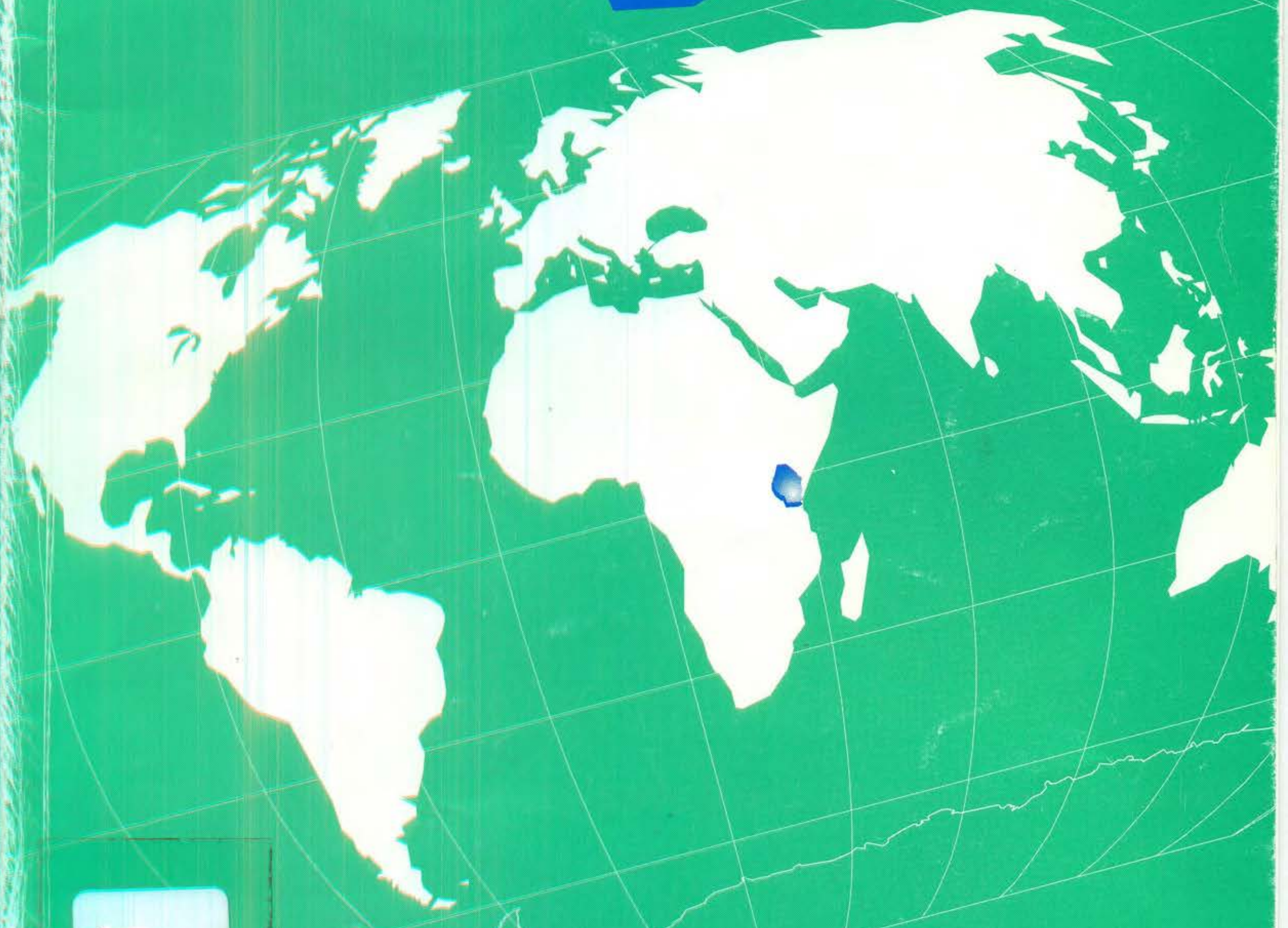
Country Case Study on Sources and Sinks of Greenhouse Gases in Tanzania

Final Report



Global Environment Facility

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PREFACE

In accordance with Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), all Parties are required to develop, periodically update, publish and make available to the Conference of the Parties, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol using comparable methodologies to be agreed upon by the Conference of the Parties.

A methodology for conducting such inventories was developed by the OECD Environment Directorate, the International Energy Agency (IEA), and the IPCC Working Group I Technical Support Unit and was proposed as the standard methodology as required under the Convention.

In order to test and further refine the method, the UNEP Atmosphere Unit, working in collaboration with the UNEP Global Environment Facility (GEF), implemented a series of nine complementary national studies using these "IPCC Guidelines for National Greenhouse Gas Inventories".

This report is one of the nine technical reports resulting from this effort. Based partly on this study and on a series of regional workshops sponsored by UNEP under the GEF funded programme and with the assistance of experts from a number of countries, an improved version of the IPCC Guidelines was prepared and approved at the Tenth Plenary Session of the IPCC in Nairobi (November 1994).

The First Conference of the Parties to the UNFCCC (Berlin, April 1995) also adopted the IPCC methodology as the recommended standard to be employed by all Parties in making their inventories in accordance with Article 4.

It is hoped that this report will assist other country study teams in the development and updating of future inventories of greenhouse gases.

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SOURCES AND SINKS OF GREENHOUSE GASES IN TANZANIA

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ACKNOWLEDGEMENT

The study on Greenhouse Gas Emissions in Tanzania was done by a team under the leadership of Prof. Mark J. Mwandosya and Prof. Matthew Luhanga. The study was carried out by the Centre for Energy, Environment, Science and Technology (CEEST) on behalf of the Department of Environment of the Ministry of Tourism, Natural Resources and Environment. The support that CEEST received from the Ministry of Tourism, Natural Resources and Environment and especially from the Director and staff of the Department of Environment contributed in no small measure to the completion of the task assigned to CEEST.

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The Centre for Energy Environment Science and Technology
February, 1996

EXECUTIVE SUMMARY

The United Nations Framework Convention on climate Change (UNFCCC) to which Tanzania is a signatory requires countries that ratify the Convention to communicate to the Conference of Parties (CoP) to the Convention information regarding human indicated emissions by sources and removal by sinks of greenhouse gases. The gases in question are those that have not been covered by the montreal Protocol.

Tanzania is also a signatory to and has ratified the Montreal Protocol. The Montreal Protocol is a follow up of the 1985 Vienna Convention on Substances that Deplete the Ozone Layer. The Montreal Protocol of 1987 has called on Parties to the Protocol to freeze consumption of Ozone Depleting Substances (ODSs) at level of 1986 by July 1989, and to phase out these as soon as possible but not later than the year 2000.

In order to prepare an inventory of emission by sources and removal by sinks of greenhouse gases (GHG), and with the benefit of grants from the United nations Environment Programme (UNEP) and from the international Development Research Centre of Canada (IDRC) to the Government and to the University of Dar es Salaam, respectively, a team of researchers was organised under the auspices of the Centre for Energy, Environment, Science and Technology (CEEST). CEEST is a Dar es Salaam-based non-governmental organisation that undertakes research and various studies related to energy, the environment, technology and science, water and sanitation, and natural resource use and management.

To facilitate implementation of the study, and following on the guidelines based on a methodology developed by UNEP, the Organisation of Economic Cooperation and Development (OECD) and the International Panel on Climate Change (IPCC), the study was organised on the basis of the sectors of energy and transport, industry, agriculture, forestry and land-use, commerce and household, and solid waste and wastewater management.

Estimates of carbon dioxide (CO_2) from energy activities is given in Chapter 2. CO_2 was estimated on a mass balance basis using information on the amount and carbon content of the fuels consumed (primary energy data), with few adjustments such as for non-oxidized products, served as the basis of the inventory calculation. The total carbon dioxide emitted from fossil fuels combustion is estimated at 1939 Gg. This figure has been disaggregated further into 1781 Gg from liquid fossil fuels, and 158 Gg from solid fossil fuels.

Emissions of greenhouse gases from the industrial sector (Chapter 3) is based on the study of energy use in the various subsectors classified according to the industrial standard industrial classification system namely; food; beverage and tobacco; textile, leather and sisal; metal and engineering; chemical; wood products and printing; and non-metal mineral products.

Emission estimates are based on the relationship between energy input into an activity and the emission per unit of energy input (the emission factor). These two parameters are based on the type of fuel, the nature of the activity, and the technology used such as the boiler, kiln and the furnace.

Special consideration has been given to emission from thermal power generation (Chapter 4) although they are in effect similar to stationary combustion processes of heavy-duty mobile, high speed medium controlled diesel engines. The total consumption of fuel for power generation has been obtained from TANESCO and emissions from thermal power plants for 1990 are as shown in Table 4.5.

Emission of greenhouse gases from the transport sector has been estimated by considering state of the transport sector including the modes of transport, the types of fuel used by the various modes, the vehicle types and the amount of energy consumed. All motor vehicles imported into Tanzania are emission-uncontrolled. International bunkers are not considered here. Estimates of emissions from the transport sector for 1990 are as shown in Table 5.6.

The study has also resulted into an estimate of greenhouse gases emission from cottage industries. These include small scale food processing industries like brewing, fish smoking, salt production, banking, small restaurants and food vending. Other cottage industries include tobacco curing, tea drying, beeswax processing, burnt brick making, lime production, smithies, foundries, pottery and other ceramics. Most of these industries are rural and depend on woodfuel as their major source of energy. Emissions from cottage industries are estimated in Chapter 6.

Biomass energy accounts for almost 90 percent of primary energy demand in the country. In Chapter 6 an attempt is made to examine greenhouse gas emission arising out of biomass in households and in the commercial and informal sectors. Emissions from fossil fuel use in these sectors are also estimated.

In the case of woodfuels the approach here is to estimate total biomass use on the basis of which trace gas emissions are estimated using emission ratios. In the case of fossil fuel use, again the approach is to estimate trace gas emissions, with carbon dioxide emission being accounted for from the supply side using the top-down approach.

In estimating biomass demand is the country, use is made of the results of an urban energy use study for urban energy demand, and results of various rural biomass energy use. Carbon dioxide emission is considered as part of emissions from land-use changes, with emissions from off site burning from the conversion of forests for permanent upland being netted-off to avoid double counting because these have been taken into account in the total biomass supply in Chapter 6.

In the mining sector (Chapter 7) emissions have been estimated from coal mining activities and exploitation of carbon dioxide. In the case of coal and mining, methane emission has been estimated from the ventilation system, degasification activities and post-mining operations of the Kiwira coal mine and the Ilima colliery.

The production of carbon dioxide at Kyejo is a human-induced activity and the output of the plant is assumed to finally end up as an emission in the year of production. The details of the emission is given in Chapter 8.

Chapter 9 presents results of estimates of emission of greenhouse gases from the transformation of raw materials into intermediate or final products in industrial processes. The main activity considered is the emission of carbon dioxide from cement production. The amount of carbon dioxide emitted is estimated from the product of the quantity of cement produced in a year and an emission factor reflecting the mass of carbon dioxide released per unit time in the cement clinker.

Chapter 10 presents estimates of greenhouse gas emission from the agricultural sector. Emissions have been estimated resulting from the following activities:- rice cultivation, use of nitrogen fertilisers; enteric fermentation of domestic animals; emission from animal wastes; burning of agricultural crop waste; and emission from wildlife. Production of methane from rice fields is a result of the decomposition of organic material by methanogenic bacteria.

Methane emission will vary according to such factors as soil type, temperature, fertilizer and water management. The amount of methane emitted from rice fields in Tanzania has been obtained using a daily emission rate and the number of hectare-days in the year for irrigated and rainfed rice growing regimes.

Methane production in animals is part of the normal digestive process in ruminants such as cattle sheep and goats. Estimation of methane emission from ruminant is based on estimation of the percentage of the total feed energy intake by the animal, that is converted to methane. The principle used in based on breaking down the total energy requirement of the animal into that required for its own maintenance, for growth, pregnancy, for work and for production of milk or wool. Methane is generated from animal wastes when the organic material decomposes anaerobically. Estimates of methane emission have been made using the direct relationship between the amount of volatile solids present in animal wastes and the potential for methane generation.

For different types of animals, numbers of which have been obtained from the Ministry of Agriculture, the methane emission potential has been obtained from information supplied by the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC). The realised methane emission has been obtained, after taking into consideration the type of waste management for each animal category. Table 10.5 summarises the emission of methane from animal wastes by animal type.

The emission of nitrous oxide is a result of natural processes in the soils and nitrification and oxidation of ammonia to nitrate. Fertilizers add nitrogen to the soil and lead to increased emission of nitrous oxide from the soil. An estimate of emission of nitrous oxide for each type if fertilizer used in the country is made from the product of fertilizer consumption and the emission coefficient (nitrous oxide released per unit weight of fertilizer used) usually specified as a range from low to medium and high. Estimates of emissions of nitrous oxide are shown in Table 10.6.

Carbon dioxide, methane, carbon monoxide, nitrous oxides and nitrogen oxides are released into the atmosphere when crop wastes are burned. Carbon dioxide release is considered to be part of a natural closed cycle, with reabsorption occurring in the next growing season. Three crops namely cotton, sugar cane and paddy, have been considered. Although other crops such as maize and millet leave behind quantities of residue, these are used mainly for mulching and as animal feed. Estimates of emission of trace gases from these crops is made by estimating first the carbon content of the residues, and later applying emission ratios from experimental results obtained at the University of Dar es Salaam in the case of methane and carbon monoxide and from IPCC in the case of other trace gases. These are shown in Table 10.11.

Savannah burning is a practice prevalent in Tanzania. It occurs every year during the dry season. It is estimated that 9,000 kha of land is subjected to above ground burning annually. An estimate of carbon dioxide emission is made in order to determine the approximate amounts of trace gases emitted into the atmosphere. Carbon dioxide emission is not accounted for in the final balance. It is considered to be part of the natural cycle, being absorbed in the next planting season. The estimate of emission from savannah burning are summarised in Table 10.16 in Chapter 10.

Changes in the use of land that result in changes in the amount of biomass on it result in net changes in greenhouse gas emission on account of the fact that about 45 percent of biomass is carbon by weight. Wetlands are a natural source of methane changes in wetlands therefore result in net changes of methane emission. A discussion of greenhouse gas emissions from land use and forestry is made in Chapter 11.

Categories of land-use change activities which contribute to emission of greenhouse gases which have been considered include:- forestry clearing for permanent cropland or pasture, conversion of grassland into cultivated land, regrowth in lands which were previously managed but were abandoned, forest management, shifting cultivation, and flooding of lands.

In order to arrive at estimates of emission of greenhouse gas emissions from landuse changes, it is necessary to have an appreciation of past changes over time, 25 years. In addition, above ground biomass which remains on land after clearing decays over an average of 10 years. Ideally, land-use changes should be monitored and recorded on a yearly basis. This has not been done in the case of Tanzania. The study has therefore made an estimate of these changes based on the reading and interpretation of vegetation maps of 1947, 1956, 1972 and 1990 and other literature.

As the population increases so does the encroachment on forests for permanent cropland and pasture. It is estimated that 88,600 ha of forest area was converted into cropland and pasture in 1990. Emission carbon dioxide from this activity is based on the estimation that 80 percent of the cleared biomass is burned off site. Of the 20 percent burned on-sight, 90 percent is oxidised and 10 percent is left to decay releasing carbon-dioxide over 10 years. Carbon dioxide release is based on the fact that biomass is 45 percent carbon by weight and nitrogen trace gases release is estimated using emission ratios.

Managed lands which have been abandoned have a capacity for vegetation regrowth, leading to reaccumulation of carbon. In this case, abandoned managed lands act as sinks of carbon dioxide. Thus far information has been obtained concerning abandonment of approximately 35 kha of cashew tree farms and 205 kha of sisal estates. It has been assumed that 80 percent of the original soil content was lost during management of the land and that 50 percent of the lost soil carbon reaccumulates as abandoned managed land is left to regrow in 25 years. The sink effect of the biomass regrowth is obtained from the product of the areas originally abandoned and the respective annual growth rates of the biomass densities.

Forests subject to human activity can either be a sink or a source of carbon dioxide depending on whether there is a net increment or decrement of carbon in a year. Emissions or removals of carbon dioxide due to plantation forests, tree planting programmes and human activity in unprotected natural forests have been considered in the study. Carbon growth in plantation forests, village woodlots, and other tree planting programmes provides a sink whereas commercial harvesting of biomass and informal woodfuel exploitation from accessible natural forests are a source of carbon dioxide.

Shifting cultivation is still being practiced in Tanzania, although more and more permanent settlements are a common feature of agriculture in the country. Information on the area subjected to shifting agriculture is unavailable. As such, the study has restricted itself to the estimation of emission of greenhouse gases from this practice arising from tobacco growing. The same considerations apply to the estimation of emissions from this practice as those that apply to conversion of forests permanent cropland.

The study has also estimated the emission of methane from man-made flooding of land from the impoundment of dams for electricity generation and water supply. It is assumed that 10 percent of the man-made flooded area is subjected to anaerobic digestion during the wet season and that methane release ceases 90 days after the start of the wet season.

In the sector of solid waste and wastewater management (Chapter 12), through literature search, the composition of municipal waste in Dar es Salaam was determined. Waste generated in major towns in the country has been estimated from the annual estimate of per capita generation. Information has been compiled concerning the characteristics of the two major waste disposal points for Dar es Salaam, the Vingunguti dumpsite and the Tabata dumpsite which has been closed. Methane emission has been estimated, from these dumpsites as well as from open dumps from other municipal waste disposal points, to be 8.363 Gg.

Emission of methane from wastewater and sanitary systems have been estimated using gas collected and analysed for composition from septic tanks,waste stabilisation ponds, drop holes of pit latrines and inspection chambers of sewerage systems. Based on estimates the amount of organic material in industrial wastewater streams and the amount of wastewater discharge from industries with wastewater treatment facilities, the study has made an estimate of methane emission from industrial water treatment.

A summary of estimates of greenhouse gas emission by source and removal by sinks is as shown in Table 13.1. Results indicate that land use changes and forestry and the energy sector contribute the largest share of greenhouse gas emissions in Tanzania. However, in respect of land-use and forestry changes, data uncertainties are such that the results should at this stage be considered indicative. More work including the refinement of data and the underlying assumptions required for the estimation of emissions and removal of greenhouse gases, is required before the results are used as a basis for definitive policy action.

Another limitation of the study has been the use of emission factors based on default values provided by IPCC as a result of absence of country-specific emission factors and emission ratios. It is recommended, therefore, that a programme be put in place to conduct studies aimed at obtaining country - specific emission factors. Furthermore, it is recommended that the completion of the exercise of creation of an inventory of sources and sinks has to lead to the creation of a mechanism for its regular updating.

These observations and recommendations were endorsed by the National Workshop on Sources and Sinks of Greenhouse Gases in Tanzania, that was convened by CEEST and held at the Tanzania Commission for Science and Technology, 26/9/1994 to 27/9/1994. In addition, the Workshop stressed the need for capacity building and capacity sharing in climate studies in developing countries. The workshop recommended that anticipatory and precautionary measures be taken by the Government to reduce vulnerability to climate change and climate variations. The workshop further recommended that even with uncertainties of data highlighted in the study, a good basis exists for the country to embark on studies on mitigation of emission and assessment of vulnerability. It was stressed that climate change and climate vulnerability should be incorporated on development policy initiatives plans and programmes. Caution was however, added, that for this exercises to be relevant, there must be a linkage between the objective of poverty alleviation and improvement of socio-economic situation of Tanzania and other developing countries.

The workshop was opened by the Principal Secretary of the Ministry of Tourism, Natural Resources and Environment, who promised that Tanzania would ratify the United Nations Convention on Climate Change. It was closed by the Principal Secretary of the Ministry of Works, Transport and Communication who on behalf the Government promised to take account of the recommendations of the workshop in its short, medium, and long-term plans.

1.0 INTRODUCTION

1.1 Background

In 1990, a group of researchers from The University of Dar es Salaam, Tanzania and the Zimbabwe Institute of Development Studies drew up a proposal on a collaborative study on greenhouse gas emissions from food production and energy production and utilization. This study funded by the IDRC and Environment Canada, was one of the first attempts by researchers in the two countries to identify sources of greenhouse gas emissions and entry points for policy interventions. In particular the study sought to compare and contrast the emissions potential of the two countries, one with an agricultural based economy and another with a robust and sizeable manufacturing base. Cross country comparisons can only be meaningful if greenhouse gas emissions inventories are based on a common methodology.

The United Nations Framework Convention on Climate Change (UNFCCC) requires countries ratifying the Convention to communicate to the Conference of Parties (CoP) national inventories of anthropogenic (human-induced) emissions by sources and sinks of all greenhouse gases (GHGs) that have not been covered by the Montreal Protocol. The Montreal Protocol of 1987 called on Parties to the Protocol to freeze consumption of Ozone Depleting Substances (ODSs) at 1986 levels by July 1989, and to phase these out as soon as possible but not later that the year 2000.

In order to support the goals of the UNFCCC, the Intergovernmental Panel on Climate Change (IPCC) working Group 1 is collaborating with the Environment Directorate of the Organisation of Economic Cooperation and Development (OECD) to develop a standard methodology for GHG emissions to enable countries involved prepare inventories which allow for cross-country comparisons. The methodology used in this study is based on the report of an OECD Expert Meeting which was held in Paris in February 1991 and which was later issued in revised form in August 1991. Subsequent to this effort IPCC Draft Guidelines for National Greenhouse Gas Inventories have been issued in three volumes:- Volume 1 on Greenhouse Gas Inventory Reporting Instructions; Volume 2 is the Greenhouse Gas Inventory Workbook; and Volume 3, the Greenhouse Gas Inventory Reference Manual. The on-going effort aims at further development and refinement of the methodology by the participating countries, and more importantly the establishment of national inventories of anthropogenic greenhouse gas emissions and removals.

In order to support Tanzania's efforts towards meeting its obligation under the UNFCCC, a Memorandum of Understanding between the United Nations Environment Programme and the Government of Tanzania was entered into in July 1993 for the application of the IPCC methodology to create an inventory of sources and sinks of greenhouse gases. Tanzania is one of the eleven countries that participated in the UNEP/IPCC Global Environment Facility (GEF) funded greenhouse gases initiative. Other countries are Uganda, Gambia, Senegal, Mexico, Venezuela, Costa Rica, and Morocco.

Tanzania was introduced to the methodology through participation at the UNEP-sponsored Training Workshop on Inventories of Net Anthropogenic Emissions of Greenhouse Gases that was held in Nairobi, Kenya, 7-9 June 1993. Further, a Regional Workshop on National Inventories of Anthropogenic Emissions and Removals of Greenhouse Gases for Africa was held in Nairobi, 21-25 March, 1994. The study has also benefitted from the collaboration between CEEST and the Southern Centre for Energy and Environment (SCEE) through the IDRC funded initiative. A number of meetings and seminars involving these two institutions have taken place in order to exchange experiences and perspectives on climate change and development.

1.2 Objective

The main purpose of the study is to identify and quantify anthropogenic sources of atmospheric emissions of greenhouse gases in Tanzania. In particular the study aims at:-

- increasing the quantity and quality of base-line data available in order to further scientific understanding of the relationship of GHG emissions to climate change;

- enhancing the ability of various institutions in Tanzania to monitor, and report national inventories of GHG sources and sinks;

- the promotion of exchange of information related to climate change and national policy options and technology choices that could lead to eventual reduction of GHG emissions world wide;

- the identification of national policy and technological options that could reduce the national level of emissions; and

- the promotion of institutional links within the country and between Tanzanian and international institutions and agencies.

1.3 Project Team

This study is a collaborative effort of various institutions including:- the Ministry of Tourism, Natural Resources and Environment (MTNRE); the National Environment Management Council (NEMC); the Directorate of Meteorology (DoM); the Ministry of Water, Energy and Minerals (MWEM); the University of Dar es Salaam (UDSM); and the Centre for Energy, Environment, Science and Technology (CEEST); with the Department of Environment (DoE) of MTNRE being the lead agency. Other researchers were coopted for short durations from the Ardhi Institute, the Water Resources Institute, the Sokoine University of Agriculture, the Ministry of Agriculture (MoA), the Ministry of Lands, Housing and Urban Development, and the Department of Forestry. The institutional links between CEEST and SCEE have been an important feature of this study.

A National Steering Committee oversaw and gave guidance on the implementation of the study. The Committee members were drawn from DoE, DoM, NEMC, MWEM, MoA and the Department of Forestry, the Ministry of Industries and Trade, the University of Dar es Salaam, and CEEST.

The team of core and coopted researchers were organised under the following categories of sectors for the study of emissions:-

- energy and transport;

- industrial activities;

- agricultural activities;

- forestry and land use;

- commercial and household energy use; and

- solid waste and wastewater management.

This report is the national inventory of Tanzania, and presents the findings of the study team. A base line inventory of sources and sinks of greenhouse gases for Tanzania is being presented. While a lot of gaps do exist in the data available and that which is required for a detailed inventory, the work highlights areas where further research is needed for such an undertaking, including that of establishing country specific emission factors.

The aforesaid notwithstanding, the study team is of the opinion that work done thus provides for an adequate basis for priority ranking of emission sources and sinks to allow for concentration of efforts towards the more significant of these. A basis also exists for embarking on work related to mitigation of greenhouse gas emissions and assessment of vulnerability and adaptation to climate change.

Finally the study team proposes that a mechanism needs to be put in place for the continued updating of the inventory.

2.0 CARBON DIOXIDE EMISSIONS FROM FUEL COMBUSTION

2.1 Introduction

Carbon dioxide (CO_2) from energy activities was estimated on a mass balance basis using information on the amount and carbon content of the fuels consumed (primary energy data), with few adjustments such as for non-oxidized products, served as the basis of the inventory calculation.

Energy data used in this inventory on all commercial fuels has been obtained from the Ministry of Water, Energy and Minerals (1). This data was compared with that from internationally-data bases for individual countries of the world, such as the International Energy Agency (IEA)(2), which did not exactly tally. For this reason raw data was used, and reconciliations were made whenever possible.

2.2 Methodology

Average emission factors have been borrowed from IPCC (4), and the IPCC reference (top-down) method for estimating CO_2 emissions from fuel combustion has been employed. Detailed sectoral calculations based on "bottom up" approach are found in Chapters 3 to 6. Aggregated fossil fuels considered include solid, liquid and gaseous fossil fuels consumed. The amount of biomass consumed is included for reference. Biomass fuels have been included in the national energy and emissions accounts for completeness. The net flux of CO_2 to the atmosphere from biomass fuels should be evident in the calculation of CO_2 emissions described in the Land-use Change and Forestry chapter. CO_2 emissions from bunker fuels used for international marine or aviation purposes have been estimated separately.

2.3 Estimation of CO_2 emissions from fuel combustion

2.3.1 Assumptions

The IPCC reference approach is based on the accounting of the carbon in fuels supplied to the economy. It involves the careful estimation of fuel production,imports of fuels and refined products, exports of fuels and refined products, and changes in the stock level for these fuels and products. The following assumptions are made:-

(i) once carbon is brought into a national economy in fuel, it is either saved in increases of fuel stock or stored in product or left unoxidized in ashes or released to the atmosphere;

(ii) energy can neither be created nor be destroyed, but it can be transformed from one form to another. CO_2 accounting is thus based on the total supply of primary fuels and the net quantities of secondary fuels brought in the country; and

(iii) adjustments should be made on apparent consumption estimates for the stored carbon, fraction oxidized, and other complications on consumption side.

2.3.2 Methodology

The conceptual approach for estimating CO_2 emissions from energy consumption is characterized by six fundamental steps that explicitly identify all the factors necessary to measure CO_2 emissions from energy consumption:-

a) estimating consumption of fuel by fuel product type, as shown in Table 2.1;

b) converting fuel data to energy units (if necessary);

c) selecting carbon emission factors for each fuel product type and total carbon potentially released from use of the fuels, as shown in Table 2.2;

d) estimating the amount of carbon stored in products for long periods of time;

e) accounting for carbon not oxidized during combustion, as shown in Table 2.3; and

f) converting emissions as carbon to full molecular weight of CO_2, as shown in Table 2.3.

For all calculations of CO_2 emissions from fuel combustion, emissions are directly related to the amount of the fuel consumed and the carbon content of the fuel.

Table 2.1: Estimates of apparent fuel consumption in 1990

Fuel Type	Production kt	Import kt	Export kt	Bunkers kt	Stock change kt	Apparent Consumption kt
	A	B	C	D	E	F=A+B-C-D-E
Crude oil	n.a	495.777	0.000	0.000	52.375	443.402
Gasoline/Petrol	n.a	42.497	0.000	0.000	7.203	35.294
Jet Kerosene	n.a	69.252	0.000	19.377	19.076	30.799
Other Kerosene	n.a	50.535	0.000	0.000	0.000	50.535
Gas Oil/Diesel	n.a	282.112	0.000	8.841	49.000	224.271
Residue Fuel Oil	n.a	n.a	58.593	8.358	99.580	-166.531
Liquefied Petroleum Gas	n.a	0.606	0.000	0.000	0.000	0.606
Bitumen	n.a	10.000	0.000	0.000	0.000	10.000
Lubricants	n.a	3.000	0.000	0.000	0.000	3.000
Sub-bituminous Coal	60.261	0.000	0.000	0.000	0.000	82.261
Solid woody biomass	36182.904	0.000	0.000	0.000	0.000	36182.904
Animal Dung	97	0.000	0.000	0.000	0.000	97.000
Agricultural Waste	5990.672	0.000	0.000	0.000	0.000	5990.672

Source: (1, 3, 4)

Notes: (1) *n.a* refer to "not applicable", so long as crude oil is not yet produced in the country.

(2) Liquid fossil fuel import/export data were obtained from audited report (2). Traditional biomass consumption figures are obtained by summing up the values in Tables 3.8 and 6.6.

(3) To avoid double counting charcoal consumption figures (Table 6.6) are excluded, as the biomass used to produce charcoal is counted in Table 6.6.

Table 2.2: Estimates of carbon content and storage in fuel consumed in 1990

Fuel Type	G Calorific value TJ/kt	H Apparent Consumption TJ	I Carbon Emission Factor t C/TJ	J Carbon Content Gg C	K Fraction Carbon Stored	L Carbon Stored Gg C
		H=FxG		J=HxI/1000		L=JxK
Crude oil	42.62	18897.778	20.0	377.956	0.10	37.796
Gasoline/Petrol	44.80	1581.171	18.9	29.884	0.01	0.299
Jet Kerosene	44.59	1373.312	19.5	26.780	0.01	0.268
Other Kerosene	44.75	2261.441	19.6	44.324	0.02	0.886
Gas Oil/Diesel	43.33	9717.662	20.2	196.297	0.03	5.889
Residue Fuel Oil	40.19	-6692.895	21.1	-141.220	0.01	-1.412
Liquefied Petroleum Gas	47.31	28.670	17.2	0.493	0.40	0.197
Bitumen	40.19	41.838	22.0	0.920	0.99	0.911
Lubricants	40.19	377.947	20.0	7.559	0.99	7.483
Sub-bituminous Coal	28.00	2303.319	26.2	60.347	0.28	16.897
Sub-total		**29992.929**		**606.114**		**71.960**
Solid woody biomass	18.50	669383.724	29.9	20014.573	0.05	1000.729
Animal Dung	10.10	979.700	30.0	29.391	0.02	0.588
Agricultural Waste	8.60	51519.779	30.0	1545.593	0.02	30.912

Notes: (1) CO_2 emissions from solid woody biomass, animal dung, and agricultural waste combustion do not form part of reported figures, they appear for informational purposes only.

As described earlier, not all carbon is oxidized during the combustion of fuels. The amount of carbon that falls into this category is usually a small fraction of total carbon, and a large portion of this carbon oxidizes in the atmosphere shortly after combustion. The IPCC has been recommending that 0.01 of carbon in fossil fuels would remain unoxidized (3). Net carbon emissions were then multiplied by the (column N of Table 2.3) fraction of carbon oxidized to obtain actual carbon emissions (column O of Table 2.3). The actual carbon emissions (column O of Table 2.3) were further multiplied by the molecular weight ratio of CO_2 (44/12) to estimate carbon dioxide emitted from fuel combustion.

2.4 Discussion

The country data on fuel import, export, bunkers, and stock change slightly differs from that compiled by the IEA. Crude oil import in 1990 is on high side while white products are on low side, in the case of IEA data (2). Reasons for this relate to sources and data gathering timing by IEA. The actual and reliable import/export figures are normally obtained after two years in audited annual reports (3). The second reason is that IEA data had a number of unfilled gaps, which affect the quality of analysed figures. Based on these reasons, the study team used country figures gathered from reliable sources (3). Efforts should be made in future to harmonize the two databases.

Table 2.3: Estimates of actual CO_2 emissions from fuel consumed in 1990

Fuel Type	Net Carbon Emissions (Gg C)	Fraction Carbon Oxidized	Actual Carbon Emissions (Gg C)	Molecular weight ratio (44/12)	CO_2 from fuels (Gg)
	M=J-L	N	O=MxN	P	Q=OxP
Crude oil	340.160	0.99	336.758	3.667	1234.781
Gasoline/Petrol	29.585	0.99	29.289	3.667	107.395
Jet Kerosene	26.512	0.99	26.247	3.667	96.238
Other Kerosene	43.438	0.99	43.003	3.667	157.679
Gas Oil/Diesel	190.408	0.99	188.504	3.667	691.181
Residue Fuel Oil	-139.808	0.99	-138.410	3.667	-507.503
Liquefied Petroleum Gas	0.296	0.99	0.293	3.667	1.074
Bitumen	0.088	0.99	0.088	3.667	0.321
Lubricants	0.024	0.99	0.024	3.667	0.088
Sub-bituminous Coal	43.450	0.99	43.015	3.667	157.723
Sub-total	**534.153**		**528.811**		**1938.976**
Solid Woody Biomass	19013.844	0.99	18823.706	3.667	69020.256
Animal Dung	28.803	0.99	28.515	3.667	104.556
Agricultural Waste	1514.681	0.99	1499.534	3.667	5498.294

The results in column Q of Table 2.3 have been summed across all fuel types (excluding solid woody biomass, animal dung, and agricultural waste) to determine the total carbon dioxide emitted from fossil fuels combustion, which is estimated at 1,939 Gg. This figure has been disaggregated further into 1,781 Gg from liquid fossil fuels, and 158 Gg from solid fossil fuels. These figures are implicit in the summary table (that is Table 13.1) under fuel combustion. Table 2.4 gives the estimate of carbon dioxide emitted from international bunkers (about 113 Gg), which is calculated for information purposes only.

Table 2.5 summarizes energy consumption based on "bottom-up" and "top-down" analyses. It has been important to us to cross check the relationship between energy balance and emissions data, so as to determine the quality and scope of the results. Available energy balance figures show that about 29.99 PJ of fossil fuels was consumed by all sectors in 1990. The difference of 1.734 PJ (that is about 6% of fossil fuel) is accounted for by errors due to rounding-off the numbers at different stages of calculations, small power generation sets (gensets of less than 5 kVA capacity), losses not declared, and fuel smuggled to and from the neighboring countries.

Table 2.4: CO_2 emissions from international bunkers (road, marine and air transport)

Fuel Types	A Quantities Delivered (kt)	B Quantities Delivered (TJ)	C Carbon Content (Gg C)	D Carbon Emissions (Gg C)	E Carbon dioxide from bunkers Gg CO_2
Jet Kerosene	19.377	864.036	16.849	16.513	60.549
Gas Oil/Diesel	8.841	383.081	7.738	7.431	27.247
Residual Fuel Oil	8.358	335.922	7.088	6.947	25.472
Total	**36.576**	**1583.039**	**31.675**	**30.891**	**113.268**

Table 2.5: Energy consumption by sectoral activities in 1990 (PJ)

Sector specific data by energy source	Total energy (Col. H Table 2.2)	Stationary combustion sources (Col. A Table 3.15)	Thermal Power Plants (Col. E Table 4.3)	Mobile combustion sources (Col. A Table 5.7)	LPG,IK (Col. A Table 6.11) Biomass (Col. A Table 6.8)	Unaccounted energy inputs
	A	B	C	D	E	F=A-(B+C+D+E)
Fossil fuels	29.993	7.892	1.007	15.630	3.730	1.734
Biofuels	721.883	16.822	n.a	n.a	705.549	-0.487

2.5 References

1. Ministry of Water, Energy and Minerals (MWEM), 1991; Internal Communication (Energy Balance 1990), Tanzania Petroleum Development Corporation (TPDC), MWEM, Dar es Salaam.

2. OECD/IEA, 1992; World Energy Statistics and Balances: 1986-1990, International Energy Agency, OECD, Paris.

3. Tanzania Petroleum Development Corporation (TPDC), 1992; 17th Annual Report, TPDC, Dar es Salaam.

4. IPCC/OECD, 1995; Greenhouse Gas Inventory, Reference Manual, Final version Vol.3, OECD/IPCC, London.

3.0 NON-CARBON DIOXIDE EMISSIONS FROM INDUSTRIES (ISIC)

3.1 Introduction

The industrial sector in Tanzania is estimated to have used about 2.2% of the total energy demand or 330,000 tonnes of oil equivalent (TOE) in 1988 (1, 2). This level of energy consumption is small compared to that of Kenya which used about 843,000 TOE. South Korea on the other hand used about 19,469,000 TOE in 1986 (3). The relatively low level of energy utilization in industry in Tanzania is a reflection of the low level of industrialization combined with a low average capacity utilization (i.e. 33%).

The strategy adopted for the development of industries after independence in 1961 was that of import substitution, as well as establishment of primary industries for processing agricultural products in order to improve export earnings. There are no heavy industries of the type of integrated iron and steel works or heavy chemical plants. Most factories are medium size and labour intensive. Most were constructed in the 1970's and the 1980's when petroleum prices in the world market were low.

Energy consumption which is the primary source of greenhouse gas emissions from industries is characterized by use of petroleum fuels in the form of fuel oil (FO) and industrial diesel oil (IDO). Biomass, in form of fuelwood, charcoal and agricultural wastes, is also consumed, and accounts for about 37% of the total energy use in the sector. Other sources of energy used in the sector include petroleum products (46%); hydro-electricity 10%; and coal and others 7% (1).

3.2 Existing set-up of the industry sector

Using the International Standard Industrial Classification (ISCI) system the industrial sector in Tanzania can be broken down into six distinct sub-sectors namely; food, beverage and tobacco; textile, leather and sisal; the metal and engineering; chemicals; wood and wood products and printing; and the non-metal and mineral products sub-sectors. Cottage industries are considered under the Traditional biomass fuel chapter. This chapter considers greenhouse emissions from fuels combustion based on detailed technology and operational conditions (3).

3.2.1 Food, beverages and tobacco industries

This sub-sector is estimated to consist of about 180 establishments spread across the country. Many of these establishments are small scale factories. There are, however, some medium scale plants such as sugar refineries, breweries, and the cigarette company. Energy input into this sub-sector is mainly biomass in form of agricultural wastes such as bagasse, coffee husks, and fuelwood and charcoal. For medium scale industries energy inputs are fuel oil and electricity. It is estimated that the sub-sector used about 110,000 TOE in 1990. Table 3.1 summarizes the consumption of various fuels in the sub-sector for the years 1988, 1989 and 1990.

3.2.2 Textile, leather and sisal industries

Most of the industrial firms in this category are situated in urban areas. 126 establishments were registered in 1988. Major energy inputs into this sub-sector include petroleum fuels in the form of fuel oil and industrial diesel oil, and electricity for the provision of motive power. It has been estimated that this sub-sector used about 25,000 TOE in 1990. Table 3.2 summarizes petroleum and coal use in the sub-sector for the years 1988, 1989 and 1990.

Table 3.1: Fuel consumption in the food, beverage and tobacco industries (metric tonnes)

Fuel Type/*Device*	1988	1989	1990
Fuel Oil (FO):			
Boiler	82040	50888	34511
Liquefied Petroleum Gas (LPG):			
Boiler	120	120	120
Industrial Diesel Oil (IDO):			
Boiler	663	786	842
Woodfuel (fuelwood):			
Furnace	735040	831800	687120
Boiler	11517	6311	7134
Agricultural Wastes (Bagasse):			
Boiler	417207	439656	393677

Table 3.2: Fuel consumption in textile, leather and sisal industries (metric tonnes)

Fuel Type/*Device*	1988	1989	1990
Fuel Oil (FO):			
Boiler	13342	13671	13733
Industrial Diesel Oil (IDO):			
Boiler	325	1072	201
Kerosene:			
Kiln	14	14	14
Sub-bituminous Coal:			
Kiln	24	68	75

3.2.3 Metal and engineering industries

There are estimated to be 137 establishments in metal and engineering situated mainly in urban areas. Electricity is the primary energy source used in most factories to provide motive power for the plant machinery. Petroleum based fuels are also used extensively. Large energy consumers are based in Dar es Salaam, Tanga and Mwanza. It is estimated that metal and engineering industries used 32,200 TOE of fuels in 1990. Table 3.3 summarizes the petroleum and coal use in this category of industries for the years 1988, 1989 and 1990. As mentioned earlier, fuel consumption in both 1988 and 1989 is provided for information purposes only.

3.2.4 Petroleum refining and chemical industries

The Tanzanian and Italian Petroleum Refinery (TIPER) is one of the largest chemical plants in the country. It processes crude oil, imported mainly from the Middle East into refined products. These include Gas Oil (GO), Industrial Diesel Oil (IDO), Motor Spirit Premium (MSP), Motor Spirit Regular (MSR), Fuel Oil (FO), Residual Fuel Oil (RFO) and Bitumen. Part of the fuel is consumed at the refinery mainly to produce electricity, and in boilers and furnaces to provide process heat. The storage facilities at the plant also accumulate sludge after operating for long periods. Sludge is mainly found in the crude storage tanks and it cannot be processed in a normal refinery operation. Because of this, it has to be disposed of when it accumulates in large quantities. Disposal of sludge at TIPER poses an environmental problem since it is mainly dumped over land interfering with vegetation and water bodies. Table 3.4 shows the amount of crude oil processed and consumed, and production losses at the plant from 1989 to 1992.

Table 3.3: Fuel consumption in metal and engineering industries (metric tonnes)

Fuel Type/*Device*	1988	1989	1990
Fuel Oil (FO):			
Furnace	1102	1078	1149
Industrial Diesel Oil (IDO)			
Boiler	292	294	294
Furnace	1906	1235	968
Coal (coke):			
Furnace	21	24	24

Table 3.4: Petroleum refining industry (metric tonnes) during the period of 1989 - 1992

Energy Activities	1989	1990	1991	1992
Crude Processed	616,975	451,899.0	482,351	558,695
Total Production	574,729	420,178.0	449,211	516,632
FO Consumption	10,799	9,241.0	9,429	13,398
IDO Consumption	2,741	2,296.0	2,442	2,765
Fuel Gas Consumption	17,183	11,397.0	13,732	15,197
Production Losses	11,505	8,787.0	7,537	10,703

A few other medium size chemical plants exist in the country include manufacturing pharmaceutical, plastics, soap and other related products. Energy input into the sub-sector is in the form of electricity, fuel oil and industrial diesel oil. Woodfuel is not used in this sub-sector. About 33,000 TOE of various petroleum fuels were used in the sub-sector in 1990. Table 3.5 provides a summary of fuel consumption in the sub-sector for the years 1988, 1989 and 1990.

3.2.5 Wood, wood products, paper and printing industries

Factories in this sub-sector rely on electricity for pulp and paper manufacturing printing, publishing and manufacture of furniture. Coal, woodfuel and fuel oil are also used in pulp and paper plants, saw mills and few other factories. Greenhouse gases resulting from coal combustion, and not from any other post-coal mining activities, are considered here. Energy is mainly used in boilers for raising steam. Table 3.6 shows the petroleum and coal use in the sub-sector for the years 1988, 1989 and 1990.

Table 3.5: Fuel consumption in petroleum refining and chemical industries (metric tonnes)

Fuel Type/*Device*	1988	1989	1990
Fuel Oil (FO)			
Boiler	3892	4057	3683
Furnace	14161	14876	12924
Industrial Diesel Oil (IDO):			
Boiler	3230	3079	3003
Fuel gas:			
Furnace	12851	17701	17183
Liquefied Petroleum Gas (LPG)			
Furnace	154	132	226

Notes: (1) Fuel gas refers to the gas derived from the refining process in the refinery. Its chemical composition varies depending on the type of crude being processed. On average its calorific value is around 45 GJ/metric tonne.

Table 3.6: Fuel consumption in wood and printing industries (metric tonnes)

Fuel Type/*Device*	1988	1989	1990
Fuel Oil (FO):			
Boiler	3667	3355	5025
Woodfuel (fuelwood):			
Boiler	4200	4480	5650
Sub-bituminous coal:			
Boiler	*	*	18689

Notes: (*) Southern Paper Mill (SPM) used to import coal from Zambia so as to meet the specifications of its boilers for both calorific value and ash contents. As from 1990, SPM adjusted its boilers to burn sub-bituminous coal of lower calorific value and higher ash content from Kiwira.

3.2.6 Non-metal and mineral products industries

This sub-sector includes cement mills, glass works and manufacture of construction materials. There are three cement mills in the country and one glass factory. The cement mills and the glass works are all energy intensive. The sub-sector consumed about 95,000 TOE in 1990. Energy consuming processes in this sub-sector include the use of rotary kilns in cement mills and furnaces in the case of the glass factory. Table 3.7 provides details of petroleum and coal use in the sub-sector for the years 1988, 1989 and 1990.

Table 3.7: Fuel consumption in non-metal and mineral products industries (metric tonnes)

Fuel Type/*Device*	1988	1989	1990
Fuel Oil (FO)			
Kiln	65900	69800	69830
Furnace	11734	13116	15699
Liquefied Petroleum Gas (LPG)			
Furnace	142	190	230
Sub-bituminous Coal:			
Kiln	7966	9400	9400

3.3 Estimation of greenhouse gas emissions from stationary industries (ISIC)

Estimation of greenhouse gas emissions from stationary combustion sources has been done using the following basic formula (3):-

$$\text{Emissions} = \Sigma(EF_{abc} * \text{Activity}_{abc})$$

where:

EF = emission factor (g/GJ)
a = fuel type
b = sector-activity
c = technology type
Activity = energy input (GJ)

In the absence of emission factors for various types of furnaces, corresponding emission factors for boilers have been used for estimating emissions from furnaces. The balance of fuel which has not been accounted for has been treated as if it had been consumed to raise steam in boilers in industry.

