Tracking Greenhouse Gases:

An Inventory Manual

Greenhouse Gas Inventory Manual

TABLES

FIGURES

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ACRONYMS

BAS - Bureau of Agricultural Statistics

BAI - Bureau of Animal Industry

BFAR - Bureau of Fisheries and Aquatic Resources

BOD - Biological oxygen demand

CEMAP - Cement Manufacturers' Association of the Philippines

CKD - Cement kiln dust

COD - Chemical oxygen demand

DENR - Department of Environment and Natural Resources

DOC - Degradable organic component

DOE - Department of Energy

DOST – FNRI - Department of Science and Technology – Food and Nutrition Research Institute

EF - Emission factor

EMB - Environmental Management Bureau

ESMAP - Energy Sector Management Assistance Program

FAO - Food and Agriculture Organization

FGAPI - Flat Glass Alliance of the Philippines Inc.

FMB - Forest Management Bureau

FOD - First order decay

GDP - Gross domestic product

GHG - Greenhouse gas

GVA - Gross value added

GWP - Global warming potential

IACCC - Inter-Agency Committee on Climate Change

IMF - International Monetary Fund

INC - Initial National Communication

IPCC - Intergovernmental Panel on Climate Change

IRRI - International Rice Research Institute

JICA - Japan International Cooperation Agency

LUCF - Land Use Change and Forestry

MCF - Methane correction factor

MMDA - Metropolitan Manila Development Authority

MSW - Municipal solid waste

NSCB - National Statistical Coordination Board

NSIC - National Statistical Information Center
NSO - National Statistics Office
NSWMC - National Solid Waste Management Commission
ODS - Ozone-depleting substances
PhilRice - Philippine Rice Research Institute
PISI - Philippine Iron and Steel Institute
POD - Philippine Ozone Desk
PULPAPEL - Pulp and Paper Manufacturer Association, Inc.
SEASI - Southeast Asia Iron and Steel Institute
SLS - Selective logging system
SNC - Second National Communication
SPIK - Samahan sa Pilipinas ng mga Industriyang Kimika
SRA - Sugar Regulatory Administration
SWDS - Solid waste disposal sites
UNDP - United Nations Development Programme
UNFCCC - United Nations Framework Convention on Climate Change Chemical
CO - Carbon monoxide
CO_2 - Carbon dioxide
HFC - Hydrofluorocarbon
NMVOC - Non-methane volatile organic compound
N_2O - Nitrous Oxide
NOx - Nitrogen Oxide
OEB - Overall energy balance
PFC - Perfluorocarbon
NRE - Non-renewable energy
SF_6 - Sulfur hexafluoride
SO_2 - Sulfur dioxide
TOC - Total Organic Carbon
VOC - Volatile Organic Compound Units
Gg - gigagram
ktoe - kilotonnes of oil equivalent
t - tonne (1000 kg)
tC - tonnes Carbon
TJ - terajoule (1 x 1012 J)

FOREWORD

Humans are active agents of climate change. The rise in the atmospheric levels of greenhouse gases in the atmosphere – driver of climate change – is brought about by increased industrial, agricultural and economic activities of humankind. This anthropogenic interference with our climate compels us, humankind, to be no less than active players in protecting our climate.

Recognizing this role in climate protection, the Philippines is committed to global, concerted efforts in curbing the rise of greenhouse gas emissions. The Philippines is party to the United Nations Framework Convention on Climate Change (UNFCCC), a covenant of parties that aims to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

As an essential first step in achieving this aim, an inventory of greenhouse gas emissions – referred to as the National Communication - is required by the UNFCCC from all its member parties. Thus, the Philippines is tasked to develop, periodically update and publish its National Communication, an inventory of the country's greenhouse gas emissions which also serves as a blueprint of the plans and strategies of the country in addressing the impacts of climate change.

The 1994 Philippine GHG Inventory, the country's Initial National Communication (INC), is a testament to its commitment to the UNFCCC and to climate protection. Published in 2000, the INC provided the basis on which succeeding national inventories were to be undertaken. Not only did it define the sectors whose emissions were to be accounted for, but also the steps on how to account for these emissions.

We are now in the Second National Communication. Banking on the lessons learned from the INC, and improving on the technical assumptions and issues of the first report, the Philippines is now ever ready to take on stronger commitments not only in complying with the mandates from the UNFCCC, but more importantly in steering the country towards a more proactive stance on climate protection.

This National GHG Inventory Manual is proof that our country is positioned, more than ever, to take on the challenge of taking a regular inventory of our greenhouse gas emissions. This Manual is a tool to identify our country's sources and sinks of GHGs on a regular basis through simplified, transparent and easy to grasp procedures and worksheets.

Through this Manual, we can properly institutionalize the conduct of our national GHG inventory in the five main sectors that are truly reflective of our economic wellbeing, namely Energy, Industrial Processes and Product Use, Agriculture, Land Use Change and Forestry (LUCF), and Waste. For each of these sectors, worksheets are provided as well as step-by-step procedures to facilitate entry of figures into the worksheets.

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The effort and pains of the various sectors experts who contributed to this Manual is acknowledged. Without them lending their expertise, this mammoth undertaking would not have been possible. The Environmental Management Bureau - Department of Environment and Natural Resources, through the steady support of the United Nations Development Programme also wish to thank all public and private institutions for providing data and for helping in the best way that they can.

We hope that you, our user, will find this Manual easy to use and that it will truly serve its purpose of quantifying the GHG emissions that are associated with our country's growth. May this manual not only aid our country in regularly fulfilling the requirements set forth by the UNFCCC for its member-parties, but most importantly make us accountable for our GHG emissions and thus, bring us to actively participate in efforts towards protecting our climate, and becoming responsible stewards of this earth.

This manual is derived from the cumulative experience from work during the Initial National Communication and the Second National Communication. It takes off from the 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Good Practice and Uncertainty Management in National Greenhouse Gas Inventories 2000, and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. It is also informed by scientific literature specific to the Philippine case, where available.

The manual is organized by sectors of which there are five: Energy, Industry, Agriculture, Land-Use Change and Forestry, and Waste. It has two components, the Users Manual and the Sector Reference Manual. Both manuals come together to generate the Greenhouse Gas (GHG) Inventory. It is intended for use by personnel who will be involved in generating GHG emissions data to be used for the inventory, from government such as the Environmental Management Bureau, the Forest Management Bureau, the Bureau of Agricultural Statistics or the National Statistics Coordination Board among others, and the private sector, such as the various industry associations, like pulp and paper, petroleum, glass manufacturing and chemicals.

The manual is organized by sectors of which there are five: ***Energy, Industry, Agriculture, Land-Use Change and Forestry, and Waste.***

The Manual focuses on providing a guide to the step by step process for each of the five sectors and to the associated worksheets and sub-worksheets. It also provides a reference manual containing background knowledge that may be needed and useful to understanding the inventory better in terms of choosing the right emission factors or equations, interpreting the output from the inventory and contributing to the analysis. Each sector manual is configured by the experts according to some convention of their sector.

It is expected that Third National Communication for which this exercise is also being undertaken may use certain steps and worksheets not used in the previous Second National Communication, such as the abandoned managed lands, and soil carbon for the LUCF sector. The manual may also be useful for doing back computations for the reference year and data for the Initial National Communication and benchmarking with the SNC, such as the Waste Sector's solid waste subsector, and the LUCF's forests' contribution. It is also to be expected that there will be changes to the manual in time, with new data and science coming in.

Energy Sector

Greenhouse gas (GHG) emissions from the energy sector come from the combustion of fuels and other activities related to the production of energy, such as coal mining, oil and gas exploration, production and processing. The majority of emissions, however, come from fuel combustion. GHGs released from fuel production activities such as coal mining, exploration, production, and processing of oil and gas products are minimal and are termed collectively as fugitive emissions (Villarin, et al. 1-1).

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the GHG's released in the combustion of fuels. Also released in the process are the GHG pre-cursors carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOC's). Of these six gases, the major gas emitted is CO_2 and the bulk of the GHG emissions calculations involve determining the amount of CO_2 released in fuel combustion activities.

There are two ways to estimate CO_2 emissions from fuel combustion: the top-down or reference approach, and the bottom-up or sectoral approach.

Computing for energy sector emissions in the Philippines is facilitated by a data system in the Department of Energy (DOE) involving the Overall Energy Balance Sheet (OEB) maintained by the Energy Policy Formulation and Research Division, an office within the Energy Policy and Planning Bureau. The Energy Policy and Planning Bureau computes GHG emissions and publishes the same for the Philippine Energy Plan.

The **Greenhouse gas (GHG)** emissions from the energy sector come from the combustion of fuels and other activities related to the production of energy, such as coal mining, oil and gas exploration, production and processing

GHG emissions from the Philippines are computed using the Revised 1996 IPCC (Intergovernmental Panel on Climate Change) Guidelines and the United Nations Framework Convention on Climate Change's (UNFCCC) GHG Inventory Software. The UNFCCC software is an excel-based program which aims to assist non-Annex I countries in developing their national GHG inventories.

GREENHOUSE GASES FROM THE ENERGY SECTOR

Greenhouse gas (GHG) emissions from the energy sector come from the combustion of fuels and other activities related to the production of energy, such as coal mining, oil and gas exploration, production, processing and transport. The majority of the emissions, however, come from fuel combustion. GHG's released from fuel production activities such as coal mining, exploration, production, and processing of oil and gas products are minimal and are termed collectively as fugitive emissions.[1]

Fossil fuels are compounds that contain hydrocarbons, i.e. carbon and hydrogen atoms bonded together. Upon combustion, the hydrocarbon is broken down into its components and energy is released. The carbon molecule then bonds with oxygen to form either carbon monoxide (CO) or CO_2 while the hydrogen molecules bond with oxygen to form water vapor. This is illustrated in the following process1:

$$\text{HC} \xrightarrow[\text{Combustion}]{} \text{H,C} \xrightarrow[\text{Energy released}]{} H_2O,\ CO_2,\ CO$$

There are two ways to estimate CO_2 emissions from fuel combustion: the top-down or reference approach, and the bottom-up or sectoral approach. In both methods, the general formula used to compute for CO_2 emissions is:

$$CO_2 \text{ Emissions } (t\ CO_2) = \sum \text{[fuel consumption (TJ) x carbon emission factor (t C/TJ)} \\ \text{– carbon stored (t C) x fraction of carbon oxidized x 44/12]}$$

where:

t CO_2 = tonnes (1000 kg) CO_2

TJ = Terajoules (1 TJ is 1,000,000,000,000 or 1 x 1012 joules)

44/12 = ratio of the molecular weight of CO_2 (44 grams/mole) to the molecular weight of C (12 grams/mole) and is used to convert from C to CO_2

Note that in the equation above, fuel consumption is expressed in terajoules (TJ) which is a unit of energy. In the OEB sheet, consumption data is expressed in kilotonnes of oil equivalent (ktoe) which is also an energy unit. The conversion from ktoe to TJ is simply given by the relation: 1 ktoe = 41.87 TJ.

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[1] Villarin, et. al. 1999. Tracking Greenhouse Gases: A Guide for Country Inventories: Reference Manual 1-1.

THE PHILIPPINE ENERGY SECTOR

The Philippine energy sector has undergone changes over the years – in particular, the composition of its energy mix has moved from heavy dependence on fuel oil to an increasing share of new and renewable energy sources (see Figure 1). The increased share of coal in the energy mix may be due to policies for self-sufficiency from imported energy (42.2% in 2000). For the year 2000, largest share of GHG emissions comes from oil (71.4%) and coal (25.5%) as NRE systems are assumed to have no net CO_2 emissions.

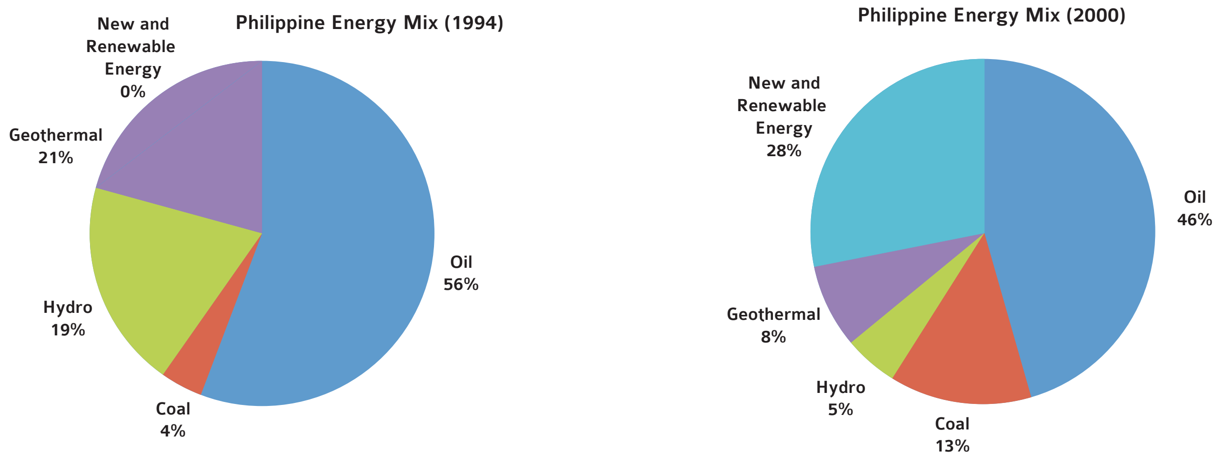

Figure 1: Dominance of Fossil Fuel- Based Energy in the 1994 Philippine Energy Mix. (Source: Department of Energy)

The calculation of GHG emissions from the energy sector is already semi-institutionalized in the Philippine Department of Energy (DOE). Computing for energy sector emissions is facilitated by a data system in DOE involving the Overall Energy Balance Sheet maintained by the Energy Policy Formulation and Research Division, an office within the Energy Policy and Planning Bureau. The Energy Policy and Planning Bureau computes GHG emissions and publishes the same for the Philippine Energy Plan.

This reference manual is a walk-through on the process of computing for GHG emissions from the Philippines using the Revised 1996 IPCC (Intergovernmental Panel on Climate Change) Guidelines and the United Nations Framework Convention on Climate Change's (UNFCCC) GHG Inventory Software. The UNFCCC software is an excel-based program which aims to assist non-Annex I countries in developing their national GHG inventories.

This manual is arranged as follows :

1. CO_2 emissions using Reference or Top-down approach and Sectoral or Bottom-up approach
2. Non- CO_2 Emissions from Fuel Combustion by Source Categories
3. SO_2 Emissions from Fuel Combustion by Source Categories
4. Fugitive emissions
5. Memo items
6. Summary of Emissions
7. Annex I - Energy Data (2000)
8. Annex II - Getting Started with the UNFCCC GHG Inventory Software
9. Annex III - List of Spreadsheets

REFERENCE OR TOP-DOWN APPROACH

The top-down approach looks at the primary level of energy supply and distribution. The basic data requirement is an overall inventory (overall energy balance sheet) of the national fuel supply which includes information on fuel quantities for each of the fuel types listed in Table 1 that are utilized in the following activities:

1. production;
2. imports;
3. exports;
4. international bunkers, or the amount of fuel used for international aviation and marine transport; and
5. stock change, or the variations in the quantity of fuel in stock.

Fuels that are exported and fuels used for international bunkers (i.e., marine and aviation transport) are subtracted from the overall apparent consumption and hence are not included in the national GHG emissions inventory. CO_2 emissions from international bunkers, nonetheless, are still computed as a separate memo item as recommended by the IPCC guidelines.

Please follow the instructions in Annex I in downloading and loading the UNFCCC Software. Open the file Module.xls and follow the directions below.[2]

Step 1: Calculating the Apparent Fuel Composition

Go to sheet 1-1s1-3. For each fuel type, enter the data (in kilotonnes oil equivalent or ktoe) on fuel production, import, export, transport through international bunkers and stock change into columns A,B,C,D and E, respectively. The data is available from the Overall Energy Balance Sheet (OEB) of the Philippines which can be obtained from the Department of Energy (DOE). Apparent Consumption = Production + Imports – Exports – International bunkers – Stock Change[3]

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[2] This document refers to columns as labeled by the UNFCCC software and not the default Microsoft Excel labels.sd

[3] Stock change is the difference in fuel stocks between the previous year and the present inventory year. A negative stock change means a decrease in the fuel stock inventory and correspondingly, this signifies an increase in the apparent consumption. A positive stock change, on the other hand, implies an increase in fuel stocks, and hence, a decrease in the apparent consumption.

Note: Change the signs (+/-) of the export, bunkering and stock change figures in the OEB as you enter them into the UNFCCC software.

The apparent fuel consumption (in ktoe) will automatically be calculated in column F. Make sure that the figures here match the figures in the "Primary Energy Supply" row of the OEB sheet. The OEB's "primary energy supply" is essentially the "apparent consumption" in the UNFCCC Software.

Enter the conversion factor (41.87 TJ/ktoe), in Column G. Column H will give the converted apparent fuel consumption figures in TJ.

Step 2: Estimating the Carbon Content of the Fuel

2.1. Input the Carbon emission factors (tC/TJ) for each fuel type in Column I. Table 1 lists the relevant fuel types used in the Philippines as per the OEB and their IPCC equivalent and their carbon emission factors. The carbon content is automatically computed by the sheet in Columns J and K, giving values for tonnes and kilotonnes (or Gigagrams) of carbon, respectively.

TABLE 1. CARBON EMISSION FACTORS AND IPCC EQUIVALENT OF FUELS IN THE OEB

FUEL CLASSIFICATION (FROM OEB SHEET)	IPCC EQUIVALENT	EMISSION FACTOR FACTOR (TC/TJ)
Asphalt	Bitumen	22.0
Avgas	Other Oil	20.0
Biomass	Solid Biomass	29.9
Coal	Sub-bituminous coal	26.2
Crude Oil	Crude Oil	20
Diesel	Gas/ Diesel Oil	20.2
Fuel Oil	Residual Fuel Oil	21.1
Gasoline (Premium and Regular)	Gasoline	18.9
Jet	Jet Kerosene	19.5
Kerosene	Other Kerosene	19.6
LPG	LPG	17.2
Lubes	Lubricants	20.0
Naptha	Naptha	20.0
Nat Gas	Natural Gas	15.3
Other PP[4]	Other Oil	20.0

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[4] Includes sulfur, propylene, mixed xylene and mixed fuel as per the DOE OEB.

Step 3: Estimating Net Carbon Emissions

3.1. To be able to fill Column L of Sheet 1-1s1-3, go to Sheet 1-1a and fill in 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 fuels5. The data for Column A of Sheet 1-1a (Estimated fuel quantities) shall be taken from the "Others, Non-energy Use" row of the OEB Sheet. Again, use 41.87 as the conversion factor (Column B).

Also, fill in Column D of Sheet 1-1a with the carbon emission factors for the relevant fuels. Copy the carbon stored (ktonnes C) figures in Column H of Sheet 1-1a into the appropriate cells in Column L of Sheet 1-1s1-3.

Step 4: Estimating Annual CO_2 Emissions

4.1. Go back to Sheet 1.1s1-3 and input the fraction of carbon oxidized when burning the fuels[6]. The figures for the actual carbon emissions and the actual CO_2 emissions shall be calculated automatically in Columns O and P, respectively.

TABLE 2. FRACTION OF CARBON OXIDIZED

FUEL CLASSIFICATION (FROM OEB SHEET)	IPCC EQUIVALENT	FRACTION OF CARBON OXIDIZED
Asphalt	Bitumen	0.99
Avgas	Other Oil	0.99
Biomass	Solid Biomass	0.99
Coal	Sub-bituminous coal	0.98
Crude Oil	Crude Oil	0.99
Diesel	Gas/ Diesel Oil	0.99
Fuel Oil	Residual Fuel Oil	0.99
Gasoline (Premium and Regular)	Gasoline	0.99
Jet	Jet Kerosene	0.99
Kerosene	Other Kerosene	0.99
LPG	LPG	0.99
Lubes	Lubricants	0.99
Naptha	Naptha	0.99
Nat Gas	Natural Gas	0.995
Other PP	Other Oil	0.99

Source: DOE 2008, IPCC (1997)

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[5] Some fuel types such as asphalt and coal are also used in non-energy activities. Road paving for example uses asphalt extensively. In this case, the carbon content of asphalt is not oxidized or combusted and is said to be stored. The release of this carbon into the atmosphere occurs gradually and is no longer covered in the fuel combustion process of energy activities. This amount of carbon must be deducted from the calculated emissions.

[6] A small part of the fuel carbon entering combustion escapes oxidation but the majority of this carbon is later oxidized in the atmosphere. It is assumed that the carbon that remains unoxidized is stored indefinitely.

4.2. Go to Sheet 1-1s4-5 and you'll see the calculations done automatically by the software for the emissions from international bunkers (fuel used in international marine and aviation transportation). These figures are excluded in the calculation of the apparent fuel consumption and are listed here as separate items (Memo Items).

SECTORAL OR BOTTOM-UP APPROACH

The preceding section calculates CO_2 emissions by considering the overall national inventory of fuel supply. Another approach is to look at the actual consumption of the specific subsectors. The subsectors are identified as the following: power generation or energy production, transportation, manufacturing, residential, commercial, and agricultural.

The methodology is basically the same as in the reference approach but is more detailed in the sense that it is applied for each specific end-user category.

The energy industries subsector refers to the fuel input of power plants needed for electricity generation. Power generation sources in the country can be categorized according to the following systems: oil, diesel, coal, gas turbines, natural gas, hydropower, geothermal, and non-conventional sources which refer to wind, solar, and biomass resources. Of these eight, five are dependent on fossil fuels: oil-based power plants, diesel and gas turbine plants, natural gas systems, and coal-fired power plants. Hence, CO_2 emissions from this subsector currently come from the combustion mainly of these four fuel types: fuel oil, diesel, natural gas, and coal.

The transportation subsector is composed of road, water, and air transport. Gasoline and diesel are the main fuel types used in road transport. In the Philippines, gasoline is further classified into premium and regular. In the IPCC guidelines, however, these fuel types are grouped into one category which is gasoline. Other fuel types which are also used (in insignificant quantities) in road transportation are kerosene and fuel oil. Fuels involved in air transport are jet kerosene and aviation gasoline while for water transport, diesel and fuel oil are the dominant fuel types.

Aside from the energy provided by power producers, manufacturing industries often buy raw fuel for their energy needs such as for their boilers and generator sets.

The residential subsector is heavily dependent on LPG, kerosene and biomass for energy-related domestic activities such as cooking. Diesel and regular gasoline are used in relatively small quantities.

Diesel, fuel oil, and LPG are the fuel types commonly used in commercial establishments. This subsector also uses regular gasoline and kerosene for its energy requirement.

In agriculture, diesel is the dominant fuel type used to run tractors and other heavy agriculture machinery. Other fuel types used in this subsector are regular gasoline, kerosene, and fuel oil.

The bottom-up approach provides a more detailed inventory of the CO_2 emissions from fuel combustion. It identifies the specific sectoral consumers of fuel and thus the major emitters of energy-related GHGs. Compared to the top-down approach, however, it requires more detailed data and is more computation-intensive. Also, the estimated CO_2 emissions may be underestimated since this approach relies heavily on data reported by fuel end-users which may not always be complete. The completeness of data submitted, if at all, to the DOE has always been a perennial problem.

It is recommended that both top-down and bottom-up analyses be done. Ideally, there should not be much of a difference in the emission calculations using the two methods.

Step 1: Calculating the Apparent Fuel Consumption for each Fuel Type

The table below contains the name of the different data input sheets for the different energy subsectors in the excel file. The directions would apply to the different sheets found in Table 3.

TABLE 3. CO_2 CALCULATION SHEETS FOR THE DIFFERENT ENERGY SUBSECTORS

SHEET NUMBER	SUBSECTOR
1-2s1-2	Energy Industries
1-2s3-4A	Manufacturing Industries and Construction – Autogeneration
1-2s3-4B	Manufacturing Industries and Construction – Process Heat
1-2s5-6	Transport
1-2s9-10A	Commercial/ Institutional Sector – Autogeneration
1-2s9-10B	Commercial/ Institutional Sector – Process Heat
1-2s11-12	Residential Sector
1-2s13-14	Agriculture/ Forestry/ Fishing

For each subsector (see relevant sheet for each subsector in the table above), enter the fuel consumption data from the OEB (ktoe) for each type of fuel in Column A of the sheets.

Note:

The emissions from manufacturing industries and construction and the commercial/institutional subsectors are both further subdivided in the UNFCCC Software into “autogeneration[7]” and “process heat”-related emissions. However, the data from the OEB is not subdivided into these categories. An assumption was made for the 2000 GHG inventory that all of the fuel was used for “process heat” because of the lack of disaggregated data and that most of the fuel consumption in these subsectors are used for process heat.

For the energy industries, input the figures from the “Fuel Input” row of the OEB. Change the sign (from – to +) as you input them into the program.

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[7] Autogeneration refers to the generation of electricity or heat that is sold as a secondary activity, i.e., not the main business of the enterprise

In Column B, use 41.87 as the factor for converting ktoe to TJ. The apparent consumption shall automatically be calculated in Column C.

Step 2: Estimating the Carbon Content of the Fuel

Input the carbon emission factor for each type of fuel in Column D of the subsector sheets. The carbon content of the fuels shall automatically be calculated in Column E and F (tonnes of C and ktonnes of C, respectively). Please refer to Table 1 for the carbon emission factors of the relevant fuels.

Step 3: Estimating Net Carbon Emissions

The estimation of the net carbon emissions would require the estimation of the carbon stored in the fuels. The Sectoral Approach categorizes fuels into four groups in the estimation of the fraction of carbon stored:

- Fuel used as feedstock
- Lubricants
- Bitumen and Coal Tars
- Fuels for which no carbon is stored.

The calculation of stored carbon from fuels used as feedstock only applies to the industry subsector.[8] For the 2000 inventory (Sectoral Approach), all the "Others, Non-energy Use" of fuels were assumed to be under the industry subsector since there is no disaggregated data for each subsector and a logical assumption that the industry subsector is the main consumer of fossil fuels for non-energy use is taken.

To be able to fill Column H of 1-2s3-4B (Carbon Stored), go to Sheet 1-2a and fill in the relevant information for calculating the carbon stored in products.

Copy the figures from Column H of Sheet 1-2a to the proper cells in Column H of Sheet 1-2s3-4B and leave Column G blank. The net carbon emissions will be given in Column I of Sheet 1-2s3-4B.

Step 4: Estimating Actual CO_2 Emissions

4.1. For each of the subsector sheets, input the fraction of carbon oxidized (see Table 2) for the relevant fuels in Column J. Columns K and L will then be automatically calculated emissions in Gg C and Gg CO_2 respectively.

Non- CO2 Emissions from Fuel Combustion by Source Categories

GHGs aside from CO_2 are also emitted during fuel combustion. When coal, gasoline, diesel, wood/woodwaste, charcoal, and other biomass fuels are burned, the following non- CO_2 gases are emitted: Methane (CH_4), Nitrous oxide (N_2O), Nitrogen oxides (NO_x), Carbon monoxide (CO), and Non-methane volatile organic compounds (NMVOC).

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[8] See Section 1.11 of IPCC (1997), Workbook.

Methane (CH_4)

Methane emissions come from the incomplete combustion of hydrocarbons in fuels. For mobile sources, the amount of CH_4 emitted is also a function of the methane content of the fuel, the amount of hydrocarbons unburnt in the engine, the engine type, and any post-combustion controls [IPCC, 1997]. CH_4 emissions from fuel combustion are relatively small on a global scale and the uncertainty is high.

Nitrogen Oxides (NO_x)

Most of the emissions of NOx from fuel combustion activities are from mobile sources. Even if it is not a GHG, NOx plays a role in the formation of tropospheric ozone, O3, as well as in the formation of acid rain.

Carbon Monoxide (CO)

In general, the release of CO from the Energy sector comes from the incomplete combustion of fuel in motor vehicles.

Non-methane Volatile Organic Compounds (NMVOCs)

Transportation and residential combustion of biomass fuels are the more important sources of NMVOCs.

Data is obtainable from the DOE. If data for the inventory year is not available, but data for other years are, interpolation or extrapolation can be done.

The estimation of the non- CO_2 emissions is done by multiplying the fuel consumption data (TJ) by the respective emission factors for each fuel (kg/TJ). The UNFCCC Software only requires the encoding of the emission factors for each of the mentioned GHGs (Fill up the relevant cells in Columns B1 to B6 of the sheets indicated below). It does the calculation automatically. See Table 4 for the specific sheets for the estimation of the non- CO_2 GHG emissions.

TABLE 4. NON-CO_2 CALCULATION SHEETS

SHEET NUMBER	GHGS
1-3s2-3CH_4	Methane
1-3s2- N_2O	Nitrous oxide
1-3s2-NO_x	Nitrogen oxide
1-3s2-CO	Carbon monoxide
1-3s2-NMVOC	Non-methane volatile organic compounds

Emission factors for different non- CO_2 GHGs are given by Tables 5 to 9. NMVOC Emission Factors (kg/TJ). They are taken from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual.

TABLE 5. CH_4 EMISSION FACTORS (KG/TJ)

ACTIVITY			COAL	NATURAL GAS	OIL		WOOD/ WOOD WASTE	CHARCOAL	OTHER BIOMASS & WASTES
Energy Industries			1	1	3		30	200	30
Manufacturing Industries & Construction			10	5	2		30	200	30
Transport	Domestic Aviation					0.5			
	Road				Gasoline	Diesel			
				50	20	5			
	Railways		10		5				
	National Navigation		10		5				
Other Sectors	Commercial/Institutional		10	5	10		300	200	300
	Residential		300	5	10		300	200	300
	Agriculture/Forestry/Fishing	Stationary	300	5	10		300	200	300
		Mobile		5	5				

Source: IPCC (1997)

TABLE 6. N_2O EMISSION FACTORS (KG/TJ)

ACTIVITY			COAL	NATURAL GAS	OIL		WOOD/ WOOD WASTE	CHARCOAL	OTHER BIOMASS & WASTES
Energy Industries			1.4	0.1	0.6		4	4	4
Manufacturing Industries & Construction			1.4	0.1	0.6		4	4	4
Transport	Domestic Aviation					2			
	Road				Gasoline	Diesel			
				0.1	0.6	0.6			
	Railways		1.4		0.6				
	National Navigation		1.4		0.6				
Other Sectors	Commercial/Institutional		1.4	0.1	0.6		4	1	4
	Residential		1.4	0.1	0.6		4	1	4
	Agriculture/Forestry/Fishing	Stationary	1.4	0.1	0.6		4	1	4
		Mobile		0.1	0.6				

Source: IPCC (1997)

TABLE 7. NO_X EMISSION FACTORS (KG/TJ)

ACTIVITY			COAL	NATURAL GAS	OIL		WOOD/ WOOD WASTE	CHARCOAL	OTHER BIOMASS & WASTES
Energy Industries			300	150	200		100	100	100
Manufacturing Industries & Construction			300	150	200		100	100	100
Transport	Domestic Aviation				300				
	Road				Gasoline	Diesel			
				600	600	800			
	Railways		300		1200				
	National Navigation		300		1500				
Other Sectors	Commercial/Institutional		100	50	100		100	100	100
	Residential		100	50	100		100	100	100
	Agriculture/Forestry/Fishing	Stationary	100	50	100		100	100	100
		Mobile		1000	1200				

Source: IPCC (1997)

TABLE 8. CO EMISSION FACTORS (KG/TJ)

ACTIVITY			COAL	NATURAL GAS	OIL		WOOD/ WOOD WASTE	CHARCOAL	OTHER BIOMASS & WASTES
Energy Industries			20	20	15		1000	1000	1000
Manufacturing Industries & Construction			150	30	10		2000	4000	4000
Transport	Domestic Aviation				100				
	Road				Gasoline	Diesel			
				400	8000	1000			
	Railways		150		1000				
	National Navigation		150		1000				
Other Sectors	Commercial/Institutional		2000	50	20		5000	7000	5000
	Residential		2000	50	20		5000	7000	5000
	Agriculture/Forestry/Fishing	Stationary	2000	50	20		5000	7000	5000
		Mobile		400	1000				

Source: IPCC (1997)

TABLE 9. NMVOC EMISSION FACTORS (KG/TJ)

ACTIVITY			COAL	NATURAL GAS	OIL		WOOD/ WOOD WASTE	CHARCOAL	OTHER BIOMASS & WASTES
Energy Industries			5	5	5		50	100	50
Manufacturing Industries & Construction			20	5	5		50	100	50
Transport	Domestic Aviation				50				
	Road				Gasoline	Diesel			
				5	1500	200			
	Railways		20		200				
	National Navigation		20		200				
Other Sectors	Commercial/Institutional		200	5	5		600	100	600
	Residential		200	5	5		600	100	600
	Agriculture/Forestry/Fishing	Stationary	200	5	5		600	100	600
		Mobile		5	200				

Source: IPCC (1997)

SO_2 EMISSIONS FROM FUEL COMBUSTION BY SOURCE CATEGORIES

Sulfur dioxide (SO_2) is not a GHG, but it has its own effect on the atmosphere as an aerosol precursor. SO_2 emissions from fuel combustion in the different subsectors are computed in this section.

Data on fuel consumption for the specific fuel types containing sulfur are found in the OEB sheet. Information on the sulfur content (in percent) of some fuel types is also obtained from the DOE.

The UNFCCC Software segregates the calculation of SO_2 emissions by subsectors. Refer to Table 10 for the listing of the different sheets for the different subsectors.

TABLE 10. SO_2 CALCULATION SHEETS FOR THE DIFFERENT ENERGY SUBSECTORS

SHEET NUMBER	SUBSECTOR
1-4s1	SO_2 Emissions from Energy Industries
1-4s2	SO_2 Emissions from Manufacturing Industries and Construction
1-4s3	SO_2 Emissions from Transport
1-4s4	SO_2 Emissions from Commercial/Institutional/Residential/Agriculture/Forestry/ Fishing
1-4s5	SO_2 Emissions from Other Subsectors (Not specified elsewhere)

Step 1. Estimating the Fuel Consumption

Go to Sheet 1-3s1 and copy the fuel consumption figures into the appropriate subsector sheets (as given in Table 10) under the appropriate fuel types and paste these into the appropriate cells in Column A of sheets 1-4s1 to 1-4s5 according to subsector.

Step 2. Estimating the SO_2 Emission Factor

The general equation for estimating the SO_2 emission factor of the fuels is:

$$SO_2 \text{ EMISSION FACTOR} = 2 * (B/100) * (1/E) * (1*10^6) * [(100-C)/100 - (100-D)/100]$$

Where

E = Emission Factor (kg/TJ)
2 = molecular weight ratio of SO_2 to S
B = sulfur content in fuel (%)
C = retention of sulfur in ash (%)
E = net calorific value (TJ/kt)
10^6 = (unit) conversion factor; and
D = efficiency of abatement technology and/or reduction efficiency (%).

The UNFCCC Software allows for the automatic calculation of the SO_2 emission factors of the different fuels. Just fill in the necessary data for the parameters stated in the equation above.

In Column B of the subsector input sheets for sulfur dioxide emissions calculations (1-4s1 to 1-4s5), enter the fuel sulfur content in percentage (%) form using data below,

TABLE 11. FUEL'S SULFUR CONTENT

FUEL TYPE	SULFUR CONTENT IN FUEL, %
Coal	3*
Fuel Oil	3
Diesel (Road)	0.8*
Gasoline (Road)	0.1*
Jet Kerosene	0.05
Fuel wood	0.2
Bagasse	0.02
Agriwaste	0.02
Animal Waste	0.02

Source: *DOE, IPCC (1997)

The values for sulfur retention in ash (in %), as shown in Error! Reference source not found., are already entered in Column C.

TABLE 12. SULFUR RETENTION IN ASH

FUEL TYPE	SULFUR RETENTION IN ASH, %
Hard Coal	5
Brown Coal	30

Source: IPCC (1997)

If applicable, input the abatement efficiency (in %) of the in Column D (Local information is not available for the year 2000).

In Column E, enter the net calorific value (in TJ/kt). TABLE 13 lists the net calorific value of selected fuels. The calorific value of a fuel is a measure of its value for heating purposes.

TABLE 13. SELECTED NET CALORIFIC VALUES

FUEL TYPE	NET CALORIFIC VALUES (TJ/KTON)
Gasoline	44.80
Jet Kerosene	44.59
Other Kerosene	44.75
Gas/Diesel Oil	43.33
Residual Fuel Oil	40.19
LPG	47.31
Naphtha	45.01
Bitumen	40.19
Lubricant	40.19
Other Oil Products	40.19

Source: IPCC (1997)

Step 3: Estimating the SO_2 Emissions for each Subsector

The SO_2 emissions for each subsector shall automatically be computed by the UNFCCC Software. Column G of the relevant SO_2 subsector sheets will give the figures for the SO_2 emissions.

FUGITIVE EMISSIONS

The process of fuel extraction, transport, storage, and refinery also cause the release of GHGs, specifically CH_4, and non-CO_2 gases into the atmosphere. This section takes into account these fugitive emissions specifically from three activities: coal mining/handling, oil/gas activities, and oil refining. Fugitive emissions are either intentional (e.g. venting and flaring) or unintentional (e.g. leaks) releases of gases from industrial activities. In particular, they may come from the production, processing, transmission, storage and use of fuels including emissions from combustion which do not support productive activity (e.g. flaring of natural gases at oil and gas production facilities).

The UNFCCC Software has separate sheets for the computation of the fugitive emissions (TABLE 14) from different activities concerning fossil fuels:

TABLE 14. FUGITIVE EMISSIONS

SHEET NUMBER	SUBSECTOR
1-6s1	Methane Emissions from Coal Mining and Handling
1-7s1 and 1-7s2	Methane Emissions from Oil and Gas Activities
1-8s1	Ozone Precursors and SO_2 from Oil Refining
1-8s2	Ozone Precursors and SO_2 from Catalytic Cracking
1-8s3	SO_2 from Sulfur Recovery Plants
1-8s4	NMVOC Emissions from Storage and Handling

Step 1: Estimating the Methane Emissions from Coal Mining and Handling

Methane is inherently generated when coal is formed over millions of years. The extent of this coal formation determines how much CH_4 is generated. Once generated, the amount of CH_4 in coal is controlled by the pressure and temperature of the coal seam. When coal is extracted or mined, the layers above the coal seam are removed, thus reducing the pressure and causing the release of CH_4 into the atmosphere.

The three main sources of CH_4 in these subsectors are underground mines, surface mines, and post-mining activities. It is important to distinguish underground mines from surface mines because depth affects the quantity of CH_4 stored in coal. Coal at greater depths will have higher concentrations of CH_4 since the pressure is greater. Hence, the emission factors are lower for surface mines and CH_4 emissions are generally also lower.

Coal processing, transport, and use are post-mining activities that also release CH_4. Desorption (or release) of CH_4 from the coal may occur while in transit or when the coal is crushed, broken and left to dry.

The actual process of mining coal and post-mining activities cause CH_4 emissions. These emissions would also depend of the type of mining process, whether underground or surface mining.

The emissions in all these processes are computed using the equation:

$$\text{EMISSIONS (GG } CH_4\text{) = EMISSION FACTOR (M}^3\text{ } CH_4\text{/TON)} \times \text{COAL PRODUCED (TONNES)} \times \text{CONVERSION FACTOR (GG/}10^6\text{ M}^3\text{)}$$

where the conversion factor converts the volume of CH_4 to a weight measure and is simply the density of methane at 20°C and 1 atm, 0.67 Gg/$10^6 m^3$.

Go to Sheet 1-6s1. Enter the amount of coal produced by each type of mining activity, in millions of tones in Column A. Data on the amount of coal produced for each type of mining is obtainable from the Coal and Mining Division of the DOE.

Input the CH_4 emission factor for the relevant mining activities.

