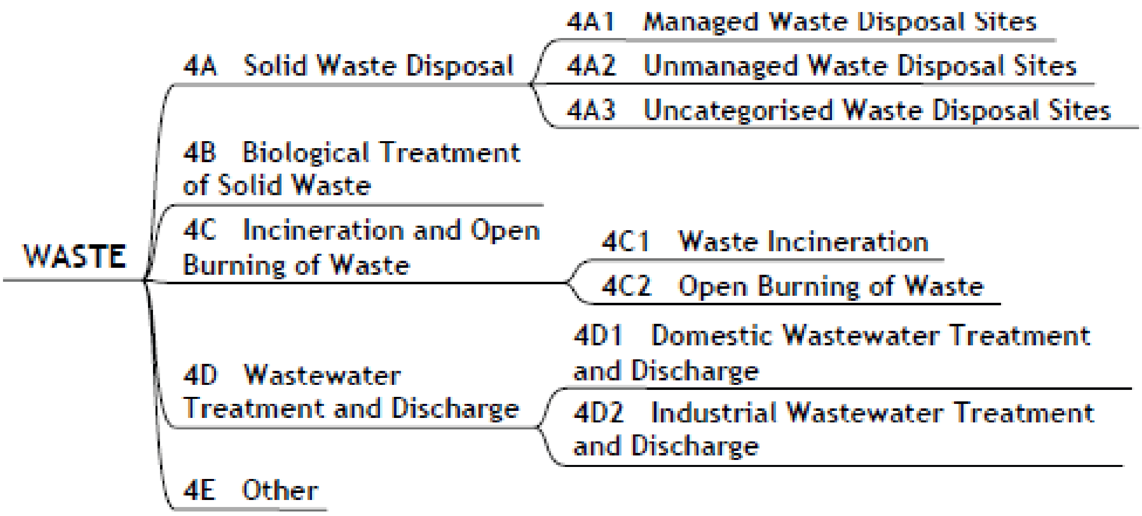


Figure 5-2. Waste categories considered in GHG emission inventory and coding of their IPCC categories (IPCC, 2006)

Every non-Annex 1 member state should collect information that will enable reporting on the national GHG emission status and allow actors to take the most appropriate action to mitigate climate change. The inventory involves obtaining data on the different categories of wastes as presented in Figure 5-2.

5.2 Solid waste Category Information (4A)

The compiler should follow these steps:

(i) Waste sector categories: Inventory data is obtained from the two main categories of waste; namely solid waste and wastewater as the main sources of GHG emissions. There are other categories of wastes such as hospital wastes and hazardous wastes which may be considered as they become significant in a country as emission sources.

(ii) Compile activity data: The first steps for the estimation of GHG emissions from solid waste disposal, biological treatment and incineration and open burning of solid waste are the compilation of activity data on waste generation, composition and management. The 2006 IPCC Guidelines provide stepwise procedures on how information can be acquired and used to estimate GHG emissions from the waste sector. This information is termed “activity data”. Relevant activity data should be obtained for each waste category that are as provided in the 2006 IPCC Guidelines.

(iii) The information to be collected should include: population (millions); waste generation rate (kg/cap/yr) and management data (municipal solid waste, sludge, industrial waste, others); and waste composition (municipal solid waste, sludge, industrial waste, others). It is important to adopt IPCC good practice guidance for the preparation of GHG inventory as illustrated Box 2.1 (IPCC 2006).

The following sections deal with the different waste categories in the waste sector to be considered for GHG emission inventories.

The IPCC methodology for estimating CH_4 emissions from SWDS (Solid Waste Disposal Sites) that is based on the First Order Decay (FOD) method should be adopted to calculate emissions from SWDS. FOD method assumes that the degradable organic component (degradable organic carbon (DOC)) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 are formed. If conditions are constant, the rate of CH_4 production depends solely on the amount of carbon remaining in the waste. The IPCC 2006 Guidelines give guidance on how to estimate historical waste disposal data (Section 3.2.2, Choice of Activity Data page 3.13), default values for all the parameters of the FOD model (Section 3.2.3, Choice of Emission Factors and Parameters, page 3.13), and a simple spreadsheet model to assist countries in using the FOD method.

5.2.1 Methodology solid waste emissions

The Tier 1 approach for GHG emission estimation was selected because of the lack of national data. By using the Tier 1 approach, the default values such as the methane emission factor and other activity parameters can be applied. The Fig 3.1 Chapter 3 (IPCC 2006) Decision Tree for CH_4 emissions from SWDS was used to arrive at the decision to use Tier 1. For solid waste, methane emissions are the most important or significant. Equation 5-1 below is the Tier 1 FOD equation from Vol.5, Chap3, page 3.8 equation 3.1, IPCC 2006 that is used to provide a time-dependent emission profile.

Equation 5-1. Estimating CH4 from Solid Waste

$$CH_4\ Emissions = \left[\sum_x CH_4\ generated_{x,T} - R_T\right] \bullet (1 - OX_T)$$

Where:

CH_4 Emissions = CH_4 emitted in year *T*, *Gg*

T = inventory year

X = waste category or type/material

R_T = recovered CH_4 in year *T, Gg*

OX_T = oxidation factor in year T, (fraction)

"The CH_4 recovered must be subtracted from the amount CH_4 generated. Only the fraction of CH_4 that is not recovered will be subject to oxidation in the SWDS cover layer." (IPCC 2006)

Equation 5-1 estimates annual CH_4 emission. The CH_4 emission potential that is generated throughout the year can be estimated on the basis of the amount of waste and composition of waste disposed into SWDS and the management practices. Emissions calculation is based on the on the Decomposable Degradable Organic Carbon ($DDOC_m$) as defined in Equation 5-2, reference Vol5. Chap3, page 3.9 Equation 3.2, 2006 IPCC . $DDOC_m$ is part of the organic carbon that will degrade under anaerobic conditions in SWDS, and is used in the Equation and spreadsheet.

Equation 5-2 General Equation Estimating Decomposable DOC

$$DDOCm = W \bullet DOC \bullet DOC_f \bullet MCF$$

Where:

$DDOC_m$ = mass of decomposable DOC deposited, Gg

W = mass of waste deposited, Gg

DOC = degradable organic carbon in the year of deposition, fraction, Gg C/Gg waste

DOCf= fraction of DOC that can decompose (fraction)

MCF = CH_4 correction factor for aerobic decomposition in the year of deposition (fraction)

Mass of decomposable DOC is calculated in two steps as provided in

Equation 5-3 and Equation 5-4 below.

Equation 5-3. Estimating mass decomposable (step1)

$$DDOCma_T = DDOCmd_T + \left(DDOCma_{T-1} \bullet e^{-k}\right)$$

Equation 5-4. Estimating mass decomposable (step 2)

$$DDOCm\ decomp_T = DDOCma_{T-1} \bullet \left(1 - e^{-k}\right)$$

Where:

T = inventory year

$DDOCma_T$ =$DDOC_m$ accumulated in the SWDS at the end of year T, Gg

$DDOCma_{T-1}$ = DDOCm accumulated in the SWDS at the end of year (T-1), Gg

$DDOCmd_T$ =DDOCm deposited into the SWDS in year T, Gg

$DDOCmdecomp_T$ = DDOCm decomposed in the SWDS in year T, Gg

k = reaction constant, k = ln(2)/t1/2 (y-1)

t1/2 = half-life time (y)

Where information is not available the Vol.5, 2006 IPCC provides default values. These default values are found in Chapter 2: Waste Generation, Composition and Management Data. ; in Table2.1. The MSW Generation and Treatment Data Regional Defaults are presented in Table 5-1. There arefound in Vol 5. Page 2.5, Table 2.1, while Industrial Waste from Selected Countries presented in page Table 2.2., The MSW Composition Data by percentage- regional default is shown in page 1.12 Table 2.3 The Default Dry Matter Content , DOC content, Total Carbon Content and Fossil Carbon Fraction of Different MSW Components is illustrated in page 2.14 Table 2.4, while Default DOC and Fossil Carbon Content in Industrial Waste (percentage in wet waste produced)in page 2.16, Table 2.5. The Default DOC and Fossil Carbon Content in other Waste (percentage in wet waste produced) in as shown in Table 2.6.

Table 5-1. MSW Generation and Treatment Data Regional Defaults.

Region	MSW Generation Rate[1, 2, 3] (tonnes/cap/yr)	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management, unspecified[4]
Asia					
Eastern Asia	0.37	0.55	0.26	0.01	0.18
South-Central Asia	0.21	0.74	-	0.05	0.21
South-East Asia	0.27	0.59	0.09	0.05	0.27
Africa[5]	0.29	0.69	-	-	0.31
Europe					
Eastern Europe	0.38	0.90	0.04	0.01	0.02
Northern Europe	0.64	0.47	0.24	0.08	0.20
Southern Europe	0.52	0.85	0.05	0.05	0.05
Western Europe	0.56	0.47	0.22	0.15	0.15
America					
Caribbean	0.49	0.83	0.02	-	0.15
Central America	0.21	0.50	-	-	0.50
South America	0.26	0.54	0.01	0.003	0.46
North America	0.65	0.58	0.06	0.06	0.29
Oceania[6]	0.69	0.85	-	-	0.15

[1] Data are based on weight of wet waste.

[2] To obtain the total waste generation in the country, the per-capita values should be multiplied with the population whose waste is collected. In many countries, especially developing countries, this encompasses only urban population.

[3] The data are default data for the year 2000, although for some countries the year for which the data are applicable was not given in the reference, or data for the year 2000 were not available. The year for which the data are collected, where available, is given in the Annex 2A.1.

[4] Other, unspecified, includes data on recycling for some countries.

[5] A regional average is given for the whole of Africa as data are not available for more detailed regions within Africa.

[6] Data for Oceania are based only on data from Australia and New Zealand.

Reference: Vol. 5. Page 2.5, Table 2.1 2006 IPCC

Table 5-2. Default Dry Matter Content, DOC content, Total Carbon Content and Fossil Carbon Fraction of Different MSW Components

MSW component	Dry matter content in % of wet weight [1]	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
	Default	Default	Range	Default	Range [2]	Default	Range	Default	Range
Paper/cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles [3]	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85 [4]	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber and Leather	84	(39) [5]	(39) [5]	(47) [5]	(47) [5]	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal [6]	100	-	-	-	-	NA	NA	NA	NA
Glass [6]	100	-	-	-	-	NA	NA	NA	NA
Other, inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

[1] The moisture content given here applies to the specific waste types before they enter the collection and treatment. In samples taken from collected waste or from e.g., SWDS the moisture content of each waste type will vary by moisture of co-existing waste and weather during handling.

[2] The range refers to the minimum and maximum data reported by Dehoust *et al*., 2002; Gangdonggu, 1997; Guendehou, 2004; JESC, 2001; Jager and Blok, 1993; Würdinger *et al*., 1997; and Zeschmar-Lahl, 2002.

[3] 40 percent of textile are assumed to be synthetic (default). Expert judgement by the authors.

[4] This value is for wood products at the end of life. Typical dry matter content of wood at the time of harvest (that is for garden and park waste) is 40 percent. Expert judgement by the authors.

[5] Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii et al., 1985; Rose and Steinbüchel, 2005).

[6] Metal and glass contain some carbon of fossil origin. Combustion of significant amounts of glass or metal is not common.

Reference: Vol. 5, Chap. 2 page 2.12, Table 2.4 , 2006 IPCC

Table 5-3. Default DOC and Fossil Carbon Content in Industrial Waste (percentage in wet waste produced).

Industry type	DOC	Fossil carbon	Total carbon	Water content [2]
Food, beverages and tobacco (other than sludge)	15	-	15	60
Textile	24	16	40	20
Wood and wood products	43	-	43	15
Pulp and paper (other than sludge)	40	1	41	10
Petroleum products, Solvents, Plastics	-	80	80	0
Rubber	(39) [3]	17	56	16
Construction and demolition	4	20	24	0
Other [4]	1	3	4	10

Source: Expert Judgement; Pipatti *et al.* 1996; Yamada *et al.* 2003.

[1] The default values apply only for process waste from the industries, office and other similar waste are assumed to be included in MSW.

[2] Note that water contents of industrial wastes vary enormously, even within a single industry.

[3] Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii, *et al.*, 1985; Rose and Steinbüchel, 2005).

[4] These values can be used also as defaults for total waste from manufacturing industries, when data on waste production by industry type are not available. Waste from mining and quarrying should be excluded from the calculations as the amounts can be large and the DOC and fossil carbon contents are likely to be negligible.

Reference: Vol. 5, Chap. 2 page 2.16, Table 2.5, 2006 IPCC

Table 5-4. Default DOC and Fossil Carbon Content in Other Waste (percentage in wet waste produced).

Waste type	DOC	Fossil carbon	Total carbon	Water Content
Hazardous waste	NA	5 - 50 [1]	NA	10 - 90 [1]
Clinical waste	15	25	40	35

NA = not available

Sources: Expert Judgement; IPCC 2000

[1] The higher fossil carbon value is for waste with lower water content. When no data on the water content are available, the mean value of the range should be used.

Reference: Vol. 5, Chap. 2 page 2.16, Table 2.6, 2006 IPCC

The amount of CH_4 formed from decomposable materials in the waste is calculated using Equation 5-5 (reference Vol.5, Chap 3, equation 3.5 page 3.9, 2006 IPCC) .

Equation 5-5. CH4 from decomposable material

$$CH_4\ generated_T = DDOCm\ decomp_T \bullet F \bullet 16/12$$

Where:

$CH_4generated_T$ = amount of CH_4 generated from decomposable material

$DDOCmdecomp_T$ = DDOCm decomposed in year T, Gg

F = fraction of CH_4, by volume, in generated landfill gas (fraction)

16/12 = molecular weight ratio CH_4/C (ratio)

For SWDS spreadsheet 4A is used (IPCC software 2006) to calculate methane emissions in Gg. This is also available in Excel format in the <IPCC_Waste_Model.xls>. The emission estimation steps are as follow:

1. Use spreadsheet 4.A (IPCC software 2006) starting with parameters where default data for Eastern Africa can be used to fill data gaps. As national data base develop these can be replaces
2. Spreadsheet number 2 is for the calculation of MCF. Here enter % of use/application of waste management methods(unmanaged-shallow; unmanaged-deep; managed aerobic; managed anaerobic; uncategorised SWDS)
3. In the next spreadsheet(No.3) enter activity data: population(million); waste generation rate (kg/cap/yr); % waste to SWDS; composition (%) of waste going to SWDS
4. spreadsheets No 4.will be automatically generates
5. spreadsheet No.5 will calculated CH_4 emission
6. In case there is any methane recovery, insert values in spreadsheet No.6.
7. Spreadsheet No.7 will generate the final CH_4emission

5.2.2 Activity data for Solid waste

It is good practice to account for all types of solid waste when estimating waste-related emissions in the GHG inventory. Solid waste activity data requirement for the determination of methane emissions from solid waste management activities are illustrated in steps 1 to 4 below.

1. Obtain population data (millions) of the waste generators
2. Determine the composition (food, garden, paper, wood, textiles, nappies, plastics & other inserts) of solid waste reaching SWDS
3. Get data on solid waste generation rates(kg/cap/yr)
4. Determine the % of waste that reach SWDS

Waste generation rate can be calculated from the annual waste production and population of the waste generators.

Data on solid waste in Uganda is often not complete because they are either in non-conformity with the IPCC 2006 data format or there are missing data. For completeness, the 2006 IPCC Guidelines provides default data and methodology for estimating the generation and DOC content of other waste types. See Section 3.5 of Chapter 3 (IPCC 2006), for information regarding data completeness for use to estimate GHG emissions from solid wastes.

Table 5-5. Activity data and sources of information

Waste Category	Activity data	Data source
4.A. Solid waste	1. Urban population (million) 2. Composition of solid waste reaching SWDS 3. Solid waste generation rates(kg/cap/yr) 4. %to SWDS 5. Fraction incinerated 6. Fraction biologically treated (composted and anaerobic digestion) 7. Solid waste management methods 8. Fraction of methane recovered	1. KCCA 2. Urban Councils 3. UBOS 4. NEMA 5. Wastewater treatment Plants 6. Water treatment plants 7. Industries

It is important to know the composition of solid wastes because it is the fraction that is degradable carbon that is significant for GHG emissions. For a comprehensive analysis waste composition data should include the following breakdown for the waste:

(1) Food waste

(2) Garden (yard) and park waste

(3) Paper and cardboard

(4) Wood

(5) Textiles

(6) Nappies (disposable diapers)

(7) Rubber and leather

(8) Plastics

(9) Metal

(10) Glass (including pottery and china)

(11) Other (e.g., ash, dirt, dust, soil, electronic waste)

Data analysis on waste streams should be done to collect comprehensive information on each waste treatment method as described in Section 2.2.1 Volume 5, Chap 2, 2006 IPCC. An illustration of the use of waste stream analysis method is provided Figure 5-3.