Table 3.8 gives a breakdown of total fuels consumption in the sector by the three main end use devices in industry namely boilers, kilns, and furnaces during the period of 1988 and 1990. In estimating greenhouse gas emissions, biomass fuels were treated separately so as to avoid double counting. The aim here is to capture non-CO_2 emissions from burning woodfuel and bagasse. No country specific emission factors have been developed so far. The figures used in calculations were borrowed from IPCC(3). Tables 3.9 to 3.13 give details of calculation procedure following six categories of industry, fuel, and devices used to burn the fossil fuels in 1990.

Certain adjustments were made while converting physical units to energy units. These adjustments take into consideration the fact that not all supplied fuel is completely burnt. Some carbon is stored in ashes, while others escape unburnt to atmosphere. As discussed earlier in Chapter 2, estimates of combustible carbon are multiplied by 0.99 to obtain adjustment figures (column D of Table 3.9), which are further multiplied by column C of Table 3.9 to estimate apparent energy consumption in industry. Apparent energy consumption is the base of greenhouse gas emissions estimates, using emission factors given in Table 3.10 (3).

Table 3.8: Fuel consumption in industry sector for 1988 - 1990 (in metric tonnes)

Fuel Type/*Device*	1988	1989	1990
Fuel Oil (FO):			
Boiler	102941	71871	56952
Kiln	65900	69800	69830
Furnace	26997	29065	29772
Kerosene:			
Kiln	14	14	14
Fuel Gas:			
Furnace	12851	17701	17183
Liquefied Petroleum Gas (LPG):			
Boiler	120	120	120
Furnace	296	322	456
Industrial Diesel Oil (IDO):			
Boiler	4510	5231	4340
Furnace	1906	1235	968
Woodfuel (Fuelwood):			
Boiler	15717	10791	12784
Furnace	735000	831800	687120
Sub-bituminous Coal:			
Boiler	24*	68*	18764
Kiln	7960	9400	9400
Agricultural Waste (Bagasse):			
Boiler	417207	439656	393672

Notes: (*) Does not include coal consumption in Southern Paper Mills (SPM).

Table 3.11 gives the results of greenhouse gas emissions calculations based on figures in Tables 3.9 and 3.10. Values in column E of Table 3.9 have been multiplied by their corresponding emission factors (full mass of pollutants in Gg/PJ) in rows of Table 3.10. As mentioned earlier in Chapter 2, CO_2 values in Table 3.11 are not included in the inventory, they appear for reference only. Table 3.11 also summarizes the total quantities of greenhouse gas emissions (in gigagrams) from fossil fuel combustion in stationary industries. Disaggregation of industry by fuels and devices in use offers the best description of areas of possible emission mitigation intervention.

For completeness, Tables 3.12 to 3.14 were used to estimate greenhouse gas emissions from woodfuel and bagasse consumed in the industry sector. The same methodology and approach followed during estimating greenhouse emissions from fossil fuels, was employed here. Only the results of non-CO_2 emissions (expressed in columns of Tables 3.11 and 3.14) were added together in Table 3.15.

Table 3.9: Estimation of apparent energy (based on fossil fuel) consumption in industry (1990)

Sector specific data by fuel and device type	A Fuel consumed kt	B Calorific value TJ/kt	C Energy consumed PJ	D Fraction of Oxidized Fuel	E Actual Energy consumed PJ
			C=AxB/1000		E=CxD
Food, Beverage, and Tobacco:					
Fuel Oil boilers	34.511	43.33	1.495	0.96	1.4352
LPG boilers	0.120	47.31	0.006	0.98	0.0059
IDO boilers	0.842	40.19	0.034	0.98	0.0333
Textile, Leather, and Sisal:					
Fuel Oil boilers	13.733	43.33	0.595	0.96	0.5712
IDO boilers	0.201	40.19	0.008	0.98	0.0078
Kerosene kilns	0.014	44.75	0.001	0.97	0.0010
Coal boilers	0.075	28.00	0.002	0.71	0.0015
Metal and Engineering:					
Fuel Oil furnaces	1.149	43.33	0.050	0.96	0.0480
IDO boilers	0.294	40.19	0.012	0.98	0.0118
IDO furnaces	0.968	40.19	0.039	0.98	0.0382
Coke furnaces	0.024	28.00	0.001	0.71	0.0005
Refinery and Chemical Products:					
Fuel Oil boilers	3.683	43.33	0.160	0.96	0.1532
Fuel Oil furnaces	12.924	43.33	0.560	0.96	0.5376
LPG Furnaces	0.226	47.31	0.011	0.98	0.0105
Fuel Gas furnaces	17.183	45.00	0.773	0.97	0.7500
Wood, Wood Products, and Printing:					
Fuel Oil boilers	5.025	43.33	0.218	0.96	0.2016
Coal boilers	18.689	28.00	0.523	0.71	0.3715
Non-metal and Mineral Products:					
Fuel Oil kilns	68.830	43.33	2.982	0.96	2.8627
Fuel Oil furnaces	15.699	43.33	0.680	0.96	0.6528
LPG furnaces	0.230	47.31	0.011	0.98	0.0108
Coal boilers	9.400	28.00	0.263	0.71	0.1867

Table 3.10: Selected technology based emission factors for fossil fuels consumed in industry

Sector specific data by fuel and device type	F	G	H	I	J
	Carbon dioxide	Methane	Nitrogen oxides	Nitrous Oxide	Carbon monoxide
	Gg CO_2/PJ	Gg CH_4/PJ	Gg NOx/PJ	Gg N_2O/PJ	Gg CO/PJ
Food, Beverage, and Tobacco:					
Fuel Oil boilers	69.70	0.0029	0.161	0.00006	0.015
LPG boilers	62.44	0.0014	0.067	0.00001	0.017
IDO boilers	71.15	0.0029	0.161	0.00006	0.015
Textile, Leather, and Sisal:					
Fuel Oil boilers	69.70	0.0029	0.161	0.00006	0.015
IDO boilers	71.15	0.0029	0.161	0.00006	0.015
Kerosene kilns	71.15	0.0010	0.527	0.00006	0.079
Coal boilers	95.00	0.0024	0.329	0.00014	0.093
Metal and Engineering:					
Fuel Oil furnaces	69.70	0.0029	0.051	0.00006	0.015
IDO boilers	71.15	0.0029	0.161	0.00006	0.013
IDO furnaces	71.15	0.0005	0.161	0.00006	0.013
Coke furnaces	95.00	0.0024	0.232	0.00014	0.484
Refinery and Chemical Products:					
Fuel Oil boilers	69.70	0.0029	0.161	0.00006	0.015
Fuel Oil furnaces	69.70	0.0005	0.051	0.00006	0.013
LPG Furnaces	62.44	0.0011	0.047	0.00001	0.010
Fuel Gas furnaces	62.44	0.0011	0.050	0.00001	0.019
Wood, Wood Products, and Printing:					
Fuel Oil boilers	69.70	0.0029	0.161	0.00006	0.015
Coal boilers	95.00	0.0024	0.329	0.00014	0.093
Non-metal and Mineral Products:					
Fuel Oil kilns	69.70	0.0010	0.527	0.00006	0.079
Fuel Oil furnaces	69.70	0.0005	0.051	0.00006	0.013
LPG furnaces	62.44	0.0011	0.047	0.00001	0.010
Coal boilers	95.00	0.0024	0.329	0.00014	0.093

Notes: (1) Emission factors in reference manual were given in kilogram per Terajoule (kg/TJ), which equals tonne per Petajoule (t/PJ), and Table 3.10 is a continuation of columns of Table 3.9 for additional information necessary in calculations.

Table 3.11: Greenhouse gas emissions from fossil fuel combustion in industry sector (1990)

Sector specific data by fuel and device type	K	L	M	N	O
	Carbon dioxide emissions Gg CO_2	Methane emissions Gg CH_4	Nitrogen oxides Gg NOx	Nitrous oxide emissions Gg N_2O	Carbon monoxide emissions Gg CO
	K=ExF	L=ExG	M=ExH	N=ExI	O=ExJ
Food, Beverage, and Tobacco:					
Fuel Oil boilers	100.058	0.00416	0.23107	0.000086	0.02153
LPG boilers	0.347	0.00001	0.00040	0.000000	0.00009
IDO boilers	2.360	0.00010	0.00530	0.000002	0.00050
Textile, Leather, and Sisal:					
Fuel Oil boilers	39.816	0.00166	0.09196	0.000034	0.00857
IDO boilers	0.563	0.00002	0.00126	0.000000	0.00012
Kerosene kilns	0.043	0.00000	0.00030	0.000000	0.00005
Coal boilers	0.142	0.00000	0.00046	0.000000	0.00013
Metal and Engineering:					
Fuel Oil furnaces	3.331	0.00014	0.00240	0.000003	0.00072
IDO boilers	0.824	0.00003	0.00190	0.000001	0.00015
IDO furnaces	2.713	0.00002	0.00610	0.000002	0.00050
Coke furnaces	0.001	0.00000	0.00010	0.000000	0.00020
Refinery and Chemical Products:					
Fuel Oil boilers	10.678	0.00044	0.02473	0.000009	0.00230
Fuel Oil furnaces	37.471	0.00027	0.02742	0.000032	0.00700
LPG Furnaces	0.654	0.00001	0.00051	0.000000	0.00011
Fuel Gas furnaces	46.832	0.00083	0.03749	0.000008	0.01425
Wood, Wood Products, and Printing:					
Fuel Oil boilers	14.569	0.00061	0.03370	0.000013	0.00314
Coal boilers	35.296	0.00089	0.12216	0.000052	0.03460
Non-metal and Mineral Products:					
Fuel Oil kilns	199.559	0.00286	1.50890	0.000172	0.22619
Fuel Oil furnaces	45.516	0.00033	0.03329	0.000039	0.00849
LPG furnaces	0.666	0.00001	0.00060	0.000000	0.00011
Coal boilers	17.753	0.00045	0.06150	0.000026	0.01736
Total	559.236	0.01284	2.19155	0.000479	0.34611

Notes: (1) High emissions is a function of quantities of fuel consumption, as well as the type of fuel and devices in use.
(2) Table 3.11 is continuation of columns of Tables 3.9 and 3.10, which contain values used in calculations.

Table 3.12: Estimation of apparent energy (based on biomass fuel) consumption in industry in 1990

Sector specific data by fuel and device type	A Fuel consumed kt	B Calorific value TJ/kt	C Energy consumed PJ	D Fraction Oxidized Fuel	E Consumed Energy PJ
			C=AxB/1000		E=CxD
Food, Beverage, and Tobacco:					
Woodfuel furnaces	687.120	18.5	12.712	0.98	12.458
Woodfuel boilers	7.134	18.5	0.132	0.98	0.129
Bagasse boilers	393.677	10.1	3.976	0.98	3.897
Wood, Wood Products and Printing:					
Woodfuel boilers	18.689	18.5	0.346	0.98	0.339

Table 3.13: Selected technology based emission factors for biomass fuels consumed in industry.

Sector specific data by fuel and device type	F	G	H	I	J
	Carbon dioxide ($Gg\ CO_2/PJ$)	Methane ($Gg\ CH_4/PJ$)	Nitrogen oxides (Gg NOx/PJ)	Nitrous oxide ($Gg\ N_2O/PJ$)	Carbon monoxide (Gg CO/PJ)
Food, Beverage, and Tobacco:					
Woodfuel furnaces	109	0.015	0.115	n.a	1.504
Woodfuel boilers	109	0.015	0.115	n.a	1.504
Bagasse boilers	131	n.a	0.088	n.a	1.706
Wood, Wood Products, and Printing:					
Woodfuel boilers	109	0.015	0.115	n.a	1.504

Table 3.14: Greenhouse gas emissions from biomass fuels combustion in industry (1990)

Sector specific data by fuel and device type	Carbon dioxide (Gg)	Methane (Gg)	Nitrogen oxides (Gg)	Nitrous oxides (Gg)	Carbon monoxide (Gg)
	J=ExF	K=ExG	L=ExH	M=ExI	N=ExJ
Food, Beverage, and Tobacco:					
Woodfuel furnaces	1357.866	0.18686	1.43261	n.a	18.7361
Woodfuel boilers	14.098	0.00194	0.01487	n.a	0.1945
Bagasse boilers	510.450	n.a	0.34290	n.a	6.6475
Wood, Wood Products, and Printing:					
Woodfuel boilers	36.933	0.00508	0.03897	n.a	0.5096
Total	1919.347	0.19388	1.82935	n.a	26.0877

3.4 Discussion

The study team has disaggregated energy consumption in each sub-sector of industry by combustion technology, fuel type, vintage, and operating conditions. This has been done in order to explore possible linkages with mitigation analysis. As emphasised above, carbon dioxide emission estimates obtained using this methodology are presented for information only. They are not part of the national inventory data. Table 3.15 gives a summary of greenhouse gas emissions from stationary combustion in 1990.

Table 3.15: Summary of greenhouse gas emissions from fuels combustion in industry (1990)

Sector specific data by fuel type	Consumed energy consumed (PJ)	Carbon dioxide (Gg)	Methane (Gg)	Nitrogen oxides (Gg)	Nitrous oxide (Gg)	Carbon monoxide (Gg)
	A	B	C	D	E	F
Fossil fuels	7.8922	559.236	0.01284	2.1916	0.0005	0.3461
Biomass fuels	16.8220	n.a	0.19388	1.8294	n.a	26.0877
Total	**24.7142**	**559.236**	**0.20672**	**4.0210**	**0.0005**	**26.4338**

Notes: n.a refers to "not applicable"

Methane (CH_4) emissions from large fossil fuel combustion facilities were relatively low. Nitrogen oxides (NO_x) emissions were relatively high due to excess air, high operating temperature, and Nitrogen content in fuels. Nitrous oxide (N_2O) emissions were considered minor relative to other anthropogenic source categories. Carbon monoxide (CO) emissions from fossil fuel combustion in large facilities were much lower compared to NO_x emissions. This is because combustion conditions in large facilities are less conducive to formation of carbon monoxide. The main combustion source of carbon monoxide emissions were biomass fuel in traditional combustion facilities, most of which are inefficient.

3.5 References

1. Ministry of Water, Energy and Minerals (MWEM), 1992; The Energy Policy of Tanzania, MWEM, Dar es Salaam.

2. Victus, P.A.M., and Mwandosya, M.J., 1994; Energy Use in industry in Urban Tanzania, Energy, Environment and Development Series, No.27, Stockholm Environment Institute, Stockholm.

3. OECD/OCDE, 1995; Intergovernmental Panel on Climate Change (IPCC) Reference Manual on National Greenhouse Gas Inventory; Final version, Vol.3; IPCC, London.

4.0 NON CO_2 EMISSIONS FROM THERMAL POWER GENERATION

4.1 Introduction

Utility thermal power generation and industrial heat production activities are similar in the sense that they are both stationary combustion processes providing combustion conditions which result in the formation of greenhouse gases including NO_x. Emissions of NO_x depend in part on nitrogen contained in the fuel and more importantly on the firing configuration of the technology employed.

Power generation plant installed capacity in Tanzania in 1990 was approximately 480 MW, of which 70% is hydro-based and the remaining 30% is thermal-based (1). Of Tanzania's population of nearly 23 million only about 6%, mainly, those living in major urban centres, has access to electricity. Electricity consumption constitutes about 1% of the total energy consumed in the country in 1990, 92% of which was provided by woodfuel and 7% by petroleum products (2). The main consumers of electricity are industry and commerce (54%), household (31%) and others, namely agriculture, water supply, public lighting and bulk sales to Zanzibar (15%).

4.2 Existing power generation facilities in 1990

Installed power generation capacity in Tanzania comprised of 333 MW of hydroelectric capacity and 145 MW of thermal power capacity. Of the thermal power capacity some 82 MW was connected to the national grid, installed at the Ubungo power station in Dar es Salaam, and the rest in stations located in other towns such as Mwanza, Mbeya, Tabora, Musoma, Dodoma, and Arusha. Thermal power plants provided an alternative source of energy during periods of low levels of water in storage dams and during equipment servicing. About 63 MW thermal power plants served isolated demand centres. Table 4.1 shows the existing power generation capacity.

Table 4.1: Grid and isolated systems power generation capacity (1990)

Power Plant	Number of installed units	Installed capacity (MW)	Available capacity (MW)
Hydroelectric (grid system):			
Pangani Falls	5	17.50	13.00
Nyumba ya Mungu	2	8.00	8.00
Hale	2	21.00	21.00
Tosamaganga	3	1.22	1.22
Kikuletwa	3	1.16	0.16
Mbalizi	2	0.34	0.00
Kidatu	4	204.00	200.00
Mtera	2	80.00	70.00
Thermal (grid system)	*	81.65	67.09
Thermal (isolated units)	*	63.24	55.28
	Total	**478.11**	**435.75**

Sources: (3, 4, 5, 6)

Notes: (*) A number of small size diesel plants scattered all over the country.

Most of the thermal power plants are powered by medium speed diesel engines using industrial diesel oil (IDO). Some high speed diesel and petrol engines are also used by some independent power producers but the greenhouse gas emissions associated to these were considered insignificant.

4.3 Estimating greenhouse gas emissions from thermal power plants

Estimation of emissions from stationary sources has been done using the following basic formula(3):-

$$Q_{ghg} = \sum (EF_{abc} \times Activity_{abc})$$

where:

Q	=	emissions (Gg)
ghg	=	greenhouse gas in question
EF	=	emission factor (Gg/PJ)
a	=	fuel type
b	=	sector activity
c	=	technology type
Activity	=	energy input (PJ)

4.3.1 Assumptions

In estimating greenhouse gas emissions from stationary thermal power utility facilities to this sector make the following assumptions have been used:-

(i) Industrial diesel oil (IDO) used in power generation is a mixture of 3% fuel oil (FO) and 97% gasoil (GO), sometimes referred to as an intermediate diesel oil.

(ii) Emission factors used for thermal generation are those recommended heavy-duty mobile high-speed, and medium-emission controlled diesel engines (7).

(iii) There are about 960 registered private thermal generators with capacity exceeding 5 kVA in the country. Most of these generators are used during prolonged power outages, something which does not occur very often. The consumption of fuel for private power generators has been difficult to quantify. Hence greenhouse gas emissions from these gensets were considered here to be insignificant.

(iv) A portion (1%) of lubricants consumed by utilities in the process of power generation.

(v) Emission factors used in estimating the greenhouse emissions from lubricants combustion are those of uncontrolled emissions non-highway mobile sources (7).

(vi) Fraction of carbon oxidized is 0.99 for both industrial diesel oil and 0.01 for lubricants combustion.

(vii) Carbon dioxide (CO_2) emissions estimates here, are for information only. They do not form part of the reported national inventory data.

4.3.2 Calculations of greenhouse gas emissions

Fossil fuel and lubricants consumptions in thermal power plants during the period of 1988 to 1990 are provided in Table 4.2. The quantities consumed (last low of Table 4.2) are divided by 1000 to obtain kilotonnes (kt) of fuel and lubricants consumptions. The results are multiplied by corresponding calorific value (column B of Table 4.3) and by the fraction of carbon oxidized (column D of Table 4.3) to obtain the actual energy consumption by utilities in petajoule (PJ), or 10^{15} joule, which is estimated at 1.01 PJ.

Table 4.2: Industrial diesel oil and lubricants consumption for power generation

Year	Industrial Diesel Oil (metric tonnes)	Lubricants (metric tonnes)
1988	35,775	422
1989	24,247	294
1990	22,935	240

Source: (3)

Table 4.3: Estimates of actual energy consumed by thermal power plants (1990)

Sector specific data by fuel type	A Fuel consumption (kt)	B Calorific value (TJ/kt)	C Energy consumption (PJ)	D Fraction of Carbon oxidized	E Actual energy consumption (PJ)
			C=AxB/1000		E=CxD
Industrial diesel oil	22.935	43.33	1.0167	0.99	1.0065
Lubricants	0.240	40.19	0.0096	0.01	0.0001

Sources: (1, 2, 3, 7)

Table 4.4: Selected emission factors for stationary thermal power plants (Gg/PJ)

Sector specific data by fuel type	F Carbon dioxide (CO_2)	G Methane (CH_4)	H Nitrogen oxides (NO_x)	I Nitrous oxide (N_2O)	J Carbon monoxide (CO)
Industrial diesel oil	73.3	0.01	0.91	0.0019	0.630
Lubricants	77.4	n.a	2.10	0.0020	0.046

Source: (7)

Estimates of emissions from the stationary diesel engines used in thermal power plants based on the assumptions stated in section 4.3.1. The actual energy consumption estimates (column E of Table 4.3) are multiplied by corresponding emission factors in Table 4.4 to obtain estimates of greenhouse gas emissions as shown in Table 4.5.

Table 4.5: Greenhouse gas emissions from stationary thermal power plants (1990)

Sector specific data by fuel type	Carbon dioxide (Gg)	Methane (Gg)	Nitrogen oxides (Gg)	Nitrous oxide (Gg)	Carbon monoxide (Gg CO)
	K=ExF	L=ExG	M=ExH	N=ExI	O=ExJ
Industrial diesel oil	73.779	0.0101	0.9159	0.00191	0.6341
Lubricants	0.007	n.a	0.0002	0.00000	0.0000
Total	73.786	0.0101	0.9161	0.00191	0.6341

4.4 Discussion

The results in columns K through O of Table 4.5 are summed across to obtain the total greenhouse gas emission from thermal power generation sources. Although emissions from lubricant use were considered during the calculations, the emissions estimates from this source are insignificant. It is important to note that NO_x emissions from thermal power generation sources are higher compared to other gases. This is due to combustion conditions conducive for formation of NO_x at high operating temperatures and excess air. The discussion on greenhouse gas emissions from stationary fuel combustion in industries in section 3.4 is also valid here.

4.5 References

1. Ministry of Water, Energy and Minerals (MWEM), 1992; The Energy Policy of Tanzania, MWEM, Dar es Salaam.

2. Ministry of Water, Energy and Minerals (MWEM); 1993, Budget Speech to the Parliament for fiscal year 1993/94, MWEM, Dar es Salaam.

3. Tanzania Electric Supply Company (TANESCO), 1994; Internal communication on diesel thermal plants, Directorate of Diesel Plants, TANESCO, Dar es Salaam.

4. Tanzania Electric Supply Company (TANESCO), 1983; Power for People, TANESCO, Dar es Salaam.

5. Tanzania Electric Supply Company (TANESCO), 1986; Power Sector in Tanzania in 1986; Planning Directorate, TANESCO, Dar es Salaam.

6. Acres International Ltd.(ACRES), 1992; Review of TANESCO Short-term Generation Expansion Requirements; ACRES, Niagara Falls, Ontario.

7. OECD/OCDE, 1995; Intergovernmental Panel on Climate Change (IPCC) Reference Manual on National Greenhouse Gas Inventory; Final version, Vol.3; IPCC, London.

5.0 NON-CARBON DIOXIDE EMISSIONS FROM MOBILE SOURCES

5.1 Introduction

A well functioning transport system is crucial to sustained development and economic recovery of Tanzania. Road infrastructure is a vital link between rural and urban communities. Records on road conditions are either unreliable or non-existent. It is estimated that only 25% of the paved trunk roads, 10% of the unpaved trunk roads, and 8% of the regional roads are presently in good condition. Furthermore, Tanzania's domestic railway system, which connects most of the major urban centers, has been unable to meet the demand for low cost, long distance transport of exports and of critical inputs to the economy. This is because of its poor operational performance. Despite these limitations there is a high demand for its services, with an average passenger load factor of 76% on all routes and 83% in the domestic market. Based on the aforesaid, it is conceivable that the economy could be losing nearly US$ 200 million per annum in direct economic costs due to the deteriorated transport infrastructure and its inefficient operation (2).

5.2 Overview of the transport sector

The trucking sector plays a major role in the domestic transport industry, carrying nearly 70% of the estimated 2.5 billion tonne-km of freight movement within Tanzania. The existing fleet size is estimated at about 14,000 trucks (over three-tonne capacity), of which 88% are owned by the private sector, and 12% by the public sector. Average daily traffic (ADT) on the roads is relatively light, ranging from 200 to 1500 vehicles per day (vpd) on paved trunk roads, and seldom exceeds an ADT of 200 vpd on unpaved trunk roads. Until 1990 the sector was characterised by chronic shortages of replacement vehicles and spare parts, fires, bad road condition, and congested urban driving. Fleet replacement has been only about 4% per annum.
The performance of the Tanzania Zambia Railway Authority (TAZARA) in terms of freight transported has been good in spite of serious constraints on the availability of its locomotive fleet. The effective haul capacity of the Tanzania Railways Corporation (TRC) has declined despite considerable additions to its asset base. The decline in traffic moved has been the result of limited access to spare parts, deficient maintenance, and poor utilization of assets when available (2). Air Tanzania Corporation (ATC) has been facing perennial problems of acquiring spare parts due to its inability to generate sufficient foreign exchange to finance its own requirements. It also has problem of fleet utilization due to lack of proper facilities, such as night-landing facilities and the poor state of runways.

However, it is hoped that the deterioration of the transport system will be reversed as the sector takes advantage of trade liberalization measures including export retention schemes, and reforms in the banking sector. Tanzania has also launched a port modernization project, and an integrated road improvement and maintenance project (2, 4). Importation of used and reconditioned ex-Japan light duty gasoline vehicles and four wheel drive (4WD) gasoil vehicles, and investment into schooners, boats, and charter planes has increased year after year. Long queues of road fleets, which are subjected to low speeds or idling of engines, are evident in Dar es Salaam. Dar es Salaam consumes over 40% of fossil fuel used in the transport sector. As the result of the implementation of the port modernization project, nearly 60% of the total port throughput at Dar es Salaam now constitutes international traffic.

Tanzania does not have emission control regulations. There are no emission standards nor emission control policies. There are no mandatory vehicle inspection and maintenance requirements. This chapter is about greenhouse gas emissions from the trunk roads, urban roads and non-road sources. Light-duty passenger cars, heavy-duty vehicles, farm and construction equipment, railway locomotives, ocean-going ships, boats and aircraft have been considered. The major fuel types considered in this study include gasoline, diesel, jet-fuel, aviation fuel and residual fuel oil.

5.3 Estimation of greenhouse gases emissions

5.3.1 Assumptions

The following assumptions are made in the estimation of greenhouse gas emissions from mobile combustion in Tanzania:-

(i) The US Environment Protection Agency (EPA) classification of vehicles and motorcycles holds;

(ii) Distribution of vehicle population by registration in 1990 included: TZ (80,000), SU (21,000), TX (20,000), TZA (7,000), TZB (5,000), Others (67,000). Others include vehicles registered in countryside and those with special registration such as government, military, railways, and diplomatic missions;

(iii) All gasoline automobiles and light-duty trucks imported into Tanzania are emission-uncontrolled models;

(iv) All diesel automobiles and light-duty trucks imported into the country are emission-uncontrolled;

(v) All heavy-duty diesel vehicles imported into the country are emission-uncontrolled;

(vi) Motorcycles in operations were of emission-uncontrolled type, for some reasons including poor maintenance and bad road conditions;

(vii) Emission factors used are those recommended in (3);

(viii) Emission factors used for calculations assume the values of 75°F (equivalent to 24°C) with diurnal range from 60°F to 85°F (15°C - 32°C), Reid Vapour Pressure of gasoline at 9 psi (62 kpa), and an average speed of 31.4 km/h, for typical uncongested urban driving; and

(ix) International bunkers (fuel for international transport, boats, planes, trains and long vehicles) have been kept separate. Emissions associated with these are not considered here.

5.3.2 Methodology

The amount of energy consumed (by fuel type) for all mobile combustion sources, the average distances driven and the vehicle population are shown in Table 5.1. There is no readily available database with desegregated information to meet the IPCC recommended approach. With the aggregate figures given in Table 5.3, it is not possible to reasonably estimate greenhouse gas emissions from mobile combustion sources. To convert the volumes (in litres) into mass units (in kilotonnes), values in column A of Table 5.1 are multiplied by those in column B of Table 5.1 then multiplied by 0.85 for gasoline or 0.87 for gasoil. The thousands cancel each other during the calculations. Each block of column D of Table 5.1 should tally with its corresponding sum in column C of Table 5.3.

Table 5.1: Basic principle of estimating fuel consumption by mobile combustion sources (1990)

Sector specific data by fuel and facility	A Vehicle population (in 1000s)	B 1000s km driven per vehicle	C Fuel consumption rate (km/lt)	D Fuel consumption (kt)	E Proportion for aggregation of fuel
				$D=[(AxB)/C]_o$	$E=D/D_{subtotal}$
Gasoline:					
Automobiles	35.0	7.6	5.5	41.11	0.368
Light duty trucks (LDGT)	20.4	7.7	3.5	38.15	0.341
Heavy duty trucks (HDGT)	3.6	6.9	2.4	8.80	0.079
Motorcycles	14.0	8.9	12.5	8.47	0.076
Piston aircrafts	n.a	n.a	n.a	15.17	0.136
Gasoil:					
Automobiles	33.0	7.7	6.0	36.84	0.163
Light duty vehicles (LDDV)	77.0	7.6	5.7	89.23	0.394
Heavy duty vehicles (HDDV)	17.0	8.2	3.4	35.67	0.157
Farm equipment	n.a	n.a	n.a	32.74	0.144
Locomotives	n.a	n.a	n.a	23.10	0.102
Construction equipment	n.a	n.a	n.a	5.04	0.022
Boats & schooners	n.a	n.a	n.a	4.18	0.018
Residual Fuel Oil:					
Lakes and Coastline	n.a	n.a	n.a	10.00	1.000
Jet-A1:					
Turbo and Jet aircraft	n.a	n.a	n.a	51.95	1.000

Sources: (1, 5, 6)

Notes: n.a refers to the data which were "*not available*" during the study period.

$_o$ refers to multiply the results by conversion factors (0.85 for gasoline and 0.87 for gasoil) to convert volume into mass units.

Based on fuel consumption pattern (column E of Table 5.1) and other parameters including operations of roads, operating vehicles, fleets, and driving habits, the study team has used its own judgement to establish a schedule of aggregated consumption pattern by fuel and vehicle types for 1988 through 1991. More research work is required in this area.

The amount of annual energy input by type of vehicle and fuel was determined by multiplying appropriate proportion in Table 5.2 by its corresponding aggregate figure of fuel consumption in Table 5.3, and multiplied further by appropriate calorific value. The results are divided by 1000 and reported in petajoules (PJ), or 10^{15} joule in Table 5.4. Calorific values used to convert physical units into energy units include 44.80 TJ/kt for gasoline, 43.33 TJ/kt for gasoil, 44.59 TJ/kt for Jet fuel, and 47.31 TJ/kt for residual fuel oil (3).

Table 5.2: Schedule of proportions of aggregate fuel consumption for 1988 - 1991

Sector specific data by fuel and vehicle types	1988	1989	1990	1991
Gasoline:				
Automobiles	0.351	0.398	0.368	0.342
Light-duty trucks	0.432	0.368	0.341	0.373
Heavy-duty trucks	0.072	0.078	0.079	0.076
Motorcycles	0.073	0.085	0.076	0.072
Piston aircraft	0.072	0.071	0.136	0.137
Gasoil:				
Automobiles	0.151	0.177	0.163	0.179
Light-duty vehicles	0.353	0.349	0.394	0.463
Heavy-duty vehicles	0.290	0.184	0.157	0.163
Construction equipment	0.019	0.021	0.144	0.013
Locomotive engines	0.063	0.140	0.102	0.098
Boats and schooners	0.021	0.020	0.022	0.009
Farm equipment	0.103	0.145	0.018	0.075
Residual Fuel Oil:				
Shipping activities	0.290	0.320	0.370	0.440
Jet-A1:				
Turbo aircraft and Jet	0.180	0.230	0.255	0.310

Notes: Fuel consumptions by international bunkers are excluded from these figures, that is why the figures on RFO and Jet-A1 do not add to one (1), as the case is for gasoline and gasoil.

Table 5.3: Annual fuel consumption by transport sector for 1988 - 1991 (kt)

Final Energy Sources	1988	1989	1990	1991
	A	B	C	D
Gasoline	124.65	118.65	111.70	86.56
Gasoil	217.47	249.97	226.80	225.41
Residual Fuel Oil (RFO)	9.55	15.31	10.01	10.45
Jet-A1	44.57	45.49	51.95	43.65

Sources: (5, 6)

For completeness, desegregated energy consumption by vehicle and fuel types in transport sector for the period of 1988-1991 were calculated and shown in Table 5.4. For the purpose of national greenhouse gas inventory, the 1990 emissions are calculated here. The emission factors used for calculations are borrowed from IPCC and are shown in Table 5.5.

Based on the assumptions made above, and appropriate emission factors in Table 5.5, the following formula was applied to estimate greenhouse gas emissions from mobile combustion sources:-

$$Q_{ghg} = \sum (EF_{abc} \times Activity_{abc})$$

where:

Q	=	emissions (Gg)
ghg	=	greenhouse gas in question
EF	=	emission factor (Gg/PJ)
a	=	transport mode (road, rail, air, marine, etc.)
b	=	fuel type (gasoline, gasoil, Jet-A1, etc.)
c	=	vehicle type (automobile, truck, motorcycle, etc.)
Activity	=	energy input (PJ)

The results of greenhouse gas emission calculations for 1990 are shown in Table 5.6.

Table 5.4: Final energy consumption by transport sector for 1988 - 1991 (PJ)

Sector specific data by fuel and vehicle types	1988	1989	1990	1991
	A	B	C	D
Gasoline:				
Automobiles	1.9601	2.1155	1.842	1.326
Light-duty trucks	2.4124	1.9561	1.706	1.446
Heavy-duty trucks	0.4021	0.4146	0.395	0.296
Motorcycles	0.4077	0.4518	0.380	0.279
Piston aircraft	0.4021	0.3774	0.681	0.531
Gasoil:				
Automobiles	1.4229	1.9164	1.602	1.748
Light-duty vehicles	3.3263	3.7786	3.872	4.522
Heavy-duty vehicles	2.7327	1.9921	1.543	1.592
Construction equipment	0.1790	0.2274	1.415	0.127
Locomotive engines	0.5936	1.5158	1.002	0.957
Boats and schooners	0.1979	0.2165	0.216	0.088
Farm equipment	0.9706	1.5699	0.177	0.733
Residual Fuel Oil:				
Shipping activities	0.1235	0.2185	0.165	0.205
Jet-A1:				
Turbo aircraft and Jet	0.3795	0.4950	0.627	0.640

Energy input into transport sector in 1990 was much higher in road transport compared to other mobile sources. About 11.34 PJ was consumed by road transport, and 4.29 PJ was consumed by non-road mobile sources. Energy input to the transport sector was 5.0 PJ and 9.8 PJ in form of gasoline and gasoil respectively. Since the amount of emitted greenhouse gas depends mainly on energy input, type of fuel, and combustion technology, it is important to compare and contrast the impact of these parameters. From the selected emission factors, for the same energy inputs, gasoline vehicle are expected to emit more CH_4, non-methane volatile organic compounds (NMVOC), and CO, while gasoil vehicles are expected to emit more CO_2, NO_x, and N_2O.

Table 5.5: Selected greenhouse gas emissions factors by fuel and vehicle type (Gg/PJ)

Sector specific data by fuel and vehicle type	CO_2	CH_4	NO_x	N_2O	NMVOC	CO
	E	F	G	H	I	J
Gasoline:						
Automobiles	69.30	0.0314	0.3900	0.0009	1.1400	7.330
Light-duty truck	69.30	0.0570	0.4100	0.0009	1.3200	6.890
Heavy-duty truck	69.30	0.0210	0.3500	0.0005	1.1200	8.860
Motorcycles	69.30	0.1300	0.0700	0.0009	2.5000	9.200
Piston aircrafts	69.30	0.0600	0.0800	0.0009	0.5400	24.000
Gasoil:						
Automobiles	73.30	0.0010	0.1400	0.0019	0.0730	0.150
Light-duty truck	73.30	0.0010	0.1700	0.0019	0.1000	0.190
Heavy-duty vehicles	73.30	0.0100	1.0100	0.0019	0.1800	0.510
Construction equipment	73.30	0.0040	1.2000	0.0020	0.0900	0.380
Locomotives	73.30	0.0060	1.8000	0.0020	0.1300	0.610
Boats and schooners	73.30	0.0050	1.6000	0.0020	0.1100	0.500
Farm equipment	73.30	0.0110	1.5000	0.0020	0.2300	0.600
Residual Fuel Oil:						
Shipping activities	77.40	0.0001	2.1000	0.0020	0.0001	0.046
Jet-A1:						
Turbo aircraft and Jet	71.50	0.0020	0.2900	0.0020	0.0180	0.120

Sources: (3)

Notes: NMVOC refers to non-methane volatile organic compounds as part of exhaust gas.

5.4 Discussion

Carbon dioxide (CO_2) emission from mobile combustion sources is significant compared to emission from stationary combustion sources. Gasoil fuelled mobile sources contributed 64% of 1,124 Gg CO_2 emitted in 1990 compared to gasoline fuelled mobile sources which contributed about half of this. Methane (CH_4) and nitrous oxide (N_2O) produced by mobile combustion sources were marginal. Nevertheless, because of the importance of methane, emissions from gasoline fuelled mobile sources, which contributed about 87% of 0.29 Gg CH_4 can not be ignored. Due to lower operating temperatures (less than 1000 K) in mobile combustion sources, which are not conducive to the formation of nitrogen oxides (NO_x), only 8.7 Gg of NO_x was produced in 1990, of which 75% were emitted by gasoil fuelled mobile sources. It is interesting to note that reduction of NO_x emissions may increase carbon monoxide (CO) formation, especially if the technique is the limiting of excess air. CO emissions were on high side (about 51.8 Gg CO) in 1990, for reasons which included start-up in mornings, inefficient, old, or poor maintained vehicles, and slow driving during the peak fleet congestion. Gasoline fuelled mobile sources contributed 94% of total CO emissions in 1990. As with CO, combustion conditions in mobile combustion sources are less conducive to form and release

NMVOC unless the facilities are kept improperly maintained or poorly operated, as may be the case for many old units. Gasoline fuelled mobile sources contributed about 85% of total 7.2 Gg NMVOC emitted in 1990.

Aggregated greenhouse gas emissions by road, non-road, and farm mobile combustion sources is shown in a summary form in Table 5.7.

Table 5.6: Greenhouse gas emissions estimates from the transport sector in 1990 (Gg)

Sector specific data by fuel and vehicle type	K	L	M	N	O	P
	CO_2	CH_4	NO_x	N_2O	NMVOC	CO
	K=CxE	L=CxF	M=CxG	N=CxH	O=CxI	P=CxJ
Gasoline:						
Automobiles	127.65	0.0578	0.7184	0.0017	2.0999	13.5019
Light-duty truck	118.23	0.0972	0.6995	0.0015	2.2519	11.7543
Heavy-duty truck	27.37	0.0083	0.1383	0.0002	0.4424	3.4997
Motorcycles	26.33	0.0494	0.0266	0.0003	0.9500	3.4960
Piston aircrafts	47.19	0.0409	0.0545	0.0006	0.3677	16.3440
Gasoil:						
Automobiles	117.43	0.0016	0.2243	0.0030	0.1169	0.2403
Light-duty truck	283.82	0.0039	0.6582	0.0074	0.3872	0.7357
Heavy-duty vehicles	113.10	0.0154	1.5584	0.0029	0.2777	0.7869
Construction equipment	103.72	0.0057	1.6980	0.0028	0.1274	0.5377
Locomotives	73.45	0.0060	1.8036	0.0020	0.1303	0.6112
Boats and schooners	15.83	0.0011	0.3456	0.0004	0.0238	0.1080
Farm equipment	12.97	0.0019	0.2655	0.0004	0.0407	0.1062
Residual Fuel Oil:						
Shipping activities	12.09	0.0000	0.3465	0.0003	0.0000	0.0076
Jet-A1:						
Turbo aircraft and Jet	44.83	0.0013	0.1818	0.0013	0.0113	0.0752
Total	**1124.01**	**0.2905**	**8.7192**	**0.0248**	**7.2272**	**51.8047**

Table 5.7: Summary of greenhouse gas emissions estimates from transport sector in 1990 (Gg)

Sector specific data	Energy input (PJ)	CO_2	CH_4	NO_x	N_2O	NMVOC	CO
	A	B	C	D	E	F	G
Road transport	11.34	813.92	0.2337	4.0236	0.0170	6.5260	34.0147
Non-road transport	4.11	297.12	0.0549	4.4301	0.0074	0.6605	17.6838
Farm equipment	0.18	12.97	0.0019	0.2655	0.0004	0.0407	0.1062
Total	**15.63**	**1124.01**	**0.2905**	**8.7192**	**0.0248**	**7.2272**	**51.8047**

5.5 References

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5. Ministry of Water, Energy and Minerals (MWEM), 1993; Internal Communication; (Budget Speeches of 1988/89 - 1992/93), MWEM, Dar es Salaam.

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6.0 NON CO2 EMISSIONS FROM HOUSEHOLD, COMMERCIAL AND INFORMAL SECTORS

6.1 Introduction

In this chapter we examine anthropogenic sources of greenhouse gas emissions arising out of biomass and fossil fuel use in households and the commercial and informal sectors. The main focus is on non-carbon dioxide (non-CO_2) gases emitted during the burning of fuels. For reporting purpose, CO_2 emissions from burning of woodfuel and other biomass is taken account under the chapter on Forestry and Land-use Changes. CO_2 emissions from other fuels such as kerosene and LPG have been considered under the chapter on fossil fuels. The main focus of this chapter is to capture non-CO_2 greenhouse emissions from household, commercial and informal sectors. The text is divided into three distinct sections namely:- greenhouse gas emissions from woodfuel consumption in cottage industries; burning of traditional biomass fuels; burning of fossil fuels in commercial and household sectors. With exception of CO_2 emissions from these sources, estimates of non-CO_2 greenhouse emissions forming part of the national greenhouse gas inventory are reported and discussed in this chapter.

6.2 Woodfuel consumption in cottage industries

Cottage industries include small-scale food processing industries like brewing, fish smoking, salt production, and baking. Other cottage industries include tobacco curing, tea drying and beeswax processing. Burnt bricks making, lime production, smithies, foundries, pottery, and ceramics. Table 6.1 provides a breakdown of woodfuel consumption in cottage industries for the years 1988, 1989 and 1990.

Table 6.1: Woodfuel consumption in cottage industries (in thousand m^3 stacked wood)

Sector specific data by type of industry	1988		1989		1990	
	(k m^3)	(kt dm)	(k m^3)	(kt dm)	(k m^3)	(kt dm)
	A	B=3A/4	C	D=3C/4	E	F=3E/4
Fish smoking *(kiln)*	238.00	178.50	227.00	170.25	192.00	144.00
Salt production *(boiler)*	n.a	n.a	n.a	n.a	350.00	262.50
Small-scale bakeries *(oven)*	129.00	96.75	132.90	99.68	136.90	112.50
Tobacco curing *(kiln)*	n.a	n.a	n.a	n.a	459.80	344.85
Lime production *(kiln)*	3.80	2.85	3.90	2.93	4.33	3.25
Pottery and Ceramics *(kiln)*	17.20	12.90	17.70	13.28	20.00	15.00
Beeswax processing *(3 stones stove)*	0.72	0.54	0.74	0.56	0.76	0.57
Total	388.72	291.54	382.24	286.70	1163.79	882.67

Sources: (1, 2, 3, 5, 7, 8)

Notes: *kt dm* refers to kilotonne of dry matter, while *k m^3* refers to thousand cubic metres, and *n.a* refers to "data not available".

Most of activities classified as cottage industries are informal in character and found in rural and peri-urban areas, and depend on woodfuel and other biomass fuels as their major source of energy. The long-term dependence of woodfuel by cottage industries has increased pressure on natural forests.

6.2.1 Brewing

Brewing of traditional beer and distilling of local gin *(gongo)* are popular activities in rural areas as well as in some urban areas in Tanzania. This activity relies mostly on the use of fuelwood or other biomass fuel such as agricultural wastes. It is an energy intensive activity using stoves identical to the open three-stone stove used in households. These stoves are very inefficient, having thermal efficiencies of less than 10%. Data on woodfuel consumption for brewing traditional beer or distilling of local gin in most cases is reported as a single package under traditional burning of biomass fuels in the household sector.

6.2.2 Fish smoking

Tanzania has inland waters which cover an area of 61,500 km^2 and has about 64,000 km^2 of coastal waters (1). The estimated potential annual fish yield is about 730,000 tonnes, while the actual annual yield is estimated to be about 320,000 tonnes (2).

Smoking and frying are the main methods of preserving fish in Tanzania. It has been estimated that about 60% of total fish catch in Tanzania is smoked (3). Smoking is done in kilns constructed as rectangular or cylindrical ovens using wood or bricks. Average dimensions are: length 2 metres, width 1 metre and depth 1 metre. On the average about 1 m^3 of wood is used to smoke 1 tonne of fish (4). Fish smoking is therefore an energy intensive activity, utilizing a significant amount of woodfuel. Because of excessive use of woodfuel, almost all fishing areas in Tanzania are experiencing woodfuel scarcity. About 192,000 m^3 of woodfuel are estimated to have been consumed for fish smoking activity in 1990 (1).

6.2.3 Salt production

Woodfuel is used extensively in table salt (NaCl) production in Tanzania. The Nyanza salt mine in Kigoma uses woodfuel in the production of salt. About 250,000 m^3 of wood were consumed in 1990 at its thermal plant. On average, about 3.5 tonnes of wood is used for every tonne of salt produced. The amount of wood used in salt production differs depending on the method used in producing salt. In total, about 350,000 m^3 of solid wood were used in 1990 for salt production in Tanzania (3). Estimates of greenhouse gas emission from salt production processes have been included in the estimates of greenhouse gas emissions under the industrial sector.

6.2.4 Small-scale bakeries

Small scale bakeries are found in many places in the sub-urban areas as well as in rural areas. Most of these bakeries rely on woodfuel as a source of energy for their baking activity. Studies done by the Forestry Division have estimated that about 2 kg of fuelwood are used to bake 1 kg of bread. It has been further estimated that the annual average woodfuel consumption for baking is around 150,000 m^3 (3).