TABLE 15. CH_4 EMISSION FACTORS FOR MINING ACTIVITIES

	UNDERGROUND	SURFACE
Mining	17.5	1.15
Post-mining	2.45	0.1

Source: IPCC (1997)

The average of the high and low emission factors from Table 1-5 High and Low Emission Factors for Mining Activities of the 1996 IPCC Guidelines for National GHG Inventories Workbook was used in the 1994 and 2000 Philippine National GHGI.

If data on the amount of methane that is flared or recovered is available, input these into Column D. The methane emissions from coal mining and handling shall be given in Column G.

Step 2: Estimating the Methane Emissions from Oil and Natural Gas Activities

Oil production, transport, and refinery and gas production/processing and transmission/ distribution are sources of CH_4 emissions.

The UNFCCC Software provides two options in computing for the CH_4 emissions from oil and natural gas activities (see Sheets 1-7s1 and 1-7s2). For the 2000 Philippine GHG Inventory, Sheet 1-7s1 was used because the data required for that sheet is available. The data for the natural gas activities is available from the Natural Gas Management Division of DOE while the data for the oil activities (production and transport) is available from the Petroleum Resource Development Division.

Go to Sheet 1-7s1. Fill out the necessary activity data in Column A. Information on the amount of oil produced, refined and transported are available from the Oil and Gas Division of the DOE. The data on natural gas can be obtained from the Natural Gas Management Division.

Enter the CH_4 emission factors available from TABLE 16 for the relevant oil and gas activities in Column B. The CH_4 emissions shall be computed for by the Software in Columns C and D (in kg and Gg, respectively).

TABLE 16. SELECTED CH_4 EMISSION FACTORS FOR OIL AND GAS ACTIVITIES

TYPE OF FUEL	ACTIVITY	CH_4 EMISSION FACTOR
Oil	Exploration a	~
	Production b	2650 kg CH4/PJ
	Transport	745 kg CH4/PJ
	Refining b	745 kg CH4/PJ
	Storage b	135 kg CH4/PJ
Natural Gas	Production/ Processing	~
	Transmission/Distribution	~
	Other Leakage	~

Source: IPCC (1997)

Average of the low and high emission factors for the category "Rest of the World" as given in Table 1-6 Revised Regional Emission Factors for Methane from Oil and Gas Activities Systems in the Revised 1996 IPCC Guidelines Workbook

Step 3: Estimating Ozone Precursors and SO_2 from Oil Refining

The process of converting crude oil into its derivatives in oil refineries causes the releases of CO, NO_x, NMVOC, and SO_2 gases. Storage and handling of oil products also emit NMVOC.

Go to Sheet 1-8s1. Enter the crude oil throughput (in kt) in Column A. Default emission factors are already inputted in Column C. The CO, NO_x, NMVOC and SO_2 emissions shall automatically be calculated. Columns D and E will give the emissions in tonnes and Gg respectively.

Go to Sheet 1-8s2. Enter the catalytic cracker throughput (in kt) in Column A. Default emission factors are already inputted in Column C. The CO, NO_x, NMVOC and SO_2 emissions shall automatically be calculated. Columns D and E will give the emissions in tonnes and Gg respectively.

Go to Sheet 1-8s3. If data is available, enter the quantity of sulfur recovered from sulfur recovery plants in Column A (in tonnes). A default emission factor is already inputted in Column B. The fugitive SO_2 emissions will be given in Column C and D (in tonnes and Gg, respectively).

Go to Sheet 1-8s4. If data is available, enter the quantity of crude oil throughput stored in secondary seals, primary seals and fixed roofs. Default emission factors are already inputted in Column B. The fugitive NMVOC emissions will be given in Column C and D (in tonnes and Gg, respectively).

MEMO ITEMS

CO_2 emissions from the combustion of biomass fuels are covered as memo items. Memo items are not included in the total GHGs in the national inventory but are reported separately. The computed CO_2 emissions, however, are not included in the inventory total since it is assumed that GHGs released from the consumed biomass is absorbed in biomass regrowth and hence, is taken up in the next growing cycle. Irretrievable CO_2 emissions from biomass sources are accounted for in the Land Use Change/Forestry Sector.

However, non-CO_2 emissions from biomass fuels such as wood/woodwaste, charcoal, and other biomass/wastes, are included in the inventory.

CO_2 FROM INTERNATIONAL BUNKERS

GHG emissions from fuel combustion in international marine and aviation are computed separately. As recommended by the IPCC, these emissions are not to be included in the inventory total.

The UNFCCC Software places the memo items at the bottom of the relevant calculation sheets. The emissions are computed automatically. Just fill in the necessary information as done with the other fuels.

SUMMARY OF EMISSIONS

The different module files are automatically linked to the overview sheet. After you have inputted all your data to the module file, save the file. Don't use another filename or the overview sheet will not automatically update. To check the summary of your emissions, go to the Overview.xls file. Save the changes as well. The summary of the CO_2 emissions of the energy sector as per the two approaches – Top-down and bottom-up - in emissions calculations are given below:

TABLE 17. SUMMARY OF 1994 AND 2000 CO_2 EMISSIONS

GIGAGRAMS			
Approach	**1994**	**2000**	**% change**
Top-Down	50,010.00	65,441.51	31%
Bottom-up	47,335.36	62,499.10	32%

TABLE 18. SUMMARY OF EMISSIONS FOR THE ENERGY SECTOR (2000)

TOP-DOWN APPROACH (GG)

FUEL	CO_2 EMISSIONS
Crude Oil	46,694.72
Sub-bit.Coal	16,716.93
Gas/Diesel Oil	2,591.59
LPG	1,798.13
Gasoline	1,483.80
Jet Kerosene	443.18
Other Kerosene	111.61
Natural Gas(Dry)	20.46
Other Oil	(376.64)
Bitumen	(235.10)
Naphtha	(1,964.08)
Residual Fuel Oil	(1,843.08)
TOTAL	65,441.51

TABLE 19. BOTTOM-UP APPROACH (GIGAGRAMS)

SOURCE	CO_2	CH_4	CO_2 EQUIVALENT	N_2O	CO_2 EQUIVALENT	TOTAL GHG EMISSIONS	%	NO_X	CO	NMVOC	SO_2
Energy Industries	21,127.35	0.40	8.45	0.27	83.88	21,219.68	30%	63.79	4.39	1.20	321.57
Residential	3,926.56	123.53	2,594.04	1.64	508.38	7,028.98	10%	47.65	2,126.93	239.86	-
Manufacturing Industries	9,015.30	1.91	40.03	0.28	87.97	9,143.30	13%	30.23	186.43	3.41	0.97
Agriculture	883.05	0.06	1.26	0.01	2.23	886.54	1%	14.41	12.01	2.40	27.26
Transport	25,792.03	3.45	72.52	0.23	72.82	25,937.37	37%	296.75	1,151.15	219.15	
Commercial	1,754.81	6.71	140.88	0.09	28.51	1,924.20	3%	4.81	128.05	11.42	
Fugitive Emissions	-	168.09	3,529.96	-	-	3,529.96	5%	0.90	1.35	82.55	13.91
TOTAL	62,499.10	304.15	6,387.14	2.53	783.79	69,670.03	100%	458.54	3,610.30	559.99	363.70

TABLE 20. OTHER ENERGY ACTIVITY DATA (2000)

OIL	
Oil Produced	2.34 PJ
Oil Refined	2.18 PJ
GAS	
Natural Gas Consumed	0.41 PJ
AMOUNT OF COAL PRODUCED IN 2000	
Coal Production – Underground	0.046 million tonnes
Coal Production- Surface	1.175 million tonnes

GETTING STARTED WITH THE UNFCCC GHG INVENTORY SOFTWARE

Download the UNFCCC National GHG Inventory Software

To download the inventory software, follow this link:

http://unfccc.int/resource/cd_roms/na1/ghg_inventories/unfccc_software/software/UNFCCC_NAI_IS_132.zip

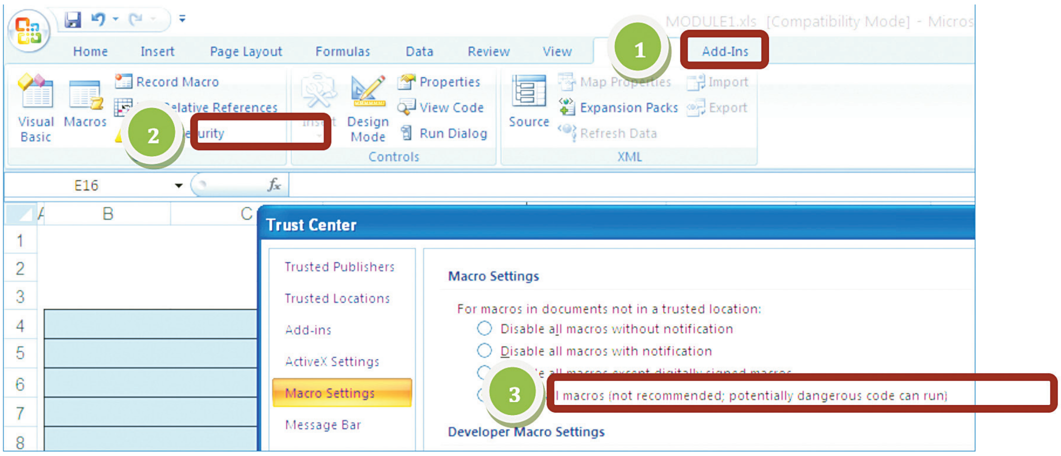
Unzip the files into a common folder

Make sure that all the extracted files are in a common folder.

Enable all macros

Set your Microsoft Excel's macro security off since the UNFCCC Software runs on different macros. For Microsoft Excel 2007 go to :

1) Developer tab > 2) Macro security > 3)Macro Settings to enable all macros.



Macro Settings

For macros in documents not in a trusted location:

○ Disable all macros without notification

○ Disable all macros with notification

○

○ l macros (not recommended; potentially dangerous code can run)

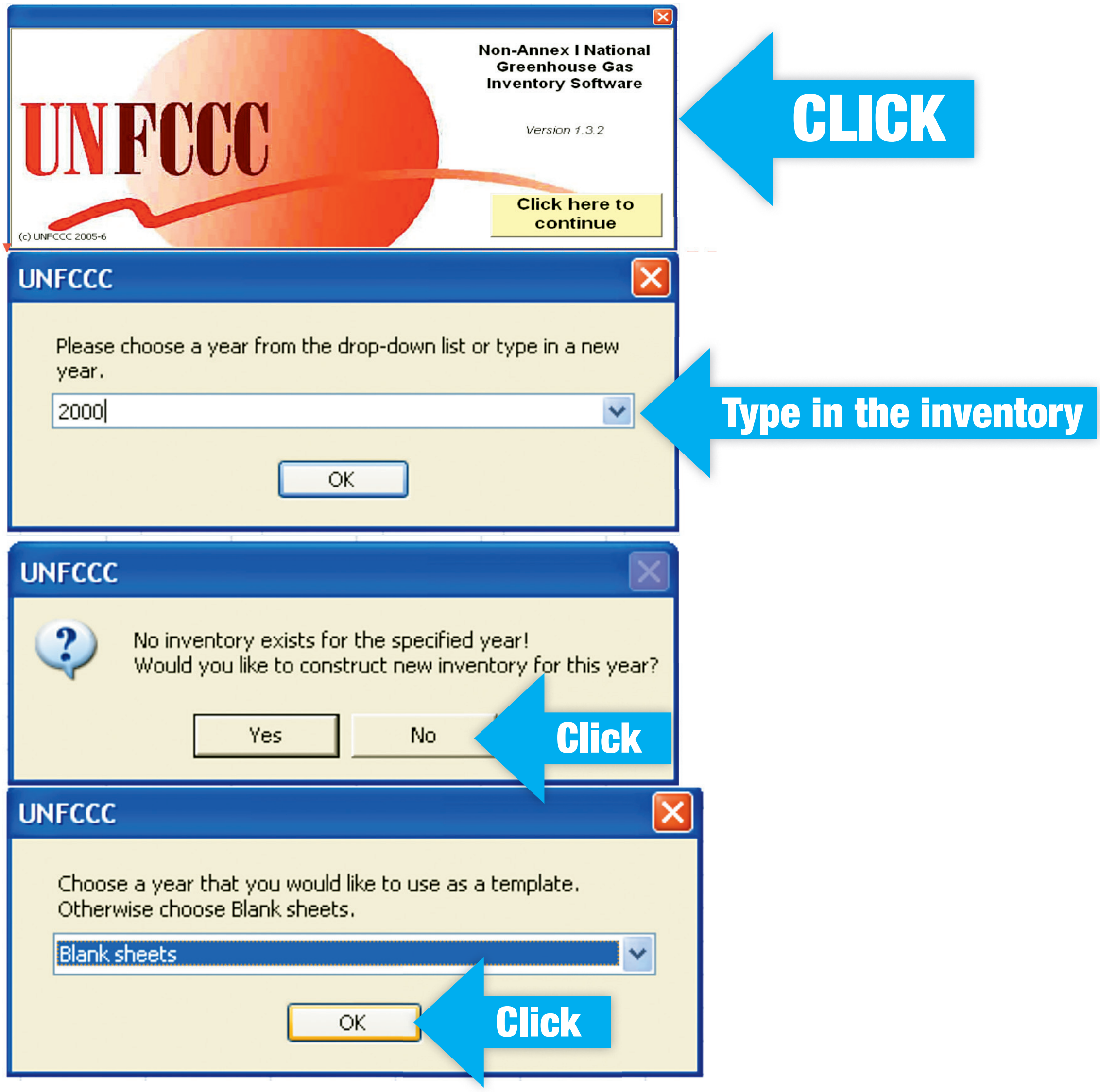
Developer Macro Settings

Note:

If the developer tab is not enabled, go to the Office excel button at the upper left portion of the window and click "Excel Options". A screen will pop-up and under the "Top options for working with Excel," check "Developer tab in the Ribbon".

Open the Start.xls file

Do the following when the pop-up boxes appear:



Non-Annex I National Greenhouse Gas Inventory Software

Version 1.3.2

CLICK

Please choose a year from the drop-down list or type in a new year.

2000

Type in the inventory

No inventory exists for the specified year!
Would you like to construct new inventory for this year?

Click

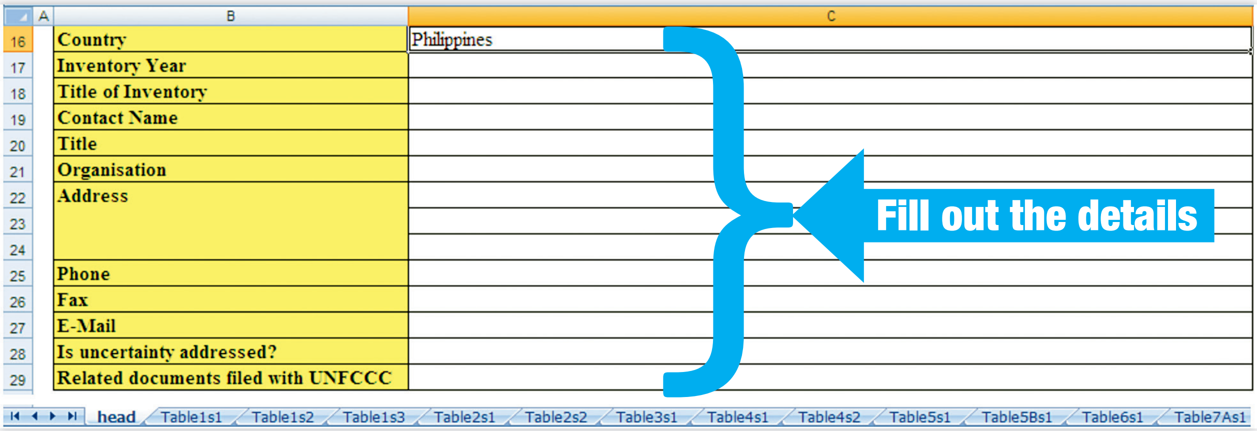
Choose a year that you would like to use as a template.
Otherwise choose Blank sheets.

Blank sheets

Click

At this point, the Excel file“Overview.xls” shall automatically open.

Fill out the details in the “Overview.xls” File



16	Country	Philippines
17	Inventory Year	
18	Title of Inventory	
19	Contact Name	
20	Title	
21	Organisation	
22	Address	
23		
24		
25	Phone	
26	Fax	
27	E-Mail	
28	Is uncertainty addressed?	
29	Related documents filed with UNFCCC	

Fill out the details

You can now open the module files (e.g. Module 1.xls = Energy Module). The Overview.xls sheet is linked with the Module sheets, which means that the overview sheet would provide the summary figures in accordance with the figures in the Module sheets. Also, remember that the module files will not open unless the overview sheet is open.

CALCULATING GREENHOUSE GAS EMISSIONS FROM THE ENERGY SECTOR

CO2 EMISSIONS FROM FUEL COMBUSTON

REFERENCE OR TOP-DOWN APPROACH

Step 1: Calculate the Apparent Fuel Consumption

Worksheet Number 1-1s1-3

1. For each fuel type, enter the data (in kilotonnes oil equivalent or ktoe) on fuel production, import, export, transport through international bunkers and stock change into columns[9] A,B,C,D and E, respectively.

   Note: Change the signs (+/-) of the export, bunkering and stock change figures in the OEB as you enter them into the UNFCCC software.

2. The apparent fuel consumption (in ktoe) will automatically be calculated in column F. Make sure that the figures here match the figures in the "Primary Energy Supply" row of the OEB sheet. The OBE's "primary energy supply" is essentially the "apparent consumption" in the UNFCCC Software.

3. Enter the conversion factor (41.87 TJ/ktoe), in Column G. Column H will give the converted apparent fuel consumption figures in TJ.

Step 2: Estimate the carbon content of the fuel

1. Input the Carbon emission factors (tC/TJ) for each fuel type in Column I. The carbon content is automatically computed by the sheet in Columns J and K, giving values for tonnes and kilotonnes (or Gigagrams) of carbon, respectively.

---

[9] This document refers to columns as labeled by the UNFCCC software and not the default Microsoft Excel labels.

Step 3: Estimate Net Carbon Emissions

Worksheet Number 1-1s1-3, Worksheet Number 1-1a

1. To be able to fill Column L of Sheet 1-1s1-3, go to Sheet 1-1a and fill in 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.[10] The data for Column A of Sheet 1-1a (Estimated fuel quantities) shall be taken from the "Others, Non-energy Use" row of the OEB Sheet. Again, use 41.87 as the conversion factor (Column B).

2. Also, fill in Column D of Sheet 1-1a with the carbon emission factors for the relevant fuels. Copy the carbon stored (ktonnes C) figures in Column H of Sheet 1-1a into the appropriate cells in Column L of Sheet 1-1s1-3.

Step 4: Estimate Annual CO_2 Emissions

Worksheet Number 1-1s1-3 Worksheet Number 1-1s4-5

1. Go back to Sheet 1.1s1-3 and input the fraction of carbon oxidized when burning the fuels[11]. The figures for the actual carbon emissions and the actual CO_2 emissions shall be calculated automatically in Columns O and P, respectively.

2. In Sheet 1-1s4-5, the calculations are done automatically by the software for the emissions from international bunkers (fuel used in international marine and aviation transportation). These figures are excluded in the calculation of the apparent fuel consumption.

SECTORAL OR BOTTOM-UP APPROACH

Step 1: Calculate the Apparent Fuel Consumption for each Fuel Type

Worksheet Numbers 1-2s1-2, 1-2s3-4A, 1-2s3-4B, 1-2s5-6, 1-2s9-10A, 1-2s9-10B, 1-2s11-12, and 1-2s13-14

1. For each subsector (see relevant sheet for each subsector), enter the fuel consumption data from the OEB (ktoe) for each type of fuel in Column A of the sheets.

   The emissions from manufacturing industries and construction and the commercial/institutional subsectors are both further subdivided in the UNFCCC Software into "autogeneration[12]" and "process heat"-related emissions. However, the data from the OEB is not subdivided into these categories. Hence, assume that all of the fuel was used for "process heat".

---

[10] Some fuel types such as asphalt and coal are also used in non-energy activities. Road paving for example uses asphalt extensively. In this case, the carbon content of asphalt is not oxidized or combusted and is said to be stored. The release of this carbon into the atmosphere occurs gradually and is no longer covered in the fuel combustion process of energy activities. This amount of carbon must be deducted from the calculated emissions.

[11] A small part of the fuel carbon entering combustion escapes oxidation but the majority of this carbon is later oxidized in the atmosphere. It is assumed that the carbon that remains unoxidised is stored indefinitely.

[12] Autogeneration refers to the generation of electricity or heat that is sold as a secondary activity, i.e., not the main business of the enterprise

For the energy industries, input the figures from the "Fuel Input" row of the OEB. Change the sign (from – to +) as you input them into the program.

2. In Column B, use 41.87 as the factor for converting ktoe to TJ. The apparent consumption shall automatically be calculated in Column C.

Step 2: Estimate the Carbon Content of the Fuel

Worksheet Numbers 1-2s1-2, 1-2s3-4A, 1-2s3-4B1-2s5-6, 1-2s9-10A, 1-2s9-10B, 1-2s11-12, 1-2s13-14

1. Input the carbon emission factor for each type of fuel in Column D of the subsector sheets. The carbon content of the fuels shall automatically be calculated in Column E and F (tonnes of C and ktonnes of C, respectively).

Step 3: Estimate Net Carbon Emissions

Worksheet Numbers 1-2s3-4B, 1-2a, and 1-2s3-4B

This step only applies to industry subsectors. The estimation of the net carbon emissions would require the estimation of the carbon stored in the fuels. The Sectoral Approach categorizes fuels into four groups in the estimation of the fraction of carbon stored:

- Fuel used as feedstock
- Lubricants
- Bitumen and Coal Tars
- Fuels for which no carbon is stored.

1. To be able to fill Column H of 1-2s3-4B (Carbon Stored), go to Sheet 1-2a and fill in the relevant information for calculating the carbon stored in products.
2. Copy the figures from Column H of Sheet 1-2a to the proper cells in Column H of Sheet 1-2s3-4B and leave Column G blank. The net carbon emissions will be given in Column I of Sheet 1-2s3-4B.

Step 4: Estimate Actual CO_2 Emissions

1. For each of the subsector sheets, input the fraction of carbon oxidized for the relevant fuels in Column J. Columns K and L will then be automatically calculated emissions in Gg C and Gg CO_2, respectively.

NON-CO_2 EMISSIONS FROM FUEL COMBUSTION BY SOURCE CATEGORIES

GHGs aside from CO_2 are also emitted during fuel combustion. When coal, gasoline, diesel, wood/woodwaste, charcoal, and other biomass fuels are burned, the following non- CO_2 gases are emitted: Methane (CH_4), Nitrous oxide (N_2O), Nitrogen oxides (NO_x), Carbon monoxide (CO), and Non-methane volatile organic compounds (NMVOC).

Data is obtainable from the DOE. If data for the inventory year is not available, but data for other years are, interpolation or extrapolation is suggested.

Step 1: Estimate Non- CO_2 Emissions

Worksheet Numbers 1-3s2-3-CH_4, 1-3s2- N_2O, 1-3s2- NO_x, 1-3s2-CO, and 1-3s2-NMVOC

1. The estimation of the non- CO_2 emissions is done by multiplying the fuel consumption data (TJ) by the respective emission factors for each fuel (kg/TJ). To do this, fill up the relevant cells in Columns B1 to B6 of the sheets corresponding to emission sources. Emissions are calculated automatically.

SO_2 EMISSIONS FROM FUEL COMBUSTION BY SOURCE CATEGORIES

Step 1. Estimate the Fuel Consumption

Worksheet Numbers 1-3s1, 1-4s1 to 1-4s5

1. Go to Sheet 1-3s1 and copy the fuel consumption figures into the appropriate subsector sheets under the appropriate fuel types and paste these into the appropriate cells in Column A of sheets 1-4s1 to 1-4s5 according to subsector.

Step 2. EstimatE the SO_2 Emission Factor

Worksheet Numbers 1-4s1 to 1-4s5

1. In Column B of the subsector input sheets for sulfur dioxide emissions calculations, enter the fuel sulfur content (in %).
2. Check the values for sulfur retention in ash (in %). These are already entered in Column C.
3. If applicable, input the abatement efficiency (in %) in Column D.
4. In Column E, enter the net calorific value (in TJ/kt).

Step 3: Estimating the SO_2 Emissions for each Subsector

1. The SO_2 emissions for each subsector shall automatically be computed for by the UNFCCC Software. Column G of the relevant SO_2 subsector sheets will give the figures for the SO_2 emissions.

Step 1: Estimating the Methane Emissions from Coal Mining and Handling

Worksheet Number 1-6s1

1. Go to Sheet 1-6s1. Enter the amount of coal produced by each type of mining activity, in millions of tonnes in Column A. Data on the amount of coal produced for each type of mining is obtainable from the Coal and Mining Division of the DOE.
2. Input the CH_4 emission factor for the relevant mining activities.
3. If data on the amount of methane that is flared or recovered is available, input these into Column D. The methane emissions from coal mining and handling shall be given in Column G.

Step 2: Estimate the Methane Emissions from Oil and Natural Gas Activities

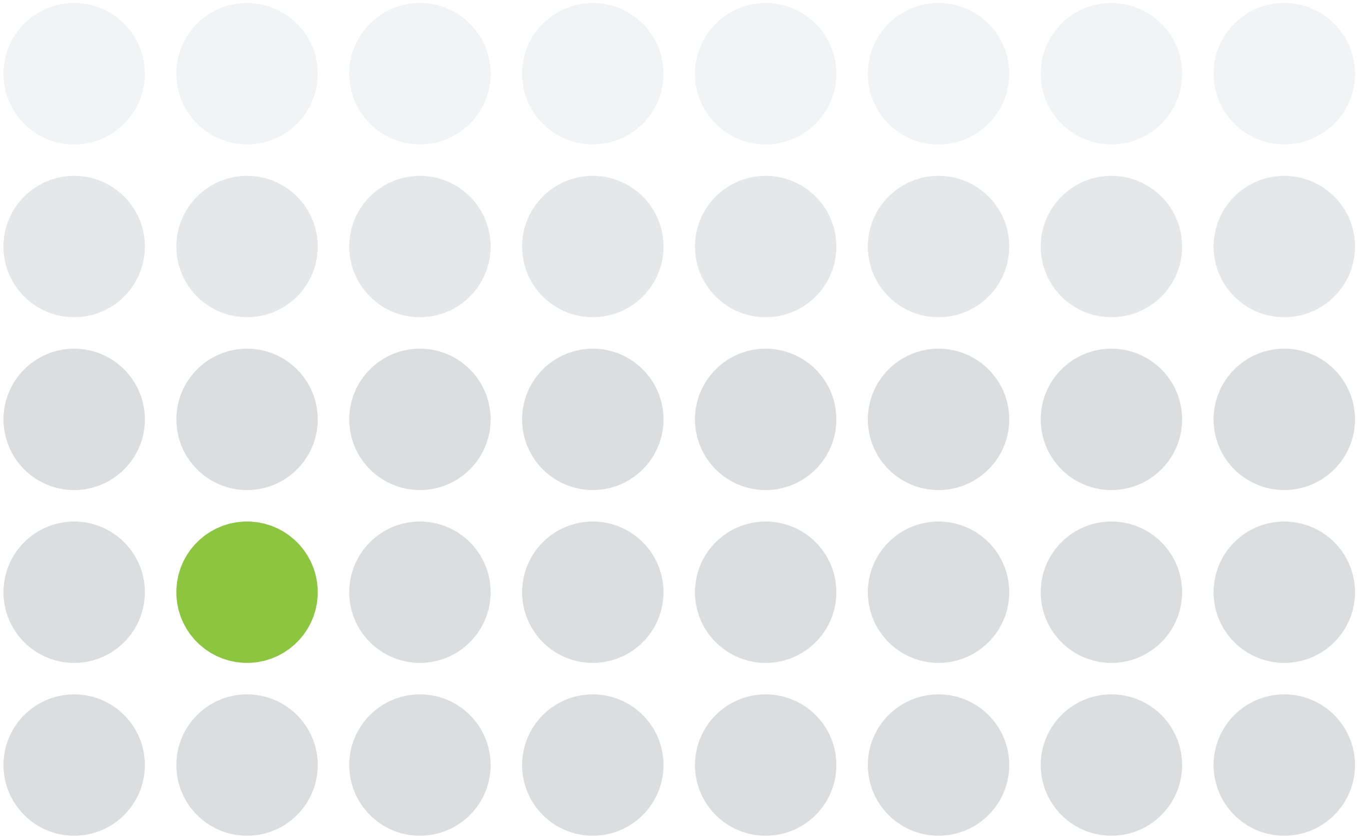
Worksheet Number 1-7s1

1. Go to Sheet 1-7s1. Fill out the necessary activity data in Column A. Information on the amount of oil produced, refined and transported are available from the Oil and Gas Division of the DOE. The data on natural gas can be obtained from the Natural Gas Management Division.
2. Enter the CH_4 emission factors for the relevant oil and gas activities in Column B. The CH_4 emissions shall be computed for by the Software in Columns C and D (in kg and Gg, respectively).

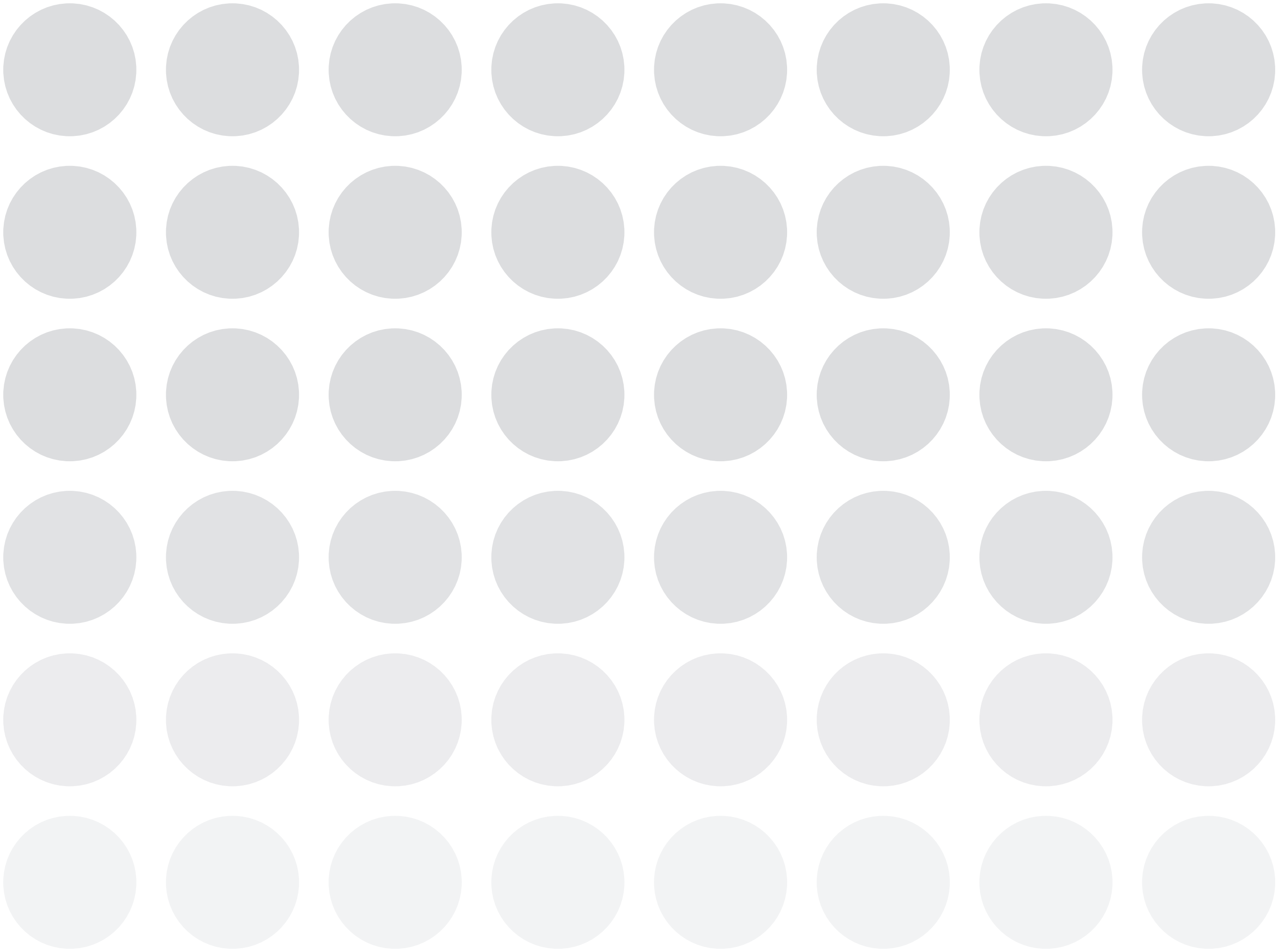
Step 3: Estimate Ozone Precursors and SO_2 from Oil Refining

Worksheet Numbers 1-8s1, 1-8s2, 1-8s3, and 1-8s4

1. Go to Sheet 1-8s1. Enter the crude oil throughput (in kt) in Column A. Default emission factors are already inputted in Column C. The CO, NOx, NMVOC and SO_2 emissions shall automatically be calculated. Columns D and E will give the emissions in tonnes and Gg, respectively.
2. Go to Sheet 1-8s2. Enter the catalytic cracker throughput (in kt) in Column A. Default emission factors are already inputted in Column C. The CO, NOx, NMVOC and SO_2 emissions shall automatically be calculated. Columns D and E will give the emissions in tonnes and Gg respectively.
3. Go to Sheet 1-8s3. If data is available, enter the quantity of sulfur recovered from sulfur recovery plants in Column A (in tonnes). A default emission factor is already inputted in Column B. The fugitive SO_2 emissions will be given in Column C and D (in tonnes and Gg, respectively).
4. Go to Sheet 1-8s4. If data is available, enter the quantity of crude oil throughput stored in secondary seals, primary seals and fixed roofs. Default emission factors are already inputted in Column B. The fugitive NMVOC emissions will be given in Column C and D (in tonnes and Gg, respectively).



Industry Sector



OVERVIEW

Greenhouse gas (GHG) emissions from the industrial sector are mainly coming from industrial production processes that transform raw materials chemically or physically. These include the production of minerals, chemicals, metals, pulp and paper, food and beverages, and the use of halocarbons. GHG emissions from the fuel consumptions of industries are covered in the Energy sector. The Revised 1996 IPCC Guidelines recommends estimation of GHG emissions from industrial processes based on the amount of material produced or consumed.

The IPCC Guidelines include several types of emissions for various industries which vary according to industrial process. These are carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O) including ozone and aerosol precursors such as nitrogen oxides (NO_x), non-methane volatile organic carbons (NMVOCs), carbon monoxide (CO) and sulfur dioxide (SO_2). Halocarbons like hydroflourocarbons (HFCs), perfluorocarbons (PFCs) including sulfur hexafluoride (SF_6) emitted as a result of consumption of the same gases in industrial processes such as refrigeration and air-conditioning, fire extinguishing, aerosols, solvents and foam production as well as production of aluminum, magnesium and halocarbons (e.g. HCFC-22) are also considered as greenhouse gases because of their high global warming potentials (GWPs) and long atmospheric lifetimes. These compounds are used as alternatives to ozone depleting substances being phased out under the Montreal Protocol.

Production data specific to a particular industry are not commonly available from generally published statistics. Normally, several types of industries are grouped into one major category and there are no itemized industry-specific production values.

The major sources of data for the inventory are the National Statistical Coordination Board (NSCB), the National Statistics Office (NSO), and the National Statistical Information Center (NSIC). They collect and maintain economic and industrial statistics for the Philippines. National industrial production and consumption data are usually reported in monetary values, e.g., income. Most of the data are also recorded as indices relative to 1994, and these values serve as baseline for future statistics. Economic values are of little use to this type of inventory which needs raw data on which they were based.

Industrial associations also offer possible sources of information by providing the necessary contacts if specific data are difficult to find. Some examples of industrial associations that may have data available are the Philippine Iron and Steel Institute (PISI), the Cement Manufacturer's Association of the Philippines (CEMAP), Pulp and Paper Manufacturer Association, Inc. (PULPAPEL), and the Samahan sa Pilipinas ng mga Industriyang Kimika (SPIK).

INTRODUCTION

Greenhouse gas (GHG) emissions from the industrial sector are mainly coming from industrial production processes that transform raw materials chemically or physically. The industrial processes include the production of minerals, chemicals, metals, pulp and paper, food and beverages, and the use of halocarbons. GHG emissions from raw material transformation during industrial processes are discussed in this chapter while GHG emissions from fuel consumptions of industries are covered in the Energy sector. The Revised 1996 IPCC Guidelines recommends estimation of GHG emissions from industrial processes based on the amount of material produced or consumed. The recommended general estimation method follows the following equation:

Where:

T_{ij} = the emission of gas *i* formed from industrial process, *j*

A_j = the amount of activity or production of process materialin industry, *j*

EF_{ij} = the emission factor (EF) of gas i per unit of activity in industrial sector, j.

The IPCC Guidelines include several types of emissions for various industries which vary according to industrial process. The most common greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O) including ozone and aerosol precursors such as nitrogen oxides (NO_x), non-methane volatile organic carbons (NMVOCs), carbon monoxide (CO) and sulfur dioxide (SO_2).

Halocarbons like hydroflourocarbons (HFCs), perfluorocarbons (PFCs) including sulfur hexafluoride (SF_6) emitted as a result of consumption of the same gases in various industrial processes are also considered as greenhouse gases because of their high global warming potentials (GWPs) and long atmospheric lifetimes. These compounds are used as alternatives to ozone depleting substances being phased out under the Montreal Protocol.

The approach for estimating GHG emissions from industrial processes used here is dependent on the type of data available. Production data specific to a particular industry are not commonly available from generally published statistics. Normally, several types of industries are grouped into one major category and there are no itemized industry-specific production values.

Most of the activity data used in this sector was acquired from reported national statistics and records of industrial associations. Some data were acquired from individual industry companies.

The National Statistical Coordination Board (NSCB), the National Statistics Office (NSO), and the National Statistical Information Center (NSIC) collect and maintain economic and industrial statistics for the Philippines. National industrial production and consumption data are usually reported in monetary values, e.g., income. Most of the data are also recorded as indices relative to 1994, and these values serve as baseline for future statistics. Economic values are of little use to this type of inventory which needs raw data on which they were based.

Industrial associations also offer possible sources of information by providing the necessary contacts if specific data are difficult to find. Some examples of industrial associations that may have data available are the Philippine Iron and Steel Institute (PISI), the Cement Manufacturer's Association of the Philippines (CEMAP), Pulp and Paper Manufacturer Association, Inc. (PULPAPEL), and the Samahan sa Pilipinas ng mga Industriyang Kimika (SPIK).

Since activity data for Nitric Acid Production, Ammonia Production, Adipic Acid Production, Carbide Production, Aluminimum Production, Other Metal Production and Halocarbon From Products With Halocarbons are not available, GHG emissions from these industrial activities were not computed and where therefore not discussedin this reference manual.

CEMENT

Cement, lime and limestone industries are classified under one major category - the mineral industries. These industries basically use the same type of raw materials. All of these industries use either calcium carbonates ($CaCO_3$) from limestone, chalk, or other calcium-rich materials as raw material and converted into calcium oxide or they directly use quicklime (CaO) or calcium oxide in production processes. These processes emit carbon dioxide (CO_2) as primary GHG but also release sulfur dioxide (SO_2) which is not a GHG but a radiatively important trace gas due to its potential to form sulfate particles that can alter regional climate.