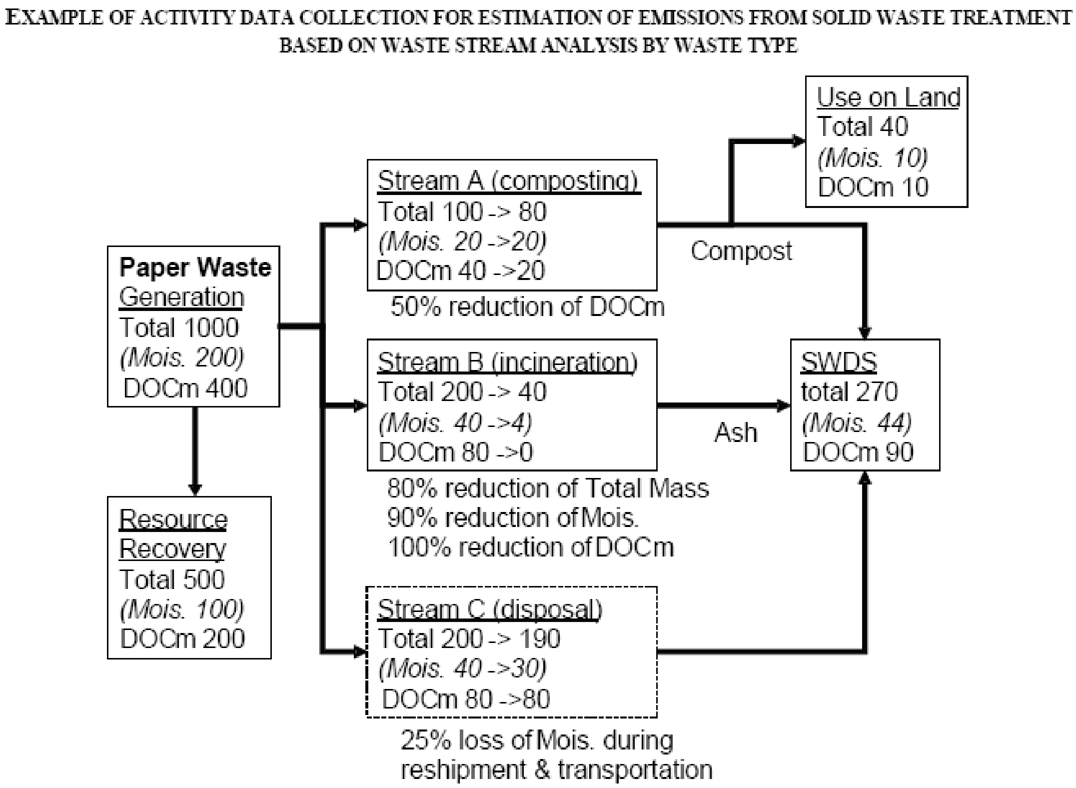


Figure 5-3. Source: from Vol 5, Cap 2, page 2.7; 2006 IPCC)

Waste types numbered (1) to (6) contain most of the degradable organic carbon (DOC) in MSW. Historical data on waste disposal at Solid Waste Disposal Sites (SWDS) are necessary to estimate methane (CH_4) emissions from this category using the First Order Decay (FOD) method. The FOD method is described in Section 3.2.1.1 and in more detail in Annex 3A.1 of the IPCC 2006 Guidelines. A spreadsheet model has been developed by the IPCC to assist countries in implementing the FOD: *IPCC Spreadsheet for Estimating Methane Emissions from Solid Waste Disposal Sites* (IPCC Waste Model). Regional default data on wastes is found in Vol.5. Chapter 2, page 2.5 of IPCC 2006. These default data can be used in cases where national data is lacking.

5.2.3 **Emission factors for solid waste**

As a first step in the emission calculations it is important to obtain the degradable organic carbon (DOC) from the bulk waste. This is the potential amount of waste that is accessible to biochemical decomposition. The following equation 5-6 (reference Vol. 5. Chapter 3, page 3.11. 2006 IPCC Guidelines) estimates DOC using default carbon content values:

Equation 5-6. Estimating DOC using Default Carbon Content values

$$DOC = \sum_i \left(DOC_i \bullet W_i \right)$$

Where:

DOC = fraction of degradable organic carbon in bulk waste, Gg C/Gg waste

DOCi = fraction of degradable organic carbon in waste type *i* e.g., the default value for paper is 0.4 (wet weight basis)

Wi = fraction of waste type *i* by waste category e.g., the default value for paper in MSW in Eastern Asia is 0.188 (wet weight basis).

The default DOC values for these fractions for MSW can be found in Table 2.4 and for industrial waste by industry in Table 2.5 in Chapter 2 of this Volume. Fraction of degradable organic carbon which decomposes (DOC_f) is an estimate of the fraction of carbon that is ultimately degraded and released from SWDS. The recommended default value for DOC_f is 0.5.

Another important parameter is the CH_4 correction factor (MCF) that accounts for the fact that unmanaged SWDS produce less CH_4 from a given amount of waste than anaerobic managed SWDS. In unmanaged SWDS, a larger fraction of waste decomposes aerobically in the top layer. Managed and unmanaged waste can exist in four categories that are assigned different MCF as shown in the Table below (see details in Vol.5. page Chapter 3 IPCC 2006 Guidelines). The SWDS classification and methane correction factor and oxidation Factor (OX) for SWDS are as shown in Tables 5.6 and 5.7 respectively.

Table 5-6. SWDS Classification and Methane Correction Factor

Type of Site	Methane Correction Factor (MCF) Default Values
Managed – anaerobic [1]	1.0
Managed – semi-aerobic [2]	0.5
Unmanaged [3] – deep (>5 m waste) and /or high water table	0.8
Unmanaged [4] – shallow (<5 m waste)	0.4
Uncategorised SWDS [5]	0.6

[1] **Anaerobic managed solid waste disposal sites**: These must have controlled placement of waste (i.e., waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste.

[2] **Semi-aerobic managed solid waste disposal sites**: These must have controlled placement of waste and will include all of the following structures for introducing air to waste layer: (i) permeable cover material; (ii) leachate drainage system; (iii) regulating pondage; and (iv) gas ventilation system.

[3] **Unmanaged solid waste disposal sites – deep and/or with high water table**: All SWDS not meeting the criteria of managed SWDS and which have depths of greater than or equal to 5 metres and/or high water table at near ground level. Latter situation corresponds to filling inland water, such as pond, river or wetland, by waste.

[4] **Unmanaged shallow solid waste disposal sites**; All SWDS not meeting the criteria of managed SWDS and which have depths of less than 5 metres.

[5] **Uncategorised solid waste disposal sites**: Only if countries cannot categorise their SWDS into above four categories of managed and unmanaged SWDS, the MCF for this category can be used.

Sources: IPCC (2000); Matsufuji *et al.* (1996)

Source: Vol. 5, Chapter 3, Page 3.14, Table 3.1.

For the fraction of methane in landfill gas a default IPCC value of 0.5 is recommended. The oxidation factor (OX) reflects the amount of CH_4 from SWDS that is oxidised in the soil or other material covering the waste . Recommended default value for Uganda is zero based on the Table below. Reference:

Table 5-7. Oxidation Factor (OX) for SWDS

Type of Site	Oxidation Factor (OX) Default Values
Managed [1], unmanaged and uncategorised SWDS	0
Managed covered with CH_4 oxidising material [2]	0.1

[1] Managed but not covered with aerated material

[2] Examples: soil, compost

Reference : Vol.5 , Chap 3, page 3.15, Table 3.2, 2006 IPCC.

For calculations the reaction constant (k) and half-life are related $k = \ln(2)/t_{1/2}$. The default values for the tropics are found in Vol.5 Chap 3, in page 3.15 and 3.16, Tables 3.3 and 3.4 (IPCC 2006 Guidelines). Other important parameters to follow are: methane recovery, which is zero for Uganda since none is recovered; delay time is taken as 6 months that can easily be changed when more knowledge is gained on the waste decomposition characteristics. The recommended default methane generation rate (k) values under Tier 1 and the recommended default half-life t ½ values under Tier 1 are as shown in Table 5.8 and 5.9 respectively.

Table 5-8. Recommended Default Methane Generation Rate (k) Values under Tier 1

(Derived from *k* values obtained in experimental measurements, calculated by models, or used in greenhouse gas inventories and other studies)

Type of Waste		Climate Zone*							
		Boreal and Temperate (MAT ≤ 20°C)				Tropical[1] (MAT > 20°C)			
		Dry (MAP/PET < 1)		Wet (MAP/PET > 1)		Dry (MAP < 1000 mm)		Moist and Wet (MAP ≥ 1000 mm)	
		Default	**Range[2]**	**Default**	**Range[2]**	**Default**	**Range[2]**	**Default**	**Range[2]**
Slowly degrading waste	**Paper/textiles waste**	0.04	0.03[3,5] – 0.05[3,4]	0.06	0.05 – 0.07[3,5]	0.045	0.04 – 0.06	0.07	0.06 – 0.085
	Wood/ straw waste	0.02	0.01[3,4] – 0.03[6,7]	0.03	0.02 – 0.04	0.025	0.02 – 0.04	0.035	0.03 – 0.05
Moderately degrading waste	**Other (non – food) organic putrescible/ Garden and park waste**	0.05	0.04 – 0.06	0.1	0.06 – 0.1[8]	0.065	0.05 – 0.08	0.17	0.15 – 0.2
Rapidly degrading waste	**Food waste/Sewage sludge**	0.06	0.05 – 0.08	0.185[4]	0.1[3,4] – 0.2[9]	0.085	0.07 – 0.1	0.4	0.17 – 0.7[10]
Bulk Waste		0.05	0.04 – 0.06	0.09	0.08[8] – 0.1	0.065	0.05 – 0.08	0.17	0.15[11] – 0.2

Reference Vol. 5 Chap 3, page 3.17 Table 3.3, 2006, IPCC

Table 5-9. Recommended Default Half-life t ½ Values under Tier 1

(Derived from *k* values obtained in experimental measurements, calculated by models, or used in greenhouse gas inventories and other studies)									
Type of Waste		Climate Zone*							
		Boreal and Temperate (MAT ≤ 20°C)				Tropical[1] (MAT > 20°C)			
		Dry (MAP/PET < 1)		Wet (MAP/PET > 1)		Dry (MAP < 1000 mm)		Moist and Wet (MAP ≥ 1000 mm)	
		Default	Range[2]	Default	Range[2]	Default	Range[2]	Default	Range[2]
Slowly degrading waste	Paper/textiles waste	17	14[3,5] – 23[3,4]	12	10 – 14[3,5]	15	12 – 17	10	8 – 12
	Wood/ straw waste	35	23[3,4] – 69[6,7]	23	17 – 35	28	17 – 35	20	14 – 23
Moderately degrading waste	Other (non – food) organic putrescible/ Garden and park waste	14	12 – 17	7	6 – 9[8]	11	9 – 14	4	3 – 5
Rapidly degrading waste	Food waste/Sewage sludge	12	9 – 14	4[4]	3[3,4] – 6[9]	8	6 – 10	2	1[10] – 4
Bulk Waste		14	12 – 17	7	6 – 9[8]	11	9 – 14	4	3 – 5[11]

Reference Vol. 5 Chap 3, page 3.16 Table 3.4, 2006, IPCC

5.2.4 Development of a consistent time series

In order to develop a consistent time series, changes have been made from the 1966 IPCC Guidelines in the 2006 IPCC Guidelines by replacing the old default (mass balance) method with the first-order decay (FOD) method, and including industrial waste and other non-MSW categories for all countries. See Section 3.6 (IPCC, 2006) for details on developing a consistent time series.

5.2.5 Uncertainty Assessment

Uncertainties in the estimation of methane emissions from SWDS arise from the estimation methods and the data (activity data and parameters). An estimate of uncertainties is presented in Table 3.5 (IPCC, 2006).

5.2.6 QA/QC, reporting and documentation

Details for QA/QC are summarized in Chapter 23, Section 3.8 (IPCC, 2006) that should be consulted by the compilers and reviewers. However, the following is important as stated in IPCC 2006.

“It is good practice to document and archive all information required to produce the national emissions inventory estimates as outlined in Chapter 6, Quality Assurance and Quality Control and Verification, in Volume 1, General Guidance and Reporting. Some examples of specific documentation and reporting relevant to this source category are provided below.

- When using the IPCC FOD model it should be included in the reporting.
- When using other methods or models, provide similar data (description of the method, key assumptions and parameters).
- If country-specific data are used for any part of the time series, it should be documented.
- The distribution of waste to managed and unmanaged sites for the purpose of methane correction factor (MCF) estimation should also be documented with supporting information.
- If CH_4 recovery is reported, an inventory of known recovery facilities is desirable.
- Flaring and energy recovery should be documented separately from each other.
- Changes in parameters from year to year should be clearly explained and referenced.

Data should be collected in forms and format presented in Table 11 Appendix 2 for consistency with the IPCC 2006. Each data compiler/provider must have a QA/QC system to ensure that good data is provided for estimation of emissions. Finally the Climate Change Department in the Ministry of Water and Environment is responsible for QA/QC of national data in a database.

“It is not practical to include all documentation in the national inventory report. However, the inventory should include summaries of methods used and references to source data such that the reported emissions estimates are transparent and steps in their calculation may be retraced”. More instructions can be found in Section 3.8 of the 2006 IPCC Guidelines.

Reporting emissions: The analysis of emissions should be performed using CO_2-equivalent emission data calculated using the global warming potentials.(GWP)Formal definition of GWP is found in IPCC WG1 2013 The Physical Science Basis. “The *key category* evaluation should be performed for each of the gases separately because the methods, EFs and related uncertainties differ for each gas. For each *key category*, the inventory agency should determine whether certain sub categories are particularly significant (i.e., represent a significant share of the emissions)”.

5.3 Biological treatment Category information (4B)

Emissions from biological treatment were previously not taken into account during GHG emission inventories. It has been found as a significant omission for some countries and the 2006 IPCC now provides for it. This is handled in Chapter 4 (IPCC ,2006) as quoted below: "Composting and anaerobic digestion is important in both developed and developing countries for the conversion of solid wastes into useful products. The products can be used as fertilisers or for soil amendments. There are no national data on the extent of composting and anaerobic digestion although composting is known to be more predominant. Emission estimates are made for CH_4 and N_2O. The steps involved are found in Chapter 4 (IPCC, 2006):

> "Step 1: Collect data on the amount and type of solid waste which is treated biologically. Data on composting and anaerobic treatment should be collected separately, where possible. Regional default data on composting are provided in Table 2.1 in Chapter 2, and country-specific data for some countries can be found in Annex 2A.1 of this Volume. Anaerobic digestion of solid waste can be assumed to be zero where no data are available. The default data should be used only when country-specific data are not available (see also Section 4.1.2)" (IPCC 2006 Guidelines).
>
> "Step 2: Estimate the CH_4 and N_2O emissions from biological treatment of solid waste using Equation 5-6 use default or country-specific emission factors in accordance with the guidance as provided in Sections 4.1.1, 4.1.2 and 4.1.3' (IPCC 2006 Guidelines).
>
> "Step 3: Subtract the amount of recovered gas from the amount of CH_4 generated to estimate net annual CH_4 emissions, when CH_4 emissions from anaerobic digestion are recovered' (IPCC 2006)."

Use worksheet 4.B, Biological Treatment of Solid Waste for the emission estimations of CH_4 and N_2O.

5.3.1 Methodology for the estimation of GHG emission from biological treatment of solid wastes

Choice of methods, choice of activity data and choice of emission factors are presented in Sections 4.1.1, 4.1.2 and 4.1.3, respectively, of IPCC 2006. Tier 1 is the best option for Uganda because of lack of data so that default values regional activity data and default IPCC parameters can be used and these are included in the spreadsheet model. Since biological treatment was not previously considered in IPCC Guidelines, it is necessary to develop completeness in data and consistency in time series as described in Chapter 4 Sections 4.2 and 4.3. Uncertainty assessment, QA/QC and reporting are considered in Sections 4.4, 4.5 and 4.6 respectively. The CH_4 and N_2O emissions of biological treatment can be estimated using the default method (reference Vol.5 chap 4 , page 4.5 equations 4.1 and 4.2, 2006 IPCC) given in Equation 5-7 and Equation 5-8 shown below:

Equation 5-7. CH4 Emissions from biological treatments

$$CH_4\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

Where:

CH_4Emissions = total CH_4 emissions in inventory year, Gg CH_4
Mi = mass of organic waste treated by biological treatment type *i*, Gg
EF = emission factor for treatment *i*, g CH_4/kg waste treated
i = composting or anaerobic digestion
R = total amount of CH_4 recovered in inventory year, Gg CH4

Equation 5-8. N_2O Emissions from biological treatment

$$N_2O\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} \quad 5\text{-}8$$

Where:

N_2O Emissions = total N_2O emissions in inventory year, Gg N_2O
Mi = mass of organic waste treated by biological treatment type *i*, Gg
EF = emission factor for treatment *i*, g N_2O/kg waste treated
i = composting or anaerobic digestion

For Uganda it is most appropriate to use Tier 1 methods for emission calculations because of lack of country specific data at the moment. Tier 1 uses the IPCC default emission factors.

5.3.2 **Choice of Activity Data**

Activity data on biological treatment can be based on national statistics. These data are normally collected by municipalities or urban authorities responsible for waste management. Table 2.1 in Chapter 2, waste generation, composition and management data (IPCC 2006 Guidelines) provides regional default values on biological treatment. These data can be used as a starting point. The county should start collecting and assembling data in IPCC compatible formats to ensure good practice.

5.3.3 Choice of Emission factors

Tier 1 Methods is recommended for Uganda; therefore emission factors to be adopted are for Tier 1 methods. Composting and anaerobic digestion will depend on factors such as type of waste composted, amount and type of supporting material (such as wood chips and peat) used, temperature, moisture content and aeration during the process. Default factors for CH_4 and N_2O emissions from biological treatment for Tier 1 method are provided in Table 4.1, Chapter 4 (IPCC 2006 Guidelines). These emission factors are presented Table 5-10 below for quick reference.

Table 5-10. Default Emission Factors for CH4 and N2O Emissions from Biological Treatment of Waste.

Type of biological treatment	CH_4 Emission Factors (g CH_4/kg waste treated)		N_2O Emission Factors (g N_2O/kg waste treated)		Remarks
	on a dry weight basis	on a wet weight basis	on a dry weight basis	on a wet weight basis	
Composting	10 (0.08 - 20)	4 (0.03 - 8)	0.6 (0.2 - 1.6)	0.3 (0.06 - 0.6)	Assumptions on the waste treated: 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. The emission factors for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.
Anaerobic digestion at biogas facilities	2 (0 - 20)	1 (0 - 8)	Assumed negligible	Assumed negligible	
Sources: Arnold, M.(2005) Personal communication; Beck-Friis (2002); Detzel *et al.* (2003); Petersen *et al.* 1998; Hellebrand 1998; Hogg, D. (2002); Vesterinen (1996).					

5.3.4 Uncertainty Assessment

Uncertainties depend on how the data was collected and handled. Uncertainties in the default emission factors can be estimated using the ranges given in Vol.5 Chap4, page 4.6, Table 4.1. (IPCC 2006, Guidelines).

5.3.5 QA/QC

The requirements on QA/QC addressed in Section 3. 8 in Chapter 3, Solid Waste Disposal, are also applicable for biological treatment of waste.