6.2.5 Tobacco curing

Tobacco is grown in five regions in Tanzania namely Tabora, Kagera, Ruvuma, Iringa and Mbeya. Most of the cultivation is carried out in small holder farms averaging about 2 hectares. Annual production of tobacco ranges from 10,000 tonnes to 15,000 tonnes. The Ministry of Agriculture and Livestock Development estimates that about 42 m^3 of solid wood are used for curing 1 tonne of tobacco. Based on the average annual production of tobacco of 11,000 tonnes between 1986 and 1991, the annual woodfuel consumption for tobacco curing is estimated to be 459,800 m^3 of solid wood. It has been further estimated that about 6,000 hectares of woodlands are cleared annually for the provision of woodfuel to cure tobacco (5). The cleared forests are not reforested, leading to deforestation and environmental degradation. Estimates of greenhouse gas emissions from tobacco drying have been included under estimates of greenhouse gas emissions from industry in Chapter 3.

6.2.6 Tea drying

Tea is grown in large scale farms in Mbeya, Iringa, Tanga and Kagera. Tea estates have established their own woodfuel plantations for drying tea and as such the industry is self sustaining in its energy requirements. Production of tea was 15,900 tonnes in 1988, 16,000 tonnes in 1989, and 24,700 tonnes in 1990. Determination of greenhouse gas emissions from tea drying has been included in the estimates of greenhouse gas emissions from Industry in the food sub-sector in Chapter 3.

6.2.7 Burnt brick production

Burnt bricks are used widely for building purposes in several parts of the country. Brick burning activities are, however, periodic and the fuelwood consumption by this activity at national level is considered insignificant according to a study done by FAO in 1984 (6). Woodfuel consumption in brick firing kilns are available, but the data on a number of kilns fired per annum is not readily available.

6.2.8 Lime production

There are a total of 13 lime production factories in the country, eleven of them relying on woodfuel as their source of energy. The remaining two use electricity. Total installed capacity is 39,000 tonnes per year of which 19,500 tonnes are produced from woodfuel-based kilns (7). It has been estimated that 1.0 m^3 of solid wood is used to produce 4.5 tonnes of lime. About 4,333 m^3 of solid wood are used annually in the production of lime.

6.2.9 Smithies and foundry

Production of hand tools and other metal work is practiced on a small scale in rural areas. Charcoal is used as the major source of energy. An estimate of the amount of charcoal consumed is lacking. It is assumed to be negligible compared to other uses of charcoal.

6.2.10 Pottery and ceramics production

Pottery and ceramics production is carried out in almost all the regions in the country. It is dominated by women who produce cooking pots, garden pots and jars. Curing of the pots and ceramics is done in kilns using woodfuel and sometimes cattle dung as source of energy. Again reliable data on the amount of fuel used in this activity is lacking. Rough estimates by the Forestry Division put the production of pots at 1 million a year using about 20,000 m^3 of solid wood (8).

6.3 Traditional biomass fuel consumption

6.3.1 The urban household energy study

One of the most comprehensive study of energy use in Tanzania resulted from Tanzania Urban Energy Project (9). The study was undertaken to quantify energy use within municipalities of varying sizes namely; Dar es Salaam, Mbeya and Shinyanga. The three urban centres represent the urban centres found in the country, with Dar es salaam being the only primate city (C - level), Mbeya, a municipality (M - level) and Shinyanga, a tertiary town (T - level). Other urban centres can be grouped into appropriate categories of these three levels. These groupings are as shown in Table 6.2.

Table 6.2: Classification of urban and rural population (in millions) in 1990

City Level	Population	Municipal Level	Population	Township Level	Population	Rural	Population
A	B	C	D	E	F	G	H
Dar es Salaam	2.3	Arusha	0.15	Dodoma	0.22	Arusha	1.31
		Mbeya	0.17	Shinyanga	0.11	Dodoma	1.08
		Morogoro	0.13	Tabora	0.10	Kilimanjaro	1.06
		Moshi	0.10	Musoma	0.08	Tanga	1.14
		Mwanza	0.50	Mtwara	0.08	Morogoro	1.16
		Tanga	0.20	Lindi	0.04	Coast	0.67
				Bukoba	0.05	Lindi	0.63
				Kigoma	0.09	Mtwara	0.84
				Iringa	0.11	Ruvuma	0.74
				Songea	0.10	Iringa	1.17
				Sumbawanga	0.11	Mbeya	1.40
				Singida	0.10	Singida	0.73
						Tabora	0.99
						Rukwa	0.65
						Kigoma	0.81
						Shinyanga	1.77
						Kagera	1.35
						Mwanza	2.48
						Mara	0.95
Total	2.3		1.25		1.19		20.43

Source: (10)

For the purpose of this study, rural households are grouped into the R - level which refers to households in rural areas, outside the above urban groupings. These R - level households were not part of the Urban Energy Study. The per capita consumption of energy in rural households has been obtained from results of other studies (11).

6.3.1.1 The household sector

The household sector is the largest energy consuming sector of the economy. It accounts for nearly 80% of total final energy consumption. Like in other developing countries in Africa, the largest share of final energy consumed in Tanzania is accounted for by biomass fuels. The term biomass refers to fuelwood, charcoal, crop residue, and cow dung in some areas. Biomass fuels account for 92% of final energy use in Tanzania. The main fuels used in households include fuelwood, charcoal, kerosene and liquified petroleum gas (LPG). The most significant energy end-use in households is cooking. In order to estimate emissions of greenhouse gases from households, both urban and rural households are considered.

The basic information required for and used in establishing emission estimates from this sector includes:

(i) the number of households/population;

(ii) the energy content per unit of each fuel;

(iii) efficiencies of end-use devices - charcoal stoves, wick stoves, etc.;

(iv) daily consumption of each fuel in households; and

(v) emission factors by fuel type.

Table 6.3 gives a summary of the basic coefficients, and household fuel consumption per day used in this study. Per capita consumption of each fuel type in urban areas is derived by taking the household consumption per day divided by household size. For rural households a per capita fuelwood consumption of 1.2 m^3 per annum is used (11).

6.3.1.2 Methodology of traditional biomass fuel consumption estimation

Traditional biomass fuel consumption in urban and rural households for the year 1990 is estimated by multiplying the values in Table 6.2 by appropriate values in Table 6.3, using the following equation:

$$TF = \sum (P_a \; x \; HH_a \; x \; Q_a)$$

where

TF	is traditional biomass fuel consumed (in kt dm)
P	is population (millions)
HH	is percentage of households using fuel type
Q	is quantity of fuel consumed per capita per annum (physical unit)
a	is type of fuel (in physical unit)

Table 6.4 gives the quantities of traditional biomass fuels consumed in household sector in 1990. The total population for each category (column B, D, F, and H of Table 6.2) is multiplied by the values of the corresponding block in Table 6.3 (column A and B for C - Level, column C and D for M-Level, columns E and F for T -Level, and columns G and H for H -Level), then by 365 (days of a calendar year); and then divided by the corresponding household size and 100 (percentage).

Table 6.3: Urban and rural households fuel consumption coefficients and uses

Sector specific data by fuel type	C - Level		M - Level		T - Level		R - Level	
	HH (%)	Consumed fuel per HH per day	HH (%)	Consumed fuel per HH per day	HH (%)	Consumed fuel per HH per day	HH (%)	Consumed fuel per HH per day
	A	B	C	D	E	F	G	H
Fuelwood (kg)	16.8	6.20	58.6	10.30	13.8	10.00	100	2.79
Charcoal (kg)	74.6	2.40	78.9	2.45	85.1	3.13	0	0
Kerosene (l)	90.5	0.69	93.9	0.32	93.1	0.45	*	*
LPG (kg)	6.4	0.42	1.61	0.23	0.67	0.25	0	0
Crop Residue (kg)	6.8	0.30	12.9	1.00	2.90	0.75	100	0.75
Cattle dung (kg)	0.0	0.00	0.16	0.22	1.11	0.20	*	0.20

Source: (9)

Notes: *HH* refers to household, while (*) refers to *"data not available"*. Average household sizes are 5 people in city, 4.6 people in municipal, 4.7 people in towns, and the rural consumption figures are for a single person.

Table 6.4: Estimated traditional biomass fuel consumption in household sector in 1990

Sector specified data by fuel type	Units	A Daily total consumption	B Number of days in a year	C Annual consumption
	Sums of Table 6.2 x Table 6.3			C=AxB
Fuelwood	kt dm	59.561	365	21740
Charcoal	kt dm	2.029	365	741
Agricultural residues	kt dm	15.333	365	5597
Cattle dung	kt dm	0.2646	365	97

6.3.1.3 Estimation of fossil fuel consumption in household sector in 1990

Kerosene has been the most important energy source for lighting in rural and urban households for many years, whereas 90% of the population depends on this source of energy. Both standard wicked-lanterns and candle-like wicked lanterns (*koroboi* or *vibatari*) are significant in number. The latter devices are inefficient, simple to operate, and least-cost to purchase. In urban areas kerosene is used in wicked-stoves for cooking. All in all, these devices have one common characteristic, which is smoking during the operation and at extinguishing. Liquefied Petroleum Gas (LPG) is mainly used in urban areas, mainly in commercial and public sector. The methodology employed in estimation of total traditional biomass fuels, was also applied to both kerosene and LPG. The use of coal in household and informal sector is insignificant. This is mainly due to logistical reasons, and the poor performance of available coal combustion technology, the fact that woodfuel supply in some areas has been declining with time not withstanding. Table 6.5 shows the estimated kerosene and LPG consumption in 1990.

Table 6.5: Estimated fossil fuel consumption in household and commercial sector in 1990

Sector specified data by fuel type	Units	A Daily consumption	B Number of days in a year	C Annual consumption
	Sums of Table 6.2 x Appropriate data in Table 6.3 x Conversion factors)*			C=AxB
Kerosene	kt	0.2159	365	78.816
Liquefied Petroleum Gas (LPG)	kt	0.0139	365	5.073

Notes: (*) Volumes (litres) in Table 6.3 are converted to mass units by multiplying volumes by 0.944. The sums (Table 6.2) per urban category are divided by 10.1 or 4.942 to estimate the number of households using kerosene and LPG, respectively.

6.3.2 Commercial and informal sector

Tanzania's commercial sector comprises of hotels and restaurants; wholesale and retail trade; public institutions; finance; insurance; and other business services. The commercial sector consumes significant quantities of fuelwood, charcoal, and petroleum products. The most important end-uses are cooking, lighting and air conditioning. In most developing countries there exists an informal sector which may in most cases be twice as much as the size of the formal sector (12). The informal sector is largely unknown in terms of its size and impact on the economy. For energy use estimates in this sector reliance has been made on information generated in the Urban Energy Use Study (12), (13).

The methodology similar to that used in estimation of household fuel consumption has been applied to the estimation of traditional fuel consumption from commercial and informal sectors, based on information gathered during the Urban Energy Survey (9). It is estimated that the total of 1,714 kt dm of fuelwood and 10.27 kt dm of charcoal were consumed by commercial and public sector, while about 3,428 kt dm of fuelwood and 20.53 kt dm of charcoal were consumed by urban informal sector in 1990.

6.4 Estimation of greenhouse gas emissions from traditional biomass fuel

Estimation of greenhouse gas emissions from burning of 35,483 kt dm of woodfuel (excluding 699.904 kt dm referred in Table 3.8), 5597 kt dm (excluding 393.672 k dm referred in Table 3.8) of agricultural residues, and about 97 kt dm of cattle dung in cottage industry, households, commercial, and informal sectors is based on the following assumptions:-

(i) CO_2 emissions calculations are for information only. CO_2 flux from woodfuels is considered under the chapter on Forestry and Land-use Changes;

(ii) an expansion factor of 10 was used on total amount of charcoal to determine equivalent wood consumption, based on carbonization technology used;

(iii) non-CO_2 trace gas emissions from charcoal production are estimated from equivalent wood cleared for charcoal production: and

(iv) non-CO_2 trace gas emissions from traditional biomass fuel combustion are estimated from quantities of carbon and nitrogen released, emission factors, and molecular weight conversion factors, all borrowed from IPCC (14).

Table 6.6 provides steps of estimating carbon released from traditional biomass fuel combustion, and in the charcoal carbonization process. The amount of oxidised biomass is obtained by multiplying column A by column B of Table 6.6. The amount of carbon released is estimated from multiplying column C by column D of Table 6.6. The equation for estimating carbon released is:-

$$C_r = T_b \times F_o \times C_f$$

where

C_r is carbon released from traditional biomass fuel (kt C)
T_b is the total traditional biomass fuel consumed (kt dm)
F_o is the fraction oxidised
C_f is carbon fraction of oxidised biomass fuel

Table 6.6: Estimation of carbon released from traditional biomass fuels

Sector specific data by fuel type		A Consumed biomass (kt dm)	B Fraction oxidised (1)	C Oxidised biomass (kt dm)	D Fraction Carbon (1)	E Carbon released (kt C)
				C=AxB		E=CxD
Fuelwood:	Cottage industries	883	0.87	768.21	0.45	345.69
	Household sector	21740	0.87	18913.80	0.45	8511.21
	Commercial sector	1714	0.87	1491.18	0.45	671.03
	Informal sector	3428	0.87	2982.36	0.45	1342.06
Charcoal:	Household sector	741	0.88	652.08	0.87	567.31
	Commercial sector	10	0.88	8.80	0.87	3.45
	Informal sector	21	0.88	18.48	0.87	7.23
Charcoal production:	N.A	7718	N.A	N.A	N.A	2801.63
Agricultural residues:	Household sector	5597	0.88	4925.36	0.41	2019.40
Cattle dung:	Household sector	97	0.85	82.45	0.36	29.68

Notes: (1) All coefficients were borrowed from the IPCC (14).

(2) The amount of biomass carbonised during the charcoal production (based on traditional earthmould kilns) equals to 10 times the charcoal consumption (15). In total, consumed biomass as fuelwood and that for charcoal production are summed up to 35,483 kt dm.

(3) Emissions from charcoal production = (fuelwood used in charcoal production x 0.45) - (charcoal produced x 0.87).

(4) N.A refers to "not applicable" and the calculations follow the formula in note 3 above.

After calculating the total amount of carbon released from burning biomass fuel (column E of Table 6.6) for each type of biomass fuel, the results are multiplied by 44/12 (the molecular weight of CO_2) to estimate the amount of CO_2 emissions (for information only).

To calculate CH_4 and CO emissions from burning of biomass fuel, the following equation is used:-

$$GHG_a = C_r \; x \; E_r \; x \; M_w$$

where
- GHG is greenhouse gas emissions (Gg)
- a is CH_4 or CO
- C_r is total carbon released by fuel type (kt C)
- E_r is selected emission ratio (refer to Table 6.7)
- M_w is molecular weight (16/12 for CH_4 and 28/12 for CO)

To calculate emissions of NO_x and N_2O from biomass burning the following equation is used:-

$$GHG_b = C_r \; x \; N_r \; x \; E_r \; x \; M_w$$

where
- GHG is greenhouse gas emissions (Gg)
- b is NO_x or N_2O
- C_r is total carbon released by fuel type (kt C)
- N_r is selected nitrogen-carbon ratio (refer to Table 6.7)
- E_r is selected emission ratio (refer to Table 6.7)
- M_w is molecular weight (46/14 for NO_x and 44/28 for N_2O)

Table 6.7 gives selected coefficients and emission factors from the IPCC Reference manual (14). As illustrated by the equations above, the local experts consider these coefficients to be reasonably representative of actual coefficients.

Table 6.7: Selected coefficients and greenhouse emission factors

Sector specific data by fuel	A N/C ratio	B CH_4-C/C ratio	C CO-C/C ratio	D NO_x-N/N ratio	**E** **N_2O-N/N ratio**
Fuelwood	0.010	0.0120	0.04	0.094	0.007
Charcoal	0.010	0.0014	0.06	0.121	0.007
Charcoal production	0.010	0.0630	0.04	0.094	0.007
Agricultural residues	0.015	0.0050	0.04	0.094	0.007
Cattle dung	0.020	0.0170	0.04	0.094	0.007

Source: (14)

Carbon dioxide estimates in column B of Table 6.8 are for information only. The difference between the energy content in wood cleared for charcoal production, and the energy content in charcoal consumed in 1990, is the energy lost during the carbonization process. Table 6.8 gives the results of calculations of greenhouse gas emissions from traditional biomass fuel combustion. Due to the lack of information on non-methane volatile organic compounds (NMVOC), no efforts were made to estimate NMVOC emissions from traditional biomass fuel consumption.

Table 6.8: Greenhouse gas estimates from traditional biomass fuels in 1990 (Gg)

Sector specific data by fuel type	A Consumed energy (PJ)	B Carbon dioxide (CO_2)	C Methane (CH_4)	D Nitrogen oxides (NO_x)	E Nitrous Oxide (N_2O)	F Carbon monoxide (CO)
Fuelwood	513.65	39856.66	173.92	33.57	1.20	1014.53
Charcoal	23.08	2167.16	1.10	2.35	0.07	82.75
Charcoal production *	119.70	10272.64	235.33	8.65	0.31	261.49
Agricultural residues	48.13	7404.46	13.46	9.36	0.33	188.48
Cattle dung	0.98	108.83	0.67	0.18	0.01	2.77
Total	**705.54**	**59809.75**	**424.48**	**54.11**	**1.92**	**1550.02**

Notes: (*) Waste energy during carbonization of charcoal is most of time left unaccounted by researchers despite the fact that the amount is so huge.

6.5 Greenhouse gas emissions estimates from burning of fossil fuels

Calculations of greenhouse gas estimates from burning of kerosene and LPG are based on energy input by combustion technology, and selected full mass emission factors, outlined in Table 6.9. Table 6.10 gives the calculation steps during the conversion of physical units to energy units.

Table 6.9: Selected full-mass greenhouse gas emission factors (Gg/PJ)

Sector specific data by fuel	A Carbon dioxide	B Methane	C Nitrogen oxides	D Nitrous oxide	E Carbon monoxide
Kerosene	71.50	0.0050	0.051	n.a	0.013
Liquefied Petroleum Gas (LPG)	63.01	0.0011	0.047	n.a	0.010

Source: (14)

To estimate the final energy consumption from kerosene and LPG, column F of Table 6.10 is multiplied by column G (calorific values), and divided by 1000 to obtain the energy input in petajoule (PJ) shown in column H of Table 6.10. This column is further multiplied by 0.99 (the oxidation fraction) to obtain the net energy consumption in column J of Table 6.10. Each value in column J of Table 6.10 is multiplied by an appropriate values in columns ranging from A to E to estimate greenhouse gas emission from kerosene and LPG, as shown in Table 6.11. The totals in Tables 6.8 and 6.11 are summarised in table 6.12, and the totals in Table 6.12 form the part of greenhouse gas inventory for 1990.

Table 6.10: Energy consumed (kerosene and LPG) in residential and commercial sectors

Sector specific data by fuel	F Consumed fuel (kt)	G Calorific value (TJ/kt)	H Consumed energy (PJ)	I Oxidised fraction	J Estimates of energy consumption (PJ)
			H=(FxG)/1000		J=HxI
Kerosene	78.816	44.75	3.527	0.99	3.492
Liquefied Petroleum Gas (LPG)	5.073	47.31	0.240	0.99	0.238

Table 6.11: Greenhouse gas estimates from kerosene and LPG combustion in 1990 (Gg)

Sector specific data	A Energy consumption (PJ)	B Carbon dioxide (CO_2)	C Methane (CH_4)	D Nitrogen oxide (NO_x)	E Nitrous oxide (N_2O)	F Carbon monoxide (CO)
Kerosene	3.492	249.727	0.017	0.178	n.a	0.045
Liquefied Petroleum Gas	0.238	15.010	0.001	0.011	n.a	0.003
Total	**3.730**	**264.737**	**0.018**	**0.189**	**n.a**	**0.048**

Table 6.12: GHG emissions from household, commercial, and informal sectors (Gg)

Sector specific data by fuel type	Energy Consumption (PJ)	Carbon dioxide (CO_2)	Methane (CH_4)	Nitrogen oxides (NO_x)	Nitrous oxide (N_2O)	Carbon monoxide (CO)
Traditional biomass fuels	705.54	n.a	424.48	54.11	1.92	1550.02
Kerosene and LPG	3.73	264.74	0.02	0.19	n.a	0.00
Total	**709.27**	**264.74**	**424.50**	**54.30**	**1.92**	**1550.02**

Notes: CO_2 emissions from traditional biomass fuel combustion are not considered here. CO_2 from woody biomass is approach differently under the chapter on Landuse Change and Forestry.

6.6 Discussion

Table 6.12 summarizes the estimates of emissions of trace gases from the household, commercial and informal sector energy use in Tanzania. As shown in Table 6.12, biomass fuels dominate the total end use energy consumption. Furthermore, the household sector is the single largest consumer of biomass fuels, with cooking being the main activity. The use of biomass for energy purposes is often linked with deforestation. However, it has not been possible to establish the extent of deforestation due to energy use. Other contributing factors include land-use changes.

The Tanzanian Urban energy study (9) has provided interesting and detailed data on energy use in urban Tanzania. The results of the study have been used to estimate greenhouse gas emissions in the household, commercial and informal sectors in urban areas.

There are a number of uncertainties and less-detailed studied combustion technologies which contribute significantly to greenhouse gas emissions. The fate of these emissions to human health, has not been accorded the necessary attention compared to other practices such as cigarette smoking in public buildings and transport.

6.7 References

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7.0 FUGITIVE EMISSIONS FROM COAL PRODUCTION AND POST-PRODUCTION HANDLING ACTIVITIES

7.1 Introduction

Coal is one of the most abundant energy resource available in Tanzania. Total inferred reserves of 1,500 million tonnes spread over the following coal fields: Songwe-Kiwira, Ngaka, Njuga, Ketewaka-Mchuchuma, Mhukuru, Mbamba Bay, Galula, Ufipa, Liweta and Lumecha (1). All coal so far investigated in Tanzania is classified as bituminous non-coking coal with high varying ash and low sulphur content, and calorific value ranging between 4500 and 7000 calories per kilogram.

Songwe-Kiwira coal field is situated to the south-east of Mbeya, at the junction of the three districts of Rungwe, Kyela and Ileje. Songwe-Kiwira coal field comprises of Kiwira Mine, Ilima Colliery, and Kabulo which is situated just after Mwalesi Gorge, south of Mount Ivogo. The area covered is defined by geographic co-ordinates East longitude stretching from 33°35' to 33°45' and South latitude stretching from 9°20' to 9°35'. Of all the coal fields, only the Songwe-Kiwira coal field is presently being exploited at two underground coal mines; the Ilima Colliery and the Kiwira mine. While the mining faces in Kiwira mine and Ilima Colliery are force ventilated using exhaust fans, the development ends in Ilima Colliery are supplied with very limited air in an endeavour to avoid spontaneous underground combustion. Force ventilation systems in both mines also take advantage of the difference of elevation between the highest point and the lowest point in Ivogo Area, the centre of the coal field, which is about 732 metres.

There have been four cases of spontaneous combustion underground of Kiwira coal mine since 1988, all of them being associated with excess supply of oxygen far above 550 m^3 of air per minute over long periods. Two cases were recorded at face 1231 between September and October 1989, another case at face 1233 in October 1990, and the recent one at face 718 in October 1993. There is a strong possibility that the coal-shale stockpile at Kiwira coal mine may catch fire due to its poor design and the probability that it contains a large percentage of coal (2). In 1993, the inner temperature of the shale stockpile was recorded at 72°C. Since then ash from the mine power station has been piled together with coal shales so as to reduce its flammability. Spontaneous combustion occurred in 1955, 1975 and 1978 on the surface of coal stockpile at the Ilima Colliery (3). In 1978 alone, six events of spontaneous combustion were recorded from July through November. One of the cases is that which happened on 6th October, 1993 when coal under the size of 38 mm and slacks were stockpiled. Two places were found smoking up to a depth of 2 to 3 metres. Such cases are not only dangerous to the mine, the local population, and the environment, they are also a waste of potentially valuable recoverable coal.

A significant amount of methane has been released from the mine mainly because increasing the surface area of coal during its mining and processing allows more methane to desorb directly from coal to the atmosphere. No attempt has been made to recover the desorbing methane from the coal. Because of limitations of the information available, it has been impossible to divide Songwe-Kiwira coalfield into zones per gas content. However, the composition of gas in different coal seams in Songwe-Kiwira coalfield is as indicated in Table 7.1. No gas emission has been experienced in Ilima Colliery. The major seam exploited in Prospect Adit 2 contains no gas at all. Furthermore at Ilima and Kiwira, coal in the upper coal member above elevation +800 m is overlain by an overburden of less than 100 metres. Gas, if any, would be liable to dissipate. In some of the seams above the elevation +800 m, the expected methane emission would be in the range of zero to 5 m^3 per tonne of coal mined in a day. As one goes deeper, methane emission in the range of 5 to 10 m^3 per tonne of coal mined in a day would be expected since the thickness of overburden increases to about 200 metres.

Table 7.1: Samples from seams of the Songwe-Kiwira coalfield

Hole number	Seam	Sampling Depth (m)	CO_2 (%)	CH_4 (%)	N_2 (%)
105	3b	65.25	20.30	2.90	76.80
105	5	80.48	10.54	0.00	89.46
403b	3b	169.18	10.14	3.15	86.71
002	3b	122.23	1.44	0.00	98.36
1305	5	549.51	4.91	38.23	56.86
1305	5	548.31	2.75	51.56	45.69

Source: (3)

7.2 Estimation of methane emissions from coal mining

Methane emissions considered here belong to three categories: the ventilation system in the underground coal mine, degasification activities, and post-mining operations. The methodology used in estimating CH_4 emissions from the three categories has been recommended by the IPCC (4). Based on the amount of available data on the underground-mines coal production, specific emission factors have been established. The following facts and assumptions are used:-

(a) the average *in-situ* CH_4 content of underground-mined coal is of the order of 5 m^3 of CH_4 per tonne;

(b) the average CH_4 emission factor for ventilation-related emission has been calculated using the equation (4):

$$EF_m = [(2.04 \; x \; I_c) + 8.61]$$

where

EF_m is the average CH_4 emissions factor for ventilation (in m^3), and
I_c is *the average in-situ* CH_4 content of underground-mined coal (in m^3)

The average underground CH_4 emission coefficient for ventilation-related emission is therefore, 18.36 m^3 CH_4 per tonne;

(c) Methane emissions from degasification activities, which depends on the type of technology used (in this case, the horizontal boreholes), the number of wells, and the gas flow rate has been calculated from 5% of the *in-situ* CH_4 content. The calculated average methane emission factor for this category is 0.25 m^3 CH_4 per tonne of mined coal. The percentage figure was realised from methane emission factor given by IPCC (4).

(d) Methane emission from post-mining operations such as coal processing, storage of fine as well as lump coal, and coal transportation over several days following extraction has been calculated from 25% of the *in-situ* CH_4 content (4). The calculated methane emission factor for this category is 1.25 m^3 CH_4 per tonne of mined coal;

(e) to convert the volume of CH_4 to weight at standard temperature and pressure, the density of methane is estimated to be 0.67 Gg per 10^6 m^3 of methane; and

(f) the total CH_4 emission arising from the three categories can be estimated from Run Of Mine (ROM) coal production (4), and is calculated from the equation:

$$Q_T = \sum (EF_{abc} \times ROM_{abc} \times D)$$

where

Q_T	is total CH_4 emissions in gigagrams (Gg)
EF	is methane emissions factor (m^3 CH_4/tonne)
ROM	is run-of-mine (ROM) coal production (in million tonnes)
D	is the density conversion factor (0.67 $Gg/10^6$ m^3)
$_a$	refers to ventilation activities
$_b$	refers to degasification activities
$_c$	refers to post-mining activities

7.3 Methane emissions from coal mining activities in Tanzania

Total CH_4 releases as a result of coal mining activities are a combination of emissions from ventilation systems, degasification activities, and post-mining operations (preparation, transportation, storage, and final crushing but not combustion). Table 7.2 summarises the total mined, imported, and consumed coal during the period of 1988 through 1993.

Table 7.2: Coal mining, imports, and consumption for the period 1988-1993 (tonnes)

Sector specific data by source	1988	1989	1990	1991	1992	1993
	A	B	C	D	E	F
ROM at Kiwira Mines	9274.00	37962.40	58206.80	86905.60	76099.00	91946.00
ROM at Ilima Colliery	2642.00	5812.00	2054.60	2363.30	6830.40	7924.00
Ex-Zambia Imports	66000.00	41180.00	22000.00	21700.00	2500.00	2500.00
Total consumption	77916.00	84957.40	82261.40	110968.90	102929.40	102370.00

Source: (5, 6)

To calculate Methane emissions from coal mining post-mining activities in 1990, column C of Table 7.2 is used, along with the assumptions, and the equations in 7.2. Tables 7.3 and 7.4 outline the procedure followed during the calculations. CO_2 and other greenhouse gas emissions from coal combustion, are accounted for in other chapters on Energy. CH_4 emissions under this chapter are fugitive in nature.

Table 7.3: Calculations of methane emissions from coal mining activities in 1990

Sector specific data by source	ROM Production (tonnes)	Combined emission factor* (m^3/tonne)	Methane emission at the mines (mill. m^3)	Ex-Zambia coal imports (tonnes)	Total coal consumption (tonnes)
	A	B	$C=AxBx10^{-6}$	D	E=A+D
Kiwira Mines	58206.80	18.61	1.083	0	58206.80
Ilima Colliery	2054.60	18.61	0.038	0	2054.60
Ex-Zambia imports	0	18.61	0	22000.00	22000.00
Total	**60261.40**		**1.121**	**22000.00**	**82261.40**

Notes: (*) Emission factors for ventilation and degasification are added together, that is 18.36 plus 0.25

Table 7.4: Methane emissions from coal mining and post-mining activities in 1990

Sector specific data by source	Total coal consumption (tonnes)	Emission factor after mining (m^3/tonne)	Methane emissions after mining (mill. m^3)	Total Methane emissions (mill. m^3)	Total Methane emissions (Gg)
	F	G	$H=FxGx10^{-6}$	I=C+H	J=Ix0.67
Kiwira Mines	58206.80	1.25	0.073	1.156	0.7745
Ilima Colliery	2054.60	1.25	0.003	0.041	0.0275
Ex-Zambia imports	22000.00	1.25	0.028	0.028	0.0188
Total	**82261.40**		**0.104**	**1.225**	**0.8208**

7.4 Discussion

Methane recovery from the mines ventilation systems seem to be uneconomic, thus Methane from underground mines will continue to be released unflared at a high dilution factor. More plans are underway to expand coal mining and post-mining activities. Kiwira coal fired thermal power plant (with installed capacity of about 1.5 MW) is already connected to the grid. It is expected to be expanded up to 6 MW installed capacity in future (5). Mchuchuma is another coal deposit planned to be developed in near future for thermal power generation (about 100 MW installed capacity) (7). All these plans have significant impact on the results in column J of Table 7.4. The estimates of methane emissions from ventilation and degasification dominate. For this matter, upstream mitigation plans will create significant emission reduction. Additional research is needed to confirm the validity of the assumptions used in this chapter, and establish the national representative Methane emission factors.

7.5 References

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8.0 FUGITIVE EMISSIONS FROM NATURAL GASEOUS SYSTEMS

8.1 Carbon Dioxide natural reserves in Tanzania

Carbon dioxide (CO_2) was discovered as a result of a leak from an underground field at Kyejo in Mbeya region in Tanzania. The gas is composed of 80% of CO_2 and 20% other gases. Kyejo is the only place, so far, where CO_2 has been discovered. It is assumed, yet to be proved, that CO_2 occurrence at Kyejo, is associated to the formation of coal in the region.

After a preliminary feasibility study on the reserves, the field was developed to seal the leakage and for the production of gas on a commercial basis. Carbon dioxide is now being produced and sold to customers in several urban centres. The biggest customers are the beverage bottling plants in Mbeya, Iringa and Dar es Salaam as well as some other food processing industries. Production of carbon dioxide has increased from 487,709 m^3 in 1984 to 727,321 m^3 in 1991. Production of carbon dioxide from the field in the past five years has been as shown in Table 8.1.

8.2 Estimation of the CO_2 emissions into the atmosphere

We have estimated the amount of CO_2 emitted to the atmosphere using the following assumptions:-

(i) leaks from the CO_2 production facility at Kyejo field are considered insignificant;

(ii) 100% of all CO_2 sold is eventually released to the atmosphere; and

(iii) there is no venting of CO_2 gas from any other underground field. The Tanzania Oxygen Company Ltd has carried out extensive studies (1) in the area around the CO_2 mine and that no other area has been found to contain any significant amount of CO_2 underground.

Underground CO_2 emission at Kyejo is a natural process and could have been discounted. However, since its exploitation is significant, and emission are now man-made, this source is considered in the final inventory. To calculate the equivalent mass of carbon produced, a factor of 12/44 derived from molecular weight is employed. Based on the above assumptions, the amount of carbon dioxide as CO_2-C released to the atmosphere is as shown in Table 8.1.

Table 8.1: Carbon Dioxide emissions from underground CO_2 sources

Year	CO_2 production (Gg)	Emission of CO_2-C (Gg)
1988	0.191	0.26
1989	1.004	0.27
1990	1.260	0.34
1991	1.560	0.42
1992	2.052	0.56

Source: (1)

8.3 Natural hydrocarbon gases

Two natural gas fields have been discovered in Tanzania; the Songo Songo field situated about 200 km south of Dar es Salaam and the Mnazi Bay gas field which is about 40 km south of Mtwara town. The Songo gas field was discovered in 1974 and the reserves have been estimated to contain 30 billion cubic metres of gas (2). The Mnazi Bay gas field is estimated to contain 16 billion cubic metres of gas. Nine wells have been drilled in Songo Songo; five of them completed as gas producer wells.

In the past gas leaks from the wells have occurred but the wells were subsequently worked-over to plug the leaks. However, on 16 June, 1992, it was reported that SS-3 and SS-4 were leaking through the master valve due to gas passage from the valve bore and clearances within valve components. The leak is audible from within a three metre radius. The quantity of gas leaking has to date not been established. Plans are underway to replace the leaking bottom hole plug and the X-mass tree with new ones. In Mnazi Bay only one well was drilled and it has been plugged. It is planned to develop the Songo Songo and the Mnazi Bay gas fields for power generation.

8.4 Discussion

Carbon dioxide emission from the exploited Kyejo deposit is considered to be anthropogenic in nature. The nature and phenomenon behind this emission is yet to be studied. IPCC (3) is silent on the methodology and reporting requirements for such gaseous occurrences.

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9.0 GREENHOUSE GAS EMISSIONS FROM NON-ENERGY INDUSTRIAL PROCESSES

9.1 Introduction

Industries emit greenhouse gases during production processes when raw materials are transformed into intermediate or final products. Greenhouse gases are also emitted in industries during combustion of fossil fuels.

Major industries in the country have been studied in order to estimate process and combustion emissions. Process emissions include those from cement production, beer production, alcohol distillation, crude oil refinery, and pulp and paper production. Greenhouse gas emissions from kilns, boilers and furnaces have been assessed and discussed in detail under Chapter 3. In this section we concentrate on emissions inherent in the processes themselves.

9.2 Carbon Dioxide emissions from the beer brewing process

9.2.1 The brewing process

Tanzania has two plants which brew beer, one is in Dar es Salaam and another at Arusha. Raw materials for beer production include barley, malt, yeast and water.

The production process is batchwise fermentation and the process is characterised by the chemical equation:

malt -------> wort ---------> Carbon Dioxide + (alcohol)
fermentation

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2\,CO_2 + 2C_2H_5OH$$

i.e. $C_6H_{12}O_6$ ----------------> 2 CO_2 + $2C_2H_5OH$

In practice the amount of CO_2 generated is dependent on the amount of extract (sugars) available for fermentation; that is the change in gravity between start and end of fermentation.

At the start the specific gravity is said to be 1050° equivalent to sucrose 12.5°P (°P = degree plato). For the first 24 hours the specific gravity drops to 1045° which is equivalent to 10.2°P. During the first 24 hours it has been established that the CO_2 discharge is 0.669 kg CO_2/hl. Fermentation continues for a further 120 hours. During this period the specific gravity drops from 10.2°P to 4.74°P. It has been established that CO_2 discharge during this period is 3.736 kg CO_2/hl. This amount is normally collected for carbonation. It follows therefore that if the amount of beer produced is known it is possible to calculate the amount of CO_2 emitted.

$$Q_c = \sum (Activity \times EF_{ab})$$

where

- Q_c is the quantity of CO_2 emitted during fermentation process (kg);
- Activity is the annual beer production level in hectalitres (hl);
- EF is the effective emission factor (0.669 and 3.736 kg/hl respectively);
- $_a$ is annotation of CO_2 discharge within the first 24 hrs;
- $_b$ is annotation of CO_2 discharge within 120 hrs after the first 24 hrs discharge.

The volume of beer produced (in thousand litres), including the industry average 3% loss, and CO_2 emissions for the years 1985-1992 are as shown in Table 9.1. It is worthwhile to note that carbon dioxide production in the brewing industry is part of a closed cycle, therefore this source is not considered in the national greenhouse gas inventory.

Table 9.1: Beer production and CO_2 emissions for the period 1985-1992

Year	Production (hl)	CO_2 Emission 1st 24 hrs (kg)	CO_2 Emission 120 hrs later (kg)
1985	784860.00	525071.34	2932236.96
1986	671302.50	449101.37	2507986.14
1987	605768.75	405259.29	2263152.05
1988	545771.25	365120.96	2039001.39
1989	553367.50	370202.85	2067380.98
1990	463886.25	310339.90	1733079.03
1991	924296.25	618354.19	3453170.79
1992	515000.00	344535.00	1924040.00

Source: (1)

9.3 Carbon dioxide emissions from spirits manufacturing

9.3.1 The distillation process

Tanzania has only one distillery plant which manufactures spirits i.e "Konyagi". Raw materials used in the manufacture include molasses, yeast dry, and nitrogen.

Molasses are obtained from sugar factories whereas dry yeast is imported. The process used is batchwise fermentation and distillation. The most important parameter is temperature, which has to be kept below 33°C. The plant has a capacity of 2200 litres/day.

9.3.2 Estimation of CO_2 emissions

Starting with molasses (sucrose) the chemical reactions are as follows:

$$C_{12}H_{22}O_{11} + H_2O \text{ ---------> } 2C_6H_{12}O_6$$
sucrose

$$C_6H_{12}O_6 \text{ ---------> } 2C_2H_5OH + 2\,CO_2$$
Zymase

It is common practice that 1 tonne of molasses yields 200 litres of spirit which has 96.3% ($^v/_v$) alcohol.

We use a constant reflecting the amount of CO_2 released per unit alcohol, that is:-

$$C_o = \frac{44\ g/mole\ CO_2}{46\ g/mole\ C_2H_5OH} = 0.95652$$

It follows therefore that if the amount of ethanol (C_2H_5OH) in the yield is known then it is possible to calculate the amount of CO_2 emission using the following relationship:

$$Q_c = 0.963 \times P_a \times D_a \times C_e$$

where

Q_c	is CO_2 emission (in kg);
P_a	is the production of alcohol (in litres);
0.963	is the fraction of alcohol in spirit;
D_a	is the density of alcohol (considered at 0.80 kg/ltr);
C_e	is the CO_2 conversion factor (estimate 0.95652) from alcohol.

Total production of fine spirit for the period from 1988 to 1992 and CO_2 emissions are as shown in Table 9.2.

Table 9.2: Production of fine spirits and CO_2 emissions for 1988 - 1992

Year	Fine Spirit (litres)	C_2H_5OH in yield (litres)	CO_2 emission (kg)
1988	395564	380928.13	291492.30
1989	445162	428691.00	328041.21
1990	407490	392412.87	300280.60
1991	513061	494077.74	378076.20
1992	627176	603970.48	462167.87

Source: (2)

Again just as in the case of beer brewing, carbon dioxide emissions from this source is part of a closed carbon cycle. It is therefore <u>not</u> considered in the national greenhouse gas inventory.

9.4 Carbon Dioxide emissions from Portland cement production

9.4.1 Introduction

Tanzania has three plants which manufacture cement. These are the Tanzania Portland Cement Company (TPCC) at Wazo Hill in Dar es Salaam, the Tanga Cement Company (TCC), and the

Mbeya Cement Company (MCC). Cement manufactured in these companies is of the "Portland" type. The fraction of lime (CaO) in cement clinker in Tanzania is 68% ($^w/_w$).

The designed capacities for these plants are:-

TPCC: 520,000 tonnes/annum
TCC: 500,000 tonnes/annum
MCC: 250,000 tonnes/annum

Cement production figures from 1985 - 1992 are as shown in Table 9.3. These production figures exclude losses due to the inefficiency of the electrostatic precipitators.

Table 9.3: Portland cement production by TPCC, TCC and MCC for 1985-1992 (tonnes)

Year	TPCC	TCC	MCC	Total
1985	179,755	162,816	41,868	384,539
1986	228,546	161,951	46,854	437,351
1987	281,655	158,939	51,617	492,211
1988	361,187	171,052	62,009	594,248
1989	320,278	189,705	84,808	594,791
1990	**378,398**	**172,844**	**92,872**	**644,144**
1991	421,900	181,500	38,200	641,600
1992	378,300	228,000	74,700	681,000

Source: (3)

9.4.2 Estimation of CO_2 emissions from cement production

Estimation of CO_2 emission has been made using the IPCC methodology for the cement production process (4). This is accomplished by applying an emission factor given as the product of the fraction of lime used in the cement clinker and a constant reflecting mass of CO_2 released per unit of lime thus:

$$EF_c = F_c \times C_o$$

where

EF_c is effective CO_2 emission per tonne of cement (kg/tonne);
F_c is the fraction of lime (CaO) in cement (0.68 w/w);
C_o is conversion factor (44g/mole CO_2 per 56.08g/mole CaO) calculated at 0.7846.

CO_2 emissions can therefore be obtained by multiplying the emission factor by tonnes of cement produced, following the relationship below:-

$$Q_c = \sum (Activity \times EF_e)$$

where

Q_c is the quantity of CO_2 emitted from the cement production process (Gg);
Activity is the annual cement production level (kilotonnes); and
EF_e is the effective CO_2 emission per tonne of cement (tonne/tonne).

Table 9.4: Carbon dioxide emission from cement production in 1990

Sector specific data by source	Production (kt)	EF_c (tonne/tonne)	CO_2 emission (Gg)
	A	B	C=AxB
TPCC	378.398	0.5335	201.875
TCC	172.844	0.5335	92.212
MCC	92.872	0.5335	49.547
Total	**644.144**		**343.634**

Sources: (3, 4)

9.5 Carbon dioxide from pulp and paper production processes in the Southern Paper Mills

The Southern Paper Mills Company Limited (SPM) is a fully integrated pulp and paper mill. The mill is located in Mgololo Valley in Mufindi District along the TAZARA railway about 600 km south west of Dar es Salaam. The mill enjoys unlimited supply of fresh logs from the Sao Hill forest Project. The mill, with installed capacity of 60,000 FTPA (finished tonnes per annum), produces chemical (kraft) and mechanical (ground wood) pulps. The mill has its own chloralkali plant producing caustic soda, chlorine and sodium hypochlorite chemicals used in the bleaching of pulp.

The major three sources of greenhouse gas emissions at SPM include:-

(i) the power boiler;
(ii) calcination of limestone to produce lime; and
(iii) the recovery process.

Of the three, only calcination of limestone yields process emissions. Process emissions are also possible from the recovery process. These two sources are discussed below while emission out of the combustion process is discussed under the appropriate chapter of on energy end-use.

9.5.2 Limestone calcination process

In this process limestone (lime mud) is calcined to generate lime (CaO) which, when treated with water, produces Calcium hydroxide.

Calcium hydroxide is used in the causticization process to convert sodium carbonate (Na_2CO_3) into active sodium hydroxide (NaOH) which is used for cooking in the kraft process. The following are the associated chemical reactions:-

(i) $CaCO_3$ ------------------> Cao + CO_2
(ii) Cao + H_2O ------------> $Ca(OH)_2$ + Heat
(iii) $Ca(OH)_2 + Na_2CO_3$ --> 2NaOH + $CaCO_3$ (lime mud)

Calcining of limestone is performed in the kiln which is fired by furnace oil. CO_2 emissions in the production process can be calculated as follows:-

$CaCO_3$ ---> CaO + CO_2
56.08g/mole 44g/mole

Emission of CO_2 per quicklime produced is estimated at 44 g/mole divided by 56.08 g/mole. This is referred to as effective emission factor, EF_c which is estimated at 0.7846. Thus knowing the amount of quicklime produced, CO_2 emitted can be calculated from the following relationship:-

$$Q_c = \sum (Activity \times EF_e)$$

where

Q_c is the quantity of CO_2 emitted from the quicklime production process (Gg);
Activity is the annual quicklime production level (kilotonnes); and
EF_e is the effective CO_2 emission per tonne of quicklime (tonne/tonne).

The calculation and amount of CO_2 emitted from quicklime production during the period of 1988-1990, is shown in Table 9.5.

Table 9.5: CO_2 emissions from limestone calcination process at SPM for 1988 - 1992

Year of production	Quicklime production level (kt)	Carbon Dioxide Emission factor	CO_2 emitted (Gg)
	A	B	C=AxB
1988	4.7436	0.7846	3.1219
1989	9.0340	0.7846	7.0881
1990	**7.3752**	**0.7846**	**5.7866**
1991	4.5745	0.7846	3.5892
1992	2.9145	0.7846	2.2867

Sources: (4, 5)

9.5.3 Chemical recovery process

In the kraft process the wood is treated with strong alkaline cooking liquor, called white liquor, containing as active compounds sodium hydroxide (NaOH) and sodium sulphide (Na_2S). These chemicals are recovered and re-used both for cost and environmental reasons. The alkaline attack causes a breaking of the lignin molecule into smaller segments whose sodium salts are soluble in the coking liquor, thus forming the black liquor. Lignin is an amorphous, highly polymerized material that forms the middle lamella (the outer layer of the fibres) thus cementing the fibres together. The structure of liquor consists primarily of phenyl propane units linked together in three dimensions.

The three linkages between the propane, side chains and the benzene rings are broken during chemical pulping operations to free the cellulosic fibres.

The black liquor (which is 60-65% solid) thus formed is concentrated at the recovery boiler plant and is burnt. The inorganic part of the black liquor which includes the coking chemicals which cannot be burnt, melts at the high temperatures in the furnace, and a smelt is formed at the furnace bottom.