The main chemical process in cement, lime, and limestone industries is:

$$CACO_3 + HEAT \text{ g } CAO + CO_2$$

Or for industries which use $CaCO_3 \cdot MgCO_3$ (dolomite) instead of calcite:

$$CACO_3 \cdot MGCO_3 + HEAT \rightarrow CAO \cdot MGO + 2CO_2$$

The formation of quicklime (CaO) and dolomitic lime ($CaO \cdot MgO$) in any of these industries entails the production of CO_2. One part of CO_2 is produced for every part of calcite and 2 parts CO_2 for every part of dolomite.

CO_2 EMISSION ESTIMATION FROM CEMENT MANUFACTURE

CO_2 emissions from the manufacture of cement can be calculated in several ways depending on available data. The following methodologies maybe adopted:

- Estimation based on clinker production rather than on cement production. This method is most preferred since clinker has a higher lime percentage than finished cement product.
- Estimation by collating all regional/country data on clinker production by type and clinker CaO content by type, and then calculate the weighted average for cement lime content in the country.
- In the absence of data on clinker production, estimation of CO_2 emissions can be calculated using the annual cement production, the average CaO content of cement and emission factors.

The CO_2 emission factor (EF) for cement production is the product of the fraction of lime used in the cement clinker and a constant reflecting the molecular mass ratio of CO_2 to CaO (44/56) derived from the general chemical equation for cement production. The EF is calculated as:

The given EF for clinker is based on the average clinker lime assumed to be 64.6% [IPCC, 1996].

If data on clinker production is not available, CO_2 emissions can be calculated from the cement production based on the average CaO content of cement assumed to be 63.5%. The IPCC EF for this method is 0.4985 tonnes CO_2/ tonne cement produced.

In 2000, cement manufacturers in the Philippines produced 11,160,000 tonnes of clinker and 11,959,000 tonnes of cement. CO_2 emissions based on the clinker production in 2000 can be calculated using the EF of 0.5071 tonne CO_2/tonne clinker. This results to 5,659.24Gg CO_2 emissions for 2000.

Cement production values are available from national yearbooks and various annual publications such as Philippine Statistical Yearbook, the Philippine Yearbook, or the Annual Economic Indicators available in the National Statistical Information Center (NSIC). Cement production and clinker production for 2000 were also provided by the Cement Manufacturers Association of the Philippines (CEMAP) in their Annual Report.

In the Philippine Statistical Yearbook, cement is listed under the major category, “non-metallics,” and is usually given either as thousand kilograms or in metric tonnes (mt). If the production of cement is given in thousand bags, the equivalent mass of production can be obtained using the conversion factor, 40.0 kg of cement per bag.

SO_2 EMISSION ESTIMATION FROM CEMENT MANUFACTURE

SO_2 emissions usually originate from the sulfur content of fuel and in the clay raw material. Only the SO_2 from clay materials is accounted in this inventory. Cement SO_2 from fuel emissions are counted as energy emissions.

In the IPCC Guidelines, SO_2 emissions can be estimated from cement production using the IPCC default EF of 0.3 kg SO_2 per tonne of cement. SO_2 emissions from cement production were estimated at 3.59Gg in 2000 and 2.871 Gg in 1994. SO_2 emissions generated by cement production had increased by 0.719 Gg from 1994 to 2000.

LIME PRODUCTION

Lime production and limestone extraction used for processes other than industrial cement also emit CO_2. By heating the quarried limestone or dolomitic limestone or magnesite, quicklime (CaO) is formed and CO_2 is emitted. The same chemical reaction shown in cement manufacture (Sect. 2.2) applies to lime production. At some facilities, with additional hydration operations, hydrated (slaked) lime may also be produced.

CO_2 EMISSION ESTIMATION FROM LIME PRODUCTION

Calculation of CO_2 emissions from lime production is estimated from the total production of quicklime. The Mineral Statistics Series (Revised November 2006) of the Mineral Economics, Information and Publications Division of the Mines and Geosciences Bureau reported the total lime as the amount of quicklime, slaked or hydrated lime and others (e.g. dolomitic lime) for the given inventory year. The amount of lime in slaked or hydrated lime was calculated by multiplying the total slaked or hydrated lime with the correction factor, 0.97. The total lime produced as quicklime was calculated by summing up the amount of corrected lime in slaked or hydrated lime and the reported total quicklime.

In 2000, the reported quicklime production was 3,337 tonnes while the slaked or hydrated lime was 1,682,510 tonnes or 1,635,372 tonnes quicklime. The estimated CO_2 emissions from quicklime production in 2000 is 1,283.77 Gg using the default EF of 785 kg CO_2/tonne of high calcium lime. This is based on the assumption that pure lime was produced. There were no reports of CO_2 emissions from quicklime production in 1994.

Data on dolomitic lime production was not available for 2000.

EF may vary depending on the purity of lime, thus it is recommended that concentration of lime be taken into account when computing for the emission factor.

LIMESTONE AND DOLOMITE USE

Limestone ($CaCO_3$) and dolomite ($CaCO_3.MgCO_3$) are basic raw materials commercially used in a number of industries including metallurgy (e.g. iron and steel) and glass manufacture. These are also used in construction and environmental pollution control. Industrial applications that involve heating of limestone or dolomite at high temperatures also cause additional CO_2 emissions. CO_2 emissions from liming of soils should be reported under the Land-use Change and Forestry. To avoid double counting of CO_2, limestone and dolomite used in cement and lime production should be reported under each specific industrial process. All other uses of limestone and dolomite which produce CO_2 emissions will be accounted for in this section.

CO2 EMISSION ESTIMATION FROM LIMESTONE AND DOLOMITE USE

In 2000, the reported limestone for industrial use was 1,604,893 tonnes while dolomite consumption was 417,185.29 tonnes. Consumption is equal to material mined plus material imported minus material exported.

Quantity of dolomite produced in 2000 was 823,302 tonnes while exported dolomite was 406,522 tonnes. The total amount of imported dolomite was 405.288 tonnes.

CO_2 emitted from the use of limestone and dolomite was estimated at 905.15 Gg in 2000. There were no reports of CO_2 emissions from limestone and dolomite use in 1994.

The recommended IPCC EFs for limestone and dolomite use are given in Table 21.

TABLE 21. IPCC EFS FOR LIMESTONE AND DOLOMITE USE

TYPE OF RAW MATERIAL USED	EMISSION FACTOR
Limestone	440 x f kg CO_2/tonne limestone ($CaCO_3$) used
Dolomite	477 x f kg CO_2/tonne dolomite ($CaCO_3.MgCO_3$) used
Where f is the fractional purity of limestone in $CaCO_3$/tonne of total raw material weight (if unknown, the default factor for f is equal to 1)	

Data for this inventory are reported in published national statistics such as Philippine Statistical Yearbook and the Mineral Economics, Information and Publications Division, Mines and Geosciences Bureau and from the national import/export data available at the National Statistics Office.

SODA ASH

Soda ash (sodium carbonate, Na_2CO_3) is used as raw material in most industries including glass manufacture, soap and detergents, pulp and paper production, and water treatment. CO_2 is emitted from the use of soda ash and may be emitted also during production, depending on the industrial process used to manufacture the ash.

CO_2 EMISSION ESTIMATION FROM SODA ASH PRODUCTION

CO2 emissions from soda ash production can be estimated based on the following chemical reaction:

$$\underbrace{NA_2CO_3 \text{ X } NAHCO_3 \text{ X } 2H_2O}_{\text{Trona}} \rightarrow \underbrace{3NA_2CO_3}_{\text{Soda Ash}} + 5H_2O + CO_2$$

An EF of 0.097 tonne CO_2/tonne of Trona utilized is recommended for the computation of CO_2 emission based on natural soda ash production. In order to avoid double counting, CO_2 emissions associated with the use of coke in soda ash production shall be accounted for separately and for those emissions associated with non-energy use of coke shall be subtracted from the total emissions in the combustion section.

Similar to the inventory in 1994, there were no data of soda ash production in 2000.

CO_2 EMISSION ESTIMATION FROM SODA ASH USE

CO_2 emissions are also associated with the use of soda ash in the manufacture of glass, chemicals, soaps, detergents and flue gas desulphurization. It is assumed that for each mole of soda ash use, one mole of CO_2 is emitted in each of this industrial process.

The reported soda ash use for 2000 was 153,228.78 tonnes. Using 415 kg CO_2/tonne Na_2CO_3 as the default EF for soda ash use, the estimated CO_2 emissions from soda ash in 2000 was 63.59 Gg.

The data for soda ash use were taken from the Philippine Chemical Industries Fact Book and the Directory of SPIK *(Samahan sa Pilipinas ng mga Industriyang Kimika),* 1998-2003.

PRODUCTION AND USE OF MISCELLANEOUS MINERAL PRODUCTS

Among the three large petroleum producing companies in the Philippines (i.e., Pilipinas Shell, Chevron Philippines, and Petron Corporation), only Pilipinas Shell and Petron Corporation produced bitumen and asphalt in 2000. Data for asphalt production was obtained directly from the sales divisions of both Pilipinas Shell and Petron Corporation. Both companies used asphalt blowing (saturation with and without spray) in their production.

ASPHALT ROOFING PRODUCTION

Production of asphalt roofing may employ asphalt blowing process which involves the use of saturation with spray or saturation without spray. This process is considered as a source of GHG emissions for it releases CO and NMVOCs.

The asphalt roofing production for 2000 employing asphalt blowing using saturation with spray was reported at 3,666 tonnes while production using saturation without spray was 210 tonnes. The total asphalt roofing production in 2000 was 3,876 tonnes. The NMVOC emissions were estimated at 523.32 kgs and CO emissions at 36.82 kgs.

Emissions from asphalt roofing production are estimated from the national annual total mass of products and the emission factors provided by IPCC (1996) as presented in TABLE 22.

TABLE 22. IPCC DEFAULT EFS FOR ASPHALT ROOFING PRODUCTION

ASPHALT TYPE	EMISSION FACTORS (KG/TONNE PRODUCT)	
	Saturation with spray	Saturation without spray
CO	Not Available	0.0095
NMVOC	0.13-0.16 (EF used = 0.14)	0.046-0.049 (EF used = 0.048)

Since default emission factors for NMVOC for both blown asphalt (saturation with spray and saturation without spray) are given in range, the mean of the low and high values were used as emission factors. Use of predetermined EF other than the given default when available is encouraged.

ROAD PAVING WITH ASPHALT

NMVOCs may be emitted from the asphalt plant, the road surfacing operations and from the subsequent road surface. Estimated emissions from these activities need to consider the type of asphalt whether slow, medium or rapid cure as well as the amount of diluents used. Other gases emitted from asphalt plant include SO_2, NO_x and CO. The recommended emission factors for these activities are presented in TABLE 23.

TABLE 23. IPCC DEFAULT EFS FOR ROAD PAVING WITH ASPHALT

	EMISSION FACTORS (KG/TONNE ASPHALT)			
	SO_2	NO_x	CO	NMVOC
Asphalt Plant	0.12	0.084	0.035	0.023
Road Surface	Not Available	Not Available	Not Available	320

If the amount of asphalt for road pavement is not known but the area of road paved is available, a conversion factor of 100 kg asphalt for each square meter of road surface is recommended by the IPCC [1996]. Total production of road paving asphalt in 2000 was 72,461 tonnes with an estimated NMVOC emission of 1,666.60 kgs.

PRODUCTION OF OTHER MINERALS

GLASS PRODUCTION

NMVOCs may be emitted in the production of glass which includes flat and container glass. NMVOC emission from glass production is calculated from the total container and flat glass produced in 2000 and a default emission factor of 4.5 kg NMVOCs/tonne product (CASPER, 1995). The lone manufacturer of flat glass in the Philippines is the Republic Glass Asahi. The reported data for flat glass production was obtained from the Flat Glass Alliance of the Philippines Inc. (FGAPI) while data on container glass were provided by glass manufacturing companies in the Philippines like Anglo Watson Glass Inc., and San Miguel Glass Plants and its subsidiaries.

In 2000, a total of 285,919 tonnes of both flat and container glass were produced emitting an estimated 1.29 Gg NMVOC. No NMVOC emission from glass production was reported in 1994.

CONCRETE PUMICE STONE PRODUCTION

One emission source in other mineral production is from the production of concrete pumice stone. SO_2 emission from concrete pumice stone production is calculated from the total concrete pumice stone produced in tonnes. An emission factor of 0.5 kg SO_2/tonne product is recommended (Rypdal 1995) and is used where plant-specific emission factor is not available.

Production data related to concrete pumice stone can be obtained from published national statistics such as Philippine Statistical Yearbook and the Mineral Statistics Series (Revised November 2006) compiled by the Mineral Economics, Information and Publications Division, Mines and Geosciences Bureau.

In 2000, SO_2 emission from concrete pumice stone production was estimated at 78.00 kgs based on a concrete pumice production of 156 tonnes.

PRODUCTION OF OTHER CHEMICALS

Production of chemicals other than ammonia, nitric acid, adipic acid and carbides are also potential sources of greenhouse gases. However, only those processes which produce CO_2, CH_4, N_2O, SO_2, CO, NMVOCs and NO_x are the concern of this inventory. Among the chemicals identified in the IPCC Guidelines, only the chemicals listed in TABLE 24 are manufactured in the Philippines as reported by the Chemical Industries Association of the Philippines or Samahan sa Pilipinas ng Industriyang kimika (SPIK). Most of the chemicals available locally are either commercially traded or imported. Although chemical processes are considered small point sources, total emissions from these sources may be equally important. TABLE 24 presents the summary of default emission factors for various identified chemicals manufactured locally.

Most of the chemical manufacturers declined to provide their actual production data. In some cases, these manufacturers refer to the annual rated capacities (ARCs) as listed in SPIK report. This may create some uncertainty in the estimation of emissions since reported ARCs may have significant difference when compared to actual production values. Overestimation may also occur if production data have to be based on ARCs since IPCC [1996] has no guidelines for ARCs.

Methane is a major GHG emitted from the manufacture of carbon black, ethylene, dichloroethylene, and other chemicals. In the Philippines, emission of methane comes mainly from carbon black production. Carbon black is used for inks, sealants, and coating primers. The default IPCC EF for CH_4 from carbon black production is 11g CH_4/ kg carbon black produced.

In 2000, a total of 21,500 tonnes of carbon black were manufactured in the Philippines and a total of 236,500 kg or 0.24 Gg of CH_4 were emitted. Production data for 2000 was taken from the Philippine Chemical Industries Fact Book and Directory Report (1998-2003) provided by the Samahan sa Pilipinas ng mga Industriyang Kimika (SPIK).

TABLE 24. IPCC DEFAULT EFS FOR SPECIFIC CHEMICALS

CHEMICALS	EMISSIONS	EMISSION FACTOR (KG/TON OF CHEMICAL)
Carbon Black	CO	10
	SO_2	3.1
	CH_4	11
	NO_x	0.4
	NMVOC	40
Polypropylene	NMVOC	12
Polystyrene		5.4
Polyethylene (Linear low and high density)		Polyethylene Linear low density) = 2 Polyethylene (high density) = 6.4 Recommended EF = 4.2 (mean of LLD PE and HD PE)
Polyvinyl Chloride		8.5
Ethylene and Propylene		1.4
Formaldehyde		5
Phthalic anhydride		6
Sulfuric Acid	SO_2	17.5

METAL PRODUCTION

IRON AND STEEL

Production of metals usually generate CO_2 from the oxidation of added reducing agents (like coke). This may also generate other trace gases such as SO_2 from sulfur in both the reducing agents or in the ore itself. Carbon monoxide (CO) is emitted from incomplete combustion of materials, NO_x from the high temperature oxidation of nitrogen in the air, and NMVOCs as minor by-products especially where coal is involved.

Crude iron is produced from iron ore through blast furnace where smelting and chemical reduction of iron oxide take place. Steel is then subsequently made from iron and scrap in other furnacess. Production of iron or steel involves the oxidation of metal ores under very high temperatures. The metal maybe reduced using coke, prebaked anodes and coal electrodes. These substances may have been added manually in the production process or may have been already present as impurities in the ores. Thus, the most accurate methodology for calculating CO_2 emissions is based on the amount of reducing agent. The following general formula may be used to estimate the emissions:

$$\text{Emission (tones } CO_2) = \text{Mass Reducing Agent} \times \text{Emission Factor}$$
$$+ (\text{Carbon in ore} - \text{Carbon in metal}) \times 3.67$$

TABLE 25. IPCC CO_2 EMISSION FACTORS FOR METAL PRODUCTION

REDUCING AGENT	EMISSION FACTOR (TONNES CO_2/TONNE REDUCING AGENT)
Coal	2.5
Coke from Coal	3.1
Petro Coke	3.6
Prebaked anodes and coal electrodes	3.6

Table 25 presents the suggested default emission factors for CO_2 emissions based on the reducing agent used.

Statistics on steel and iron production are available from the Steel Statistical Yearbook 2000 issued by the South East Asia Iron and Steel Institute (SEAISI) and made available through the Philippine Iron and Steel Institute (PISI). The Mineral Statistics Series (Revised November 2006) of the Mineral Economics Information and Publications Division, Mines and Geosciences Bureau and the published national statistics, e.g. the Philippine Statistical Yearbook also contain data on metallic production which includes iron and steel.

CO_2 EMISSIONS FROM IRON AND STEEL PRODUCTION

Philippine production of crude steel products is in the form of billets produced in an electric furnace. If the amount of reducing agent used in the production of iron and steel is not available, CO_2 emissions are calculated based on production data.

SEAISI/PISI statistics show that 426,000 metric tonnes (mt) of crude steel were produced in 2000. There were also 1,405,000 mt of hot-rolled steel products and 220,000 mt of cold-rolled steel products produced, giving a total of 1,625,000 mt of rolled steel products (processed from rolling mills). To account for emissions from steel production, a default EF of 1.5 tonnes CO_2/ton iron or steel was used for non-integrated facility. For an integrated facility where coke plus iron and/or steel are produced, an emission factor of 1.6 tonnes CO_2/ton iron or steel product is suggested as default EF. No methodology exists for the estimation of emissions from crude steel production.

In 2000, CO_2 emission from iron and steel production was 639 Gg. This emission had greatly reduced compared to 4,270.40 Gg in 1994. This was largely attributed to the closure of the Philippines' biggest steelmaker, the National Steel Corp (NSC) in November 1999.

EMISSIONS OF OZONE PRECURSORS AND SO_2 FROM IRON AND STEEL PRODUCTION

With the closure of National Steel Corporation, most of the steel industries in the Philippines employ rolling mills in their process. The emissions from these rolling mills are mostly from the fuel used to heat the process. However, cold-rolling will emit a range of gases in addition to the fuel combustion emissions, thus emissions of trace gases were dependent on the total amount of cold rolled steel products produced. Default EFs for CO, NO_x, NMVOC, and SO_2 are available in the IPCC [1996]. The estimation of emissions is straightforward assuming that the activity data on steel and metal production are available. The recommended IPCC EFs for iron and steel are given in TABLE 26.

TABLE 26. IPCC EFS FOR IRON PRODUCTION AND STEEL PROCESSING

PROCESS	EFS (G GAS/TON OF IRON OR STEEL PRODUCED)			
	NO_x	NMVOC	CO	SO_2
Blast Furnace Charging		100	1330	1000-3000
Pig Iron tapping	76	20	112	30
Rolling Mills	40	30	1	45

PULP AND PAPER

Pulp and paper production has three major steps: pulping, bleaching and paper production. Kraft (sulphate) pulping is the most widely used pulping process which employs bleaching, chemical recovery, and by-product recovery. Kraft pulping emits NO_x, NMVOC, CO, and SO_2.

The Paper Industries Corporation of the Phils (PICOP) is an integrated paper plant producing both pulp and paper and the only producer of virgin pulp from wood in the Philippines. PICOP produces Kraft pulp (12% moisture) and refiner ground wood pulp. Refiner ground pulp is produced using mechanical pulping process without any chemical added, thus no emissions from this source. Five paper mills use neutral sulphite semi-chemical process in abaca pulping however, emission from this source cannot be determined since IPCC Guidelines has no default emission factors for this type of process, only data for the Kraft and acid sulphite processes are available. The rest of the paper manufacturers, about 37 paper mills, either utilizes wastepaper or recycled fibers by re-pulping process using NaOH. A large amount of paper produced in the Philippines comes from recycled materials, and the pulp used by most of the paper-producing industries is purchased from other local producers, wholesalers, or retailers. The EFs for Kraft and acid sulfite processes are given in TABLE 27.

TABLE 27. DEFAULT IPCC EFS FOR PULPING PROCESSES

ACID SULFITE PULPING		
	EF (KG/TON OF DRIED PULP)	EF (RANGE)
SO_2	30	8-50
KRAFT PULPING		
SO_2	7	0.005-10
NO_x	1.5	0.017-1.5
NMVOC	3.7	0.1-4.9
CO	5.6	Not available

Default IPCC EFs were used for estimating the emissions of both GHG precursors and SO_2 which are generally straightforward for both Kraft and acid sulfite pulping processes.

In 2000, PICOP produced a total of 6,000 tonnes of Kraft Pulp and 36 tonnes of refiner ground wood pulp based on annual rated capacity (ARC). As reported by PULPAPEL, the total tonnes of Kraft pulp produced in 2000 are 167,400 tonnes (ARC). Using the default EFs listed in TABLE 27, 0.25 Gg NO_x, 0.62 Gg NMVOC, 0.94 Gg CO, and 1.17 Gg SO_2 were emitted from the pulp and paper industry.

FOOD AND DRINK

The relevant precursor gas emitted during food production is NMVOC. NMVOC emissions from the production of food and beverages stem mainly from the fermentation of fruits and cereals and the production of alcoholic beverages. Emissions from the production of carbonated drinks are also possible, but no estimation procedures are included in the IPCC Guidelines.

ALCOHOLIC BEVERAGES

The annual Philippine production of alcoholic beverages is given in the Food Balance Sheets of the Philippines from the National Statistical Coordination Board (NSCB). Since alcoholic beverage production is given in metric tonnes rather than hectoliters (hL) as required by the IPCC Guidelines, an equation discussed below can be used to convert production in tonnes to equivalent liters (or hectoliters, hL).

The density of ethanol (EtOH), the alcohol in beverages, is 0.789 kg/L and that of water (H_2O) is 0.997 kg/L [CRC, 1985], at a temperature of 20°C. The density of a mixture of ethanol and water can be estimated assuming a specific percentage of alcohol and the formula:

where densities are represented by ρ and percentages by χ. If we assume an alcohol content of 14%, as suggested by the Center for Alcohol Research and Development (CARD), χ_{EtOH} is 0.14 and $(1 - \chi_{EtOH})$ is 0.86. The density of the beverage (ρ_{bev}) is merely a weighted average and can be calculated once the densities of ethanol and water are known. For 14% alcohol, the beverage density is assumed to be 0.96788 kg/L or 0.096788 tonnes/hL, following:

Multiplying beverage production (tonnes) by 1,000 gives beverage production in kilograms. This value divided by the average density of 0.96788 kg/L, yields beverage production in liters (or if divided further by 100, in hL).

Values for alcoholic beverages are also lumped under one category without specifying the type of beverage. This makes it difficult to assess emissions from specified sources, e.g., beer or wine. The national production of alcoholic beverages involves only some of the beverage types listed under the IPCC guidelines. Thus, an EF of 5.15 kg NMVOC per hL of beverage was used for this estimation. It is a composite value derived from the average EFs of the alcoholic beverage types listed in the 1996 IPCC guidelines. The individual EFs for alcoholic beverages are given in Table 28.

TABLE 28. IPCC DEFAULT EFS FOR ALCOHOLIC BEVERAGES

ALCOHOLIC BEVERAGES	EF (KG NMVOC/HL BEVERAGE)
Wine	0.08
Red wine	0.08
White wine	0.035
Beer	0.035

Spirits (unspecified)	15.00
Malt whiskey	15.00
Grain whiskey	7.50
Brandy	3.50

The Food Balance Sheet of the Philippines reports 1,013,000 tonnes of alcoholic beverages produced in 2000. Using an average beverage density of 0.96788 kg/L from the assumption of 14% alcohol content for alcoholic beverages, the production is equivalent to 10,466,173.49 hectoliters. Multiplying this value by the average EF (5.15 kg/hL), an estimated 53.9 Gg of NMVOC was emitted from alcoholic beverages in 2000.

BREAD MAKING AND OTHER FOOD

The NMVOCs are produced during the processing of cereals and fruits in preparation for the fermentation processes.

The estimation of NMVOCs can be straightforward, but care must be taken in considering the food categories included in the computations that use the default IPCC EFs. There are pitfalls in the selection of food items to be included in the inventory because a major category, e.g., meat, may list several entries and thus, lead to either double counting or underestimation. The default EFs for food are given in TABLE 29.

TABLE 29. IPCC DEFAULT EFS FOR FOOD PRODUCTION

FOOD PRODUCTION PROCESS	EF (KG NMVOCS/TON)
Meat, Fish, & Poultry	0.3
Sugar	10
Margarine And Solid Cooking Fats	10
Cakes, Biscuits And Breakfast Cereals	1
Bread	8
Animal Feed	1
Coffee Roasting	0.55

In the Food Balance Sheet of the Philippines, several categories are listed under meat, fish and poultry. Beef, carabao, pork, goat, sheep, organ meat, and other processed meats were included in the inventory under the general category of “Meats.” Chicken and duck were included under “Poultry.” Fish and other crustaceans, fresh or processed were included under “Fish.” Bread, cakes, biscuits, and animal feed were not included because statistics were not available. Likewise, solid cooking fats were not specified because the food category in the Balance Sheet combined both solid and non-solid fat products. The default EF for solid cooking fats was still adopted to account for emissions from both solid and non-solid fat products.

As an example, the total amount of meat, fish, and poultry produced in 2000 was 9,363,000 tonnes. The default EF given from the IPCC Guidelines is 0.3 kg NMVOC per ton of processed food. Multiplying production by EF, the estimated amount of NMVOCs emitted from meat, fish, and poultry for 2000 was 2,808,900 kg or roughly 2.81 gigagrams. The calculation is merely repeated for other food types.

Data on annual production of food can also be obtained from annual statistics provided by several bureaus of the Department of Agriculture (DA) such as the Bureau of Fisheries and Aquatic Resources (BFAR), Sugar Regulatory Authority (SRA) and the Bureau of Animal Industry (BAI).

EMISSIONS RELATED TO PRODUCTION OF HALOCARBONS AND SULPHUR HEXAFLOURIDE (HFCS, PFCS & SF_6)

Halocarbons such as HFC-23 and HCFC-22 are produced as chemical by-product of industrial processes or as fugitive emissions during production and distribution of a chemical. Partially fluorinated hydrocarbons (HFCs), perfluorinated hydrocarbons (PFCs) and sulphur hexafluoride (SF_6) are serving as alternatives to ozone-depleting substances (ODS) being phased out under the Montreal Protocol. Although HFCs and PFCs are not controlled by the Montreal Protocol, emissions of these compounds indicate high global warming potentials and long atmospheric residence times. The following formula applies for estimating emissions from production of these halocarbons:

By-product Emissions (tonnes) = By-product Factor (tonnes)

x Total HCFC-22 Production (tonnes)

Fugitive Emissions (tonnes) = Fugitive Release factor (tonnes)

x Individual HFC or PFC Production (tonnes)

EMISSIONS RELATED TO CONSUMPTION OF HALOCARBONS AND SULPHUR HEXAFLUORIDE (HFCS, PFCS AND SF6)

The Philippines is not a producer of these halocarbons and demand for these substances is met by imports primarily from developed countries as indicated by data provided by the Ozone Desk at the Environmental Management Bureau of the Department of Environment and Natural Resources. HCFC 22 is widely used in the Philippines followed by HCFC 141b and HCFC 123. HCFC-22 has been used as primary refrigerant for small to medium-sized air conditioners, and has increasingly been used in medium-temperature retail food refrigeration systems. The use of HCFCs in the

Philippines has been allowed until safer alternatives are made available. The current level of consumption of HCFCs as well as the demand projections indicate that the Philippines is within the control schedules and phase out dates specified for developing countries.

There are two approaches in conducting GHG inventory from the use of halocarbons and SF_6: estimation of potential emissions and actual emissions. There is not enough Philippine data to determine actual emissions in detail. Until there are better data and compilation methods available, only estimations of potential emissions can be satisfactorily obtained.

Data obtained from the Philippine Ozone Desk (POD) at the Environmental Management Bureau (EMB) refers to imported halocarbons which are mixtures of both HCFCs and HFCs. Thus, the chemical components of these halocarbons were obtained from POD where HFC component of a certain mixture is calculated from its percentage in the formulation. For example, the chemical R-404A is labeled HFC-125/HFC-134a/HFC-143a (44/4/52) which means that R404A is composed of 44% HFC-125, 4% HFC-134a, and 52% HFC-143a.

IF THE TOTAL AMOUNT OF CHEMICAL IS AVAILABLE IN BULK (KG OR TONNES) THE AMOUNT OF HALOCARBONS CAN BE CALCULATED FROM THE LABELED PERCENTAGE AND TABULATED. THE VARIOUS COMPONENT HALOCARBONS USED IN THIS INVENTORY ARE GIVEN IN TABLE 30.

TABLE 30. HALOCARBONS USED IN THE PHILIPPINES

HALOCARBON	RELATIVE COMPOSITION
HCFC-22	HCFC-22
HCFC-123	HCFC-123
HCFC-141B	HCFC-141B
HFC-134A	HFC-134A
R-404A	HFC-125/HFC-134A/HFC-143A (44/4/52)
R-401A	HCFC-22/HCFC-124/HFC-152A (53/34/13)
R-401B	HCFC-22/HCFC-124/HFC-152A (61/28/11)
R-402B	HCFC-22/HFC-125/PROPANE (38/60/2)
R407C	HFC-32/HFC-125/HFC-134A (23/25/52)
R410A	HFC 32/HFC-125 (50/50)
R-507A	HFC-125/ /HFC-143A (50/50)
R-508B	HFC-23/PFC-116 (46/54)

Source: EMB Ozone Desk, 2000

Information from the Philippine Ozone Desk at EMB indicates that 352.63 tonnes of HFC-134a and 0.61 tonnes as calculated from R-404A and R-407C were imported in 2000. Calculating the amount of HFC-134a in R-404A (4% of the total amount of R-404A) and R-407C (52% of the total amount of R-407C) yielded 0.61 tonnes. A total of 353.24 tonnes (or 352.63 + 0.61 mt) of HFC-134a was therefore, assumed to be consumed in the Philippines in 2000.

The total potential HFC-134a emission can be calculated from:

Potential Emission of HFC-134a = (Produced + Imported) – (Exported + Destroyed)

Where: only imported and exported hfcs/pfcs in bulk are considered in the above formula.

Although relatively low in atmospheric concentration, halocarbons have very high global warming potentials (GWP) which means that on a per molecule basis, they have greater warming capacity relative to CO_2. For example, from Table 31, a molecule of hfc-152a, have a GWP of 140 and that is 140 times more effective than CO_2 in warming the planet. Below is a summary of GWPs of halocarbons being used in the Philippines.

TABLE 31. GLOBAL WARMING POTENTIAL VALUES FOR CFC SUBSTITUTES

HALOCARBON NAME	GLOBAL WARMING POTENTIAL
HFC-134A	1300
HFC-125	2800
HFC-143A	1300
HFC-152A	140
HFC-32	650
HFC-23	11700

Source: IPCC, 1996

Since no HFC-134a was produced, exported, or destroyed in 2000, potential emission of HFC-134a is equal to the amount imported. Since no data for products containing HFC-134a are available, this is not included in the calculations and the total potential HFC-134a emission is equal to the potential bulk HFC-134a emission.

2000 INDUSTRY ACTIVITY DATA

CEMENT PRODUCTION

Clinker Produced (t)	11,160,000
Cement Produced (t)	11,959,000
Lime Production	
Lime Produced (t)	1,635,372
Limestone or Dolomite Use	
Limestone used (t)	1,604,893
Dolomite Used (t)	417,185.29
Soda Ash Use	
Soda Ash used (t)	153,228.78

PRODUCTION AND USE OF MISCELLANEOUS MINERAL PRODUCTS

Asphalt Roofing Production

Process Type	Blowing	
Asphalt Roofing Produced (t)	Saturation with spray	3,666
	Saturation without spray	210
Total Asphalt Roofing Produced (t)	3,876	

ROAD PAVING WITH ASPHALT

Emission Source	Asphalt Plant
Road Paving Material Used (t)	72,461

GLASS PRODUCTION

Container Glass Produced (t)	138,240
Flat Glass Produced (t)	147,679
Concrete Pumice Stone Produced (t)	156
Carbide Production	
Calcium carbide produced (t)	30,000

PRODUCTION OF OTHER CHEMICALS

Chemical	Quantity (t)
Carbon black	21,500
Polypropylene	3,35,000
Polystyrene	62,312
Polyethylene (Linear low and high density)	455,000
Polyvinyl Chloride	174,100
Ethylene and Propylene	266,000
Formaldehyde	40,000
Phthalic anhydride	14,000
Sulfuric Acid	1,401,569.34

METAL PRODUCTION	
Steel Produced (t)	426,000
Rolled Steel Produced (t)	220,000
PULP AND PAPER INDUSTRIES	
Air Dried Pulp Produced (t)	167,400
FOOD AND DRINK	
Food Production Type	Alcoholic Beverage Produced (hL)
Alcoholic Beverages	10,466,173.49
Food Production Type	Food produced (t)
Meat, Fish and Poultry	9,363,000
Sugar	1,802,750.73
Margarine and Solid Cooking Fats	243,000
Cakes, Biscuits and Breakfast Cereals	338,000
Bread	17
Animal Feed	1,212,710.
Coffee Roasting	117,000
CONSUMPTION OF HALOCARBONS AND SULPHUR HEXAFLUORIDE	
Halocarbon Name	**Potential Bulk Halocarbon Emissions (t)**
HCFC-22	1,223.57
HCFC-123	50.66
HCFC 124	0.16
HCFC 141b	188.17
HFC-134a	353.24
HFC 23	4.18
HFC 125	1.67
HFC 32	0.26
HFC143a	1.54
HFC 152A	0.06
PFC 116	4.90

CALCULATING GREENHOUSE GAS EMISSIONS

Fourteen basic worksheets are used for calculating GHG emissions from Industrial Processes. Each worksheet has several component sheets needed to complete the calculations. These worksheets and component sheets, together with the respective titles are shown in the table below. Activity data for 2000 can be found in Appendix 2A of the Industry Reference Manual.

Worksheet 2-1: Emissions from Cement Production

Sheet 2-1B: CO_2 Emissions

Sheet 2-1: SO_2 Emissions

Worksheet 2-2: Emissions from Lime Production

Sheet 1: CO_2 Emissions

Worksheet 2-3: Emissions from Limestone and Dolomite Use

Sheet 1: CO_2 Emissions

Worksheet 2-4: Emissions from Soda Ash

Sheet 1: CO_2Emissions from Soda Ash Production

Sheet 2: CO_2 Emissions from Soda Ash Use

Worksheet 2-5: Emissions from Production and Use of Miscellaneous Mineral Products

Sheet 1: NMVOC emissions (Asphalt Roofing Production)

Sheet 2: CO Emissions (Asphalt Roofing Production)

Sheet 3: NMVOC Emissions (Road Paving with Asphalt)

Sheet 4: NMVOC Emissions (Glass Production)

Sheet 5: SO_2 Emissions (Concrete Pumice Stone)

Worksheet 2-6: Emissions from Ammonia Production

Sheet 1: CO_2Emissions from Gas Consumed

Sheet 2: CO_2 Emissions from Ammonia Production

Sheet 3: NMVOC, CO and SO_2Emissions

Worksheet 2-7: Emissions from Nitric Acid Production

Sheet 1: N_2O and NO_x Emissions

Worksheet 2-8: Emissions from Adipic Acid Production

Sheet 1: N_2O, NO_x, NMVOC and CO Emissions

Worksheet 2-9: Emissions from Carbide Production

Sheet 1: CO_2 Emissions from Coke Production

Sheet 2: CH_4 Emissions from Petrol Coke Production

Sheet 3: CH_4 Emissions from Silicon Carbide Production

Sheet 4: CO_2 Emissions from Coke Production

Worksheet 2-10: Emissions from Chemical Production

Sheet 1: CH4 Emissions (Carbon Black)

Sheet 2: NOx Emissions (Carbon Black)

Sheet 3: NMVOC Emissions

Sheet 4: CO Emissions

Sheet 5: SO_2 Emissions

Worksheet 2-10: Emissions from Steel and Ferroalloy Production

Sheet 1: CO_2 Emissions Based on Reducing Agent

Sheet 2: NOx Emissions

Sheet 3: NMVOC Emissions

Sheet 4: CO Emissions

Sheet 5: SO_2 Emissions

Worksheet 2-12: Emissions from Pulp and Paper Industries

Sheet 1: NOx, NMVOC and CO Emissions

Sheet 2: SO_2 Emissions

Worksheet 2-13: Emissions from Food and Alcoholic Beverage Production

Sheet 1: NMVOC Emission from Alcoholic Beverage Production

Sheet 2: NMVOC Emissions from Food Production

Worksheet 2-14: Emissions from the use of Halocarbons

Sheet 1: Bulk Halocarbon Emissions

Sheet 2: Potential Halocarbon Emissions

EMISSIONS FROM CEMENT PRODUCTION

Worksheet 2-1 is used to calculate CO_2 emissions from cement production given the total production of cement and the total production of clinker and the SO_2 emissions from total cement production for the given inventory year. Total cement production can be found from published national statistics like Philippine Statistical Yearbook. CEMAP (Cement Manufacturers Association of the Philippines) Annual Report, www.cemap.org.ph, also provides data on total cement production and the total clinker production. It is preferred to use Worksheet 2-1A-Sheet 2B, if the data on total clinker is available with the assumption that the average clinker lime percentage is 64.6%.

CO_2 EMISSIONS

Step 1: Estimate the CO_2 emitted from the annual production of cement

Worksheet 2-1, Sheet 1A

1. Enter into Column A the quantity (tonnes) of cement produced annually.
   Data given as "bags of cement" can be multiplied by 40 kg cement/bag then divided by 1000 kg/ton to obtain the quantity of cement produced in tonnes.
2. Column B contains the default emission factor for cement which can be used on the assumption that the average CaO content of cement is 63.5%.
3. Multiply Columns A and B to get the amount of CO2 emitted in tonnes. Enter this value in Column C.
4. Tonne CO2 is converted into gigagrams CO2 by dividing Column C by 103, reported under Column D. Kilotonnes and gigagrams are equivalent to each other.

Step 2: Estimate the CO_2 emitted from the annual production of clinker

Worksheet 2-1, Sheet 1B

1. Enter into Column A the quantity (tonnes) of clinker produced annually.
2. Column B and C contains the default value for CKD (Cement Kiln Dust) correction factor and emission factor for clinker.
3. Multiply Columns A, B and C to get the amount of CO_2 emitted in tonnes. Enter this value in Column D.
4. In Column E, tonnes CO_2 is converted into gigagrams CO_2 by dividing Column D by 10^3.

SO_2 EMISSIONS

Step 1: Estimate the SO_2 emitted from the annual production of cement

Worksheet 2-1, Sheet 2

1. Enter into Column A the quantity of cement produced (tonnes) annually.
2. Column B contains the default emission factor for cement.
3. Multiply Columns A and B to get the amount of SO_2 emitted in tonnes. Enter this value in Column C.
4. Tonne SO_2 is converted into gigagrams SO_2 by dividing Column C by 10^3, reported under Column D.

EMISSIONS FROM LIME PRODUCTION

Worksheet 2-2 is used to calculate CO_2 emissions from lime production given the total production of quicklime. Sources for the data needed in this inventory can be found in Philippine Statistical Yearbook and the Mineral Economics, Information and Publications Division, Mines and Geosciences Bureau. The Mineral Statistics Series (Revised November 2006) of the Mineral Economics, Information and Publications Division of the Mines and Geosciences Bureau has a data on the total lime as the amount of quicklime, slaked or hydrated lime and others (e.g., dolomitic lime).