5.4 Incineration and Open Burning category Information (4.C)

5.4.1 Waste incineration (4.C.1)

Waste incineration is the combustion of solid or liquid waste under controlled conditions. The types of wastes incinerated include MSW, industrial waste, domestic waste, hazardous waste, clinical waste and sewage sludge. In Uganda it is clinical incineration which is common.

“Emissions from waste incineration without energy recovery are reported in the Waste Sector, while emissions from incineration with energy recovery are reported in the Energy Sector, both with a distinction between fossil and biogenic carbon dioxide (CO_2) emissions.

5.4.2 Open burning (4.C.2)

Open burning is the combustion of unwanted combustible materials that is common practice in developing countries. It is done in the open with smoke and other releases getting straight into the air without passing through a chimney of a stack. “Incineration and open burning of waste are sources of greenhouse gas emissions, like other types of combustion. Relevant gases emitted include CO_2, methane (CH_4) and nitrous oxide (N_2O).

As described in the 1996 IPCC guidelines, only CO_2 emissions from incineration and open burning of carbon of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) should be considered for net emissions and included in the national inventory. The CO_2 originating from the burning of biomass materials (e.g., paper, food, and wood waste) are of biogenic origin and should not be included in national emission estimates. If incineration is used for energy generation, then both fossil and biogenic CO_2 emissions should be estimated.

The compiler of inventories should take note of this statement from IPCC 2006: “Traditional air pollutants from combustion - non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx) - are covered by existing emission inventory systems. Therefore, the IPCC does not provide new methodologies for these gases here, but recommends that national experts or inventory compilers use existing published methods under international agreements such as EMEP/EEA Emission inventory guidebook 2013.

5.4.3 **Methodology**

5.4.3.1 Estimating CO_2 emissions

For the time being the Tier 1 method is a simple method that can be used to estimate the CO_2 emissions from incineration/open burning. Tier 1 method is normally used when incineration and open burning are not a key category. When this category becomes key, then the higher Tier methods have to be adopted.

Use Equation 5-9 to estimate total emission from combustion and for MSW composition combustion use Equation 5-10.

Equation 5-9. CO2 estimates based on total amount of waste combusted

$$CO_2\ Emissions = \sum_i \left(SW_i \bullet dm_i \bullet CF_i \bullet FCF_i \bullet OF_i \right) \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions in inventory year, Gg/yr
SWi = total amount of solid waste of type *i* (wet weight) incinerated or open-burned, Gg/yr
dmi = dry matter content in the waste (wet weight) incinerated or open-burned, (fraction)
CFi = fraction of carbon in the dry matter (total carbon content), (fraction)
FCFi = fraction of fossil carbon in the total carbon, (fraction)
OFi = oxidation factor, (fraction)
44/12 = conversion factor from C to CO_2
i = type of waste incinerated/open-burned specified as follows:
MSW: municipal solid waste (if not estimated using Equation 5.2), ISW: industrial solid waste, SS: sewage sludge, HW: hazardous waste, CW: clinical waste, others (that must be specified)

Equation 5-10. CO2 estimates based on municipal waste composition

$$CO_2\ Emissions = MSW \bullet \sum_j \left(WF_j \bullet dm_j \bullet CF_j \bullet FCF_j \bullet OF_j \right) \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions in inventory year, Gg/yr
MSW = total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/yr
WFj = fraction of waste type/material of component j in the MSW (as wet weight incinerated or open burned)

dmj = dry matter content in the component j of the MSW incinerated or open-burned, (fraction)

CFj = fraction of carbon in the dry matter (i.e., carbon content) of component j

FCFj = fraction of fossil carbon in the total carbon of component j

OFj = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2

with: 1=∑jjWF

j = component of the MSW incinerated/open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

If data by waste type/material are not available, the default values for waste composition given in Section 2.3 Waste composition could be used(IPCC 2006 Guidelines). Use worksheet 4.C.1 of the IPCC Inventory software to estimate the CO_2 emission

5.4.3.2 Estimating CH_4 emissions

Emissions of CH_4 from incineration and open burning of waste are a result of incomplete combustion. Important factors affecting the emissions are temperature, residence time, and air ratio (i.e., air volume in relation to the waste amount). The CH_4 emissions are particularly relevant for open burning, where a large fraction of carbon in the waste is not oxidised. The conditions can vary much, as waste is a very heterogeneous and a low quality fuel with variations in its calorific value. Tier 1 is used for the calculation of the emission of methane. the emission is based on the amount of waste incinerated/open-burned and related emission factors as in Equation 5-11 below.

Equation 5-11. CH4 emission Estimates based on total amount of waste combusted

$$CH_4\ Emissions = \sum_i (IW_i \bullet EF_i) \bullet 10^{-6}$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, Gg/yr

IWi = amount of solid waste of type i incinerated or open-burned, Gg/yr

EFi = aggregate CH_4 emission factor, kg CH_4/Gg of waste

10^{-6} = conversion factor from kilogram to gigagram

i = category or type of waste incinerated/open-burned, specified as follows:

MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

The amount and composition of waste should be consistent with the activity data used for estimating CO_2 emissions from incineration/open burning. Default emission factors are provided under Section 5.4.2, CH_4 emission factors, for incineration and open burning of waste(IPCC 2006 Guidelines).

5.4.4 **Choice of method for estimating N_2O emissions.**

The calculation of N_2O emissions is based on the waste input to the incinerators or the amount of waste open-burned and a default emission factor. This relationship is summarised in the following Equation 5-12 below.

Equation 5-12. N2O Emission estimates based on amount of waste open burnt

$$N_2O\ Emissions = \sum_i (IW_i \bullet EF_i) \bullet 10^{-6}$$

Where:

N_2O Emissions = N_2O emissions in inventory year, Gg/yr

IWi = amount of incinerated/open-burned waste of type i , Gg/yr

EFi = N_2O emission factor (kg N_2O/Gg of waste) for waste of type *i*

10^{-6} = conversion from kilogram to gigagram

i = category or type of waste incinerated/open-burned, specified as follows:

MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

The amount and composition of waste should be consistent with the activity data used for the calculation of CO_2 and CH_4 emissions.

5.4.5 **Choice of Activity data**

Chapter 2 of the IPCC 2006 Guidelines give general information on activity data. Waste Generation, Composition and Management. Activity data needed in the context of incineration and open burning of waste includes the amount of waste incinerated or open-burned, the related waste fractions (composition) and the dry matter content (see sections 5.3.1 and 5.3.2 of IPCC 2006 guidelines).

5.4.6 **Choice of Emission Factors**

Due to lack of national statistics, default values found in Tables 5.2 and 5.3 for CO_2 and CH_4 respectively of Vol5. Chapter 5 IPCC 2006, can be used. Tables 5.4, 5.5 and 5.6 of the same guidelines give emission factors for N_2O.

There is no national comprehensive data on incineration and open burning of wastes. Therefore regional default values should be used until national database is built. For emission estimations worksheet 4.C.1 should be used for incineration where data inputs are : wet weight incinerated, dry matter content, fraction of carbon in dry matter(CF), fraction of fossil carbon (FCF),oxidation factor (use default values since national values are not available) and worksheet 4.C .2 for open burning where data inputs are: population, fraction of population burning waste, waste generation rate, fraction of waste burned, number of days by year.

5.5 Category Information wastewater treatment and Discharge (4.D)

Wastewater is a source of methane (CH_4) when undergoing anaerobic treatment. Nitrous oxide (N_2O) can also be emitted from wastewater. IPCC 2006 states that "Carbon dioxide (CO_2) emissions from wastewater are not considered in the IPCC Guidelines because these are of biogenic origin and should not be included in national total emissions". This section deals with wastewater from domestic and commercial that are assessed together and industrial wastewater.

The most common wastewater treatment methods in developed countries are centralized aerobic wastewater treatment plants and lagoons for both domestic and industrial wastewater. To avoid charges most large industries have onsite pre-treatment facilities. While others carry out full treatment and discharge into the environment. Some domestic wastewaters are treated onsite in septic systems (Septic tank). In Uganda where connection to centralised system is below 10% most treatments are onsite. Pit latrines and lagoons are commonly used to treat domestic wastewater. Figure 5-4 shows different pathways for wastewater treatment and discharge.

5.5.1 **Methodological issues**

Emissions are a function of the amount of organic waste generated and an emission factor that characterises the extent to which this waste generates CH_4. Tier 1 is the selected method for the country because of limited data. The methodology for estimation of emission, time series consistency, uncertainties, quality assurance/quality control, reporting, and documentation are described in Section 6.2 of IPCC 2006. Nitrous oxide (N_2O) emission inventories reconsidered under Section 6.3. In all cases the activity data are described and default values for the region provided. Tier one method should be used for the emission estimates because of lack of data. The Tier 1 method applies default values for the emission factor and activity parameters. This method is considered good practice for countries with limited data.

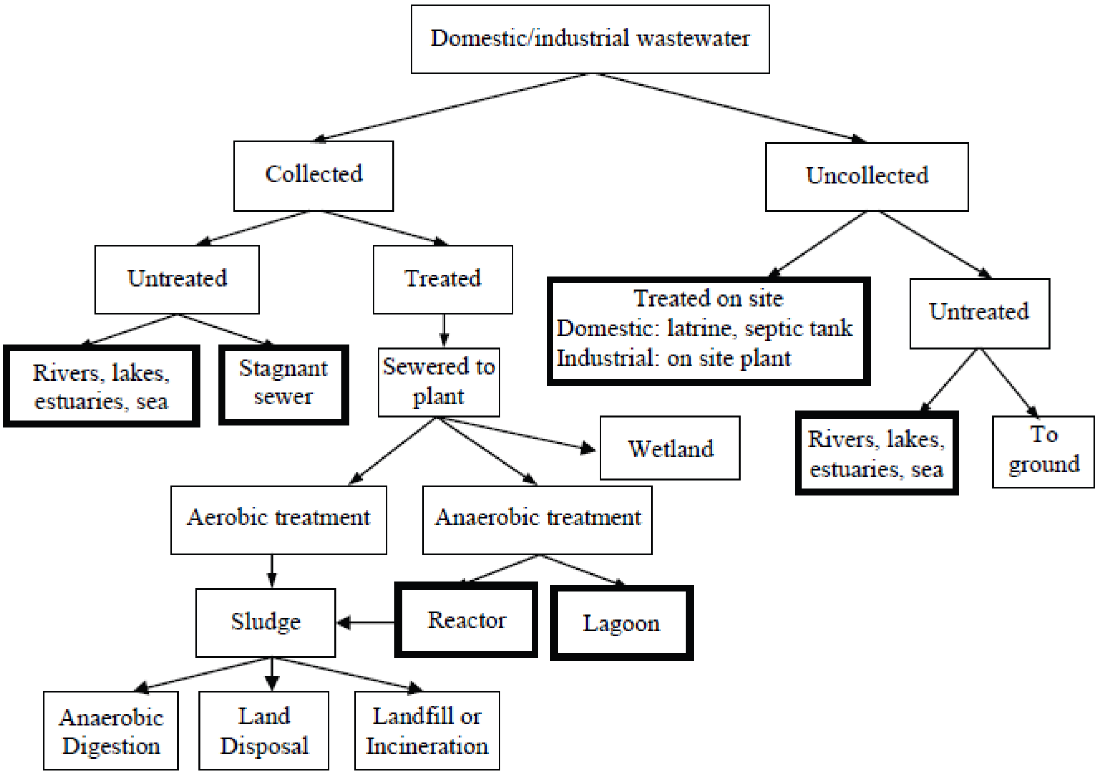


Figure 5-4. Wastewater treatment systems and discharge pathways (IPCC 2006 Guidelines)

The steps for good practice in inventory preparation for CH_4 from domestic wastewater are as follows:

Step 1: Use Equation 5-13 to estimate total organically degradable carbon in wastewater (TOW).

Step 2: Select the pathway and systems (See Figure 5-4) according to available activity data. Use Equation 5-15 to obtain the emission factor for each domestic wastewater treatment/discharge pathway or system.

Step 3: Equation 5-13 to estimate emissions, adjust for possible sludge removal and/or CH_4 recovery and sum the results for each pathway/system.

5.5.2 **Domestic Water Treatment and discharge**

As described earlier, the wastewater characterisation will determine the fraction of wastewater treated or disposed of by a particular system. To determine the use of each type of treatment or discharge system, it is good practice to refer to national statistics (e.g., NWSC). If these data are not available, wastewater associations or international organisations such as the World Health Organization (WHO) or World Bank may have data on the system usage.

Equation 5-13. Total CH4 emissions from domestic water

$$CH_4\ Emissions = \left[\sum_{i,j}\left(U_i \bullet T_{i,j} \bullet EF_j\right)\right]\left(TOW - S\right) - R$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH4/yr

TOW = total organics in wastewater in inventory year, kg BOD/yr

S = organic component removed as sludge in inventory year, kg BOD/yr

Ui= fraction of population in income group i in inventory year, See Table 6.5(IPCC 2006 Guidelines).

Ti,j = degree of utilisation of treatment/discharge pathway or system, j, for each income group fraction i in inventory year, See Table 6.5 (IPCC 2006 Guidelines).

i = income group: rural, urban high income and urban low income

j = each treatment/discharge pathway or system

EFj = emission factor, kg CH_4 / kg BOD

R = amount of CH_4 recovered in inventory year, kg CH4/yr

5.5.2.1 Choice of Activity Data

Table 5-11 provides some of the activity data information sources on waste in Uganda. The activity data for this source category is the total amount of organically degradable material in the wastewater (TOW). This parameter is a function of human population and BOD generation per person. It is expressed in terms of biochemical oxygen demand (kg BOD/year). Equation 5-14 which estimates TOW is:

Equation 5-14. Total organically degradable material in domestic waste water

$$TOW = P \bullet BOD \bullet 0.001 \bullet I \bullet 365$$

Where:

TOW = total organics in wastewater in inventory year, kg BOD/yr

P = country population in inventory year, (person)

BOD = country-specific per capita BOD in inventory year, g/person/day, See Table 6.4(IPCC 2006).

0.001 = conversion from grams BOD to kg BOD

I = correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00.)

The factor I values in Equation 6.3 are based on expert judgment by the authors. It expresses the BOD from industries and establishments (e.g., restaurants, butchers or grocery stores) that is co-discharged with domestic wastewater. CH_4 and N_2O emission potentials from the different wastewater treatment and disposal is summarised in Table 6.1 of the IPCC 2006 Guidelines.

Table 5-11. Waste Water treatment Activity Data sources.

4.D.1 Domestic wastewater	1. Wastewater characteristics (biochemical oxygen demand or BOD) 2. Wastewater treatment methods/technology 3. Wastewater volumes treated and discharged daily 4. Fraction of methane flared 5. MCF	1. NWSC 2. Institutions 3. Housing estates
4.D.2.Industrial wastewater	1. Wastewater characteristics (chemical oxygen demand or COD) 2. Wastewater treatment methods/technology 3. Wastewater volumes treated and discharged daily 4. Fraction of methane flared 5. Default factors	1. Industries 2. UBOS

Important issues to consider to produce a good inventory for domestic wastewater are: time series consistency, uncertainties, QA/QC, completeness, reporting and documentations that are in sections 6.2.2.4, 6.2.2.5, and 6.2.2.6 respectively of the IPCC, 2006 Guidelines. The inventory compiles should refer to these sections.

Spreadsheet 4.D.1for domestic wastewater of the IPCC Inventory software should be used to enter the relevant data (Population and BOD-kg BOD/ cap.yr)

Worksheet

Sector: Waste

Category: Domestic Wastewater Treatment and Discharge

Subcategory: 4.D.1 - Domestic Wastewaster Treatment and Discharge

Sheet: 1 of 3 Estimation of Organically Degradable Material in Domestic Wastewater

1995

Data

	A	B	C	D	
Region, city, etc.	Population - P [Capita]	Degradable organic component - BOD [kg BOD/cap.yr]	Correction factor for industrial BOD discharged in sewers [I]	Organically degradable material in wastewater - TOW [kg BOD/yr]	
				D = A * B * C	

Worksheet

Sector: Waste

Category: Wastewater Treatment and Discharge

Subcategory: 4.D.2 - Industrial Wastewater Treatment and Discharge

Sheet: 1 of 3 Total Organic Degradable Material in wastewater for each industry sector

1995

Data

	A	B	C	D	
Industry sectors	Total industry product (Pi) (t/yr)	Wastewater generated (Wi) (m3/t)	Chemical Oxygen Demand (CODi) (kg COD/m3)	Total organic degradable material in wastewater for each industry sector (TOWi) (kg COD/yr)	
				D = A * B * C	
*					

Figure 5-5. Estimating Domestic and Industrial Waste Treatment Emissions

5.5.2.2 Emission Factors (domestic water)

The emission factor for a wastewater treatment and discharge pathway and system (terminal blocks with bold frames in Figure 5-4 is a function of the maximum CH_4 producing potential (B_o) and the methane correction factor (MCF) for the wastewater treatment and discharge system, as shown in the Equation below.

Equation 5-15. CH4 Emission Factor for domestic waste water

$$EFj = Bo \bullet MCFj)$$

Where:

EFj = emission factor, kg CH_4/kg BOD

j = each treatment/discharge pathway or system

B_o = maximum CH_4 producing capacity, kg CH_4/kg BOD

MCFj = methane correction factor (fraction), See Table 6.3 in IPCC 2006 Guidelines.

It is good practice for countries to have their own Bo values, but where it is not possible default values (Table 6.2 of IPCC 2006 Guidelines) derived from expert judgment can be used.

5.5.3 **Industrial waste water category Information**

Industrial Waste water (4.D.2) may be treated on site or released into domestic sewer systems. If it is released into the domestic sewer system, the emissions are to be included with the domestic wastewater emissions. This section of the manual deals with estimating CH_4 emissions from on-site industrial wastewater treatment.

A decision tree for industrial wastewater is included in Figure 5-5 of the IPCC 2006 Guidelines, where Tie1 will be the most appropriate for Uganda. Tier 1 uses default data for calculating methane emission. CH_4 emission is estimated based on the concentration of degradable organic matter in the wastewater and anaerobic onsite treatment of the wastewater. Some of the major industries in Uganda are:

- meat and poultry processing (slaughterhouses),
- alcohol, beer production,
- organic chemicals production,
- other food and drink processing (dairy products, vegetable oil, fruits and vegetables, canneries, juice making, etc.).