The organic constituents are burnt completely. Gases emitted during the combustion process are CO_2, CO, SO_2, H_2. However, since the chemistry of lignin is extremely complex, it has been difficult to calculate the emissions from black liquor. It is recommended that, experimental work to determine emissions from black liquor be undertaken. The quantity of black liquor burnt is shown in Table 9.6.

Table 9.6: Black liquor burnt in the recovery process at SPM

Year	Quantity (M^3)
1990	38901
1991	26845
1990	26571

Source: (4)

9.6 Crude oil refining

Emissions from the oil refinery, TIPER, have already been considered from the point of view of fuel and waste gases used in the combustion process to generate heat. Other emissions from the refinery process include:-

(i) CH_4 - This and other light hydrocarbons such as C_2-C_5 are recycled and used in the furnaces resulting into CO_2 emissions which have already been accounted for.

(ii) NO_x - Crude oil processed at TIPER normally contains 0.001 - 0.005% of nitrogen. This nitrogen is strongly bonded in heavy hydrocarbons and can only be emitted during the burning of petroleum products such as gasoline. These emissions have already been taken into account.

(iii) CO - This is avoided by supplying excess air in the furnaces.

9.7 Discussion

Calcination process in pulp and paper production releases significant CO_2 emissions compared to the amount released during the portland cement production process. Due to the lack of an established methodology, and unavailability of information on non-CO_2 emission, significant amounts of nitrous oxides (N_2O), and non-methane volatile organic compounds (NMVOC) have been left un-accounted. Table 9.7 gives the summary of emissions from non-energy industrial processes. From the results, it is interesting to note the significant of emissions from the pulp and paper production process. The calcination process in pulp and paper production processes should be looked into further.

Table 9.7: CO_2 emissions due to non-energy industrial processes in 1990

Sector specific data	Carbon Dioxide (in Gg)
Portland cement production process	343.634
Calcination process at SPM - pulp and paper	5.787
Total	**349.421**

9.8 References

1. Tanzania Breweries Ltd. (TBL), 1993; Beer Production Statistics 1985 - 1992, Internal Communication, TBL, Dar es Salaam.

2. Tanzania Distillery Ltd. (TDL), 1992; Annual Production Statistics 1988 - 1992, Internal Communication, TDL, Dar es Salaam.

3. Tanzania Saruji Corporation, 1993; Annual Production Statistics, Internal Communication, Tanzania Saruji Corporation, Dar es Salaam.

4. OECD/OCDE, 1995; Intergovernmental Panel on Climate Change (IPCC) Reference Manual on National Greenhouse Gas Inventory; Final version, Vol.3; IPCC, London.

5. Southern Paper Mills (SPM), 1993; Quicklime and Black liquor Statistics, Internal Communication; SPM, Mgololo.

10.0 ESTIMATION OF GREENHOUSE GAS EMISSIONS FROM THE AGRICULTURE SECTOR

10.1 Introduction

Tanzania has an area of 94.5 million hectares of which 44.4 million hectares is arable and 39.2 million hectares is suitable for rainfed agriculture. However, only 8.8 million hectares are currently utilised. Agriculture accounts for 50% of the Gross Domestic Product (GDP) and 75% of external earnings. Except for years of uncertain rainfall, Tanzania is largely self-sufficient in food production. It is estimated that in 1990 about 40% of the population of 27 million was engaged directly in agricultural production.

Agricultural activities do contribute to greenhouse gases emissions. In this chapter we consider greenhouse gas emission due to the following six activities:-

- CH_4 emission from rice cultivation;
- N_2O emissions from the use of nitrogen fertilizers;
- CH_4 emissions from enteric fermentation of domestic animals;
- CH_4 emissions from animal wastes;
- Greenhouse gas (CH_4, CO, NO_x and N_2O) emission from burning of agricultural crop wastes;
- CH_4 emissions from wildlife; and
- Greenhouse gas (CH_4, CO, NO_x and N_2O) emissions from savanna burning.

10.2 Methane emissions from rice cultivation

Production of methane in rice fields is the result of the decomposition of organic material (root exudates, rice straws, algae, etc.) by methanogenic bacteria which begins after certain soil conditions have been established in the fields. Methane escapes to the atmosphere mainly by diffusion through rice plants during the growing season. Part of the methane produced (60-80%) is oxidized by aerobic bacteria. Unoxidised methane escapes by diffusion, bubbling, and through the plant (2).

Experiments elsewhere (2) have shown that methane emission from rice fields varies with a number of factors. These include, soil type, temperature, reduction - oxidation potential, and pH. The type, timing, application method, amount of fertilizer used, and water management techniques also influence the rate of emission.

10.2.1 Estimating emissions of methane from rice fields

Simple methodology was used to estimate the amount of methane emitted from rice fields (2). In this methodology a daily emission rate is used to obtain annual emission. The number of hectare-days in the year is normally used rather than hectares in order to capture the possibility of two or more crops in a year. However, in the case of Tanzania there is usually only one crop per year.

Table 10.1: Total agricultural land under rain-fed (paddy) rice cultivation in kha

Administrative region	1988/89	1989/90	1990/91
Arusha	1.41	1.08	3.80
Coast	27.03	26.41	15.60
Dar es Salaam	4.30	2.83	1.56
Iringa	3.54	0.78	1.20
Kigoma	1.84	6.87	1.50
Kilimanjaro	3.92	3.63	2.80
Lindi	7.75	1.16	8.50
Mara	3.56	1.11	2.00
Mbeya	35.82	28.42	23.60
Morogoro	47.25	36.36	66.40
Mtwara	28.41	16.14	27.40
Mwanza	40.89	46.45	63.40
Rukwa	0.51	6.63	14.30
Ruvuma	12.52	23.70	27.20
Shinyanga	89.93	71.53	67.80
Singida	1.41	1.44	1.40
Tabora	71.98	32.93	34.40
Tanga	3.24	5.59	4.20
Total	**385.31**	**289.29**	**347.66**

Source: (1)

In Tanzania rice cultivation is done under three regimes i.e. flooded or irrigated, lowland rain-fed, and upland rain-fed. The number of days in a growing season under irrigation has been found to be 120 days and 95 days for the lowland rain-fed regimes. The total area under rice growing for the years 1988/1989, 1989/1990 and 1990/1991 is as shown in Table 10.1. FAO estimated 375 kha as a land area under rice cultivation for 1990 (2). Out of this 10 percent was assumed to be under continuous irrigated scheme, and 26 percent under upland rice cultivation. The seasonal length was estimated at 137 days. FAO data source might have been obtained from projections of previous years. Table 10.1 makes reference on the actual data from the sectoral ministry (1). The 3-year average acreage is 340.75 kilohectares (kha). Out of this, about 72.7 kha is under upland rice cultivation (in Ulanga, Uluguru, Mitalula and Usangu), 41.9 kha is under lowland irrigated regime (in Ruvu, Sahara, and Kilingali), the rest is under lowland rain-fed regime (in Wembere, Kilosa, Kwimba, Kibondo, Bahi, and Mpanda) (1). Upland rice cultivation does not emit significant methane emissions.

On average 268.05 kha are cultivated in the case of the lowland rain-fed regime/intermittent.
The number of kilohectare-days is therefore 25464.75. We add 5028 kha-days due to flooded regime.

The total number of kilohectare-days for Tanzania is therefore 30492.75. The average methane emission from rice cultivation is estimated to be 84.756 Gg. Disaggregated figures are shown in Tables 10.3.

Table 10.2: Estimation of kilohectare-days (kha-days) for rice cultivation

Rice cultivation regimes	Area covered annually (kha)	Number of flooding days (days)	Kilohectare-days (kha-days)
	A	B	C=AxB
Lowland rain-fed	268.05	95	25464.75
Flooded or Irrigated	41.90	120	5028.00
Total	309.95		30492.75

IPCC (2) recommends that country specific emission factors be determined for emissions of methane from rice cultivation. The procedure recommended for estimating these emissions is described by the following formula:-

$$ME = A_R \times EF_R \times F_c$$

where

ME is methane emission (Gg);
A_R is the kilohectare-days (kha-days)
EF_R is the average methane emission flux (g/m^2-day)
F_c is the unit conversion factor (10^{-2} G m^2/kha)

It is further recommended that the relationship above be modified accordingly to incorporate such additional factors as the fertilizer effect and soil type. Furthermore the methane emission ME should be corrected for temperature effect. In the case of Tanzania, therefore, further research needs to be undertaken to take into consideration the above observations.

Table 10.3: Methane emission calculations from rice cultivation in 1990

Sector specific data by source	Area-duration of floods per annum (kha-days)	Methane emission flux (g/m^{-2}-day)		Area conversion factor (m^2/kha)	Average Methane emission from rice cultivation (Gg)	
		High	Low		High	Low
	A	B	C	D	E=AxBxD	F=AxCxD
Flooded or Irrigated	5080.00	0.466	0.368	0.01	23.6728	18.6944
Lowland rain-fed	25464.75	0.28	0.221	0.01	71.3013	56.2771
Total	**30492.75**			**Average**	**84.7560**	

IPCC (2) has further recommended seasonal average emission factors according to water management regimes, taking into account average temperatures. In Tanzania in rice growing areas, growing seasonal average temperatures range between 19°C and 23°C. We estimate emissions of methane using these two averages.

Using the lower number of the temperature range, the suggested emission factors are 0.368 g/m^2-day and 0.221 g/m^2-day for continuously irrigated and intermittently flooded regimes, respectively at 19° C. At higher temperatures, say 23° C, emission factors are 0.466 g/m^2-day and 0.280 g/m^2-day, respectively.

10.3 Methane emissions from enteric fermentation in domestic animals

Methane production in animals is part of the normal digestive process among livestock ruminant animals such as cattle, sheep, goats, and buffalo. The rumen, the fore-stomach, is a characteristic physiological feature of ruminant animals on account of which these are major emitters of methane.

Ruminant animals consume plant cellulosic material. These carbohydrates are broken down in the rumen by micro organisms, into simple molecules for absorption into the bloodstream. In the process, methane is released. The amount of methane will vary with the animal category, the type of food, the expenditure of energy by the animal and the production level of such products as milk and wool. Methane is also produced from non-ruminant herbivorous animals as part of the digestive process. However, because of the absence of a rumen, a smaller amount of feed energy is converted into methane compared with ruminants. Non ruminants convert between 1% and 4% of gross energy intake into methane whereas for ruminants the range is 4% to 9%.

10.3.1 The methodology

IPCC has provided the baseline for estimating the emission of methane from enteric fermentation based largely on defining various systems of feeding requirements of domestic ruminant animals. The principle is based on the concept of breaking down the total energy requirement of the animal into that required for its own maintenance, for growth, pregnancy, work and for production of milk or wool. Total emissions will therefore depend on a number of factors including the number and type of animals, the characteristics of the populations of animals including livestock management systems, the size, feeding and production characteristics. Tier 2 approach (2) is based on obtaining simplified relationships for the estimation of methane emissions based on:-

- estimation of the total feed energy intake by the animal, age and activity;

- estimation of the percentage of feed energy that is converted to methane by the animal, Y_m; and

- multiplication of the conversion percentage by the feed intake, and division by 55.65 MJ/kg.

10.3.1.1 Proportion of feed converted to methane

The ratio of the total feed intake of an animal that is converted into Methane can be represented thus (2):-

$$Y_m = 1.3 \times 0.112D + L\,(2.37 - 0.05D)$$

where

Y_m	is the empirical methane yield conversion factor per gross energy intake;
L	is the ratio of the energy intake to maintenance energy requirement;
D	is the ratio of digestibility of the feed.

The values of Y_m used in this study are based on recommendations given by IPCC for ruminant animals in Africa (8). Indigenous cattle are assumed to have a value of Y_m of 0.07, for beef cattle equals 0.065; while Y_m is 0.06 for dairy cattle. Goats and sheep have a conversion ratio of 0.075.

10.3.1.2 Estimation of the total feed energy intake

To estimate the total feed energy intake, we first estimate the actual amount of feed energy used and then use a scaling factor to determine the total energy. The net energy estimate in the case of cattle can be obtained using the following equations (2, 8):-

$$E_m = 0.322 \times W^{0.75} \times 1.37 \text{ (for grazing cattle)}$$
$$E_m = 0.335 \times W^{0.75} \times 1.17 \text{ (for dairy cows)}$$
$$E_g = 4.18 \times (0.035 \times W^{0.75} \times WG^{1.119} + WG)$$
$$E_l = (1.47 + 0.40 \times F) \times \text{milk production per day}$$
$$E_d = 0.10 \times E_m \times \text{hours of work per day}$$
$$E_p = 28 \times \text{calf birth weight}$$
$$= 28 \times 0.266 \times (W)^{0.79}$$

where

E_m	is the net energy requirement for maintenance, in MJ/day;
E_g	is the net energy required for growth in MJ/day;
E_l	is the net energy required for milk production in MJ/day;
E_d	is the energy required for work by draught animals in MJ/day (5 hour-day);
E_p	is the energy required for pregnancy in MJ per 281 - day period;
W	is the weight of the animal in kilograms ;
WG	is the daily weight gain in kilograms; and
F	is the fat content in % (assumed to be 4%).

The net energy intake is estimated as follows (2), (8):-

$$L_1 = 0.298 + 0.00335 \times DE\%$$
$$L_2 = -0.036 + 0.00535 \times DE\%$$

where

L_1	is the ratio of the net energy consumed for maintenance, lactation, work, and pregnancy to digestible energy consumed (E_m/DE).
L_2	is the ratio of the net energy consumed for growth to digestible energy consumed (E_g/DE).
DE%	is the digestible energy as percentage of gross energy,

Table 10.4: Estimation of methane emissions from enteric fermentation in ruminant livestock in 1990

Animal category in thousands	Population in thousands	W	WG	Average milk yield (kg/day)	DE (%)	Em	Eg	El	Ep	Ed	Em/DE	Eg/DE	E_{intake} (MJ/day)	Ym	Emission Factor kg/hd/yr	Emission by source (Gg)
		(kg)				(MJ/ day)										
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Indigenous (11510.22) Male	1188.40	250	0	0	55	27.74	0.00	0.00	0.00	0.00	0.48	0.26	104.6	0.070	48.01	57.05
Fenop	3738.15	250	0	2	55	27.74	0.00	2.97	0.00	0.00	0.48	0.26	115.8	0.070	53.15	198.70
Fepr	934.54	250	0	2	55	27.74	0.00	2.97	2.08	0.00	0.48	0.26	123.6	0.070	56.76	53.04
Young	5649.13	180	0.15	0	55	21.68	1.49	0.00	0.00	0.00	0.48	0.26	97.8	0.070	44.91	253.69
Beef (115.8) Male	23.90	450	0.10	0	65	43.10	1.51	0.00	0.00	0.00	0.52	0.31	140.5	0.065	59.89	1.43
Fenop	27.80	450	0.10	4	65	43.10	1.51	5.94	0.00	0.00	0.52	0.31	158.2	0.065	67.45	1.88
Fepr	13.90	450	0.10	4	65	43.10	1.51	5.94	3.31	0.00	0.52	0.31	168.1	0.065	71.66	1.00
Young	50.20	300	0.30	0	65	31.80	4.00	0.00	0.00	0.00	0.52	0.31	126.5	0.065	53.93	2.71
Dairy (209.76) Male	17.30	350	0	0	65	31.72	0.00	0.00	0.00	0.00	0.52	0.31	94.6	0.060	37.23	0.64
Fenop	55.99	350	0	15	65	31.72	0.00	22.29	0.00	0.00	0.52	0.31	161.1	0.060	63.40	3.55
Fepr	27.99	350	0	10	65	31.72	0.00	14.86	2.71	0.00	0.52	0.31	147.0	0.060	57.86	1.62
Young	108.48	250	0.25	0	65	24.64	3.00	0.00	0.00	0.00	0.52	0.31	97.2	0.060	38.26	4.15
Oxen (900)	900 .00	300	0.20	0	55	31.80	2.58	0.00	0.00	15.90	0.48	0.26	207.7	0.070	95.36	85.82
Goat (8533.7) Male	3515.12	22	0.06	0	50	4.48	0.32	0.00	0.00	0.00	0.47	0.23	23.3	0.075	11.47	40.33
Female	5018.58	22	0.06	1	50	4.48	0.32	1.49	0.31	0.00	0.47	0.23	31.0	0.075	15.26	76.57
Sheep (5551.4) Male	2254.90	27	0.10	0	52	5.23	0.55	0.00	0.00	0.00	0.47	0.24	27.9	0.075	13.72	30.93
Female	3296.50	27	0.10	1	52	5.23	0.55	1.49	0.36	0.00	0.47	0.24	35.4	0.075	17.41	57.40
															Grand total	870.50

Notes: Fenop = Non pregnant cows at any given time in a year (estimated at 75% for indigenous and 67% for the diary and beef)
Fepr = Pregnant cows at any given time in a year. It is customary in Tanzania to milk pregnant cow until two months before delivery. However the average milk yield is about 10 kg/head/day.
Young cattle (include heifers)

DE is expressed in percent (Digestibility of the feed); and
E_{intake} is the gross energy intake estimated using the relationship:-

$$E_{intake} = \frac{\left[\frac{(E_m + E_g + E_l + E_d + E_p)}{L_1} + \frac{E_g}{L_2}\right]}{DE}$$

The annual methane emission (ME) from enteric fermentation in gigagram (Gg) is thus, estimated from:-

$$ME = \frac{E_{intake} \ x \ Y_m \ x \ 10^{-6}}{55.65}$$

where
Y_m is the methane conversion rate in decimal form;
55.65 is the conversion factor from energy to methane (in MJ/kg).

10.3.1.3 Illustration of Methane emissions from enteric fermentation

For transparency purposes, we have chosen the information on pregnant beef cow in Table 10.4, to work out the amount of Methane emitted annually. Using the formula given above, let us determine the net energy requirement as per Tier 2 (8), and follow closely how Table 10.4 was produced with all available information. Note that Columns A to E are statistical data and coefficients cited in literature. The calculations proceeded this way:-

Column F: Em, the net energy for body maintenance (MJ/day)
E_m = 0.322 x (Column B)$^{0.75}$ x 1.37 *Column B refers to animal weight;*
= 0.322 x $450^{0.75}$ x 1.37
= 43.1 MJ/day

Column G: Eg, the net energy required for growth (MJ/day)
E_g = 4.18 x [0.035 x (Column B)$^{0.75}$ x (Column C)$^{1.119}$] + Column C;
= 4.18 x [0.035 x $450^{0.75}$ x $0.1^{1.119}$] + 0.1 *Column C refers to weight gain;*
= 1.505 MJ/day

Column H: El, the net energy required for lactation (MJ/day)
E_l = Column D x [1.47 + (0.4 x F)] *Column D refers to average milk production;*
= 4 x [1.47 + (0.4 x 0.04) *F refers to percentage fat in milk (assumed 4%);*
= 5,944 MJ/day

Column I: Ep, the energy required for pregnancy (MJ/day)
E_p = 28 x (Column B)$^{0.79}$]/281 *281 pregnancy days are assumed;*
= 28 x $450^{0.79}$/281
= 3.307 MJ/day

Column J: Ed, the energy required for draught-power (MJ/day

E_d = 0.1 x Column F x day working hours *Column F refers to maintenance energy;*
= 0.1 x 43.1 x 0 *Zero hours assumed for non-draught animal;*
= 0 MJ/day

Column K: L_1 or Em/DE, the ratio of energy requirements (excluding growth) to digestibility

L_1 = 0.298 + (0.0035 x Column E) *Column E refers to Digestibility, DE*
= 0.298 + (0.0035 x 65)
= 0.5158

Column L: L_2 or Eg/DE, the ratio of energy requirement for growth to digestibility

L_2 = -0.036 + (0.00535 x Column E)
= -0.036 + (0.00535 x 65)
= 0.3118

Column M: E_{intake}, the gross energy requirement (MJ/day)

E_{intake} = [(sum(Columns F to J)/Column K) + (Column G/Column L)]/(Column E/100)
= [(53.856/0.5158) + (1.505/0.3118)]/0.65
= 168.06 MJ/day

Column N: Selected average Ym factor is 0.065

Column O: ME, methane emission factor (kg/hd/yr)

ME = (Column M x Column N x 365)/55.65
= (168.06 x 0.065 x 365)/55.65
= 71.66 kg CH_4/head

Column P: Q, annual Methane emissions for pregnant beef cows (Gg)

Q = (Column A x Column O x 10^{-6}
= (13900 x 71.66) x 10^{-6}
= 0.996 Gg CH_4

The same procedure was followed for the rest of calculations. Statistics for numbers, average weight and feed per day have been obtained from the Ministry of Agriculture.

The total amount of methane emitted by ruminant animals per year is estimated to be 870.74 Gg. For non-ruminants, pigs and asses have been considered. A simplified method to estimate emissions based on their numbers and emission factors of 1.0 kg of methane per head per year and 10 kg of methane per head per year for pigs and asses, respectively, has been used. The emissions from non-ruminants is estimated at 2.775 Gg. The total estimate of methane generation from domestic animals is 872.275 Gg.

10.4 Methane emissions from animal wastes

Methane is generated from animal wastes when the organic material in the wastes decomposes anaerobically. The amount of methane so produced does depend on the type of animal, the waste characteristics and the management of the waste.

There is a direct correspondence between the amount of volatile solids (VS) present in the animal waste and methane generation. In estimating emission from wastes we define the different types of animals and hence waste types, and the way the waste is managed. The amount of methane that could potentially be produced from volatile solids for each type of animal (methane emission potential) has been obtained from information supplied by the Centre for Agricultural Mechanisation and Rural Technology (CAMARTEC).

The realized methane emissions are obtained through use of the Methane Coefficient Factor (MCF) which is dependent on how the waste is managed. The estimate of the total emission of methane is represented thus (2), (8):-

$$T_m = \sum \frac{(P_i \ x \ W_i \ x \ F_{vs}) \ x \ B_o \ x \ MCF \ x \ d \ x \ 365}{10^6}$$

where

T_m	is the total methane (in Gg)
P_i	is the population of livestock (heads)
W_i	is the animal waste generated (kg/head/day)
F_{vs}	is the fraction of volatile solids in animal waste
B_o	is the Methane emission factor (in m^3/kg VS)
MCF	is the Methane emission coefficient (assume 10 percentage)
d	is the density of Methane (in kg/m^3)
365	is the number of days in a year
10^6	is units conversion factor (kg to Gg)

VS represents the organic fraction of total solids (TS) in the waste that will oxidize and become gaseous at 600°C. Total solids remain after waste has been subjected to a temperature of 103 - 105°C. The methane emission factor B_o is the methane producing capacity giving the quantity of methane produced per kilogram of VS in the manure. It is also known as the methane production potential. The methane emission coefficient (MCF) is the portion of B_o that is realized from each manure management system. MCF ranges from 0 to 1.0. For Tanzania methane emission from different animal types has been estimated for 1990 using the above method and on the basis of the following assumptions:

(i) most cattle are grazed under the pastoral system with the methane conversion factor assumed at 0.1, at the maximum.

(ii) In the case of poultry, the litter and dry lot systems apply. The methane conversion factor of 0.1 has been assumed (2).

(iii) Swine, horses, goats and sheep graze under the pastoral and dry-lot systems. An MCF of 0.1 has been assumed.

(iv) It is estimated that out of the total cattle population, 900,000 cattle are used for draught purposes, working for an average of 5 hours a day.

(v) It is also estimated that out of the total population of donkeys, 250,000 work for an average of 1 hour per day.

The total methane emissions from animal waste management has been estimated to be 7.702 Gg. Recovery of methane as biogas for cooking, lighting, cooling, and engine running is practiced in few areas where the population of livestock is marginal. For this reason, no adjustment was made on total estimates.

Table 10.5: Estimation of Methane emission from animal wastes management

Sector specific data by animal types	Population (thousands)	Waste produced kg/hd/yr	F_{vs}	B_o m³/kg VS	MCF	D kg/m³	Methane emissions (Gg)
	A	B[1]	C	D	E	F	G*
Indigenous cattle	11510.22	547.50	0.13	0.084	0.1	0.66	4.542
Beef cattle	115.80	657.00	0.13	0.084	0.1	0.66	0.055
Dairy cattle	209.76	876.00	0.13	0.084	0,1	0.66	0.132
Oxen	900.00	657.00	0.13	0.084	0.1	0.66	0.355
Goats	8533.70	109.50	0.20	0.120	0.1	0.66	1.480
Sheep	5551.40	109.50	0.20	0.120	0.1	0.66	0.963
Pigs	275.00	219.00	0.14	0.014	0.1	0.66	0.008
Poultry	21617.50	18.25	0.16	0.090	0.1	0.66	0.375
Mules and asses	250.00	120.45	0.29	0.260	0.1	0.66	0.147
Total							**8.057**

Notes: (1) Daily animal waste production rate is multiplied by 365 days a year.
(*) Column G is obtained by multiplying Column A, B, C, D, E, and F, then divided by 10^6.

10.5 Emission of nitrous oxide (N_2O) from mineral fertilizer use

Nitrous oxide (N_2O) is produced naturally in the soils by denitrification, the reduction of nitrate to nitrogen or its oxide, and nitrification, the oxidation of ammonia to nitrate (2). Fertilizers are an additional source of nitrogen and therefore lead to an increase of emission of nitrous oxide from the soil. A number of factors influence nitrous oxide emission from fertilizer use. These factors include natural processes and farm management practices. The former include temperature, porosity, precipitation, soil moisture and soil type, among others. The latter include fertilizer type, crop type, fertilizer application method, timing of use, irrigation and husbandry practices. Tanzania uses an average of 125,023 metric tonnes of fertilizers annually. The types of fertilizer used and the nitrogen percentage per fertilizer type are listed in Table 10.6.

10.5.1 N_2O emissions estimating methodology

Aggregated information on fertilizer and corresponding crop types was not readily available. Thus a simple methodology proposed by IPCC (2) was adopted:-

$$Q_n = \sum \left(\frac{F_f \times E_f \times C_o}{10^3} \right)$$

where

Q_n is the quantity of N_2O emission (Gg)

F is the fertilizer consumption (tonnes N)

E	is the emission coefficient (tonnes N_20-N released/tonne N applied)
f	refers to fertilizer type
C_o	is the molecular weight conversion factor (44/28)
10^3	convert tonnes into kilotonnes (Gg)

Another Methodology, also proposed by IPCC (2), involves the consumption of fertilizers by crop-type, that is:-

$$Q_n = \sum \left(\frac{F_{fc} \; x \; E_{fc} \; x \; C_o}{10^3} \right)$$

where

Q_n	is the quantity of N_2O emission (Gg)
F	is the fertilizer consumption (tonnes N)
E	is the emission coefficient (tonnes N_20-N released/tonne N applied)
f	refers to fertilizer type
c	refers to crop type
C_o	is the molecular weight conversion factor (44/28)
10^3	convert tonnes into kilotonnes (Gg)

The figures for the percentage of nitrogen are as per manufacturers' specifications.

Data on fertilizer application by crop type was not readily available, and as such the first methodology is used in the study. Emission factors used are given in ranges and are borrowed from IPCC (2), that is 1% of nitrogen applied. From the methodology adopted, we estimate N_20 emissions to be as shown on Table 10.6. From the above calculations it is seen that annual N_20 emissions from Tanzania is estimated at 0.567 Gg.

10.6 Non-CO_2 emissions from burning of agricultural crop residues

The burning of crop wastes leads to instantaneous emission of Methane, Carbon Monoxide, Nitrous Oxides and Nitrogen Oxides. The Carbon Dioxide released is considered to be part of a closed cycle, being released and re-absorbed during the next growing season. It will not therefore be considered in the final balance.

In the case of Tanzania, only three crops: cotton, sugarcane and paddy are considered. Although other crops such as maize, sorghum, millet and beans leave behind substantial quantities of residues, the fraction of the residue which is burned is negligible. Residues of these crops are put into other uses like mulching and the making of animal feed. Coffee husks are sometimes mixed with bagasse and combusted together in boilers. Where this happens, account has been taken in the relevant section on emission due to combustion. However, much of coffee waste is used for mulching in coffee plantations.

Paddy straws are normally not burned. They are left in the field for livestock grazing. In this study only rice husks have been considered. All cotton residues are burnt because this is an important husbandry practice. It minimizes the possibility of some destructive pests (eg. American ballworm - *Heliothis armigera*) being carried into the next season. Sugarcane fields are normally set on fire 48 hours before harvesting. Usually about $^1/_5$th of the field is not burned. This area is left for various purposes such as preparation of planting material for the next season. The burning of bagasse is considered elsewhere in this study.

Table 10.6: N_2O emissions estimates from fertilizers using the simplified methodology

Sector specific data by fertilizer type	Amount consumed (kt)	Fraction of Nitrogen in fertilizer	Fraction released as N_2O	Molecular weight conversion	Total N_2O emissions (Gg)
	A	B	C	D	E=AxBxCxD
Ammonia Aqua	6.500	0.25	0.01	1.5714	0.0255
Ammonium Nitrate	1.500	0.34	0.01	1.5714	0.0080
Ammonium Sulphate	29.083	0.21	0.01	1.5714	0.0960
Urea	37.450	0.46	0.01	1.5714	0.2707
NPK 6:20:18	11.297	0.06	0.01	1.5714	0.0107
NPK 25:5:5	3.971	0.25	0.01	1.5714	0.0156
NPK 20:10:10	3.269	0.20	0.01	1.5714	0.0103
Calcium Ammonium Nitrate	31.953	0.26	0.01	1.5714	0.1306
				Total	**0.5673**

Notes: (*) Source of information on quantities and Nitrogen content in fertilizers is Ministry of Agriculture and Livestock development (1) and (3).

Greenhouse gas emissions from the burning of agricultural wastes are estimated on the basis of the amount of carbon burned and the emission ratios of the gases using the equation (2):-

$$T_c = \sum (P_t \times R_t \times B_t \times dm_t \times C_t)$$

where

- T_c is the total Carbon emissions (kt C)
- P is crop production (kilotonnes)
- R is the residue/crop ratio
- B is the fraction of residue burned
- dm is the fraction of dry matter in burned residue
- C is carbon content (kt C/kt dm)
- t refers to crop type

Calculations of non-CO_2 emissions are provided in Tables 10.7 to 10.11.

In respect of cotton and sugarcane the following assumptions are made:-

(i) The average productivity of cotton in the eastern cotton growing area (ECGA) is 450 kg/ha. Based on the recommended 90 cm x 30 cm spacing and on a 0.6 kg/plant weight (on dry basis) the ratio of residue/crop product has been estimated to be 50.

(ii) Each sugarcane plant contains approximately 0.5 kg of green and dry leaves adding up to 2.4 tonnes residue per hectare. The total area under cultivation is about 23,000 ha and normally about $^1/_5$th of the total area is not burnt. The area harvested annually is therefore of the order of 18,400 hectares giving a total residue amount of 44,160 tonnes.

Table 10.7: Parameters necessary in estimation of carbon release from agricultural residues

Sector specific data by residue type	Annual crop yield (kt)	Residue: crop ratio	Fraction of burned residues	Fraction dry matter	Fraction Carbon kt C/kt dm
	A	B	C	D	E
Cereal - Rice husks	761.80	0.26	0.56	0.967	0.30
Sugar cane - leaves	289.16	0.15	1.00	0.843	0.41
Others - Cotton residues	216.95	50.00	1.00	0.879	0.36

Source: (1)

Using the above relationship and the statistics in Table 10.7, the amount of carbon burned for rice husks is 32 kt dm, for cotton 3,433 kt dm, and for sugar cane leaves 15 kt dm, as shown in Table 10.8.

Table 10.8: Estimation of amount of residue burned and released carbon and nitrogen

Sector specific data by residue type	Amount of residues burned (kt dm)	Amount of carbon released (kt C)	Nitrogen: Carbon ratio	Amount of Nitrogen released (kt N)
	F=AxBxCxD	G=ExF	H	I=GxH
Cereal - Rice husks	107.258	32.177	0.015	0.4827
Sugar cane - leaves	36.564	14.991	0.015	0.2249
Others - Cotton residues	9534.953	3432.583	0.015	51.4887
Total	**9678.775**	**3479.751**		**52.1963**

To calculate emissions of CH_4 and CO, emission ratios have been established by local experts, specifically for Tanzania are used (4). These emission ratios are shown in Table 10.9.

Table 10.9: Selected country and default emission ratios based on carbon and nitrogen release

Sector specific data by residue type	Methane	Nitrogen oxides	Nitrous Oxide	Carbon Monoxide
	J	K	L	M
Cereal - Rice husks	0.01	0.094	0.005	0.14
Sugar cane - leaves	0.11	0.148	0.009	0.05
Others - Cotton residues	0.07	0.121	0.007	0.13

In order to calculate emissions of nitrous oxide and nitrogen oxides due to the burning of the three crops, an N/C ratio of 0.015 due to Crutzen and Andreae (2) has been used. Furthermore emission ratios used for the calculations are also due to Crutzen and Andreae modified according to the crop type within the given ranges (2).

Table 10.10: Default molecular weight conversion factors (in fractions)

$CH_4:CO_2$-C	$NO_x:N_2$-N	$N_2O:N_2$-N	$CO:CO_2$-C
N	O	P	Q
1.3333	3.2857	1.5714	**2.3333**

Source: (2)

The non-CO_2 greenhouse gas emissions due to the burning of agricultural residues are as summarized in Table 10.11.

Table 10.11: Non-CO_2 greenhouse gas emission due to burning of agricultural residues in 1990

Sector specific data by residue type	Methane (Gg)	Nitrogen oxides (Gg)	Nitrous oxide (Gg)	Carbon monoxide (Gg)
	R=GxJxN	S=IxKxO	T=IxLxP	U=GxMxQ
Cereal - Rice husks	0.429	0.149	0.004	10.511
Sugar cane - leaves	2.199	0.109	0.003	1.749
Others - Cotton residues	320.374	20.470	0.566	1041.217
Total	**323.002**	**20.728**	**0.573**	**1053.477**

10.7 Methane emission from managed wildlife in Tanzania in 1990

The IPCC (2) guidelines consider wildlife management as a natural activity. For curiosity, the Tanzanian greenhouse gas inventory team studied this sector for the following reason. Tanzania's wildlife is described as unique in abundance and variety. A quarter of Tanzania is devoted to national parks, game reserves, and 'no shooting' areas. Tanzania does possess some of the finest game reserves in the world, with almost every species of African game (6).

Tanzania has 13 national parks which include the world famous Ngorogoro Conservation Area, Serengeti, Lake Manyara, and Tarangire, among others, covering an area of 10.27 million hectares. There are 16 game reserves covering on area of 13.41 million hectares, with the famous Selous Wildlife Reserve in Southern Tanzania being the largest, covering on area of 5.50 million hectares.

Wild animals, especially the ruminant type do produce methane. A large percentage of these animals in Tanzania are in protected game parks and game reserves. Although no agreement has as yet been reached as to whether or not to include these emissions in national inventories (2), it has been found expedient to estimate emissions from this natural managed source in order to assess its significance compared with domesticated animals. Besides, since national parks and reserves are managed, data is available on the population of different animals.

Unlike domestic animals, it has not been easy to obtain all the necessary feed and other characteristics for detailed calculations of methane emission. The following simplified approach has been used:-

(i) estimation of the percentage of feed energy that is converted to methane by animal type;

(ii) estimation of the total feed energy intake by animal;

(iii) multiplication of the conversion factor by the feed intake.

The following assumptions are made as the basis for the estimates:

(i) the activity factor used is 1.5. This is the factor applied to domestic animals grazing over very large areas (2).

(ii) 7.5% of feed energy is converted to methane, Y_m.

(iii) The digestibility of the feed, DE, is 50%.

(iv) for simplicity, only energy requirement for maintenance was considered.

Based on the above assumptions the following equations were used to obtain the methane emissions by animal species (2):

$$E_m = 0.322\ W^{0.75}\ x\ A_F$$

where

E_m is the net energy requirement for body maintenance (MJ/day)
W is the average animal weight (in kg)
A_F is the activity factor (i.e 1.5)

$$L_I = 0.298 + 0.00335\ x\ DE\%$$

where

L_I is the ratio of gross energy requirement to feed digestibility
DE% is the digestibility (in percentage), that is 50 for this case

$$E_{intake} = \frac{\left(\frac{E_m}{L_1}\right)}{DE}$$

where

E_{intake} is the gross energy intake per animal type (MJ/day)
DE is the digestibility (in fraction), that is 0.50 for this case

$$ME = \frac{E_{intake}\ x\ Y_m\ x\ 365}{55.65}$$

where

ME is methane emissions per each type of wildlife animals (kg)
Y_m is the methane conversion rate in decimal form, 0.075 was assumed;
55.65 is the conversion factor from energy to methane (in MJ/kg).

$$T_m = \sum (ME_o \times P_o \times 10^{-6})$$

where

T_m is total methane emissions due to managed wildlife animals (Gg)
P_o is the population of each type of managed wildlife animals

Table 10.12 gives the estimates of methane emissions from different animal types in 1990 using the formulas, above. The total emissions of methane from wildlife in Tanzania is about 425.6 Gg.

10.8 Non-CO_2 greenhouse gas emissions due to Savanna burning

Savanna refers to tropical formations or open forests or cleared Miombo forests with a continuous grass cover, occasionally interrupted by trees and shrubs (2). Most of vegetation growth occurs during wet season; and man-made fires frequently occur during the dry season resulting in nutrient re-cycling and vegetation re-growth. Savanna in Tanzania covers an estimated 16.0 million hectares (Mha), of which 65 percent is humid savanna (i.e annual rainfall is 800 mm or more) and 35 percent is arid savanna (i.e annual rainfall of less 800 mm)(9, 10).

Savanna burning is practiced in Tanzania primarily for weed and pest control, honey collection and hunting. Sometimes fires are accidentally set by pedestrians, or purposely to prepare for new green pastures for animal grazing. Different areas of Savanna in Tanzania burn at least once in four years. Woody vegetation in savanna is generally resistant to bush fires (11).

This study attempts to establish annual instantaneous release of non-CO_2 gases due to savanna burning based on biomass density of the savanna aboveground biomass, and the area burned annually. It is assumed that CO_2 is recycled as part of the natural cycle. However, non-CO_2 emissions can only be estimated once the instantaneous release of CO_2 is known. Accurate data on the extent of savanna burning is non-existent. The burning frequency is a mere estimate. A number of assumptions have been made to arrive at reasonable estimates of emissions from savanna burning:-

(i) About 32 percent of the savannas is burned annually. Of the area subjected to savanna burning, 65 percent is humid savanna, and 35 percent is arid savanna. The humid savanna is frequented more by herders, pastoralist and by agriculturists.

(ii) Above ground biomass density (i.e only grass and litter) is estimated at 6.6 tonnes dm/ha/yr and at 4.5 tonnes dm/ha/yr for humid savanna and arid savanna, respectively (2).

(iii) The fraction of aboveground biomass actually burned is estimated at 85 percent for humid savanna, and 90 percent for arid savanna. The fraction of above ground biomass that is living is estimated at 85 percent for humid savanna, and 65 percent for arid savanna (2).

(iv) Fraction of aboveground biomass oxidized, expressed as combustion efficiency is estimated at 0.8 for living aboveground biomass and 0.99 for dead aboveground biomass.

(v) Nitrogen/Carbon ratio of the fuel is estimated at 0.006 (2).

(vi) Carbon content of the living biomass is estimated at 0.40 kt C/kt dm and for dead aboveground biomass at 0.45 kt C/kt dm.

(vii) Emission ratio for trace gas emissions are 0.004 for CH_4-C/CO_2-C, 0.06 for CO-C/CO_2-C, 0.007 for N_2O-N/N_2-N, and 0.121 for NO_x-N/N_2O-N; (2)

(viii) Conversion factors of carbon and nitrogen into carbon dioxide, methane, carbon monoxide, nitrous oxide, and nitrogen oxides are 44/12; 16/12; 28/12; 44/28; and 46/14 respectively (2).

The following equations summarize the calculations to estimate the total carbon and nitrogen released due to the burning of savannas:-

$$AF = A_T \times F_b \times B_d \times F_a$$

where

- AF is activity factor (kt dm);
- A_T is total area of savannas (kha);
- F_b is the fraction of savannas burned annually;
- B_d is the aboveground biomass density (t/ha/yr);
- F_a is the fraction of aboveground biomass actually burned.

$$EF = C_E \times C_c$$

where

- EF is emission factor (in kt C/kt dm);
- C_E is combustion efficiency of oxidized biomass (fraction);
- C_c is carbon content of oxidized biomass (kt C/kt dm)

$$C_T = \sum AF_{(h,a)} \times EF_{(l,d)}$$

where

- C_T is total carbon released due to savanna burning (kt CO_2-C);
- h,a refers to aggregation of savannas by humid and arid types, respectively;
- l,d refers to aggregation of aboveground biomass by live and dead, respectively.

$$N_T = C_T \times \frac{N}{C}$$

where

- N_T is total nitrogen released due to savanna burning (kt N_2-N)
- N/C is nitrogen:carbon ratio

Table 10.12: Estimation of methane emissions due to wildlife in 1990

Sector specific data by animal type	P_o Animal population ('000 hd)	W Animal weight (kg)	E_m Energy for maintenance (MJ/hd/day)	E_{intake} Gross energy (MJ/hd/day)	ME Emission factor (kg/hd/yr)	T_m Methane emissions (Gg)
Non-ruminant						
Elephant	100.0	7000	369.633	1562.930	768.827	76.88
Zebra	700.0	600	58.555	247.588	121.792	85.25
Ruminant						
Hippo	150.0	1500	116.417	492.249	242.144	36.32
Wildebeest	2000.0	200	25.687	108.615	53.429	106.90
Buffalo	400.0	800	72.655	307.209	151.120	60.45
Giraffe	20.0	1200	98.477	416.392	204.829	4.10
Impala	200.0	60	10.413	44.028	21.658	4.33
Eland	80.0	1000	85.891	363.175	178.651	14.29
Kudu	80.0	200	25.687	108.615	53.429	4.27
Hartebeest	120.0	160	21.729	91.877	45.195	5.42
Gazelle	250.0	30	6.191	26.179	12.878	3.22
Sable	30.0	250	30.367	128.402	63.429	1.90
Roan	25.0	270	32.171	136.031	66.916	1.67
Orys	0.8	200	25.687	108.615	53.429	0.04
					Total	**405.00**

Sources: (2, 5, 6)

Notes: L_1 = 0.473 DE = 50% A_F = 1.5

Based on the above assumptions (columns A and B of Table 10.13), of the 5,120 kha burned annually (column C of Table 10.13), 3,328 kha is humid savanna, and the rest 1,792 kha is arid savanna. The product of these figure and their corresponding aboveground biomass densities i.e 6.6 t dm/ha and 4.5 t dm/ha for humid and arid savannas respectively, and the fraction of biomass actually burned, gives the total annual aboveground biomass subjected to burning at 25,928 kt dm (column F of Table 10.13).

The quantities estimated to be burned are multiplied by the corresponding fractions of burned biomass considered to be living i.e 0.85 for humid savanna and 0.65 for arid savanna, to obtain 15,870 kt dm, and 4,717 kt dm respectively. The results are subtracted from the total amount burned to obtain the amount of burned dead biomass i.e 2,800 kt dm, and 2,540 kt dm for humid and arid savanna respectively. These figures are multiplied by the burning efficiency factors estimated to be 0.8 for living biomass and 0.99 for dead biomass, to obtain 15,469 kt dm and 6,289 kt dm for humid and arid savanna respectively. The results are further multiplied by the fraction carbon content estimated at 0.40 of living biomass and 0.45 of dead biomass, to obtain the carbon released from savanna burning, i.e 6,326 kt CO_2-C for humid, and 2,641 kt CO_2-C for arid savanna. The total carbon, which is estimated at 8,967 kt CO_2-C (column J of Table 10.14), is multiplied by the nitrogen/carbon ratio i.e 0.006, to obtain 54 kt N_2-N (column K of Table 10.14). Columns J and K of Table 10.15 are multiplied by appropriate factor and conversion coefficient in Table 10.15. The estimates of non-CO_2 greenhouse gas emissions, as summarized in Table 10.16.

Table 10.13: Estimation of aboveground (savanna) biomass burned in 1990

Sector specific data by savanna types	(h,a) humid, arid savanna (fraction)	F_b Fraction of savanna burned	A_b Savanna area burned annually (kha)	B_d Aboveground biomass density (t dm/ha)	F_o Portion actually burned	$(AT)_{h,a}$ Aboveground biomass burned (kt dm)
	A	B	C=AxBxTa*	D	E	F=CxDxE
Humid savanna	0.65	0.32	3328	6.6	0.85	18670.08
Arid savanna	0.35	0.32	1792	4.5	0.90	7257.60
Total	**1.00**		**5120**			**25927.68**

Notes: Ta* is the total savanna area in Tanzania, estimated at 16,000 kha.

Table 10.14: Estimation of total carbon and nitrogen released due to savanna burning

Sector specific data by savanna types and nature of burned biomass		(l,d) Fraction of biomass which is live, dead	C_E Combustion efficiency (in fraction)	C_c Carbon fraction in biomass (kt C/kt dm)	C_T Total Carbon released (kt C)	N_T Total Nitrogen released (kt N)
		G	H	I	J=FxGxHxI	$K=JxC_r^*$
Humid	Live biomass	0.85	0.80	0.40	5078.262	30.470
	Dead biomass	0.15	0.99	0.45	1247.628	7.486
Arid	Live biomass	0.65	0.80	0.40	1509.581	9.057
	Dead biomass	0.35	0.99	0.45	1131.641	6.790
Total					**8967.112**	**53.803**

Notes: (*) C_r is the nitrogen:carbon ratio estimated at 0.006

Table 10.15: Emission ratios and molecular weight conversion coefficients

	Non-CO_2 greenhouse gas emission factors		
Methane	Nitrogen Oxides	Nitrous Oxide	Carbon Monoxide
L	M	N	O
0.004	0.121	0.007	0.06
	Molecular weight conversion coefficients		
P	Q	R	S
1.3333	3.8333	1.5714	2.3333

Source: (2)

Table 10.16: Non-CO_2 greenhouse gas emissions due to savanna burning in 1990 (Gg)

Sector specific data by Savanna types and nature of burned		CH_4	NO_x	N_2O	CO
		T=JxLxP	U=KxMxQ	V=KxNxR	W=JxOxS
Humid Savannas	Live biomass	27.083	14.133	0.335	710.947
	Dead biomass	6.654	3.472	0.082	174.665
Arid Savannas	Live biomass	8.051	4.201	0.010	211.338
	Dead biomass	6.035	3.149	0.075	158.427
	Total	**47.825**	**21.390**	**0.592**	**1255.396**

Table 10.17: Summary of greenhouse gas emissions from agriculture in 1990 (in Gg)

Sector specific data by source	Methane	Nitrogen oxides	Nitrous oxide	Carbon Monoxide
Rice cultivation	84.756	n.a	n.a	n.a
Enteric fermentation	872.275	n.a	n.a	n.a
Animal waste management	8.057	n.a	n.a	n.a
Nitrogenous fertilizers	n.a	n.a	0.567	n.a
Burning of agricultural residues	323.002	20.470	0.573	1053.460
Savanna burning	47.825	21.390	0.592	1255.396
Total	**1335.915**	**41.860**	**1.732**	**2308.856**

10.9 Discussion

Table 10.17 gives the overall greenhouse gas emissions from the agriculture sector. Because of unique in abudance and variety of wild animal species in Tanzania, attempts to estimate methane emissions from wildlife has been considered. However, these estimates do not form part of the final reporting. For this sector enteric fermentation is the significant source of methane emissions.