The amount of lime in slaked or hydrated lime can be calculated by multiplying the total slaked or hydrated lime by a correction factor of 0.97. The total lime produced as quicklime can then be calculated by adding the amount of lime in slaked or hydrated lime.

CO_2 EMISSIONS

Step 1: Estimate the CO_2 emitted from the annual production of lime

Worksheet 2-2, Sheet 1 of 1

1. Enter into Column A the quantity of lime produced (tonnes) whether as quicklime, dolomitic lime or both produced annually.

2. Column B contains the default emission factor for quicklime or dolomitic lime produced.
3. In Column C, multiply Columns A and B to get the amount of CO_2 emitted in tonnes.
4. In Column D, Tonnes CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3.

EMISSIONS FROM LIMESTONE AND DOLOMITE USE

Worksheet 2-3 is used to calculate CO_2 emissions from the total limestone and dolomite used. Total dolomite can be calculated by subtracting the total dolomite export from the total dolomite production while total limestone is equivalent to the total limestone for industrial use. Sources for these data are published national statistics, the Philippine Statistical Yearbook and the Mineral Statistics Series (Revised November 2006) compiled by the Mineral Economics, Information and Publications Division, Mines and Geosciences Bureau.

Step 1: Estimate the CO_2 emitted from the annual use of limestone and dolomite

Worksheet 2-3, Sheet 1 of 1

1. Enter into Column A the quantity of limestone and dolomite used (tonnes) annually.
2. Column B contains the default emission factors for limestone and dolomite.
3. In Column C, multiply Columns A and B to get the amount of CO_2 emitted.
4. In Column D, Tonnes CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3.

EMISSIONS FROM SODA ASH PRODUCTION AND USE

Worksheet 2-4 is used to calculate CO_2 emissions from soda ash production and use. CO_2 emission from soda ash production is calculated based on the total trona (principal ore from which natural soda ash is produced) used. If data on total trona utilized during the inventory year is not available, only CO_2 emission from soda ash can be calculated. Data to be used can be taken from the Philippine Chemical Industries Fact Book and Directory of *SPIK (Samahan sa Pilipinas ng mga Industriyang Kimika)*.

CO_2 EMISSIONS

Step 1: Estimate the CO_2 emitted from annual soda ash production

Worksheet 2-4, Sheet 1 of 2

1. Enter into Column A the quantity of trona (tonnes) utilized annually.
2. Column B contains the default emission factor for soda ash production.
3. In Column C, Multiply Columns A and B to get the amount of CO_2 emitted in tonnes.
4. In Column D, tonne CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3.

Step 2: Estimate the CO_2 emitted from the annual soda ash use

Worksheet 2-4, Sheet 2 of 2

1. Enter into Column A the quantity of soda ash (tonnes) used annually.
2. Column B contains the default emission factor for soda ash use.
3. In Column C, multiply Columns A and B to get the amount of CO_2 emitted in tonnes.
4. In Column D, tonne CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3.

EMISSIONS FROM PRODUCTION AND USE OF MISCELLANEOUS MINERAL PRODUCTS

EMISSIONS FROM ASPHALT ROOFING PRODUCTION

Of the three largest petroleum producing companies in the Philippines (Pilipinas Shell, Chevron Philippines, and Petron Corporation), only two produce bitumen and asphalt. Data for asphalt production can be obtained directly from the sales divisions of both the Pilipinas Shell and Petron Corporation.

Worksheet 2-5 is used to calculate NMVOC and CO emissions from total asphalt roofing production. NMVOC emission from asphalt roofing production was calculated from total asphalt roofing production by blown process (saturation with and without spray).

NMVOC EMISSIONS

Step 1: Estimate NMVOC emitted from the annual asphalt roofing production by blown process (saturation with and without spray) and saturation process

Worksheet 2-5, Sheet 1 of 5

1. Enter total asphalt roofing production from blown process (saturation with and without spray) and saturation process (tonnes) under Column A.
2. Column B contains the default emission factor for NMVOC from the production of asphalt roofing.
   The default emission factor for asphalt roofing production is given in range. Get the average and choose this as the emission factor.
3. In Column C, multiply Columns A and B to get the amount of NMVOC emitted.
4. In Column D, kilograms NMVOC is converted into gigagrams NMVOC by dividing Column C by 1^{06}.

CO EMISSIONS

Step 2: Estimate CO emitted from the annual production of asphalt roofing

Worksheet 2-5, Sheet 2 of 5

1. Total asphalt roofing production (tonnes) is entered under Column A.
2. Column B contains the default emission factor for CO from the production of asphalt roofing.
3. In Column C, multiply Columns A and B to get the amount of CO emitted.
4. In Column D, kilograms CO is converted to gigagrams CO by dividing Column C by 1^{06}.

EMISSIONS FROM ROAD PAVING WITH ASPHALT

NMVOC EMISSIONS

Step 3: Estimate NMVOC emitted from the annual road paving material used

Worksheet 2-5, Sheet 3 of 5

1. Total road paving material used from asphalt plant (tonnes) is entered under Column A.
2. Column B contains the default emission factor for NMVOC from the total road paving material used.
3. In Column C, multiply Columns A and B to get the amount of NMVOC emitted.
4. In Column D, kilograms NMVOC is converted into gigagrams NMVOC by dividing Column C by 106.

EMISSIONS FROM GLASS PRODUCTION

NMVOC emission from glass production can be calculated from the total quantity (tonnes) of container and flat glass produced annually. The data for flat glass can be taken from Flat Glass Alliance of the Philippines Inc. (FGAPI), while data on container glass can be provided by the glass manufacturing companies in the Philippines, such as Anglo Watson Glass Inc. and San Miguel Glass Plants.

NMVOC EMISSIONS

Step 4: Estimate NMVOC emitted from the annual glass production

Worksheet 2-5, Sheet 4 of 5

1. Total glass production which comes from flat and container glass production (tonnes) is entered under Column A.
2. Column B contains the default emission factor for NMVOC from the total glass produced.
3. In Column C, multiply Columns A and B to get the amount of NMVOC emitted.
4. In Column D, kilograms NMVOC is converted into gigagrams NMVOC by dividing Column C by 1^{06}.Emissions from Concrete Pumice Stone Production

SO_2 emission from concrete pumice stone production is calculated from the total quantity of concrete pumice stone (tonnes) produced annually. The data can be found from published national statistics such as the Philippine Statistical Yearbook and the Mineral Statistics Series (Revised November 2006) compiled by the Mineral Economics, Information and Publications Division, Mines and Geosciences Bureau.

SO_2 EMISSIONS

Step 5: Estimate SO_2 emitted from the annual concrete pumice stone production

Worksheet 2-5, Sheet 5 of 5

1. Total quantity of concrete pumice stone produced (tonnes) is entered under Column A.
2. Column B contains the default emission factor for SO_2 from the total concrete pumice stone produced.
3. In Column C, multiply Columns A and B to get the amount of SO_2 emitted.

In Column D, kilograms NMVOC is converted into gigagrams SO_2 by dividing Column C by 1^{06}.

EMISSIONS FROM AMMONIA PRODUCTION

Worksheet 2-6 is used to calculate $CO_{2,}$ NMVOC, CO and SO_2 emissions from ammonia production for the given inventory year.

CO_2 EMISSIONS

Step 1: Estimated CO_2 emitted from the annual ammonia production given the amount of gas consumed

Worksheet 2-6, Sheet 1 of 3

1. Amount of gas (usually natural gas) consumed (m^3) is entered under Column A.
2. Carbon content of gas in kg/m^3 is entered in Column B. Column C contains the ratio 44/12 (CO_2/C) to convert to amount CO_2.
3. Multiply Columns A, B and C to get the amount of CO_2 emitted in kilograms. Enter this value in Column D.
4. In Column E, Kilograms CO_2 is converted into gigagrams CO_2 by dividing Column D by 10^6.

Step 2: Estimate CO_2 emitted from the annual ammonia production

Worksheet 2-6, Sheet 2 of 3

1. Total quantity of ammonia produced (tonnes) is entered under Column A.
2. Column B contains the default emission factor for CO_2 from the total ammonia produced.
3. In Column C, multiply Columns A and B to get the amount of CO_2 emitted.
4. In Column D, tonnes CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3.

NMVOC, CO, AND SO_2 EMISSIONS

Step 3: Estimate NMVOC, CO and SO_2 emitted from the annual ammonia production

Worksheet 2-6, Sheet 3 of 3

1. Total quantity of ammonia produced (tonnes) is entered under Column A.
2. Column B contains the default emission factor for CO, SO_2 and TOC (Total organic compounds) from each method of ammonia production.
3. In Columnc C, multiply Columns A and B to get the amount of CO, SO_2 and TOC emitted.
4. In Column D, kilograms pollutant emitted is converted into gigagrams CO_2 by dividing Column C by 10^6.

EMISSIONS FROM NITRIC ACID PRODUCTION

Worksheet 2-7 is used to calculate N_2O and $NO_{x,}$ emissions from nitric acid production for the given inventory year.

N_2O AND NO_x EMISSIONS

Step 1: Estimate N_2O and NO_x emitted from the annual nitric acid production

Worksheet 2-7, Sheet 1 of 1

1. Total quantity of nitric acid produced (tonnes) is entered under Column A.
2. Column B contains the default emission factor for N_2O and NO_x.
3. In Column C, multiply Columns A and B to get the amount of N_2O and NO_x emitted.
4. In Column D, Ttonnes N_2O and NO_x is converted into gigagrams N_2O and NO_x by dividing Column C by 10^3.

EMISSIONS FROM ADIPIC ACID PRODUCTION

Worksheet 2-8 is used to calculate N_2O, $NO_{x,}$ NMVOC and CO emissions from adipic acid production for the given inventory year.

N_2O, NO_x, NMVOC AND CO EMISSIONS

Step 1: Estimate N_2O, $NO_{x,}$ NMVOC and CO emitted from the annual adipic acid production

Worksheet 2-8, Sheet 1 of 1

1. Total quantity of adipic acid produced (tonnes) is entered under Column A.
2. Column B contains the default emission factor for N_2O, $NO_{x,}$ VOC and CO from adipic acid production.
3. Multiply Columns A and B to get the amount of N_2O, $NO_{x,}$ VOC and CO emitted in kilograms. Enter this value in Column C.
4. Tonnes N_2O, $NO_{x,}$ VOC and CO is converted into gigagrams N_2O, $NO_{x,}$ NMVOC and CO by dividing Column C by 10^3, reported under Column D. Kilotonnes and gigagrams are equivalent to each other.

EMISSIONS FROM CARBIDE PRODUCTION

Worksheet 2-9 is used to calculate CO_2 emissions from silicon carbide production based on the consumption of coke and CH_4 emissions as petrol coke consumed or silicon carbide produced

CO_2 EMISSIONS

Step 1: Estimate CO_2 emitted from the annual coke consumption

Worksheet 2-9, Sheet 1 of 4

1. Total quantity of coke consumed (tonnes) is entered under Column A.
2. Carbon content in coke (%) is entered under Column B.
3. Carbon input sequestered in product (%) is entered under Column C.
4. Tonnes CO_2 emitted is calculated by getting the total percent carbon content in coke after removing the fraction of carbon sequestered in the product then multiplying with column A and multiply with 3.67/10000. Ton CO_2 emitted is entered in Column D.
5. In Column D, tonne CO_2 is converted into gigagrams by dividing Column D by 10^3, reported under Column E.

Step 2: Estimate CO_2 emitted from the amount of calcium carbide produced

Worksheet 2-9, Sheet 4 of 4

1. Total annual production of calcium carbide (tonnes) is entered under Column A.
2. Column B contains the default emission factor for CO_2 from the production of calcium carbide.
3. In Column C, multiply Columns A and B to get the amount of CO_2 emitted.
4. In Column D, tonne CO_2 is converted into gigagrams CO_2 by dividing Column C by 1^{03}.

CH_4 EMISSIONS

Step 3: Estimate CH_4 emitted from the amount of petrol coke consumption

Worksheet 2-9, Sheet 2 of 4

1. Total annual consumption of petrol coke (tonnes) is entered under Column A.
2. Column B contains the default emission factor for CH_4 from the consumption of petrol coke.
3. Multiply Columns A and B to get the amount of CH_4 emitted. Enter this value in Column C.
4. In Column D, tonnes CH_4 is converted into gigagrams CH_4 by dividing Column C by 10^3.

Step 4: Estimate CH_4 emitted from the amount of silicon carbide produced

Worksheet 2-9, Sheet 3 of 4

1. Total annual silicon carbide produced (tonnes) is entered under Column A.
2. Column B contains the default emission factor for CH_4 from the consumption of petrol coke.
3. In Column C, multiply Columns A and B to get the amount of CH_4 emitted.
4. In Column D, tonnes CH_4 is converted into gigagrams CH_4 by dividing Column C by 10^3.

EMISSIONS FROM OTHER CHEMICAL PRODUCTION

The emissions of GHGs and other precursor or climate critical trace gases from the production of industrial chemicals depend on what chemical is produced. Statistics on chemical production for the inventory year can be taken from the Philippine Chemical Industries Fact Book and Directory Report provided by *Samahan sa Pilipinas ng mga Industriyang Kimika (SPIK)*.

Most of the manufacturing firms which are members of SPIK reports annual rated capacities which are used as basis for computing GHG emissions. This leads to relative inaccuracies, and the results of the inventory, at best, can only be considered upper bound estimates.

Worksheet 2-10 is used to calculate GHG emissions from various industrial chemical productions.

CH_4 EMISSIONS

Step 1: Estimate CH_4 emitted from the annual production of chemical manufacturing processes (e.g. Carbon Black)

Worksheet 2-10, Sheet 1 of 5

1. Total chemical production (tonnes) is entered under Column A as listed on the left side of Sheet 1 of Worksheet 2-10.
2. Column B contains the default emission factor for CH_4 from chemical produced (e.g. Carbon Black).
3. Multiply Columns A and B to get the amount of CH_4 emitted. Enter this value in Column C.
4. In Column D, kilograms CH_4 is converted into gigagrams CH_4 by dividing Column C by 10^6.

NO_x EMISSIONS

Step 2: Estimate NOx emitted from the annual production of chemical manufacturing processes (e.g. Carbon Black)

Worksheet 2-10, Sheet 2 of 5

1. Total chemical production (tonnes) is entered under Column A as listed on the left side of Sheet 2 of Worksheet 2-10.
2. Column B contains the default emission factor for NO_x from carbon black production.
3. In Column C, multiply Columns A and B to get the amount of NO_x.
4. In Column D, kilograms NO_x is converted into gigagrams NO_x by dividing Column C by 10^6.

NMVOC EMISSIONS

Step 3: Estimate NMVOC emitted from the annual production of various chemicals

Worksheet 2-10, Sheet 3 of 5

1. Total chemical production (tonnes) is entered under Column A as listed on the left side of Sheet 3 of Worksheet 2-10.
2. Column B contains the default emission factor for NMVOC from the production of various chemicals.
3. In Column C, multiply Columns A and B to get the amount of NMVOC emitted.
4. In Column D, kilograms NMVOC is converted into gigagrams NMVOC by dividing Column C by 1^{06}.

CO EMISSIONS

Step 4: Estimate CO emitted from the annual production of various chemicals (e.g. carbon black)

Worksheet 2-10, Sheet 4 of 5

1. Total chemical production (tonnes) is entered under Column A as listed on the left side of Sheet 4 of Worksheet 2-10.
2. Column B contains the default emission factor for CO from the production of various chemicals .
3. In Column C, multiply Columns A and B to get the amount of CO emitted in kilograms.
4. In Column D, kilograms CO is converted into gigagrams CO by dividing Column C by 10^6.

SO_2 EMISSIONS

Step 5: Estimate SO_2 emitted from the annual production of various chemicals

Worksheet 2-10, Sheet 5 of 5

1. Total chemical production (tonnes) is entered under Column A as listed on the left side of Sheet 5 of Worksheet 2-10.
2. Column B contains the default emission factor for SO_2.
3. In Column C, multiply Columns A and B to get the amount of SO_2 emitted in kilograms. Enter this value in Column C.
4. In Column D, kilograms SO_2 is converted into gigagrams SO_2 by dividing Column C by 10^6.

EMISSIONS FROM STEEL AND FERROALLOY PRODUCTION

Worksheet 2-11 is used to calculate trace gas emissions from steel and ferroalloy production for the inventory year. Data sources for the inventory can be taken from published statistics by the Southeast Asia Iron and Steel Institute (SEAISI),the Mineral Statistics Series (Revised November 2006) of the Mineral Economics Information and Publications Division, Mines and Geosciences Bureau and the published national statistics, e.g. the Philippine Statistical Yearbook.

Philippine production of crude steel products is in the form of billets produced in an electric furnace. CO_2 emissions basically come from the production of crude steel products. Carbon and alloy steel produced in an electric arc furnace is usually charged with 100 percent scrap iron. The emissions of CO_2 as well as trace gases from steel production are also considered, where emissions of trace gases are dependent on the total amount of cold rolled steel products.

CO_2 EMISSIONS (STEEL PRODUCTION)

Step 1: Estimate the CO_2 emitted from the mass of reducing agent used for iron and steel, ferroalloys and aluminum production

Worksheet 2-11, Sheet 1 of 11

1. Enter into Column A the total mass of reducing agent used to reduce the type of metal listed on the left side of Sheet 1 of Worksheet 2-11.
2. Column B contains the default IPCC emission factor for CO_2 per ton of reducing agent used for the specific type of metal production.
3. Enter in Column C the amount of carbon (tonnes) lost during the reduction process by subtracting the amount of carbon sequestered by the metal product from the amount of carbon in the ore and multiplying the result by 3.67 (MW CO_2/MW C)
4. Tonnes CO_2 emitted is calculated by multiplying Columns A and B then adding Column C to the final result and reported under Column D.
5. In Column E, tonnes CO_2 emitted is converted into gigagrams CO_2 by dividing Column C by 10^3.

Step 2: Estimate the CO_2 emitted from the annual production of crude steel

Worksheet 2-11, Sheet 2 of 11

1. Enter into Column A the quantity of iron or steel produced for the inventory year.
2. Column B contains the default IPCC emission factor for CO_2 from iron and steel production.
3. In Column C, multiply Columns A and B to get the amount of CO_2 emitted in tonnes.
4. Tonne CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3, reported under Column D.

TRACE GAS EMISSIONS (NO_x, NMVOC, CO, AND SO_2)

Step 3: Estimate trace gases emitted from the annual production of cold rolled steel

Worksheet 2-11, Sheet 3 of 11

1. The annual amount of iron or steel produced for cold rolled steel production is entered under Column A.
2. Column B contains the default emission factors for trace gases from cold rolled steel production.
3. In Column C, multiply Columns A and B to get the amount of trace gas emitted.
4. In Column D, grams is converted into gigagrams trace gas by dividing Column C by 10^9, reported under Column D.

CO_2 EMISSIONS (FERROALLOY PRODUCTION)

Step 4: Estimate the CO_2 emitted from the annual production of ferroalloys

Worksheet 2-11, Sheet 4 of 11

1. Enter into Column A the quantity of ferroalloys produced for the inventory year.
2. Column B contains the default IPCC emission factor for CO_2 from ferroalloy production.
3. Multiply Columns A and B to get the amount of CO_2 emitted in tonnes. Enter this value in Column C.
4. In Column D, tonne CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3.

CO_2 EMISSIONS (ALUMINUM PRODUCTION)

Step 5: Estimate the CO_2 emitted from the annual production of aluminum

Worksheet 2-11, Sheet 5 of 11

1. Enter into Column A the quantity of aluminum produced for the inventory year.
2. Column B contains the default IPCC emission factor for CO_2 from aluminum production.
3. In Column C, multiply Columns A and B to get the amount of CO_2 emitted in tonnes.
4. In Column D, tonnes CO_2 is converted into gigagrams CO_2 by dividing Column C by 10^3.

EMISSIONS FROM PULP AND PAPER INDUSTRIES

Worksheet 2-12 is used to calculate trace gas (NO_x, NMVOC, CO, and SO_2) emissions as well as SO_2 emissions from total amounts of air dried pulp produced by Kraft and Acid Sulfite processes for the inventory year. Production data are available for various types of pulp as provided by PULPAPEL.

NO_x, NMVOC AND CO EMISSIONS

Step 1: Estimate trace gases emitted from the annual production of Kraft pulp

Worksheet 2-12, Sheet 1 of 2

1. With reference to the trace gases listed at the left side of Column B of Sheet 1 of Worksheet 2-12, enter total Kraft pulp production under Column A.
2. Column B contains the default emission factors for trace gases from Kraft pulp production.
3. In Column C, multiply Columns A and B to get the amount of trace gas emitted.
4. In Column D, kilograms trace gas are converted into gigagrams trace gas by dividing Column C by 10^6.

SO_2 EMISSIONS

Step 2: Estimate SO_2 emissions from the annual production of pulp from Kraft and Acid Sulphite Process

Worksheet 2-12, Sheet 2 of 2

1. Enter total air-dried pulp produced for each pulp process type (e.g. Kraft pulp and Acid Sulphite process) in Column A.
2. Column B contains the default emission factors for SO_2 emissions from air-dried pulp production using Kraft pulp and acid sulphite process.
3. In Column C, multiply Columns A and B to get the amount of SO_2 emitted.
4. In Column D, kilograms SO_2 are converted into gigagrams trace gas by dividing Column C by 10^6.

EMISSIONS FROM FOOD AND ALCOHOLIC BEVERAGES PRODUCTION

EMISSIONS FROM ALCOHOLIC BEVERAGES PRODUCTION

Worksheet 2-13 is used to calculate NMVOC emissions from total amounts of food and alcoholic beverage produced for the inventory year. Data on the annual production of alcoholic beverages can be obtained from the *Food Balance Sheet of the Philippines*, available from the National Statistics Coordination Board.

NMVOC EMISSIONS (ALCOHOLIC BEVERAGES PRODUCTION)

Step 1: Estimate NMVOC emitted from the production of alcoholic beverages

Worksheet 2-13, Sheet 1 of 2

1. Enter the total alcoholic beverage production (hL) in Column A.
2. Column B contains the default emission factor for NMVOCs from beverage production
3. In Column C, multiply Columns A and B to get the amount of NMVOCs emitted.
4. In Column D, kilograms NMVOC is converted into gigagrams by dividing Column C by 10^6.

EMISSIONS FROM FOOD PRODUCTION

Data on the annual production of food can be obtained from the *Food Balance Sheet of the Philippines*, available from the National Statistics Coordination Board and from annual statistics provided by several bureaus of the Department of Agriculture such as the Bureau of Fisheries and Aquatic Resources (BFAR), Sugar Regulatory Authority and the Bureau of Animal Industry.

NMVOC EMISSIONS (FOOD PRODUCTION)

Step 1: Estimate NMVOC emitted from the production of food

Worksheet 2-13, Sheet 2 of 2

1. The types of food are listed on the left of Sheet 1 of Worksheet 2-13.Enter the total food production (tonne) in Column A.
2. Column B contains the default emission factor for NMVOC from food production.
3. In Column C, multiply Columns A and B to get the amount of NMVOCs emitted in kilograms.
4. In Column D, kilograms NMVOC is converted into gigagrams by dividing Column C by 10^6.

EMISSIONS FROM THE USE OF HALOCARBONS

The Philippines does not produce halocarbons and data on their importation can be obtained from the Philippine Ozone Desk (POD) at the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources.

BULK EMISSIONS FROM HALOCARBON IMPORTS

Step 1: Estimate bulk amounts of halocarbons emitted from their importation

Worksheet 2-14, Sheet 1 of 2

1. Obtain the national importation statistics for halocarbons from the Ozone desk and determine the volume of halocarbons from percentage compositions.
2. The amount of bulk emission for each halocarbon is the same as that of imported since the Philippines neither produces nor destroys these. Enter potential emissions (in tonnes) in Column E.

POTENTIAL EMISSIONS FROM HALOCARBON IMPORTS

Step 2: Estimate potential amounts of halocarbons emitted from their importation

Worksheet 2-14, Sheet 2 of 2

1. Since halocarbons are only imported, bulk emissions are carried over from Column E to Columns F and H as potential emissions in tonnes.
2. In Column I, convert the amount of potential emission for each halocarbon from tonnes to gigagrams by dividing Column H by 10^3. This is reported under Column I.
3. Calculate CO_2 equivalents for each halocarbon in Column I using their GWP values.

Agriculture Sector

Rice paddy cultivation, burning of grasslands and agricultural residues, and agricultural soils management are the main sources of greenhouse gas emissions for the agriculture sector. TABLE 32 below summarizes the activities and the corresponding greenhouse gas emitted.

TABLE 32. GREENHOUSE GAS EMISSIONS PER AGRICULTURE SUBSECTOR

SUBSECTOR	GREENHOUSE GAS EMITTED			
	CH_4	CO	N_2O	NO_x
Domestic Livestock	✓		✓	
Rice Paddy Cultivation	✓			
Grassland Burning	✓	✓	✓	✓
Agricultural Residue Burning	✓	✓	✓	✓
Agricultural Soils			✓	

REFERENCE MANUAL

INTRODUCTION

The IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997; and IPCC 2007) identified five sources of GHG emissions in Agriculture as follows:

- Emissions from domestic livestock such as methane (CH_4) from enteric fermentation and CH_4 and nitrous oxide (N_2O) from manure management;
- CH_4 emissions from rice cultivation;
- non- CO_2 emissions from prescribed burning of savannas or grasslands;
- non- CO_2 emissions from burning of agricultural residues; and
- N_2O emissions from agricultural soils.

This Reference Manual describes the methods used in estimating GHG inventory in Agriculture sector in the Philippines for the year 2000. Each section gives a brief background of the source of emissions as it relates to the country. The method used to estimate emission and the basis for using such method are also presented and discussed in each section. The activity data are described including relevant information and sources of information. Emission factors are presented and discussed in each section explaining why those factors are appropriate to national circumstances.

DOMESTIC LIVESTOCK

INTRODUCTION

Livestock production could result in methane (CH_4) emissions from enteric fermentation and both CH_4 and nitrous oxide (N_2O) emissions from livestock manure management systems. In 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. Greenhouse gases are also emitted from the management of animal manure. Methane is produced from decomposition of manure under anaerobic conditions, which usually occur in manure stored in large piles or disposed off in lagoons. During storage of manure, some nitrogen in manure are oxidized and converted into N_2O.

Livestock sub-sector is one of the major sources of greenhouse gas emission in the Philippines' Agriculture sector, second only to rice. In the 1994 GHG inventory, total emission from domestic livestock accounted for 32% of the country's total GHG emission. GHG emissions occurred mainly from three major ruminants, namely cattle, buffalo, and goats with small contributions from non-ruminants, including horse, swine, and poultry (Note: Sheep, which is a ruminant animal, was included in the 1994 inventory. It was excluded in the 2000 GHG inventory since sheep is not traditionally domesticated in the Philippines, apart from the fact that sheep population was so small to significantly contribute to GHG emissions).

METHANE FROM ENTERIC FERMENTATION

In the absence of any country-specific methods to estimate methane emission from enteric fermentation and due to lack of activity data to perform enhanced characterization of livestock population, the simple IPCC Tier 1 approach was used in the year 2000 (IPCC, 1997). This method was used in the 1994 GHG inventory.

$$Ch_4\ Enteric_a = Pop_a \times EF\_enteric_a \times 10^{-3}$$

where:

$Ch_4\ Enteric_a$ = Methane emission from enteric fermentation for animal type “a” (Gg/yr)

Pop_a = Population of animal type “a” (x 1000 heads)

$EF\_enteric_a$ = Emission factor for enteric fermentation for animal type “a” (kg CH_4/head/yr)

10^{-3} = Conversion factor (to Gg)

For 2000 GHG inventory, the major ruminants considered in the Philippines are cattle (subcategorized as dairy and non-dairy), buffalo or carabao (subcategorized as dairy and non-dairy), and goats (subcategorized as meat goats and dairy goats). The non-ruminant animals included in the inventory are poultry, swine, duck, and horses. Almost all major ruminants are raised for meat (non-dairy) with less than 1% raised for dairy purposes.

TABLE 33 summarizes the livestock type and population in the Philippines in year 2000 as compared to 1994 livestock population. Considerable increases in livestock population were observed in non-dairy cattle (28%), swine (28%), and horses (27%). Buffalo population also increased by 16% while goat population by 18%. Dairy cattle population shrank by half from 14,000 heads to only 7,100 heads.

TABLE 33. DOMESTIC LIVESTOCK POPULATION IN THE PHILIPPINES, 2000

LIVESTOCK TYPE	LIVESTOCK POPULATION, NUMBER OF ANIMALS		
	1994	2000	% CHANGE
DAIRY CATTLE	14,000	7,100	-49
NON-DAIRY CATTLE	1,943,000	2,478,853	28
NON-DAIRY BUFFALO	2,614,000	3,024,403	16
DAIRY BUFFALO		11,070	-
MEAT GOAT	2,674,000	3,151,472	18
DAIRY GOAT		770	-
HORSE	181,000	230,000	27
DUCK		9,264,658	-
SWINE	8,374,000	10,710,690	28
POULTRY	93,201,007	115,186,981	24
SHEEP	24,000		-

Source: BAS (2008); NDA (2000); FAO (2008).

Livestock population has been increasing consistently since 1994. Swine production has among the highest increase of 28% from 8.4 million heads in 1994 to 10.7 million heads in 2000 (Figure 2). Cattle (non-dairy) population also increased by 28% from 1.9 million heads in 1994 to 2.5 million heads in 2000. Goat population increased by 18%, while buffalo population increased by 16% between 1994 and 2000. Major swine production areas were Region 3 (Central Luzon), Region 4A (CALBARZON), and Region 6 (Western Visayas) (Figure 3). Buffalo and cattle populations were widely distributed all over the country while goat populations were highest in Region 7 (Central Visayas) and Region 1 (Ilocos Region).

Philippine ruminants comprise primarily a smallholder-based industry with 97% of the ruminant animals raised in backyard or small holder farms (≤20 heads). For swine, backyard and commercial operators make up the industry with about 80% of swine raised under backyard condition.

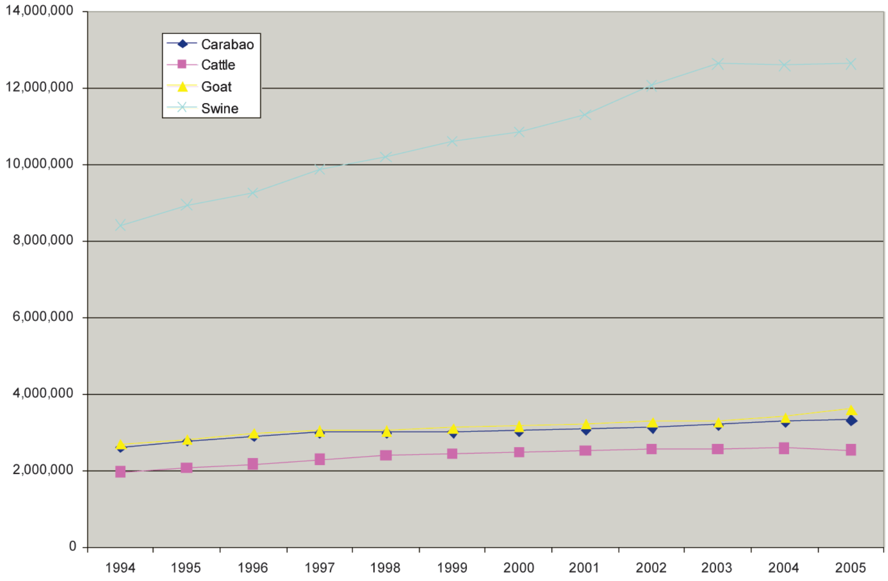


Figure 2. Trends in Livestock Population in the Philippines, 1994-2005

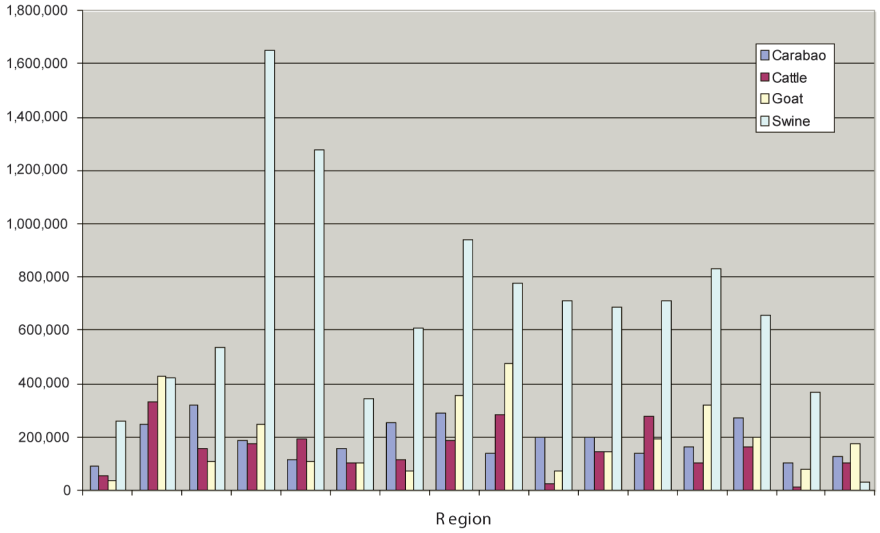


Figure 3. Regional Distribution of Livestock Population in the Philippines

The poultry population in the Philippines is made up of broiler, layer and native chicken. Trend in broiler production has not been consistent as compared to the trend in layer and native chicken production (TABLE 34). Layer chicken inventory increased significantly from 8.3 million in 1994 to 14.9 million in 2000. Similarly, native chicken population considerably increased from 50.1 million in 1994 to 71.2 million in 2000. Overall, total poultry population increased by 24% from 93.2 million in 1994 to 115.2 million in 2000. Total poultry inventory grew by an annual average of 4% with Region III (Central Luzon) as the top producer (Figure 4).

TABLE 34. POULTRY INVENTORY, 1994-2000

	1994	1995	1996	1997	1998	1999	2000
BROILER	34,771,288	27,884,980	39,311,760	46,558,072	46,386,172	32,719,544	29,023,772
LAYER	8,342,140	9,364,485	10,795,977	11,465,905	13,169,673	13,366,526	14,913,360
NATIVE	50,087,584	58,966,260	65,674,656	76,938832	78,964,816	67,702,968	71,249,848
PHILIPPINES	93,201,007	96,215,724	115,782,395	134,962,808	138,520,659	113,789,037	115,186,981

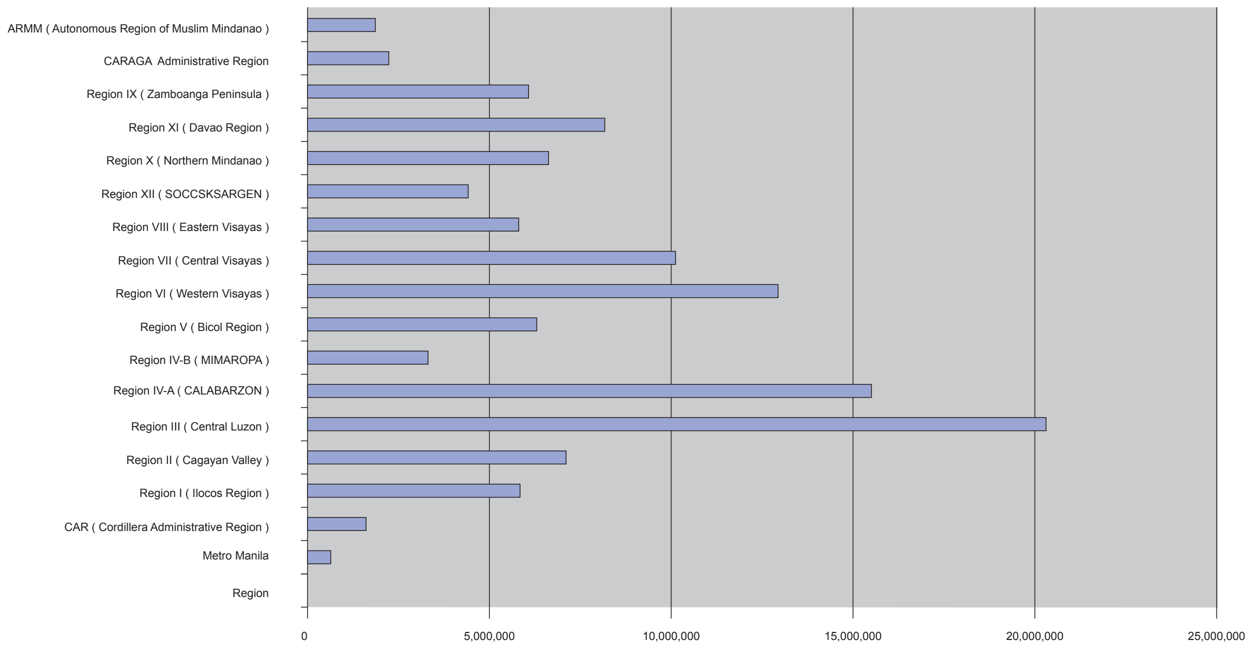


Figure 4. Regional Distribution of Poultry Population in the Philippines

Duck ranked next to chicken in terms of meat and egg production. The Philippines has domesticated about 9.3 million ducks in 2000, a 13% increase over the 1994 population, of which 7.0 million or 77% were in backyard farms while the rest were in commercial establishments (TABLE 35). The duck population between 1994 and 2000 increased at a rate of 2.2%/ year. The highest duck population was recorded in Region 3 (Central Luzon).

TABLE 35. DUCK POPULATION IN THE PHILIPPINES, 1994-2000

	1994	1995	1996	1997	1998	1999	2000
BACKYARD	7,585,108	6,855,460	7,335,159	6,762,241	6,953,335	6,589,101	7,096,891
COMMERCIAL	601,769	2,216,743	2,134,534	2,161,255	1,870,231	2,024,550	2,167,767
TOTAL	8,186,877	9,072,203	9,469,693	8,923,496	8,823,566	8,613,651	9,264,658

Horse population in the Philippines grew minimally between 1994 and 2000 (TABLE 36). Horse population in 2000 reached a total of 230,000 heads or a 4.5% increase over the 1994 population.

TABLE 36. HORSE INVENTORY, 1994-2000

	1994	1995	1996	1997	1998	1999	2000
NO. OF HEADS	220,000	220,000	220,000	230,000	230,000	230,000	230,000

The Philippines has not yet developed country-specific emission factors for enteric fermentation in ruminant and non-ruminant animals. In 1994 GHG inventory, the Philippines used the IPCC default emission factor values for enteric fermentation available that time in the 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997). For the year 2000, in the absence of any country-specific emission factors for enteric fermentation, the updated emission factors in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories were used (IPCC, 2007).

Table 37 summarizes the emission factors used to estimate methane emissions from enteric fermentation in the Philippines for the year 2000 in comparison with the IPCC default values used in 1994 GHG inventory. The 2006 IPCC Guidelines have increased the values of emission factors for dairy and non-dairy cattle. The value for swine decreased while the rest remain the same.

TABLE 37. IPCC DEFAULT EMISSION FACTORS ON METHANE EMISSION FROM ENTERIC FERMENTATION

ANIMAL TYPE	EMISSION FACTOR (KG CH_4/HEAD/YR)	
	1996 GUIDELINES	2006 GUIDELINES
DAIRY CATTLE	56	61
NON-DAIRY CATTLE	44	47
NON-DAIRY BUFFALO	55	55
DAIRY BUFFALO	55	55
MEAT GOATS	5	5
DAIRY GOAT	5	5
HORSES	18	18
DUCK	-	-
SWINE	1.5	1
POULTRY	-	-

Source: IPCC (1997); IPCC (2007)

ESTIMATES OF METHANE EMISSION FROM ENTERIC FERMENTATION

For the year 2000, the total methane emission from enteric fermentation was estimated at 314,502 tonnes CH_4 with non-dairy buffalo and non-dairy cattle contributing 54% and 37%, respectively, or a combined emission of 91% of the total (Figure 5).