Wastewater treatment methods used are lagoons and anaerobic reactors. The method for estimating emissions from industrial wastewater is similar to the one used for domestic wastewater. See the decision tree in Figure 5-5 (IPCC 2006 Guidelines).

The inventory compilers should use a top-down approach that includes the following general steps:

Step 1: Use Equation 6.6 to estimate total organically degradable carbon in wastewater (TOW) for industrial sector *i*
Step 2: Select the pathway and systems (Figure 5-4) according to country activity data. Use Equation 6.5 to obtain emission factor. For each industrial sector estimate the emission factor using maximum methane producing capacity and the average industry-specific methane correction factor.
Step 3: Use Equation 6.4 to estimate emissions, adjust for possible sludge removal and or CH_4 recovery and sum the results.

5.5.3.1 Methodology Industrial water

The general equation to estimate CH_4 emissions from industrial wastewater is in Equation 5-16 below:

Equation 5-16. Total CH4 emission from industrial waste water

$$CH_4\ Emissions = \sum_i \left[\left(TOW_i - S_i\right) EF_i - R_i\right]$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr
TOW_i = total organically degradable material in wastewater from industry i in inventory year, kg COD/yr
i = industrial sector
Si = organic component removed as sludge in inventory year, kg COD/yr
EFi = emission factor for industry i, kg CH_4/kg COD for treatment/discharge pathway or system(s) used in inventory year
If more than one treatment practice is used in an industry this factor would need to be a weighted average.
Ri = amount of CH_4 recovered in inventory year, kg CH_4/yr

5.5.3.2 Choice of Activity Data

The activity data for this source category is the amount of organically degradable material in the wastewater. This parameter is a function of industrial output (product) P (tons/yr), wastewater generation W (m^3/ton of product), and degradable organics concentration in the wastewater COD (kg COD/m^3). this is seen in Equation 5-18.

Equation 5-17. Organically degradable material industrial waste water

$$TOW_i = P_i \bullet W_i \bullet COD_i$$

Where:

TOWi = total organically degradable material in wastewater for industry i, kg COD/yr
i = industrial sector
Pi = total industrial product for industrial sector i, t/yr
Wi = wastewater generated, m3/t product
CODi = chemical oxygen demand (industrial degradable organic component in wastewater),kg COD/m^3

The following steps are required for determination of TOW:

(i) Identify the industrial sectors that generate wastewater with large quantities of organic carbon, by evaluating total industrial product, degradable organics in the wastewater, and wastewater produced.

(ii) Identify industrial sectors that use anaerobic treatment. Include those that may have unintended anaerobic treatment as a result of overloading of the treatment system. Experience has shown that usually three or four industrial sectors are key.

For each selected sector estimate total organically degradable carbon (TOW).
Industrial production data and wastewater outflows may be obtained from national statistics, regulatory agencies (DWRM, NEMA), NWSC or industry associations (UMA). Examples are in Table 6.9 of IPCC 2006 that could be used as default values.

5.5.3.3 Choice of Emission Factors.

Different types of industrial wastewaters have significant differences in CH_4 emission potentials. therefore to the extent possible, data should be collected to determine the maximum CH_4 producing capacity (Bo) in each industry. MCF(what does stands for) indicates the extent to which the CH_4 producing potential (Bo) is realised in each type of treatment method. Thus, it is an indication of the degree to which the system is anaerobic Equation 5-18.

Equation 5-18. CH4 Emission for Industrial Water

$$EF_j = B_o \bullet MCF_j$$

Where:

EFj = emission factor for each treatment/discharge pathway or system, kg CH_4/kg COD, (See Table 6.8. IPCC 2006 Guidelines)

j = each treatment/discharge pathway or system

Bo = maximum CH_4 producing capacity, kg CH_4/kg COD

MCFj = methane correction factor (fraction) (See Table 6.8. IPCC 2006 Guidelines)

If no country-specific data are available, it is good practice to use the IPCC COD-default factor for Bo (0.25 kg CH_4/kg COD). it is recommended to use expert judgment to determine MCF.

5.5.3.4 Uncertainties

Uncertainty estimates for Bo, MCF, P, W and COD are provided in Table 6.10 found in the IPCC 2006 Guidelines. Default Uncertainty rages for Industrial Waste Water is as shown in Table 5-12.

Table 5-12. Default Uncertainty ranges for Industrial Waste Water

Parameter	Uncertainty Range
Emission Factor	
Maximum CH_4 producing capacity (B_o)	± 30%
Methane correction factor (MCF)	The uncertainty range should be determined by expert judgement, bearing in mind that this is a fraction and uncertainties cannot take it outside the range of 0 to 1.
Activity Data	
Industrial production (P)	± 25% Use expert judgement regarding the quality of data source to assign more accurate uncertainty range.
Wastewater/unit production (W)	These data can be very uncertain as the same sector might use different waste handling procedures at different plants and in different countries. The product of the parameters (W•COD) is expected to have less uncertainty. An uncertainty value can be attributed directly to kg COD/tonne of product. −50 %, +100% is suggested (i.e., a factor of 2).
COD/unit wastewater (COD)	
Source: Judgement by Expert Group (Co-chairs, Editors and Authors of this sector).	

Reference: Vol.5 Chap 6, Page 6.23, Table 6.0.

5.5.3.5 QA/QC

The inventory compiler should consult section 6.2.3.6 of Chapter 6 of the IPCC 2006 guidelines on issues of QA/QC, completeness, reporting and documentation for the Industrial sector inventory.

Spreadsheet 4.D.2 Industrial Wastewater Treatment and discharge of the IPCC Inventory Software should be used by the inventory compiler to estimate the emissions from the industrial sector

Table 5-13. Estimates of the uncertainties associated with default activity data and parameters in the FOD method for CH4 Emissions from SWDS

Activity data and emission factors	Uncertainty Range
Total Municipal Solid Waste (MSW_T)	**Country-specific:** 30% is a typical value for countries which collect waste generation data on regular basis. ±10% for countries with high quality data (e.g., weighing at all SWDS and other treatment facilities). For countries with poor quality data: more than a factor of two.
Fraction of MSW_T sent to SWDS (MSW_F)	±10% for countries with high quality data (e.g., weighing at all SWDS). ±30% for countries collecting data on disposal at SWDS. For countries with poor quality data: more than a factor of two.
Total uncertainty of Waste composition	±10% for countries with high quality data (e.g., regular sampling at representative SWDS). ±30% for countries with country-specific data based on studies including periodic sampling. For countries with poor quality data: more than a factor of two.
Degradable Organic Carbon (DOC)[7]	**For IPCC default values** : ±20% **For country-specific values**: Based on representative sampling and analyses: ±10%
Fraction of Degradable Organic Carbon Decomposed (DOC_f)	**For IPCC default value (0.5)**: ± 20% **For country-specific value** ± 10% for countries based on the experimental data over longer time periods.
Methane Correction Factor (MCF) = 1.0 = 0.8 = 0.5 = 0.4 = 0.6	**For IPCC default value:** –10%, +0% ±20% ±20% ±30% –50%, +60%
Fraction of CH_4 in generated Landfill Gas (F) = 0.5	**For IPCC default value**: ±5%
Methane Recovery (R)	The uncertainty range will depend on how the amounts of CH_4 recovered and flared or utilised are estimated: ± 10% if metering is in place. ± 50% if metering is not in place.
Oxidation Factor (OX)	Include OX in the uncertainty analysis if a value other than zero has been used for OX itself. In this case the justification for a non-zero value should include consideration of uncertainties.
half-life ($t_{1/2}$)	Ranges for the IPCC default values are provided in Table 3.4. Country-specific values should include consideration of uncertainties.
Source: Expert judgement by Lead Authors of the Chapter.	

Reference Vol 5, Chapter 3 Table 3.5 page 3.27, 2006 IPCC

5.6 Suggested improvements:

There are many organisations involved in waste data collection in Uganda. The format and parameters collected defer depending on their intended use. Such data can only be used in national inventory development if standardised. Currently most are in formats which cannot be used in the inventory. It is thus imperative that standardised data collection procedures, data analysis and storage formats compatible with the IPCC 2006 software format should be adopted to ensure that proper and relevant data is be captured. The CCD should standards and probably develop tools to guide key data providers.

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7 Appendices: Reference Tables for Default EFs and coefficients

Appendix A Energy Sector Emission Factor References Tables

Reference Table A-1. Default Values of Carbon Content.

Fuel type English description	Default carbon content [1] (kg/GJ)	Lower	Upper
Crude Oil	20.0	19.4	20.6
Orimulsion	21.0	18.9	23.3
Natural Gas Liquids	17.5	15.9	19.2
Motor Gasoline	18.9	18.4	19.9
Aviation Gasoline	19.1	18.4	19.9
Jet Gasoline	19.1	18.4	19.9
Jet Kerosene	19.5	19	20.3
Other Kerosene	19.6	19.3	20.1
Shale Oil	20.0	18.5	21.6
Gas/Diesel Oil	20.2	19.8	20.4
Residual Fuel Oil	21.1	20.6	21.5
Liquefied Petroleum Gases	17.2	16.8	17.9
Municipal Wastes (non-biomass fraction) [8]	25.0	20.0	33.0
Industrial Wastes	39.0	30.0	50.0
Waste Oils [9]	20.0	19.7	20.3
Peat	28.9	28.4	29.5
Wood/Wood Waste [10]	30.5	25.9	36.0
Sulphite lyes (black liquor) [11]	26.0	22.0	30.0
Other Primary Solid Biomass [12]	27.3	23.1	32.0
Charcoal [13]	30.5	25.9	36.0
Biogasoline [14]	19.3	16.3	23.0
Biodiesels [15]	19.3	16.3	23.0
Other Liquid Biofuels [16]	21.7	18.3	26.0
Landfill Gas [17]	14.9	12.6	18.0

Table 1.3, Chapter 1, Volume 2, page 1.21, 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Reference Table A-2.**Default CO_2 Emission Factors for Combustion.**

Fuel type English description		Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO_2 emission factor (kg/TJ) [2]		
				Default value [3]	95% confidence interval	
		A	B	C=A*B*44/12*1000	Lower	Upper
Crude Oil		20.0	1	73 300	71 100	75 500
Orimulsion		21.0	1	77 000	69 300	85 400
Natural Gas Liquids		17.5	1	64 200	58 300	70 400
Gasoline	Motor Gasoline	18.9	1	69 300	67 500	73 000
Gasoline	Aviation Gasoline	19.1	1	70 000	67 500	73 000
Gasoline	Jet Gasoline	19.1	1	70 000	67 500	73 000
Jet Kerosene		19.5	1	71 500	69 700	74 400
Other Kerosene		19.6	1	71 900	70 800	73 700
Shale Oil		20.0	1	73 300	67 800	79 200
Gas/Diesel Oil		20.2	1	74 100	72 600	74 800
Residual Fuel Oil		21.1	1	77 400	75 500	78 800
Liquefied Petroleum Gases		17.2	1	63 100	61 600	65 600
Ethane		16.8	1	61 600	56 500	68 600
Naphtha		20.0	1	73 300	69 300	76 300
Bitumen		22.0	1	80 700	73 000	89 900
Lubricants		20.0	1	73 300	71 900	75 200
Petroleum Coke		26.6	1	97 500	82 900	115 000
Refinery Feedstocks		20.0	1	73 300	68 900	76 600
Other Oil	Refinery Gas	15.7	1	57 600	48 200	69 000
Other Oil	Paraffin Waxes	20.0	1	73 300	72 200	74 400
Other Oil	White Spirit & SBP	20.0	1	73 300	72 200	74 400
Other Petroleum Products		20.0	1	73 300	72 200	74 400
Natural Gas		15.3	1	56 100	54 300	58 300
Municipal Wastes (non-biomass fraction)		25.0	1	91 700	73 300	121 000
Industrial Wastes		39.0	1	143 000	110 000	183 000
Waste Oil		20.0	1	73 300	72 200	74 400
Peat		28.9	1	106 000	100 000	108 000
Solid Biofuels	Wood/Wood Waste	30.5	1	112 000	95 000	132 000
Solid Biofuels	Sulphite lyes (black liquor)[5]	26.0	1	95 300	80 700	110 000
Solid Biofuels	Other Primary Solid Biomass	27.3	1	100 000	84 700	117 000
Solid Biofuels	Charcoal	30.5	1	112 000	95 000	132 000

Reference: Table 1.4, Chapter 1, Volume 2, page 1.23, 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Table A-3: Default Emission Factors for Stationary Combustion in the energy industries (kg of greenhouse gas per TJ on a Net Calorific Basis)

Fuel		CO_2 Default Emission Factor	CO_2 Lower	CO_2 Upper	CH_4 Default Emission Factor	CH_4 Lower	CH_4 Upper	N_2O Default Emission Factor	N_2O Lower	N_2O Upper
Crude Oil		73 300	71 100	75 500	r 3	1	10	0.6	0.2	2
Orimulsion		r 77 000	69 300	85 400	r 3	1	10	0.6	0.2	2
Natural Gas Liquids		r 64 200	58 300	70 400	r 3	1	10	0.6	0.2	2
Gasoline	Motor Gasoline	r 69 300	67 500	73 000	r 3	1	10	0.6	0.2	2
Gasoline	Aviation Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
Gasoline	Jet Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
Jet Kerosene		r 71 500	69 700	74 400	r 3	1	10	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	r 3	1	10	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	r 3	1	10	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	r 3	1	10	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	r 3	1	10	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	r 1	0.3	3	0.1	0.03	0.3
Solid Biofuels	Wood / Wood Waste	n 112 000	95 000	132 000	30	10	100	4	1.5	15
Solid Biofuels	Sulphite lyes (Black Liquor)[a]	n 95 300	80 700	110 000	n 3	1	18	n 2	1	21
Solid Biofuels	Other Primary Solid Biomass	n 100 000	84 700	117 000	30	10	100	4	1.5	15
Solid Biofuels	Charcoal	n 112 000	95 000	132 000	200	70	600	4	1.5	15

Reference: Volume 2, Chapter 2, Table 2.2, Page 1.14, 2006 IPCC Guidelines.

Table A-.4: Emission for stationary combustion in Manufacturing industries and construction. (kg of greenhouse gas per TJ on a Net Calorific Basis).

Fuel		CO_2			CH_4			N_2O		
		Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper
Crude Oil		73 300	71 100	75 500	r 3	1	10	0.6	0.2	2
Orimulsion		r 77 000	69 300	85 400	r 3	1	10	0.6	0.2	2
Natural Gas Liquids		r 64 200	58 300	70 400	r 3	1	10	0.6	0.2	2
Gasoline	Motor Gasoline	r 69 300	67 500	73 000	r 3	1	10	0.6	0.2	2
Gasoline	Aviation Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
Gasoline	Jet Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
Jet Kerosene		71 500	69 700	74 400	r 3	1	10	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	r 3	1	10	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	r 3	1	10	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	r 3	1	10	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	r 3	1	10	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	r 1	0.3	3	0.1	0.03	0.3
Solid Biofuels	Wood / Wood Waste	n 112 000	95 000	132 000	30	10	100	4	1.5	15
Solid Biofuels	Sulphite lyes (Black Liquor)[a]	n 95 300	80 700	110 000	n 3	1	18	n 2	1	21
Solid Biofuels	Other Primary Solid Biomass	n 100 000	84 700	117 000	30	10	100	4	1.5	15
Solid Biofuels	Charcoal	n 112 000	95 000	132 000	200	70	600	4	1.5	15

Reference: Volume 2, Chapter 2, page 1.18-1.19. 2006, IPCC Guidelines

Table A-5: Default Emission Factor for Stationary Combustion in the Commercial / Institutional Category (kg of greenhouse gas per TJ based on Net Calorific Basis) OUT

Fuel		CO_2			CH_4			N_2O		
		Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper
Crude Oil		73 300	71 100	75 500	10	3	30	0.6	0.2	2
Orimulsion		r 77 000	69 300	85 400	10	3	30	0.6	0.2	2
Natural Gas Liquids		r 64 200	58 300	70 400	10	3	30	0.6	0.2	2
Gasoline	Motor Gasoline	r 69 300	67 500	73 000	10	3	30	0.6	0.2	2
Gasoline	Aviation Gasoline	r 70 000	67 500	73 000	10	3	30	0.6	0.2	2
Gasoline	Jet Gasoline	r 70 000	67 500	73 000	10	3	30	0.6	0.2	2
Jet Kerosene		r 71 500	69 700	74 400	10	3	30	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	10	3	30	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	10	3	30	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	10	3	30	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	10	3	30	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	5	1.5	15	0.1	0.03	0.3
Peat		106 000	100 000	108 000	n 10	3	30	n 1.4	0.5	5
Solid Biofuels	Wood / Wood Waste	r 112 000	95 000	132 000	300	100	900	4	1.5	15
Solid Biofuels	Sulphite lyes (Black Liquor)[a]	n 95 300	80 700	110 000	n 3	1	18	n 2	1	21
Solid Biofuels	Other Primary Solid Biomass	n 100 000	84 700	117 000	300	100	900	4	1.5	15
Solid Biofuels	Charcoal	n 112 000	95 000	132 000	200	70	600	1	0.3	3

Reference: Volume 2, Chapter 2, Table 2.4, page 2.20 , 2006 PICC guidelines

Table A-6: Road Transport Default CO_2 Emission Factor and Uncertainty Ranges

Fuel Type	Default (kg/TJ)	Lower	Upper
Motor Gasoline	69 300	67 500	73 000
Gas/ Diesel Oil	74 100	72 600	74 800
Liquefied Petroleum Gases	63 100	61 600	65 600
Kerosene	71 900	70 800	73 700
Lubricants [b]	73 300	71 900	75 200
Compressed Natural Gas	56 100	54 300	58 300
Liquefied Natural Gas	56 100	54 300	58 300

Source: Table 1.4 in the Introduction chapter of the Energy Volume.

Notes:
[a] Values represent 100 percent oxidation of fuel carbon content.
[b] See Box 3.2.4 Lubricants in Mobile Combustion for guidance for uses of lubricants.