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11.0 GREENHOUSE GAS EMISSIONS FROM LAND-USE CHANGE AND FORESTRY

11.1 Introduction

Changes in land-use often result in changes in the quantity of biomass on the land and produce a net change of greenhouse gases. Since biomass is about 45 percent carbon by weight, forest clearing leads to the release of carbon dioxide to the atmosphere. Clearing by burning also leads to instantaneous release of not only carbon dioxide but also methane, carbon monoxide, nitrous oxide and nitrogen oxides. In the case of carbon dioxide however, we are concerned with the net releases since regrowth of vegetation leads to uptake of carbon dioxide.

Soil disturbance also leads to greenhouse gases emission. Forest conversion into pasture or cropland results in release of soil carbon through oxidation of organic matter contained in the soil. Soils are also a natural sinks of methane, nitrous oxide and carbon by bio-fixation process. Fresh water wetlands are a natural source of methane. Destruction of freshwater wetlands by drainage or filling increases methane and carbon dioxide emissions by oxidation of soil organic matter (1). In estimating greenhouse gases from land-use changes, activities which contribute to these emissions are divided into several categories, including (1):-

(i) Forest clearing for permanent cropland or pasture .
(ii) Conversion of grassland to cultivated lands.
(iii) Abandonment of managed land.
(iv) Forests subject to human activity.
(v) Shifting cultivation.
(vi) Forest degradation due to air pollution.
(vii) Flooding of lands.

Before we embark on estimating the greenhouse gas emissions, we examine the type and distribution of vegetation and land use patterns and changes in Tanzania. In so doing, however, we are mindful of the problems related to the scarcity, quality and reliability of data in this sector. No continuous data of land use changes has been kept over time. Estimates have had to be made from a number of sources and vegetation as well as land use maps. The legends as well as classifications have changed over time and are subject to different interpretations. We have, however, endeavoured to present as much information as we could obtain. To assist the study team in this endeavour, a researcher was commissioned to put together in a consistent framework and to the extent possible, the information on land use since 1947 (11). This information, together with that gathered from literature, forms the basis of Tables 11.1 to 11.9.

11.2 Land-use patterns and changes in Tanzania

Tanzania has a total area of 94.5 million hectares, out of which some 44.37 million hectares (47%) are estimated to be potentially arable (3). The average population density in the country is still relatively low, at 25.4 inhabitants per square kilometre (km^2). In less fertile lands vast areas are still uninhabited. In the heavily populated areas soil fertility and water resources are under pressure. Sectors of importance to land-use in Tanzania are agriculture and livestock development. The overall regional distribution of cattle rearing in Tanzania is largely determined by the tse-tse fly infestation. The areas with a high cattle population claim a large share of the land classified as "grazing land". These are also the areas with high human population densities. Land use patterns and changes in mainland Tanzania, shown in Table 11.1 are based on the study of atlas maps and the Landsat MSS data (2, 11, 14).

Based on this information, projections have been made on land-use changes as a function of time, population, climate change, land tenure policies, by-laws, and other factors. An understanding of vegetation cover dynamics and change matrices between 1947 and 1990 is necessary in estimating greenhouse gas emissions from land-use changes in Tanzania. Attempts have been made to aggregate possible transformations of vegetation classes as a first order estimate, opening an avenue for further research in this important field.

Table 11.1: Land-use patterns and changes in Tanzania

Major land-use types	Area in 1982 (mill. ha)	Area in 1990 (mill. ha)	Change (%)
Water catchment protection	1.0	0.9	-10.0
Forestry and woodland exploitation	37.2	37.3	+ 0.3
Cultivation (small/large scale)	4.6	5.4	+17.4
Rough grazing (induced vegetation)	44.2	43.1	- 2.5
Roads, rivers and urban settlements	1.5	1.9	+26.7
Fishing, hydropower and navigation	6.0	5.9	- 1.7
Total	94.5	94.5	

Sources: (2, 14)

11.3 Vegetation distribution and change in Tanzania

Tanzania comprises of a wide range of vegetation types, including closed forests, mangroves, many types of woodlands, grasslands, swamps and bogs, cultivated lands and active induced vegetation, and areas of semi-desert. Closed canopy forests occur in very restricted areas and are mostly limited to uplands and coastal lowlands. However, the most common types of vegetation are miombo woodlands and related wooded grasslands. The areas covered by each of vegetation class have been summarized in Table 11.2. However, it is important to note that estimates of vegetation areas are based on limited inventories.

Table 11.2: Vegetation distribution in Tanzania (kha)

Vegetation class types / Year	1947	1956	1976	1990
Tropical Closed Forests	7727[1]	1885	1455	1100[2]
Mangrove Forests	93	80	80	80
Woodlands (wet, seasonal, dry)	35392	38706	26702	25616
Wooded Grasslands (Savanna)	19746	20037	14205	16662
Bushland/Thickets	9481	10551	9878	7464
Thickets	772	569	727	784
Grasslands	6049	4011	4770	6295
Desert/Semi Desert	867	460	491	163[3]
Cultivated/Abandoned Lands/Settlement	8407	12227	28481[4]	28215
Swamps, Bogs and Water Bodies	5975	5983	7720[5]	8130
Total	94509	94509	94509	94509

Source: (11)

Note: (1) Desert, semi desert, and bare lands decrease soon after the rainy season and increase during prolonged dry seasons. Depending on the season when the area maps were annotated, this category seems to decline with time but in strict sense the so called desert or semi desert may have remained the same or increased rather.

(2) From 1947 to 1956 forests were cleared with the aim of establishing cash crop plantations, and tse-tse fly eradication.

(3) Closed broadleaf forest has been reduced at the rate of 2000 ha per annum between 1976 and 1990 (12).

(4) Agrarian reforms including the policy of 'Ujamaa Villages' and specific campaigns such as "Agriculture for Survival" from 1973 to 1976, and the abandoned large-scale managed lands such as cashewnut and sisal estates increased land area under rural settlement and fallow.

(5) A portion of grasslands and agricultural lands has been converted to irrigation such as in the Usangu basin where rice cultivation is undertaken.

Table 11.3: Land area covered by various forest types during the period of 1956 - 1976

Sector specific data by forest types		1956 (kha)	1976 (kha)	Change (%)
Tropical Closed Forests	Broadleaf	1486	1055	-29.0
	Conifer (plantation forest)	79	80	+1.3
	Unproductive	320	320	0.0
Tropical Open Forests	Miombo Woodlands	38706	26702	-31.0
Other Forests	Mangrove	80	80	0.0
	Bushland Thickets	11120	10605	-4.6
	Total	51791	38842	-25.0

Source: (4, 11, 14)

Table 11.4: Land area covered by various forest types during the period of 1976 - 1990

Sector specific data by forest types		1976 (kha)	1990 (kha)	Change (%)
Tropical Closed Forests	Broadleaf	1055	823	-22.0
	Conifer (plantation forest)	80	80	+0.0
	Unproductive	320	307	-4.1
Tropical Open Forests	Miombo Woodlands	26702	25616	-4.1
Other Forests	Mangrove	80	80	0.0
	Bushland Thickets	10605	8248	-22.2
	Total	38842	35154	-9.5

Source: (4, 11, 14)

Note: (1) Acreage differences between 1976 and 1990 in Table 11.4 don't mean anything other than the total changes of typical forest land to other types of land uses, including other forms of forests.

(2) To rescue mangrove forest from overexploitation of 93.24 kha (in 1947) for salt pan making, charcoal production, construction pole yield, and fuelwood production for fish smoking, the Government had intervened by gazetting mangrove forests under forest reserves. This increased the acreage from 79.77 kha (in 1956) to 79.90 kha (in 1990).

Table 11.5: Land area covered by reserved forests during the period of 1947 - 1990

Sector specific data by forest management type	1947 (kha)	1956 (kha)	1972 (kha)	1990 (kha)
Productive forests	1059	5726	10535	11025
Protective forests	151	999	1570	3184
Total	1210	6725	12105	14209

Sources: (11, 14)

Vegetation class to class changes being reported in Tables 11.6 and 11.7 highlight the complexity of dynamics involved. Clearing of forests is only one of the types of changes involved in a complex process of land-use. It is important to consider all possible explanations for these land-use changes. Estimates of class-to-class changes are read from each row. For example, the following information on changes in tropical closed forests between 1976 and 1990 can be obtained by examining the "Tropical Closed Forest (TF)" row of Table 11.7.

Thus, during the period of 1976 through 1990, 24.4 percent of original tropical closed forest cover was transferred to other classes as follows:-

(i) 115 kilo-hectares (kha) were converted to permanent agricultural land and pasture. This was more likely a result of population pressure rather than planned land-use change;

(ii) 38 kha were converted to secondary forest; that is thickets (8 kha) and bushland/thickets (30 kha); and

(iii) 202 kha converted to wooded grassland or fragmented forest which in turn changed to other land cover as an intermediate stage towards permanent agriculture and pasture.

Likewise, other land-use changes can be analysed from Table 11.6 and Table 11.7.

11.3.1 Forest cover and changes in Tanzania

Before we deal with specific land-use activities and their greenhouse emissions/uptake potential, we examine further the forestry sector of Tanzania. Penetration into forest reserves for logging often opens up avenues for subsequent invasion by permanent inhabitants, who take over closed canopy forests, and miombo woodland. These two forest ecosystems are at most risk, and declining rapidly. The distribution of forests in the country is as shown in Tables 11.2 to 11.7.

Forest reserves or "gazetted" forests include "productive", "unproductive" and "protective" forests and land area under national parks and game reserves. "Productive" forest areas are those whose terrain and soil conditions are suitable for production of wood and other forestry products on a sustainable basis. "Unproductive" forest areas are located on terrain too steep or rough or subject to periodic or permanent incantation which makes forestry management impractical. "Protective" forest areas have been created to protect water catchments, valuable ecosystems and rare species. Unreserved forests in public lands are the most affected forest types by human activities. Table 11.5 shows the changes in reserved forests from 1947 to 1990.

Estimations of vegetation changes as a result of land use changes during 1956-1976 and 1976-1990 are provided in Tables 11.6 and 11.7, respectively.

Table 11.6: Vegetation cover change as a result of land use changes during the period of 1956 - 1976

Vegetation Cover Classes in 1976	Vegetation cover class to class changes (kha)										Vegetation cover in 1956	
	TF	MG	WL	WG	BT	TK	GL	DS	AS	SW	(kha)	(%)
Tropical Closed Forest (TF)	**1455**	0	35	0	63	108	0	0	224	0	1885	2.0
Mangrove (MG)	0	**80**	0	0	0	0	0	0	0	0	80	0.1
Woodlands (WL)	0	0	**26667**	7834	0	0	0	0	4203	0	38706	40.9
Wooded Grasslands (WG)	0	0	0	**6371**	0	0	0	0	13666	0	20037	21.2
Bushland/Thickets (BT)	0	0	0	0	**9779**	30	0	0	742	0	10551	11.2
Thickets (TK)	0	0	0	0	36	**533**	0	0	0	0	569	0.6
Grasslands (GL)	0	0	0	0	0	0	**2963**	148	900	0	4011	4.2
Desert/Arid/Semi-arid (DS)	0	0	0	0	0	0	0	**343**	0	117	460	0.5
Arable/Settlements (AS)	0	0	0	0	0	56	1807	0	**8744**	1620	12227	12.9
Swamps/Water Bodies (SW)	0	0	0	0	0	0	0	0	0	**5983**	5983	6.4
Vegetation cover in 1976	1455	80	26702	14205	9878	727	4770	491	28481	7720	**94509**	100.0
Percentage	1.5	0.1	28.3	15.0	10.5	0.8	5.0	0.5	30.1	8.2	100.0	

Notes:
1. Zero means less than 1000 ha. or insignificant changes.
2. Rows provide vegetation cover lost by one class to other classes.
3. Columns provide vegetation cover gained by one class from other classes.
4. Diagonal bold numbers indicate the original vegetation cover which remained unchanged.

Table 11.7: Vegetation cover change as a result of land use changes during the period of 1976 - 1990

Vegetation Cover Classes in 1990	Vegetation Cover Class to Class Changes (kha)										Vegetation Cover in 1976	
	TF	MG	WL	WG	BT	TK	GL	DS	AS	SW	(kha)	(%)
Tropical Closed Forest (TF)	**1100**	0	0	202	30	8	0	0	115	0	1455	1.5
Mangrove (MG)	0	**80**	0	0	0	0	0	0	0	0	80	0.1
Woodlands (WL)	0	0	**25076**	823	319	0	159	0	325	0	26702	28.3
Wooded Grasslands (WG)	0	0	0	**12538**	204	0	1085	0	343	35	14205	15.0
Bushland/Thickets (BT)	0	0	0	2586	**6683**	22	335	0	252	0	9878	10.5
Thickets (TK)	0	0	0	0	200	**525**	2	0	0	0	727	0.8
Grasslands (GL)	0	0	0	236	0	131	**1593**	0	2387	423	4770	5.0
Desert/Semi Desert (DS)	0	0	0	0	0	0	39	**45**	79	328	491	0.5
Arable/Settlements (AS)	0	0	540	272	28	98	3082	18	**24440**	3	28481	30.1
Swamps/Water Bodies (SW)	0	0	0	5	0	0	0	100	274	**7341**	7720	8.2
Vegetation cover in 1990	1100	80	25616	16662	7464	784	6295	163	28215	8130	**94509**	100.0
Percentage	1.2	0.1	27.1	17.6	7.9	0.8	6.7	0.2	29.9	8.6	100.0	

Notes:
1. Zero means less than 1000 ha or insignificant changes.
2. Rows provide vegetation cover lost by one class to other classes.
3. Columns provide vegetation cover gained by one class from other classes.
4. Diagonal bold numbers indicate the original vegetation cover which remained unchanged.

Table 11.8: Comparison of agricultural land-use pattern in 1982 and 1990

Sector specific data by land-use	Area in 1982 (kha)	Area in 1990 (kha)	**Change (%)**
Subsistence farming	3047	4186	+ 37.4
Large scale plantations	1151	1020	- 11.4
Area under short fallow[1]	402	922	+129.4
Area under long fallow[2]	22116	20453	- 7.5
Total	26716	26581	- 0.5

Sources: (11, 14)

Note: (1) Area under short fallow supports shifting cultivation. This area increased by about one and half times between 1982 and 1990. This increase is the result of a reduction in areas under long fallow.

(2) Long fallow areas are also partial pasture lands in some places. Ordinarily, they regain to at least 75 percent of original aboveground biomass cover in 25 years. However, because some of these areas are subjected to other land uses, regrowth is less.

11.4 Forests clearing for permanent cropland and pasture

Conversion of forests to permanent croplands or pasture is a practice prevalent in public lands in unreserved forests although at times encroachment of reserved forests has been occurring. The changes in land area under agriculture are shown in Table 11.8 above. It is estimated that 88.6 kha of forest area was converted to permanent cropland and pasture in 1990 as shown in Table 11.9 (11). This estimate (that is 88.6 kha) is implicit in Table 11.7 in particular, when you look at vegetation cover change from tropical forest (TF), woodlands (WL), wooded grasslands (WG), bushlands and thickets (BT) to arable and settlements (AS). However, the total change arrived at this way makes reference to arable land and settlements over 15 years. Okello (11) estimated the 10-year forest conversion to permanent agriculture and pasture to be comprised of 58.9 kha of broadleaf closed forest, 594.8 kha of miombo woodlands, and 232.4 kha of bushland/thickets. In order to arrive at reasonable estimates of sources and sinks of greenhouse gas emissions, a number of assumptions have been made. These assumptions are:-

a) Conifer forests are not susceptible to conversion to agricultural land. Thus, 88 percent of clearing occurs in broadleaf logged forests, and the remaining 12 percent in unproductive closed forests. In the case of open forests 78 percent of clearing occurs in productive forests with the remaining 22 percent in unproductive forests.

b) Not all cleared aboveground biomass is burned. About 75 percent of total cleared biomass is collected as woodfuel. Approximately 20 percent of aboveground biomass is burned in fields (where 10 percent of the burned carbon remains on the ground as charcoal), and the remaining cleared biomass (5 percent of aboveground biomass such as foliage, twigs and humus) decays in fields over an average of 10 years releasing one-tenth of its carbon content on dry weight basis annually (1).

c) Aboveground dry matter densities in tropical forests before clearing are 202 tonnes of dry matter per hectare (t dm/ha), 59.46 t dm/ha, and 185 t dm/ha for undisturbed, logged, and unproductive broadleaf closed forests, respectively; 130 t dm/ha, 60 t dm/ha, and 110 t dm/ha for undisturbed, logged, and unproductive conifer closed forests, respectively (16), while in open and other forests aboveground biomass densities are 32 t dm/ha and 12 t dm/ha for productive and unproductive forests, respectively (14).

d) After clearing and conversion of forest to permanent cultivated land aboveground dry matter densities in tropical forests depend on whether the cleared land has been turned into cropland or pasture. Openshaw (14) has estimated densities of 18 t dm/ha for agricultural crops in closed forest, 10 t dm/ha in open forests, and 4 t dm/ha for pastures and crops in cleared miombo woodlands.

e) Emission ratios used in biomass burning calculations are a result of extensive work done by other researchers elsewhere (1).

Table 11.9: Total biomass lost during forest clearing for permanent agriculture (1990)

Sector specific data by forest type				Area cleared in 1990	Biomass Before Clearing	Biomass after Clearing	Net Change in Biomass	Annual loss of Biomass
				(kha)	(t dm/ha)			(kt dm)
				A	B	C	D=B-C	E=AxD
Tropical	Closed forests	Broadleaf forests	Logged	5.19	59	18	41	212.79
			Unproductive	0.71	185	18	167	118.57
			Sub-total	**5.90**				**331.36**
	Open forests	Miombo Woodlands	Productive	46.41	32	10	22	1021.02
			Unproductive	13.09	12	10	2	26.18
			Sub-total	**59.50**				**1047.20**
Others	Open woodlands	Bushlands and Thickets	Productive	18.10	32	4	28	506.80
			Unproductive	5.10	10	4	6	30.60
			Sub-total	**23.20**				**537.40**
			Total	**88.60**				**1915.96**

Note: (1) Area cleared in 1990 (column A of Table 11.9) is a 10-year average estimate (11).

Emissions from forest clearing for permanent agricultural land are estimated in Tables 11.10 and 11.11, and described as follows:-

(i) The area of forest converted into agricultural land by type of forest in 1990 is estimated at 5.9 kha of tropical closed forests (Broadleaf), 59.5 kha of miombo woodland, and 23.2 kha of bushland and thickets (see Table 11.9)).

(ii) These figures (column A) are then multiplied by the difference in biomass densities before and after clearing of corresponding biomass types (column D) to obtain the annual loss of biomass (column E of Table 11.9).

(iii) 20 percent of annual loss of biomass (column H of Table 11.10) is burned on-site, oxidizing 90 percent of on-site biomass, (column J of Table 11.10).

(iv) Multiplying column J by carbon fraction of aboveground biomass as fuel (default value is 0.45) the quantity of carbon released as carbon is estimated to be 155.19 kt C (column L of Table 11.11).

Based on the quantity of CO_2 released from on-site burning of aboveground biomass, trace gases which are released instantaneously on-site are estimated from Table 11.12 as follows:-

(i) The nitrogen/carbon ratio used is 0.01. Multiplying the quantity of carbon released by burning aboveground biomass on-site (column L of Table 11.11) by 0.01, the total nitrogen released instantaneously to atmosphere is estimated to be 1.55 kt N.

(ii) For the open burning of cleared aboveground biomass, the methane/carbon and carbon monoxide/carbon ratios used are 0.012 and 0.075 respectively (1). Likewise, the nitrous oxide/nitrogen and NO_x/nitrogen ratios used are 0.007 and 0.121 respectively (1).

(iii) Multiplying these ratios (columns O to R of Table 11.12) by quantities of carbon (column L of Table 11.11) and nitrogen (column N of Table 11.11) released instantaneously on-site respectively, the results are multiplied by the corresponding molecular weight conversion factors (columns O to R of Table 11.12) to obtain the quantities of trace gas emissions (columns S to V of Table 11.12) in gigagram (Gg).

Table 11.10: Biomass oxidised on-site during forest clearing for permanent agriculture (1990)

Sector specific data by forest type				Biomass burned Off-site (kt dm)	Biomass decaying On-site (kt dm)	Biomass burned On-site (kt dm)	Fraction Oxidised On-site	Biomass oxidised On-site (kt dm)
				F=0.75xE[1]	G=0.05xE	H=0.20xE	I	J=HxI
Tropical	Closed forests	Broadleaf forests	Logged	159.59	10.64	42.56	0.9	38.30
			Unproductive	88.93	5.92	23.71	0.9	21.34
			Sub-total	**248.52**	**16.57**	**66.27**		**59.64**
	Open forests	Miombo Woodlands	Productive	765.77	51.05	204.44	0.9	183.78
			Unproductive	19.64	1.31	5.24	0.9	4.71
			Sub-total	**758.40**	**52.36**	**209.44**		**188.50**
Others	Open woodlands	Bushlands and Thickets	Productive	380.10	25.34	101.36	0.9	91.22
			Unproductive	22.95	1.53	6.12	0.9	5.51
			Sub-total	**403.05**	**26.87**	**107.48**		**96.73**
			Total	**1438.97**	**95.80**	**383.19**		**344.87**

Notes: (1) Table 11.10 is a continuation of Table 11.9, thus column E is found in Table 11.9.

(2) Total off-site biomass harvested (Column F of Table 11.10) is implicit in supplementary biomass (column B of Table 11.19).

(3) Biomass decaying on-site (column G of Table 11.10) is estimated from 10-year clearance

Table 11.11: Instantaneous carbon and nitrogen released from burning the cleared biomass

Sector specific data by forest type				Carbon in fraction biomass	Total Carbon released	N/C ratio	Total Nitrogen released
					(kt C)		(kt N)
				K	L=JxK	M	N=LxM
Tropical	Closed forests	Broadleaf forests	Logged	0.45	17.24	0.012	0.17
			Unproductive	0.45	9.60	0.012	0.10
	Open forests	Miombo Woodlands	Productive	0.45	82.70	0.012	0.83
			Unproductive	0.45	2.12	0.012	0.02
Others	Open woodlands	Bushlands and Thickets	Productive	0.45	41.05	0.012	0.41
			Unproductive	0.45	2.48	0.012	0.02
			Total		**155.19**		**1.55**

Table 11.12:Trace gas release from on-site burning of cleared biomass for agricultural land

Sector specific data	Methane	Carbon monoxide	Nitrogen oxides	Nitrous oxide
	O	**P**	**Q**	**R**
Trace gas emission ratio	0.012	0.075	0.121	0.007
Molecular weight conversion factor	1.333	2.333	3.286	1.571
Calculation of trace gas emissions	**S**	**T**	**U**	**V**
	S=LxO* (Gg)	T=LxP (Gg)	U=NxQ* (Gg)	V=NxR (Gg)
Total instantaneous trace gas emissions	**2.483**	**27.158**	**0.617**	**0.017**

Note: (*) Table 11.12 is the continuation of Tables 11.10 and 11.11. Columns L and N are found in Table 11.11.

Carbon from the decay of aboveground biomass is released over a period of 10 years, and is estimated from Table 11.13 as follows:-

(i) The annual average area cleared is estimated by dividing the forest area cleared in 10 year period i.e 58.93 kha of tropical closed forest, 594.82 kha of miombo woodland, and 232.44 kha of bushland and thickets by 10 (column A).

(ii) Multiplying the annual areas cleared (column A) by their corresponding net biomass density change (column D), we obtain the average annual cleared aboveground biomass, estimated to be 1,916 kt dm (column E).

Table 11.13: Average annual CO_2 release from on-site decay of biomass cleared for permanent agricultural lands for the last 15 years

Sector specific data by forest types		10-year* average area cleared annually (kha)	Biomass before clearing (t dm/ha)	Biomass after clearing (t dm/ha)	Net Change in Biomass (t dm/ha)	Annual biomass loss (kt dm)	Fraction left in fields to decay	Quantity of decaying biomass (kt dm)	Carbon Fraction in cleared Biomass	Carbon released as CO_2 (kt C)
		A	B	C	D	E	F	G	H	I
					D=(B-C)	E=(AXD)		G=(ExF)		I=(GxH)
Tropical Closed Forests	Logged	5.19	59.46	18.00	41.46	212.79	0.05	10.64	0.45	4.79
	Unproductive	0.71	185.00	18.00	167.00	118.57	0.05	5.92	0.45	2.66
Miombo Woodlands	Productive	46.41	32.00	10.00	22.00	1021.02	0.05	51.05	0.45	22.97
	Unproductive	13.09	12.00	10.00	2.00	26.18	0.05	1.31	0.45	0.59
Bushlands and Thickets	Productive	18.10	32.00	4.00	28.00	506.80	0.05	25.34	0.45	11.40
	Unproductive	5.10	10.00	4.00	6.00	30.60	0.05	1.53	0.45	0.69
Total		**88.60**				**1915.96**		**95.80**		**43.10**

Note: (*) Since decaying rate is 10% of biomass left to decay annually, a 10-year average forest area cleared is used for calculations.

(iii) Multiplying column E by the fraction of aboveground biomass which is left to decay on-site i.e 5 percent, we obtain the average annual quantity of biomass left on-site to decay (column G). This quantity is estimated to be 95.8 kt dm.

(iv) Column G is multiplied by the fraction of carbon as fuel in biomass i.e 45 percent, to obtain the total annual carbon released from decay of biomass (column J). This amount is estimated to be 43.1 kt C.

Table 11.14: Carbon dioxide emissions from forest clearing for permanent agricultural lands

Immediate Release from burning On-Site (from Col. L Table 11.11)	Delayed Emissions from decay of cleared Biomass (from Col.I Table 11.13)	Long Term Emissions from disturbed soil	Total annual Carbon release from forest clearing	Total annual CO_2 release from forest clearing for agriculture
(kt C)	(kt C)	(kt C)	(kt C)	(Gg)
A	B	C	D=A+B+C	E
				E=(Dx[44/12])
155.19	43.10	N.A	198.29	727.06

The total amount of carbon dioxide released from forests cleared for permanent agricultural land, namely: on-site burning, and decay of cleared biomass is estimated from Table 11.14 to be 727 Gg per annum.

11.5 Emissions from conversion of grasslands to cultivated lands

Conversion of natural grasslands to cultivated lands is a common occurrence in Tanzania. IPCC ignores soil-carbon from the tropics, on the ground that soil-carbon release in the tropics is yet un-proven phenomenon. For our future reference, the workings on this source has been retained, but the results do not form part of the national greenhouse gas inventory. To calculate net release of CO_2 due to this land-use change, the area of grassland converted into cultivated land in the last 25 years is estimated and the following assumptions are made:-

(i) The carbon density of the aboveground vegetation of grasslands is approximately the same as that of the aboveground biomass in crops or pastures. Any significant changes in carbon stocks will therefore be due to changes in the soil carbon content after conversion of grasslands into other land-uses (Table 11.15).

(ii) For calculating the carbon flux from this land use change, a 25 year time horizon is considered, and carbon stock changes are taken to be linear (1).

(iii) Conversion of natural grasslands to managed grassland and cultivated lands may affect the net CO_2, CH_4, N_2O and CO emissions, but it is not yet clear what the effect on CH_4, N_2O and CO fluxes would be. These gases and their associated effects are not considered here.

(iv) The annual rate of soil carbon loss is the total change in soil carbon stock before and after grassland conversion. Since the loss is 50 percent over a 25 year period, the annual rate of loss is 2 percent. The average soil carbon content in grasslands is 67.2 t CO_2-C/ha (16).

To calculate the net release of CO_2, from Table 11.15 the total area of grassland converted into cultivated land i.e 3,120 kha (column A) is multiplied by the difference in soil carbon before and after clearing i.e 50 percent of 67.2 t C/ha, then divided by 25, to obtain the annual loss of soil Carbon from conversion. This annual loss of soil Carbon is estimated to be 4,193 kt C (column D of Table 11.15). The figure is converted to kt CO_2 by multiplying column D by 44/12 to yield 15,375 kt CO_2. As mentioned earlier, CO_2 emission from this source is for information only and does not form part of the national greenhouse gas inventory for 1990.

Table 11.15: CO_2 emissions from conversion of grasslands to cultivated lands

25 year Total Conversion of Grasslands to Cultivation	Soil Carbon Content of Grassland (*)	Fraction annual rate of Carbon release from soil	Total annual Soil Carbon release from grassland conversion	Total annual CO2 released from historical conversion over 20 years
(kha)	(t C/ha)		(kt C)	(kt CO2)
A	B	C	D	E
			D=(AxBxC)	E=(Dx[44/12])
3120	67.2	0.020	4193	15375

Notes: (*) Soil-carbon release figures were borrowed from Uganda (16).

11.6 Atmospheric carbon uptake by abandoned managed lands

Much of agricultural production in Tanzania is from peasant farming, with management of the smallholder farms being a family responsibility. Large scale estates are for the production of cash crops for export or primary processing of sisal, coffee, tea, cotton and other crops.

With the change in land ownership policies, marketing policies and the decline in producer prices in the world commodity markets a substantial part of sisal, coffee and tea estates and cashewnuts plantations were abandoned in the late sixties and in the seventies. In the case of coffee and tea, however, there has been a marked increase of acreage under cultivation. For example in 1972, about 126 kha were planted for coffee. The present area under coffee plantation is 235 kha. The area under tea plantations has also more than doubled from 7.3 kha in pre-independence days to 18.7 kha today. Sisal and cashewnuts are an exception.

It is estimated that 35 kha of cashew tree farms in Lindi, Mtwara and Coast regions, and 205 kha of sisal estates in Morogoro and Tanga were abandoned and left to regrow naturally during the mid sixties and early seventies. These are the only two types of abandoned managed lands on which some information has been obtained and are the only ones considered here. A number of assumptions are made so as to arrive at estimates of removals (sinks) of greenhouse gases. These assumptions are:-

a) Almost all of the abandoned managed lands allowed re-accumulation of carbon naturally;

b) Re-accumulated biomass created a net uptake of atmospheric carbon dioxide; and

c) Carbon uptake by soil, as it is for CO_2 release, it is an unproven phenomenon, and this sink is excluded from the national greenhouse gas inventory.

Based on the above assumptions the carbon uptake from abandoned managed lands is estimated from Tables 11.17 as follows:

(i) To calculate the annual aboveground biomass uptake in the inventory year, the total areas abandoned in the last 25 years i.e 35 kha and 205 kha re-grown into woodlands and grasslands respectively are multiplied by the annual growth rates of aboveground biomass densities which are estimated at 10 t dm/ha and 4 t dm/ha for woodlands and wooded grasslands respectively (column B of Table 11.16), to obtain 1,170 kt dm.

(ii) Multiplying this figure by the fraction of biomass as carbon (column D of Table 11.16), the annual Carbon uptake in aboveground biomass (column E of Table 11.16) is estimated at 527 kt C (column E of Table 11.16).

(iii) The estimated total carbon uptake in aboveground biomass in the abandoned managed lands is 527 kt C (column E of Table 11.16). This column is multiplied by 44/12 to obtain 1930.5 Gg CO_2 (column F of Table 11.16).

Table 11.16: Carbon dioxide uptake by abandoned managed lands left to re-grow for 25 years

Sector specific data by forest types	25-Year total abandoned area	Annual Rate of biomass increase	Annual biomass increase	Fraction Carbon in biomass	Annual Carbon uptake in biomass	Total CO_2 uptake
	(kha)	(t dm/ha)	(kt dm)		(kt C)	(Gg)
	A	B	C	D	E	F
			C=(AxB)		E=(CxD)	F=Ex(44/12)
Tropical Open Forests	35	10.0	350	0.45	157.5	577.5
Wooded Grasslands	205	4.0	820	0.45	369.0	1353.0
Total	**240**		**1170**		**526.5**	**1930.5**

Sources: (11, 14)

11.7 Net carbon emissions or uptake by forests subject to human activity

Forests which are subject to human activity can be either a sources or a sinks of carbon dioxide depending on whether there is a positive or negative net increment or decrement of carbon in a year. Emissions or removals of carbon dioxide due to plantation forests, unprotected forests, and other community tree planting programmes are considered here. Forests on public lands are not legally protected. They are accessible and their utilization is without any control.

Information required for the estimation of greenhouse gas emissions and uptake includes that of land areas of forests in the inventory year, the mean annual increment (MAI) of biomass in forests which are logged or harvested, and the number of growing trees in community plantations. Undisturbed natural forests, and forests re-growing naturally on abandoned lands are excluded from this category. Furthermore since it has not been possible to estimate the total area of accessible unprotected natural forests available for logging or harvesting for woodfuel, the mean annual increment of biomass has not been taken into account for these forests.

Activities in forests subject to human activity category which can potentially produce significant carbon fluxes include:-

(i) the growth of logged and planted forests; and

(ii) the harvesting and exploitation of accessible natural forests.

Each of these activities is examined independently, and then the net effect is examined.

11.7.1 Total carbon in annual growth of forests subject to human activity

Three potential uptake categories are considered here in the context of typical forest management practices in Tanzania. These categories are discussed in the following sections.

11.7.1.1 Carbon in annual growth of natural forest subjected to human activity

Most of productive forests in Tanzania are the disturbed natural forests which support logging substantially. Of these, closed broadleaf, miombo, and mangrove forests are most susceptible to non-sustainable logging. Logging for production of fine timber, poles, fencing materials, and pit props is a common practice in Tanzania. FAO (12) has estimated the average logged area in 1990 to be 2 kha at a logging intensity of less than 5 m^3/ha compared to 30 m^3/ha in Burundi and Rwanda, or 15 m^3/ha in Malawi (12). The mean annual increment (MAI) of standing biomass stock in the productive forests is estimated at 4.4 tonnes dry matter per hectare per annum (t dm/ha/year)(2). The natural forests areas subject to human activity considered here are those subjected to and regaining from shifting cultivation. These forests are mainly comprised of 55.2 kha of miombo woodlands, as shown in Table 11.21.

11.7.1.2 Carbon in annual growth of plantation forests

National plantation forests in Tanzania are estimated to cover about 80 kha. Of these, mixed softwood forests cover an estimated 70 kha, with the remaining 10 kha being mixed fast growing hardwood forests. Another 12 kha are woodlot community forests planted from late sixties. It has not been possible to desegregate these two major types of forests by species and restocking. Data is not readily available. In order to estimate the carbon uptake of planted forests, the following assumptions are made:-

(i) All the aboveground mixed hardwoods grow at equal rate.

(ii) Black wattle plantations and eucalyptus biofuel plantations dedicated to tea factories estimated at 12 kha are not considered. The assumption here is that prescribed harvesting ensures sustainability.

(iii) Mean annual increments (MAIs) of dry matter biomass in plantations are estimated at 11.0 t dm/ha/year and 4.9 t dm/ha/year for mixed softwoods, and mixed fast growing hardwoods, respectively.

Table 11.17: Average annual carbon changes in forests subject to human activity and growing woody biomass stocks

Sector specific data by forest and non-forest types			Forest area (subject to human activity)	Annual growth Rate	Annual biomass increase	Wood Carbon content	Total Carbon uptake
			(kha)	(t dm/ha)	(kt dm)		(kt C)
			A	B	C	D	E
					C=(AxB)		E=(CxD)
Tropical Forests	Plantation Forests	Mixed softwoods	70	11.00	770	0.45	346.50
		Mixed hardwoods	10	4.90	49	0.45	22.05
	Natural forest	Miombo woodlands	55.2	4.00	220.8	0.45	99.36
	Others	Village woodlot	12	5.00	60	0.45	27.00
Non-forest tree planting programmes in urban and rural areas			Number of Trees (1000s of trees)	Annual Growth (kt dm per 1000 trees)	Annual biomass increment	Wood Carbon content	Total Carbon uptake
			A	B	C=(AxB)	D	E=(CxD)
Urban and rural tree planting programmes			12	0.0049	0.059	0.45	0.03
Total					**1099.9**		**494.94**

Sources:(2, 5)

Carbon uptake due to growing plantation forests is estimated using the following steps:

(i) The carbon content increase due to annual growth of plantation forests and village woodlot is obtained when the area of each type of forest i.e 70 kha of mixed softwoods (column A) is multiplied by MAI i.e 11.0 t dm/ha/year (column B); and the rest i.e 10 kha of mixed fast growing hardwoods by 4.9 t dm/ha/year; 55.2 of miombo woodlands by 4 t dm/ha/year; and 12 kha of village woodlot by 5 t dm/ha/year (column B) to obtain 1,236.4 kt dm (column C).

(ii) The figures obtained in column C are multiplied by carbon fraction of dry biomass i.e 0.45 t C per t dm (column D of Table 11.17) to obtain the carbon uptake in biomass, estimated at 556.38 kt C (column E of Table 11.17).

11.7.1.3 Village forests and other tree planting programmes

Information related to tree planting activities is required in order to calculate the net uptake of carbon by this sink. These activities include village afforestation efforts, village agroforestry, urban tree planting, and other tree planting activities. Urban and village tree planting activities are estimated to have resulted in 12,000 trees being planted in 1990 at roughly 2.5 m x 2.5 m spacing. Carbon uptake estimations follow the method used above, based on the following assumptions:

a) Out of 1600 planted trees per hectare 1000 trees are assumed to survive.

b) Eucalyptus is a representative tree grown. A mean annual increment of 4.9 t dm/ha/year is therefore used.

c) All trees planted through afforestation programmes are assumed to grow at equal rates.

Carbon uptake due to annual growth of planted trees is estimated as follows:

(i) The total number of trees is divided by 1000, to obtain 12 thousand trees (column A of Table 11.17).

(ii) To estimate carbon content in annual growth of planted trees, the 12 thousand of mixed fast growing hardwoods (column A of Table 11.17) is multiplied by MAI i.e 0.0049 kt dm/1000 trees/year (column B of Table 11.17), to obtain 0.059 kt dm (column C of Table 11.17).

(iii) The figures in column C of Table 11.17 are multiplied by the carbon fraction of dry biomass column D of Table 11.17, to obtain the carbon uptake in biomass, estimated at 0.03 kt C (column E of Table 11.17).

The estimates of carbon uptakes in sections 11.7.1.1 through 11.7.1.3 are added, to the total carbon content in annual growth of logged and planted trees, which is estimated to 494.94 kt C (see column E of Table 11.17).

11.7.2 Harvest and exploitation of accessible natural forests and plantation forests

11.7.2.1 Commercial biomass harvested

Commercial wood harvesting in natural forests has concentrated on only a few species. Miombo and intermediate woodlands face the risk of destruction, particularly those in the proximity of towns, human settlements, and near access roads. Commercial biomass refers to timber, industrial roundwood e.g poles, and woodfuel for commercial purposes. The amount of timber harvested in 1990 was estimated to be 270,400 m^3 and 40,100 m^3 from non-coniferous and coniferous forests, respectively (11). The annual harvest of poles is estimated to be 260,000. The amount of fuelwood harvested in plantation forests in 1990 was estimated to be 79,518 m^3. This is part of amount of woodfuel reported in column I of Table 11.18.

Table 11.18: Annual balance of woody biomass stock in forest and non-forest formations

Sector specific data by forest harvest	Commercial Harvest	Biomass Expansion Factor	Total Biomass removed in commercial harvest	Total annual traditional woodfuel consumed	Total direct biomass removed	Total indirect biomass removed
	(k m^3)	(t dm m^{-3})	(kt dm)	(kt dm)	(kt dm)	(kt dm)
	F	G	H	I	J	K
			H=(FxG)	(from column A, Table 6.6)	J=(H+I)	(from Tables 11.10 and 11.21)
Fine timber	310.5	0.855	265.478	0	265	0
Fuelwood	0	0.855	0	27765	27765	1853
Charcoal	0	0.855	0	7718	7718	0
Wooden Poles[1]	6.5	0.855	5.558	0	6	0
Total	**317.0**		**271.036**	**35483**	**35754**	**1853**

Note: (1) 40 poles are equivalent to 1 m^3 of solid wood.

In order to calculate the amount of biomass harvested, the following assumptions are made:-

a) The factor used to convert volume to mass of dry matter is 0.45 t dm/m^3 (1). An expansion factor is applied to account for non-commercial biomass harvested with the commercial roundwood and left to decay is 1.90.

b) Combining both the conversion and expansion factors results into a new conversion factor of 0.855 t dm/m^3 for commercial roundwood.

c) One cubic metre of roundwood is equivalent to 40 poles (10 cm diameter and 3 metres long each).

d) The Carbon fraction for live biomass is assumed to be 0.45 CO_2-C/dm by weight.

To calculate the amount of dry biomass harvested, the following steps (Table 11.18) are used:-

(i) To estimate the mass of dry matter from round wood expressed as kilo-tonnes (kt dm), the total amount of roundwood harvested i.e 311 kilo-m^3 (column F) is multiplied by the conversion factor, i.e 0.855 (column G). The harvested biomass is thus estimated to be 265 kt dm (column H).

(ii) To estimate the mass of dry matter from poles expressed as kilo tonnes (kt dm), we divide the amount of poles i.e 260,000 by 40 and 1,000 to obtain the amount of poles expressed as roundwood volumes (kilo-m^3). This figure is multiplied by 0.855, to obtain the mass of dry biomass, estimated to be 5.6 kt dm (column J).

11.7.2.2 Informal woodfuel exploitation from natural forests

Literature on fuelwood use in Tanzania tends to overestimate wood energy use. No country-wide study on fuelwood consumption has been done. Estimates of fuelwood use based on a number of localised studies range from the per capita per annum use of 1.1 to 2.1 cubic metres of roundwood. An average per capita demand is then multiplied by the total population to obtain total country wide consumption. With better understanding of the volume of standing woody biomass per hectare, the area harvested is then obtained. A range of 130 kha to 400 kha is usually quoted as the annual deforestation rate due to fuelwood use and cropland expansion (2).

There are a number of reasons as to why the higher figure above would seem to be too high. In villages, where majority live people do not fell trees for woodfuel; twigs, dead branches and foliage are used.

It is intended here to capture the loss of carbon that results from biomass that does not regenerate. It has not been possible to establish accurate forest area from which woodfuel is extracted non-sustainably, however, the following approach can used:-

a) Based on the results of the Urban Energy Study (16), the total woodfuel consumption in 1990 is estimated at 27,765 kt dm and 7,718 kt dm of fuelwood and charcoal respectively (column A of Table 6.6), which add to 35,483 kt dm (column I of Table 11.18).

b) All the consumed charcoal is produced using earth kiln technology, which requires 10 t dm of roundwood to produce one tonne of charcoal on dry mass basis.

The following approach (Tables 11.19 and 11.20) was used to estimate the amount of biomass exploited:-

(i) The quantities of aboveground biomass removed on-site during forest clearing for permanent crop land and pasture i.e 1,439 kt dm from 88.6 kha (column F of Table 11.10); during shifting cultivation practice i.e 414 kt dm from 55.2 kha (column D of Table 11.21), add up to 1,853 kt dm (column K of Table 11.18).

(ii) Subtracting 1,853 kt-dm from the total annual woodfuel consumption of 35,754 kt dm (column J of Table 11.18), the quantity of woodfuel exploited informally is estimated to be 33,902 kt dm (column C of Table 11.19).

Table 11.19: Estimating net carbon release from annual woody biomass harvest (1990)

Total annual biomass harvest (kt dm)	Supplementary biomass supply from agricultural activities (kt dm)	Net biomass harvest (release) annually (kt dm)	Fraction Carbon in biomass	Net Carbon harvest (release) annually (kt C)
A	B	C=A-B	D	E=CxD
35754	1853	33902	0.45	15255.685

The amount of wood exploited informally i.e. 33,902 kt dm (column C of Table 11.19) is converted to carbon dioxide by multiplying this figure by the carbon fraction for live biomass i.e 0.45 C per dm (column D of Table 11.19), to obtain 15255.685 kt C.

Table 11.20: Carbon balance (emission and uptake) by forests subject to human activity in 1990

Net carbon release annually through biomass uses (kt C)	Net carbon uptake from column E, Table 11.17 (kt C)	Net carbon emissions by forests which are subjected to human activity (kt C)	Net carbon emissions as carbon dioxide (Gg)
F	G	H=F-G	I=Hx[44/12]
15255.685	494.940	14760.746	54122.735

The net annual carbon uptake or emission is estimated from the difference between annual carbon release i.e 15255.685 kt C (column F Table 11.20), and the annual carbon uptake i.e. 494.940 kt C (column E of Table 11.17). In 1990 therefore there was a net carbon emissions of 14760.746 kt C (column H of Table 11.20), equivalent to 54122.735 Gg CO_2 (column I of Table 11.20) when column H is multiplied by 44/12 (the molecular weight).

11.8 Other possible categories of activity

Shifting cultivation is another land-use activity affecting carbon dioxide and other trace gases. Although the methodology associated with this land-use practice is not yet fully developed, an attempt to estimate emissions due to this land-use category has been made. We also estimate methane emissions due to flooding of land, and comment on degradation of forests due to air pollution.

11.8.1 Non-CO_2 emissions from non-sustainable shifting cultivation practice

Shifting cultivation is a common agricultural practice in Tanzania, whereby short periods of cultivation (ranging from 1 year to 6 years) alternate with longer periods of fallow, about 25 years. Shifting cultivation is practiced mainly in south-west Tanzania and in places where flue tobacco is grown i.e Tabora. It is estimated that 27.6 kha of miombo woodlands were cleared for tobacco growing in 1990 (15). Since an equivalent area is required for flue curing, the total area cleared was about 55.2 kha.