Total methane emission from enteric fermentation in 2000 increased by 21% over the 1994 total estimate with the highest increase contributed by non-dairy cattle, 36%; followed by horses 27% (TABLE 38). Decrease in the population of dairy cattle resulted in the decrease of methane emission by 45% of 1994 estimate. Enteric methane emissions from buffalos and goats increased by 16% and 18%, respectively, since 1994. Methane emission from swine slightly decreased by 15%, even with the increase in swine population, due to the use of lower (updated) emission factor.

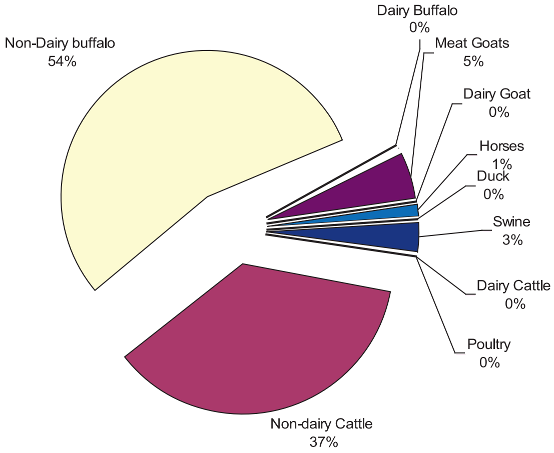


Figure 5.

Methane Emission from Enteric Fermentation in the Philippines, 2000

TABLE 38. ESTIMATES OF METHANE EMISSIONS FROM ENTERIC FERMENTATION IN THE PHILIPPINES IN 2000 IPCC AS COMPARED TO 1994 ESTIMATES

LIVESTOCK TYPE	CH4 EMISSION FROM ENTERIC FERMENTATION, T CH4/YR		
	1994 ESTIMATES	2000 ESTIMATES	% CHANGE OVER 1994
DAIRY CATTLE	784	433	-45
NON-DAIRY CATTLE	85,492	116, 506	36
NON-DAIRY BUFFALO	143, 770	166, 342	
DAIRY BUFFALO		609	16
MEAT GOATS	13,370	15,757	
DAIRY GOAT		4	18
HORSES	3,258	4,140	27
DUCK	-	-	
SWINE	12,561	10,711	-15
POULTRY	-	-	
SHEEP	192	-	-
TOTAL	259,427	314,502	21

Methane emission from enteric fermentation is increasing in the Philippines with major contributions from two major ruminant animals: cattle and buffalo. Most of these animals are widely distributed across the country. Two major factors could have contributed to the increase in emissions namely (i) the increase in livestock population; and (ii) the use of higher value of emission factors for dairy and non-dairy cattle. However, it was the increasing livestock population that significantly contributed to the increase in methane emission.

It should be noted that, for consistency overtime, the 1994 estimates of methane emission from enteric fermentation should be recalculated using the updated enteric emission factors used in 2000 GHG inventory.

METHANE FROM MANURE MANAGEMENT

The method used to estimate methane emission from manure management was similar in form with that used in estimating methane emission from enteric fermentation. It was a simple IPCC Tier 1 approach as shown below:

$$CH_4\ Manure_a = Pop_a * EFmanure_a * 10^{-3}$$

where:

$CH_4\ Manure_a$ = Methane emission from manure management for animal type "a" (Gg/yr)

Pop_a = Population of animal type "a" (in 1000 heads)

$EFmanure_a$ = Emission factor for manure management for animal type "a" (kg CH_4/head/yr)

10^{-3} = Conversion factor (to Gg)

The same livestock types and number of animals used in estimating methane emissions from enteric fermentation were used in estimating methane emission from manure management. Population data of different livestock types were obtained from National Dairy Authority (NDA, 2000); Bureau of Agricultural Statistics (BAS, 2008); and Food and Agriculture Organization (FAO, 2008 database at http://faostat.fao.org).

Again, the Philippines has not yet developed country-specific emission factors for manure management that could allow the use of Tier 2 approach or higher. The 1996 IPCC Guidelines have provided default emission factors, which were updated in the 2006 IPCC Guidelines. These updated emission factors were applied in 2000 GHG inventory to estimate methane emissions from manure management in the Philippines. Comparison of emission factors in the 1996 and 2006 Guidelines is shown in TABLE 39. The 2006 IPCC Guidelines increased the value of emission factor for dairy cattle by 4 points, reduced the value for non-dairy cattle by a single point, while for other livestock types the values remained almost the same.

TABLE 39. COMPARISON OF THE IPCC DEFAULT EMISSION FACTORS ON METHANE EMISSION FROM MANURE MANAGEMENT

ANIMAL TYPE	EMISSION FACTOR (KG CH_4/HEAD/YR)	
	1996 GUIDELINES	2006 GUIDELINES
DAIRY CATTLE	27	31
NON-DAIRY CATTLE	2	1
NON-DAIRY BUFFALO	3	2
DAIRY BUFFALO	3	2
MEAT GOATS	0.22	0.22
DAIRY GOAT	0.22	0.22
HORSES	2.18	2.19
DUCK	0.023	0.02
SWINE	7	7
POULTRY	0.023	0.02

Source: IPCC (1997); IPCC (2007)

ESTIMATES OF METHANE EMISSION FROM MANURE MANAGEMENT

In 2000, the Philippine emitted 87,431 tonnes of methane from animal manure. About 85% of the total emission occurred from the management of swine manure followed by non-dairy buffalo, which contributed only 7% (Figure 6). Total methane emission from manure management increased by 18% over the 1994 estimate (Table 40) with the highest increase of 28% from swine and horses.

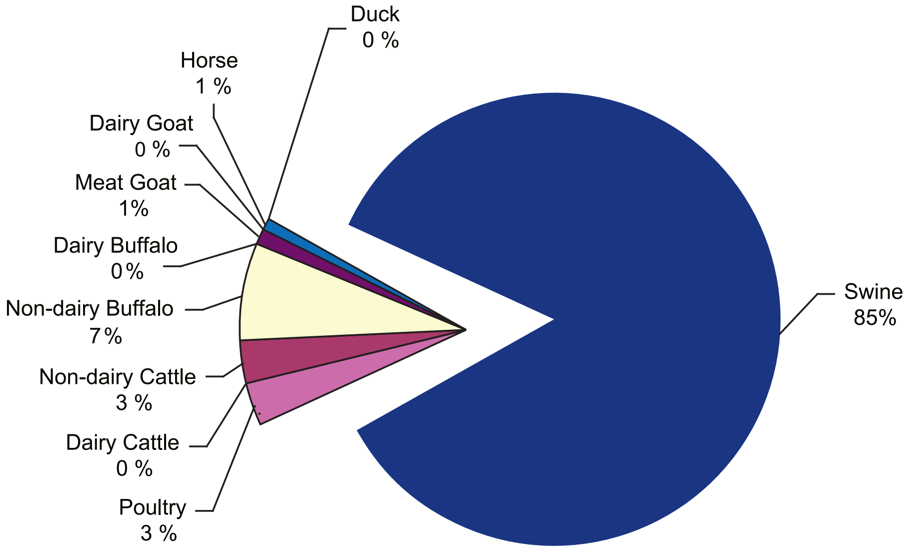


Figure 6. Methane Emission from Manure Management in the Philippines, 2000

TABLE 40. ESTIMATES OF METHANE EMISSIONS FROM MANURE MANAGEMENT IN THE PHILIPPINES IN 2000 IPCC AS COMPARED TO 1994 ESTIMATES

LIVESTOCK TYPE	CH4 EMISSION FROM MANURE MANAGEMENT, T CH4/YR		
	1994 ESTIMATES	2000 ESTIMATES	% CHANGE OVER 1994
DAIRY CATTLE	378	220	-42
NON-DAIRY CATTLE	3,886	2,479	-36
NON-DAIRY BUFFALO	7,842	6,049	
DAIRY BUFFALO		22	-23
MEAT GOATS	588	693	
DAIRY GOAT		0	18
HORSES	395	504	28
DUCK		185	
SWINE	58,618	74,975	28
POULTRY	2,332	2,304	-1
SHEEP	5		
TOTAL	74,044	87,431	18

Methane emission from manure management in the Philippines is increasing. The largest part of the total emission occurred in the management of swine manure, which is most abundant in Region 3 (Central Luzon) and Region 4A (CALABARZON).

Overall, considering methane emissions from enteric fermentation and manure management, the Philippines emitted a total of 402 Gg CH_4 in the year 2000 which is an increase of 21% over the 1994 methane emission from domestic livestock.

NITROUS OXIDE FROM MANURE MANAGEMENT

The amount of N_2O emitted from manure management was estimated using the IPCC Tier 1 approach where the total amount of N excretion (from all livestock species/categories) in each type of manure management system was multiplied by an emission factor for that type of manure management system, as shown in the equation below.

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

where:

$N_2O_{D(mm)}$ = direct N_2O emissions from Manure Management, kg N_2O yr-1

$N_{(T)}$ = number of head of livestock species/category T

$Nex_{(T)}$ = annual average N excretion per head of species/category T, 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, dimensionless

$EF3_{(S)}$ = emission factor for direct N_2O emissions from manure management system S, kg N_2O-N/kg N in manure management system S

S = manure management system

T = species/category of livestock

44/28 = conversion of (N_2O-N)(mm) emissions to N_2O(mm) emissions

The following five steps were used to estimate direct N_2O emissions from manure management in the Philippines in 2000:

- Collect animal population data for year 2000;
- Use default values for the annual average nitrogen excretion rate per head ($Nex_{(T)}$) for each defined livestock species/category T;
- Use country-specific data on the fraction of total annual nitrogen excretion for each livestock species/category T that is managed in each manure management system S ($MS_{(T,S)}$);
- For each manure management system type S, multiply default values for N_2O emission factors for each manure management system S ($EF_{3(S)}$) by the total amount of nitrogen managed (from all livestock species/categories) in that system, to estimate N_2O emissions from that manure management system; and
- Add all manure management systems.

The same data on livestock characterization and populations, used in estimating methane emissions from domestic livestock, were used in estimating N_2O emissions from manure management. In the absence of any country-specific data on nitrogen excretion (Nex) per animal type, the IPCC default values in 2006 Guidelines were used (TABLE 41). The same Nex values are in the 1996 Guidelines.

TABLE 41. NITROGEN EXCRETION AND FRACTION OF MANURE N IN DIFFERENT MANURE MANAGEMENT SYSTEMS IN THE PHILIPPINES

LIVESTOCK TYPE	NUMBER OF ANIMALS	NITROGEN EXCRETION (NEX) (KG/HEAD/YR)
NON-DAIRY CATTLE	2,478,853	40
DAIRY CATTLE	7,100	60
POULTRY	115,186,981	0.6
DUCK	9,264,658	0.6
SWINE	10,710,690	16
NON-DAIRY BUFFALO	3,024,403	40
DAIRY BUFFALO	11,070	40
MEAT GOAT	3,151,472	12
DAIRY GOAT	770	12
HORSE	230,000	40

Source: BAS, 2008; IPCC, 2007 and BAI, 2008

For type of manure management practices, three manure management systems commonly practiced in the Philippines were considered: (i) liquid system; (ii) solid storage and dry lot system; and (iii) pasture range and paddock. TABLE 42 compares the manure management system allocations used in 1994 GHG inventory and 2000 GHG Inventory.

TABLE 42. COMPARISON OF MANURE MANAGEMENT SYSTEM ALLOCATIONS USED IN 1994 AND 2000 GHG INVENTORIES

LIVESTOCK TYPE	LIQUID SYSTEM		SOLID STORAGE AND DRYLOT		PASTURE RANGE AND PADDOCK	
	1994	2000	1994	2000	1994	2000
NON-DAIRY CATTLE	0	0	0.83	0.2	0.17	0.8
DAIRY CATTLE	0	0	0.83	0.2	0.17	0.8
POULTRY	0	0.2	0.73	0.8	0	0
DUCK	-	0.1	-	0.9	-	0
SWINE	0.17	0.2	0.83	0.8	0	0
NON-DAIRY BUFFALO	0	0	0	0.01	1	0.99
DAIRY BUFFALO	0	0		0.01		0.99
MEAT GOAT	0	0	1	0.5	0	0.5
DAIRY GOAT	0	0		0.5		0.5
HORSE	-	0	-	0.5	-	0.5

Source: BAI, 2008; Expert judgment

For cattle, it was a common practice for farmers in the Philippines to graze their animals in idle lands, along roadsides or under coconuts and orchards. Thus it was assumed that about 80% of manure excreted by the animal was directly applied to pasture or graze lands and only 20% was managed in solid storage and dry lot. This assumption was the opposite of what was allocated in cattle in 1994 inventory.

For poultry, duck, and swine, manure management system allocations were almost the same in both inventory years where manure excreted was mostly managed in solid storage and dry lot (about 70 to 90%) and about 10 to 30% was managed in liquid system. It should be noted that 70% of swine-raising in the Philippines (in 2000) was managed in backyards while 30% in commercial scale. Backyard swine system mostly managed the manure in solid storage and dry lot (about 80%) while 20% was managed using lagoon (liquid) system. The reverse, however, was practiced in the case of commercial swine-raising where about 60% of manure was managed in lagoon (liquid) system. Since backyard raising in year 2000 was the dominant practice of swine-raising, the associated manure management system was adopted.

For buffalo, almost all manure excreted by the animal was assumed to be directly managed in pasture lands. For goats and horses, based on expert judgment, it was assumed that 50% of the manure was managed in solid storage and drylot while the remaining 50% was managed in pasture lands.

Pasture range and paddock system directly applies manure nitrogen into the soil and does not entail any storage and handling of manure. Thus, N_2O emissions from pasture range and paddock are calculated and reported in Section 3-6 (N_2O from Agricultural Soils).

In the absence of any country-specific emission factors, the IPCC default emission factors for nitrogen excretion, and emission factor for manure management system (EF_3) were used. TABLE 43 provides the emission factors used for each type of manure management system (EF_3) as taken from the 2006 IPCC Guidelines. The table also compares the EF_3 used in 1994 GHG inventory and 2000 GHG inventory.

TABLE 43. COMPARISON OF EMISSION FACTOR FOR MANURE MANAGEMENT SYSTEM (EF_3) IN 1996 AND 2006 IPCC GUIDELINES, KG N_2O -N/KG N

MANURE MANAGEMENT SYSTEM	1996 GUIDELINES	2006 GUIDELINES
SOLID STORAGE AND DRYLOT	0.02	0.02
LIQUID SYSTEM	0.001	0.005

The Philippines, in 2000, was estimated to produce 514,067,967 kg of nitrogen from animal excretions which were mostly managed in liquid systems, solid storage and dry lots, and in pasture lands (TABLE 44). From the liquid systems, and solid storage and dry lots alone, about 8 Gg N_2O were emitted (TABLE 45). (Note that N_2O emissions from pasture range and paddocks are reported in Section 3.6. Agricultural Soils). This 2000 estimate of N_2O emission from manure management was 29% lower than the 1994 estimate. This reduction in N_2O emission estimate, despite the increase in the livestock population, was mainly due to the allocation of manure management in cattle where a large part was allocated in solid storage and dry lot system.

TABLE 44. ESTIMATED NITROGEN EXCRETION (N_{EX}) FROM DIFFERENT ANIMAL WASTE MANAGEMENT SYSTEMS IN THE PHILIPPINES IN THE YEAR 2000.

ANIMAL WASTE MANAGEMENT SYSTEM (AWMS)	NITROGEN EXCRETION, NEX (KG N/YR)
ANAEROBIC LAGOONS	0
LIQUID SYSTEMS	48,652,525
DAILY SPREAD	0
SOLID STORAGE & DRYLOT	242,033,163
PASTURE RANGE AND PADDOCK	223,382,279
OTHER	0
TOTAL	514,067,967

TABLE 45. N_2O EMISSIONS FROM MANURE MANAGEMENT IN THE PHILIPPINES IN 2000 AS COMPARED TO 1994 INVENTORY, GG N_2O

MANURE MANAGEMENT SYSTEM	1994 ESTIMATES	2000 ESTIMATES	% CHANGE
SOLID STORAGE AND DRYLOT	11.211	7.607	-32
LIQUID SYSTEM	0.062	0.382	517
TOTAL	11.273	7.989	-29

It would be difficult to conclude at this stage if N_2O emission from manure management in the Philippines has decreased or increased. Clearly, if allocation of cattle manure in solid storage and drylot will be adjusted using the assumptions in 2000 Inventory, N_2O emission from manure management in 2000 will increase. There is still much to improve in estimating N_2O emission from this source category particularly in allocating the appropriate manure management system for each animal type. This could be a big challenge in future GHG inventory.

RICE PADDY CULTIVATION

Rice is the Philippines' staple food and many Filipinos depend on it for a living. Rice production remains the highest contributor to the country's gross value added (GVA) in the agriculture sector. In 2007, rice production contributed 34% GVA to the agriculture sector. About 35% of the country's population in 2007 was employed in agriculture with the largest part engaged in rice production. Thus, rice production is crucial to the Philippines' political stability and national security.

Flooding of ricefield leads to anaerobic decomposition of organic material which produces methane (CH_4). This methane escapes to the atmosphere primarily by transport through the rice plants. From the submerged soils, methane also escapes to the atmosphere through diffusion of dissolved methane and ebullition of gas bubbles. The annual amount of methane emitted from a given area of rice field is a function of the number and duration of crops grown, water regime before and during growing period, and the amount of organic and inorganic soil amendments. Soil type, temperature, and rice cultivar or variety also affect methane emissions.

The IPCC Tier 2 approach, using country-specific emission factor for rice cultivation, was applied to estimate methane emissions from rice field in the Philippines in 2000 (IPCC, 2007). The basic equation follows:

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

where:

$CH_{4\ Rice}$ = annual methane emissions from rice cultivation, Gg CH_4/yr

EF_{ijk} = a daily emission factor for *i*, *j*, and *k* conditions, kg CH_4/ha day

t_{ijk} = cultivation period of rice for *i*, *j*, and *k* conditions, day

A_{ijk} = annual harvested area of rice for *i*, *j*, and *k* conditions, ha/yr

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 daily emission factor (EF_{ijk}) was adjusted to account for the differences in water regime before and during the cultivation period, and the amount and type of organic amendments applied into the soil. Effect of soil type and rice cultivar were not accounted for at this stage, due to unavailability of data. The adjusted daily emission factor (EF_i) was derived using the equation developed by IPCC (2007) as follows:

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

where:

EF_i = adjusted daily emission factor for a particular harvested area

EF_c = baseline emission factor for continuously flooded fields without organic amendments

SF_w = scaling factor to account for the differences in water regime during the cultivation period (see 2006 IPCC Guidelines, Table 5.12)

SF_p = scaling factor to account for the differences in water regime in the pre-season before the cultivation

period (see 2006 IPCC Guidelines, Table 5.13)

SF_o = scaling factor should vary for both type and amount of organic amendment applied (see 2006 IPCC Guidelines Equation 5.3 and Table 5.14)

$SF_{s,r}$ = scaling factor for soil type, rice cultivar, etc., if available.

HARVESTED RICE AREA IN YEAR 2000

Rice lands represent about 30% of total crop area harvested in the Philippines. Rice is grown in two seasons: dry season and wet season; and in three ecosystems: irrigated, rainfed, and upland. Upland rice areas are known to contribute insignificant amount of methane emission as compared to irrigated and rainfed areas. Thus, for methane emission, upland rice areas are excluded in the analysis.

Of the 4-million-hectare harvested rice area in 2000, about 67% was irrigated and 33% was rainfed (TABLE 46). There were more rice areas planted in wet season than in dry season obviously due to availability of more water in wet season. For instance, in 2000 dry season, the Philippines cultivated 1,265,742 hectares of rice area under irrigated condition while 471,881 hectares under rainfed (TABLE 46). In the year 2000 wet season, the irrigated area planted to rice increased by 14% while the rainfed area by 83%. Overall, the total harvested area in 2000 was 4,038,085 hectares, exceeding by 15% the reported harvested area of 3,514,200 hectares in 1994 GHG inventory.

TABLE 46. HARVESTED RICE AREAS IN THE PHILIPPINES, 2000

CROPPING SEASON	RICE ECOSYSTEM	AREA, HA	% TOTAL
DRY SEASON	irrigated	1,265,742	31
	rainfed	471,881	12
WET SEASON	Irrigated	1,437,612	36
	Rainfed	862,850	21
TOTAL HARVESTED AREA		4,038,085	100

Source: BAS, 2008

To estimate methane emission from rice cultivation in the Philippines in 2000, data of annual harvested rice area were characterized as follows:

By region: 12 regions plus 3 additional autonomous and administrative regions;
By cropping season: dry season and wet season; and
By rice ecosystem: irrigated rice and rainfed rice.

SEASON LENGTH

The length of growing season for popular rice varieties in the Philippines ranges from 106 to 135 days for irrigated rice; and 109 to 130 for rainfed lowland rice (transplanted). For the 2000 inventory, mean season length values of 114 and 113 days were used for irrigated and rainfed rice, respectively. These season length values were the same as in the 1994 inventory.

The default baseline methane emission factor (Ef_c) provided in the 2006 IPCC Guidelines (IPCC, 2007), for a given rice area with no flooding for less than 180 days prior to rice cultivation and continuously flooded during rice cultivation without organic amendments, is 1.3 kg CH_4 /ha/day with an error range from 0.80 to 2.20 kg CH_4 /ha/day. For the 2000 inventory, country specific methane emission factors were developed using data from methane measurement experiments conducted by the International Rice Research Institute (IRRI) between 1993 and 1999 in the Philippines and other countries in Asia. These data are published in the book "Methane emissions from major ecosystems in Asia", which was reprinted from "Nutrient cycling in Agroecosystems, Volume 58, Nos 1-3 (2000). TABLE 47 presents the country-specific baseline emission factors (Ef_c) for dry and wet season rice cropping in the Philippines based on the IRRI data.

TABLE 47. BASELINE EMISSION FACTOR (EF_c) FOR RICE CULTIVATION IN THE PHILIPPINES

VARIETY	WATER MANAGEMENT	ORGANIC AMENDMENT	CROPPING SEASON	EMISSION FACTOR, KG/HA/DAY
IR72	CONTINUOUS FLOODING	NONE	DRY SEASON	1.46 (0.64 – 2.27)
IR 72	CONTINUOUS FLOODING	NONE	WET SEASON	2.95 (1.39 – 5.16)

Source: Corton *et al.* 2000, Wassman *et al.* 2000

Values in parentheses are the minimum and maximum values applied in different rice growing regions of the Philippines.

Baseline emission factors for the two cropping seasons were adjusted according to rice ecosystem, water regime, and organic amendments. This was done by applying scaling factors for: (i) water regime during the cultivation period, SF_w; (ii) water regime before the cultivation period (pre-season), SF_p; and (iii) the way organic amendments were managed, Sf_o. The scaling factors used were those from 2006 IPCC Guidelines for rice cultivation (IPCC, 2007). TABLE 48 summarizes the mean scaling factors for water regime and organic amendments; the country-specific baseline methane emission factors (Ef_c), and the adjusted daily emission factors (Ef_i) used in estimating methane emissions from irrigated and rainfed rice areas for both dry and wet season cropping.

To obtain the value for the scaling factor SF_p, which describes the water regime before the rice growing period, it was assumed that most rice fields in the Philippines were not flooded during preseason (i.e. before the growing period) for less than 180 days. Hence, the IPCC SF_p default value of 1.0 was used for both seasons and rice ecosystems (see 2006 IPCC Guidelines Table 5.13).

For the scaling factor SF_w, which describes the water regime during rice cultivation period, the factors used for irrigated rice in most regions of the country range from 0.52 (for intermittently flooded rice with multiple aeration) to 0.60 (for intermittently flooded rice with single aeration) or a mean value of 0.57 for irrigated rice field. In rainfed rice, the factors used in most of the regions range from 0.25 (for drought prone regions like Regions 1 and 2) to 0.28 (for regular rainfed areas) or a mean value of 0.27 for rainfed rice field.

The equation below was used to obtain the value for the adjusted scaling factor Sf_o, which describes the type and amount of organic amendment applied on the soil:

$$SF_0 = \left(1 + \sum ROA_i \bullet CFOA_i\right)^{0.59}$$

Where:

SF_0 = 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, 111one/ha; and

$CFOA_i$ = conversion factor for organic amendment i (in terms of its relative effect with respect to straw applied shortly before cultivation; see Table 5.14, 2006 IPCC Guidelines)

Table 49 shows the assumptions used to estimate the scaling factor SFo (farther down).

TABLE 48. SUMMARY OF SCALING FACTORS (SF), BASELINE EMISSION FACTORS (EF_C), AND ADJUSTED DAILY EMISSION FACTORS (EF_I) USED IN ESTIMATING METHANE EMISSIONS FROM RICE CULTIVATION IN THE PHILIPPINE, 2000

CROPPING SEASON	RICE ECOSYSTEM	SF_P	SF_W	SF_O	EF_C KG/HA/ DAY	EF_I KG/HA/ DAY
DRY SEASON	Irrigated	1.0	0.57	1.27	1.46	1.05
	Rainfed	1.0	0.57	1.27		0.46
WET SEASON	Irrigated	1.0	0.57	1.76	2.95	2.97
	Rainfed	1.0	0.27	1.54		1.23

For Regions 1 to 3, after the dry season harvest, it was assumed that 70% of rice straw produced was fed to animals, 20% was burned, and the remaining 10% was left in the field to decompose. During wet season, same percentage was fed to animals, only 5% was burned, while the rest was returned to soils to decompose. However, for rice farmers in Regions 4 to 12, it was assumed that most of the rice straws produced are burned during dry season and returned to the field (soils) to decay during wet season.

TABLE 49. ASSUMPTION ON RICE STRAW MANAGEMENT TO ESTIMATE SCALING FACTOR (SFO) FOR ORGANIC AMMENDMENT APPLIED.

RICE STRAW MANAGEMENT	REG 1 TO 3		REG 4 TO 14	
	DS	WS	DS	WS
FED TO ANIMALS	0.7	0.7	0	0
BURNED	0.2	0.05	0.75	0.15
RETURNED TO SOIL				
- STUBLE	0.1	0.1	0.25	0.25
- STACKED/DECOMPOSED	0	0.15	0	0.6

The emission factors used in 1994 estimates for irrigated rice was 2.3kg/ha/day and 0.4kg/ha/day for rainfed rice. These values were obtained from the IRRI experiments conducted in 1994. At that time, IRRI had just started their project on methane emission measurements. Compared with the updated emission factors in Table 48 derived from more than 5 years of continuous measurements also by IRRI, the 1994 EF values were much lower than the factors used in 2000 estimates, apart from the value used in dry season irrigated rice. Clearly, the wet season Ef_s are much higher than the dry season Efs due to more flooded conditions during wet season.

ESTIMATE OF METHANE EMISSIONS FROM RICE FIELD

The Philippines, in the year 2000, emitted 782.7 Gg of methane from rice cultivation (TABLE 50). This estimate is 23% higher than the 1994 estimate of methane emission from rice cultivation.

About 78% of the total emission occurred during the wet season (where more rice areas were flooded most of the time) and only 22% during the dry season. Irrigated rice areas contributed 82% of the total methane emission while rainfed areas contributed only 18%.

TABLE 50. ESTIMATES OF METHANE EMISSIONS FROM RICE CULTIVATION IN THE PHILIPPINES, 2000

CROPPING SEASON	RICE ECOSYSTEM	2000 ESTIMATES (GG CH_4)	% TOTAL
DRY SEASON	Irrigated	151.5	19.4
	Rainfed	24.5	3.1
WET SEASON	Irrigated	486.8	62.2
	Rainfed	119.9	15.3
TOTAL		**782.7**	**100.0**

It is not appropriate to compare the 1994 estimate of methane emission with the 2000 estimates since the emission factors used were very much different and scaling factors were not applied. Also, the 2000 estimates include methane emissions from pre-season (prior to cultivation) which was not considered in the 1994 estimates.

GRASSLAND BURNING

The Agriculture sector in the IPCC Guidelines accounts for the emissions of greenhouse gases from prescribed burning of savannas. The term *savanna* refers to tropical and subtropical vegetative formations with grass coverage occasionally interrupted by some shrubs and small trees. However, savanna does not appear in the Philippine inventory of vegetative coverage, primarily because the term is not widely used by local foresters. For this reason, Philippine grassland, which more or less resembles a typical savanna in terms of vegetative cover, is substituted in its place.

The IPCC Guidelines considers grassland as a source of non-CO_2 gases such as methane (CH_4), carbon monoxide (CO), nitrous oxide (N_2O), and oxides of nitrogen (NO_x) and not as a net source of CO_2 emission. The Guidelines assumes that the CO_2 released from burning will be reabsorbed eventually during the next growing season. Grasslands are burned during the dry season primarily for agricultural purposes such as ridding the areas of weeds and pests, promoting nutrient cycling, and encouraging the growth of new grasses for animal grazing.

The IPCC Tier 1 method was used in estimating GHG emissions from grassland burning which consist of two basic components. The first component estimated the total amount of carbon released to the atmosphere from grassland burning. This calculation required the annual grassland area burned. Based on the area and type of grassland burned, the amount of carbon released was calculated (a reflection of biomass densities, fractions burned, carbon contents and fractions oxidized). The following equations summarize the calculations to estimate the total carbon released due to the burning of grassland:

Area of Savanna Burned Annually (ha) = Total Area of Savanna (ha) x Fraction Burned Annually;

Biomass burned (t dm) = Area of Savanna Burned Annually (ha) x Aboveground Biomass Density (t dm/ha) x Fraction Actually Burned;

Carbon Carbon Released from Live Biomass (t C) = Biomass Burned (t dm) x Fraction that is Live x Fraction Oxidised x Carbon Content of Live Biomass (t C/t dm);

Carbon Released from Dead Biomass (t C) = Biomass Burned (t dm) x Fraction that is Dead x Fraction Oxidised x Carbon Content of Dead Biomass (t C/t dm)

Total Carbon Released (t C) = C Released from Live Material (t C) + C Released from Dead Material (t C)

The second component of the calculation involved the multiplication of emission ratios to estimate the amount of trace gas released based on the amount of carbon released. The amount of carbon released due to burning was multiplied by the emission ratios of CH_4 and CO relative to total carbon released to yield emissions of CH_4 and CO (each expressed in units of C). The emissions of CH_4 and CO are multiplied by 16/12 and 28/12, respectively, to convert to full molecular weights. To calculate emissions of N_2O and NO_x, first, the carbon released was multiplied by the estimated ratio of nitrogen to carbon (N/C ratio) in grassland biomass by weight (0.006 is a general default value for savanna biomass burning (Crutzen and Andreae, 1990). This yielded the total amount of nitrogen (N) released from the biomass burned. The total N released was then multiplied by the ratios of emissions of N_2O and NO_x relative to the N released to yield emissions of N_2O and NO_x (expressed in units of N). To convert to full molecular weights, the emissions of N_2O and NO_x were multiplied by 44/28 and 46/14, respectively. The non-CO_2 trace gas emissions calculations from grassland burning are summarised as follows:

CH_4 Emissions = (carbon released) x (emission ratio) x 16/12
CO Emissions = (carbon released) x (emission ratio) x 28/12
N_2O Emissions = (carbon released) x (N/C ratio) x (emission ratio) x 44/28
NO_x Emissions = (carbon released) x (N/C ratio) x (emission ratio) x 46/14

The total grassland area in the Philippines was estimated between 1 to 5 million hectares, though the figure has not been accurately determined due to constant land use change, that is, from idle grasslands to cultivated farms and vice-versa (Lasco et al., 2006). Most of these grassland areas are found in the provinces of Cagayan and Isabela in Luzon; in the island provinces of Masbate and Occidental Mindoro; and in the provinces of South Cotabato, North Cotabato, and Bukidnon in Mindanao.

Grassland areas in the Philippines are dominated by “cogon grass” (*Imperata cylindrica*), which constitutes about 50% of the total grazing area (Orlido-Aguilar, 1995). These grasslands are usually subject to a vicious grass-fire-grass cycle by upland farmers who manage the land for subsistence. Cogon grass is considered a noxious weed not only because it reduces agricultural productivity but it is also toxic to grazing animals and a host to many plant pathogens and pests. Ways to control cogon grass include pulling (which is labor intensive), poisoning with herbicide, and burning.

Due to lack of data on the extent of burning cogon areas in the Philippines, for 2000 inventory, it was assumed that about 5% of the total cogon areas in the country were burned based on expert judgment. Hence, the total area of grassland burned was estimated at 75,000 ha annually based on the following computation:

Area of Grassland Burned Annually (ha) = 3 million ha of grassland x 0.5 (as cogon areas) x 0.05 (as fraction burned annually) = 75,000 ha

In the absence of any data to establish country-specific factors, the default values contained in the 1996 IPCC Guidelines were used:

COUNTRY-SPECIFIC FACTOR	VALUE	REFERENCES
ABOVEGROUND BIOMASS DENSITY	4.9 t dm/ha	see 1996 IPCC Guidelines, Workbook, Table 4-12 for Tropical Asia
FRACTION ACTUALLY BURNED	0.83	see 1996 IPCC Guidelines, Workbook, page 4.25
FRACTION OF LIVING BIOMASS BURNED	0.5	expert judgment with reference to 1996 IPCC Guidelines, Workbook, Table 4-12
FRACTION OXIDIZED OF BIOMASS	0.80 for living biomass and 1.0 for dead biomass	see 1996 IPCC Guidelines, Workbook, Table 4-13
CARBON FRACTION OF BIOMASS	0.50 for living and 0.50 for dead	Lasco and Pulhin, 1999
NITROGEN-CARBON RATIO	0.006	see 1996 IPCC Guidelines, Workbook, page 4.28
EMISSION RATIO	0.004 for CH_4; 0.06 for CO; 0.007 for N_2O; and 0.121 for NO_x	see 1996 IPCC Guidelines, Workbook, Table 4-14

For the Conversion Ratio for non- CO_2 gases, see Table 51 below:

TABLE 51. MOLECULAR CONVERSION RATIOS

COMPOUND	DEFAULT VALUE
Methane (CH_4)	16/12
Carbon Monoxide (CO)	28/12
Nitrous Oxide (N_2O)	44/28
Nitrogen Oxides (NO_x)	46/14

ESTIMATES OF GHG EMISSIONS FROM GRASSLAND BURNING

From the 75,000 ha of cogon areas burned in 2000, it was estimated that the Philippines grasslands emitted about 0.73, 19.22, 0.01, and 0.33 Gg of CH_4, CO, N_2O, and NO_x, respectively (TABLE 52). These emission estimates were considerably higher than the 1994 GHG estimates from grassland burning due to the assumption that the area burned was believed to be much higher than the 1,660 ha assumed in 1994.

TABLE 52. NON-CO_2 EMISSIONS FROM GRASSLAND BURNING, 2000

COMPOUND	AMOUNT EMITTED, GG
Methane (CH_4)	0.73
Carbon Monoxide (CO)	19.22
Nitrous Oxide (N_2O)	0.01
Nitrogen Oxides (NO_x)	0.33

GHG emissions from grassland burning could be considered small as compared to other categories. The current emission estimates could be highly uncertain due to lack of data and the appropriate emission factors. If grassland areas will increase in the future, due to land degradation (i.e. caused by soil erosion, deforestation, etc.), the Philippines has to put forth additional effort to improve its grassland database including the activities therein.

AGRICULTURAL RESIDUE BURNING

Agriculture produces large quantities of wastes in the form of crop residues. It is a common farming practice in many developing countries like the Philippines to burn such agricultural residues. The most common of which are from rice, corn, and sugarcane.

Grown in about 4 million hectares or 30% of the total crop area harvested in the Philippines, rice produces large quantities of straw, which in most provinces are burned during the dry season (although in the northern part of the country, rice straw is used as important feed source for animals and as mulching material for vegetable crops). Traditionally, Filipino farmers heap the rice straw into piles at threshing sites (normally in several spots within the field) and then burned after harvest (Dobermann and Fairhurst 2002) to prevent the straw from obstructing succeeding field activities. However, during the wet season, burning becomes less common as rains moisten the rice straw. In such instances when rice straw are too moist to burn, farmers leave them in heaps and allow them to decompose until before the next cropping.

Sugarcane is among the top five agricultural crops in the Philippines in terms of hectarage, which at 0.38 million hectares represents about 3% of the country's total crop area. Production is concentrated in four regions: (1) Western Visayas; (2) Northern Mindanao; (3) Southern Tagalog; and (4) Central Luzon. Like rice, it produces large volumes of residue, which are traditionally burned by farmers. Farmers practice burning of sugarcane trash (leaves and tops) to make harvesting easier and to prevent the trash from obstructing succeeding land operations.

Corn, as a second staple (white corn) and an important input (yellow corn) for the livestock industry is grown widely across the country although production volume is dominated by Mindanao and some provinces in Luzon. Similar to that of rice, corn stovers are normally left in the field to dry up and decompose naturally while corn cobs are normally piled up outside processing plants after shelling for use as fuel and for other minor purposes (Ramat 2007). Only a few farmers practice burning of corn residues and it is difficult to measure how much of the corn residues are burned as no agency monitors this kind of activity. However, it is included in this estimation as this crop, like rice and sugarcane, is grown in large quantities.

Burning of crop residues is not thought to be a net source of carbon dioxide (CO_2) because the carbon released to the atmosphere during burning is reabsorbed during the next growing season. However, burning emits not only CO_2, but also other greenhouse gases, or precursors of greenhouse gases that originate from incomplete combustion of the fuel. Thus, crop residue burning is a significant net source of carbon monoxide (CO), methane (CH_4), non-methane volatile organic compounds (NMVOC) and nitrogen (e.g., N_2O, NO_x) species (Levine, 1994).

The following sections discuss the methodology, activity data, and emission factors used to estimate non-CO_2 emissions from the burning of agricultural residues in the Philippines for the year 2000. Burning of crop residues for purposes other than the disposal and reduction of the volume of agricultural waste is not covered in this section. Emissions from crop residues removed from fields and burned for fuel are reported in the Energy sector.

The IPCC Tier 1 method was used to estimate non-CO_2 emissions from burning of agricultural residues. This is similar to the method used in estimating GHG emissions from savanna (grassland burning) as presented in Section 3.4. The method estimates (i) total carbon released, which is a function of the amount and efficiency of biomass burned and the carbon content of the biomass, and (ii) the application of emission ratios of CH_4 and CO to total carbon released, and of N_2O and NO_x to total nitrogen released from biomass fires.

The 1996 IPCC guidelines recommend, if available, the use of 3-year averages of activity data for crop residues burned, to estimate non-co_2 emissions from burning of agricultural residues. For the estimates of annual crop production in the year 2000, the 3-year averages of annual production between 1999 and 2001, for rice, sugarcane, and corn, were used as presented in Table 53.