Reference: Volume 2, Chapter 3, Page 3.16, 2006 IPCC Inventory.

Table A-6 Road Transport N_2O and CH_4 Default Emission Factors and Uncertainty Ranges

Fuel Type/Representative Vehicle Category	**CH_4 (kg /TJ)**			**N_2O (kg /TJ)**		
	Default	**Lower**	**Upper**	**Default**	**Lower**	**Upper**
Motor Gasoline -Uncontrolled [(b)]	33	9.6	110	3.2	0.96	11
Motor Gasoline –Oxidation Catalyst [(c)]	25	7.5	86	8.0	2.6	24
Motor Gasoline –Low Mileage Light Duty Vehicle Vintage 1995 or Later [(d)]	3.8	1.1	13	5.7	1.9	17
Gas / Diesel Oil [(e)]	3.9	1.6	9.5	3.9	1.3	12
Natural Gas [(f)]	92	50	1 540	3	1	77
Liquified petroleum gas [(g)]	62	na	na	0.2	na	na
Ethanol, trucks, US [(h)]	260	77	880	41	13	123
Ethanol, cars, Brazil [(i)]	18	13	84	na	na	na

Sources: USEPA (2004b), EEA (2005a), TNO (2003) and Borsari (2005) CETESB (2004 & 2005) with assumptions given below. Uncertainty ranges were derived from data in Lipman and Delucchi (2002), except for ethanol in cars.

(a) Except for LPG and ethanol cars, default values are derived from the sources indicated using the NCV values reported in the Energy Volume Introduction chapter; density values reported by the U.S. Energy Information Administration; and the following assumed representative fuel consumption values: 10 km/l for motor gasoline vehicles; 5 km/l for diesel vehicles; 9 km/l for natural gas vehicles (assumed equivalent to gasoline vehicles); 9 km/l for ethanol vehicles. If actual representative fuel economy values are available, it is recommended that they be used with total fuel use data to estimate total distance travelled data, which should then be multiplied by Tier 2 emission factors for N_2O and CH_4.

(b) Motor gasoline uncontrolled default value is based on USEPA (2004b) value for a USA light duty gasoline vehicle (car) – uncontrolled, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(c) Motor gasoline – light duty vehicle oxidation catalyst default value is based on the USEPA (2004b) value for a USA Light Duty Gasoline Vehicle (Car) – Oxidation Catalyst, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(d) Motor gasoline – light duty vehicle vintage 1995 or later default value is based on the USEPA (2004b) value for a USA Light Duty Gasoline Vehicle (Car) – Tier 1, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(e) Diesel default value is based on the EEA (2005a) value for a European heavy duty diesel truck, converted using values and assumptions described in table note (a).

(f) Natural gas default and lower values were based on a study by TNO (2003), conducted using European vehicles and test cycles in the Netherlands. There is a lot of uncertainties for N_2O. The USEPA (2004b) has a default value of 350 kg CH_4/TJ and 28 kg N_2O/TJ for a USA CNG car, converted using values and assumptions described in table note (a). Upper and lower limits are also taken from USEPA (2004b)

(g) The default value for methane emissions from LPG, considering for 50 MJ/kg low heating value and 3.1 g CH_4/kg LPG was obtained from TNO (2003). Uncertainty ranges have not been provided.

(h) Ethanol default value is based on the USEPA (2004b) value for a USA ethanol heavy duty truck, converted using values and assumptions described in table note (a).

(i) Data obtained in Brazilian vehicles by Borsari (2005) and CETESB (2004 & 2005). For new 2003 models, best case: 51.3 kg THC/TJ fuel and 26.0 percent CH_4 in THC. For 5 years old vehicles: 67 kg THC/TJ fuel and 27.2 percent CH_4 in THC. For 10 years old: 308 kg THC/TJ fuel and 27.2 percent CH_4 in THC.

Reference: Vol. 2, Chapter 3, page 3.21 Table 3.2.2, 2006 IPCC Inventory Guidelines

Table A-7 : N_2O and CH_4 Emission Factors for USA Gasoline and Diesel Vehicles

Vehicle Type	Emission Control Technology	N_2O		CH_4	
		Running (hot)	Cold Start	Running (hot)	Cold Start
		mg/km	mg/start	mg/km	mg/start
Light Duty Gasoline Vehicle (Car)	Low Emission Vehicle (LEV)	0	90	6	32
	Advanced Three-Way Catalyst	9	113	7	55
	Early Three-Way Catalyst	26	92	39	34
	Oxidation Catalyst	20	72	82	9
	Non-oxidation Catalyst	8	28	96	59
	Uncontrolled	8	28	101	62
Light Duty Diesel Vehicle (Car)	Advanced	1	0	1	-3
	Moderate	1	0	1	-3
	Uncontrolled	1	-1	1	-3
Light Duty Gasoline Truck	Low Emission Vehicle (LEV)	1	59	7	46
	Advanced Three-Way Catalyst	25	200	14	82
	Early Three-Way Catalyst	43	153	39	72
	Oxidation Catalyst	26	93	81	99
	Non-oxidation catalyst	9	32	109	67
	Uncontrolled	9	32	116	71
Light Duty Diesel Truck	Advanced and moderate	1	-1	1	-4
	Uncontrolled	1	-1	1	-4
Heavy Duty Gasoline Vehicle	Low Emission Vehicle (LEV)	1	120	14	94
	Advanced Three-Way Catalyst	52	409	15	163
	Early Three-Way Catalyst	88	313	121	183
	Oxidation catalyst	55	194	111	215
	Non-oxidation catalyst	20	70	239	147
	Heavy Duty Gasoline Vehicle - Uncontrolled	21	74	263	162
Heavy Duty Diesel Vehicle	All -advanced, moderate, or uncontrolled	3	-2	4	-11
Motorcycles	Non-oxidation catalyst	3	12	40	24
	Uncontrolled	4	15	53	33

Reference: USEPA , 2004b; Vol. 2, Chapter 3, Table 3.2.3, page 3.22, 2006 IPCC Inventory Manual

Table A- D: Default Emission Factors for off road mobile sources

	CO_2			CH_4 (b)			N_2O (c)		
Off-Road Source	Default (kg/TJ)	Lower	Upper	Default (kg/TJ)	Lower	Upper	Default (kg/TJ)	Lower	Upper
Diesel									
Agriculture	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Forestry	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Industry	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Household	74 100	72 600	74 800	4.15	1.67	10.4	28.6	14.3	85.8
Motor Gasoline 4-stroke									
Agriculture	69 300	67 500	73 000	80	32	200	2	1	6
Forestry	69 300	67 500	73 000						
Industry	69 300	67 500	73 000	50	20	125	2	1	6
Household	69 300	67 500	73 000	120	48	300	2	1	6
Motor Gasoline 2-Stroke									
Agriculture	69 300	67 500	73 000	140	56	350	0.4	0.2	1.2
Forestry	69 300	67 500	73 000	170	68	425	0.4	0.2	1.2
Industry	69 300	67 500	73 000	130	52	325	0.4	0.2	1.2
Household	69 300	67 500	73 000	180	72	450	0.4	0.2	1.2

Source: EEA 2005.

Note: CO_2 emission factor values represent full carbon content.

[a] Data provided in Table 3.3.1 are based on European off-road mobile sources and machinery. For gasoline, in case fuel consumption by sector is not discriminated, default values may be obtained according to national circumstances, e.g. prevalence of a given sector or weighting by activity

[b] Including diurnal, soak and running losses.

[c] In general, off-road vehicles do not have emission control catalysts installed (there may be exceptions among off-road vehicles in urban areas, such as ground support equipment used in urban airports and harbours). Properly operating catalysts convert nitrogen oxides to N_2O and CH_4 to CO_2. However, exposure of catalysts to high-sulphur or leaded fuels, even once, causes permanent deterioration (Walsh, 2003). This effect, if applicable, should be considered when adjusting emission factors.

Reference Vol.2, Chap 3 page Table 3.3.1, 2006 IPCC

Table A-8: Marine Emission Factors for CO_2 Emissions

		kg/TJ		
Fuel		Default	Lower	Upper
Gasoline		69 300	67 500	73 000
Other Kerosene		71 900	70 800	73 600
Gas/Diesel Oil		74 100	72 600	74 800
Residual Fuel Oil		77 400	75 500	78 800
Liquefied Petroleum Gases		63 100	61 600	65 600
Other Oil	Refinery Gas	57 600	48 200	69 000
	Paraffin Waxes	73 300	72 200	74 400
	White Spirit & SBP	73 300	72 200	74 400
	Other Petroleum Products	73 300	72 200	74 400
Natural Gas		56 100	54 300	58 300

Reference: Vol. 2 Chap 3, Table 3.5.2 page 3.41 2006 IPCC

Table B8,%:Marine Non CO2

	CH_4 (kg/TJ)	N_2O (kg/TJ)
Ocean-going Ships *	7 ± 50%	2 +140% -40%

*Default values derived for diesel engines using heavy fuel oil.
Source: Lloyd's Register (1995) and EC (2002)

Reference: Vol. 2 Chap 3, Table 3.5.3 page 3.41 2006 IPCC

Appendix B Industrial Sector References and Data collection tools

Table B-1: Clinker Fraction of blended cement 'recipes' and Overall mixes (based on U.S. Standards ASTM. C150

TABLE 2.2
CLINKER FRACTION OF BLENDED CEMENT 'RECIPES' AND OVERALL PRODUCT MIXES (BASED ON U.S. STANDARDS ASTM C-150 AND C-595; U.S. DATA MAY BE ILLUSTRATIVE FOR OTHER COUNTRIES)

Cement Name	Symbol	Recipe	% Clinker	Notes
Portland	'PC'	100% PC	95 - 97 90 - 92	Some U.S. states allow inclusion of 3% GGBFS. Latest standards allow inclusion of ≤ 5% ground limestone.
Masonry	'MC'	2/3 PC	64	varies considerably
Slag-modified portland	I(SM)	slag < 25%	>70 - 93	
Portland BF Slag	IS	slag 25-70%	28 - 70	
Portland pozzolan	IP and P	pozz 15-40%	28 - 79/81	base is PC and/or IS
Pozzolan-modified portland	I(PM)	pozz <15%	28 - 93/95	base is PC and/or IS
Slag cement	S	slag 70+%	<28/29	can use CaO instead of clinker

PERCENT CLINKER IN THE PRODUCT MIX
Percent Additives (Pozzolan + Slag) in the Blended Cement*

Product Mix (PC/blend)**	0%	10%	20%	30%	40%	75%
100/0	95 - 97	0	0	0	0	0
0/100	0	85.5	76	66.5	57	23.8
15/85	14.2	86.9	78.9	70.8	62.7	26.4
25/75	23.8	87.9	80.8	73.6	66.5	41.6
30/70	28.5	88.35	81.7	75.1	68.4	45.2
40/60	38	89.3	83.6	77.9	72.2	52.3
50/50	47.5	90.3	85.5	80.8 ***	76	59.4
60/40	57	91.2	87.4	83.6	79.8	66.5
70/30	66.5	92.2	89.3	86.5	83.6	73.6
75/25	71.1	92.6	90.1	87.8	85.4	77.1
85/15	80.8	93.6	92.2	90.7	89.3	84.3

Notes:
* The inclusion of slag allows for the blend to be portland and/or portland blast furnace slag cement.

Appendix C AFOLU References and Data collection Tools

Livestock Sector

Reference Table C-1. Default Livestock (other than cattle) Enteric Fermentation CH_4 EF. Source: Table 10.10 Vol4. 2006 IPCC

ENTERIC FERMENTATION EMISSION FACTORS FOR TIER 1 METHOD[1] (KG CH_4 $HEAD^{-1}$ YR^{-1})			
Livestock	**Developed countries**	**Developing countries**	**Liveweight**
Buffalo	55	55	300 kg
Sheep	8	5	65 kg - developed countries; 45 kg - developing countries
Goats	5	5	40 kg
Camels	46	46	570 kg
Horses	18	18	550 kg
Mules and Asses	10	10	245 kg
Deer	20	20	120 kg
Alpacas	8	8	65 kg
Swine	1.5	1.0	
Poultry	Insufficient data for calculation	Insufficient data for calculation	
Other (e.g., Llamas)	To be determined[1]	To be determined[1]	

Reference Table C-2. . Default Cattle Enteric Fermentation CH_4 EF. Source Table 10.11 Vol4. 2006 IPCC

TIER 1 ENTERIC FERMENTATION EMISSION FACTORS FOR CATTLE[1]			
Regional characteristics	**Cattle category**	**Emission factor [2,3] (kg CH_4 $head^{-1}$ yr^{-1})**	**Comments**
Africa and Middle East: Commercialised dairy sector based on grazing with low production per cow. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Some cattle graze over very large areas. Cattle are smaller than those found in most other regions.	Dairy Other Cattle	46 31	Average milk production of 475 kg $head^{-1}$ yr^{-1} Includes multi-purpose cows, bulls, and young

Reference Table C-3. Default Manure Management CH_4 EF for cattle and Swine by temperature in Africa. Source: table 10.14, Vol 4., 2006 IPCC

TABLE 10.14
MANURE MANAGEMENT METHANE EMISSION FACTORS BY TEMPERATURE FOR CATTLE, SWINE, AND BUFFALO[a]
(KG CH_4 $HEAD^{-1}$ YR^{-1})

Regional characteristics	Livestock species	CH_4 emission factors by average annual temperature (°C)[b]																		
		Cool					Temperate											Warm		
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28
Africa: Most livestock manure is managed as a solid on pastures and ranges. A smaller, but significant fraction is burned as fuel.	Dairy Cows	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Other Cattle	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Swine	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2

Reference Table C-4. . Default Manure Management CH_4 EF for Sheep, Goats, Camels and Poultry (Developed and Developing countries). Source: table 10.15, Vol 4., 2006 IPCC.

Livestock	CH_4 emission factor by average annual temperature (°C)		
	Cool (<15°C)	Temperate (15 to 25°C)	Warm (>25°C)
Sheep			
Developed countries	0.19	0.28	0.37
Developing countries	0.10	0.15	0.20
Goats			
Developed countries	0.13	0.20	0.26
Developing countries	0.11	0.17	0.22
Camels			
Developed countries	1.58	2.37	3.17
Developing countries	1.28	1.92	2.56
Poultry			
Developed countries			
Layers (dry)[b]	0.03	0.03	0.03
Layers (wet)[c]	1.2	1.4	1.4
Broilers	0.02	0.02	0.02
Turkeys	0.09	0.09	0.09
Ducks	0.02	0.03	0.03
Developing countries	0.01	0.02	0.02

Reference Table C-5. Default Manure Management CH4 EF for Rabbits and Fur- bearing animals. Source: table 10.16, Vol 4., 2006 IPCC

TABLE 10.16
MANURE MANAGEMENT METHANE EMISSION FACTORS FOR DEER, REINDEER, RABBITS, AND FUR-BEARING ANIMALS

Livestock	CH_4 emission factor ($kg\ CH_4\ head^{-1}\ yr^{-1}$)
Deer[a]	0.22
Reindeer[b]	0.36
Rabbits[c]	0.08
Fur-bearing animals (e.g., fox, mink)[b]	0.68

The uncertainty in these emission factors is ±30 %.
[a] Sneath *et al.* (1997)
[b] Estimations of Agricultural University of Norway, Institute of Chemistry and Biotechnology, Section for Microbiology.
[c] Judgement of the IPCC Expert Group

Reference Table C-6. Default N Excretion Rate, kg N (1,000 Kg) /Animal mass. Source: table 10.19, Vol 4., 2006 IPCC

TABLE 10.19
DEFAULT VALUES FOR NITROGEN EXCRETION RATE [a] ($kg\ N\ (1000\ kg\ animal\ mass)^{-1}\ day^{-1}$)

Category of animal	Region							
	North America	Western Europe	Eastern Europe	Oceania	Latin America	Africa	Middle East	Asia
Dairy Cattle	0.44	0.48	0.35	0.44	0.48	0.60	0.70	0.47
Other Cattle	0.31	0.33	0.35	0.50	0.36	0.63	0.79	0.34
Swine[b]	0.50	0.68	0.74	0.73	1.64	1.64	1.64	0.50
Market	0.42	0.51	0.55	0.53	1.57	1.57	1.57	0.42
Breeding	0.24	0.42	0.46	0.46	0.55	0.55	0.55	0.24
Poultry	0.83	0.83	0.82	0.82	0.82	0.82	0.82	0.82
Hens >/= 1 yr	0.83	0.96	0.82	0.82	0.82	0.82	0.82	0.82
Pullets	0.62	0.55	0.60	0.60	0.60	0.60	0.60	0.60
Other Chickens	0.83	0.83	0.82	0.82	0.82	0.82	0.82	0.82
Broilers	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Turkeys	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Ducks	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Sheep	0.42	0.85	0.90	1.13	1.17	1.17	1.17	1.17
Goats	0.45	1.28	1.28	1.42	1.37	1.37	1.37	1.37
Horses (and mules, asses)	0.30	0.26	0.30	0.30	0.46	0.46	0.46	0.46
Camels[c]	0.38	0.38	0.38	0.38	0.46	0.46	0.46	0.46
Buffalo[c]	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Mink and Polecat ($kg\ N\ head^{-1}\ yr^{-1}$)[d]	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59
Rabbits ($kg\ N\ head^{-1}\ yr^{-1}$)	8.10	8.10	8.10	8.10	8.10	8.10	8.10	8.10
Fox and Racoon ($kg\ N\ head^{-1}\ yr^{-1}$)[d]	12.09	12.09	12.09	12.09	12.09	12.09	12.09	12.09

The uncertainty in these estimates is ±50%.
[a]Summarized from *1996 IPCC Guidelines*, 1997; European Environmental Agency, 2002; USA EPA National NH_3 Inventory Draft Report, 2004; and data of GHG inventories of Annex I Parties submitted to the Secretariat UNFCCC in 2004.
[b]Nitrogen excretion for swine are based on an estimated country population of 90% market swine and 10% breeding swine.