When practiced in the traditional manner, about 55.2 kha of land under shifting cultivation may produce no net CO_2 emissions if vegetation regrowth is allowed to occur during the fallow period. As the pressure on land increases, the fallow time shortens, and the proportion of woodland, sparse thickets and bushlands increases. Assumptions made for estimation of emissions are as follows:-

a) Short fallow cycles make shifting cultivation similar to forest clearing for permanent cropland.

b) To estimate the net emissions due to shifting cultivation, assumptions (a), (b), and (e) in Section 11.4 above refer.

c) Considering regrowth during fallow periods, a net biomass density change to be about 10 t dm/ha is assumed between clearing and regrowth.

Table 11.21: Estimating biomass cleared during shifting cultivation practice

Annual area cleared (kha)	Net biomass change (t dm/ha)	Total biomass cleared (kt dm)	Biomass burned off-site (kt dm)	Biomass left to decay (kt dm)	Biomass burned on-site (kt dm)
A	B	C=AxB	D=0.75xC	E=0.05xC	F=0.20xC
55.20	10.0	552	414.0	27.6	110.4

Table 11.22: Estimating instantaneous carbon and nitrogen release from shifting cultivation

Fraction oxidised	Oxidised biomass (kt dm)	Fraction Carbon	Carbon released (kt C)	Nitrogen Carbon ratio	Nitrogen released (kt N)
G	H=F*xG	I	J=HxI	K	L=JxK
0.9	99.36	0.45	44.712	0.01	0.447

Notes: (*) Table 11.22 is the continuation of Table 11.21.

Table 11.23: Trace gas emissions from instantaneous biomass combustion

Sector specific data	Methane	Nitrogen oxides	Nitrous oxide	Carbon monoxide
	M	N	O	P
Default emission ratio	0.012	0.094	0.007	0.040
Molecular weight factor	1.333	3.286	1.571	4.173
Trace gas emissions (Gg)	**0.715**	**0.138**	**0.005**	**4.173**

From the above assumptions, emissions from this land-use activity have estimated using the same method as that in section 11.4 above. The results are summarised as follows:

(i) Annual quantity of carbon released instantaneously on-site is estimated to be 45 kt C.

(ii) Trace gas emissions from instantaneous burning of cleared biomass in fields, are estimated to be 0.715 Gg CH_4, 0.138 Gg NO_x, 0.005 Gg N_2O, and 4.173 Gg CO.

11.8.2 Degradation of forests from air pollution

Virtually no degradation of forest has been associated with air pollution in Tanzania. There is however noticeable but scattered degradation of forest selected species of coniferous type. This is possibly due to disease.

11.8.3 Methane emissions due to man-made flooding of lands

Land areas flooded due to man-made causes in Tanzania belong to the category of artificial impoundment mostly for hydroelectric generation. There are a few irrigation dams. These areas are as summarized in Table 11.24. Although IPCC (1) does not earmark this source of methane, it is a common experience in Tanzania to have temporary submerged land in the vicinities of man-made dams, for both water supply and hydropower generation.

Table 11.24: Land area covered by the existing man-made flooded (water dams) in 1990

Reservoir	Region	Area (kha)
Nyumba ya Mungu	Kilimanjaro	18.0
Mtera	Iringa	61.0
Kidatu	Morogoro	15.0
Others (Water supply and irrigation)	Others	11.3
	Total	**105.3**

Source: (9)

It is assumed that 10 percent of the man-made flooded area is subjected to anaerobic digestion during the wet seasons. From the perspective of local weather changes, water levels in dams keep on changing, hence creating conducive condition for fast plant growth in dry seasons, followed by anaerobic fermentation during the wet seasons. The annual flooded area releasing methane is therefore estimated at 10.53 kha. We estimated methane emissions due to flooding of lands in Tanzania as follows:

(i) Multiplying 10.53 kha (column A of Table 11.25) by the average daily methane release estimated at 0.4267 t CH_4/kha, the total daily quantity released is 4.48 t CH_4.

(ii) Multiplying this figure by 90 on the assumption that methane release ceases after 90 days then dividing the product by 1000, the annual methane emission is estimated at 0.303 kt CH_4 (column D of Table 11.25).

Based on results obtained, this land-use activity is insignificant in terms of methane emission compared to other land-uses i.e forest clearing and shifting cultivation.

Table 11.25: Methane emission estimates from man-made flooded lands

Sector specific data	Submerged land area (kha)	Daily methane emission factor (t CH_4/kha)	Number of days conducive for anaerobic fermentation	Total annual methane emissions (Gg)
	A	B	C	D=[AxBxCx10^{-3}]
Man-made flooded lands	10.53	0.4267	90	0.404

Note: (1) Daily methane emission factor is calculated from multiplying 0.32 t CH_4-C/kha by 16/12 (molecular conversion factor), to obtain 0.4267 t CH_4/kha

11.9 Discussion

After considering a number of land-use activities which result into greenhouse gas emissions, the results are summarised in Table 11.26. From the results, the importance of managed forest activities predominate as far as carbon cycle is concerned. It must, however, be stressed that this sector is difficult to assess since the data is not reliable. Furthermore the nomenclature of IPCC differs to that of natural vegetation delineation in the tropics and in Tanzania. Table 11.26 shows the summary of net estimated greenhouse gas emissions and uptake due to land use practices and forestry in 1990.

The net emission of carbon dioxide is consistent with the net loss of natural vegetation due to agriculture and energy related activities (woodfuel use and clearing land for agriculture). This net loss of vegetation has not been ascertained fully. There are various estimates of deforestation rate ranging from 130 kha to 400 kha per year. However, as can be seen from Table 11.9 it is estimated by the study team that 88.6 kha was the area cleared in 1990. Emphasis here must be made that what has been considered is the emission due to that area subjected to human activity. It is conceivable that if all the natural vegetation were to be considered, there would be net removal of carbon dioxide. This study is about anthropogenic activities only.

Table 11.26: Summary of emissions and removals due to land-use changes and forestry in 1990

Sector specific data by source or sink activity		CO_2	CH_4	NO_x	N_2O	CO
		Gigagrams (Gg)				
Forest clearing for agriculture	On-site burning	569.03	2.485	0.617	0.017	27.158
	Decay of cleared biomass	158.03	N.A	N.A	N.A	N.A
	Sub-total (1)	**727.06**	**2.485**	**0.617**	**0.017**	**27.158**
Abandonment of managed lands	Wooded grasslands	-1353.00	N.A	N.A	N.A	N.A
	Tropical open forests	-577.50	N.A	N.A	N.A	N.A
	Sub-total (2)	**-1930.50**	**N.A**	**N.A**	**N.A**	**N.A**
Management of forests	Wood exploited informally (woodfuel, and clearing for agriculture)	55937.51	N.A	N.A	N.A	N.A
	Plantation forests	-1351.35	N.A	N.A	N.A	N.A
	Natural forests subject to human activity (shifting cultivation)	-364.32	N.A	N.A	N.A	N.A
	Village woodlot, and urban and rural tree planting	-99.10	N.A	N.A	N.A	N.A
	Sub-total (3)	**54122.74**	**N.A**	**N.A**	**N.A**	**N.A**
Others	Shifting cultivation	N.A	0.715	0.138	0.005	4.173
	Man-made flooded lands	N.A	0.404	N.A	N.A	N.A
	Sub-total (4)	**N.A**	**1.119**	**0.138**	**0.005**	**4.173**
	TOTAL (1+2+3+4)	**52919.30**	**3.064**	**0.755**	**0.022**	**31.331**

Notes:
(1) *N.A* refers to "not applicable".
(2) The negative sign (-) stands for "uptake".
(3) The positive numbers refer to emissions.

11.10 References

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12.0 EMISSIONS FROM MUNICIPAL SOLID WASTE AND WASTEWATERS

12.1 Greenhouse gas composition in open dumpsites and landfills

Greenhouse gas (GHG) emissions from open dumpsites and landfills are composed mainly of methane (CH_4) and Carbon dioxide (CO_2). The emitted gas is produced when degradable organic wastes decompose anaerobically. Initially the organic waste decomposes aerobically. It is then attacked by anaerobic bacteria breaking down the waste into simpler forms of organic compounds with the resulting gas comprising of CH_4 and CO_2 almost in equal proportions. This process begins 10 to 50 days after the waste has been subjected to anaerobic conditions. Much of the gas is generated and emitted within 20 years of the completion of landfill or alike environment. Emissions from this source can however continue for a century or more.

Table 12.1: Municipal solid waste (MSW) generation in large towns in Tanzania (1990)

Major Towns	Population	Municipal Solid Waste generated (tonnes/day)				Tonnes of Waste/year (Thousands)
		Household	Market	Others	Total	
Arusha	145140	58.1	25.3	15.5	98.9	36.08
Bukoba	49582	19.8	8.5	5.2	33.5	12.24
Dar es Salaam	1494627	597.9	374.9	230.0	1202.8	439.00
Dodoma	213734	85.5	36.4	22.3	144.2	52.63
Iringa	89504	35.6	17.7	10.9	64.2	23.44
Kigoma	89454	35.8	15.3	9.4	60.5	22.08
Lindi	43267	17.3	7.3	4.5	29.1	10.62
Mbeya	162467	65.0	28.0	17.2	110.2	40.22
Morogoro	123963	49.6	21.2	13.0	83.8	30.58
Moshi	100948	40.4	17.1	10.5	68.0	24.81
Mtwara	78793	31.5	13.2	8.1	52.8	19.28
Musoma	72569	29.0	12.5	7.6	49.1	17.93
Mwanza	234760	93.9	70.0	22.9	186.8	68.18
Shinyanga	106651	42.7	18.3	11.2	72.2	26.34
Singida	85087	34.0	16.5	10.1	60.6	22.13
Songea	92888	37.2	16.1	9.9	63.2	23.05
Sumbawanga	100052	40.0	17.6	10.8	68.4	24.97
Tabora	98048	39.2	16.7	10.2	66.1	24.13
Tanga	195098	78.0	33.1	20.3	131.3	47.94
Zanzibar	169842	67.9	20.6	18.2	106.7	38.96
Others*	-	-	-	-	324.7	118.52
Total	3746474				2752.4	1004.63

Sources: (1, 2, 3, 4, 5, 6)

Notes: (*) Include district townships.

Numerous factors affect the amount of gas produced in open dumpsites and landfills. These factors are site-specific and include waste composition, moisture content, temperature of the landfill, pH level, nutrients, refuse density, and particle size. Gas generation will also depend on whether the waste is managed via open dumping or through sanitary landfilling.

12.2 Nature and type of municipal solid waste

Municipalities and townships generate solid wastes which are collected and deposited in landfills. Concentration of wastes leads to the generation of GHGs. It is therefore essential to characterise, to the extent possible, the nature and composition of municipal solid wastes in Tanzania. Estimates of municipal solid wastes generated and collected for disposal in selected municipalities in Tanzania are shown in Table 12.1. It is estimated that the per capita waste generation rate for Tanzania's urban population ranges between 0.35 to 0.50 kg/day. A generation rate of 0.4 kg per capita per day has been used to calculate waste generated in Dar es Salaam and in provincial municipalities/towns, while a generation rate of 0.2 kg per capita has been used for district centres. It is further estimated that urban councils collect between 5 percent and 30 percent of the generated waste (7).

12.3 Municipal solid waste management in Dar es Salaam

12.3.1 Municipal solid waste disposal sites

Sanitary landfill is not a new solid waste management practice in Tanzania, although crude or open dumping has been popular. Much of the municipal solid waste (MSW) in Tanzania is generated and collected in Dar es Salaam. Dar es Salaam whose population in 1990 was estimated to be 2.3 million (6% of the country's population) living within 1,393 sq. km, is the country's most populous settlement. It is also the largest industrial, commercial and administrative centre. MSW disposal site for Dar es Salaam had for many years been Tabata. Tabata was initially operating as a sanitary landfill in 1962, thereafter turned into crude or open dumpsite, and closed down in 1992. Kunduchi-Mtongani was briefly used as a dump for MSW before the sanitary landfill was located at Vingunguti in 1992.

12.3.2 Composition of municipal solid waste

MSW supply the necessary material for generation of GHG emissions in open dumpsites and landfills through provision of Degradable Organic Carbon (DOC). Data on the nature and composition of MSW in Tanzania is scanty. The composition of MSW for Dar es Salaam is as shown in the Table 12.2.

Table 12.2: Waste types generated in 1988 in Dar es Salaam

Category	Generated tonnes/day	Collected tonnes/day
Domestic	650	195
Commercial	45	33
Institutional	60	10
Markets	200	45
Streets, Drains, Sewers	35	-
Hospitals	20	-
Car wrecks	325	-
Construction debris	5	-
Slaughter houses	5	-
Industrial	100	20
Total	1140	283

Source (7, 8)

Much of the waste (about 55%) is generated from households. The composition of the domestic waste in Dar es Salaam is such that vegetable matter constitutes 62.5%, followed by inert matter, 27.5%. The composition of domestic solid wastes is as shown in Table 12.3.

Table 12.3: Composition of typical domestic waste in 1990

Solid Waste Types	Percent by Weight
Vegetable	62.5
Paper	6.2
Glass	0.3
Metals	1.2
Textiles	1.2
Plastics and Rubber	1.8
Bones	0.3
Inert matter	27.5

Source: (9)

Note: (1) Other characteristics of the collected samples of MSW include: the gross density of 390 kg/m^3), moisture content of 58%, and an average organic matter content of 65% on dry weight.

12.3.3 Collection of MSW in Dar es Salaam

Public utility collection of MSW in Dar es Salaam is the responsibility of the City Council Public Health Department. Collection of domestic solid waste is mainly concentrated in the city centre. Outside this area, MSW collection is either very limited or not performed at all. In the city centre about 64% of domestic waste is collected. Elsewhere, only about 13% of the waste is collected, the rest is either buried in pits or burnt on site (7). Methane generation from MSW buried in shallow pits or thrown away in streets is insignificant. MSW buried in shallow pits decompose aerobically, releasing mainly CO_2 in the process.

Commercial solid wastes originate from hotels, restaurants and shops and consists of food remains and packing materials, respectively. Solid wastes from institutions comprise mainly of paper and food remains.

There are over 20 markets in Dar es Salaam. MSW dumps in the neighborhood of the markets are a common sight. About 2 percent of the market solid waste is paper, glass and plastics. The rest is vegetable, fruit and cereal waste. Collection of the MSW is done by the City Council which has limited resources and is therefore of limited success (9).

Hospital wastes comprise of domestic and hazardous wastes. Hazardous hospital waste is incinerated at Muhimbili and is burnt in situ elsewhere. Other wastes are collected by the City Council for disposal at Vingunguti open dumpsite. Industrial solid wastes in Dar es Salaam comprise of inert non-flammable wastes including glass, rocky debris, sand, mineral sludge etc; domestic solid wastes comprise of kitchen wastes, paper etc; and hazardous wastes comprise of petrochemicals, pesticides, pharmaceutical, battery remains, metals, plastics, paints, and industrial sludge.

12.3.4 Vingunguti sanitary landfill

After the closure of the Tabata open dumpsite in 1992, Vingunguti is at present the largest disposal point for MSW in Dar es Salaam and therefore, in the country. Vingunguti open dumpsite was converted into a sanitary landfill. Waste disposed of at the Vingunguti landfill is regularly compacted and covered with soil. It is estimated that about 2,000 tonnes of MSW is monthly disposed of at Vingunguti (9). The type and quantity of the MSW at Vingunguti is as shown in Table 12.4.

Table 12.4: Type and quantity of MSW at Vingunguti sanitary landfill in 1993

Type of waste	Quantity (tonnes)	Proportion (percentage)
Chemicals	93	4.6
Metals	418	20.7
Glass	210	10.4
Paper	183	9.1
Food	190	9.4
Husks	84	4.1
Other (Hospitals)	272	13.3
Market, Garden vegetable	567	28.2
Total	2,016	100.0

Source: (9)

Organic solid waste disposed of at the site is about 1024 tonnes per month or 50.7% of the total MSW dumped. This amount and type of waste has the potential of generating GHGs. Scavenging of both organic and non-organic solid waste takes place at the dumpsite. It is estimated that 53% of the total MSW, and 33% of the organic solid waste is scavenged (8). The removal of non-organic solid waste from the dump increases the percentage of degradable organic carbon (DOC) in the waste, and therefore facilitates emission of methane (8).

12.4 Estimation of CH_4 emissions from MSW disposal sites in Tanzania

The landfill CH_4 emission estimate model based on a mass balance approach as provided by IPCC was used to estimate CH_4 emissions from MSW disposal sites in Tanzania (10). This methodology assumes instantaneous release of methane which is therefore assumed to enter the atmosphere during the same year that the refuse is placed in the landfill. The annual emissions were calculated using the equation below:-

$$Q_m = [T_o \times D_m \times P_a \times P_d \times F_m \times F_c] - Q_r$$

where

Q_m	is the amount of methane emitted in a given year (kg/yr)
T_o	is the total MSW generated (kg/yr)
D_m	is the portion of MSW decomposed anaerobically (in fraction)
P_a	is the DOC portion in MSW (in fraction)
P_d	is the dissimilated DOC portion (in fraction)
F_m	is the methane portion in biogas by weight (0.5 g CH_4-C/g biogas)
F_c	is the conversion factor (16 g of CH_4 per 12 g of CH_4-C)
Q_r	is the recovered CH_4 from dumpsites in the same year (kg/yr)

There was no landfill gas recovery system in Tanzania in early 1990s, thus the gas recovery part of the model equation for 1990 is not applicable. Initiatives to implement a pilot project to extract gas from Vingunguti sanitary landfill for electricity generation (about 1 MW) commenced in 1994.

For open dumping methane emissions are reduced by 50 percent compared to sanitary landfilling. The only sanitary landfills in Tanzania are Tabata (after its closure in 1992) and Vingunguti in Dar es Salaam. All other municipalities and townships have open MSW dumps.

For developing countries it has been estimated that the percentage of degradable organic carbon (DOC) is 15 percent of MSW. Dissimilated DOC is the fraction of carbon in substrates that is converted to biogas (Carbon dioxide and Methane) and assimilated DOC is the remainder of the carbon that is used to produce new microbial cells. Dissimilated DOC can be estimated using the equation (11):-

$$\frac{C_c}{C_T} = 0.014T + 0.28$$

where

C_c	is the carbon converted to biogas
C_T	is the total carbon in the substrate
C_c/C_T	is the dissimilated DOC (fraction)
T	is the landfill temperature

Landfill temperatures in the anaerobic zone (1m-2m) have been measured for Vingunguti dumpsite in Dar es Salaam and Nyakato dumpsite in Mwanza. An average temperature of 50°C can be used to calculate the dissimilated DOC for Vingunguti and 32°C for the Nyakato. Potentially DOC is therefore 0.987 for

Vingunguti and 0.728 for Nyakato. The obtained DOC values are not conclusive, since the time spent to gather them was too short. For this reason we did not use them as country specific factors. Table 12.5 shows CH_4 emission estimates in major towns in Tanzania for 1990. However carbon cycle is always a closed cycle, hence CO_2 emissions are not part of anthropogenic GHG emissions.

Table 12.5: CH_4 emissions from MSW in major towns in Tanzania in 1990

City, Municipality or town	Total MSW generated (kt)	Total MSW disposed of at dumpsite (kt)	Portion of DOC in MSW	Dissimilated DOC in MSW	Adjustment and conversion factor (0.50x16/12) = 0.6667	Methane emissions at open dumpsites (Gg) CH_4
	A	B	C	D	E	F=0.5x(BxCxDxE)
Arusha	36.08	4.51	0.15	0.77	0.6667	0.17
Bukoba	12.24	1.53	0.15	0.77	0.6667	0.06
Dar es Salaam	439.00	54.88	0.15	0.77	0.6667	5.07
Dodoma	52.63	6.58	0.15	0.77	0.6667	0.25
Iringa	23.44	2.93	0.15	0.77	0.6667	0.11
Kigoma	22.08	2.76	0.15	0.77	0.6667	0.11
Lindi	10.62	1.33	0.15	0.77	0.6667	0.05
Mbeya	40.22	5.03	0.15	0.77	0.6667	0.19
Morogoro	30.58	3.82	0.15	0.77	0.6667	0.15
Moshi	24.81	3.10	0.15	0.77	0.6667	0.12
Mtwara	19.28	2.41	0.15	0.77	0.6667	0.09
Musoma	17.93	2.24	0.15	0.77	0.6667	0.09
Mwanza	68.18	8.52	0.15	0.77	0.6667	0.33
Shinyanga	26.34	3.29	0.15	0.77	0.6667	0.13
Singida	22.13	2.77	0.15	0.77	0.6667	0.11
Songea	23.05	2.88	0.15	0.77	0.6667	0.11
Sumbawanga	24.97	3.12	0.15	0.77	0.6667	0.12
Tabora	24.13	3.02	0.15	0.77	0.6667	0.12
Tanga	47.94	5.99	0.15	0.77	0.6667	0.23
Zanzibar	38.96	4.87	0.15	0.77	0.6667	0.19
Other towns	118.52	39.00	0.15	0.77	0.6667	0.57
Total	**1004.63**	**125.58**				**8.36**

Notes:
(1) These emissions do not take into account scavenging. Actual emissions will be lower.

(2) The carbon cycle is a closed cycle and as such CO_2 emissions are not considered in IPCC report.

(3) Other towns refer to urban district centres of Tanzania Mainland.

(4) With exception of Dar es Salaam column B is almost 12.5% of column A. For Dar es Salaam collection is 30%.

(5) Emissions are reduced by 50% as open dumping was the only method practiced in 1990.

12.4.1 Alternative methods of methane emissions estimation from the Tabata dumpsite

Tabata dumpsite was started in 1962. Up to the time of its closure in 1992, it is estimated that about 450,000 tonnes of wastes had been deposited at the dump. Crude dumping or open dumping was exercised. The dump had an average thickness of about 3 metres and an area of about 12 hectares (7).

The amount of methane emitted from the Tabata dumpsite in 1990 has been estimated using the relationship provided above for calculating emissions from municipal solid wastes. Since the estimated amount of waste deposited at the dump at the time of its closure in 1992 is known, the amount of waste at the dump in 1990 can be estimated from multiplying the 1990 population by the per capita waste generation (0.9 kg/day), the average collection efficiency (12.5%), and the number of days in a year (7, 8).

Subsequent to the closure of the Tabata dumpsite methane emission has been calculated using two methods. Methane emission has been estimated using the formula for specific gas production (10), and using the first order kinetic model (22). The formula for specific gas production relates methane emissions to open dump characteristics thus:-

$$Q_m = 0.8 \times k \times P_o \times R \times e^{-kt}$$

where

Q_m	is quantity of methane production in m^3;
P_o	is concentration of degradable organic mater in kg/tonne of refuse;
R	is the quantity of refuse landfilled (in tonnes)
k	is the degradable rate coefficient (0.1 per year); and
t	is the time, in years, after landfill closure.

For the Tabata dumpsite the concentration of degradable matter, P_o is therefore 687 m^3/tonne, k = 0.1 per year, t = 1 for 1992 and 2 for 1993. The MSW landfilled at Tabata, R is about 450,000 tonnes. Methane generated for 1992 is estimated at 22.378 x 10^7 m^3 or using the density of methane of 0.553 kg/m^3 this was equivalent to 12.37 x 10^3 tonnes, that is 12.37 Gg. For 1993 methane generated is estimated at 20.25 x 10^7 m^3 or 11.20 Gg.

For a dumpsite that has been closed and landfilled, methane can also be estimated using the first order kinetic model (10):-

$$Q_m = L_o \times R \times (e^{-kc} - e^{-kt})$$

where

Q_m	is the methane generation rate in m^3/year;
L_o	is the DOC available for methane generation (m^3/Mg of refuse);
R	is the quantity of refuse landfilled in Megagrammes (Mg);
k	is the methane generation rate constant (yr^{-1});
c	is the time since landfill closure (yr); and
t	is time since initial refuse placement (yr).

For the Tabata dumpsite, L_o = 55 m^3/Mg (12), R = 450,000 Mg, k = 0.1 yr^{-1}, c = 1 for 1992, c = 2 for 1993, t = 29 years for 1992 and t = 30 for 1993. The amount of methane emitted in 1992 therefore was 21.03 x 10^7 m^3 or 11.63 Gg. For 1993 methane emitted was 19.03 x 10^7 m^3 or 10.52 Gg. Note that the two methods give about the same estimates of methane generated. Either method can therefore be used in the future.

12.5 Methane emissions from other sources of solid wastes

12.5.1 CH_4 emissions from sisal solid wastes

On average, $^1/_3$ of organic wastes generated from sisal fibre production comprise of volatile solids. It is estimated that $^2/_3$ of the wastes can be anaerobically degraded. It has been estimated that 1 kg of volatile solids can generate 0.193 kg of CH_4. The amount of sisal waste generated per year is 720,000 tonnes. Using these constants, the annual emission of methane from sisal wastes is estimated to be 30.88 Gg per year.

12.5.2 CH_4 emissions from coffee solid wastes

Coffee wastes generated at the Bukoba, Moshi, Mbozi and Mbinga coffee processing plants is estimated to amount to 90,000 tonnes/year. About $^1/_3$ is assumed to be dumped and 15% of this is anaerobically degraded. The emission of methane from this source is estimated by applying the formula for the emission of methane from sanitary landfills used above. The amount of methane emitted is estimated to be 2.23 Gg.

12.6 Methane emissions from waste waters

12.6.1 Methane emissions from domestic, commercial and industrial wastewaters

As part of an effort to determine sources and sinks of greenhouse gases in Tanzania, it has been found prudent to examine the nature and magnitude of methane emitted from wastewaters and other sanitary systems. Only municipalities have been considered because of the concentration of population and attendant problems associated with disposal of human waste and wastewater. The task here is to estimate the quantity of sewerage generated per person per year and the resulting methane produced due to human managed biological decomposition. For this purpose, the population is apportioned on the basis of sanitary facilities such as the percentage of sewered population, and unsewered population using pit latrines or flushed toilets connected to septic tanks.

12.6.2 Estimation of sewered population

The population served by existing sanitary facilities is based on 1988 census (14, 15). It was not possible to gather reliable information on length of sewer system. However, Table 12.6 gives estimates of population served by sewer systems being connected to shallow aerobic ponds, stand alone septic tanks, and pit latrines in urban areas for 1990. Population projections based on region specific growth rates on compound basis. Some information in Table 12.7 were also useful.

According to a local census for Dar es Salaam taken in 1988, it is estimated that 12 percent of the population of Dar es Salaam use flush toilets inside houses. About 4.4 percent have outside and shared flush toilets, while 80 to 85 percent use pit latrines (13, 14, 15). Tables 12.8 and 12.9 provide the methodology used to estimate emissions from this source.

Table 12.6: Sanitary system utilization pattern for major urban areas in Tanzania (1990)

Major Towns	Population	Fraction of population served by various sanitary systems			Population served by various sanitary systems		
		Aerobic ponds	Septic tanks	Pit latrines	Aerobic ponds	Septic tanks	Pit latrines
Arusha	145140	0.25	0.17	0.58	36272	24673	84195
Bukoba	49582	0.00	0.20	0.80	0	9916	39665
Dar es Salaam	1494627	0.03	0.16	0.81	50214	243105	121308
Dodoma	213734	0.00	0.25	0.75	0	53433	160301
Iringa	89504	0.00	0.20	0.80	0	17901	71603
Kigoma	89454	0.00	0.20	0.80	0	17891	71563
Lindi	43267	0.00	0.20	0.80	0	8653	34614
Mbeya	162467	0.00	0.20	0.80	0	32494	129974
Morogoro	123963	0.00	0.20	0.80	0	24793	99171
Moshi	100948	0.10	0.30	0.60	10095	30283	60570
Mtwara	78793	0.00	0.20	0.80	0	15759	63034
Musoma	72569	0.00	0.20	0.80	0	14514	58055
Mwanza	234760	0.10	0.30	0.60	22567	71337	140856
Shinyanga	106651	0.00	0.20	0.80	0	21330	85320
Singida	85087	0.00	0.20	0.80	0	17018	68069
Songea	92888	0.00	0.20	0.80	0	18578	74310
Sumbawanga	100052	0.00	0.20	0.80	0	20010	80041
Tabora	98048	0.00	0.20	0.80	0	19610	78438
Tanga	195098	0.13	0.17	0.70	26061	33166	135871
Zanzibar	169842	0.00	0.20	0.80	0	33969	135873
Total	3746474				145209	728433	2872832

Sources: (7, 8, 11, 13)

Notes: (1) With exception of towns with known sanitary system patterns (Table 12.7), unsewered urban centres were assumed to follows the patters of Morogoro and Mbeya.

(2) The whole population was assumed to be served by either of the three sanitary systems regardless the ownership of those systems.

12.6.3 Methane emission estimates from municipal wastewater treatment

Industrial and municipal wastewater with high organic content can emit significant amounts of methane. The principal factor which determines the methane generation potential of wastewater is the amount of organic material in the wastewater stream. The Biological Oxygen Demand (BOD) of the wastewater is main indicator of the methane emission potential of wastewater during its decomposition.

The method used to estimate greenhouse gas emissions (CH_4) is based on the organic material in wastewater. The organic content is multiplied by the fraction of wastewater which is anaerobically treated. The final calculation leads to an estimate of methane emission based on the product of the quantity of BOD_5 anaerobically treated and the emission factor.

Table 12.7: Existing aerobic (shallow) ponds in urban areas in Tanzania

Town	No of Pond system[(a)]	Area (ha)	Population served	Flows[(b)] m^3/day	Remarks
Arusha	1	6.90	33,665	8,470	
Dar es Salaam					
1.Buguruni	1	1.12	1,400	615	(c)
2.Mgulani	1	2.30	13,300	1,937	
3.Msasani	1	10.96	9,500	1,776	
4.Ubungo	1	2.50	5,500	4,211	
5.Ukonga	1	0.70	2,000	475	
6.University	1	3.40	6,000	1,000	
7.Vingunguti	1	4.90	12,500	1,762	
Morogoro	-	4.58	-	-	(d)
Moshi	Biofilter	-	9,684	-	
Mwanza	1	-	21,438	-	
Tanga	-	-	25,000	-	

Source: (7, 11, 13)

Notes: (a) The pond system means the series of ponds from primary facultative to the maturation ponds.

(b) The total flow which enters the pond system.

(c) Buguruni ponds ceased to function in 1986.

(d) Under construction but drawings and other data were not available.

Table 12.8: Estimation of BOD_5 generation by municipal wastewater in urban areas in 1990

Sanitation facility	Population (1990) using sanitary facilities (from Table 12.6)	Average daily BOD_5 generation (kg BOD_5/capita)	Number of days per annum	BOD_5 generation in 1990 (Gg BOD_5)
	A	B	C	D=(AxBxC)/1000
Aerobic ponds	145,209	0.037	365	1.960
Septic tanks	728,433	0.037	365	9.834
Pit latrine	2,872,832	0.037	365	38.783
Total	**3,746,474**			**50.577**

Notes: (1) Default BOD_5 generation, assumed at 0.0135 Gg/1000 persons/year (16).

Table 12.9: Methane emission estimates from municipal waste waters

Sanitary facilities in use	Fraction treated anaerobically	Emission factor ($Gg\ CH_4/Gg\ BOD_5$)		Methane emissions (Gg)	
		country data	default data	using country data	using default data
	E	F	G	H=(DxExF)	I=(DxExG)
Aerobic ponds	0.1	0.0769	0.22	0.015	0.043
Septic tanks	0.1	0.0857	0.22	0.084	0.216
Pit latrines	0.1	0.0227	0.22	0.088	0.853
Total				**0.187**	**1.112**

Notes: (1) Table 12.9 is a continuation of Table 12.8 above.

(2) The methane emission factors used in this study were obtained from experiments conducted in Dar es Salaam.

(3) The results in column H form part of this inventory.

(4) No methane emissions was recovered for domestic or other uses.

The estimation of CH_4 emission from municipal wastewater is made using the relationship (10):-

$$Q_m = [P_o \times C_a \times D_{365} \times Q_g \times F_t \times F_c] - Q_r$$

where

- Q_m is CH_4 emission ($kg\ CH_4/yr$);
- P_o is the served population (by different types of sanitary facilities);
- C_a is per capita daily BOD_5 contribution ($kg\ BOD_5$/capita-day;
- D_{365} is the number of day a year (365 days/yr);
- Q_g is methane generated per kilogramme BOD_5;
- F_t is fraction wastewater treated;
- F_c is methane conversion factor;
- Q_r is quantity of methane recovered ($kg\ CH_4/yr$); and
- BOD_5 is the Biological Oxygen Demand, is a measure of oxygen required by micro-organisms to decompose organic waste. Laboratory analysis of BOD is normally carried out for first five days.

The following parameters are required for the calculation of methane emission from municipal wastewater:-

a) Population: Wastes in the rural areas decompose in an aerobic environment. Therefore CH_4 emission is calculated on the basis of the urban population which uses septic tank and sewer systems.

b) kg BOD_5 per capita per day: For African countries kg BOD per capita per day is 0.037 or 0.0135 Gg per 1000 persons per annum (16).

c) The fraction of total wastewater treated using various treatment methods: In the absence of a known country specific factor a default value of 0.1 has been used (10).

d) The methane conversion factor (F_c) of each treatment method: There is no information on F_cs available for different treatment methods. A default value of 100% is adopted.

Using the above equation, methane emissions from municipal wastewater, flush toilets, and pit latrines for 1990 were estimated and the results are shown in Table 12.9. Pit latrines in rural areas and a number of towns are seldom utilized above 30% of their capacities. The waste treatment process is more aerobic (10), and the magnitude of methane generated is insignificant compared to other sources. For water logged pit latrines in a number of towns, the total of 75.28 Gg BOD_5 is expected to be generated, of which 10 percent is treated anaerobically, liberating about 0.17 Gg CH_4 annually.

It is interesting to note that, experimental results on country emission factors gave low values. For instance, methane emission factor for pit latrines is one-tenth of default emission factor. Further work will be necessary in future to establish such big deviation. For the purpose of this study, the total emissions due to municipal wastewaters treatment are those obtained using default data.

12.6.4 Experimental results

As a first step towards establishing country specific emission factors for wastewater and sanitary systems, it has been found expedient to do practical measurements of emissions since hardly any work has been done in this area before.

A device to collect samples of gases from septic tanks, aerobic ponds, and pit latrines has been fabricated. It has been used to sample and quantify gases collected from:-

a) septic tanks (vent pipe) and inspection chambers without opening;

b) waste stabilisation ponds (shallow aerobic ponds); and

c) drop holes of pit latrines; and vent pipes for ventilated improved pit (VIP) latrines.

Based on the analysis of gas emitted from anaerobic ponds at the University of Dar es Salaam, it has been established that the average amount of methane gas emitted into the atmosphere is 0.0959 $g/m^2/day$. Dar es Salaam has a total surface area of waste stabilisation ponds of 2.28×10^5 m^2. This includes primary facultative ponds, anaerobic ponds and maturation ponds. We assumed that all ponds are capable of producing the same rate of methane. The total methane liberated into the atmosphere in Dar es Salaam is therefore 21.865 kg per day, equivalent to 7.981 tonnes in 1990.

With regard to pit latrines, experiments done in Dar es Salaam indicated that the average methane liberated from a pit latrine is $5.8 \times 10^{-6} g/m^3$ of excreta per day. In Dar es Salaam, the average excreta expected to be generated per year is 1.54 Gg, the equivalent of 1.06×10^6 m^3/year in volume. The amount of methane liberated to the atmosphere in Dar es Salaam, is therefore 6.15 g per day equivalent to 2.245 kg in 1990.

The average amount of methane gas liberated from septic tanks has been found to be 0.028 $g/m^3/day$. With 28,249 m^3/day being the average expected volume of sewage treated by septic tanks in Dar es Salaam in 1990, a total of 791 g CH_4 per day or 288.7 kg CH_4 was released into the atmosphere from this source.

The emission factors for the potential emission from the three sources namely the septic tank, the anaerobic ponds, and the pit latrines have been found to be 0.0857 Gg CH_4/Gg BOD_5, 0.0769 Gg CH_4/Gg BOD_5 and 0.0227 Gg CH_4/Gg BOD_5, respectively. Ultimate Biological Oxygen Demand (BOD_u) is the measure of the total amount of oxygen required by micro-organisms to decompose organic material. However, the actual emission is much smaller reflecting dissolution, breakdown of gas by bacteria, etc. The generation of methane and carbon dioxide from pit latrines, ponds and septic tanks depends on many factors which include, temperature, toxicity, population of methanogenic bacteria, and other environmental factors. Experimental results for Dar es Salaam are representative of the coastal regions of Tanga, Lindi, Mtwara, and Coast.

12.6.5 Estimation of methane from industrial wastewater treatment

The principal factor which determines the methane generation potential of industrial wastewater treatment is the amount of organic material in the wastewater stream. This is indicated by the Biological Oxygen Demand (BOD) of the wastewater. Treatment of industrial wastewater under anaerobic conditions results into methane emission.

The methodology used to produce estimates of methane emission from industrial wastewater treatment is based on the BOD loading and other specific parameters like amount of industrial wastewater discharged. Wastewater discharged (outflow by industries) is estimated on the basis of either production figures or water consumed.

Default values of the BOD content of wastewater for each industry are borrowed from IPCC. A value of 0.1 as the fraction of industrial wastewater treated anaerobically is used to estimate methane emissions (10).

Table 12.10: BOD_5 loading from industrial wastewaters (in Gg BOD_5 per year)

Sector specific data by industry type	1990	1991	1992	1993
Mwanza Textile	3.05	2.61	1.74	1.31
Musoma Textile	0.35	0.47	0.82	1.06
Urafiki Textile	0.37	0.50	0.87	1.13
SPM Mufindi	49.50	88.20	21.80	16.40
Kilombero Sugar (K2)	0.58	0.77	-	-
Morogoro Complex treatment plant	0.51	0.68	1.20	1.76
Total	**54.36**	**93.23**	**26.43**	**21.66**

Source: (9)

The following equation was used to estimate methane emission from industrial wastewater (10). The results are summarized in Tables 12.11 and 12.12:-

$$Q_m = (Q_w \times BOD_{5_f} \times E_f \times F_t) - Q_r$$

where

Q_m is the quantity of methane emitted annually in Gg
Q_w is the wastewater discharged by industries in million litres
BOD_{5f} is the BOD_5 concentration in kg per litre
E_f is the methane emission factor estimated at 0.22 kg CH_4 per kg BOD_5
F_t is the fraction wastewater treated anaerobically, estimated at 0.1
Q_r is the methane recovered for economical use (which is zero in this case).

Table 12.11: BOD_5 loading estimates to industrial wastewaters treatment systems

Sector specific data by industry type	Annual wastewater outflow (million litres)	BOD_5 concentration in wastewater (kg BOD_5 per litre)	Total BOD_5 loading (Gg/yr)
	A	B	C=AxB
Mwanza Textile	3050.25	0.001	3.05
Musoma Textile	350.40	0.001	0.35
Urafiki Textile	372.30	0.001	0.37
SPM Mufindi	12375.00	0.004	49.50
Kilombero Sugar (K2)	291.00	0.002	0.58
Morogoro Complex treatment plant	256.96	0.002	0.51
Total	**16695.91**		**54.36**

Source: (16, 17)

Notes: (1) Morogoro industrial complex wastewater treatment plant receives wastewater from polytex, tanneries and the canvas mill. The plant was commissioned in early 1987.

Table 12.11: Methane emissions from industrial wastewaters treatment

Sector specific data by industry type	Emission factor (Gg CH_4/Gg BOD_5)	Fraction treated anaerobically	Methane emissions (Gg)
	D	E	F=CxDxE
Mwanza Textile	0.22	0.1	0.067
Musoma Textile	0.22	0.1	0.008
Urafiki Textile	0.22	0.1	0.008
SPM Mufindi	0.22	0.1	1.089
Kilombero Sugar (K2)	0.22	0.1	0.013
Morogoro Complex treatment plant	0.22	0.1	0.011
Total			**1.196**

There are very few industries in Tanzania which have incorporated facilities for treating the wastewater they generate. Industrial wastewater is haphazardly discharged into nearby streams, rivers and lakes. For the few industries which have incorporated systems for treating wastewater, many of the treatment facilities are not operating. The waste water treatment plants were either not completed or they have broken down. None of those working have methane recovery systems. Table 12.13 summarizes the greenhouse gas emissions from waste management by sources.

Table 12.13: Summary of greenhouse emissions from waste management in 1990

Sector specific data by source	Methane emission (Gg)
Municipal solid waste	8.363
Solid waste from other sources	33.108
Municipal waste waters	1.112
Industrial waste waters	1.196
Total	**43.779**

12.7 Discussion

The results in Table 12.13 are on the lower side due to poor performance of waste collection, treatment, and disposal in environmentally sound manner. For many years, municipal solid waste and wastewaters management have been considered as one of public services to be rendered by local governments. Recently, endeavours have been made by some local governments to commercialize waste management business. There is a lot to be done in this sector, ranging from establishing reliable database on waste generation, commercializing collection and treatment of wastes, to recovery of methane from this source.

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13. CONCLUSIONS

Work done thus for in the creation of an inventory of greenhouse gas emission in Tanzania should be seen in a wider context of global efforts to understand the complexities of climate change. It provides a basis upon which further studies can be done, especially those that relate to mitigation options and the assessment of vulnerability of the country to climate change. To policy makers, the study should throw some light into linkages that exist between climate variability and development, in particular how anthropogenic activities influence the concentration of atmospheric gases and ultimately the climate itself. There is a need therefore to factor in climate change considerations in development policies in order to limit economic and social vulnerability.

The study on the creation of an inventory of sources and sinks in Tanzania cannot be considered to have come to an end. On the contrary it has provided a basis for future work including that of regular reviews and updates of the same. The study has also identified a number of areas on which further work needs to be done. Some of these gaps are itemized below as follows:-

Burning of traditional biomass

- cottage industry and informal sector were not adequately covered;
- biomass energy transformation systems need to be revisited;
- the present methodology need to be modified, and collected data need to be updated.
- the use of biomass in boilers emphasize the need to study further the corresponding emission factors.

Stationary combustion

- Emission factors are based on IPCC default values;
- pumping stations belonging to Tazama Pipelines have not been covered;
- the survey did not cover all industries; and
- there is a need to go beyond greenhouse gas emissions and link this work with pollution in industries in general.

Mobile combustion

- data on transportation is unreliable. Sources of statistics are dispersed and the information lacks details;
- emission factors used are based on default values suggested by IPCC; and
- regular surveys and emission monitoring by vehicle and fuel type are necessary.

Agriculture

- there is need to study parameters that determine the rate of emission of methane from rice production in Tanzania;

- the emission factor used is based on rice cultivation elsewhere. Country or even regional specific emission factors should be established;

- only three crops have been considered as being responsible for emissions resulting from their wastes; and

- the emission factor used for enteric fermentation and animal waste are borrowed from IPCC.

Forestry and Land-use Changes

- there is need to establish a mechanism to monitor and quantify land-use changes over time;

- detailed information on land-use, when obtained is extremely site specific;

- there is need to validate many of the assumptions made on forest clearing;

- it is necessary to reorient the IPCC classifications to tropical forestry classifications;

- information on forest use/logging not properly recorded. Gaps exist and the information is open to differing interpretation;

- fuelwood use still a grey area; and

- link land-use planning, management, implementation of projects/programmes and emissions.

Municipal wastes and wastewater management

- the quantities of emissions from this sector have been obtained for Dar es salaam only. In the case of waste water ponds say, taken refer to those of the University of Dar es Salaam ponds. Furthermore samples were collected only for a short period of time;

- in the case of industrial wastewater, the emission factors are based on default values provided by IPCC; and

- above all there is a need to relate emissions and wastewater management.

13.1 Technical conclusions

By way of summary, scientific assessment by IPCC points out that there is a change in climate over along time. The link between enhanced greenhouse effect, global warming and anthropogenic activities has been underscored. Activities on mitigation of greenhouse gas emission are now being carried out at global and national levels guided by the principles outlined in the UNFCCC.

This study presents results of work carried out to determine sources and sinks of greenhouse gases in Tanzania. The results as shown in Table 13.1 indicate that land use changes and forestry and the energy sector contribute the largest share of greenhouse gas emissions in Tanzania.

Results obtained are based mainly on default emission factors. There is need for more research to establish country-specific emission factors especially in agriculture, livestock and land-use sectors.

13.2 Policy conclusions

It is generally accepted by the scientific community that issues surrounding climate change and climate vulnerability are complex and that present knowledge must be improved upon in order to reduce the uncertainty which could hamper policy formulation. In respect of Tanzania, and as shown above, studies are being undertaken to improve the knowledge level in order to allow for policy formulation. Even at this early stage a number of policy related issues emerge.

In countries that are beset with numerous developmental problems the issue of relevance of atmospheric changes and their impacts cannot be ignored. However, it has been shown that it is precisely because of the inability of developing countries to respond to even the slightest charges or variations, that priority must be accorded to the understanding of linkages between climate change and climate variation and development.

Climate variation is perhaps easier to appreciate because its impacts are felt in the short term. Floods and droughts are an example. Developing countries by and large have agricultural based economies relying mostly on rain-fed agriculture. The amounts, temporal and spatial distribution of rainfall are critical to agriculture. Crops are temperature dependent. Any change in atmospheric temperatures will affect negatively or positively crop production. There is need therefore to recognize, in policy formulation, the cross-sectoral linkages and exploit synergies so that climate variation does not hinder development. Climate change is not easy to discern in the short run. Increases in sea levels by a few centimeters may take a century. For sustainable development, a concept which takes into account intergenerational equity, the international community has decided to take preventive and precautionary measures to mitigate emission levels of greenhouse gases and to encourage and support studies and actions on assessment of vulnerability, and adaptation to climate change.

Instruments or agents for effecting policy in climate change and climate variation include institutions to implement policies and the medium of transmission of policies, plans, and knowledge in the subject matter. Awareness creation on issues of climate change and atmospheric protection has been underscored.

International and bilateral cooperation is increasingly evolving around issues of environmental protection including protection of the atmosphere. Mechanisms such as the Global Environment Facility and Joint Implementation in respect of the UNFCCC and the Multilateral Fund in respect of the Montreal Protocol will become new avenues of cooperation on issues such as research, exchange of information, transfer of technology and as channels for new investment.