TABLE 53. ANNUAL PRODUCTION OF MAJOR CROPS IN THE PHILIPPINES (GG)

CROP	1999	2000	2001	MEAN
Rice : Dry Season	5,272.05	5,442.50	5,567.83	5,427.46
Rice : Wet Season	6,514.57	6,946.92	7,387.04	6,949.51
Sugarcane	23,777.83	21,223.44	21,708.72	22,236.66
Corn	4,584.59	4,511.10	4,525.01	4,450.24

Source: BAS, 2009

In the absence of any data to establish country-specific factors, the default values contained in the 1996 IPCC Guidelines were used. Some values were similar to what had been used in the 1994 GHG inventory:

COUNTRY-SPECIFIC FACTOR	VALUE	REFERENCE
Residue to Crop Ratio	1.4 for rice and 1.0 for corn; and 0.8 for sugarcane	1996 IPCC Guidelines, Workbook, Table 4-15; Hawaii, 1999
Dry matter fraction	0.83 for rice and 0.40 for corn; and 0.9 for sugarcane	1996 IPCC Guidelines, Workbook, Table 4-15; Hawaii, 1999
Fraction burned in fields	0.59 for dry season rice and 0.12 for wet season rice; and 0.25 for corn and sugarcane	1996 IPCC Guidelines Reference Manual, page 4.83
Fraction oxidized	0.9 for dry season rice and 0.7 for wet season rice; and 0.9 for corn and sugarcane	1996 IPCC Guidelines, Workbook, page 4.31
Carbon fraction of residue	0.4144 for rice; 0.5 for sugarcane; and 0.4709 for corn	1996 IPCC Guidelines, Workbook, Table 4-15
Nitrogen-Carbon Ratio	0.014 for rice; 0.015 for sugarcane; and 0.020 for corn	1996 IPCC Guidelines, Workbook, Table 4-15
Emission Ratio	0.004 for CH_4; 0.06 for CO; 0.007 for N_2O; and 0.121 for NO_x	1996 IPCC Guidelines, Workbook, Table 4-14

For the Conversion Ratio for non- CO_2 gases, see Table 51 above.

ESTIMATES OF GHG EMISSIONS FROM BURNING OF AGRICULTURAL RESIDUES

For the year 2000, it was estimated that the Philippines emitted 24.42, 512.74, 0.60, and 21.56 Gg of CH_4, CO, N_2O, and NO_x, respectively. These estimates are slightly higher than the 1994 GHG emissions from the burning of agricultural residues.

Non-CO_2 emissions from the burning of agricultural residues are also considerably small in the case of the Philippines. It may likely continue to decrease in the future as farmers in the Philippines are becoming aware of the adverse impact of burning biomass (i.e. contributing to the increase in atmospheric GHG concentrations), and the positive consequences of organic farming for sustainable development.

AGRICULTURAL SOILS

Agricultural soils may emit or remove nitrous oxide (N_2O). N_2O emission occurs in soils through the processes of nitrification and denitrification. Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). There are three known pathways of N_2O emissions from soils: (i) direct emissions of N_2O from agricultural soils; (ii) direct soil emissions of N_2O from animal production; and (iii) indirect emissions of N_2O from nitrogen used in agriculture.

Anthropogenic input of nitrogen into the agricultural system is known to promote N_2O emissions in soils. Such inputs include the nitrogen from the application of synthetic fertilizer, nitrogen from animal wastes, nitrogen from increased biological N-fixation, and nitrogen derived from cultivation of mineral and organic soils through enhanced organic matter mineralisation.

N_2O may also be produced and emitted directly in agricultural fields, animal confinements or grazing areas or be transported from agricultural systems into ground and surface waters through surface runoff, nitrogen leaching, consumption by humans and introduction into sewage systems which transport the nitrogen ultimately into surface water. Ammonia and oxides of N (NO_x) are also emitted from agricultural systems and may be transported off-site and serve to fertilise other systems which leads to enhanced production of N_2O.

This section estimates direct and indirect N_2O emissions from the anthropogenic input of nitrogen into agricultural soils in the Philippines for the inventory year 2000.

DIRECT NITROUS OXIDE EMISSIONS FROM AGRICULTURAL SOILS

Direct N_2O emission from agricultural soils was estimated using the Tier 1 method provided in the 1996 IPCC Guidelines. The method is summarized in the following equation:

$$N_2O_{DIR} = \left[\frac{(F_{SN} + F_{AW} + F_{BN} + F_{CR}) \times EF_1}{10^3} + \frac{F_{OS} + EF_2}{10^6} \right] \times \frac{44}{28}$$

where:

N_2O_{DIR} = direct N_2O emissions from agricultural soils (Gg N_2O/yr);

F_{SN} = synthetic nitrogen fertilizer applied, corrected for NH_3 and NO_X emissions (t N/yr);

F_{AW} = amount of manure nitrogen used as fertilizer, excluding manure produced during grazing and corrected for NH_3 and NO_X emissions;

F_{BN} = amount of nitrogen fixed by N-fixing crops (t N/yr);

F_{CR} = amount of nitrogen in crop residues returned to soils (t N/yr);

EF_1 = emission factor for direct soil emissions (t N_2O-N/t N input);

F_{OS} = area (ha) of cultivated organic soils (histosols);

EF_2 = emission factor for organic soil mineralization due to cultivation (kg N_2O-N/ha/yr); and

$44/28$ = molecular conversion ratio.

To obtain F_{SN}, the synthetic nitrogen fertilizer consumption data is multiplied by a correction factor to account for the fraction of nitrogen in the fertilizer that is emitted as NH_3 and NO_X, as shown by the equation below:

$$F_{SN} = N_{FERT} \times (1 - Frac_{GASF})$$

where:

F_{SN} = corrected total synthetic N fertilizer (t N/yr);

N_{FERT} = total synthetic nitrogen consumed in the country (t N/yr); and

$Frac_{GASF}$ = fraction of synthetic nitrogen fertilizer that volatilizes as NH_3 and NO_x (see Table 11.3 of the 2006 IPCC Guideleines).

The corrected nitrogen input from animal wastes (F_{AW}) is obtained by multiplying the value of the total manure nitrogen excreted (N_{EX}) by a correction factor. The correction factors account for the fraction of nitrogen that volatilizes as NH_3 and NO_X, fraction of N manure used as fuel, and fraction of N manure deposited in soils during grazing;

$$F_{AW} = N_{EX} \times [1 - (Frac_{GASM} + Frac_{FUEL} + Frac_{GRAZING})]$$

where:

F_{AW} = corrected manure nitrogen (t N/yr);

N_{EX} = total livestock nitrogen excretion (t N/yr);

$Frac_{GASM}$ = fraction of manure nitrogen that volatilizes as NH_3 and NO_X;

$Frac_{FUEL}$ = fraction of manure nitrogen burned for fuel; and

$Frac_{GRAZING}$ = fraction of manure nitrogen deposited onto soil during grazing.Nitrogen derived from the N-fixation of crops (F_{BN}) is computed using the equation below,

$$F_{BN} = 2 \times Crop_{BF} + Frac_{NCRBF}$$

where:

F_{BN} = nitrogen input from N-fixing crops (t N/yr);

$Crop_{BF}$ = seed yield of legumes in the country (t dry biomass/yr); and.

$Frac_{NCRBF}$ = fraction of nitrogen in N-fixing crops.

The factor 2 converts the edible portion of the crop (which is reflected in the production data) to total crop biomass.

Nitrogen returned to soil from crop residues left to decompose in the fields, on the other hand, is estimated using the equation,

$$F_{CR} = 2 \times [\,Crop_{O} \times Frac_{NCRO} \times Crop_{BF} \times Frac_{NCRBF}\,] \times (1 - Frac_{R}) \times (Frac_{BURN})$$

where:

F_{CR} = nitrogen input to soils from crop residues (t N/yr)

$Crop_{BF}$ = production of legumes in the country (t dry biomass/yr)

$Crop_{O}$ = production of all food crops in the country minus $Crop_{BF}$ (t dry biomass/yr)

$Frac_{NCRBF}$ = fraction of nitrogen in N-fixing crops

$Frac_{NCRO}$ = fraction of nitrogen in non-N-fixing crops

$Frac_{R}$ = fraction of crop residues that is removed from the field as crop

$Frac_{BURN}$ = fraction of crop residue that is burned

The factor 2 converts edible crop production to total crop biomass production.

As required in the above equation, the following nitrogen inputs were estimated for the Philippines in the year 2000:

(i) total amount of synthetic fertilizer applied to soil = 488,200 kg N/yr;

(ii) the total amount of animal waste produced = 514,067,967 kg N/yr (see Section 3.2 on N_2O Emission from Manure Management);

(iii) production of non-N fixing crops = 59,171,426,010 kg dry biomass/yr (see below);

(iv) production of N-fixing crops = 246,283,000 kg dry biomass/yr (see TABLE 54 below);

(v) the amount of N input from N fixing crop was obtained using the data of production of N fixing crops (see TABLE 50) multiplied by fraction of nitrogen in N-fixing crop (default value was 0.03 kg N/kg of dry biomass) and then multiplied by 2 to convert production to total biomass. The resulting amount was = 14,776,980 kg N.

TABLE 54. PRODUCTION OF NON-N-FIXING CROPS IN THE PHILIPPINES, 2000

NON-FIXING CRIOS	DOMESTIC PRODUCTION (METRIC TONS)
CEREALS, RICE, CORN, ETC.	27,546,031.27
ROOT CROPS	2,805,889.40
SUGARCANE	27,913,407.90
VEGETABLES	906,097.44
TOTAL	59,171,426.01

Source: National Statistical Coordination Board (NSCB), 2006.

TABLE 55. PRODUCTION OF N-FIXING CROPS IN THE PHILIPPINES, 2000

N-FIXING CROPS	DOMESTIC PRODUCTION (METRIC TONS)
MUNGBEAN	27,459
OTHER DRIED BEANS	1,842
SOYBEANS	953
PEANUTS	26,622
OTHER PULSES AND NUTS	189,407
TOTAL	246,283

Source: National Statistical Coordination Board (NSCB), 2006.

In the absence of any country-specific emission factors the IPCC default values contained in the 1996 IPCC Guidelines and updated in the 2006 IPCC Guidelines were used:

(i) For the manure nitrogen used,

a. The fraction of nitrogen burned for fuel is assumed to be zero (manure is not used as fuel in the Philippines);

b. Fraction of nitrogen excreted during grazing = 0.02 (see 1996 IPCC Guidelines, Workbook, Table A-1 for Asia and Far East);

c. Fraction of nitrogen excreted emitted as NOx and NH3 = 0.2 kg NH3–N + NOx –N/kg of nitrogen excreted by livestock (see 1996 IPCC Guidelines, Workbook, Table 4-17).

(ii) For nitrogen input from crop residues,

a. Fraction of nitrogen in non-N-fixing crops = 0.015 kg N/kg of dry biomass see 1996 IPCC Guidelines, Workbook, Table 4-17);

b. Fraction of nitrogen in N fixing crops = 0.03 kg N/kg of dry biomass (see 1996 IPCC Guidelines, Workbook, Table 4-17);

c. Fraction of crop residue removed from field = 0.45 kg N/kg crop N (see 1996 IPCC Guidelines, Workbook, Table 4-17);

d. Fraction of crop residue burned = 0.25 kg N/kg crop-N for developing countries (see 1996 IPCC Guidelines, Workbook, Table 4-17)

(iii) For the factor for direct N_2O emission (EF^1),

a. For synthetic fertilizer (FSO) = 0.003 kg N20 –N/kg N for rice (most of the fertilizers in the Philippines are applied in rice); (see 2006 IPCC Guidelines, Vol. 4, Table 11.1);

b. For animal waste (FAW) = 0.01 kg N20 –N/kg (see 2006 IPCC Guidelines, Vol. 4, Table 11.1);

c. For N-fixing crops (FBN) = 0.01 kg N20 –N/kg (see 2006 IPCC Guidelines, Vol. 4, Table 11.1);

d. For crop residues (FCR) = 0.01 kg N20 –N/kg (see 2006 IPCC Guidelines, Vol. 4, Table 11.1)

ESTIMATES OF DIRECT N_2O EMISSION FROM MANAGEMENT OF AGRICULTURAL SOILS

In 2000, management of agricultural soils in the Philippines resulted in direct emissions of N_2O amounting to 11.542 Gg N_2O-N (TABLE 56). About 64% of the N_2O emission was due to the incorporation of crop residues into the soils while 35% occurred from the addition of animal waste in the soils.

TABLE 56. DIRECT N_2O EMISSIONS FROM MANAGEMENT OF AGRICULTURAL SOILS IN THE PHILIPPINES, 2000

TYPE OF N INPUT TO SOILS	DIRECT N_2O EMISSIONS (GG N_2O-N/YR)	% TOTAL
SYNTHETIC FERTILISER (FSN)	0.001	0.01
ANIMAL WASTE (FAW)	4.010	34.74
N-FIXING CROPS (FBN)	0.148	1.28
CROP RESIDUE (FCR)	7.383	63.97
TOTAL	11.542	100.00

DIRECT NITROUS OXIDE EMISSIONS FROM CULTIVATION OF HISTOSOLS

N_2O emissions from cultivation of histosols were obtained using the IPCC Tier 1 method as shown in the equation below:

$$N_2O_{OS} = (F_{OS} \times EF_2) / 1000,000$$

where:

N_2O_{OS} = direct N_20 emissions from histosols, Gg N_20 –N/yr

F_{OS} = area of cultivated organic soils, ha

EF_2 = emission factor for direct soil emissions, kg N_20 –N/ha/yr

According to the interpreted World Soil Map by Van Englen and Hutin (2002), the Philippines has 853 km^2 of histosols or organic soils. For the year 2000, and for this GHG inventory, it was assumed (by expert judgment) that 10% of the total area (8,530 ha) were cleared and drained for agriculture in the Philippines.

The IPCC emission factor (EF_2) for tropical organic cropland soils of 16 kg N_20-N/ha was used to estimate direct N_20 emissions from cultivated organic soils (see 2006 IPCC Guidelines, Vol. 4, Table 11.1).

ESTIMATES OF DIRECT N_2O EMISSION FROM CULTIVATION OF HISTOSOLS

For the year 2000, it was estimated that cultivation of organic soils in the Philippines contributed around 0.14 Gg of N_20 -N. No estimate from this source category was reported in the 1994 GHG Inventory.

DIRECT NITROUS OXIDE EMISSIONS FROM GRAZING ANIMALS

N_20 emissions from grazing animals are estimated by multiplying the total nitrogen excretion value, N_{EX}, for pasture range and paddock by an appropriate emission factor and by the molecular conversion ratios:

$$N_2O_{GRAZING} = \left(\frac{N_{EXPR} \times EF_3 \times \frac{44}{28}}{1000} \right)$$

where:

$N_2O_{GRAZING}$ = N_20 emissions from grazing animals (t N_20/yr)

N_{EXPR} = nitrogen excretion value for pasture range and paddock (t N/yr)

EF_3 = N_20 emission factor for pasture range and paddock (t N_20-N/yr)

The values 44/28 and 1000 convert N_20 emissions to total molecular weight and gigagrams, respectively.

The IPCC default emission factor (EF_3) for cattle (dairy, non-dairy and buffalo), poultry and pigs of 0.02 kg N_20 –N/kg N was used in the absence of any country-specific emission factor (see 2006 IPCC Guidelines, Vol. 4, Table 11.1).

ESTIMATES OF DIRECT N_2O EMISSIONS FROM GRAZING OF ANIMALS

The Philippines, in 2000, was estimated to have emitted 7.02 Gg N_2O from animal grazing. This estimate presents a significant increase from the estimate in the 1994 inventory since it is assumed (based on expert judgment) that 80% of cattle manure in the Philippines are disposed (excreted) in pasture lands instead of 17% assumed in the 1994 inventory.

Overall, the total direct N_2O emission from the philippines in the year 2000 is 25.37 gg N_2O with about 72% accounted for by the management of agricultural soils (n inputs) and 28% from the grazing of animals (Table 57).

TABLE 57. TOTAL DIRECT N_2O EMISSIONS IN THE PHILIPPINES, 2000

SOURCE CATEGORY	DIRECT N_2O EMISSION	
	(GG N_2O-N)	(GG N_2O)
Management of Agricultural Soils	11.542	
Cultivation of Organic Soils	0.140	
Subtotal		18.35
Grazing Animals		7.02
Total Direct N_2O Emissions		25.37

Note: Conversion factor 44/28 is multiplied to convert N_2O-N to N_2O.

INDIRECT NITROUS OXIDE EMISSIONS FROM ATMOSPHERIC DEPOSITION OF NH_3 AND NO_x

The IPCC Tier 1 method of estimating indirect N_2O emissions from atmospheric deposition of N that volatilized from agricultural soils is given by the equation:

$$N_2O_{(G)} = (N_{FERT} \times FRAC_{GASF} + NEX \times FRAC_{GASM}) \times EF_4$$

where:

$N_2O_{(G)}$ = N_2O emissions from country due to atmospheric deposition of NH_3 and NO_x (kg N/yr);

N_{FERT} = total use of synthetic fertilizer in country (kg N/yr);

NEX = total nitrogen excretion by animals in country (kg N/yr);

$FRAC_{GASF}$ = fraction of total synthetic fertiliser nitrogen that is emitted as $NO_x + NH_3$ (kg N/kg N);

$FRAC_{GASM}$ = fraction of total nitrogen excretion that is emitted as NO_x or NH_3 (kg N/kg N); and

EF_4 = Emission factor for atmospheric deposition (kg N_2O –N/kg N)

As shown above, the data needed to estimate indirect N_2O emissions from atmospheric deposition of NH_3 and NO_x are the total amount of synthetic fertilizer used in the country, and the total nitrogen excretion by animals. In 2000, it was estimated that the Philippines applied a total of 488,200 kg N from synthetic fertilizer. The total amount of animal excretion was estimated to have contributed 514 million kg N.

In the absence of any country-specific emission factors for indirect N_2O emissions from atmospheric deposition, the following IPCC default values were used:

(i) Fraction of synthetic N fertilizer applied that volatilizes = 0.10 kg (NH_3–N + NO_x –N)/kg N applied (see 2006 IPCC Guidelines, Vol. 4, Table 11.3)

(ii) Fraction of total manure N excreted that volatilizes = 0.20 kg (NH_3–N + NO_x –N)/kg N applied or deposited(see 2006 IPCC Guidelines, Vol. 4, Table 11.3)

(iii) Emission Factor (EF4) for N volatilization and re-deposition = 0.01 kg N_2O –N/(kg NH_3–N + NO_x –N) volatilized; (see 2006 IPCC Guidelines, Vol. 4, Table 11.3)

ESTIMATES OF INDIRECT N_2O EMISSION FROM ATMOSPHERIC DEPOSITION OF NH_3 AND NO_x

From the half a million kg of nitrogen applied in the soil through the use of synthetic fertilizer, and the half billion kg N produced from animal waste, it was estimated that the Philippines in 2000 emitted 1.03 Gg N_2O -N.

INDIRECT NITROUS OXIDE EMISSIONS FROM LEACHING

To estimate indirect N_2O emissions from leaching, the following IPCC Tier 1 equation was used:

$$N_2O_{(L)} = (N_{FERT} + NEX) \times FRAC_{LEACH} \times EF_5.$$

where:

$N_2O_{(L)}$ = N_2O emissions from country due to atmospheric deposition of NH_3 and NO_x (kg N/yr);

$FRAC_{LEACH}$ = total nitrogen excretion by animals in country (kg N/yr);

$EF_5.$ = Emission factor for leaching (kg N_2O –N/kg N leached)

As shown in the above equation, data on fertilizer use and animal excretion are needed to estimate indirect N_2O emissions from leaching. For the year 2000, it was estimated that the Philippines applied a total amount of 488,200 kg N of synthetic fertilizer and about half a billion kg N was produced from animal excretion (see Table 11a).

The following IPCC default emission factors were used to estimate indirect N_2O emissions from leaching:

(i) Fraction of N that leaches = 0.30 kg N/ kg N additions or deposition by grazing animals (see 2006 IPCC Guidelines, Vol. 4, Table 11.3)

(ii) Emission Factor (EF_5) for leaching = 0.0075 kg N_2O –N/kg N leaching and runoff (see 2006 IPCC Guidelines, Vol. 4, Table 11.3)

Overall, the Philippines in the year 2000, indirectly emitted a total of 3.44 Gg N_2O into the atmosphere with 47% of the total contributed by the atmospheric deposition of NH_3 and NO_x.

TABLE 58. TOTAL INDIRECT N_2O EMISSIONS IN THE PHILIPPINES, 2000

SOURCE CATEGORY	DIRECT N_2O EMISSION	
	(GG N_2O-N)	(GG N_2O)
Atmospheric deposition of NH_3 and NO_x	1.030	
Leaching	1.160	
TOTAL DIRECT N_2O EMISSIONS		3.44

Note: Conversion factor 44/28 is multiplied to convert N_2O-N to N_2O.

TABLE 59 summarizes the total N_2O emission of the Philippines in 2000. The country emitted 28.81 Gg N_2O with 88% of total contributed by the direct application of N fertilizer, crop residues, and animal wastes; cultivation of organic soils; and grazing of domestic livestock.

TABLE 59. TOTAL N2O EMISSIONS FROM AGRICULTURAL SOILS IN THE PHILIPPINES, 2000

SOURCE CATEGORY	(GG N_2O)
Total Direct N_2O Emission	25.37
Total Indirect N_2O Emission	3.44
TOTAL	28.81

Most of the methodologies used in estimating N_2O emissions from Agricultural soils were taken from the IPCC Guidelines and were only based on Tier 1 approach. To improve the reliability of estimates, the Philippines should aim to use higher tiers. But this of course will depend on the availability of activity data and emission factors which currently are still very limited in the country.

There is still a lot of room to improve the estimates from this source category. If GHG contribution from this source category will continue to increase due to intensified agricultural production (i.e. high N input) in response to increasing demand for food , the Philippines should strive to strengthen its effort to improve its database particularly in determining: (i) the amount of synthetic fertilizers applied per type of crop; (ii) the amount of animal waste that is disposed in each type of manure management system; and (iii) the area of organic soils (peat land) that is drained and used for agricultural production.

TABLE 60. SUMMARY OF GHG EMISSIONS FROM AGRICULTURE IN THE PHILIPPINES, 2000

SOURCE	EMISSIONS OF GAS, GG				GG CO2 EQUIVALENT
	CH_4	N_2O	NO_x	CO	
Enteric Fermentation	314.50				6,604.54
Manure Management	87.43	7.90			4,312.65
Rice Cultivation	782.71				16,436.95
Agricultural Soils		28.81			8,930.66
Prescribed Burning of Savannas	0.73	0.01	0.33	19.22	18.18
Field Burning of Agricultural Residues	24.42	0.60	21.56	512.74	697.67
Total Agriculture	1,209.79	37.40	21.89	531.74	37,000.65

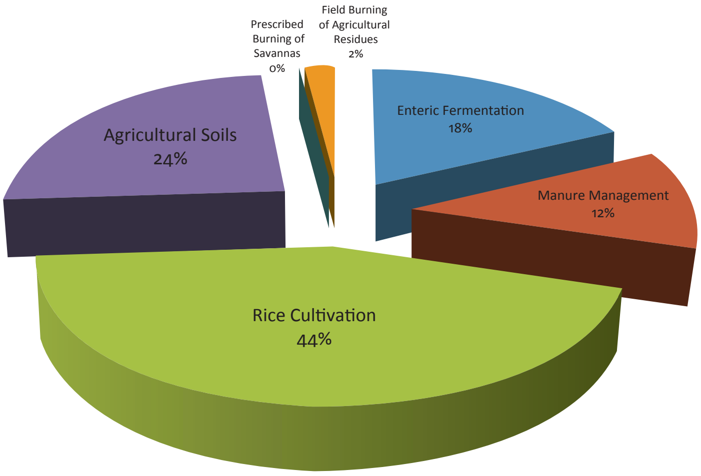


Figure 7. Summary Of GHG Emissions from Agriculture in the Philippines, 2000.

Clearly, rice cultivation, domestic livestock, and agricultural soils are important sources of GHG emissions in the Philippines. To improve future estimates of GHG inventory in these important source categories, the country would need to rally in terms of strengthening its database for activity data, and research efforts to develop country-specific emission factors.

In terms of methane emission from rice cultivation, further improvement can be done to enhance the characterization of areas under different water management practices and residue management practices. There was no database available that describes rice areas under different water regimes and organic amendments. It will also improve the annual estimate of methane emissions from rice cultivation if it will try to consider those days between cropping seasons (particularly in continuously flooded areas) when methane emissions could have occurred even without the planted rice.

For domestic livestock, most of the estimates are based on the IPCC default values. The challenge to improve the estimates from this source category is to develop country-specific emission factors that would be applicable to the type and breed of animals that the Philippines has. The characterization of manure management practices in the Philippines is also a big challenge. Currently, there is no available database that describes how animal manure is managed in the country.

The estimates of N_2O emissions from agricultural soils are still highly uncertain aside from the fact that most of the emission factors used are IPCC default values. The big challenge is to improve the database for activity data on the amount of N fertilizer applied to the soil, the amount of animal manure that is incorporated into the soil, the amount of animal excretion in pasture lands that went into the soil. The information has not yet been established and there was very limited information available when this 2000 GHG inventory was performed.

CALCULATING GREENHOUSE GAS EMISSIONS

Five worksheets are used for calculating greenhouse gas emissions from this sector. Each worksheet has several component sheets needed to complete the calculations. These are listed in below.

Worksheet 4-1: CH_4 and N_2O Emissions from Domestic Livestock

Sheet 1: CH_4 from Enteric Fermentation and Manure Management
Sheet 2: N_2O Emissions from Manure Management
Supplementary: Nitrogen Excretion for AWMS

Worksheet 4-2: CH_4 Emissions from Flooded Rice Fields

Sheet 1: Rice Paddy Emissions

Worksheet 4-3: Prescribed Burning of Grassland

Sheet 1: Biomass Burned
Sheet 2: Total Carbon Released
Sheet 3: Total Emissions from Grassland Burning

Worksheet 4-4: Field Burning of Agricultural Residues

Sheet 1: Total Biomass Burned

Sheet 2: Total Nitrogen Released

Sheet 3: Total Trace Gas Emissions

Worksheet 4-5: Agricultural Soils

Sheet 1: Direct N_2O Emissions from Agricultural Fields

Sheet 2: Direct N_2O Emissions Including Histosols

Sheet 3: N_2O Soil Emissions from Grazing Animals

Sheet 4: Indirect N_2O Emissions from Atmos Deposition

Sheet 5: Indirect N_2O Emissions from Leaching

EMISSIONS FROM DOMESTIC LIVESTOCK

Worksheet 4-1 estimates methane and nitrous oxide emissions from domestic livestock by determining the amount of livestock population and the emission factors for enteric fermentation. The livestock population data may be obtained from the database of the Bureau of Animal Statistics at http://countrystat.bas.gov.ph/index.asp. Other possible sources of data are the Bureau of Animal Industry (BAI), National Statistical Coordination Board (NSCB), and the Food and Agriculture Organzation (FAO). Because nationally developed emission factors for enteric fermentation is absent, the IPCC default values may be used.

CH_4 EMISSIONS

Step 1: Estimate the Methane Emitted from Enteric Fermentation and Manure Management

Worksheet 2-1, Sheet 1 of 2

1. Specify the types of livestock in the first column.
2. Enter the population (in number of heads) for each type of livestock in column A and its corresponding emission factor (in kg/head/year) in column B.
3. Multiply column A with column B and divide the product by 1000 to obtain the emissions from each type of livestock in terms of ton/year. Enter the result in column C.
4. Add all the values in column C and enter the result at the bottom of the column.
5. Enter the methane emission factor for manure management (kg/head/year) for each type of livestock in column D.
6. Multiply column A with column D and divide the product by 1000 then enter the result in column E.
7. Add all the values in column E and enter the result at the bottom of the column.
8. In column F, enter the sum of column C and E divided by 1000.
9. Add all the values in column F and enter the sum at the bottom of the column.

N_2O EMISSIONS

STEP 1: Estimate the Nitrogen Excretion per animal waste management system

Worksheet 2-1, Supplementary Sheet

1. Specify the types of livestock in the first column.
2. For each type of livestock, enter the animal population and nitrogen excretion in columns A and B respectively.
3. Enter in column C the fraction of manure handled in different Animal Waste Management Systems (AWMS).

Step 2: Estimate the Nitrogen Oxide Emissions form Manure Management

Worksheet 4-1, Sheet 2 of 2

1. Enter the emission factor for each type of AWMS in column B. If local data is unavailable, refer to Appendix X, Table Y for IPCC default values.
2. Add all the values in column C and generate the sum at the bottom of the column.

EMISSIONS FROM RICE CULTIVATION

Worksheet 4-2 calculates the methane emissions from the flooded rice fields by determining the annual harvested area of rice, the cultivation period of rice, and the daily emission factor for methane emission in rice. The data on harvested rice can be obtained from the Bureau of Agricultural Statisics (BAS) at http://countrystat.bas.gov.ph/index.asp and the International Rice Research Institute (IRRI) at http://beta.irri.org. The data on season length of rice varieties can be obtained from the research publications of the Philippine Rice Research Institute (PhilRice) and IRRI. Country-specific emission factors were developed by IRRI in 2000.

CH_4 EMISSIONS

Step 1: Estimate emissions from flooded rice fields

Worksheet 4-2, Sheet 1 of 1

1. Under the “Water Management” column, characterize the harvested rice area according to season and rice ecosystem.
2. For each water management scheme, enter the data on harvested area in column A, season length in column B, and the adjusted daily emission factors (EFi) in column D. Refer to XX for the EFis.
3. For column E, multiply the values in columns A,B, and D and divide the product by 1000.
4. The sum of the values in column E is the total methane emissions from rice paddy cultivation.

EMISSIONS FROM GRASSLAND BURNING

Worksheet 4-3 estimates GHG emissions from the burning of savannas. A savanna, characterized by tropical and subtropical vegetative formations with grass coverage occasionally interrupted by shrubs and small trees, is not common in the Philippines. Hence, for the Philippine inventory, the savanna may be substituted by grassland which resembles a typical savanna in terms of vegetative cover. The data on grassland area may be obtained in published research papers and country profiles. Supplementary data may be obtained from international databases on Pasture and Grassland Management. IPCC default values may be used in sections where country-specific data is unavailable.

Step 1: Estimate the Quantity of the Biomass burned

Worksheet 4-3, Sheet 1 of 3

1. Enter the area (in kilohectares) of grassland burned in column A.
2. Enter the biomass density of the grassland in column B. If local data is unavailable, the 1996 IPCC default value for Tropical Asia (4.9 t dm/ha) may be used.
3. Enter the product of columns A and B in column C.
4. Enter the fraction of biomass that actually burned. If local value is unavailable, the IPCC default value (0.80-0.85) may be used.
5. Enter the product of columns C and D to column E.
6. Enter the fraction of living biomass burned in column F.
7. Enter the product of columns E and F in column G.
8. Subtract column G from E and enter the difference in column H.

STEP 2: Estimate the total carbon released

Worksheet 4-3, Sheet 2 of 3

1. In column I, enter in the appropriate boxes the fraction oxidized for living and dead biomass.
2. Enter the carbon fraction for living and dead biomass in column K. 0.50 for both living and dead biomass may be used (Lasco and Pulhin, 1999).
3. The sum of the values in column L is the amount of carbon released from living and dead biomass.

CH_4, CO, N_2O, AND NO_x EMISSIONS

Step 1: Estimate the total emissions from burning

Worksheet 4-3, Sheet 3 of 3

1. Enter nitrogen to carbon ratio in column M.
2. Enter the product of columns L and M in column N.
3. Enter the emission ratio for each gas in column O.

4. Enter the following molecular conversion ratio for each gas in column 4: 16/12 for CH_4, 28/12 for CO, 44/28 for N_2O, and 46/14 for NO_x.
5. Column R shows the emissions from grassland b$_u$rning for each gas emitted.

EMISSIONS FROM FIELD BURNING OF AGRICULTURAL RESIDUES

Agriculture produces large quantities of wastes in the form of crop residues. It is a common practice among farmers in the Philippines to burn such agricultural residues. The most common agricultural residues burned in the country are from rice, corn, and sugarcane. Burning of crop residues is not a net source of carbon dioxide (CO_2) because the carbon released to the atmosphere during burning is reabsorbed during the next growing season. However, burning emits not only CO_2, but also other greenhouse gases, or precursors of greenhouse gases that originate from incomplete combustion of the fuel. Thus, crop residue burning is a significant net source of carbon monoxide (CO), methane (CH_4), non-methane volatile organic compounds (NMVOC) and nitrogen species (Levine, 1994).

Worksheet 4-4 estimates the non-CO_2 GHG emissions by determining the crop residue management practices and inferring the crop residue burned from the crop production data. This data can be obtained from Bureau of Agricultural Statistics and published research journals. In the absence of country specific emission factors and other activity data, the IPCC default values may be used.

TRACE GASES

Step 1: Estimate the amount of agricultural residues burned

Worksheet 4-4, Sheet 1 of 3

1. In the first column, specify locally important crops whose resides are burned in the fields.
2. Input the annual production (in Gg) for each crop type in column A. The IPCC recommends using three-year averages (centered on the inventory year) of crop production data.
3. Enter the crop residue ratio for each type of crop in column B.
4. Enter the dry matter fraction of each type of crop.
5. Input the fraction of crop residue burned in the fields for each crop type in column F.
6. Input the fraction oxidized for each crop type in column G

Step 2: Estimate the amount of Nitrogen Released

Worksheet 4-4, Sheet 2 of 3

1. Enter the carbon fraction of each residue in column I.
2. Enter the nitrogen to carbon ratio for each crop type in column K.
3. Column L shows the amount of nitrogen released.

Step 3: Estimate the total trace gas emissions

Worksheet 4-4, Sheet 3 of 3

1. Enter the emission ratio for each gas in column M.
2. Enter the molecular conversion ratio for each gas in column O.
3. Column P shows the total trace gas emissions from the field burning of agricultural residues.

EMISSIONS FROM AGRICULTURAL SOILS

Worksheet 4-5 calculates N_2O emissions from agricultural soil systems including direct N_2O emissions from agricultural soils, N_2O soil emissions from grazing animals, and indirect N_2O emissions from nitrogen used in agriculture. These data can be obtained from the National Statistical Coordination Board (NSCB), and the databases of the Bureau of Agricultural Statistics (BAS -http://countrystat.bas.gov.ph/index.asp) and the Food and Agriculture Organization (FAO-http://faostat.fao.org/default.aspx).

DIRECT N_2O EMISSIONS

Step 1: Estimate direct nitrous oxide emissions excluding the cultivation of histosols

Worksheet 4-5, Sheet 1 of 5

1. The first box of column A requires the total synthetic fertilizer N (F_{SN}) that is not emitted as NH_3 and NO_x. To obtain this, go to Worksheet 4-5, Sheet 4 of 5.
    a. 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).
    b. The software automatically calculates F_{SN}.
    c. Go back to Worksheet 4-5, Sheet 1 of 5.
2. The second box of column A requires the amount of manure nitrogen used as fertilizer (F_{AW}), corrected for NH_3 and NO_x emissions, and excluding manure produced during grazing. To obtain this, use 4-5A (Supplement).
    a. Enter the fraction of N burned for fuel. For the Philippines, the fraction of N burned is 0.0 because manure is not used for fuel.
    b. Enter the fraction of N excreted during grazing in column C. Use the 1996 IPCC default value for Asia and the Far East: 0.02.
    c. Enter the fraction of N excreted that is emitted as NOX and NH3. The 1966 IPCC default value of 0.2kg may be used.
    d. The software automatically calculates FAW.
    e. Go back to Worksheet 4-5, Sheet 1 of 5.

3. The third box in column A required the total N input from N-fixing crops (F_{BN}). This can be obtained by doing the following:
    a. Get the amount of N (in kg) input from N fixing crops in the NSCB.
    b. Multiply it by the 0.03 (kg N/kg of dry biomass).
    c. The product is the F_{BN}
4. The fourth box in column A requires the total N input from crop residues (F_{CR}). To obtain this, go to Worksheet 4-5B (Supplemental).
    a. In column A, enter the amount (in kg dry biomass/yr) of non-N fixing crops produced in the country. This can be obtained from the NSCB.
    b. Enter the fraction of nitrogen in non-N fixing crops ($Frac_{NCRO}$). If a country-specific value is absent the 1996 IPCC default value of 0.015 (N/kg of dry biomass) can be used.
    c. Enter the production of N-fixing crops ($Crop_{BF}$) in kg dry biomass/yr in column C. This can also be obtained from the NSCB.
    d. Enter the fraction of nitrogen in N-fixing crops ($Frac_{NCRBF}$) in column D. The 1996 IPCC default value of 0.03 may be used.
    e. Input 0.55 in column E. (E= 1-$Frac_R$, whereby $Frac_R$ default value is 0.45).
    f. Input 0.75 in column F. (F=1-$Frac_{BURN}$ whereby $Frac_{BURN}$ default value is 0.25).
    g. Go back to Worksheet 4-5, Sheet 1 of 5.
5. Enter the factor for direct N_2O emission for each type of N input in column B. If local data is unavailable, use the following IPCC default values:
    a. FSO: 0.003 kg N2O-N/kg N for rice
    b. FAW: 0.01 kg N2O-N/kg
    c. FBN: 0.01 kg N2O-N/kg
    d. FCR: 0.01 kg N2O-N/kg
    6. The direct soil emissions for each type of N can be found in column C.

Step 2: Estimate the direct Nitrous Oxide Emissions from the Cultivation of Histosols

Worksheet 4-5, Sheet 2 of 5

1. Enter the area (in hectares) of cultivated organic soils (called Histosols) in column D.
2. Enter in column E the emission factor (EF_2) for direct soil emissions. If the country-specific EF_2 is unavailable, 16 kg N_2O-N/ha for organic cropland soils may be used (2006 IPCC Guidelines).
3. The N_2O emission from soils can be seen in column G.

Step 3: Estimate the N_2O emissions from grazing animals

Worksheet 4-5, Sheet 3 of 5

1. Enter the emission factor (EF_3) for pasture range and paddock in column B. The 2006 default value of 0.02 kg N_2O-N/kg for cattle (non-dairy and buffalo), poultry and pigs may be used if local EF_3 is unavailable.
2. The software automatically calculates the N_2O emissions from grazing animals in column C.

Step 1: Estimate the Indirect Nitrous Oxide Emissions from Atmospheric Deposition

Worksheet 4-5, Sheet 4 of 5

1. Enter the total synthetic nitrogen applied to the soil in column A.
2. Input the fraction of synthetic nitrogen fertilizer 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.
3. Enter the fraction of total N manure excreted that volatilized as NH_4 and NO_x in column E. The 2006 IPCC default value of 0.20 kg (NH_3-N + NO_x-N)/kg N applied or deposited may be used.
4. Enter the emission factor (EF_4) for N volatilization and re-deposition in column G. Use the IPCC 2006 default value of 0.01 kg N_2O -N/kg(NH_3-N+ NO_x -N) volatilized if local data is absent.

Step 2: Indirect Nitrous Oxide Emissions from Leaching

Worksheet 4-5, Sheet 5 of 5

1. Enter the fraction of N that leaches in column K. The 2006 IPCC default value of 0.30 kg N/ kg N additions or deposition by grazing animals may be used.
2. Enter the emission factor (EF_5) for leaching in column L. Use the 2006 IPCC default value of 0.0075 kg N_2O-N/kg N leaching and runoff if national values are absent.
3. The total indirect N_2O emissions are automatically calculated in column N and the total N_2O emission from agricultural soils in column O.

Land Use Change and Forestry Sector

OVERVIEW

Majority of the greenhouse gas emissions from the Land Use Change and Forestry Sector (LUCF) are attributed to anthropogenic activities such as timber harvesting and conversion of forest into other land uses such as agriculture, settlement, etc. Forest can be a source or sink of carbon depending on the balance between photosynthesis and respiration and the degree to which it is converted into other land uses. In photosynthesis, trees absorb carbon dioxide (CO_2) from the atmosphere and store carbon in their biomass and soil (Brown *et. al.*, 1992; and Trexler *et al.* 1992).

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

a) Changes in forest/woody carbon stocks due to the net annual biomass growth of existing forest and non-forest stands, and possible biomass regrowth in abandoned lands;

b) Land use and forest conversion practices which affect the carbon chemistry of the atmosphere via biomass burning, decay, and soil carbon release or uptake.