Reference Table C-7.Default Direct N_2O EFs From manure Management. Source: table 10.21, Vol4., 2006 IPCC

TABLE 10.21 DEFAULT EMISSION FACTORS FOR DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT				
System	Definition	EF_3 [kg N_2O-N (kg Nitrogen excreted)$^{-1}$]	Uncertainty ranges of EF_3	Source[a]
Pasture/Range/ Paddock	The manure from pasture and range grazing animals is allowed to lie as is, and is not managed.	Direct and indirect N_2O emissions associated with the manure deposited on agricultural soils and pasture, range, paddock systems are treated in Chapter 11, Section 11.2, N_2O emissions from managed soils.		
Daily spread	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion. N_2O emissions during storage and treatment are assumed to be zero. N_2O emissions from land application are covered under the Agricultural Soils category.	0	Not applicable	Judgement by IPCC Expert Group (see Co-chairs, Editors and Experts; N_2O emissions from Manure Management).
Solid storage[b]	The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.	0.005	Factor of 2	Judgement of IPCC Expert Group in combination with Amon *et al.* (2001), which shows emissions ranging from 0.0027 to 0.01 kg N_2O-N (kg N)$^{-1}$.
Dry lot	A paved or unpaved open confinement area without any significant vegetative cover where accumulating manure may be removed periodically. Dry lots are most typically found in dry climates but also are used in humid climates.	0.02	Factor of 2	Judgement of IPCC Expert Group in combination with Kulling (2003).
Poultry manure with litter	Similar to deep bedding systems. Typically used for all poultry breeder flocks and for the production of meat type chickens (broilers) and other fowl.	0.001	Factor of 2	Judgement of IPCC Expert Group based on the high loss of ammonia from these systems, which limits the availability of nitrogen for nitrification/denitrification.
Poultry manure without litter	May be similar to open pits in enclosed animal confinement facilities or may be designed and operated to dry the manure as it accumulates. The latter is known as a high-rise manure management system and is a form of passive windrow composting when designed and operated properly.	0.001	Factor of 2	Judgement of IPCC Expert Group based on the high loss of ammonia from these systems, which limits the availability of nitrogen for nitrification/denitrification.

Reference Table C-8. Default Values N loss due to Volatilisation NH_3 and NOx, Source: table 10.22, Vol4., 2006 IPCC

TABLE 10.22
DEFAULT VALUES FOR NITROGEN LOSS DUE TO VOLATILISATION OF NH_3 AND NO_X FROM MANURE MANAGEMENT

Animal type	Manure management system (MMS) [a]	N loss from MMS due to volatilisation of $N\text{-}NH_3$ and $N\text{-}NO_x$ (%) [b] $Frac_{GasMS}$ (Range of $Frac_{GasMS}$)
Swine	Anaerobic lagoon	40% (25 – 75)
	Pit storage	25% (15 – 30)
	Deep bedding	40% (10 – 60)
	Liquid/slurry	48% (15 – 60)
	Solid storage	45% (10 – 65)
Dairy Cow	Anaerobic lagoon	35% (20 – 80)
	Liquid/Slurry	40% (15 – 45)
	Pit storage	28% (10 – 40)
	Dry lot	20% (10 – 35)
	Solid storage	30% (10 – 40)
	Daily spread	7% (5 – 60)
Poultry	Poultry without litter	55% (40 – 70)
	Anaerobic lagoon	40% (25 – 75)
	Poultry with litter	40% (10 – 60)
Other Cattle	Dry lot	30% (20 – 50)
	Solid storage	45% (10 – 65)
	Deep bedding	30% (20 – 40)
Other [c]	Deep bedding	25% (10 – 30)
	Solid storage	12% (5 – 20)

Reference Table C-9. Default Values for total N loss Manure management, Source: table 10.23, Vol4., 2006 IPCC

TABLE 10.23
DEFAULT VALUES FOR TOTAL NITROGEN LOSS FROM MANURE MANAGEMENT

Animal category	Manure management system [a]	Total N loss from MMS [b] $Frac_{LossMS}$ (Range of $Frac_{LossMS}$)
Swine	Anaerobic lagoon	78% (55 – 99)
	Pit storage	25% (15 – 30)
	Deep bedding	50% (10 – 60)
	Liquid/Slurry	48% (15 – 60)
	Solid storage	50% (20 – 70)
Dairy Cow	Anaerobic lagoon	77% (55 – 99)
	Liquid/Slurry	40% (15 – 45)
	Pit storage	28% (10 – 40)
	Dry lot	30% (10 – 35)
	Solid storage	40% (10 – 65)
	Daily spread	22% (15 – 60)
Poultry	Poultry without litter	55% (40 – 70)
	Anaerobic lagoon	77% (50 – 99)
	Poultry with litter	50% (20 – 80)
Other Cattle	Dry lot	40% (20 – 50)
	Solid storage	50% (20 – 70)
	Deep bedding	40% (10 – 50)
Other [c]	Deep bedding	35% (15 – 40)
	Solid storage	15% (5 – 20)

[a] Manure Management System here includes associated N losses at housing and final storage system.

[b] Total N loss rates based on judgement of IPCC Expert Group and following sources: Rotz (2003), Hutchings *et al.* (2001), and U.S EPA (2004). Rates include losses in forms of NH_3, NO_x, N_2O, and N_2 as well from leaching and runoff from solid storage and dry lots. Values represent average rates for typical housing and storage components without any significant nitrogen control measures in place. Ranges reflect values that appear in the literature. Where measures to control nitrogen losses are in place, alternative rates should be developed to reflect those measures.

Reference Table C-10. Default Values for total N loss Manure management, Source: table 10.23, Vol4., 2006 IPCC ghg

TABLE 4.3
CARBON FRACTION OF ABOVEGROUND FOREST BIOMASS

Domain	Part of tree	Carbon fraction, (CF) [tonne C (tonne d.m.)$^{-1}$]	References
Default value	All	0.47	McGroddy *et al.*, 2004
Tropical and Subtropical	All	0.47 (0.44 - 0.49)	Andreae and Merlet, 2001; Chambers *et al.*, 2001; McGroddy *et al.*, 2004; Lasco and Pulhin, 2003
	wood	0.49	Feldpausch *et al.*, 2004
	wood, tree d < 10 cm	0.46	Hughes *et al.*, 2000
	wood, tree d ≥ 10 cm	0.49	Hughes *et al.*, 2000
	foliage	0.47	Feldpausch *et al.*, 2004
	foliage, tree d < 10 cm	0.43	Hughes *et al.*, 2000
	foliage, tree d ≥ 10 cm	0.46	Hughes *et al.*, 2000

TABLE 4.5 (CONTINUED)
DEFAULT BIOMASS CONVERSION AND EXPANSION FACTORS (BCEF), TONNES BIOMASS (M^3 OF WOOD VOLUME)$^{-1}$

BCEF for expansion of merchantable growing stock volume to above-ground biomass ($BCEF_S$), for conversion of net annual increment ($BCEF_I$) and for conversion of wood and fuelwood removal volume to above-ground biomass removal ($BCEF_R$)

Climatic zone	Forest type	BCEF	Growing stock level (m^3)							
			<10	11-20	21-40	41-60	61-80	80-120	120-200	>200
Humid tropical	conifers	$BCEF_S$	**4.0** (3.0-6.0)	**1.75** (1.4-2.4)	**1.25** (1.0-1.5)	**1.0** (0.8-1.2)	**0.8** (0.7-1.2)	**0.76** (0.6-1.0)	**0.7** (0.6-0.9)	**0.7** (0.6-0.9)
		$BCEF_I$	2.5	0.95	0.65	0.55	0.53	0.58	0.66	0.70
		$BCEF_R$	4.44	1.94	1.39	1.11	0.89	0.84	0.77	0.77
	natural forests	$BCEF_S$	**9.0** (4.0-12.0)	**4.0** (2.5-4.5)	**2.8** (1.4-3.4)	**2.05** (1.2-2.5)	**1.7** (1.2-2.2)	**1.5** (1.0-1.8)	**1.3**(0.9-1.6)	**0.95** (0.7-1.1)
		$BCEF_I$	4.5	1.6	1.1	0.93	0.9	0.87	0.86	0.85
		$BCEF_R$	10.0	4.44	3.11	2.28	1.89	1.67	1.44	1.05

TABLE 2.3
DEFAULT REFERENCE (UNDER NATIVE VEGETATION) SOIL ORGANIC C STOCKS (SOC_{REF}) FOR MINERAL SOILS (TONNES C HA^{-1} IN 0-30 CM DEPTH)

Climate region	HAC soils[1]	LAC soils[2]	Sandy soils[3]	Spodic soils[4]	Volcanic soils[5]	Wetland soils[6]
Boreal	68	NA	10#	117	20#	146
Cold temperate, dry	50	33	34	NA	20#	87
Cold temperate, moist	95	85	71	115	130	
Warm temperate, dry	38	24	19	NA	70#	88
Warm temperate, moist	88	63	34	NA	80	
Tropical, dry	38	35	31	NA	50#	86
Tropical, moist	65	47	39	NA	70#	
Tropical, wet	44	60	66	NA	130#	
Tropical montane	88*	63*	34*	NA	80*	

Note: Data are derived from soil databases described by Jobbagy and Jackson (2000) and Bernoux *et al.* (2002). Mean stocks are shown. A nominal error estimate of ±90% (expressed as 2x standard deviations as percent of the mean) are assumed for soil-climate types. NA denotes 'not applicable' because these soils do not normally occur in some climate zones.

# Indicates where no data were available and default values from *1996 IPCC Guidelines* were retained.

* Data were not available to directly estimate reference C stocks for these soil types in the tropical montane climate so the stocks were

TABLE 4.4
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R)

Domain	Ecological zone	Above-ground biomass	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	References
Tropical	Tropical rainforest		0.37	Fittkau and Klinge, 1973
	Tropical moist deciduous forest	above-ground biomass <125 tonnes ha^{-1}	0.20 (0.09 - 0.25)	Mokany *et al.*, 2006
		above-ground biomass >125 tonnes ha^{-1}	0.24 (0.22 - 0.33)	Mokany *et al.*, 2006
	Tropical dry forest	above-ground biomass <20 tonnes ha^{-1}	0.56 (0.28 - 0.68)	Mokany *et al.*, 2006
		above-ground biomass >20 tonnes ha^{-1}	0.28 (0.27 - 0.28)	Mokany *et al.*, 2006
	Tropical shrubland		0.40	Poupon, 1980
	Tropical mountain systems		0.27 (0.27 - 0.28)	Singh *et al.*, 1994

TABLE 2.6
COMBUSTION FACTOR VALUES (PROPORTION OF PREFIRE FUEL BIOMASS CONSUMED) FOR FIRES IN A RANGE OF VEGETATION TYPES
(Values in column 'mean' are to be used for quantity C_f in Equation 2.27)

Vegetation type	Subcategory	Mean	SD	References
Primary tropical forest (slash and burn)	Primary tropical forest	0.32	0.12	7, 8, 15, 56, 66, 3, 16, 53, 17, 45,
	Primary open tropical forest	0.45	0.09	21
	Primary tropical moist forest	0.50	0.03	37, 73
	Primary tropical dry forest	-	-	66
All primary tropical forests		**0.36**	**0.13**	
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3-5 yrs)	0.46	-	61
	Intermediate secondary tropical forest (6-10 yrs)	0.67	0.21	61, 35
	Advanced secondary tropical forest (14-17 yrs)	0.50	0.10	61, 73
All secondary tropical forests		**0.55**	**0.06**	56, 66, 34, 30
All tertiary tropical forest		**0.59**	-	66, 30
Boreal forest	Wildfire (general)	0.40	0.06	33
	Crown fire	0.43	0..21	66, 41, 64, 63
	surface fire	0.15	0.08	64, 63
	Post logging slash burn	0.33	0.13	49, 40, 18
	Land clearing fire	0.59	-	67
All boreal forest		**0.34**	**0.17**	45, 47
Eucalyptus forests	Wildfire	-	-	
	Prescribed fire – (surface)	0.61	0.11	72, 54, 60, 9
	Post logging slash burn	0.68	0.14	25, 58, 46
	Felled and burned (land-clearing fire)	0.49	-	62
All Eucalyptus forests		**0.63**	**0.13**	
Other temperate forests	Post logging slash burn	0.62	0.12	55, 19, 27, 14
	Felled and burned (land-clearing fire)	0.51	-	53, 24, 71
All "other" temperate forests		**0.45**	**0.16**	53, 56

TABLE 2.6 (CONTINUED)
COMBUSTION FACTOR VALUES (PROPORTION OF PREFIRE FUEL BIOMASS CONSUMED) FOR FIRES IN A RANGE OF VEGETATION TYPES
(Values in column 'mean' are to be used for quantity C_f in Equation 2.27)

Vegetation type	Subcategory	Mean	SD	References
Shrublands	Shrubland (general)	0.95	-	44
	Calluna heath	0.71	0.30	26, 56, 39
	Fynbos	0.61	0.16	70, 44
All shrublands		**0.72**	**0.25**	
Savanna woodlands (early dry season burns)*	Savanna woodland	0.22	-	28
	Savanna parkland	0.73	-	57
	Other savanna woodlands	0.37	0.19	22, 29
All savanna woodlands (early dry season burns)		**0.40**	**0.22**	
Savanna woodlands (mid/late dry season burns)*	Savanna woodland	0.72	-	66, 57
	Savanna parkland	0.82	0.07	57, 6, 51
	Tropical savanna	0.73	0.04	52, 73, 66, 12
	Other savanna woodlands	0.68	0.19	22, 29, 44, 31, 57

All savanna woodlands (mid/late dry season burns)*		**0.74**	**0.14**	
Savanna Grasslands/ Pastures (early dry season burns)*	Tropical/sub-tropical grassland	0.74	-	28
	Grassland	-	-	48
All savanna grasslands (early dry season burns)*		**0.74**	-	
Savanna Grasslands/ Pastures (mid/late dry season burns)*	Tropical/sub-tropical grassland	0.92	0.11	44, 73, 66, 12, 57
	Tropical pasture~	0.35	0.21	4, 23, 38, 66
	Savanna	0.86	0.12	53, 5, 56, 42, 50, 6, 45, 13, 44, 65, 66
All savanna grasslands (mid/late dry season burns)*		**0.77**	**0.26**	
Other vegetation types	Peatland	0.50	-	20, 44
	Tropical Wetlands	0.70	-	44
Agricultural residues (Post harvest field burning)	Wheat residues	0.90	-	see Note b
	Maize residues	0.80	-	see Note b
	Rice residues	0.80	-	see Note b
	Sugarcane [a]	0.80	-	see Note b

* Surface layer combustion only

~ Derived from slashed tropical forest (includes unburned woody material)

[a] For sugarcane, data refer to burning before harvest of the crop.

[b] Expert assessment by authors.

TABLE 4.6 EMISSION FACTORS FOR DRAINED ORGANIC SOILS IN MANAGED FORESTS		
Climate	**Emission factors (tonnes C ha^{-1} yr^{-1})**	
	Values	**Ranges**
Tropical	1.36	0.82 – 3.82
Temperate	0.68	0.41 – 1.91
Boreal	0.16	0.08 – 1.09
Source: *GPG-LULUCF*, Table 3.2.3		

Agriculture

TABLE 5.5 RELATIVE STOCK CHANGE FACTORS (F_{LU}, F_{MG}, AND F_I) (OVER 20 YEARS) FOR DIFFERENT MANAGEMENT ACTIVITIES ON CROPLAND						
Factor value type	**Level**	**Temper-ature regime**	**Moist-ure regime[1]**	**IPCC defaults**	**Error[2,3]**	**Description**
Land use (F_{LU})	Long-term culti-vated	Tem-perate/ Boreal	Dry	0.80	± 9%	Represents area that has been continuously managed for >20 yrs, to predominantly annual crops. Input and tillage factors are also applied to estimate carbon stock changes. Land-use factor was estimated relative to use of full tillage and nominal ('medium") carbon input levels.
			Moist	0.69	± 12%	
		Tropical	Dry	0.58	± 61%	
			Moist/ Wet	0.48	± 46%	
		Tropical montane[4]	n/a	0.64	± 50%	
Land use (F_{LU})	Paddy rice	All	Dry and Moist/ Wet	1.10	± 50%	Long-term (> 20 year) annual cropping of wetlands (paddy rice). Can include double-cropping with non-flooded crops. For paddy rice, tillage and input factors are not used.
Land use (F_{LU})	Peren-nial/ Tree Crop	All	Dry and Moist/ Wet	1.00	± 50%	Long-term perennial tree crops such as fruit and nut trees, coffee and cacao.
Land use (F_{LU})	Set aside (< 20	Tempe-rate/ Boreal and Tropical	Dry	0.93	± 11%	Represents temporary set aside of annually cropland (e.g., conservation reserves) or other idle cropland that has been revegetated with perennial grasses.
			Moist/ Wet	0.82	± 17%	

Land use (F_{LU})	Set aside (< 20 yrs)	Tempe-rate/ Boreal and Tropical	Dry	0.93	± 11%	Represents temporary set aside of annually cropland (e.g., conservation reserves) or other idle cropland that has been revegetated with perennial grasses.
			Moist/ Wet	0.82	± 17%	
		Tropical montane[4]	n/a	0.88	± 50%	
Tillage (F_{MG})	Full	All	Dry and Moist/ Wet	1.00	NA	Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g., <30%) of the surface is covered by residues.
Tillage (F_{MG})	Re-duced	Tem-perate/ Boreal	Dry	1.02	± 6%	Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with >30% coverage by residues at planting.
			Moist	1.08	± 5%	
		Tropical	Dry	1.09	± 9%	
			Moist/ Wet	1.15	± 8%	
		Tropical montane[4]	n/a	1.09	± 50%	
Tillage (F_{MG})	No-till	Temperat e/ Boreal	Dry	1.10	± 5%	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.
			Moist	1.15	± 4%	
		Tropical	Dry	1.17	± 8%	
			Moist/ Wet	1.22	± 7%	
		Tropical montane[4]	n/a	1.16	± 50%	

TABLE 6.2 RELATIVE STOCK CHANGE FACTORS FOR GRASSLAND MANAGEMENT					
Factor	**Level**	**Climate regime**	**IPCC default**	**Error** [1,2]	**Definition**
Land use (F_{LU})	All	All	1.0	NA	All permanent grassland is assigned a land-use factor of 1.
Management (F_{MG})	Nominally managed (non –degraded)	All	1.0	NA	Represents non-degraded and sustainably managed grassland, but without significant management improvements.
Management (F_{MG})	Moderately degraded grassland	Temperate /Boreal	0.95	± 13%	Represents overgrazed or moderately degraded grassland, with somewhat reduced productivity (relative to the native or nominally managed grassland) and receiving no management inputs.
		Tropical	0.97	± 11%	
		Tropical Montane[3]	0.96	± 40%	
Management (F_{MG})	Severely degraded	All	0.7	± 40%	Implies major long-term loss of productivity and vegetation cover, due to severe mechanical damage to the vegetation and/or severe soil erosion.
Management (F_{MG})	Improved grassland	Temperate /Boreal	1.14	± 11%	Represents grassland which is sustainably managed with moderate grazing pressure and that receive at least one improvement (e.g., fertilization, species improvement, irrigation).
		Tropical	1.17	± 9%	
		Tropical Montane[3]	1.16	± 40%	
Input (applied only to improved grassland) (F_I)	Medium	All	1.0	NA	Applies to improved grassland where no additional management inputs have been used.
Input (applied only to improved grassland) (F_I)	High	All	1.11	± 7%	Applies to improved grassland where one or more additional management inputs/improvements have been used (beyond that is required to be classified as improved grassland).