Tanzania has signed the UNFCCC and is a Party to Montreal Protocol. It is strongly recommended that Tanzania ratifies the UNFCCC as soon as possible.

Table 13.1 Summary report on inventory of greenhouse gas emissions and removals (Gg) for 1990

Greenhouse gas source and sink categories	CO_2 emissions	CO_2 removals	CH_4 emissions	NO_x emissions	N_2O emissions	CO emissions
1.Energy *Sub-total (1)*	***1940.236***	***NA***	***425.828***	***67.955***	***1.9358***	***1628.876***
A. Fuel combustion[1]	1938.976	NA	NA	NA	NA	NA
i. Stationary combustion in industry	NA	NA	0.207	4.021	0.0005	26.434
ii. Thermal power generation plants	NA	NA	0.010	0.916	0.0019	0.634
iii.Mobile combustion activities	NA	NA	0.291	8.719	0.0248	51.805
iv. Others (fossil fuels in households)	NA	NA	0.018	0.189	NA	0.003
v. Traditional biomass energy	NA	NA	424.481	54.110	1.9086	1550.000
B. Fugitive emissions from fuels						
i. Coal activities	NA	NA	0.821	NA	NA	NA
ii. Natural occurring exploited gases	1.260	NA	NA	NA	NA	NA
2.Industrial processes *Sub-total (2)*	***349.421***	***NE***	***NA***	***NA***	***NA***	***NA***
A. Non-metal processes (cement)	343.634	NE	NA	NA	NA	NA
B. Non-mineral processes (pulp + paper)	5.787	NE	NA	NA	NA	NA
3.Agriculture *Sub-total (3)*	***NA***	***NA***	***1335.915***	***42.118***	***1.7323***	***2308.873***
A. Rice cultivation	NA	NA	84.756	NA	NA	NA
B. Enteric fermentation	NA	NA	872.275	NA	NA	NA
C. Manure management	NA	NA	8.057	NA	NA	NA
D. Nitrogenous fertilizers	NA	NA	NA	NA	0.5673	NA
E. Burning of agricultural residues	NA	NA	323.002	20.728	0.5730	1053.477
F. Burning of Savannas	NA	NA	47.825	21.390	0.5920	1255.396
4.Landuse and Forestry *Sub-total (4)*	***56664.570***	***3745.270***	***3.602***	***0.756***	***0.0220***	***31.331***
A. Forest clearing for agricultural lands	727.060	NA	2.483	0.617	0.0170	27.158
B. Abandonment of managed lands	NA	1930.500	NA	NA	NA	NA
C. Forests subject to human activities	55937.510	1814,770	NA	NA	NA	NA
D. Others (Shifting cultivation + Dams)	NA	NA	0.579	0.139	0.0050	4.173
5.Waste Management *Sub-total (5)*	***NA***	***NA***	***43.779***	***NA***	***NA***	***NA***
A. Municipal Solid Waste disposal	NA	NA	8.363	NA	NA	NA
B. Waste water treatment	NA	NA	2.308	NA	NA	NA
C. Others (Industrial waste management)	NA	NA	33.108	NA	NA	NA
GRAND TOTAL	**58954.227**	**3745.270**	**1809.124**	**110.829**	**3.6901**	**3969.080**

Notes: (1) CO_2 estimates was obtained by "top-down" approach from Chapter 2. Technology based approach gives slightly higher estimates by up-to 10%.
(2) NA and NE refer to "not applicable" and "not estimated", respectively.
(3) Some figures are slightly higher or lower by up to 0.25 Gg due to rounding-off of results at various stages during the calculations.

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Government of the United Republic of Tanzania
United Nations Environment Programme (UNEP)
Organisation for Economic Cooperation and Development (OECD)
Intergovernmental Panel on Climate Change (IPCC)
Global Environment Facility (GEF)

SOURCES AND SINKS OF GREENHOUSE GASES IN TANZANIA

Volume II : Revised Standard Data Tables

February, 1996

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LIST OF TABLES

ACKNOWLEDGEMENT

This report is an Annex to the submission of the United Republic of Tanzania Final Report on Country Case Study on Sources and Sinks of Greenhouse Gases (CEEST Report No: 5/1994), which is referred to herein as the main document submitted to the United Nations Environment Programme (UNEP) in November, 1994. Both the main document (Volume I) and its annex (Volume II) have been reviewed and reconciliated.

The main document provides the detailed background, calculation procedures, and the conclusions. The Annex summarises the numerical results of the 1990 Greenhouse Gases inventory by the application of the Intergovernmental Panel on Climate Change (IPCC) Guidelines for Reporting National Greenhouse Gas Emissions Inventories as given in Volume 1, 2 and 3 of the IPCC Guidelines Workbooks (1995) and as commented by the Organisation for Economic Cooperation and Development (OECD). The Annex, however, should be read in conjunction with the main document for better understanding.

The study on Greenhouse Gas Emissions in Tanzania was done by a team under the leadership of Prof. Mark J. Mwandosya and Prof. Matthew Luhanga. The study was carried out by the Centre for Energy, Environment, Science and Technology (CEEST) on behalf of the Department of Environment of the Ministry of Tourism, Natural Resources and Environment. The support that CEEST received from the Ministry of Tourism, Natural Resources and Environment and especially from the Director and staff of the Department of Environment contributed in no small measure to the completion of the task assigned to CEEST.

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1.0 INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) to which Tanzania is a signatory requires countries that ratify the Convention to communicate to the Conference of Parties (CoP) to the Convention information regarding human indicated emissions by sources and removal by sinks of greenhouse gases. The gases in question are those that have not been covered by the montreal Protocol. Tanzania is also a signatory to and has ratified the Montreal Protocol. The Montreal Protocol is a follow up of the 1985 Vienna Convention on Substances that Deplete the Ozone Layer. The Montreal Protocol of 1987 has called on Parties to the Protocol to freeze consumption of Ozone Depleting Substances (ODSs) at level of 1986 by July 1989, and to phase out these as soon as possible but not later than the year 2000.

In order to prepare an inventory of emission by sources and removal by sinks of greenhouse gases (GHG), and with the benefit of grants from the United nations Environment Programme (UNEP) and from the international Development Research Centre of Canada (IDRC) to the Government and to the University of Dar es Salaam, respectively, a team of researchers was organised under the auspices of the Centre for Energy, Environment, Science and Technology (CEEST). CEEST is a Dar es Salaam-based non-governmental organisation that undertakes research and various studies related to energy, the environment, technology and science, water and sanitation, and natural resource use and management.

This report, which is an annex to the main document (CEEST No. 5/1994) is organised in the following seven chapters:-

i) Introduction,
ii) Energy,
iii) Industrial Processes,
iv) Agriculture,
v) Land use change and Forestry,
vi) Waste management, and
vii) Conclusions and Recommendations.

Some greenhouse sources and sinks in this report are grouped in different manner compared to those in the main document, but the end results are the same.

The success of the study is the results of collaborative effort of various institutions including:- the Ministry of Tourism, Natural Resources and Environment (MTNRE); the National Environment Management Council (NEMC); the Directorate of Meteorology (DoM); the Ministry of Water, Energy and Minerals (MWEM); the University of Dar es Salaam (UDSM); and the Centre for Energy, Environment, Science and Technology (CEEST); with the Department of Environment (DoE) of MTNRE being the lead agency.

The results using the IPCC Guidelines are summarised in the following chapters. In the Summary Tables 7A and 7B of the National Greenhouse Gases Emissions by sources and removal by sinks, land use changes and forestry and the energy sector have been singled out to contribute the largest share of greenhouse gas emissions in Tanzania.

2.0 ENERGY

2.1 Emissions from fuel combustion

Two approaches are useful in estimation of greenhouse gas emissions. One of these are "top-down" or mass balance approach, where of calculations depends on properties and characteristics of fuels. The second one is the "bottom-up" approach, which depends on types of technologies practiced. Discussions on input data, methodologies, approaches, calculation procedures and results, as well as background information are detailed in Chapters 2, 3, 4, 5 and 6 of the main document.

2.1.1 Carbon dioxide emissions from fossil fuels

Carbon dioxide emissions from all energy activities are estimated based on mass balances with few adjustments based on properties and characteristics of the fuel consumed. The "top-down" approach is used as a reference approach so as to avoid double counting. Standard Data Table 1A consisting of Sheets 1 to 5 of Worksheet 1-1 provides the minimum data necessary for carbon dioxide emissions re-calculation.

2.1.2 Emissions from stationary combustion in industry (ISIC)

Emissions of greenhouse gases from the industrial sector is based on the study of energy use in the various sub-sectors classified according to the industrial standard industrial classification system namely; food; beverage and tobacco; textile, leather and sisal; metal and engineering; chemical; wood products and printing; and non-metal mineral products.

Emission estimates are based on the relationship between energy input into an activity and the emission per unit of energy input (the emission factor). These two parameters are based on the type of fuel, the nature of the activity, and the technology used such as the boiler, kiln and the furnace. Sheets 5 to 7 of the Standard Data Table 1A provide minimum data required to establish the emissions inventory for 1990.

2.1.3 Emissions from thermal power generation plants

Special consideration has been given to emission from thermal power generation although they are in effect similar to stationary combustion processes of heavy-duty mobile, high speed medium controlled diesel engines. The total consumption of fuel for power generation has been obtained from TANESCO and emissions from thermal power plants for 1990 have been estimated. Sheet 4 of Standard Data Table 1A refers.

2.1.4 Emissions from transportation activities

Emission of greenhouse gases from the transport sector has been estimated by considering state of the transport sector including the modes of transport, the types of fuel used by the various modes, the vehicle types and the amount of energy consumed. All motor vehicles imported into Tanzania are emission-uncontrolled. International bunkers are not considered here. Sheets 8, 9, and 14 of Standard Data Table 1A outline different modes of transportation. Sheets 13 and 15 of Standard Data Table 1A outline emissions estimates from mobile farm and construction equipment, respectively.

2.1.5 Emissions from cottage industries, household and informal sectors

The study has also resulted into an estimate of greenhouse gases emission from cottage industries. These include small scale food processing industries like brewing, fish smoking, salt production, banking, small restaurants and food vending. Other collage industries include tobacco curing, tea drying, beeswax processing, burnt brick making, lime production, smithies, foundries, pottery and other ceramics. Sheets 11 and 16 of Standard Data Table 1A provide calculation workings for fossil and traditional fuels.

Biomass energy accounts for almost 90 percent of primary energy demand in the country. An attempt has been made to examine greenhouse gas emission arising out of biomass in households and in the commercial and informal sectors. In the case of woodfuels the approach here is to estimate total biomass use on the basis of which trace gas emissions are estimated using emission ratios. In the case of fossil fuel use, again the approach is to estimate trace gas emissions, with carbon dioxide emission being accounted for from the supply side using the "top-down" approach.

In estimating biomass demand is the country, use is made of the results of an urban energy use study for urban energy demand, and results of various rural biomass energy use. Carbon dioxide emission is considered as part of emissions from land-use changes, with emissions from off-site burning from the conversion of forests for permanent upland being netted-off to avoid double counting because these have been taken into account in the total biomass supply. Sheet 2 of Standard Data Table 1A is the summary of group summaries consisting of Sheets 3, 5, 8, 10, 15, and 16.

2.2 Fugitive fuel emissions

In the mining sector emissions have been estimated from coal mining activities and exploitation of carbon dioxide. In the case of coal and mining, methane emission has been estimated from the ventilation system, degasification activities and post-mining operations of the Kiwira coal mine and the Ilima colliery. The production of carbon dioxide at Kyejo is a human-induced activity and the output of the plant is assumed to finally end up as an emission in the year of production. Fugitive fuel emissions are shown in Standard Data Table 1A consisting of Sheet 1B1. Discussions and calculation procedures are detailed in Chapters 7 and 8 of the main document.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 1) - IPCC Reference Approach

		MODULE	ENERGY					
		SUBMODULE	CO2 FROM ENERGY SOURCES (REFERENCE APPROACH)					
		WORKSHEET	1-1					
		SHEET	1 OF 5					
			STEP 1					
FUEL TYPES			A Production kt	B Imports kt	C Exports kt	D International Bunkers kt	E Stock Change kt	F Apparent Consumption kt F=(A+B-C-D-E)
Liquid Fossil	Primary Fuel	Crude Oil	NA	495.777	0.000		52.375	443.402
		Natural Gas Liquids	NA	NA	NA		NA	NA
	Secondary Fuel	Gasoline		42.497	0.000	0.000	7.203	35.294
		Jet Kerosene		69.252	0.000	19.377	19.076	30.799
		Other kerosene		50.535	0.000	0.000	0.000	50.535
		Gas/Diesel oil		282.112	0.000	8.841	49.000	224.271
		Residual Fuel Oil		NA	58.593	8.358	99.580	-166.531
		LPG		0.606	0.000		0.000	0.606
		Ethane		NA	NA		NA	NA
		Naphtha		NA	NA		NA	NA
		Bitumen		10.000	0.000		0.000	10.000
		Lubricants		3.000	0.000	0.000	0.000	3.000
Liquid Fossil Totals			***NA***	***953.779***	***58.593***	***36.577***	***227.234***	***631.375***
Solid Fossil	Primary Fuel	Sub-bituminous Coal	60.261	22.000	0.000	0.000	0.000	82.261
Solid Fossil Totals			***60.261***	***22.000***	***0.000***	***0.000***	***0.000***	***82.261***
Gaseous Fossil	Primary Fuel	Natural Gas (Dry)	NO	NO	NO		NO	NO
Traditional Biofuel	Primary Fuel	Solid Woody Biomass	36182.904				0.000	36182.904
		Animal Dung	97.000				0.000	97.000
		Agricultural Waste	5990.672				0.000	5990.672

Notes:

(1) NA refers to "not applicable"

(2) Grey shaded blocks refer to "not considered"

(3) NO refers to "not occuring" as neither exploration nor production occured in 1990.

(4) Traditional biofuel consumption figures are obtained by summing-up values in Tables 3.8 and 6.6 of the main document (CEEST No.5/1994).

(5) Stock change in 1990 was strategically on high side to hedge the country's normal petroleum supplies against any Gulf War related interruption.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 1) - IPCC Reference Approach

		MODULE	ENERGY				
		SUBMODULE	CO2 FROM ENERGY SOURCES (REFERENCE APPROACH)				
		WORKSHEET	1-1				
		SHEET	2 OF 5				
			STEP 2		STEP 3		
			G Conversion Factor (TJ/kt)	H Apparent Consumption (TJ)	I Carbon Emission Factor (t-C/TJ)	J Carbon Content (tC)	K Carbon Content (GgC)
	FUEL TYPES			H=(FxG)		J=(HxI)	K=(Jx10E-3)
Liquid Fossil	Primary Fuel	Crude Oil	42.6200	18897.7780	20.0000	377955.5605	377.9556
		Natural Gas Liquids	NA	NA	NA	NA	NA
	Secondary Fuel	Gasoline	44.8000	1581.1712	18.9000	29884.1357	29.8841
		Jet Kerosene	44.5900	1373.3118	19.5000	26779.5802	26.7796
		Other kerosene	44.7500	2261.4413	19.6000	44324.2485	44.3242
		Gas/Diesel oil	43.3300	9717.6624	20.2000	196296.7811	196.2968
		Residual Fuel Oil	40.1900	-6692.8950	21.1000	-141220.0836	-141.2201
		LPG	47.3100	28.6699	17.2000	493.1216	0.4931
		Ethane	NA	NA	NA	NA	NA
		Naphtha	NA	NA	NA	NA	NA
		Bitumen	40.1900	401.9000	22.0000	8841.8000	8.8418
		Lubricants	40.1900	120.5700	20.0000	2411.4000	2.4114
Liquid Fossil Totals				***27689.6096***			***545.7665***
Solid Fossil	Primary Fuel	Sub-bituminous Coal	28.0000	2303.3192	26.2000	60346.9630	60.3470
Solid Fossil Totals				***2303.3192***			***60.3470***
Gaseous Fossil	Primary Fuel	Natural Gas (Dry)	NO	NO	NO	NO	NO
Total (Liquid+Solid Fossils)				***29992.9288***			***606.1135***
Traditional Biofuel	Primary Fuel	Solid Woody Biomass	18.5000	669383.7240	29.9000	20014573.3476	20014.5733
		Animal Dung	10.1000	979.7000	30.0000	29391.0000	29.3910
		Agricultural Waste	8.6000	51519.7792	30.0000	1545593.3760	1545.5934
Traditional Biofuel Totals				***721883.2032***			***21589.5577***

Notes:

(1) NA refers to "not applicable"
(2) Grey shaded blocks refer to "not considered"
(3) NO refers to "not occuring" as neither exploration nor production occured in 1990.
(4) Carbon dioxide emissions from traditional biofuels do not directly form part of reported figures in Tables 7A1 and 7A2.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 1) - IPCC Reference Approach

		MODULE	ENERGY				
		SUBMODULE	CO2 FROM ENERGY SOURCES (REFERENCE APPROACH)				
		WORKSHEET	1-1				
		SHEET	3 OF 5				
			STEP 4		STEP 5		STEP 6
			L Carbon Stored (GgC)	M Net Carbon Emissions (GgC)	N Fraction of Carbon Oxidised	O Actual Carbon Emissions (GgC)	P Actual CO2 Emissions (GgCO2)
	FUEL TYPES			M=(K-L)		O=(MxN)	P=(Ox[44/12])
Liquid Fossil	Primary Fuel	Crude Oil	37.7956	340.1600	0.9900	336.7584	1234.7808
		Natural Gas Liquids	NA	NA	NA	NA	NA
	Secondary Fuel	Gasoline	0.2988	29.5853	0.9900	29.2894	107.3946
		Jet Kerosene	0.2678	26.5118	0.9900	26.2467	96.2378
		Other kerosene	0.8865	43.4378	0.9900	43.0034	157.6791
		Gas/Diesel oil	5.8889	190.4079	0.9900	188.5038	691.1806
		Residual Fuel Oil	-1.4122	-139.8079	0.9900	-138.4098	-507.5026
		LPG	0.1972	0.2959	0.9900	0.2929	1.0740
		Ethane	NA	NA	NA	NA	NA
		Naphtha	NA	NA	NA	NA	NA
		Bitumen	8.7534	0.0884	0.9900	0.0875	0.3210
		Lubricants	2.3873	0.0241	0.9900	0.0239	0.0875
Liquid Fossil Totals			***55.0633***	***490.7032***		***485.7962***	***1781.2528***
Solid Fossil	Primary Fuel	Sub-bituminous Coal	16.8971	43.4498	0.9900	43.0153	157.7228
Solid Fossil Totals			***16.8971***	***43.4498***		***43.0153***	***157.7228***
Gaseous Fossil	Primary Fuel	Natural Gas (Dry)	NO	NO	NO	NO	NO
Liquid, Solid and Gaseous (Fossil fuels) Totals			***71.9604***	***534.1531***		***528.8115***	***1938.9756***
Traditional Biofuel	Primary fuel	Solid Woody Biomass	1000.7287	19013.8447	0.9900	18823.7062	69020.2562
		Animal Dung	0.5878	28.8032	0.9900	28.5151	104.5555
		Agricultural Waste	30.9119	1514.6815	0.9900	1499.5347	5498.2939
Traditional Biofuel Totals			***1032.2284***	***20557.3294***		***20351.7561***	***74623.1056***

Notes:
(1) NA refers to "not applicable"
(2) Grey shaded blocks refer to "not considered"
(3) NO refers to "not occuring" as neither exploration nor production occured in 1990.
(4) Amounts of carbon stored (column L above) are calculated from (column K of Table 2.2, page 6) of the main document (CEEST No. 5/1994).

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 1) - IPCC Reference Approach

MODULE	ENERGY
SUBMODULE	CO2 FROM ENERGY SOURCES (REFERENCE APPROACH)
WORKSHEET	1-1
SHEET	4 OF 5 EMISSIONS FROM INTERNATIONAL BUNKERS (INTERNATIONAL MARINE AND AIR TRANSPORT)

	STEP 1	STEP 2			STEP 3	
	A Quantities Delivered kt	B Conversion Factor (TJ/kt)	C Quantities Delivered (TJ)	D Carbon Emission Factors (tC/TJ)	E Carbon Content (tC)	F Carbon Content (GgC)
FUEL TYPES			C=(AxB)		E=(CxD)	F=(Ex10E-3)
Jet Kerosene	19.3774	44.5900	864.0360	19.5000	16848.7027	16.8487
Gas/Diesel oil	8.8410	43.3300	383.0805	20.2000	7738.2267	7.7382
Residual Fuel Oil	8.3584	40.1900	335.9221	21.1000	7087.9560	7.0880
		Total	**1583.0387**		**31674.8854**	**31.6749**

MODULE	ENERGY
SUBMODULE	CO2 FROM ENERGY SOURCES (REFERENCE APPROACH)
WORKSHEET	1-1
SHEET	5 OF 5 EMISSIONS FROM INTERNATIONAL BUNKERS (INTERNATIONAL MARINE AND AIR TRANSPORT)

	STEP 4			STEP 5		STEP 6
	G Fraction of Carbon Stored	H Carbon Stored (GgC)	I Net Carbon Emissions (GgC)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (GgC)	L Actual CO2 Emissions (GgCO2)
FUEL TYPES	G	H=(FxG)	I=(F-H)		K=(IxJ)	L=(Kx[44/12])
Jet Kerosene	0.0100	0.1685	16.6802	0.99	16.5134	60.5492
Gas/Diesel oil	0.0300	0.2321	7.5061	0.99	7.4310	27.2471
Residual Fuel Oil	0.0100	0.0709	7.0171	0.99	6.9469	25.4720
					Total	**113.2682**

Notes:

(1) NA refers to "not applicable"

(2) Grey shaded blocks refer to "not considered"

(3) NO refers to "not occuring".

(4) Carbon dioxide emissions from international bunkers do not from part of the reported figures in Tables 7A1 and 7A2

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 2) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tPollutant/TJ) C=B/A					
		CO_2	CH_4	N_2O	NO_x	CO	NMVOC	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
1A Fuel Combustion Activities													
1A1 Energy Transformation	19.84	222.66	0.207	0.0020	3.02	26.79	0.13	11.22	0.010	0.0001	0.15	1.35	0.007
1A2 Industry (ISIC)	5.89	410.36	0.010	0.0004	1.92	0.27	NA	69.71	0.002	0.0001	0.33	0.05	NA
1A3 Transport	14.03	1007.33	0.283	0.0220	6.75	51.17	7.06	71.79	0.020	0.0016	0.48	3.65	0.503
1A4 Small Combustion	3.91	277.68	0.020	0.0004	0.46	0.15	0.04	71.07	0.005	0.0001	0.12	0.04	0.010
1A5 Other Modes	1.42	103.73	0.006	0.0028	1.70	0.54	0.13	73.31	0.004	0.0020	1.20	0.38	0.090
1A16 Traditional Biofuel	705.54	NA	424.481	1.9086	54.11	1550.00	NE	NA	0.60	0.0027	0.08	2.20	NE
Total	***750.62***	***2021.76***	***425.01***	***1.94***	***67.96***	***1628.92***	***7.36***						

Notes:
(1) This sheet is a summary of Sheets No. 3, 7, 8, 10, 15, and 16, respectively.
(2) This summary covers Chapters 3, 4, 5, and 6 of the main document (CEEST No. 5/1994).
(3) Carbon dioxide emissions from burning of traditional biofuels (say in 1A1 Sheet No. 6) in industries, as they fall in a closed cycle.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 3) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tPollutant/TJ) C=B/A					
		CO_2	CH_4	N_2O	NO_x	CO	NMVOC	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
1A1 Energy Transformation													
1A1a Electricity and Heat Production	1.01	73.79	0.010	0.00200	0.92	0.63	0.131	73.3	0.010	0.001986	0.91	0.63	0.130
1A1b Petroleum Refining	1.45	95.64	0.002	0.00005	0.09	0.02	NA	65.9	0.001	0.000034	0.06	0.02	NA
1A1c Solid Fuel Transformation	17.38	53.24	0.195	0.00008	2.01	26.14	NA	3.1	0.011	0.000004	0.12	1.50	NA
Total	***19.84***	***222.66***	***0.207***	***0.002***	***3.02***	***26.80***	***0.131***						

Notes:
(1) This is a summary sheet of Sheets No. 4, 5, and 6, respectively.
(2) Some figures do not necessarily add to exact totals simply because they are truncated figures.
(3) Chapters 3 and 4 (CEEST No. 5/1994) provide the inputs to these sheets.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 4) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DAT	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tPollutant/TJ) C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1A1a Electricity and Heat Production													
i Industrial Diesel Oil	1.0065	73.779	0.010	0.0019124	0.9159	0.634116	0.1308	73.3	0.01	0.0019	0.91	0.630	0.130
ii Lubricants	0.0001	0.007	NA	0.0000002	0.0002	0.000004	NA	77.4	NA	0.0020	2.10	0.046	NA
Total	***1.007***	***73.786***	***0.010***	***0.002***	***0.916***	***0.634***	***0.131***						

Notes:

(1) Industrial Diesel Oil (IDO) used in power generation is a mixture of 3% Fuel Oil (FO) and 97% Gas Oil (GO).

(2) Some (about 10%) of lubricants are assumed to be trapped in fuel system and eventually burned. However, the effect is less significant.

(3) Input data are found in Chapter 4 of CEEST No. 5/1994.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 5) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tPollutant/TJ) C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1A1b Petroleum Refining													
i Fuel Oil Boilers	0.153	10.68	0.00044	0.0000092	0.0247	0.0023	NA	69.70	0.0029	0.00006	0.161	0.015	NA
ii Fuel Oil Furnaces	0.538	37.47	0.00027	0.0000323	0.0274	0.0070	NA	69.70	0.0005	0.00006	0.051	0.013	NA
iii LPG Furnaces	0.010	0.65	0.00001	0.0000001	0.0005	0.0001	NA	62.44	0.0011	0.00001	0.047	0.010	NA
iv Fuel Gas Furnaces	0.750	46.83	0.00083	0.0000075	0.0375	0.0143	NA	62.44	0.0011	0.00001	0.050	0.019	NA
Total	*1.451*	*95.635*	*0.00155*	*0.00005*	*0.090*	*0.0236*	*NA*						

Notes:
(1) Fuel gas has properties very close to propane/butane (LPG).
(2) NA refers to "not applicable"
(3) These emissions are the result of flaring combusted gases during the petroleum refining process.
(4) Input data and the methodology are found in Tables 3.9 to 3.11 (Chapter 3 of CEEST No. 5/1994).

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 6) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES					AGGREGATE EMISSION FACTORS				
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)					C Emission Factors (t Pollutant/TJ) C=B/A				
		CO2	CH4	N2O	NOx	CO	CO2	CH4	N2O	NOx	CO
1A1c Solid Fuel Transformation											
a Food, Beverages and Tobacco											
i Woodfuel Furnaces	12.4575	NA	0.186862	NA	1.4326	18.7361	NA	0.015	NA	0.115	1.504
ii Woodfuel Boilers	0.1293	NA	0.001940	NA	0.0149	0.1945	NA	0.015	NA	0.115	1.504
iii Bagasse Boilers	3.8966	NA	NA	NA	0.3429	6.6475	NA	NA	NA	0.088	1.706
b Textile, Leather and Sisal											
i Sub-bituminous Coal Boilers	0.0015	0.142	0.000004	0.0000002	0.0005	0.0001	95	0.0024	0.0001	0.329	0.093
c Metal and Engineering											
i Coke Furnace	0.0005	0.045	0.000001	0.0000001	0.0001	0.0002	95	0.0024	0.0001	0.232	0.484
d Wood, WoodProducts and Printing											
i Woodfuel Boilers	0.3388	NA	0.005082	NA	0.0390	0.5096	NA	0.015	NA	0.115	1.504
ii Sub-bituminous Coal Boilers	0.3715	35.296	0.000892	0.0000520	0.1222	0.0346	95	0.0024	0.0001	0.329	0.093
e Non-metal and Mineral Products											
i Sub-bituminous Coal Boilers	0.1869	17.753	0.000448	0.0000262	0.0615	0.0174	95	0.0024	0.0001	0.329	0.093
Total	***17.383***	***53.236***	***0.1952***	***0.000078***	***2.0137***	***26.140***					

Notes: (1) Woodfuels, agricultural wastes (baggase), and sub-bituminous coal consumed in industries (ISIC).
(2) NA refers to "not applicable".
(3) Input data and the methodology are found in Chapter 3 of CEEST 5/1994.
(4) Carbon dioxide emissions are not applicable here as they fall under closed carbon cycle.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 7) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tPollutant/TJ) C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1A2 Industry (ISIC)													
a Food, Beverages and Tobacco													
i Fuel Oil Boilers	1.436	100.06	0.004163	0.00008613	0.2311	0.02153	NA	69.70	0.0029	0.00006	0.161	0.015	NA
ii LPG Boilers	0.006	0.35	0.000008	0.00000006	0.0004	0.00009	NA	62.44	0.0014	0.00001	0.067	0.017	NA
iii Industrial Diesel Oil Boilers	0.033	2.36	0.000096	0.00000199	0.0053	0.00050	NA	71.15	0.0029	0.00006	0.161	0.015	NA
b Textiles, Leather and Sisal													
i Fuel Oil Boilers	0.571	39.82	0.001657	0.00003427	0.0920	0.00857	NA	69.70	0.0029	0.00006	0.161	0.015	NA
ii Industrial Diesel Oil Boiler	0.008	0.56	0.000023	0.00000047	0.0013	0.00012	NA	71.15	0.0029	0.00006	0.161	0.015	NA
iii Kerosine Kilns	0.001	0.04	0.000001	0.00000004	0.0003	0.00005	NA	71.15	0.0010	0.00006	0.527	0.079	NA
c Metal and Engineering													
i Fuel Oil Furnaces	0.048	3.33	0.000139	0.00000287	0.0024	0.00072	NA	69.70	0.0029	0.00006	0.051	0.015	NA
ii Industrial Diesel Oil Boilers	0.012	0.82	0.000034	0.00000069	0.0019	0.00015	NA	71.15	0.0029	0.00006	0.161	0.013	NA
iii Industrial Diesel Oil Furnace	0.038	2.71	0.000019	0.00000229	0.0061	0.00050	NA	71.15	0.0005	0.00006	0.161	0.013	NA
d Wood, Wood Products and Printin													
i Fuel Oil Boilers	0.209	14.57	0.000606	0.00001254	0.0337	0.00314	NA	69.70	0.0029	0.00006	0.161	0.015	NA
e Non-metal and Mineral Products													
i Fuel Oil Kilns	2.863	199.56	0.002863	0.00017179	1.5089	0.22619	NA	69.70	0.0010	0.00006	0.527	0.079	NA
ii Fuel Oil Furnaces	0.653	45.52	0.000327	0.00003918	0.0333	0.00849	NA	69.70	0.0005	0.00006	0.051	0.013	NA
iii LPG Furnaces	0.011	0.67	0.000012	0.00000011	0.0005	0.00011	NA	62.44	0.0011	0.00001	0.047	0.010	NA
Total	***5.887***	***410.36***	***0.010***	***0.0004***	***1.917***	***0.270***	***NA***						

Notes:
(1) Some figures do not necessarily add to exact totals simply because they are truncated figures.
(2) Input data and the methodology are found in Chapter 3 of CEEST No. 5/1994.
(3) Petroleum refining and chemical processes are covered in Sheet No. 5.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 8) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (t Pollutant/TJ)					
								C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1A3 Transport													
1A3a Civil Aviation	1.308	92.02	0.042	0.0019	0.24	16.420	0.379	70.35	0.032	0.0015	0.18	12.554	0.2898
1A3b Road Transportation	11.340	813.93	0.234	0.0170	4.02	34.015	6.526	71.78	0.021	0.0015	0.35	3.000	0.5755
1A3c Rail Transportation	1.002	73.45	0.006	0.0020	1.80	0.610	0.130	73.30	0.006	0.0020	1.80	0.609	0.1300
1A3d Marine Transportation	0.381	27.93	0.001	0.0008	0.69	0.120	0.024	73.31	0.003	0.0021	1.81	0.315	0.0625
Total	***14.031***	***1007.33***	***0.283***	***0.022***	******	***51.165***	***7.059***						

Notes:

(1) These estimates are summaries of Sheets No. 9 and 14. All GHG emissions associaed with International Bunkers are excluded.
(2) The input details and real workings are found in Chapter 5 of the CEEST No. 5/1994.
(3) Some figures do not necessarily add to exact totals simply because they are truncated figures.
(4) The nomenclature of transport modes may differ from that in the main documents, but are self-explanatory.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 9) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tPollutant/TJ) C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1A3b Road Transportation													
i Gasoline Automobiles	1.842	127.65	0.058	0.0017	0.718	13.502	2.0999	69.3	0.031	0.0009	0.39	7.33	1.140
ii Gasoline Light-duty trucks	1.706	118.23	0.097	0.0015	0.699	11.754	2.2519	69.3	0.057	0.0009	0.41	6.89	1.320
iii Gasoline Heavy-duty trucks	0.395	27.37	0.008	0.0002	0.138	3.500	0.4424	69.3	0.021	0.0005	0.35	8.86	1.120
iv Gasoline Motorcycle	0.380	26.33	0.049	0.0003	0.027	3.496	0.9500	69.3	0.130	0.0009	0.07	9.20	2.500
v Diesel Automobiles	1.602	117.43	0.002	0.0030	0.224	0.240	0.1169	73.3	0.001	0.0019	0.14	0.15	0.073
vi Diesel Light-duty trucks	3.872	283.82	0.004	0.0074	0.658	0.736	0.3872	73.3	0.001	0.0019	0.17	0.19	0.100
vii Diesel Heavy-duty trucks	1.543	113.10	0.015	0.0029	1.558	0.787	0.2777	73.3	0.010	0.0019	1.01	0.51	0.180
Total	***11.340***	***813.93***	***0.234***	***0.017***	***4.024***	***34.015***	***6.526***						

Notes:
(1) All vehicles were assumed to be emission uncontrolled, due to vehicle ages, maintainance procedure, and poor road condition.
(2) Classification of vehicle by weight and capacity followed U.S. EPA categories in the IPCC Reference Manual.
(3) Aggregation of fuel combustion by vehicle categories were done by i teration method.
(4) Input data and detailed methodology are found in Chapter 5 of the main document (CEEST No. 5/1994).

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 10) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tonnes of Pollutant/TJ) C=B/A					
		CO_2	CH_4	N_2O	NO_x	CO	NMVOC	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
1A4 Small Combustion (fossil fuels)													
1A4a HH/Commercial/Institution	3.730	264.70	0.018	NA	0.189	0.048	NE	70.97	0.0048	NA	0.051	0.013	NE
1A4b Households (fossil fuels)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1A4c Agriculture/Forestry	0.177	12.97	0.002	0.0004	0.266	0.106	0.041	73.30	0.0107	0.002	1.500	0.600	0.2299
Total	***3.907***	***277.675***	***0.020***	***0.0004***	***0.455***	***0.154***	***0.041***						

Notes:

(1) NE refers to "not estimated", while NA refers to "not aggregated".

(2) It was not easy to aggregate fossil fuels consumed in households (HH) from those consumed in commercial, institutional, and informal sectors.

(3) Sheet 10 summarizes sheets 11, 12, and 13. The actual workings are found in Chapters 6 and 5 (CEEST No. 5/1994), repectively.

(4) These estimates are extracts of the main documents under different titles (say Farm Equipment for Agriculture/Forestry).

::

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 11) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tonnes of Pollutant/TJ)					
		B=AxC						C=B/A					
		CO_2	CH_4	N_2O	NO_x	CO	NMVOC	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
1A4a Commercial/Institutional/Households													
(i) Kerosine Stoves and Lanterns	3.492	249.691	0.017	NA	0.178	0.045	NA	71.50	0.0050	NA	0.051	0.013	NA
(ii) LPG stoves	0.238	15.010	0.000	NA	0.011	0.002	NA	63.01	0.0011	NA	0.047	0.010	NA
Total	*3.730*	*264.701*	*0.018*	*NA*	*0.189*	*0.048*	*NA*						

Notes:
(1) It was not possible to aggregate residential from both commercial and institutional kerosine use.
(2) Tables 6.2, 6.3, and 6.5 of the main document (CEEST No. 5/1994) are basis for total kerosene and LPG consumption calculations.
(3) Default greenhouse gas emission factors (Table 6.9 of CEEST No. 5/1994) were borrowed from the Reference Manual.
(4) Some figures may not add exactly to real totals (cf. Table 6.11 of CEEST No. 5/1994) simply because they are truncated numbers.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 12) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tPollutant/TJ) C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1 A4b Households (fossil fuels)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: (1) It was not possible to aggregate household figures from commercial and institutional fossil fuel consumptions.
(2) NA refers to "unable to aggregated" from (Sheet 11). Chapter 6 (of CEEST No. 5/1994) covers both traditional biofuels and fossil fuel use.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 13) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tonnes of Pollutant/TJ) C=B/A					
		CO_2	CH_4	N_2O	NOx	CO	NMVOC	CO_2	CH_4	N_2O	NOx	CO	NMVOC
1A4c Agriculture/Forestry													
(i) Diesel Farm Equipment	0.177	12.974	0.0019	0.0004	0.2655	0.1062	0.0407	73.3	0.011	0.002	1.500	0.600	0.230
Total	***0.177***	***12.974***	***0.0019***	***0.0004***	***0.2655***	***0.1062***	***0.0407***						

Notes:
(1) Consumption inputs were extracted from Table 5.3 (of CEEST No. 5/1994) based on Tables 5.1, 5.2 and 5.3 of the main document.
(2) Default GHG emission factors were borrowed from the IPCC Reference Mannual. All equipment were assumed to be emission uncontrolled.
(3) Farm and forestry equipment were considered under mobile sources of GHG emissions.
(4) Some figures (to the second or third decimal places) do not necessarily add to exact totals simply because are truncated figures.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 14) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tonnes of Pollutant/TJ) C=B/A					
		CO_2	CH_4	N_2O	NO_x	CO	NMVOC	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
1A3 (a,c,d) Non-road Transport													
1A3ai Gasoline Piston Aircrafts	0.681	47.19	0.04086	0.0006	0.05	16.34	0.3677	69.3	0.0600	0.0009	0.08	24.00	0.5400
1A3a ii Jet and Turbo Aircrafts	0.627	44.83	0.00125	0.0013	0.18	0.08	0.0113	71.5	0.0020	0.0020	0.29	0.12	0.0180
Sub-total	***1.308***	***92.02***	***0.04211***	***0.0019***	***0.24***	***16.42***	***0.3790***						
1A3c Diesel Locomotive Engines	1.002	73.45	0.00601	0.0020	1.80	0.61	0.1303	73.3	0.0060	0.0020	1.80	0.61	0.1300
Sub-total	***1.002***	***73.45***	***0.00601***	***0.0020***	***1.80***	***0.61***	***0.1303***						
1A3d i Boats and Schooners	0.216	15.83	0.00108	0.0004	0.35	0.11	0.0238	73.3	0.0050	0.0020	1.60	0.50	0.1100
1A3d ii Shipping activities	0.165	12.09	0.00002	0.0003	0.35	0.01	0.0000	73.3	0.0001	0.0020	2.10	0.05	0.0001
Sub-total	***0.381***	***27.93***	***0.00110***	***0.0008***	***0.69***	***0.12***	***0.0238***						
Grand total	***2.691***	***193.4***	***0.04922***	***0.0046***	***2.73***	***17.15***	***0.5331***						

Notes:
(1) Calculation inputs were extracted from Tables 5.4 and 5.5 (of CEEST No. 5/1994). All GHG emissions from International Bunkers were excluded.
(2) NA refers to "not applicable'.
(3) Default GHG emission factors were borrowed from the IPCC Reference Manual, and all equipment were assumed to be emission uncontrolled.
(4) Some figures (to the second or third decimal places) do not exactly add to totals simply because they are truncated numbers.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 15) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (unit) by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (tonnes of Pollutant/TJ) C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1A5 Other Modes													
1A5a Construction Equipment	1.415	103.72	0.00566	0.0028	1.70	0.54	0.1274	73.3	0.0040	0.0020	1.20	0.38	0.0900
Total	***1.415***	***103.72***	***0.00566***	***0.0028***	***1.70***	***0.54***	***0.1274***						

Notes:
(1) Calculation inputs were extracted from Tables 5.4 and 5.5 (of CEEST No. 5/1994). All GHG emissions from International Bunkers were excluded.
(2) Default GHG emission factors were borrowed from the IPCC Reference Manual, and all equipment were assumed to be emission uncontrolled.
(3) Some figures (to the second or third decimal places) do not exactly add to totals simply because they are truncated numbers.

STANDARD DATA TABLE 1

Energy: 1A Fuel Combustion Activities (Sheet 16) - Traditional Biomass Burned for Energy

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (units)	A Apparent Consumption (kt dm)	B Quantities Emitted (Gg)						C Emission Factors (t Pollutant/t dm) C=B/A					
		CO_2	CH_4	N_2O	NO_x	CO	NMVOC	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
Fuelwood	27765	39856.66	173.92	1.20	33.57	1014.53	NE	1.44	0.006	0.00004	0.0012	0.037	NE
Agricultural Wastes	5597	7404.46	13.46	0.33	9.36	188.48	NE	1.32	0.002	0.00006	0.0017	0.034	NE
Cattle Dung	97	108.83	0.67	0.01	0.18	2.77	NE	1.12	0.007	0.00007	0.0019	0.029	NE
Charcoal (Consumption)	772	2167.16	1.10	0.07	2.35	82.75	NE	2.81	0.001	0.00008	0.0030	0.107	NE
Charcoal (Production)	7718	10272.02	235.32	0.31	8.65	261.47	NE	1.33	0.030	0.00004	0.0011	0.034	NE
	Total	***59809.13***	***424.481***	***1.91***	***54.11***	***1550.00***	***NE***						

Notes:
(1) NE refers to "not estimated". Discussion on NMVOC is found on page 44 (Chapter 6 of CEEST No. 5/1994)
(2) Input data are extracted from Tables 6.6 and 6.7 (CEEST No. 5/1994).
(3) These estimates include GHG emissions from household and informal sectors, cottage industry, as well as commercial and service institutions.
(4) Carbon dioxide emissions from biofuels fall under closed carbon cycle.
(5) Wood to charcoal conversion ratio was estimated at 10:1 for traditonal earthmould kilns.
(6) The molecular weight ratio for NOx is 46/14.
(7) Fuelwood and baggase transformed into industrial (ISIC) heat energy are not considered here.

STANDARD DATA TABLE 1

Energy: 1B Fugitive Emissions from Fuels (Coal Mining and Carbondioxide Exploitation)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES		AGGREGATE EMISSION FACTORS	
Sector Specific Data (unit)	A Production and Importation (Million tonnes)		B Emission Estimates (Gg)		C (kg/t) C=(B/A)	
	Coal	CO2	CH4	CO2	CH4	CO2
1B Fugitive Emissions						
1B1 Solid Fuels						
1B1a Coal Mining						
1B1ai Underground Mines						
Underground activities	0.0603		0.751		12.47	
Post-mining activities	0.0823		0.069		0.84	
1B1b Gaseous Exploitation						
1B1bi Carbondioxide Exploitation		0.00126		1.260		1000
Total	***0.0823***	***0.00126***	***0.820***	***1.260***		

Notes:
(1) Carbon dioxide released from mining naturally occuring deposits is reported under fugitive emissions.
(2) Post-mining coal activities include handling of imported sub-bituminous coal.
(3) Inputs and the methodologies are found in Chapters 7 and 8 of CEEST No. 5/1994

3.0 INDUSTRIAL PROCESSES

3.1 Emissions from non-metallic mineral products

Estimates of emission of greenhouse gases from the transformation of raw materials into intermediate or final products in industrial processes have been considered. The main activity considered is the emission of carbon dioxide from cement production. The amount of carbon dioxide emitted is estimated from the product of the quantity of cement produced in a year and an emission factor reflecting the mass of carbon dioxide released per unit time in the cement clinker. Estimates of emissions from paper and pulp mills were also made. The results are summarised in Standard Data Table 2A. Discussions and calculation procedures are detailed in Chapter 9 of the main document.

STANDARD DATA TABLE 2

Industrial Processes

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific data (Units)	A Production Quantity (kt)	B Full Mass of Pollutant (Gg)						C Tonne of pollutant per tonne of Product (t/t)					
		CO	CO_2	CH_4	N_2O	NOx	NMVOC	CO	CO_2	CH_4	N_2O	NOx	NMVOC
E Non-metallic Mineral Products													
Cement	644.14	NE	343.666	NE	NA	NA	NE	NE	0.534	NE	NA	NA	NE
F Other Products (ISIC)													
Pulp and Paper	7.38	NE	5.787	NE	NA	NA	NE	NE	0.785	NE	NA	NA	NE
	Total	***NE***	********	***NE***	***NA***	***NA***	***NE***						

Notes:
(1) NE refers to "not estimated"
(2) NA refers to "not applicable".
(3) Calcination of limestones to produce calcium hydroxide at 44.00g CO_2 per 56.08g $Ca(OH)_2$ rate.
(4) Portland cement clinker contains about 68% of quick lime by weght, and 44 g CO_2 is produced by 56.08 g CaO.
(5) Inputs for this sheet are found in Chapter 9 of the CEEST No. 5/1994.

4.0 AGRICULTURE

Greenhouse gas emissions from the agricultural sector have been estimated resulting from the following activities:- rice cultivation, use of nitrogen fertilizers; enteric fermentation of domestic animals; emission from animal wastes; burning of agricultural crop waste; and emission from wildlife. Discussions and calculation procedures are detailed in Chapter 10 of the main document.

4.1 Methane emissions from enteric fermentation

Methane production in animals is part of the normal digestive process in ruminants such as cattle sheep and goats. Estimation of methane emission from ruminant is based on estimation of the percentage of the total feed energy intake by the animal, that is converted to methane. The principle used in based on breaking down the total energy requirement of the animal into that required for its own maintenance, for growth, pregnancy, for work and for production of milk or wool. Emission estimates are summarised in Standard Data Table 4A&B.

4.2 Methane emissions from animal wastes management

Methane is generated from animal wastes when the organic material decomposes anaerobically. Estimates of methane emission have been made using the direct relationship between the amount of volatile solids present in animal wastes and the potential for methane generation.