REFERENCE MANUAL

Majority of the greenhouse gas emissions from the Land Use Change and Forestry Sector (LUCF) are attributed to anthropogenic activities such as timber harvesting and conversion of forest into other land uses such as agriculture, settlement, etc. Forest can be a source or sink of carbon depending on the balance between photosynthesis and respiration and the degree to which it is converted into other land uses. The net carbon uptake or emission of the LUCF sector is dependent on two basic biophysical processes:

a) Changes in forest/woody carbon stocks due to the net annual biomass growth of existing forest and non-forest stands, and possible biomass regrowth in abandoned lands;

b) Land use and forest conversion practices which affect the carbon chemistry of the atmosphere via biomass burning, decay, and soil carbon release or uptake.

GHG emissions or uptake from biomass regrowth in abandoned lands and soil carbon are not accounted in this inventory because of data unavailability. Thus, the inventory of GHG sources and sinks for the LUCF sector is limited only to the influence of net annual biomass growth, roundwood harvests, and biomass burning and decay.

CHANGES IN FOREST/WOODY BIOMASS STOCKS

BIOMASS GROWTH

Of the total land area of the Philippines covering 30 million ha, 15.9 million ha is classified as forest land and the remaining 14.1 million ha is categorized as alienable and disposable land (A & D). While more than half of the land area has been legally classified as forestlands, not all of the forestland is covered with the original cover of lush tropical rainforest as most of them had been converted into other land uses such as grassland, brushland, upland farms etc.

The annual uptake of carbon due to biomass growth is determined using the following equation:

$$G = A \times B \times C \times 1000$$

where G is the annual carbon uptake due to biomass growth (in kilotonnes carbon or kt C), A is the land area covered by a particular land use (in million hectares or Mha), B is the annual biomass growth rate (in tonnes dry matter per hectare per year, or t dm/ha/yr), C is the percent carbon contained in the biomass which is valued at 45 (average percent carbon value for forests in the Philippines), and **1000** is a factor to convert MtC to kt C.

One of the factors that determine the amount of carbon uptake due to biomass growth of the LUCF is the area covered by each land use. Data for this parameter is derived from the Forestry Statistics being published yearly by the Forest Management Bureau of the Department of Environment and Natural Resources. *Table 61* shows the area covered by each land use expressed in million ha for the year 2000.

TABLE 61. AREA COVERED BY VARIOUS LAND USES IN THE PHILIPPINES

LAND USE	AREA (MHA)	PERCENT
Old growth	0.805	5.07
Residual	2.731	17.20
Pine	0.228	1.44
Submarginal	0.475	2.99
Mossy	1.040	6.55
Mangrove	0.112	0.71
Tree Plantation	0.492	3.10
Upland farms	2.693	16.96
Brushland	4.794	30.19
Grassland	2.509	15.80

Source: FMB, 2000

As shown in *Table 61*, bulk of the legally classified forestlands is covered with brush while mangrove occupies the least land area. These land uses represent 30% and 0.71%, respectively. Old growth forests which used to occupy most of the land area of the Philippines when the Spanish colonizers first set foot in the country in 1521 inhabits less than a million ha. Most of the old growth forests had been converted to other land uses through time because of a number of factors: population growth, policies, logging, among others. Residual forests covers 2.7 Mha representing around 17% of the total classified forestlands. Upland farms and grassland occupy more or less equal space as the former has a total land area of 2.69 Mha while the latter covers 2.51 Mha. Mossy forests while they can be found in the upper slopes of the forestlands, seems not spared from exploitation as the area it occupies also declined from 1.07 Mha in 1994 to 1.04 Mha in 2000. Mossy forests represent a mere 6.5% of the total forestlands while tree plantations represent 3% only. Pine and submarginal forests have 0.228 Mha (or 1.44%) and 0.475 Mha (2.99%).

A brief description of the different land uses are found below. These are taken verbatim from the glossary definitions in the 2000 Philippine Forestry Statistics book of the FMB-DENR.

Dipterocarp Forest: Forest stand dominated by trees of dipterocarp species such as red and white lauan, tanguile, tiaong, almon, bagtikan and myapis of the Philippine mahogany group, apitongs and yakals.

Old growth forest (dipterocarp): tropical rain forest dominated by Dipterocarpaceae without traces of commercial logging.

Residual forest (dipterocarp): tropical rain forest dominated by Dipterocarpaceae with traces of commercial logging.

Mangrove forest: occurring on tidal flats along the sea coast extending along the streams where the water is brackish and composed mainly of bakauan, pototan, langarai, api-api, nipa palm, and the like.

Mossy forest: tropical rain forest of the high elevations dominated by Podocarpaceae, Myrtaceae, and Fagaceae with trees of medium height and short boled, covered epiphytes.

Pine (closed) forest: pure stands of Benguet or Mindoro pine with crown cover above 30%.

Pine (open) forest: pure stands of Benguet or Mindoro pine with crown cover of 10-30%.

Submarginal forest: tropical forest dominated by Leguminosae and lesser utilized species, mainly restricted to shallow and excessively drained limestone soils.

Brushland: degraded or untimbered areas dominated by a discontinuous cover of shrubby vegetation.

The areas covered by tree plantations are derived by taking the sum of the reported reforested areas from 1990 to 2000. Upland farms on the other hand are taken from the areas that are planted to different types of agroforestry systems.

In terms of grasslands, various sources report different areas covered. Since the Forestry Statistics of the FMB-

DENR is the agency that officially releases data in forestry, the area for grasslands is derived from the difference between the total land area classified as forestland and the sum of the other land uses reported in the FMB Forestry Statistics. It should be noted that the area of grassland is not very crucial as it is assumed that the net carbon uptake of this land use is zero as it is regularly being burned.

In calculating the biomass uptake, data of mean annual increment of each land use and carbon content are needed. Values for these components are derived from the studies conducted in the Philippines for several years (Please see TABLE 62).

TABLE 62. MAI OF ABOVE GROUND BIOMASS AND CARBON IN THE PHILIPPINES

LAND COVER	AGE(YR)	BIOMASS MAI (T/HA)	CARBON MAI (T/HA)	LOCATION	SOURCE OF DATA
A. Protection Forests	Nd	Nd	Nd		
B. Secondary Forest	nd	2.1	0.9	Leyte	Lasco et al., 1999
	nd	4.9	1.19	Mindanao	Kawahara et al., 1981
Mean		3.5	1.1		
C. Brushlands		9.5	4.3	Leyte	Lasco et al., 1999
D. Tree Plantation					
S. Macrophylla	44	14.24	6.4	Makiling	Racelis, 2000
Dipterocarps	66	7.37	3.3	Makiling	Racelis, 2000
A. auriculiformis	16	9.08	4.1	N. Ecija	Lasco et al., 2000
S. macrophylla		8.39	3.3	Leyte	Lasco et al., 1999
G. arborea		18.84	8.2	Leyte	Lasco et al., 1999
G. arborea	7	11.3	5.51	Mindanao	Kawahara et al., 1981
G. arborea	9	10.5	4.37	Mindanao	Kawahara et al., 1981
G. arborea	9	9.6	6.04	Mindanao	Kawahara et al., 1981
P. falcataria	4	20.2	7.82	Mindanao	Kawahara et al., 1981
P. falcataria	5	11.2	6.8	Mindanao	Kawahara et al., 1981
P. falcataria	7	8.4	6.2	Mindanao	Kawahara et al., 1981
P. falcataria	7	2.2	0.52	Mindanao	Kawahara et al., 1981
P. falcataria	9	5.3	5.41	Mindanao	Kawahara et al., 1981
P. falcataria	9	3.7	1.44	Mindanao	Kawahara et al., 1981
S. macrophylla	16	19.6	7.33	Mindanao	Kawahara et al., 1981
A. auriculiformis*	6	1.231766	0.6	N. Ecija	Lasco, 2001
A. auriculiformis 2*	6	1.661289	0.7	N. Ecija	Sakurai et al., 1994
A. auriculiformis 3*	9	4.723807	2.1	N. Ecija	

A. auriculiformis 4*	9	3.555892	1.6	N. Ecija	
A. auriculiformis 5*	9	5.123389	2.3	N. Ecija	
A. auriculiformis 6*	9	4.414571	2.0	N. Ecija	
T. grandis 1*	13	0.669576	0.3	N. Ecija	
T. grandis 2*	13	1.71554	0.8	N. Ecija	
G. arborea 1*	6	2.869172	1.3	N. Ecija	
G. arborea 2*	6	1.285075	0.6	N. Ecija	
Pinus kesiya*	13	8.29455	3.7	N. Ecija	
P. kesiya + broadleaf spp*.	13	6.403308	2.9	N. Ecija	
Acacia mangium*	4	14.225	6.4	Leyte	Buante, 1997Lasco 2001
G. arborea*	4	17.55	7.9	Leyte	Buante, 1997Lasco 2001
A. auriculiformis*	4	15.875	7.1	Leyte	Buante, 1997Lasco 2001
Acacia neriifolia*	4	21.78127	9.8	Iloilo	Lasco, 2001
A. holosericea*	4	8.599975	3.9	Iloilo	Lachica-Lustica, 1997
A. crassicarpa*	4	38.94815	17.5	Iloilo	
A. aulacocarpa*	4	14.09045	6.3	Iloilo	
Leucaena diversifolia*	4	0.164304	0.1	Iloilo	
Casuarin cuminghiana*	4	0.802636	0.4	Iloilo	
C. equisitifolia*	4	3.886252	1.7	Iloilo	
Eucalyptus citrodora*	4	13.10143	5.9	Iloilo	
E. cloeziana*	4	12.06799	5.4	Iloilo	
E. pellita*	4	8.498015	3.8	Iloilo	
E. tereticornis*	4	12.46637	5.6	Iloilo	
S. macrophylla	80	7.061438	3.2	Makiling	Lasco 2001
S. macrophylla	80	7.937386	3.6	Makiling	Sakurai et al., 1994
Dipterocarps	80	6.701469	3.0	Makiling	
Dipterocarps	80	3.489233	1.6	Makiling	
Mean		9.1	4.2		
E. Grasslands	nd	Nd	nd		
F. Agroforestry					
Fallow system**	nd	10.6	5.3	Cebu	Lasco and Suson, 1989

Source of area: FMB, 1998 except tree plantations. Grasslands and agroforestry which are estimates from various literature sources

% Carbon of trees only

Carbon content assumed to be 45% for all data from Kawahara et al., 1981

* Carbon content assumed to be 45%

** Carbon content assumed to be 50%

BIOMASS REMOVAL VIA HARVEST

Forests emit carbon into the atmosphere through biomass removal via harvest. Biomass removed from the forests come in two forms: timber and fuelwood. Amount of timber removed from the forests are reflected in the Forestry Statistics as commercial harvest. Since this data is expressed in cu. m., the value has to be multiplied with average wood density value for tropical forests and the expansion ratio. The expansion ratio allows the inclusion of wastes that are generated during logging operations. Wood density used for this inventory is the average wood density value of 0.57 t dm/m3 for Asian broadleaf forests.

Data for total commercial harvest for the year 2000 was derived from the Forestry Statistics while the fuelwood and charcoal production data for the same year was derived from the FAO statistics published in 2002. This source was used in place of the Forestry Statistics as recommended by FMB staff because the estimate made by the FAO include fuelwood and charcoal consumed by the industries and household. The Forestry Statistics on the other hand include those consumed only by the household hence volume reported in such source is very small.

Expansion ratio used is '3' to indicate that for every ton of wood harvested, three tonnes are actually removed from the forest. The 2 tonnes account for the waste produced during logging. In the Philippines, the Selective Logging System (SLS) is the harvesting technique being used. The major goal of using the SLS as a harvesting technique is to promote the concept of "sustained yield" forest management. Under this system, the prescribed cyclic cut is 35 years. This is based on the assumption that after 35 years after the logging operation had been done in the area, the residual forest will give the same volume of timber as the initial harvest. In the Philippines, SLS involves three phases: (1) tree marking – conducted to ensure that adequate residual growing stock are left after logging; (2) residual inventory – conducted to determine the actual amount and condition of the residual stock after logging; and (3) timber stand improvement – conducted to improve growth, quality and composition of residual stands by providing growing space for crop trees and by enrichment planting (Rapera et. al., 1987).

In a study conducted by Lasco et al (2006) in a logging company in Mindanao, results show that carbon stocks of the forests declined by 50% after logging operation was conducted in the area. The findings indicate that destructive logging causes emission of huge amount of carbon from the forests.

Thus, biomass removed via harvest is expressed in the equation:

$$R = H + F - W$$

where R is the total amount of carbon removed (in kt C), H is the amount of carbon removed via commercial harvest (in kt C), F is the total amount of carbon in wood (both forest and non-forest) that was harvested as fuelwood, and W is the amount of carbon (kt C) in wood that was harvested from the forest as fuelwood. The amount of fuelwood derived from the forest (W) is subtracted from the total amount of fuelwood harvest to avoid double counting when emissions from off site burning is calculated in the next section. The off site burning of forest biomass is due largely to fuelwood consumption of domestic households.

The net annual amount of carbon taken up by biomass growth is therefore the difference between the equations above:

$$U = G - R$$

where U is the net annual carbon uptake, G is the gross carbon absorbed in biomass growth, and R

is the carbon removed via harvest (all variables in units of kt C).

FOREST AND LAND USE CONVERSION

Changes in land uses are significant sources of GHG emissions in the LUCF sector. During conversion of forested forest lands into other land uses, three processes occur. These include: on site burning, off-site burning and biomass decay. GHG emissions during on site burning occur during the clearing activities while the off site burning takes place due to consumption of fuelwood both for domestic and industrial purposes. Both activities (on site and off site burning) results to immediate release of carbon into the atmosphere. Biomass decay, on the other hand represents those wastes left in the forest. Unlike in the off site and on site burning, GHG in biomass decay is released slowly into the atmosphere. Two parameters that are taken into consideration in estimating GHG emissions associated with land use change include: (1) annual loss of aboveground biomass and (2) fraction of cleared biomass that is burned on site, off site and left to decay.

ANNUAL BIOMASS LOSS

In calculating the annual biomass loss, the areas covered by each land use in the two time periods (e.g. 1990 and 2000) and the biomass densities of the land uses must be determined first. Data for these years are derived from the FMB Forestry Statistics *(TABLE 63)*.

TABLE 63. AREA OF THE VARIOUS LAND USES IN THE PHILIPPINES, 1990 AND 2000

Land Use	Area (Mha)	
	1990	2000
Old Growth	0.861	0.805
Residual	3.279	2.731
Pine	0.236	0.228
Submarginal	0.527	0.475
Mossy	1.114	1.040
Mangrove	0.133	0.112
Tree Plantation	0.730	0.492
Upland farms	0.259679	2.693
Brushland	2.4556	4.794
Grassland	6.285	2.509

Biomass densities of the different land uses are derived from the results of the studies conducted in the Philippines (TABLE 64).

TABLE 64. ABOVE GROUND BIOMASS AND CARBON DENSITY OF FOREST LAND COVER IN THE PHILIPPINES CARBON CONTENT, BIOMASS DENSITY AND BIOMASS ACCUMULATION FOR LUCF IN THE PHILIPPINES

FOREST LAND USE	CARBON CONTENT OF BIOMASS (%)	TOTAL ABOVE-GROUND BIOMASS (T/HA)	RATE OF ABOVE-GROUND BIOMASS CHANGE (T/HA/YR)	SOURCE OF DATA
Protection forest Old-growth forest Mossy forest Pine Submarginal Mangrove	44.7 (Visayas)	OGF 446 in Visayas Mossy forest, Submarginal and Mangrove forests 175	2.1 in Visayas	Lasco *et al.*, (1999) Lasco *et al.*, (2000)
Second-growth forest (SGF)	43, 45 (Luzon) (Mean = 44)	279 in Luzon 262 in Mindanao (Mean =270)	7.81 in Luzon 5.2 in Mindanao (Mean = 6.5)	Lasco *et al.* (1999); Kawahara *et al.* (1981)
Brushlands	45.3 for wood (Visayas)	65 in Visayas	9.4 in Visayas	Lasco *et al.* (1999)
Grasslands	44.5 (Visayas)	29 in Visayas	0 (because regularly burned)	Lasco *et al.* (1999)

FOREST LAND USE	CARBON CONTENT OF BIOMASS (%)	TOTAL ABOVE-GROUND BIOMASS (T/HA)	RATE OF ABOVE-GROUND BIOMASS CHANGE (T/HA/YR)	SOURCE OF DATA
Tree plantations	45 (Luzon) Visayas: 39.2 for mahogany wood 43.3 for gmelina wood 45.0 for mangium wood (Mean = 43.1)	In Luzon: *S. .macrophyla:* 600 *P. malaanonan + A. Thurifera:* 536 *P. malaanonan + D. grandiflorus:* 279 *A. auriculiformis:* 30 *T. grandis*: 16 *G. arborea:* 12 *P. kesiya*: 108 *P. kesiya + broadleaf spp.:* 83 In Visayas: *Sweitenia. macrophyla:* 67, 17 *G. arborea:* 180, 70, 124 *A. mangium:* 245, 57, 196	In Luzon: *S. macrophylla:* 7.5 *P. malaanonan + A. thurifera:* 6.7 *P. malaanonan + D. grandiflorus:* 3.5 *A. auriculiformis:* 3.5 *T. grandis:* 1.2 *G. arborea:* 2.1 *P. kesiya:* 8.3 *P. kesiya +* broadleaf spp.: 6.4 In Visayas: *S. macrophylla:* 8.4, 1.6 *G. arborea:* 18.8, 17.6, 7.8 *A. mangium:* 41.6, 14.2, 17.8	Lasco *et al.* (1999) Lasco *et al.* (1998b) Kawahara (1991)
		A. auriculiformis: 64 ***Acacia neriifolia***: 87 ***A. holosericea:*** 34 *A. crassicarpa:* 156 *A. aulacocarpa:* 56 *Leucaena diversifolia: 0.66* *Casuarina cuminghiana:* 3 *C. equisitifolia:* 16 *Eucalyptus citrodora:* 52 *E. cloeziana:* 48 *E. pellita:* 34 *E. tereticornis:* 50 In Mindanao G. arborea: 133 *Paraserianthes falcataria:* 82, 108 and 35 S. macrophylla: 261 (Mean =116)	*A. auriculiformis:* 15.9 ***Acacia neriifolia***: 21.8 ***A. holosericea:*** 8.6 *A. crassicarpa: 39* *A. aulacocarpa:* 14.1 *Leucaena diversifolia:* 0.2 *Casuarina cuminghiana:* 0.8 *C. equisitifolia:* 3.9 *Eucalyptus citrodora:* 13.1 *E. cloeziana:* 12.1 *E. pellita:* 8.5 *E. tereticornis:* 12.5 In Mindanao: *P. falcataria:* 6.0 and 9.8 *G. arborea:* 10.8 (Mean = 11.1)	

Agroforestry	45 *Gliricidia sepium*-based alley cropping(Luzon) 45 *Gmelina arborea* and cacao multistorey system (Luzon)	Multistorey system (Luzon): 236 Alley cropping (Luzon): 68 Fallow system (Visayas): 32 (Mean = 112)	Improved fallow (Visayas): 6.0	Lasco *et al.* (1998a,b) Kungu (1993)

The annual loss of biomass of a particular land use is due to two factors: (1) decrease of the area covered by such land use in the two time periods, for which in this case 1990 and 2000 and (2) assumption for which the land use has been converted into (e.g. old growth to second growth). For this inventory, it was assumed that the old growth forests is converted to second growth forests, while the pine, submarginal, mossy, mangrove, tree plantations, upland farms and brushlands are converted into grasslands. It should be noted that not all second growth forests are assumed to be transformed into brushlands since according to the FMB staff the second growth forests do not automatically become brushland until further exploitation occur in the area. Thus biomass density used for secondary growth forest after conversion is the average of the biomass density of brushland and second growth forest.

Thus, biomass loss associated with land conversion is calculated by simply multiplying the net change in biomass density with the annual area lost. This is expressed in the equation:

$$L = (B_{INITIAL} - B_{FINAL}) \times A$$

EQ 5-4

where L is the annual biomass loss (in t dm), A is the area (in ha) converted annually, $B_{initial}$ is biomass density (in t dm/ha) associated with the land use type prior to conversion, and B_{final} is the biomass density after conversion.

ON/OFF SITE BIOMASS BURNING AND DECAY

The value used for the fraction of forest biomass that is burned off site is 10%. This is the same value used during the GHG inventory of 1994 where the value is drawn from the conclusions of the UNDP-ESMAP (1992) study which stated that fuelwood demand does not put much pressure on the forest resources. According to that report, most of the fuelwood comes from trees and plants in the surrounding agricultural areas. Also, the same study revealed that fuelwood obtained from the forests represent only about 6% of the annual biomass yield of the country's forest resources.

For the fraction of biomass burned on site, the value used is derived by deducting the assumed value for the fraction of biomass burned off site which is 10% from the recommended IPCC default global average for biomass burned on and off site amounting to 50%. Thus, the fraction of biomass consumed on site is 40%.

The value used for the fraction of biomass devoted to the processing of long term wood products is the same value used for the 1994 GHG inventory for LUCF. Such value is 5% since not all the 6% of the yearly total forest biomass removed come from the forest resources. It is highly possible that some of the raw materials used to produce "long term" wood may have been taken from tree plantations and agroforestry farms.

The value used for the fraction of biomass left to decay is again the same value used in the 1994 GHG inventory for LUCF. This is merely the residual of all the fractional values estimated for burned off site, burned on site and biomass devoted to long term product. This accounts for 45% which approximates the IPCC recommended value of 50%.

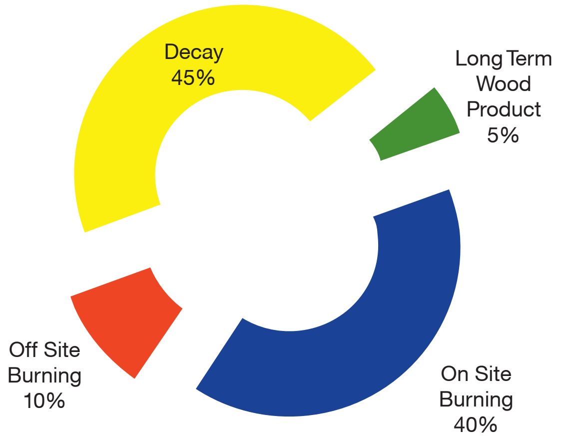


Figure 8. Fractional Values for Different Fates of Cleared Forest Biomass

Figure 8 summarizes the fractional values of forest biomass that are burned on and off site, left to decay and devoted to long term wood products. On the average, these values are assumed to hold for all forest types.

NON CO_2 TRACE GASES

During forest clearing, gases emitted not only include CO_2 but also gases such as methane (CH_4), carbon monoxide (CO), nitrous oxide (N_2O), and nitrogen oxide (NO_x). These non CO_2 gases have the potential to alter the chemical balance of the atmosphere and consequently the climate. Hence, these gases must be quantified as well.

The amount of CH_4, CO, N_2O, and NO_x emitted are estimated by using the emission ratios. These ratios represent the ratio of these trace gases to the total amount of carbon released in the burning process. Emission ratios used are the same values applied during the 1994 GHG inventory for LUCF. The emission ratios are shown in TABLE 65.

TABLE 65. EMISSION RATIOS FOR OPEN BURNING OF FORESTS.

COMPOUND	RATIO	RANGE
CH_4	0.012	0.009 - 0.015
CO	0.06	0.04 - 0.08
N_2O	0.007	0.005 - 0.009
NO_X	0.121	0.094 - 0.148

It must be noted that only non-CO_2 trace gases released from on site burning of forest biomass are accounted in the inventory because it is assumed that non- CO_2 gases released from fuelwood consumption has already been accounted for in the Energy sector. Also, calculation of the same gases released from biomass decay was not estimated because it is assumed that they are negligible.

The calculation for these trace species follows a simple two step process:

1) The total carbon released from on-site burning is determined
2) Trace gas amounts are estimated from the emission ratios of these compounds to total carbon.

Step 1 has already been obtained from the computations of the previous section. Once total carbon has been calculated, trace gas emissions are estimated by straightforward application of these emission ratios. The calculation for the nitrogen based compounds is slightly different since a nitrogen-carbon ratio first needs to be determined. For this inventory, a nitrogen-carbon ratio of 0.01 (1 unit of nitrogen per 100 units of carbon released in biomass burning) is adopted. After applying these emission ratios, the resulting values are the total emissions of these compounds in units of either C (carbon) or N (nitrogen). Conversion of these units to full molecular weight values of CH_4, CO, N_2O, or NO_x merely entails multiplying these C or N units with their respective molecular weight ratios. Thus, for example, CH_4 and CO are determined by multiplying 16/12 and 28/12, respectively to the carbon values obtained. Likewise, multiplying 44/28 and 46/14 to the nitrogen values yields the amount of N_2O and NO_x respectively.

IPCC [1997] SUMMARIZES THE TRACE GAS CALCULATION BELOW:

CH_4 = (Total carbon released) x (Emission Ratio) x 16/12

CO = (Total carbon released) x (Emission Ratio) x 28/12

N_2O = (Total carbon released) x (N/C ratio) x (Emission Ratio) x 44/28

NO_x = (Total carbon released) x (N/C ratio) x (Emission Ratio) x 46/14

To be able to compare the influence of these non-CO_2 trace gases with that of CO_2, global warming potential (GWP) values are applied to the GHG trace compounds, CH_4 and N_2O. The GWP for CH_4 and N_2O are 21 and 310, respectively.

SOIL CARBON AND ABANDONED LANDS

The inventory of carbon emissions from both belowground (soil) biomass and the regrowth of vegetation in abandoned lands requires the availability of a 20-year data set that ends on the inventory year itself. This is so because of the time scales (such as the 20 year time horizon recommended by IPCC [1997]) of the physical processes that are responsible for the release of carbon into the atmosphere. In the case of soil carbon emissions, for example, data on land use management systems, Philippine soil type, and soil carbon stock for the years 1980 to 2000 are necessary. The oldest data on hand for land use management systems dates back to the mid-80's, and is listed by province. Because of inherent difficulties in obtaining data, the inventory of carbon emissions from both soil in land conversion activities and biomass regrowth in abandoned lands has been excluded.

CALCULATING GREENHOUSE GAS EMISSIONS

In calculating for the GHG emissions/absorption of the LUCF sector, there are five basic worksheets that have to be completed. These worksheets include: (1) Changes in Forest and Other Woody Biomass Stocks, (2) Forest and Grassland Conversion, (3) Non CO_2 from on Site Burning of Biomass, (4) Abandonment of Managed Lands,and Emissions from Soil. Each of these five worksheets has corresponding components.

Worksheet 5-1 Changes in Forest and other Woody Biomass Stocks

Sheet 1: Gross Annual Carbon Uptake
Sheet 2 Total Biomass Removed via Harvest
Sheet 3 Net Annual Carbon Uptake

Worksheet 5-2 Forest and Grassland Conversion

Sheet 1: Annual Biomass Cleared
Sheet 2: Carbon Emitted by On Site Biomass Burning
Sheet 3: Carbon Emitted by Off Site Biomass Burning
Sheet 4: Carbon Emitted by Biomass Decay
Sheet 5: Summary and Conversion to CO_2

Worksheet 5-3 Non-CO_2 from On Site Burning of Biomass

Sheet 1: Release of Nitrogen – Based Trace Compounds
Sheet 2: Release of Trace Gases

The following clusters of worksheet were not part of the 2000 GHG Inventory, but are however included here, as they will likely be used in the succeeding inventories. In addition, it gives the option for the inclusion in the inventory.

Worksheet 5-4 Abandonment of Managed Lands

Sheet 1: Carbon Uptake by Aboveground Regrowth – First 20 Years
Sheet 2: Carbon Uptake by Aboveground Regrowth - > 20 Years
Sheet 3: Total CO_2 Removals from Abandoned Lands

Worksheet 5-5 Soil Carbon

Sheet 1: Change in Soil Carbon from Mineral Soils
Sheet 2: Soil Carbon from Intensively Managed Organic Soils
Sheet 3: Carbon Emissions from Liming of Agricultural Soils
Sheet 4: Total CO_2 Emissions from Agriculturally Impacted Soils

EMISSIONS FROM CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS

This worksheet estimates the net amount of CO_2 that the LUCF sector either absorbs or releases from the atmosphere. As mentioned earlier, the LUCF sector can absorb carbon during biomass growth and it can release carbon through deforestation/harvesting of wood. Data used in this worksheet can be taken from the Forestry Statistics published yearly by the Forest Management Bureau of the Department of Environment and Natural Resources and other published studies.

CO_2 EMITTED OR ABSORBED

Step 1: Estimate the Gross Annual Carbon Uptake

Worksheet 5-1, Sheet 1 of 3

1. Enter in the first column, the types of land uses in the Philippines.
2. Enter in column A the corresponding area covered by each land use.
3. Enter in column B the annual biomass growth rate associated with each land use type.
4. In Column C, compute for the annual biomass increment of each land use by multiplying the values in Columns A and B.
5. Enter in Column D the carbon fraction of dry matter.
6. In Column E, calculate the total carbon uptake increment of each land use, expressed in kiloton, by multiplying the values in Columns C and D.

Step 2: Estimate the Total Biomass Recovered Via Harvest

Worksheet 5-1, Sheet 2 of 3

1. Enter in column F (Commercial Harvest), the total volume (in 1,000 m^3) of roundwood produced.
2. Enter in column G1 the Biomass Conversion Value.
3. Enter in column G2 the Expansion Ratio.
4. Calculate the 'Total Biomass Removed in Commercial Harvest (kt dm)' in column H by multiplying values in Columns F, G1 and G2.

   Enter in column I (Total Traditional Fuelwood Consumed in kt dm), the total fuelwood and charcoal production expressed in kiloton dry matter (kt dm).
5. Leave Column J blank.
6. Calculate the 'Total Biomass Consumption' in Column K by summing values in Columns H, I and J.

Step 3: Estimate the Net Annual Carbon Uptake

Worksheet 5-1, Sheet 3 of 3

1. Enter in column L (Wood Removed from Forest Clearing) the value that will be derived from column M of Worksheet 5-2 (Quantity of Biomass Burned Off Site). This represents the amount of fuelwood taken from the forests.

2. Calculate the 'Total Biomass Consumption from Stocks in column M by taking the difference of the values in Column K found in sheet 2 of Worksheet 5-1 and Column L located in sheet 3 of Worksheet 5-1.
3. Enter the value of the carbon fraction of biomass harvested in column N.
4. Estimate the 'Annual Carbon Release' (column O) by multiplying Values in columns M and N.
5. Calculate the net annual carbon uptake or release in Column P by subtracting the value derived in column O from subtotal derived in column E found in sheet 1 of Worksheet 5-1.
6. To determine the CO_2 equivalent of the carbon uptake in column P (Net Annual Carbon Uptake or Release), the value is multiplied by 44/12.

EMISSIONS FROM FOREST AND GRASSLAND CONVERSION

This worksheet is used to estimate carbon emissions from on-site burning, off-site burning, and biomass decay

CO_2 EMISSIONS

Step 1: Estimate Annual Biomass Cleared

Worksheet 5-2, Sheet 1 of 5

1. Enter in the first column, the types of land uses in the Philippines.
2. Enter in the columns AA and BB the corresponding area covered by each land use in Years 1 and 2, respectively.
3. Calculate the 'Area Converted Annually' in Column A by subtracting values in Column BB from column AA.
4. Enter in column B (Biomass Before Conversion) the corresponding biomass density value of each land use type.
5. Enter in column C (Biomass After Conversion), the biomass density of the most probable land use to which the existing land use will be converted.
6. Calculate the 'Net Change in Biomass Density' in Column D by taking the difference between columns B and C.
7. Estimate the 'Annual Biomass Loss' in Column E by multiplying Column A with Column D. Since the unit should be in kilo ton, multiply the resulting value with 1,000.

Step 2: Estimate Carbon Emitted by ON Site Biomass Burning

Worksheet 5-2, Sheet 2 of 5

1. Enter in Column F (Fraction of Biomass Burned On-Site) for each vegetation type.
2. Estimate the quantity of biomass burned on site in Column G by multiplying the values in Column E with those in Column F.
3. Enter in Column H the Fraction of Biomass Oxidised On-Site for each vegetation type.
4. Compute for the quantity of biomass oxidized on site in Column I by getting the product of the values in

Columns G and H.

5. Enter in column J the carbon fraction of aboveground biomass. Use values in Table 5.
6. Calculate the carbon released from on site biomass burning in Column K by multiplying the values in Columns I and J.

Step 3: Estimate Carbon Emitted by Off Site Biomass Burning

Worksheet 5-2, Sheet 3 of 5

1. Enter into Column L the fraction of biomass that is burned off-site.
2. Estimate the quantity of biomass burned off site in Column M by multiplying the values in Columns E and L.
3. Enter the fraction of biomass that is oxidized off-site in Column N.
4. Calculate the quantity of biomass oxidized off site in Column O by getting the product of the values in Columns M and N.
5. Enter in Column P the fraction of carbon that is present in aboveground biomass.
6. Estimate the amount of carbon released from off site biomass burning In Column Q by multiplying the values in Columns O and P.
7. Get the total carbon released in Column R by adding the values derived from Columns K and Q.

Step 4: Estimate Carbon Emitted by Biomass Decay

Worksheet 5-2, Sheet 4 of 5

1. Enter into Column S the fraction of biomass that is left to decay.
2. Calculate the quantity of biomass left to decay in Column T by multiplying the values in Columns E and S.
3. Enter into Column U the fraction of carbon present in the aboveground biomass. Compute for the total carbon released from aboveground decay in Column V by getting the product of the values in Columns T and U.

Step 5: Estimate Total CO_2 Emitted

Worksheet 5-2, Sheet 5 of 5

1. Enter in Column A (Immediate Release from Burning), the total carbon released from on-site and off-site burning. Copy this value from subtotal box of Column R in Sheet 3 of Worksheet 5-2.
2. Enter in Column B (Delayed Emissions from Decay) the total carbon released from biomass decay. Copy this value from the subtotal box of Column V in Sheet 4 of Worksheet 5-2.
3. Calculate the total annual carbon release in Column C by adding the values in Column A with that of column B.
4. Get the total annual CO_2 release in Column D by multiplying the value derived in column C by 44/12.

NON-CO_2 EMISSIONS FROM ON SITE BURNING OF BIOMASS

Worksheet 5-3 is used to calculate non-CO_2 trace gas emissions associated with on-site biomass burning. The two sheets that comprise Worksheet 5-3 calculate the amount of nitrogen and non- CO_2 carbon compounds released from the on-site burning process.

Step 1: Estimate Release of Nitrogen-Based Trace Compounds

Worksheet 5-3, Sheet 1 of 2

1. Enter in Column A (Quantity of Carbon Released) the amount of carbon released from on-site biomass burning. Get this value from the subtotal of Column K, Sheet 2 of Worksheet 5-2.
2. Enter in Column B the nitrogen-carbon ratio of biomass burned.
3. Calculate the total nitrogen released in Column C by multiplying the values in Columns A and B.
4. Enter in Column D the respective emission ratios for N_2O and NO_x.
5. Estimate the total amount of nitrogen-based trace gases emitted in Column E by multiplying Columns C and D.
6. Enter in column F the molecular conversion ratios for N_2O (44/28) and NO_x (46/14).
7. Estimate the nitrogen-based trace gases emissions from burning of cleared forests in Column G by getting the product of Columns E and F.

Step 2: Estimate Trace Gas Emissions

Worksheet 5-3, Sheet 2 of 2

1. Enter the subtotal value of column K, sheet 2 of Worksheet 5-2 in column A (Quantity of Carbon Released).
2. Enter in Column B the trace gas emission ratios for CH_4 and CO. Use 0.012 for CH_4 and 0.60 for CO.
3. Calculate the total amount of trace gas emissions by multiplying values in Columns A and B.
4. Enter in column D the molecular conversion ratios. For CH_4 use 16/12 while for CO, 28/12 should be applied.
5. Compute for the trace gas emissions from burning of cleared forests in Column E by multiplying the values in Columns C and D.

Waste Sector

Rapid urbanization in developing countries is positively correlated with the increase in the production and consumption of goods. This subsequently led to the increase in the volume of waste generated by the commercial, domestic, and industrial sectors. Aside from the environmental and health risks associated with the wastes, it also releases greenhouse gases in the atmosphere that could interfere with our climate systems.

The significant GHGs from waste are CH_4 which come from the anaerobic decomposition of the organic matter in wastes, and N_2O which is emitted as a byproduct of the chemical processes in the human waste. The net CO_2 emissions generated from aerobic decomposition were considered insignificant because they come from biomass that captures CO_2 during its growth. Also, the biomass that was not grown sustainably is accounted for in the LUCF and agricultural sectors.

The GHG inventory of the Waste Sector has four subsectors: (1) CH_4 from Solid Waste Disposal; (2) CH_4 from Domestic/Commercial Wastewater Treatment (3) CH_4 from Industrial Wastewater Treatment, and (4) N_2O from Human Sewage.

REFERENCE MANUAL

INTRODUCTION

Solid waste sector deals with four components namely solid waste, domestic wastewater and sludge, industrial waste water and human sewage. Solid waste includes municipal, commercial and industrial sources. Waste water and sludge including human sewage come from domestic and commercial sources. All calculations for year 2000 were eventually translated into carbon dioxide equivalents and methane emissions as shown in.

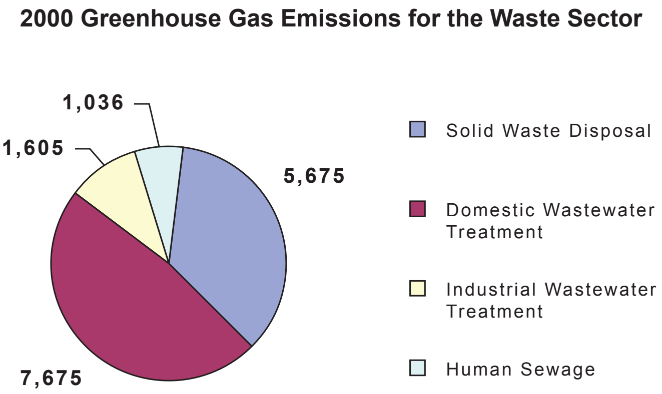


Figure 9. Greenhouse Gas Emissions for Various Types of Waste, percentage

The country's population in 2000 is 76,504,077 M. In Table 66, the population of the country from 1950 to 2005 shows an increasing trend through time. Based on the study of ADB (Asian Development Bank), 60.1% of the population is concentrated in urban centers. Together with the growing population through time, urban centers are responsible for a large amount of waste produced as a result of growing consumption in the commercial, industrial and domestic sectors. All of these wastes can be translated into a significant amount of GHGs.

TABLE 66. TOTAL POPULATION OF THE PHILIPPINES FROM 1950 TO 2005, INCLUDING URBAN POPULATION.

YEAR	URBAN POPULATION (M)	TOTAL POPULATION (M)
1950	16,171,023	19,234,182
1955	17,653,268	21,309,060
1960	18,797,445	27,087,685
1965	20,520,429	31,234,728
1970	21,850,437	36,684,486
1975	25,071,229	42,070,660
1980	28,766,771	48,098,460
1985	32,353,459	54,787,744
1990	36,387,341	60,703,206
1995	40,903,717	68,616,536
2000	45,980,664	76,504,077
2005	50,918,227	85,967,830

The waste from the various sources is handled by garbage collectors recognized by the local government units. Some of the wastes are recovered by recyclers and finally, the residual is brought to the dumpsite.