[1] ± two standard deviations, expressed as a percent of the mean; where sufficient studies were not available for a statistical analysis a default, based on expert judgement, of ± 40% is used as a measure of the error. NA denotes 'Not Applicable', for factor values that constitute reference values or nominal practices for the input or management classes.

TABLE 8.4 DEFAULT BIOMASS CARBON STOCKS REMOVED DUE TO LAND CONVERSION TO SETTLEMENTS		
Land-use category	**Carbon stock in biomass before conversion (B_{Before}) (tonnes C ha^{-1})**	**Error range** [#]
Forest Land	See Chapter 4, Tables 4.7 to 4.12 for carbon stocks in a range of forest types by climate regions. Stocks are in terms of dry matter. Multiply values by a carbon fraction (CF) 0.5 to convert dry matter to carbon.	See Section 4.3 (Land Converted to Forest Land)
Grassland	See Table 6.4, Chapter 6 for carbon stocks in a range of grassland types by climate regions.	± 75%
Cropland	For cropland containing annual crops: Use default of 4.7 tonnes of carbon ha^{-1} or 10 tonnes of dry matter ha^{-1} (see Chapter 6, Section 6.3.1.2)	± 75%.

[#] Represents a nominal estimate of error, equivalent to two times standard deviation, as a percentage of the mean.

TABLE 7.4 EMISSION FACTORS FOR CO_2–C AND ASSOCIATED UNCERTAINTY FOR LANDS MANAGED FOR PEAT EXTRACTION, BY CLIMATE ZONE			
Climate zone	**Emission factor (tonnes C ha^{-1} yr^{-1})**	**Uncertainty [a] (tonnes C ha^{-1} yr^{-1})**	**Reference/Comment [b]**
Boreal and Temperate			
Nutrient – Poor $EF_{CO_2 peatPoor}$	0.2	0 to 0.63	Laine and Minkkinen, 1996; Alm *et al.*, 1999; Laine *et al.*, 1996; Minkkinen *et al.*, 2002
Nutrient – Rich $EF_{CO_2 peatRich}$	1.1	0.03 to 2.9	Laine *et al.*, 1996; LUSTRA, 2002; Minkkinen *et al.*, 2002; Sundh *et al.*, 2000
Tropical			
$EF_{CO_2 peat}$	2.0	0.06 to 7.0	Calculated from the relative difference between temperate (nutrient-poor) and tropical

[a] Range of underlying data

[b] The boreal and temperate values have been developed as the mean from a review of paired plot measurements, assuming that conditions on organic soils converted to peat extraction are lightly drained only. Most of the data are from European peatlands not necessarily under production.

TABLE 7.5 CONVERSION FACTORS FOR CO_2–C FOR VOLUME AND WEIGHT PRODUCTION DATA		
Climate zone	**$Cfraction_{wt\_peat}$ [tonnes C (tonne air-dry peat)$^{-1}$]**	**$Cfraction_{vol\_peat}$ (tonnes C m^{-3} air-dry peat)**
Boreal and Temperate		
Nutrient –Poor	0.45	0.07
Nutrient –Rich	0.40	0.24
Tropical		
Tropical humus	0.34	0.26

Computed from US Geological Survey (2004): survey average bulk density, and typical moisture content and carbon contents. Based on a 35-55% moisture content of air-dry peat.

TABLE 7.6
DEFAULT EMISSION FACTORS FOR N_2O EMISSIONS FROM MANAGED PEATLANDS

Climate zone	Emission factor EF_{N_2O} (kg N_2O-N ha^{-1} yr^{-1})	Uncertainty range (kg N_2O-N ha^{-1} yr^{-1})	Reference/ Comments
Boreal and Temperate Climate			
Nutrient-poor organic Soil	negligible	negligible	Alm *et al*., 1999; Laine *et al*., 1996; Martikainen *et al*., 1995; Minkkinen *et al*., 2002; Regina *et al*., 1996
Nutrient-rich organic Soil	1.8	0.2 to 2.5	
Tropical Climate	3.6	0.2 to 5.0	The value for tropical areas is twice that for northern climates, based on the relative difference between temperate and tropical N_2O EF in Table 11.1, Chapter 11.
Most of the data are from European peatlands not necessarily under production. Climate zones are as described in Chapter 3.			

TABLE 11.1 DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N_2O EMISSIONS FROM MANAGED SOILS		
Emission factor	**Default value**	**Uncertainty range**
EF_1 for N additions from mineral fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03
EF_{1FR} for flooded rice fields [kg N_2O–N (kg N)$^{-1}$]	0.003	0.000 - 0.006
$EF_{2\,CG,\,Temp}$ for temperate organic crop and grassland soils (kg N_2O–N ha^{-1})	8	2 - 24
$EF_{2\,CG,\,Trop}$ for tropical organic crop and grassland soils (kg N_2O–N ha^{-1})	16	5 - 48
$EF_{2F,\,Temp,\,Org,\,R}$ for temperate and boreal organic nutrient rich forest soils (kg N_2O–N ha^{-1})	0.6	0.16 - 2.4
$EF_{2F,\,Temp,\,Org,\,P}$ for temperate and boreal organic nutrient poor forest soils (kg N_2O–N ha^{-1})	0.1	0.02 - 0.3
$EF_{2F,\,Trop}$ for tropical organic forest soils (kg N_2O–N ha^{-1})	8	0 - 24
$EF_{3PRP,\,CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs [kg N_2O–N (kg N)$^{-1}$]	0.02	0.007 - 0.06
$EF_{3PRP,\,SO}$ for sheep and 'other animals' [kg N_2O–N (kg N)$^{-1}$]	0.01	0.003 - 0.03

Sources:
EF_1: Bouwman et al. 2002a,b; Stehfest & Bouwman, 2006; Novoa & Tejeda, 2006 in press; EF_{1FR}: Akiyama *et al.*, 2005; $EF_{2CG,\,Temp}$, $EF_{2CG,\,Trop}$, $EF_{2F,Trop}$: Klemedtsson *et al.*, 1999, IPCC Good Practice Guidance, 2000; $EF_{2F,\,Temp}$: Alm *et al.*, 1999; Laine *et al.*, 1996; Martikainen *et al.*, 1995; Minkkinen *et al.*, 2002: Regina *et al.*, 1996; Klemedtsson *et al.*, 2002; $EF_{3,\,CPP}$, $EF_{3,\,SO}$: de Klein, 2004.

TABLE 11.3 DEFAULT EMISSION, VOLATILISATION AND LEACHING FACTORS FOR INDIRECT SOIL N_2O EMISSIONS		
Factor	**Default value**	**Uncertainty range**
EF_4 [N volatilisation and re-deposition], kg N_2O–N (kg NH_3–N + NO_X–N volatilised)$^{-1}$ [22]	0.010	0.002 - 0.05
EF_5 [leaching/runoff], kg N_2O–N (kg N leaching/runoff) $^{-1}$ [23]	0.0075	0.0005 - 0.025
$Frac_{GASF}$ [Volatilisation from synthetic fertiliser], (kg NH_3–N + NO_x–N) (kg N applied) $^{-1}$	0.10	0.03 - 0.3
$Frac_{GASM}$ [Volatilisation from all organic N fertilisers applied , and dung and urine deposited by grazing animals], (kg NH_3–N + NO_x–N) (kg N applied or deposited) $^{-1}$	0.20	0.05 - 0.5
$Frac_{LEACH-(H)}$ [N losses by leaching/runoff for regions where Σ(rain in rainy season) - Σ (PE in same period) > soil water holding capacity, OR where irrigation (except drip irrigation) is employed], kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.30	0.1 - 0.8

Note: The term $Frac_{LEACH}$ previously used has been modified so that it now only applies to regions where soil water-holding capacity is exceeded, as a result of rainfall and/or irrigation (excluding drip irrigation), and leaching/runoff occurs, and redesignated as $Frac_{LEACH-(H)}$. In the definition of $Frac_{LEACH-(H)}$ above, PE is potential evaporation, and the rainy season(s) can be taken as the period(s) when rainfall > 0.5 * Pan Evaporation. (Explanations of potential and pan evaporation are available in standard meteorological and agricultural texts). For other regions the default $Frac_{LEACH}$ is taken as zero.

Illustration of estimating Uncertainties in Living Biomass

The example below illustrates the steps of uncertainty assessment, applied for the land use sector. It considers a simple case where carbon stock changes, emissions and removals are estimated for two sub-categories within the forest land category: i) forest land that remains as forest land, and ii) the conversion of forest land to grassland. Non-CO2 gases and emissions from soils are not considered here. The example concentrates on simple numerical estimates of uncertainty, not taking into account correlations between input parameters.

The estimation involves three steps:

- Step 1: Estimate emissions or removals related to each activity for forest land remaining as forest and to convert from forest to grassland.
- Step 2: Assess uncertainties related to both activities.
- Step 3: Assess the total uncertainties on forestry and other lands.

Data requirements

Activity data, Emission Factors and uncertainty data required is presented below in step by step approach.

Step 1: Estimate emissions or removals for each activity

Before conducting an uncertainty assessment, estimates of the carbon stock change are prepared for both subcategories: forest land remaining forest land and forest land converted to grassland. These estimates are prepared following the detailed 2006 IPCC guidelines.

Forest Land Remaining as Forest Land

In this example, Method 1 (Gain and loss method) which requires the biomass carbon loss to be subtracted from the biomass increment was used.

$$\Delta CFF_{LB} = (\Delta CFF_G - \Delta CFF_L)$$

where:

- ΔCFF_{LB} = annual change in carbon stocks in living biomass (includes above- and belowground biomass) on forest land remaining forest land, tonnes C/ yr tonnes (Hypothetical uncertainty value provided) .

- ΔCFF_G = average annual increase in carbon due to biomass growth (also called biomass increment), tonnes C /yr (Hypothetical uncertainty value provided)
- ΔCFF_L = annual average decrease in carbon due to biomass loss, tonnes C /yr (Hypothetical uncertainty value provided).

To simplify, the example we assume that there is no biomass loss, so that $\Delta CFF_L = 0$. Hence in this example, $\Delta CFF_{LB} = \Delta CFF_G$. The biomass increment ΔCFF_G is calculated according to Equation:

$$\Delta CFF_G = \sum ij \, (Aij \bullet GTOTALij) \bullet CF$$

where:

- ΔCFF_G = average annual increase in carbon due to biomass increment in forest land remaining forest land by forest type and climatic zone, tonnes C yr^{-1}
- Aij = area of forest land remaining forest land, by forest type (i= 1 to n) and climatic zone (j=1 to m), ha (uncertainty estimated at 2.5%)
- GTOTALij = annual average increment rate in total biomass in units of dry matter by forest type (i= 1 to n) and climatic zone (j=1 to m), , tonnes d.m. ha^{-1} yr^{-1}
- CF = carbon fraction, tonnes C $(\text{tonnes d.m.})^{-1}$ (default value 0.5, with 2% uncertainty)

In this example, the area of forest land remaining as forest is assumed to be 1 million hectares only first forest type in one ecological zone is considered. This simplifies the expression of ΔCFF_G above to be:

$$\Delta CFF_G = A \bullet GTOTAL \bullet CF$$

where GTOTAL is now the annual average increment rate in total biomass, averaged over the whole land area. In the present example, a default value of 3.1 tonnes d.m. ha^{-1} yr^{-1}, with a default percent uncertainty of 50%. The average annual increase in carbon stock due to biomass increment on forest land remaining forest land is:

$$\Delta CFF_G = 1{,}000{,}000 \bullet 3.1 \bullet 0.5 \text{ tonnes C/ yr} = 1{,}550{,}000 \text{ tonnes C } yr^{-1}$$

Forest Land converted into grasland

Since zero biomass loss is assumed, then $\Delta CFF_{LB} = \Delta CFF_G$

Forest Land Converted to Grassland

The annual carbon stock change from the conversion of forest land into grassland, assuming the year of conversion, as:

$$\Delta CLG_{LB} = AConversion \bullet (CConversion + CGrowth)$$

$$CConversion = CAfter - CBefore$$

where:

- ΔCLG_{LB} = Annual change in carbon stocks in living biomass as a result of land use conversion to grassland from some initial land use, tonnes C /yr^{-}
- AConversion =Annual area of land converted to grasslands from some initial use, ha yr^{-1} (error estimated at 24%)
- CConversion = Carbon stocks removed when lands are converted from some initial use to grassland, tonnes C ha^{-1}
- CGrowth = Carbon stocks from one year of growth of grassland vegetation after conversion, tonnes C ha^{-1} (60% uncertainty)
- CAfter = Carbon stocks in biomass immediately after conversion to grassland, tonnes C ha^{-1}
- CBefore = Carbon stocks in biomass immediately before conversion to grassland, tonnes C ha^{-1}

If the default values are expressed as biomass per hectare, it will be necessary to convert to carbon using CF of 0.5 as a default, with an uncertainty for CF of 2%. In this example, the area of forest converted to grassland is 500 hectares. CF_{LB} = CBefore = 80 tonnes C ha^{-1}, with percent uncertainty of 24%

- CAfter = 0 tonne C ha^{-1}, with percent uncertainty of 0%
- CG_{LB} = CGrowth = 3 tonnes C ha^{-1}, with percent uncertainty of 60%

Replacing the above values in the equation gives:

$\Delta CLG_{LB} = AFG \bullet (-CF_{LB} + CG_{LB}) = 500 \text{ ha} \bullet (-80 + 3) \text{ tonnes C ha}^{-1} = -38{,}500$ tonnes C

Assessment of uncertainties for each activity

Forest Land Remaining as Forest Land

The uncertainty associated with estimated forest land area is determined based statistical methods since in Uganda, area was derived from interpretation and classification of satellite image using standard methods and procedures. Sample error estimated at 2.5%.

The uncertainty of the annual biomass growth depends on the uncertainty of input parameters. Annual growth in biomass is calculated according to the equation above and converted to carbon with CF. The uncertainty estimate of the growth in biomass carbon ($U_{\Delta CFF}$) is obtained as:

$$U_{\Delta CFF} = \sqrt{50\%^2 + 2\%^2}$$

$$U_{\Delta CFF} = 50.04$$

It is advisable that before the combined uncertainties of the activity information AFF (area of forest land remaining forest land) and the emission factor (annual biomass growth in terms of carbon, GCTOTAL) can be calculated, it must be determined whether they are correlated. In this example, the inputs are derived from independent sources, and it is reasonable to assume that they are not correlated. Consequently, combined uncertainty can be as follows: $^{U}\Delta CFF_{G}$

$$U_{\Delta CFF} = \sqrt{U_{1AFF}^2 + U_{GCTOTAL}^2}$$

Where

$U_{\Delta CFF} = \sqrt{2.5\%^2 + 50.04}$ = 50.1

where:

- $U_{\Delta CFF\ G}$ = percent uncertainty of the change in carbon stock
- U_{AFF} = percent uncertainty of the forest land area estimates
- GCTOTAL = annual biomass growth in terms of carbon

Forest land converted to Grassland

In this example, we estimate the uncertainty associated with the carbon stock change resulting from land-use change. If NBS data is used, then the statistical error associated with the data should be used. In this case, let us assume that default values are used and type and density of the data, statistical error estimates are not know. Expert judgement will be used. Since the carbon stock immediately after the conversion CAfter is assumed to be zero, the uncertainty of the carbon stock change, has three components: the uncertainty in carbon stock immediately before the conversion UC_F, (F = Forest), the uncertainty in carbon stock of grassland vegetation after the conversions UC_G, (G = Grassland) and the uncertainty associated with the estimate of the area that has been converted UA_{FG}. Using the combined uncertainty example, the percent uncertainty of the carbon stock change per hectare UΦ is estimated as:

$$U_{\varphi} = \frac{\sqrt{(U_{CF} \bullet U_F)^2 + (U_{GF} \bullet U_G)^2}}{C_F + C_G}$$

$$U_{\varphi} = \frac{\sqrt{(24\% \bullet (-80))^2 + (60\% \bullet 3)^2}}{-80 + 3} = 25\%$$

The total uncertainty for biomass carbon stock change for this simplified example of land-use change is then calculated by combining the uncertainty in carbon stock change per hectare with the uncertainty in the estimate of the converted area, which in our example is assumed to be 30%. Hence:

$$U_{\Delta CFG} = \sqrt{U_{AFG}^2 + U_{\varphi}^2}$$

$$= \sqrt{30^2 + 25^2} = 39\%$$

Example of combining land sector uncertainties

In this simple example, the uncertainty of the LULUCF Sector is estimated by combining the uncertainty of the estimates of the two activities. Uncertainties for a real world case with more category estimates can be combined in the same way.