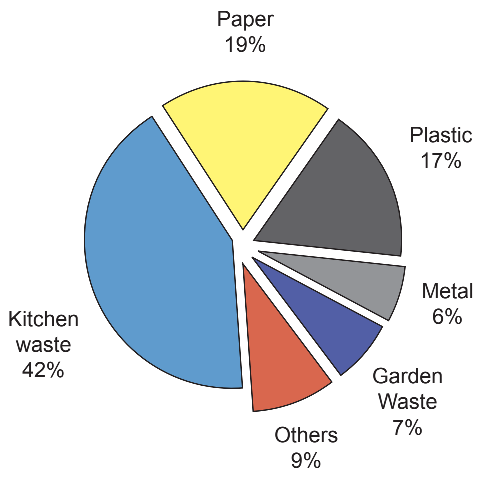
Waste water collected from domestic and commercial areas including wastewater from industry also produce methane. Wastewater involves anaerobic treatment, and with the action of methanogenic bacteria generates methane. The increase in population is proportional to the increase in the methane generated by this subsector of waste. There is also an increasing trend of commercial areas in urban centers in the country which also contribute a significant amount of waste water.

An increasing population in urban center translates into increased human sewage. Protein is an important component of the Filipino diet and when protein is digested N_2O is produced, which is a GHG.

SOLID WASTE DISPOSAL

Solid waste generally comes from households, municipalities, commercial areas and industries. Waste generation is associated with population, socio economic development and extent of industrialization of a country. The increase in the production of solid waste is generally proportional with the growth of a population. The daily generation of waste by a Filipino is from 0.3 to 0.7 kg of garbage depending on the economic status. Households produced 10 million tonnes of solid waste in year 2000 (Environment Monitor, 2001).

Waste characterization of Metro Manila area is shown in Figure 10. For this large urban center, household waste contributed 42% while garden waste contributed 7% to the solid waste generated. The calculations of the methane and corresponding CO_2 equivalents for the organic component of the waste were done using the first order decay method instead of the mass balance approach. The latter assumes that the degradable organic component (DOC) in the waste decays immediately upon disposal while the former assumes that DOC slowly decays. With the action of bacteria and fungi, more methane is produced during the first few years after decomposition.



Source: The Study on Hazardous Waste Management in the Republic of the Philippines, JICA, June 2001

Figure 10. Municipal Waste Characterization in Metro Manila, 1999.

Solid waste from domestic, commercial and industrial sources are collected by legitimate collection trucks. A system of informal sorting takes place before all the wastes go to the transfer stations. By then a large portion of the waste are now residual in form which goes to the dumpsite. Various types of waste disposal methods such as landfills, open dumps, composting, incineration and others are utilized in the Philippines. It is noticeable that the Philippines in 1997 had more open dumps compared to landfills.

Treatment and disposal of solid waste produces significant amounts of methane (CH_4). CH_4 produced at solid waste disposal sites (SWDS) contributes 3-4% to the annual global anthropogenic greenhouse gas emissions (IPCC, 2001). SWDS also produce biogenic carbon dioxide (CO_2), non-methane volatile organic compounds (NMVOCs), nitrous oxide (N_2O) nitrogen oxides (NO_x), carbon monoxide (CO) although CH_4 is the primary greenhouse gas in SWDS.

In many countries waste management has changed much over the last decade in the aspect of waste minimization and recycling/reuse, policies to reduce the amount of waste generated, alternative waste management practices and landfill gas recovery. In the Philippines, R.A. 9003 otherwise known as the Solid Waste Management Act, was implemented in January 2001.

Three levels of approach are done to estimate the CH_4 emissions which is highly dependent on the data available (Figure 11). Tier 1 uses default activity data and default parameters. Tier 2 uses some default parameters, and good quality country-specific data on current and historical waste disposal at SWDS. Tier 3 on the other hand uses country-specific activity data, and nationally developed key parameters such as half-life, methane generation potential, degradable organic content (DOC) in the waste, and fraction of DOC that decomposes.

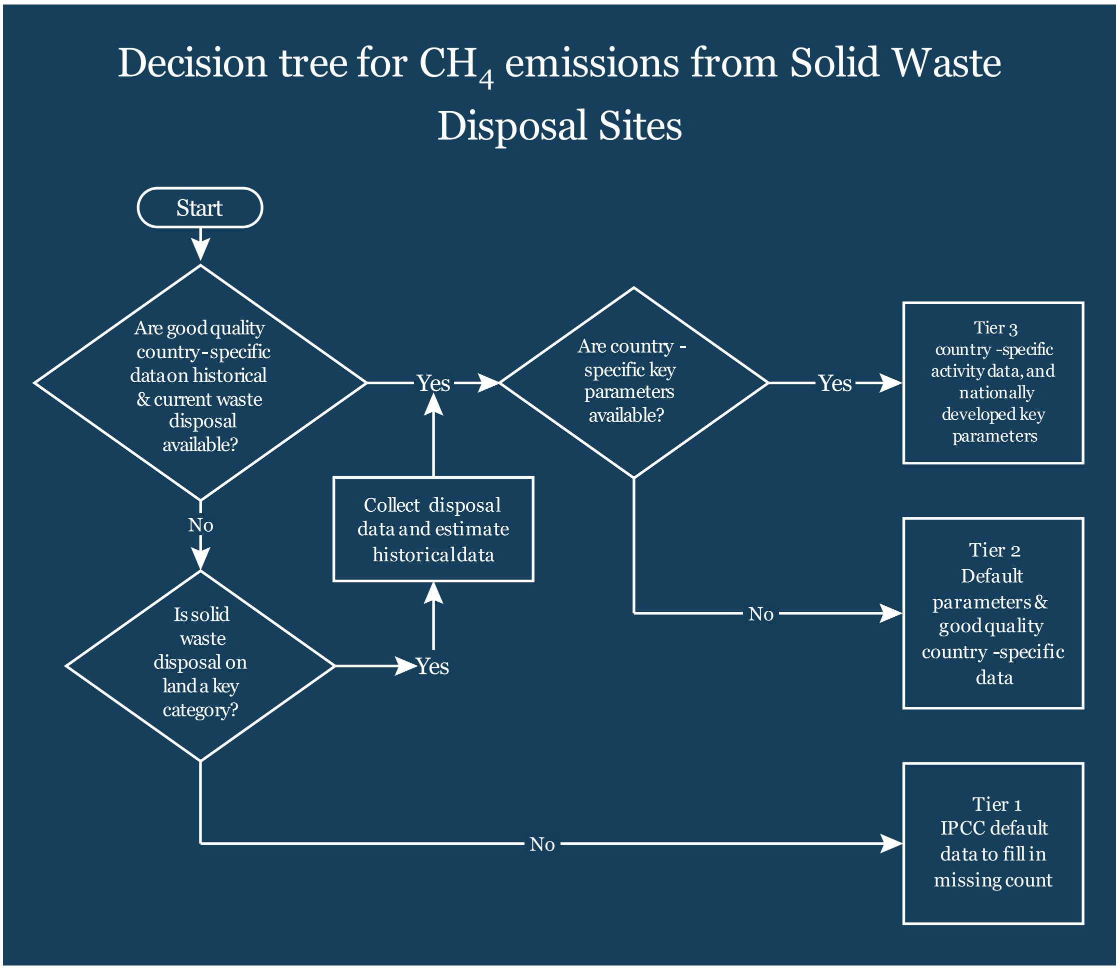


Figure 11. Decision Tree for CH4 Emissions from Solid Waste Disposal Sites.

Two models were utilized to estimate CH_4 emissions from SWDS namely the mass balance approach and the first order decay (FOD) method. The mass balance approach was used in the 1994 Philippine GHG inventory. It does not distinguish between various types of disposal sites such as open dump or sanitary landfill.

In the FOD method, it is assumed that degradable organic component (DOC) decays slowly throughout a few decades (IPCC, 2006). If the conditions are constant the methane released from the decomposition of wastes is proportional to the amount of carbon remaining in the waste. Thus, more methane is released during the first few years after deposition because more degradable organic carbon is available for bacterial decay.

The conversion of the degradable material in waste to methane and carbon dioxide is complex because it is composed of a chain of reactions and parallel reactions. The series of equations below is a simplified version of the DOC transformation to CO_2 and CH_4 (methanogenesis):

$$\text{ORGANIC MATTER} \rightarrow H_2, CO_2, \text{ \& CARBOXYLIC ACIDS}$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

$$CH_3COOH \rightarrow CH_4 + CO_2$$

Laboratory and field data suggest that the decomposition process can be estimated using first order kinetics which is represented in the equation:

DDOCm = DDOCm0*e-kt

Where:

- **DDOCm** : mass of DOC that will decompose under anaerobic conditions in disposal site at time t;
- **DDOCm0** : mass of DDOC in the disposal site at time 0, when the reaction starts;
- **k** : decay rate constant in y-1; and
- **t**: time in years.

The FOD method required data to be estimated for historical disposals of waste over a time period of 3 to 5 half lives to yield an accurate result. Half life is affected by the following factors: composition of waste, climactic conditions at the SWDS, characteristics of the SWDS and waste disposal practices. Since half-lives for different types of waste vary from a few years to several decades, it is good practice to use disposal data for at least 50 years because this yields more accurate results.

The IPCC waste model (2006) requires the following data namely: urban population, waste per capita generation rate (kg/cap/year), percentage of waste that goes to different disposal sites, percent composition of wastes that goes to the disposal sites, GDP (gross domestic product), industrial waste generation rate (Gg/$M GDP/yr), percent of industrial solid waste that goes to solid waste disposal sites and the amount of methane recovered. The difference in the production of CH_4 and CO_2 is shown in using two types Table 67 of approach (Mass Balance and FOD).

TABLE 67. COMPARISON OF CH_4 AND CO_2 USING THE MASS BALANCE APPROACH AND FIRST ORDER MODEL, 1994 AND 2000.

	CH4 (GG)	CO2 (GG)
1994 (MASS BALANCE)	302.73	6,357.3
1994 (FOD)	307	6,447
2000 (FOD)	287	6,027

WATER FROM MUNICIPAL, COMMERCIAL AREAS AND INDUSTRY

Sources of wastewater can come from households, commercial areas and industries. Treatments can be on site, centralized or directly disposed into nearby bodies of water. Anaerobic treatment produces methane and may also be a source of CO_2 and N_2O. Gases produced differ between countries, and between rural and urban area, in part because of the processes and environs prevailing.

Methane generation potential of wastewater depends on the amount of degradable organic material present. The parameters used to characterize waste water are biochemical oxygen demand (BOD) and chemical oxygen demand (COD). BOD concentration indicates only the amount of carbon that is aerobically biodegraded appropriate for determining the organic components in anaerobic environments. COD measures the total material available for oxidation (both biodegradable and non-biodegradable). Reported COD/BOD ratios can be used to determine the COD if the BOD is known. Higher BOD or COD means more methane generation.

Methane production from wastewater varies depending on the handling system. Anaerobic handling generally produces CH_4 while the aerobic system generally produces little or no methane. Considering the depth of storage, shallow lagoons less than 1m deep are aerobic, while lagoons about 2-3m deep or deeper are considered anaerobic. Temperatures of 15°C and higher also affect methane production. Increase in temperature is directly correlated with increased methane production. However, at temperatures below 15°C, fermentation proceeds so that CH_4 production is negligible and lagoon serves as a sedimentation tank.

The calculation of the GHG generation potential of the wastewater is driven by the organic content of the wastewater stream (BOD) and the volume of wastewater. Data needed are degradable organic component (DOC) indicator in kg DOC per 1000 persons per year; country population in thousands and fraction of BOD removed as sludge. For domestic wastewater and sludge, BOD is the recommended DC indicator. Below is the equation used for the calculation of the total organic waste water:

$$TOW_{dom} = P \times D_{dom} \times (1 - DS_{dom})$$

where:

TOW_{dom} = total domestic/commercial organic wastewater in kg BOD/yr

P = population in 1000 persons

D_{dom} = domestic/commercial DOC in kg BOD/1000 persons/yr

DS_{dom} = fraction of domestic/commercial DOC removed as sludge

For sludge on the other hand, below is the equation used:

$$TOSdom = P \times Ddom \times DSdom$$

where:

TOSdom = total domestic/commercial organic sludge in kg BOD/yr

A summary of the CH_4 and CO_2 produced from domestic and industrial wastewater for the year 1994 and 2000 is shown in Figure 11.

TABLE 68. CH_4 AND CO_2 PRODUCED FROM DOMESTIC AND INDUSTRIAL WASTEWATER, 1994 AND 2000

	1994		2000	
	CH_4	CO_2	CH_4	CO_2
Domestic	46.02	966.47	307.43	6,456.03
Industrial	43.83	920.5	64.2	1348.2

HUMAN SEWAGE

Data needed for the computation of Nitrous Oxide (NO) from human sewage are the following: per capita protein consumption, national population and amount of sewage applied to soils as sewage sludge. These data can be sourced from the National Statistical Information Center (NSIC), Department of Science and Technology (DOST), Food and Nutrition Research Institute (DOST- FNRI) and the Manila Water Company.

The N_2O emissions for 2000 is 3.5 (Gg) and 1,036 (Gg) CO_2 equivalents

CALCULATING GREENHOUSE GAS EMISSIONS

EMISSIONS FROM SOLID WASTE DISPOSAL SITES (SWDS)

The 2006 SWDS Worksheet is used to calculate methane emissions from domestic/ commercial solid waste disposal sites. This worksheet employs the First Order Decay Method (FOD) as opposed to a Mass Balance Approach to calculate CH_4 emissions. Historical data (from year 1950) of the following are required for this calculation:

- urban population,
- waste per capita generation rate(kg/cap/year),
- percentage of waste that goes to different disposal sites,
- percent composition of wastes that goes to the disposal sites,
- Gross Domestic Product (GDP),
- percent of solid waste that goes to solid waste disposal sites, and
- amount of methane recovered.

These data may be acquired from the various government agencies involved in waste management and data collection such as the Metropolitan Manila Development Authority (MMDA), the Environmental Management Bureau (EMB), National Solid Waste Commission (NSWC) and the National Statistical Information Center (NSIC). The GDP and growth rate may be obtained from the International Monetary Fund (IMF) website.

STEP 1: SELECT APPROPRIATE PARAMETERS FOR THE PHILIPPINES

2006 SWDS Worksheet, Parameters Tab, Sheet 2 of 19

1. Type “Philippines” beside the country and choose “Asia-Southeast” from the Region drop-down menu.
2. Choose “Waste by Composition” from the DOC menu.
3. Choose “Moist and wet tropical” from the Methane generation rate constant drop-down menu.
4. Copy the default values from the third column to the fourth column (country-specific parameters).

STEP 2: COMPUTE FOR THE METHANE CORRECTION FACTOR (MCF)

2006 SWDS Worksheet, MCF Tab, Sheet 3 of 19

1. Copy the IPCC default values in the first row to the country specific values in the second row.
2. Enter the proportion of waste (by weight) for each type of municipal solid waste disposal site in the third row. Use the following equivalence for disposal site categories:

R.A. 9003	IPCC 2006/WORKSHEET
Controlled disposal facilities	Unmanaged, deep type
Sanitary Landfills	Anaerobic, managed
Open dumpsites	Unmanaged, deep type

R.A. = Republic Act

3. Enter the proportion of waste (by weight) for each type of industrial solid waste disposal site in the third row. Use IPCC default values that are already inputted in the worksheet if no specific data can be obtained.
4. The remaining columns in the worksheet are calculated automatically.

STEP 3: INPUT MSW AND INDUSTRIAL WASTE ACTIVTY DATA

2006 SWDS Worksheet, Activity Tab, Sheet 4 of 19

1. Enter the urban population (in millions) from 1950 onwards in the second column. If data is absent, use the population equation

$$A_t = A_0 e^{kt}$$

where:

A_t is the population at time t,

A_0 is the known population,

k is the growth rate, and

t is the time in years.

2. Enter the waste per capita (kg/cap/year) in the third column. If the waste per capita data is expressed in kg/cap/day, multiply it by 365 to obtain the annual waste per capita generation.
3. Enter the fraction of MSW (by weight) that is disposed solid waste disposal sites in the fifth column. As an initial assumption, the garbage collection efficiency is equated to the fraction of MSW that is disposed to SWDS.
4. In columns 6 to 12, enter the composition of wastes that goes to SWDS according to the following categories: Food, Garden, Paper, Wood, Textile, Nappies, and Plastics and other inert. The waste composition should be expressed in % by weight.
5. For the Industrial waste data table, enter the GDP (expressed in $ millions) in the second column. If yearly GDP is absent, calculate GDP using the following equation:

$$GDP_t = GDP_{t+1} + GDP_{t+1} * k$$

where:

GDP_t is the known gross domestic product at year t

GDP_{t+1} is the gross domestic product a year after

k is the growth rate

6. Enter the waste generation rate in the third column. It should be expressed in Gg/$GDP/yr.
7. Enter the fraction of industrial waste (by weight) that goes to the solid waste disposal sites. The remaining columns in the worksheet are calculated automatically.

STEP 4: COMPUTE FOR METHANE RECOVERY AND METHANE OXIDIZED IN TOP LAYER

2006 SWDS Worksheet, Recovery O_x_Tab, Sheet 6 of 19

1. Enter the amount of methane recovered (Gg) from SWDS in the second column. After entering the figure, the remaining columns are calculated automatically.

EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER AND SLUDGE TREATMENT

The treatment of domestic/commercial wastewater and sludge can generate a significant amount of CH_4 because it contains dissolved organic matter. The main factor that is used to determine the CH_4 generation potential of the system is the Biochemical Oxygen Demand (BOD) which indicates the level of aerobically biodegradable carbon in the wastewater.

To calculate for CH_4 emissions from the handling of domestic/commercial wastewater, the following data are required:

- urban population,
- Degradable Organic Component (DOC) in kg BOD/1000 persons/year,
- fraction of DOC removed as sludge,
- Fraction of wastewater treated by handling systems,
- Fraction of sludge treated by handling systems, and
- CH_4 recovered (if any).

STEP 1: COMPUTE FOR THE BOD OF ORGANIC WASTEWATER AND SLUDGE

Worksheet 6-2 Domestic/ Commercial Wastewater and Sludge Treatment, Sheet 1 of 4

1. Enter the name of region or city in column A.
2. Enter the population (in 1,000 persons) in column B.
3. Enter the Degradable Organic Component (DOC) in terms of kg BOD per 1000 persons per year in column C.
4. Enter the fraction of DOC component removed as sludge in column D.
5. In column E, the values in columns B, C, and (1 subtracted with D) are automatically multiplied to get the total domestic and commercial wastewater (in kg BOD / year).
6. In column F, the values in columns B, C and D are automatically multiplied to get the total domestic and commercial sludge (in kg BOD / year).
7. Add the values in column E to get the total domestic and commercial organic wastewater.
   Add the values in column F to get the total domestic and commercial organic sludge.

STEP 2: COMPUTE FOR THE EMISSION FACTOR FOR WASTEWATER HANDLING SYSTEMS

Worksheet 6-2 Domestic/Commercial Wastewater and Sludge Treatment, Sheet 2 of 4

1. Enter in column A the type of wastewater handling system.
2. Enter in column B the fraction of wastewater treated by the handling system.
3. In column C, enter the CH_4 Conversion Factor (MCF) for the handling system. In the absence of specific data, use default values from IPCC, 2006.
4. In column D, multiply the values in column B and C.
5. Enter the maximum CH_4 producing capacity in column E. In the absence of specific data, use default value of 0.6 kg CH_4/ kg BOD (IPCC, 1996).
6. In column F, the values in columns D and E will then be automatically multiplied to get the emission factor for domestic and commercial wastewater (in kg CH_4/ kg BOD).
7. Add the values in column F to get the aggregate methane correction factor (in kg CH_4/ kg BOD).

STEP 3: COMPUTE FOR THE EMISSION FACTOR FOR SLUDGE HANDLING SYSTEM

Worksheet 6-2 Domestic and Commercial Wastewater and Sludge Treatment, Sheet 3 of 4

1. Enter in column A a label for the type of sludge handling system.
2. Enter in column B the fraction of sludge treated by the handling system.
3. In column C, enter the CH_4 Conversion Factor (MCF) for the handling system. The default values used were from IPCC, 2006.
4. In column D, multiply the values in column B and C.
5. Enter the maximum CH_4 producing capacity in column E.
6. In column F, the values in columns D and E will then be automatically multiplied to get the emission factor for domestic and commercial wastewater (in kg CH_4/ kg BOD).

STEP 4: COMPUTE FOR METHANE EMISSIONS FROM DOMESTIC/COMMERCIAL WASTEWATER AND SLUDGE TREATMENT

Worksheet 6-2 Domestic & Commercial Wastewater and Sludge Treatment, Sheet 4 of 4

1. Enter into column A the total organic product (refer to Worksheet 6-2, Sheet 1, Columns E and F).
2. Enter into column B the emission factor (refer to Worksheet 6-2, Sheets 2 and 3, Column F).
3. In column C, values in columns A and B will be multiplied automatically. This is the gross amount of CH_4 generated without any recovery or flaring (in kg CH_4).
4. Enter into column D the amount of CH_4 recovered (in kg CH_4).
5. In column E, subtract the value in column D from the value in column C. Convert the value into Gg, to get the net amount of CH_4 released from domestic and commercial wastewater treatment (in Gg CH_4).

EMISSIONS FROM INDUSTRIAL WASTEWATER TREATMENT

The use of water in industry is manyfold: among other things, it is used as a cooling, cleansing or manufacturing agent. The wastewater by-product of these industrial processes is normally treated. It is in this treatment of wastewater, which contains dissolved organic matter, where methane is emitted.

For this type of process, the main factor used in the computation of CH_4 emissions is the Chemical Oxygen Demand (COD) which indicates the amount of material available for oxidation. To calculate for CH_4 emissions from industrial wastewater treatment, the following data are required:

- Industry cod loads (in kg cod / year)
- Industrial growth rate
- Wastewater handling system
- Sludge handling system

STEP 1: COMPUTE FOR TOTAL ORGANIC WASTEWATER AND SLUDGE

Revised Worksheet 6-3 Industrial Wastewater and Sludge Treatment, Sheet 1 of 4

1. Enter the type of industry in the Industry Column.
2. Enter in column A the total COD loads (in kg COD/yr) of each of the industry.
3. Add all the values in column A to get the total industrial COD load in kg COD per year.
4. Enter in column B the fraction of degradable organic compound removed as sludge.
5. The total organic wastewater from the industrial source is computed in column C by multiplying the value in column A with (1 minus the value in column B) or simply put, [C= A x (1-B)].
6. Add all the values in column C to get the total organic wastewater from the industrial source.
7. The total organic sludge from the industrial source is computed in column D by multiplying the value in column A with the value in column B (A x B).
8. Add all the values in column D to get the total organic sludge from the industrial source.

STEP 2: COMPUTE FOR THE EMISSION FACTOR FOR WASTEWATER HANDLING SYSTEM

Revised Worksheet 6-3 Industrial Wastewater and Sludge Treatment, Sheet 2 of 4

1. Enter in column A the type of wastewater handling system.
2. Enter in column B the fraction of wastewater treated by each type of handling system.
3. Enter in column C the methane correction factor (MCF) of the handling system. In the absence of specific values, use default values from IPCC 1996 and 2006.
4. In column D, multiply the values in columns B and C.
5. Enter the maximum methane producing capacity in column D. In the absence of specific values, use default values of 0.25 kg CH4 /kg BOD (IPCC, 2006).
6. In column F, multiply the values in columns D and E to get the emission factor for industrial waste

STEP 3: COMPUTE FOR THE EMISSION FACTOR FOR SLUDGE HANDLING SYSTEM

Revised Worksheet 6-3 Industrial Wastewater and Sludge Treatment, Sheet 3 of 4

1. Enter in column A the type of sludge handling system.
2. Enter in column B the fraction of sludge treated by each type of handling system.
3. Enter in column C the methane correction factor (MCF) of the handling system. In column D, multiply the values in columns B and C.
4. Enter the maximum methane producing capacity in column D. In the absence of specific values, use default value of 0.25 kg CH4 /kg BOD (IPCC, 2006).
5. In column E, multiply the values in columns D and E to get the emission factor for industrial waste source.
6. Add the values in column E to get the aggregate emission factor.

STEP 4: COMPUTE FOR THE METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER AND SLUDGE

Revised Worksheet 6-3 Industrial Wastewater and Sludge Treatment, Sheet 4 of 4

1. Enter the total organic product of the wastewater and sludge (in kg COD/yr) in column A. These values are from Revised Worksheet 6-3, Sheet 1.
2. Enter the emission factors of wastewater and sludge in column B. The values are from Revised Worksheet 6-3, Sheets 2 and 3.
3. In column C, multiply the values in columns A and B to get the methane emissions without recovery or flaring.
4. Enter the methane recovered or flared (in kg CH4) in column D.
5. In column E, subtract the value in column D form the value in column C (C - D) to get the net methane emission.
6. Add the values in column D to get the total net methane emissions.

INDIRECT NITROUS OXIDE EMISSIONS FROM HUMAN SEWAGE

Basic human sewage contains proteins which in turn contain nitrogen. Human sewage participates in the nitrogen cycle, indirectly emitting N_2O. To calculate for the indirect emissions of this GHG from human sewage, these data are required:

- per capita protein consumption,
- national population, and
- amount of sewage applied to soils as sewage sludge.

Data may be acquired from the National Statistical Information Center (NSIC) and the Department of Science and Technology–Food and Nutrition Research Institute (DOST– FNRI).

Step 1: Compute for Nitrous Oxide Emissions from Human Sewage

Worksheet 6-4 Human Sewage, Sheet 1 of 1

1. Enter the per capita protein consumption in terms of kg/person/year in column A.
2. Enter the national population in column B.
3. Enter the fraction of nitrogen in protein in column C. The default value is 0.16 kg N per kg protein (IPCC, 1996).
4. In column D, the amount of sewage N produced (in kg N/yr) is calculated automatically by multiplying values in columns A, B and C.
5. Enter the amount of sewage N applied to soils as sewage sludge (in kg N/yr) in column E.
6. In column F, the net amount of sewage produced (in kg N/yr) is calculated by subtracting value in column D with value in column E (D - E).
7. Enter the emission factor EF in column G. The default value is 0.01 kg N_2O per kg sewage–N produced (IPCC, 1996).
8. In column H, multiply together the values in columns A, B, C, D, and the molecular conversion ratio, 44/28. Then convert this to Gg. This yields the total annual N_2O emissions from human sewage (in Gg N_2O).

Energy Data for 2000

	Coal	Natgas	Crude	PremGas	RegGas	Kero	Diesel	Fuel Oil	LPG	Jet	Avgas	Naphtha
Indigeneous	644.66	8.75	55.97	-	-	-	-	-	-	-	-	-
Imports (+)	3,596.20	-	15,272.28	626.86	5.99	47.24	1,000.28	415.87	696.29	154.81	4.65	57.20
Exports (-)	-	-	-	(146.86)	(3.13)	-	(86.69)	(910.27)	(6.25)	(5.28)	-	(635.36)
Bunkering (-)	-	-	-	-	-	-	(105.29)	(105.44)	-	-	-	-
Stock Change (+/-)	-	-	33.06	37.35	(3.67)	(9.78)	35.83	25.13	(2.21)	-	(1.47)	(10.77)
Primary Energy Supply	4,240.87	8.75	15,361.31	517.35	(0.81)	37.47	844.12	(574.72)	687.83	149.53	3.18	(588.94)
Refinery (Crude Run)	-	-	(14,955.05)	1,517.41	625.93	532.29	4,706.69	5,290.67	434.45	675.35	-	800.12
Power Generation	-	-	-	-	-	-	-	-	-	-	-	-
Fuel Input (-)	(3,784.43)	(8.75)	-	-	-	-	(252.03)	(1,688.65)	-	-	-	-
Electricity Generation	1,433.02	1.46	-	-	-	-	82.91	707.00	-	-	-	-
Gas Manufacture	-	-	-	-	-	-	-	-	-	-	-	-
Transmission/Dist. Loss (-)	-	-	-	-	-	-	-	-	-	-	-	-
Energy Sector Use & Loss (-)	-	-	(771.66)	-	-	-	-	-	-	-	-	-
Net Domestic Supply	456.44	-	(365.40)	2,034.75	625.13	569.76	5,298.78	3,027.31	1,122.28	824.89	3.18	211.18
Statistical Difference	(383.57)	-	-	(115.30)	(54.25)	(10.47)	(114.46)	482.61	(10.68)	(24.78)	(0.27)	153.99
% Statistical Difference	(84.04)		-	(5.67)	(8.68)	(1.84)	(2.16)	15.94	(0.95)	(3.00)	(8.46)	72.92
Net Domestic Consumption	840.01	-	-	2,150.05	679.38	580.22	5,413.24	2,544.70	1,132.95	849.67	3.45	57.20
INDUSTRY	700.70	-	-	-	-	41.98	474.47	1,414.72	51.48	-	-	-
Manufacturing	700.70	-	-	-	-	40.36	278.15	1,374.37	51.37	-	-	-
Beverages	-	-	-	-	-	0.48	19.01	107.12	2.30	-	-	-
Tobacco	-	-	-	-	-	-	2.93	9.85	0.63	-	-	-
Coco/Vegetable Oil	-	-	-	-	-	0.10	10.29	43.54	-	-	-	-
Sugar	-	-	-	-	-	0.02	39.86	57.33	-	-	-	-
Other Food Processing	-	-	-	-	-	0.85	33.92	191.45	8.78	-	-	-
Textiles/Apparel	-	-	-	-	-	0.78	3.99	157.66	0.56	-	-	-
Wood Prod/Furniture	-	-	-	-	-	0.02	9.10	5.49	0.00	-	-	-
Paper Prod/Printing	-	-	-	-	-	1.42	2.32	191.47	0.29	-	-	-
Chemicals Except Fertilizer	1.40	-	-	-	-	24.54	33.50	147.92	7.98	-	-	-
Fertilizer	5.52	-	-	-	-	-	3.13	21.22	0.54	-	-	-
Rubber/ Rubber Products	-	-	-	-	-	0.05	1.88	27.48	-	-	-	-
Glass/Glass Products	-	-	-	-	-	0.36	5.80	59.86	3.04	-	-	-
Cement	685.67	-	-	-	-	0.01	14.70	185.41	2.89	-	-	-
Lube Refining	-	-	-	-	-	-	6.59	1.54	0.15	-	-	-
Other Non-Metlc Minerals	-	-	-	-	-	7.48	0.90	3.40	10.83	-	-	-
Basic Metal	8.10	-	-	-	-	3.54	83.30	160.80	12.81	-	-	-
Machinery/Equipment	-	-	-	-	-	0.72	6.93	2.85	0.56	-	-	-
Other Manufacturing	-	-	-	-	-	-	-	-	-	-	-	-
Mining	-	-	-	-	-	0.00	46.73	32.04	0.08	-	-	-
Construction	-	-	-	-	-	1.62	149.60	8.30	0.02	-	-	-
TRANSPORT	-	-	-	2,150.05	677.63	-	4,468.11	916.75	0.01	849.67	3.45	-
Railway	-	-	-	-	-	-	1.28	-	-	-	-	-
Road Transport	-	-	-	2,150.05	599.47	-	4,083.94	-	0.01	-	-	-
Water Transport	-	-	-	-	78.16	-	382.89	916.75	-	-	-	-
Domestic Air Transport	-	-	-	-	-	-	-	-	-	337.74	3.45	-
International Civic Aviation	-	-	-	-	-	-	-	-	-	511.92	-	-
RESIDENTIAL	-	-	-	-	-	536.58	-	-	890.57	-	-	-
COMMERCIAL	-	-	-	-	-	-	208.34	192.13	190.89	-	-	-
AGRICULTURE	-	-	-	-	1.75	1.67	262.32	21.11	-	-	-	-
Agri-Industry	-	-	-	-	1.74	1.67	257.94	21.09	-	-	-	-
Agri Crops Product	-	-	-	-	0.21	0.25	11.91	-	-	-	-	-
Livestock/Poultry	-	-	-	-	0.02	-	1.15	4.24	-	-	-	-
Agri Services	-	-	-	-	0.01	0.16	3.75	1.30	-	-	-	-
Fishery	-	-	-	-	1.49	1.26	241.14	15.55	-	-	-	-
Forestry	-	-	-	-	0.01	-	4.38	0.01	-	-	-	-
OTHERS, NON-ENERGY USE	139.31	-	-	-	-	-	-	-	-	-	-	57.20

OVERALL ENERGY BALANCE SHEET, PHILIPPINES (2000)

Asphalt	Lubes	OtherPP	Hydro	Geo	Biomass	Ricehull	Charcoal	Fuelwood	Bagasse	Agriwaste	animal waste	Biofuels	Electricity	Total
-	-	-	1,941.85	9,998.36	6,670.04	50.8	630.6	4,362	585	1,030	12	-	-	19,319.64
6.84	-	-	-	-	-	-	-	-	-	-	-	-	-	21,884.53
(1.35)	-	-	-	-	-	-	-	-	-	-	-	-	-	(1,795.19)
-	-	-	-	-	-	-	-	-	-	-	-	-	-	(210.74)
1.67	-	1.97	-	-	-	-	-	-	-	-	-	-	-	107.11
7.17	-	1.97	1,941.85	9,998.36	6,670.04	50.8	630.6	4,362	585	1,030	12	-	-	39,305.35
69.05	6.78	5.92	-	-	-	-	-	-	-	-	-	-	-	(290.39)
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	(1,941.85)	(9,998.36)	-	-	-	-	-	-	-	-	-	(17,674.07)
-	-	-	670.71	999.84	-	-	-	-	-	-	-	-	3,894.94	3,894.94
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	(545.71)	(545.71)
-	-	-	-	-	-	-	-	-	-	-	-	-	(205.52)	(977.18)
76.22	6.78	7.89	-	-	6,670.04	50.8	630.6	4,362	585	1,030	12	-	3,143.71	23,712.93
(1.26)	6.78	(121.17)	-	-	-	-	-	-	-	-	-	-	-	(558.23)
(1.65)	100.00	(1,535.47)			-	-	-	-	-	-	-	#DIV/0!	-	(2.35)
77.48	-	129.06	-	-	6,670.04	50.8	630.6	4,362	585	1,030	12	-	3,143.71	24,271.16
-	-	-	-	-	1,011.96	29.2	-	140	585	246	12	-	1,134.91	4,830.21
-	-	-	-	-	1,011.96	29.2	-	140	585	246	12	-	1,093.15	4,550.06
-	-	-	-	-	-	-	-	-	-	-	-	-	26.66	155.56
-	-	-	-	-	-	-	-	-	-	-	-	-	4.91	18.32
-	-	-	-	-	-	-	-	-	-	-	-	-	4.75	58.67
-	-	-	-	-	584.58	-	-	-	585	-	-	-	11.92	693.70
-	-	-	-	-	419.19	29.2	-	140	-	246	4	-	122.40	776.58
-	-	-	-	-	-	-	-	-	-	-	-	-	75.89	238.88
-	-	-	-	-	-	-	-	-	-	-	-	-	4.97	19.59
-	-	-	-	-	-	-	-	-	-	-	-	-	62.89	258.38
-	-	-	-	-	-	-	-	-	-	-	-	-	211.44	426.78
-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.41
-	-	-	-	-	-	-	-	-	-	-	-	-	9.72	39.12
-	-	-	-	-	-	-	-	-	-	-	-	-	7.00	76.05
-	-	-	-	-	-	-	-	-	-	-	-	-	77.24	965.93
-	-	-	-	-	-	-	-	-	-	-	-	-	0.44	8.71
-	-	-	-	-	-	-	-	-	-	-	-	-	43.59	66.21
-	-	-	-	-	-	-	-	-	-	-	-	-	120.42	388.96
-	-	-	-	-	-	-	-	-	-	-	-	-	304.11	315.17
-	-	-	-	-	8.20	-	-	-	-	-	8	-	4.83	13.03
-	-	-	-	-	-	-	-	-	-	-	-	-	16.45	95.30
-	-	-	-	-	-	-	-	-	-	-	-	-	25.31	184.85
-	-	-	-	-	-						-	-	4.75	9,070.42
-	-	-	-	-	-	-	-	-	-	-	-	-	4.75	6.03
-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,833.48
-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,377.79
-	-	-	-	-	-	-	-	-	-	-	-	-	-	341.20
-	-	-	-	-	-	-	-	-	-	-	-	-	-	511.92
-	-	-	-	-	5,368.50	-	501.1	4,084	-	783	-	-	1,108.88	7,904.53
-	-	-	-	-	289.58	21.6	129.5	138	-	-	-	-	870.18	1,751.12
-	-	-	-	-	-	-	-	-	-	-	-	-	24.99	311.84
-	-	-	-	-	-	-	-	-	-	-	-	-	24.99	307.44
-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.38
-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.40
-	-	-	-	-	-	-	-	-	-	-	-	-	24.99	30.22
-	-	-	-	-	-	-	-	-	-	-	-	-	-	259.44
-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.40
77.48	-	129.06	-	-	-	-	-	-	-	-	-	-	-	403.05

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Activity Data - Data derived from the weight of any human activity that lead to emissions or removals of GHGs during a specified period.

Aerosol - Solid or liquid particles with aerodynamic diameters ranging from 0.01 to 10 micrometers or microns. They remain in the atmosphere for several hours and can influence the climate by scattering and absorbing radiation, acting as a cloud condensation nuclei, or modifying the optical properties and lifetime of clouds.

Anaerobic Decomposition – Conversion of organic matter into energy and simpler chemical compounds by microorganisms in the absence of oxygen.

Base Year - Starting year for the inventory.

Biomass - Organic matter derived from living organisms.

Bottom Up Approach – A shorthand for disagreggated models which employs technological and engineering details in the data analysis.

Calorific Value - Amount of chemical energy stored in a fuel that can be released as thermal energy during its combustion.

Carbon Dioxide Equivalent - A quantity referring to the amount of CO_2 that has the same Global Warming Potential with a certain mixture and amount of greenhouse gases.

Conversion Factor - A value used to convert data from one unit of measurement to another.

Emission Factor - Coefficient used to estimate amount of gas produced or removed per unit activity.

Expansion Ratio – Coefficient used for the estimating the quantity of logging wastes produced during timber harvesting which are left in the logging area to decay.

First Order Decay Model – Method for GHG inventory from solid waste that assumes that the rate of anaerobic decomposition is proportional to the mass of degradable organic carbon.

Fugitive Emissions - The greenhouse gases that may be released during the extraction, processing, handling and delivery of fossil fuels to the point of final use.

Land Use - Total anthropogenic activities undertaken in a particular type of land cover.

Mass Balance Approach - Method for GHG inventory from solid waste that assumes that methane is released in the same year that the waste is deposited and its formation is constant over time.

Methane Conversion Factor - Actual methand produced from a potential capacity termed as, methane producing capacity (see next)produced.

Methane Producing Capacity - Amount of methane that can be produced by a wastewater handling system given a quantity of wastewater sludge.

Ozone Depleting Substances - Compounds that lead to the depletion of ozone in the stratosphere under intense ultraviolet light. Examples are CFCs HCFCs, halons, methyl bromide, carbon tetrachlorise, and methyl chloroform.

Precursor Gas - Gases that lead to the formation of substances in the atmosphere with a climate change impact. Examples are SO_2, NO_x, NMVOC and CO.

Renewable Energy - Energy resources that do not have an upper limit on the total quantity to be used. Such resources are renewable on a regular basis and the renewable rate is rapid enough to consider availability over an indefinite time. Examples are biomass, solar, wind, hydro and ocean energy.

Sink - A mechanism that removes a greenhouse gas or its precursor from the atmosphere.

Sludge - Semi-solid residue from wastewater treatment process.

Tier 1 - Use of default activity and parameters in the inventory.

Tier 2 - Use of some default parameters and good quality country-specific data in the inventory.

Tier 3 - Good quality country-specific data and nationally developed key parameters in the inventory.

Top Down Approach - Shorthand for aggregated models. It uses macro-economic theory and econometric techniques to model demand and supply from sectors like the energy and agriculture sector.

Trace Gas - All atmospheric gases that make up 1% (by volume) of the atmosphere. Carbon dioxide, argon, and ozone are examples.

Volatile Organic Compound - Man-made chemicals characterized by their high vapor pressure and low water solubility.

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