Table Appendix 4 -1: Example Combining uncertainty for a sector

Total uncertainty for this example		
Land-Use Category	Estimate of the associated carbon stock change (tonne C yr -1)	U∆C
Forest Land Remaining as Forest	1,550 000	50.1%
Forest Land Converted to Grassland	-38 500	39%
Total	1,511 500	51.4%

The overall uncertainty is then estimated from Equation below to be:

$$U_{TOTAL} = \frac{\sqrt{(50.1\% \bullet 1{,}550{,}000)^2 + (39\% \bullet (-38{,}500)^2}}{1{,}550{,}000 + (-38{,}500)} = 51.4\%$$

The overall uncertainty from these two LULUCF activities, when expressed as percent uncertainty is 51.4%.

Uncertainty in DOM and Soils

When using Tier 1, uncertainty is optional

Example, calculating carbon stock change in cropland (inorganic soils)

As an example, if we assume that in 1995 the area with low activity clay soils of tropical moist area under crop in central Uganda was 1,000,000 ha with 33% under perennial crops (coffee / banana) with no or minimum tillage and medium carbon input (mulching with no manure application), 5% perennial (coffee / banana) with no or minimum tillage and high carbon input (mulching plus manure application), 2% rice with fulltime tillage with low C input and 60% annual crops with full time tillage and low c input. The above text is presented in a tabular form in table 16.

Uganda mineral soils (organic carbon reference)

Uganda soils are described as generally highly weathered (dominated by 1:1 clay mineral and amorphous iron and aluminium oxide). These fall in the Low Activity Clay (LAC) and, in some instances, sandy category. Thus Uganda Soil carbon reference (tones per hectare within the 0-30cm) will range between 35 and 47 tones per hectare for tropical moist LAC to dry LAC category. For tropical moist sandy to dry sandy categories the carbon content range is 31 to 39 tones per hectare respectively. Volcanic soils may range from 50 to 70 tones per hectare. Montane may go up to 80 tones per hectare while wetland soils may go up to 86 tons of carbon per hectare.

Tabulated example on land and cropping system

Year	Area	Soil Carbon /Ha	Cropping system	Tillage	Carbon in put	Tones C (Millions)
1995	330,000	47	Perennial (Coffee banana) =1	Minimum =1.02	Mulching = 1	15.8
1995	50,000	47	Perennial (Coffee banana) =1	Minimum =1.02	Mulching + manure = 1.44	3.5
1995	20,000	47	Rice wet =1.1	Full time =1	Low carbon input = 0.92	1.0
1995	600,000	47	Annual crops 0.48	Full time =1	Low carbon input = 0.92	12.5

Total soil carbon at the beginning (SOC0-T) would be 330,000 ha ● (47 tonnes C/ha ● 1 ● 1.02 ● 1) +50,000 ha ● (47 tonnes C/ha ● 1 ● 1.02 ● 1.44) +20,000 ha ● (47 tonnes C/ha ● 1.1 ● 1 ● 0.92) + 600,000 ha ● (47 tonnes C /ha● 0.48 ● 1 ● 0.92) = 32.7 million tonnes C.

If 10 years later (the last year of inventory time), the total area under coffee / banana plantations had reduced to 35% (possibly due to banana wilt) with no or minimum tillage and medium carbon input (only mulching no manure), rice was 5% with fulltime tillage with low C input and 60% was annual crops, with full time tillage and low c input. Total soil carbon in inorganic soils in last year (SOC0) would be 350,000 ha ● (47 tonnes C ha-1 ● 1 ● 1.02 ● 1) +50,000 ha ● (47 tonnes C ha-1 ● 1.1 ● 1 ● 0.92) + 600,000 ha ● (47 tonnes C ha-1 ● 0.48 ● 1 ● 0.92) = 31.6 million tonnes C.

$$\Delta C_{Mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

The average annual stock change over the period for the entire area is: 31.6 – 32.7 = 1.07 million tonnes/20 yr = 53,298 tonnes C per year soil C stock decrease (Note: 20 years is the time dependence of the stock change factor, i.e., the factor that represents the annual rate of change over 20 years).

Climate region	HAC soils[1]	LAC soils[2]	Sandy soils[3]	Spodic soils[4]	Volcanic soils[5]	Wetland soils[6]
Boreal	68	NA	10#	117	20#	146
Cold temperate, dry	50	33	34	NA	20#	87
Cold temperate, moist	95	85	71	115	130	
Warm temperate, dry	38	24	19	NA	70#	88
Warm temperate, moist	88	63	34	NA	80	
Tropical, dry	38	35	31	NA	50#	86
Tropical, moist	65	47	39	NA	70#	
Tropical, wet	44	60	66	NA	130#	
Tropical montane	88*	63*	34*	NA	80*	

Note: Data are derived from soil databases described by Jobbagy and Jackson (2000) and Bernoux *et al.* (2002). Mean stocks are shown. A nominal error estimate of ±90% (expressed as 2x standard deviations as percent of the mean) are assumed for soil-climate types. NA denotes 'not applicable' because these soils do not normally occur in some climate zones.

# Indicates where no data were available and default values from *1996 IPCC Guidelines* were retained.

* Data were not available to directly estimate reference C stocks for these soil types in the tropical montane climate so the stocks were based on estimates derived for the warm temperate, moist region, which has similar mean annual temperatures and precipitation.

[1] Soils with high activity clay (HAC) minerals are lightly to moderately weathered soils, which are dominated by 2:1 silicate clay minerals (in the World Reference Base for Soil Resources (WRB) classification these include Leptosols, Vertisols, Kastanozems, Chernozems, Phaeozems, Luvisols, Alisols, Albeluvisols, Solonetz, Calcisols, Gypsisols, Umbrisols, Cambisols, Regosols; in USDA classification includes Mollisols, Vertisols, high-base status Alfisols, Aridisols, Inceptisols).

[2] Soils with low activity clay (LAC) minerals are highly weathered soils, dominated by 1:1 clay minerals and amorphous iron and aluminium oxides (in WRB classification includes Acrisols, Lixisols, Nitisols, Ferralsols, Durisols; in USDA classification includes Ultisols, Oxisols, acidic Alfisols).

[3] Includes all soils (regardless of taxonomic classification) having > 70% sand and < 8% clay, based on standard textural analyses (in WRB classification includes Arenosols; in USDA classification includes Psamments).

[4] Soils exhibiting strong podzolization (in WRB classification includes Podzols; in USDA classification Spodosols)

[5] Soils derived from volcanic ash with allophanic mineralogy (in WRB classification Andosols; in USDA classification Andisols)

[6] Soils with restricted drainage leading to periodic flooding and anaerobic conditions (in WRB classification Gleysols; in USDA classification Aquic suborders).

Aggregate Sources

TABLE 2.5
EMISSION FACTORS (g kg^{-1} DRY MATTER BURNT) FOR VARIOUS TYPES OF BURNING. VALUES ARE MEANS ± SD AND ARE BASED ON THE COMPREHENSIVE REVIEW BY ANDREAE AND MERLET (2001)
(To be used as quantity 'G_{ef}' in Equation 2.27)

Category	CO_2	CO	CH_4	N_2O	NO_X
Savanna and grassland	1613 ± 95	65 ± 20	2.3 ± 0.9	0.21 ± 0.10	3.9 ± 2.4
Agricultural residues	1515 ± 177	92 ± 84	2.7	0.07	2.5 ± 1.0
Tropical forest	1580 ± 90	104 ± 20	6.8 ± 2.0	0.20	1.6 ± 0.7
Extra tropical forest	1569 ± 131	107 ± 37	4.7 ± 1.9	0.26 ±0.07	3.0 ± 1.4
Biofuel burning	1550 ± 95	78 ± 31	6.1 ± 2.2	0.06	1.1 ± 0.6

Note: The "extra tropical forest' category includes all other forest types.

Note: For combustion of non-woody biomass in Grassland and Cropland, CO_2 emissions do not need to be estimated and reported, because it is assumed that annual CO_2 removals (through growth) and emissions (whether by decay or fire) by biomass are in balance (see earlier discussion on synchrony in Section 2.4.

Appendix D Waste Sector Reference Tables

Reference Table D-1. Regional default values; MSW Generation and Treatment. Source: Table 2.1 Vol5., 2006 IPCC

TABLE 2.1
MSW GENERATION AND TREATMENT DATA - REGIONAL DEFAULTS

Region	MSW Generation Rate[1, 2, 3] (tonnes/cap/yr)	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management, unspecified[4]
Asia					
Eastern Asia	0.37	0.55	0.26	0.01	0.18
South-Central Asia	0.21	0.74	-	0.05	0.21
South-East Asia	0.27	0.59	0.09	0.05	0.27
Africa[5]	0.29	0.69	-	-	0.31
Europe					
Eastern Europe	0.38	0.90	0.04	0.01	0.02
Northern Europe	0.64	0.47	0.24	0.08	0.20
Southern Europe	0.52	0.85	0.05	0.05	0.05
Western Europe	0.56	0.47	0.22	0.15	0.15
America					
Caribbean	0.49	0.83	0.02	-	0.15
Central America	0.21	0.50	-	-	0.50
South America	0.26	0.54	0.01	0.003	0.46
North America	0.65	0.58	0.06	0.06	0.29
Oceania[6]	0.69	0.85	-	-	0.15

[1] Data are based on weight of wet waste.

[2] To obtain the total waste generation in the country, the per-capita values should be multiplied with the population whose waste is collected. In many countries, especially developing countries, this encompasses only urban population.

[3] The data are default data for the year 2000, although for some countries the year for which the data are applicable was not given in the reference, or data for the year 2000 were not available. The year for which the data are collected, where available, is given in the Annex 2A.1.

Reference Table D-2. MSW composition data by % - Regional Defaults. Source: Table 2.3 Vol5., 2006 IPCC

TABLE 2.3
MSW COMPOSITION DATA BY PERCENT - REGIONAL DEFAULTS

Region	Food waste	Paper/cardboard	Wood	Textiles	Rubber/leather	Plastic	Metal	Glass	Other
Asia									
Eastern Asia	26.2	18.8	3.5	3.5	1.0	14.3	2.7	3.1	7.4
South-Central Asia	40.3	11.3	7.9	2.5	0.8	6.4	3.8	3.5	21.9
South-Eastern Asia	43.5	12.9	9.9	2.7	0.9	7.2	3.3	4.0	16.3
Western Asia & Middle East	41.1	18.0	9.8	2.9	0.6	6.3	1.3	2.2	5.4
Africa									
Eastern Africa	53.9	7.7	7.0	1.7	1.1	5.5	1.8	2.3	11.6
Middle Africa	43.4	16.8	6.5	2.5		4.5	3.5	2.0	1.5
Northern Africa	51.1	16.5	2	2.5		4.5	3.5	2	1.5
Southern Africa	23	25	15						
Western Africa	40.4	9.8	4.4	1.0		3.0	1.0		
Europe									
Eastern Europe	30.1	21.8	7.5	4.7	1.4	6.2	3.6	10.0	14.6
Northern Europe	23.8	30.6	10.0	2.0		13.0	7.0	8.0	
Southern Europe	36.9	17.0	10.6						
Western Europe	24.2	27.5	11.0						
Oceania									
Australia and New Zealand	36.0	30.0	24.0						
Rest of Oceania	67.5	6.0	2.5						
America									
North America	33.9	23.2	6.2	3.9	1.4	8.5	4.6	6.5	9.8
Central America	43.8	13.7	13.5	2.6	1.8	6.7	2.6	3.7	12.3
South America	44.9	17.1	4.7	2.6	0.7	10.8	2.9	3.3	13.0
Caribbean	46.9	17.0	2.4	5.1	1.9	9.9	5.0	5.7	3.5

Reference Table D-3. Default Matter Content, DOC, Total C Content and Fossil C Fraction different MSW Components. Source: Table 2.4 Vol5., 2006 IPCC

TABLE 2.4
DEFAULT DRY MATTER CONTENT, DOC CONTENT, TOTAL CARBON CONTENT AND FOSSIL CARBON FRACTION OF DIFFERENT MSW COMPONENTS

MSW component	Dry matter content in % of wet weight [1]	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
	Default	Default	Range	Default	Range [2]	Default	Range	Default	Range
Paper/cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles [3]	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85 [4]	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber and Leather	84	(39) [5]	(39) [5]	(47) [5]	(47) [5]	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal [6]	100	-	-	-	-	NA	NA	NA	NA
Glass [6]	100	-	-	-	-	NA	NA	NA	NA
Other, inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

[1] The moisture content given here applies to the specific waste types before they enter the collection and treatment. In samples taken from collected waste or from e.g., SWDS the moisture content of each waste type will vary by moisture of co-existing waste and weather during handling.

[2] The range refers to the minimum and maximum data reported by Dehoust *et al*., 2002; Gangdonggu, 1997; Guendehou, 2004; JESC, 2001; Jager and Blok, 1993; Würdinger *et al*., 1997; and Zeschmar-Lahl, 2002.

[3] 40 percent of textile are assumed to be synthetic (default). Expert judgement by the authors.

[4] This value is for wood products at the end of life. Typical dry matter content of wood at the time of harvest (that is for garden and park waste) is 40 percent. Expert judgement by the authors.

[5] Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii et al., 1985; Rose and Steinbüchel, 2005).

Reference Table D-4. Default DOC and Fossil C content in Industrial waste (% in wet waste produced). Source: Table 2.5 Vol5., 2006 IPCC

TABLE 2.5
DEFAULT DOC AND FOSSIL CARBON CONTENT IN INDUSTRIAL WASTE (PERCENTAGE IN WET WASTE PRODUCED)[1]

Industry type	DOC	Fossil carbon	Total carbon	Water content [2]
Food, beverages and tobacco (other than sludge)	15	-	15	60
Textile	24	16	40	20
Wood and wood products	43	-	43	15
Pulp and paper (other than sludge)	40	1	41	10
Petroleum products, Solvents, Plastics	-	80	80	0
Rubber	(39) [3]	17	56	16
Construction and demolition	4	20	24	0
Other [4]	1	3	4	10

Source: Expert Judgement; Pipatti *et al.* 1996; Yamada *et al.* 2003.

[1] The default values apply only for process waste from the industries, office and other similar waste are assumed to be included in MSW.

[2] Note that water contents of industrial wastes vary enormously, even within a single industry.

[3] Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii, *et al.*, 1985; Rose and Steinbüchel, 2005).

[4] These values can be used also as defaults for total waste from manufacturing industries, when data on waste production by industry type are not available. Waste from mining and quarrying should be excluded from the calculations as the amounts can be large and the DOC and fossil carbon contents are likely to be negligible.

Reference Table D-5. Recommended Default CH4 Generation Rate(k) values. Source: Table 2.3 Vol5., 2006 IPCC

TABLE 3.3
RECOMMENDED DEFAULT METHANE GENERATION RATE (k) VALUES UNDER TIER 1

(Derived from k values obtained in experimental measurements, calculated by models, or used in greenhouse gas inventories and other studies)

Type of Waste		Climate Zone*							
		Boreal and Temperate (MAT ≤ 20°C)				Tropical[1] (MAT > 20°C)			
		Dry (MAP/PET < 1)		Wet (MAP/PET > 1)		Dry (MAP < 1000 mm)		Moist and Wet (MAP ≥ 1000 mm)	
		Default	Range[2]	Default	Range[2]	Default	Range[2]	Default	Range[2]
Slowly degrading waste	Paper/textiles waste	0.04	0.03[3,5] – 0.05[3,4]	0.06	0.05 – 0.07[3,5]	0.045	0.04 – 0.06	0.07	0.06 – 0.085
	Wood/ straw waste	0.02	0.01[3,4] – 0.03[6,7]	0.03	0.02 – 0.04	0.025	0.02 – 0.04	0.035	0.03 – 0.05
Moderately degrading waste	Other (non – food) organic putrescible/ Garden and park waste	0.05	0.04 – 0.06	0.1	0.06 – 0.1[8]	0.065	0.05 – 0.08	0.17	0.15 – 0.2
Rapidly degrading waste	Food waste/Sewage sludge	0.06	0.05 – 0.08	0.185[4]	0.1[3,4] – 0.2[9]	0.085	0.07 – 0.1	0.4	0.17 – 0.7[10]
Bulk Waste		0.05	0.04 – 0.06	0.09	0.08[8] – 0.1	0.065	0.05 – 0.08	0.17	0.15[11] – 0.2

[1] The available information on the determination of k and half-lives in tropical conditions is quite limited. The values included in the table, for those conditions, are indicative and mostly have been derived from the assumptions described in the text and values obtained for temperate conditions.

[2] The range refers to the minimum and maximum data reported in literature or estimated by the authors of the chapter. It is included, basically, to describe the uncertainty associated with the default value.

[3] Oonk and Boom (1995).

Reference Table D-6. Default MCF values for Domestic wastewater. Source: Table 2.6 Vol5., 2006 IPCC

TABLE 6.3
DEFAULT MCF VALUES FOR DOMESTIC WASTEWATER

Type of treatment and discharge pathway or system	Comments	MCF [1]	Range
Untreated system			
Sea, river and lake discharge	Rivers with high organics loadings can turn anaerobic.	0.1	0 – 0.2
Stagnant sewer	Open and warm	0.5	0.4 – 0.8
Flowing sewer (open or closed)	Fast moving, clean. (Insignificant amounts of CH_4 from pump stations, etc)	0	0
Treated system			
Centralized, aerobic treatment plant	Must be well managed. Some CH_4 can be emitted from settling basins and other pockets.	0	0 – 0.1
Centralized, aerobic treatment plant	Not well managed. Overloaded.	0.3	0.2 – 0.4
Anaerobic digester for sludge	CH_4 recovery is not considered here.	0.8	0.8 – 1.0
Anaerobic reactor	CH_4 recovery is not considered here.	0.8	0.8 – 1.0
Anaerobic shallow lagoon	Depth less than 2 metres, use expert judgment.	0.2	0 – 0.3
Anaerobic deep lagoon	Depth more than 2 metres	0.8	0.8 – 1.0
Septic system	Half of BOD settles in anaerobic tank.	0.5	0.5
Latrine	Dry climate, ground water table lower than latrine, small family (3-5 persons)	0.1	0.05 – 0.15
Latrine	Dry climate, ground water table lower than latrine, communal (many users)	0.5	0.4 – 0.6
Latrine	Wet climate/flush water use, ground water table higher than latrine	0.7	0.7 – 1.0
Latrine	Regular sediment removal for fertilizer	0.1	0.1

[1] Based on expert judgment by lead authors of this section.