For different types of animals, numbers of which have been obtained from the Ministry of Agriculture, the methane emission potential has been obtained from information supplied by the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC). The realized methane emission has been obtained, after taking into consideration the type of waste management for each animal category. Emission estimates are summarised in Standard Data Table 4A&B.

4.3 Methane emissions from rice cultivation

Production of methane from rice fields is a result of the decomposition of organic material by methanogenic bacteria. Methane emission will vary according to such factors as soil type, temperature, fertilizer and water management. The amount of methane emitted from rice fields in Tanzania has been obtained using a daily emission rate and the number of hectare-days in the year for irrigated and rain-fed rice growing regimes. Emissions estimates are summarised in Standard Data Table 4C.

4.4 Emissions from nitrogenous fertilizers

The emission of nitrous oxide is a result of natural processes in the soils and nitrification and oxidation of ammonia to nitrate. Fertilizers add nitrogen to the soil and lead to increased emission of nitrous oxide from the soil. An estimate of emission of nitrous oxide for each type if fertilizer used in the country is made from the product of fertilizer consumption and the emission coefficient (nitrous oxide released per unit weight of fertilizer used) usually specified as a range from low to medium and high. Emissions estimates are summarised in Standard Data Table 4D.

4.5 Emissions from burning of agricultural residues

Carbon dioxide, methane, carbon monoxide, nitrous oxides and nitrogen oxides are released into the atmosphere when crop wastes are burned. Carbon dioxide release is considered to be part of a natural closed cycle, with re-absorption occurring in the next growing season. Three crops namely cotton, sugar cane and paddy, have been considered. Although other crops such as maize and millet leave behind quantities of residue, these are used mainly for mulching and as animal feed. Estimates of emission of trace gases from these crops is made by estimating first the carbon content of the residues, and later applying emission ratios from experimental results obtained at the University of Dar es Salaam in the case of methane and carbon monoxide and from IPCC in the case of other trace gases. The results are presented in Standard Data Table 4E.

4.6 Emissions from un-prescribed burning of Savannas

Savanna burning is a practice prevalent in Tanzania. It occurs every year during the dry season. It is estimated that 9,000 kha of land is subjected to above ground burning annually. An estimate of carbon dioxide emission is made in order to determine the approximate amounts of trace gases emitted into the atmosphere. Carbon dioxide emission is not accounted for in the final balance. It is considered to be part of the natural cycle, being absorbed in the next planting season. Non-carbon dioxide greenhouse gas emissions are summarised in Sheet 2 of Standard Data Table 4F.

STANDARD DATA TABLE 4

Agriculture: 4A&B Enteric Fermentation and Manure Management

SOURCES AND SINKS CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES		AGGREGATE EMISSION FACTOR	
	A	B		C	
	Number of Animals	Enteric Fermentation	Manure Management	Enteric Fermentation	Manure Management
	(thousands)	(Gg CH_4)		(kg CH_4 per head per year) C=(B/A)x1000	
1 Cattle					
a Indigenous	11510.22	562.48	4.542	48.87	0.39
b Beef	115.80	7.01	0.055	60.53	0.47
c Dairy	209.76	9.96	0.132	47.50	0.63
d Oxen	900.00	85.82	0.355	95.36	0.39
2 Buffalo					
3 Sheep	5551.40	116.90	0.963	21.06	0.17
4 Goats	8533.70	88.32	1.480	10.35	0.17
5 Camels and Llamas					
6 Horses					
7 Mules/Asses	250.00	2.50	0.147		0.59
8 Swine	275.00	0.28	0.008		0.03
9 Poultry	21617.50		0.375		0.02
10 Other					
Total		*873.271*	*8.057*		

Notes:

(1) Buffalos, camels, llamas, horses were not considered here, as their numbers are insignificant.

(2) Input data and the methodologies are found in Chapter 10 of CEEST No. 5/1994.

(3) Emissions from wildlife management are beyond the scope of this inventory.

(4) Some figures do not necessarily add to exact totals simply because they are truncated figures

(5) Non-ruminant animals, especially mules and swines generate 10 and 1 kg per head per annum, respectively.

STANDARD DATA TABLE 4

Agriculture: 4C Rice Cultivation - Flooded Rice Fields

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES	AGGREGATE EMISSION FACTOR
	A	B	C	D
Sector Specific Data (units)	Area Calculated in Megahectares	Megahectares-Days Cultivation	Methane	CH4 Average Emission Factor
	(Mha)	(Mha-Days)	(Gg CH4)	(kg CH4 per ha-day)
				D=C/B
1 Flooded or irrigated	0.04	5.03	20.967	4.17
2 Intermitently lowland rain-fed	0.27	25.46	63.789	2.51
3 Other				
Total	***0.31***	***30.49***	***84.756***	

Notes:
(1) Flooded or irrigated rice cultivation is a continuous process practiced in Tanzania
(2) Intermitently lowland rain-fed rice cultivation is preferred practice in most regions.
(3) The number of days are obtained by dividing column B by A.
(4) Input data and the methodology are found in Chapter 10 of CEEST No. 5/1994.
(5) Some figures may not necessarily add to the exact totals simply because they are truncated figures.

STANDARD DATA TABLE 4

Agriculture: 4D Agricultural Soils - Nitrogenous Fertilizers

SOURCE AND SINK CATEGORIES	ACTIVITY DATA			EMISSIONS			REMOVALS	AGGREGATE EMISSION FACTOR(S)		
Fertiliser Type	A Amount of Nitrogen Applied in Fertiliser and Manure (t N)	B Area Cultivated (ha)	C Amount of Biological Fixation of Nitrogen (tN)	D E F Emissions of N2O, CO2, CH4 at low emission rate (Gg)			G Removals of CO2 (Gg CO2)	H (t N2O/t N) (Dx1 000)/A	(t CO2/ha) (Ex1 000)/B	(t CH4/ha) (Fx1 000)/B
				D N2O	E CO2	F CH4		N2O	CO2	CH4
Ammonia Aqua	1625			0.026				0.016		
Ammonium Nitrate	510			0.008				0.016		
Ammonium Sulphate	6107			0.096				0.016		
Urea	17227			0.271				0.016		
NPK 6:20:18	678			0.011				0.016		
NPK 25:5:5	993			0.016				0.016		
NPK 20:10:10	654			0.010				0.016		
Calcium Ammonium Nitrate (CAN)	8308			0.131				0.016		
Total				*0.567*						

Notes: (1) Because of the limitations of available data and the scope of the study, a value of 1% of nitrogenous fertiliser was used to estimate nitrous oxide.
(2) Nitrous oxide estimates for this matter are on low side.
(3) Shaded cells refer to 'not applicable' or 'not occuring' or 'data unavailability'
(4) Input data and the methodology are found in Chapter 10 of CEEST No. 5/1994.

STANDARD DATA TABLE 4

Agriculture: 4E Field Burning of Agricultural Residues

SOURCE AND SINK	ACTIVITY DATA		EMISSIONS ESTIMATES					AGGREGATE EMISSION FACTORS				
Crop Type	A Amount Burning of Crop Residues (Gg dm)	B Carbon Fraction (t / t dm)	C Full Mass of Pollutant (Gg)					E Pollutant per tonne of Dry Matter (kg / t dm) D=(C/A)x1 000				
			CH4	N2O	NOx	CO	C	CH4	N2O	NOx	CO	CO2
1. Cereal (Rice husks)	107.258	0.30	0.429	0.004	0.149	10.51	32.18	4.0	0.0	1.4	98.0	1100
2. Pulse												
3. Tuber and roots												
4. Sugar cane (leaves)	36.564	0.41	2.199	0.003	0.109	1.75	14.99	60.1	0.1	3.0	47.8	1503
5. Other (Cotton residuals)	9534.953	0.36	320.374	0.566	20.470	1041.22	3432.58	33.6	0.1	2.1	109.2	1320
Total			***323.002***	***0.573***	***20.729***	***1053.477***						

Notes:
(1) Carbon released data in column C form the basis of estimating methane, carbon monoxide, and nitrogen released.
(2) Emission factors for methane and carbon monoxide were established by Tanzanian local experts.
(3) Input data and methodology are found in Chapter 10 of CEEST No. 5/1994.
(4) Some figures may not add to the exact totals simply because they are truncated figures.

STANDARD DATA TABLE 4

Agriculture: 4F (Sheet 1) Unprescribed Burning of Savannas - Carbondioxide Released

SOURCE AND SINK CATEGORIES		ACTIVITY DATA										EMISSIONS ESTIMATES	
Sector Specific Data (units) Land Type		A Estimated Area under Savanna (kha)	B Fraction Annually Burned	C Aboveground Biomass Density (t dm/ha)	D Fraction Actually Burned	E Fraction of Aboveground Biomass		F Combustion Efficiency		G Fraction of Carbon in Biomass		H Total Carbon Released (Gg) H=AxBxCxDxExFxG	
						Living	Dead	Living	Dead	Living	Dead	Living	Dead
Savanna	Humid	10400	0.32	6.60	0.85	0.85	0.15	0.80	0.99	0.40	0.45	5078.262	1247.628
	Semi Arid	5600	0.32	4.50	0.90	0.65	0.35	0.80	0.99	0.40	0.45	1509.581	1131.641
	Total	***16000***											***8967.112***

Notes: (1) Carbon dioxide figures does not form part of Table 7A. They are used to estimate non-carbon dioxide emissions.
(2) Input data and methodologies are found in Chapter 10 of CEEST No. 5/1994.

STANDARD DATA TABLE 4

Agriculture: 4F (Sheet 2) Unprescribed Burning of Savannas - Non-Carbondioxide Greenhouse Gas Emissions

SOURCE AND SINK	ACTIVITY DATA				EMISSIONS ESTIMATES				AGGREGATE EMISSION RATIOS			
Sector Specific Data (units) Land Type	A Total carbon released (kt C)		B Equivalent nitrogen released (kt N)		C Full Mass of Pollutant (Gg)				D Pollutant per tonne of Dry Matter (kg / t dm)			
	Living	Dead	Living	Dead	CH4	CO	N2O	NOx	CH4	CO	N2O	NOx
Humid Savanna	5078.262	1247.628	30.470	7.486	33.738	885.625	0.418	15.090	2.18	57.25	0.03	0.98
Semi-arid Savanna	1509.581	1131.641	9.057	6.790	14.087	369.771	0.174	6.300	2.24	58.80	0.03	1.00
Total	***6587.843***	***2379.269***	***39.527***	***14.276***	***47.825***	***1255.396***	***0.592***	***21.390***				

Notes:
(1) Input data is found in Sheet No. 1 of Table 4F. The methodology is obtained in Chapter 10 of CEEST No. 5/1994.
(2) Nitrogen released is calculated from on-site carbon release estimates by applying default conversion factors of 0.006 kt N per kt C.
(3) This Sheet forms part of inventory data found in Sheet no. 2 of Table 7A.

5.0 LAND USE CHANGE AND FORESTRY

Changes in the use of land result in changes in the amount of biomass on land which results in net changes in greenhouse gas emission. Categories of land-use change activities which contribute to emission of greenhouse gases which have been considered include:- forestry clearing for permanent cropland or pasture, conversion of grassland into cultivated land, regrowth in lands which were previously managed but were abandoned, forest management, shifting cultivation, and flooding of lands.

In order to arrive at estimates of emission of greenhouse gas emissions from landuse changes, it is necessary to have an appreciation of past changes over time, 25 years, say. Aboveground biomass which remains on land after clearing decays over an average of 10 years. Ideally, land-use changes should be monitored and recorded on a yearly basis. This has not been done in the case of Tanzania. The study has therefore made an estimate of these changes based on the reading and interpretation of vegetation maps of 1947, 1956, 1972 and 1990 and other literature. Discussions and calculation procedures are detailed in Chapter 11 of the main document.

5.1 Changes in forest and other woody biomass stocks

Information required for the estimation of greenhouse gas emissions and uptake includes that of land area of managed forest in the inventory year, the corresponding mean annual biomass increments, quantities of harvested aboveground biomass, and quantities of biomass consumed as traditional biofuel.

Accessible forests can either be a sink or a source of carbon dioxide depending on whether there is a net increment or decrement of carbon in a year. Emissions or removals of carbon dioxide due to plantation forests, tree planting programmes and human activity in unprotected natural forests have been considered in the study. Carbon growth in plantation forests, village woodlot, and other tree planting programmes provides a sink whereas commercial harvesting of biomass and informal woodfuel exploitation from accessible natural forests are a source of carbon dioxide. Sheet 3 of Standard Data Table 5A summarises the emission and uptake results.

5.2 Forest conversion to permanent croplands and pasture

Conversion of forests to permanent croplands or pasture is a practice prevalent in public lands in unreserved forests although at times encroachment of reserved forests has been occurring. It is estimated that on average 88,600 ha of land was converted from forest to cropland in 1990.

As the population increases so does the encroachment on forests for permanent cropland and pasture. Emission carbon dioxide from this activity is based on the estimation that 80 percent of the cleared biomass is burned off-site. Of the 20 percent burned on-sight, 90 percent is oxidized and 10 percent is left to decay releasing carbon-dioxide over 10 years. Carbon dioxide release is based on the fact that biomass is 45 percent carbon by weight and nitrogen trace gases release is estimated using emission ratios. Emissions are summarised in Sheets 2 and 5 of Standard Data Table 5B.

5.3 Abandonment of managed lands

Managed lands which have been abandoned have a capacity for vegetation regrowth, leading to re-accumulation of carbon. In this case, abandoned managed lands act as sinks of carbon dioxide. Few information has been obtained concerning the abandonment of approximately 35 kha of cashew tree farms, and 205 kha of sisal estates. The sink effect of the biomass regrowth is obtained from the product of the areas originally abandoned and the respective annual growth rates of the biomass densities. Removals are summarised in Standard Data Table 5C.

5.4 Other land-based greenhouse gas emission sources and sinks

Shifting cultivation is still being practiced in Tanzania, although more and more permanent settlements are a common feature of agriculture in the country. Information on the area subjected to shifting agriculture is unavailable. As such, the study has restricted itself to the estimation of emission of greenhouse gases from this practice arising from tobacco growing. The same considerations apply to the estimation of emissions from this practice as those that apply to conversion of forests permanent cropland.

The study has also estimated the emission of methane from man-made flooding of land from the impoundment of dams for electricity generation and water supply. It is assumed that 10 percent of the man-made flooded area is subjected to anaerobic digestion during the wet season and that methane release ceases 90 days after the start of the wet season. The results of emission estimates from shifting cultivation practice and water dams are summarised in Sheets 2 and 3 of Standard Data Table 5D.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5A (Sheet 1) Changes in Forest and Other Woody Biomass Stocks - Annual Growth Increment

SOURCE AND SINK CATEGORIES			ACTIVITY DATA	UPTAKE ESTIMATES	AGGREGATE UPTAKE FACTOR
Sector Specific Data (units) Land Type			A Area of Forest/Biomass Stocks (kha)	B Total Carbon Uptake Increment (Gg C)	C Annual carbon uptake factor (t C/ha) C=B/A
Tropical Forests	Plantation Forests	Mixed Softwoods	70.00	346.500	4.95
		Mixed Hardwoods	10.00	22.050	2.21
	Natural Forests	Miombo woodlands	55.20	99.360	1.80
	Others	Village Woodlot	12.00	27.000	2.25
Non-forest trees planting programmes in urban and rural areas			Number of Trees (thousands)	Annual Carbon Uptake (Gg)	Annual carbon uptake factor (kg C/tree) C=(B/A)x1 000
Urban and Rural Tree Planting Programmes			12.00	0.026	2.21
Total				***494.936***	

Notes:
(1) Mixed fast growing hardwood species include teak, Elgon olive (Loliondo or Musharagi)
(2) Only natural forests (miombo woodlands) supporting day-to-day human activities are considered here.
(3) Woody savannas in South-Western Tanzania are known as miombo woodlands, and support shifting cultivation.
(4) Annual regaining savannas are considered to be equal to annual accessed miombo.
(5) The mean annual increment (MAI) ranges from 0.45 to 6.75 t C/ha. The IPCC default values seem to be on high side.
(6) Input data and the methodology are found in Chapter 11 of CEEST No. 5/1994.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5A (Sheet 2) Changes in Forest and Other Woody Biomass Stocks - Annual Biomass Harvest

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	CARBON EMISSION ESTIMATES	AGGREGATE CARBON CONTENT FACTOR
	A	B	C
Sector Specific Data (units)	Amount of Biomass Removed (kt dm)	Carbon emission estimates (Gg C)	Carbon content factor (t C/t dm) C=B/A
Total biomass removed (commercial harvest)	265.478		
Traditional biofuel consumption (HH/commercial/informal)	35483.000		
Other wood use (mainly poles)	5.558		
Surplus (from off-site burning) aboveground biomass	-1852.510		
Net biomass consumption	***33901.525***	***15255.686***	***0.45***

Notes:
(1) Fine timbers were considered as commercial harvest, while construction poles were considered as other wood use.
(2) Input data and the methodology are found in Chapter 11 of CEEST No. 5/1994.
(3) Woodfuel consumed as traditional biofuel (which is discussed in Chapter 6) is considered here.
(4) Some figures may not necessarily add to the exact totals simply because they are truncated figures.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5A (Sheet 3) Changes in Forest and Other Woody Biomass Stocks - Net Carbondioxide Emissions or Removals

SOURCE AND SINK CATEGORIES	EMISSIONS/UPTAKE	EMISSIONS/REMOVALS
Sector Specific Data (units)	A Carbon (Gg)	B Carbondioxide (Gg)
		B=A x(44/12)
Total annual growth increment of woody biomass	-494.936	
Total annual harvest and biofuel consumption	15255.686	
Net carbon dioxide emissions or removals	***14760.750***	***54122.750***

Notes:
(1) Input data are found in Sheets No. 1 and 2 of Table 5A.
(2) Discussions on input data and results are found in Chapter 11 of CEEST No. 5/1994.
(3) The emission figure could be associated with the current deforestation rate in Tanzania.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5B (Sheet 1) Forest conversion for permanent agriculture - Carbon dioxide release from burning aboveground bomass

SOURCE AND SINK CATEGORIES				ACTIVITY DATA				EMISSION ESTIMATES		AGGREGATE EMISSION FACTOR	
Sector Specific Data (units) Land Type				A Area Converted Annually (kha)	B Annual Loss of Biomass (kt dm)	C Quantity of Biomass Burne (On-Site and Off-Site) (kt dm)		D Quantity of Carbon Released (kt C)		E Carbon Fraction of Biomass Burned E=D/C	
						On-Site	Off-Site	On-Site	Off-Site	On-Site	Off-Site
Tropical Forests	Closed Forests	Broadleaf Forests	Logged	5.19	212.79	42.56	159.59	17.24		0.41	
			Unproductive	0.71	118.57	23.71	88.93	9.60		0.41	
			Sub-total	***5.90***	***331.36***	***66.27***	***248.52***	***26.84***		0.41	
	Open Forests	Miombo Woodlands	Productive	46.41	1021.02	204.20	765.77	82.70		0.41	
			Unproductive	13.09	26.18	5.24	19.64	2.12		0.41	
			Sub-total	***59.50***	***1047.20***	***209.44***	***785.40***	***84.82***		0.41	
	Open Woodlands	Bushlands and Thickets	Productive	18.10	506.80	101.36	380.10	41.05		0.41	
			Unproductive	5.1	30.60	6.12	22.95	2.48		0.41	
			Sub-total	***23.20***	***537.40***	***107.48***	***403.05***	***43.53***		0.41	
Total on-site carbon released				***88.60***	***1915.96***	***383.19***	***1436.97***	***155.19***		0.41	

Notes:
(1) Unproductive forests are also referred to as undisturbed or inaccessible forests.
(2) Logged forests are also referred to as productive, encroached or accessible forests.
(3) Aboveground biomass burned off-site (75% of ceared biomass) is part of traditional biofuels accounted for in Sheet No. 2 of Table 5A.
(4) Aboveground biomass cleared during shifting cultivation practices is not considered here.
(5) An aggregate emission factor was obtained by multiplying carbon fraction of dry matter (about 0.45) by the combustion efficiency (about 90%).
(6) About 5% of cleared aboveground biomass is left in fields to decay.
(7) Input data and the methodology are found in Chapter 11 of CEEST No. 5/1994.
(8) Some figures may not necessarily add to the exact totals simply because they are truncated figures.
(9) 20% of aboveground biomass is burnt on-site.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5B (Sheet 2) Forest conversion for permanent agriculture - Release of non-carbon dioxide GHG from on-site burning of aboveground biomass

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS ESTIMATES				AGGREGATE EMISSION RATIOS			
Sector Specific Data (units) Land Type	A Carbon Released (Gg C)	B Nitrogen Released (Gg N)	C Emissions Estimates (Gg)				D Aggregate Emissions Ratios			
							D=C/A		D=C/B	
			CH4	CO	N2O	NOx	CH4	CO	N2O	NOx
On-site burning of aboveground biomass	155.19	1.55	*2.483*	*27.158*	*0.017*	*0.617*	0.016	0.175	0.011	0.398

Notes:
(1) Input data to this sheet is from Sheet No.1 of Table 5B.
(2) Nitrogen release is calculated from on-site carbon release estimates by applying default conversion factors.
(3) Some figures may not necessarily add to the exact totals simply because they are truncated figures.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5B (Sheet 3) Forest conversion for permanent agriculture - Carbondioxide release from decay of aboveground biomass

SOURCE AND SINK CATEGORIES				ACTIVITY DATA			EMISSIONS ESTIMATES	AGGREGATE EMISSIONS FACTOR
Sector Specific Data (units) Land Type				A 10-year average area converted annually (kha/year)	B 10-year average annual loss of biomass (kt dm/year)	C Average quantity of biomass left to decay (kt dm/year)	D Carbon Released from Decay (kt C)	E Carbon Fraction of Aboveground Biomass
								E=D/C
Tropical Forests	Closed Forests	Broadleaf Forests	Logged	5.19	215.18	10.76	4.84	0.45
			Unproductive	0.71	118.57	5.93	2.67	0.45
	Open Forests	Miombo Woodlands	Productive	46.41	1021.02	51.05	22.97	0.45
			Unproductive	13.09	26.18	1.31	0.59	0.45
	Open Woodlands	Bushlands and Thickets	Productive	18.10	506.80	25.34	11.40	0.45
			Unproductive	5.10	30.60	1.53	0.69	0.45
			Total	***88.6***	***1918.35***	***95.92***	***43.163***	
Total Carbondioxide Released (44/12 x C Released)							***158.264***	

Notes:
(1) 15-year data were used to calculate the 10-year average annual values.
(2) Unproductive forests are also referred to as inaccessible forests.
(3) Logged forests are also referred to as productive, encroached, accessible forest.
(4) 5% of cleared aboveground biomass is left to decay in field for 10 years.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5B (Sheet 4) Forest and Grassland Conversion - Soil Carbon Release

SOURCE AND SINK CATEGORIES				ACTIVITY DATA		EMISSIONS ESTIMATES	AGGREGATE EMISSIONS FACTOR
Sector Specific Data (units) Land Type				A Average annual forest/grassland converted to pasture or croplands over 25 years (kha)	B Carbon content of soil before conversion (tC/ha)	C Carbon released from soil (Gg Carbondioxide)	D Aggregate emission factor from soil carbon (tC/ha) D=C/A
Tropical Forests	Closed Forests	Broadleaf Forest	Logged	NA			
			Unproductive	NA			
	Open Forests	Miombo Woodlands	Productive	NA			
			Unproductive	NA			
	Open Woodlands	Bushlands and Thickets	Productive	NA			
			Unproductive	NA			
Grasslands				NA	NA	NA	NA
Total Carbon Released						NA	
Total Carbondioxide Released (44/12 x C Released)						NA	

Notes: (1) There is a lot of uncertainities regarding soil carbon release phenomenon in Tropical Forests. For this matter this component is ignored.

(2) Soil carbon emissions from Tropical Grasslands are also estimated with high uncertainity of the phenomenon.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5B (Sheet 5) Forest and grassland conversion - Total carbon dioxide emissions

CATEGORIES	EMISSIONS (Gg)	
	Carbon	Cabon dioxide
Carbon dioxide release from aboveground burning of biomass	155.190	569.030
Carbon dioxide from decay of aboveground biomass	43.163	158.264
Carbon dioxide from soil carbon release	NA	NA
Total	***198.353***	***727.294***

Notes: (1) Input data to this sheet are from Sheets No. 1, 3, and 4 of Table 5B, respectively.
(2) NA referrs to `not applicable'

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5C (Sheet 1) Abandonment of Managed Lands - Annual Carbon Uptake from Lands Abandoned Over the Previous 20 Years

SOURCE AND SINK CATEGORIES		AVERAGE ANNUAL TOTAL AREA ABANDONE (PREVIOUS 20 YEARS)			ANNUAL CARBON UPTAKE ESTIMATES			AGGREGATE ANNUAL RATE OF UPTAKE	
Sector Specific Data (units) Land Type		A Total Area Abandoned (kha)	B Annual Rate of Aboveground Biomass Growth (t dm/ha)	C Carbon Fraction of Aboveground Biomass	D Aboveground Biomass Carbon Uptake (Gg C/yr)	E Soil carbon uptake (Gg C/yr)	F Total (Gg C)	G Rate of aboveground biomass carbon uptake (tC/ha/yr)	H Rate of soil carbon uptak (tC/ha/yr)
							F=D+E	G=D/A	H=E/A
Tropical	Open forests	35.00	10.00	0.45	157.50		157.500	4.5	
Forests	Wooded graslands	205.00	4.00	0.45	369.00		369.000	1.8	
	Total	***240.00***			***526.50***		***526.500***		
Total carbon dioxide removal							***1930.500***		

Notes: (1) Soil carbon release or uptake in Tropical Forests is ignored at a moment following the debate among the Scientists.
(2) Input data and the methodology are found in Chapter 11 of CEEST No. 5/1994.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5C (Sheet 2) Abandonment of Managed Lands - Annual Carbon Uptake from Lands Abandoned for more than 20 Years

SOURCE AND SINK CATEGORIES		AVERAGE ANNUAL TOTAL AREA ABANDONED (20 - 100 YEARS AGO)			ANNUAL CARBON UPTAKE ESTIMATES			AGGREGATE ANNUAL RATE OF UPTAKE	
Sector Specific Data (units) Land Type		A Total area abandoned (longer than 20 years) (kha)	B Annual rate of aboveground biomass Growth (t dm/ha)	C Carbon fraction of aboveground biomass	D Aboveground biomass carbon uptake (Gg C/yr)	E Soil Carbon Uptake (Gg C/yr)	F Total (Gg C)	G Rate of Aboveground Biomass Carbon Uptake (tC/ha/yr)	H Rate of Soil Carbon Uptake (tC/ha/yr)
							F=D+E	G=D/A	H=E/A
Tropical	Open forests	NE							
Forests	Wooded graslands	NE							
Total Carbon Uptake		NE					NE		

Notes: (1) Soil carbon release or uptake in Tropical Forests is ignored at a moment following the debate among the Scientists.
(2) NE refers to "not estimated" due to lack of supportive information.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5C (Sheet 3) Abandonment of Managed Lands - Total Carbondioxide Removals

SOURCE AND SINK CATEGORIES	CARBON UPTAKE	CARBONDIOXIDE REMOVALS
	A (kha)	D (Gg CO2) B=Ax(44/12)
Lands abandoned over the previous 20 years	526.50	1930.50
Lands abandoned between 20 and 100 years previously	NA	NA
Total	***526.50***	***1930.50***

Notes: (1) Input data to this sheet are from Sheets No. 1 and 2 of Table 5C.
(2) Discussions on abandonment of managed lands are found in Chapter 11 of CEEST No. 5/1994.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5D (Sheet 1) Others - Carbon release from on-site burning of aboveground biomass in shifting cultivation practices

SOURCE AND SINK CATEGORIES	ACTIVITY DATA						EMISSIONS ESTIMATES	
	A	B	C	D	E	F	G	H
Sector Specific Data (units) Land Type	Annual area cleared (kha)	Aboveground biomass cleared (kt dm)	Aboveground biomass burne on-site (kt dm)	Fraction of Aboveground biomass oxidised	Carbon content in biomass	Nitrogen: Carbon ratio	Total carbon released (Gg C)	Total nitrogen released (Gg N)
							G=CxDxE	H=FxG
Miombo woodlands	*55.20*	*552*	*110.40*	0.90	0.45	0.01	*44.712*	*0.447*

Notes: (1) The last two columns do not form part of Table 7A, they are used to estimate non-carbon dioxide emissions.
(2) Carbon released from burning of aboveground biomass falls in closed carbon cycle.
(3) Input data, the methodology and discussions on this source are found in Chapter 11 of CEEST No. 5/1994.

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5D (Sheet 2) Others - Release of non-carbon dioxide GHG emissions from on-site burning of aboveground biomass in shifting cultivation practices

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS ESTIMATES				AGGREGATE EMISSION RATIOS			
Sector Specific Data (units) Land Type	A Carbon Released (Gg C)	B Nitrogen Released (Gg N)	C Emissions Estimates (Gg)				D Aggregate Emissions Ratios			
							D=C/A		D=C/B	
			CH_4	CO	N_2O	NO_x	CH_4	CO	N_2O	NO_x
On-site burning of aboveground biomass	44.712	0.447	*0.715*	*4.173*	*0.005*	*0.138*	0.016	0.093	0.011	0.309

Notes:
(1) Input data to this sheet is from Sheet No.1 of Table 5D.
(2) Nitrogen release is calculated from on-site carbon release estimates by applying default conversion factors.
(3) Some figures may not necessarily add to the exact totals simply because they are truncated figures.
(4) Discussions on the results are found in Chapter 11 of CEEST No. 5/1994.

6.0 WASTE MANAGEMENT

6.1 Emissions from solid wastes management

In the sector of solid waste management, through literature search, the composition of municipal waste in Dar es Salaam was determined. Waste generated in major towns in the country has been estimated from the annual estimate of per capita generation. Information has been compiled concerning the characteristics of the two major waste disposal points for Dar es Salaam, the Vingunguti dumpsite and the Tabata dumpsite which has been closed. Methane emission has been estimated from the dump sites existed in 1990, as well as from open-dump sites at district level. Emissions from sisal and coffee wastes also have been estimated. The results of emissions from solid waste disposal on land, waste incineration, and wastes from sisal and coffee are shown in Standard Data Table 6A. Discussions and calculation procedures are detailed in Chapter 12 of the main document.

6.2 Methane emissions from wastewater management

Emission of methane from wastewater and sanitary systems have been estimated using gas collected and analysed for composition from septic tanks, waste stabilisation ponds, drop-holes of pit latrines, and inspection chambers of sewerage systems. Based on estimates the amount of organic material in industrial wastewater streams and the amount of wastewater discharge from industries with wastewater treatment facilities, the study has made an estimate of methane emission from industrial water treatment. Methane emissions estimates from wastewaters are shown in Standard Data Table 6B.

STANDARD DATA TABLE 6

Waste: 6A Solid waste disposal on land, 6C Waste incineration, and 6D Other solid waste management systems

0 CATEGORIES	ACTIVITY DATA (Gg)	EMISSION ESTIMATES (Gg)						AGGREGATE EMISSION FACTORS (kg/tonne)						CH4 Recovered Gg
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Disposal Method	Annual DOC disposed	CO2	CH4					CO2 (Bx1 000)/A	CH4 (Cx1 000)/A					
A1 Landfills	NO	NA	NO					NO	NO					0.00
A2 Open Dumping	32.58	NA	8.363					NA	256.67					0.00
	Quantity of Waste Treated	CO2	CH4	N2O	NOx	CO	NMVOC	CO2 (Bx1 000)/A	CH4 (Cx1 000)/A	N2O (Dx1 000)/A	NOx (Ex1 000)/A	CO (Fx1 000)/A	NMVOC (Gx1 000)/A	
C Waste Inceneration	NO	NO	NO	NO	NO	NO	NO	NO	NA	NO	NO	NO	NO	0.00
D Other Wastes														
D1 Sisal Wastes	160.00	NA	30.880	NA	NA	NA	NA	NA	193.00	NA	NA	NA	NA	0.00
D1 Coffee husks	4.50	NA	2.228	NA	NA	NA	NA	NA	495.00	NA	NA	NA	NA	0.00

Notes:
(1) NA refers to "not applicable", NE refers to "not estimated", and NO refers to "not occuring".
(2) No attempt has been made to recover methane from open dumping practice before 1990.
(3) Input data and the methodology are found in Chapter 12 of CEEST No. 5/1994.
(4) Landfill and incineration practices have not been popular in Tanzania.

STANDARD DATA TABLE 6

Waste: 6B Wastewater Treatment - Industrial, Commercial, and domestic wastewaters

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES			AGGREGATE EMISSION FACTORS			Quantity Recovered
	A	B	C	D	E	F	G	H	N
Wastewater Type	Annual average BOD5 generation (Gg BOD5)	Quantity of BOD anaerobically treated (Gg BOD5)	Total methane released (Gg)	Carbon dioxide released (Gg)	Nitrous oxide released (Gg)	Methane Gg CH4 per Gg BOD5	Carbondioxide Gg CO2 per Gg BOD5	Nitrous Oxid Gg N2O per Gg BOD5	Methane (Gg)
						F=C/B	G=D/B	H=E/B	
B1 Industrial Wastewater	54.369	5.437	1.1961	NA	NA	0.22	NA	NA	0.00
B2 Domestic and Commercial Wastewater (sewers + septic tanks)	11.799	1.180	0.2596	NA	NA	0.22	NA	NA	0.00
B3 Other (Pit Latrines)	38.798	3.880	0.8535	NA	NA	0.22	NA	NA	0.00

Notes:
(1) NA refers to `not applicable'.
(2) No methane was recovered by open dumping practice.
(3) Experimental results were not used because they have a number of uncertainities which are considered higher than default factors.
(4) Pit latrines in rural areas are assumed to treat BOD5 loading aerobically due to less volumes deposited on daily basis.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The summary report for National Greenhouse Gas Emissions by sources and removal by sinks categories has been presented in Table 7A and 7B. From the Tables it could be observed that land use changes and forestry, and the energy sector contribute the largest share of greenhouse gas emissions in Tanzania. An overview of the study and estimates of uncertainties due to emission factors and data activities have been summarised in Table 8A and Table 8B1-1, respectively.

With the creation of the inventory of greenhouse gas emissions by sources and sinks, the study has provided for an adequate basis for priority ranking of emission sources and sinks to allow for concentration of efforts towards the more significant of these in the future. Furthermore it has provided the basis for embarking on studies related to mitigation of greenhouse gas emissions and assessment of vulnerability and adaptation to climate change.

Through the study the team have learnt that these studies should be directly or indirectly linked to the national developmental goals for example how an improved efficient technology could minimize greenhouse gases emissions and at the same time increase productivity and efficient use of resources.

7.2 Recommendations

While a lot of gaps do exist in the data and information available and that which is required for a detailed inventory, it is recommended that countries should carry similar work in the future by adopting a more flexible methodologies which are country specific. This will avoid limitations of the scope which result from one being limited by standard methodologies.

Classification of terms used in various sectors in the standard methodologies should be clearly defined and broadened to fit the local terms without ambiguity. For example in the forestry sector, in another country an open forest may be termed as woodland by another country or woody savanna be called grassland or woodland. This total create confusion in reporting the study results. There should be some sort of standardization of concepts and phenomena. Various concepts and phenomena differ from one region to another. For example the case of soil carbon in tropics and savanna burning have brought some controversy.

In order to meet objectives of future work, it is recommended that follow-up projects be evolved in line with national action plans.

The study has been constrained by the use of emission factors based on default values provided by IPCC as a result of absence of country-specific emission factors and emission ratios. It is recommended, therefore, that a programme be put in place to conduct studies aimed at obtaining country - specific emission factors.

Furthermore, it is recommended that the completion of the exercise of creation of an inventory of sources and sinks has to lead to the planning of strategies to evolve a mechanism for its regular updating and to enhance public outreach on climate change and related activities. These recommendations were also stressed in the National Workshop on Greenhouse Gases held in September, 1994.

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (SHEET 1)
(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2 Emissions	CO2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SFs
Total National Emissions and Removals										
1. All Energy (Fuel Combustion + Fugitive)										
A Fuel combustion										
1 Energy Transformation	1938.98	NA	0.21	0.0021	3.02	26.80	0.13	NA	NA	NA
2 Industry (ISIC)	NA	NA	0.01	0.0004	1.92	0.27	NA	NA	NA	NA
3 Transport	NA	NA	0.28	0.0217	6.75	51.17	7.06	NA	NA	NA
4 Small Combustion	NA	NA	0.02	0.0004	0.46	0.15	0.04	NA	NA	NA
5 Other Modes	NA	NA	0.01	0.0028	1.70	0.54	0.13	NA	NA	NA
6 Traditional Biofuels	NA	NA	424.48	1.9086	54.11	1550.00	NE	NA	NA	NA
Sub-total	*1938.98*	*NA*	*425.01*	*1.9360*	*67.96*	*1628.92*	*7.36*	*NA*	*NA*	*NA*
B Fugitive Emissions from Fuels										
1 Solid Fuels	NA	NA	0.82	NA	NA	NA	NA	NA	NA	NA
2 Natural Occuring Exploited Gases	1.26	NA	NE	NA	NA	NA	NA	NA	NA	NA
Sub-total	*1.26*	*NA*	*0.82*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
2. Industrial Processes										
1 Non-Metal Processes (Cement)	343.67	NA	NE	NA	NA	NA	NA	NA	NA	NA
2 Non-Mineral Processes (Pulp and Paper)	5.79	NA	NE	NA	NA	NA	NA	NA	NA	NA
Sub-total	*349.45*	*NA*	*NE*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
3. Solvent and Other Product Use										
Sub-total	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*

Notes:
(1) Mining naturally occuring carbondioxide deposits results in anthropogenic emissions.
(2) Small combustion include fossil fuel combustion in farms, households, commercial, and informal sector. Small gensets and flour mills are not implied.
(3) NO, NE, and NA refer to "not occuring", "not estimated", and "not applicable", respectively.
(4) Other modes include construction equipment running on fossil fuels.
(5) Carbon dioxide emissions from energy transformation were determined by "top-down" approach (cf. Chapter 2 of CEEST No. 5/1994)
(6) Carbon dioxide emissions from traditional biofuels fall under closed carbon cycle, thence are indirectly considered .

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (SHEET 2)
(Gg)

GHG SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	HFCs	PFCs	SFs
4. Agriculture										
A Enteric Fermentation	NA	NA	873.27	NA	NA	NA	NA	NA	NA	NA
B Manure Management	NA	NA	8.06	NA	NA	NA	NA	NA	NA	NA
C Rice Cultivation	NA	NA	84.76	NA	NA	NA	NA	NA	NA	NA
D Nitrogenous fertilizers	NA	NA	NA	0.57	NA	NA	NA	NA	NA	NA
E Field Burning of Agricultural Residues	NA	NA	323.00	0.57	20.73	1053.48	NA	NA	NA	NA
F Unprescribed Burning of Savannas	NA	NA	47.83	0.59	21.39	1255.40	NA	NA	NA	NA
G Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sub-total	***NA***	***NA***	***1336.91***	***1.73***	***42.12***	***2308.87***	***NA***	***NA***	***NA***	***NA***
5. Land Use Change and Forestry										
A Changes in Forest and Other Woody Biomass Subject to Human Activity, and Growing Stocks	55937.51	1814.77	NA	NA	NA	NA	NA	NA	NA	NA
B Forest and Grassland Conversion	727.29	NA	2.48	0.02	0.62	27.16	NA	NA	NA	NA
C Abandonment of Managed Lands	NA	1930.50	NA	NA	NA	NA	NA	NA	NA	NA
D Other (Shifting cultivation and Dams)	NA	NA	1.12	0.01	0.14	4.17	NA	NA	NA	NA
Sub-total	***56664.80***	***3745.27***	***3.60***	***0.02***	***0.76***	***31.33***	***NA***	***NA***	***NA***	***NA***
6. Waste Management										
A Municipal Solid Waste Disposal on Land	NA	NA	8.36	NA	NA	NA	NA	NA	NA	NA
B Wastewater (industrial and municipal) Treatment	NA	NA	2.31	NA	NA	NA	NA	NA	NA	NA
C Waste Inceneration	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D Other solid wastes from industries	NA	NA	33.11	NA	NA	NA	NA	NA	NA	NA
Sub-total	***NA***	***NA***	***43.78***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***
7. Other										
International Bunkers	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: (1) NA refers to `not applcable'

Tanzania: National Greenhouse Gas Inventory, 1990

TABLE 7B SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2 Emissions	CO2 Removals	CH4	N2O	NOx	CO	NMVOC	HFCs	PFCs	SFs
Total National Emissions and Removals										
1. All Energy (Fuel Combustion + Fugitive)										
A Fuel combustion	1938.98	NA	425.01	1.94	67.96	1628.92	7.36	NA	NA	NA
B Fugitive Fuels	1.26	NA	0.82	NA	NA	NA	NE	NA	NA	NA
Sub-total (i)	*1940.24*	*NA*	*425.83*	*1.94*	*67.96*	*1628.92*	*7.36*	*NA*	*NA*	*NA*
2. Non-energy Industrial Processes	349.45	NA	NE	NE	NE	NE	NE	NA	NA	NA
3. Solvent and Other Product Use	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4. Agriculture	NA	NA	1336.91	1.73	42.12	2308.87	NA	NA	NA	NA
5. Land Use Change and Forestry	56664.80	3745.27	3.60	0.02	0.76	31.33	NA	NA	NA	NA
6. Waste	NA	NA	43.78	NA	NA	NA	NE	NA	NA	NA
7. Other	NA	NA	NE	NE	NE	NE	NE	NA	NA	NA
Sub-total (ii)	*57014.25*	*3745.27*	*1384.29*	*1.75*	*42.87*	*2340.20*	*NE*	*NA*	*NA*	*NA*
Grand total	*58954.49*	*3745.27*	*1810.12*	*3.69*	*110.83*	*3969.12*	*7.36*	*NA*	*NA*	*NA*

Notes:
(1) NA and NE refer to "not applicable" and "not estimated", respectively.
(2) The net carbon dioxide emissions are obtained by deducting total CO_2 removals from the total CO_2 emissions.
(3) These figures exclude emissions from International bunkers of jet fuel, gas oil, and residual fuel oil.
(4) Solvent products, CFCs, HFCs, PFCs, and SFs are beyond the scope of GHG study, and all these are considered under the Montreal Protocol.
(5) The detailed discussions on each of theses sources are foun in CEEST No. 5/1994.

TABLE 8A OVERVIEW TABLE FOR NATIONAL GREENHOUSE GAS INVENTORIES

OVERVIEW TABLE (SHEET 1)
(Gg)

GHG SOURCE AND SINK CATEGORIES	CO2		CH4		N2O		NOx		CO		NMVOC		HFCs		PFCs		SFs		Documentation	Disaggregation	Footnotes
	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality			
Total National Emissions and Removals																					
1. All Energy (Fuel Combustion + Fugitive)																					
A Fuel combustion																					
1 Energy Transformation	PART	M	PART	M	PART	L	PART	M	PART	M	PART	L	NA	L	NA	L	NA	L	H	1	3
2 Industry (ISIC)	PART	M	PART	M	PART	L	PART	M	PART	M	PART	L	NA	L	NA	L	NA	L	H	3	3
3 Transport	PART	M	PART	M	PART	L	PART	M	PART	M	PART	L	NA	L	NA	L	NA	L	H	3	3
4 Small Combustion	PART	M	PART	M	PART	L	PART	M	PART	M	PART	L	NA	L	NA	L	NA	L	L	3	3
5 Other modes	PART	M	PART	M	PART	L	PART	M	PART	M	PART	L	NA	L	NA	L	NA	L	L	1	3
6 Traditional Biofuels	NA	L	ALL	L	ALL	L	ALL	L	ALL	L	NA	L	NA	L	NA	L	NA	L	H	3	3
B Fugitive Emissions from Fuels																					
1 Solid Fuels	PART	M	ALL	M	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	H	3	3
2 Oil and Natural Gases	NE	L	NE	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	H	1	3
2. Industrial Processes	PART	H	NA	L	NE	L	NE	L	NE	L	NA	L	NA	L	NA	L	NA	L	H	0	3
3. Solvent and Other Product Use	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	L	0	3

Notes:
(1) PART and ALL refer to "partial estimates" and "all estimates", respectively.
(2) NA and NE refer to "not applicable", and "not estimated", respectively.
(3) H, M, and L refer to "high", medium", and "low", respectively.
(4) 0, 1, 2, and 3 refer to number of levels of disaggregation.

TABLE 8A OVERVIEW TABLE FOR NATIONAL GREENHOUSE GAS INVENTORIES

OVERVIEW TABLE (SHEET 2)

(Gg)

GHG SOURCE AND SINK CATEGORIES	CO2		CH4		N2O		NOx		CO		NMVOC		HFCs		PFCs		SFs		Documentation	Disaggregation	Footnotes
	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality			
4. Agriculture																					
A Enteric Fermentation	NA	L	PART	M	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	H	3	3
B Animal Wastes	NA	L	PART	M	NE	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	H	3	3
C Rice Cultivation	NA	L	PART	M	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	H	3	3
D Nitrogenous fretilizers	NA	L	PART	M	ALL	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	H	3	3
E Field Burning of Agricultural Residues	PART	M	PART	M	PART	M	PART	M	PART	M	ALL	M	NA	L	NA	L	NA	L	H	3	3
F Unprescribed Burning of Savannas	NA	M	ALL	M	ALL	M	ALL	M	ALL	M	NA	L	NA	L	NA	L	NA	L	H	1	3
G Other	NE	L	NE	L	NE	L	NE	L	NE	L	NE	L	NA	L	NA	L	NA	L	L	0	0
5. Land Use Change and Forestry																					
A Changes in Forest and Other Woody Biomass Stocks	PART	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	H	3	3
B Forest and Grassland Conversion	PART	L	PART	M	PART	M	PART	M	PART	M	NE	L	NA	L	NA	L	NA	L	H	1	3
C Abandonment of Managed Lands	PART	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	M	2	3
D Other	NA	L	PART	M	PART	M	PART	M	PART	M	NA	L	NA	L	NA	L	NA	L	L	2	3
6. Waste																					
A Solid Waste Disposal on Land	NA	L	PART	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	M	3	3
B Wastewater Treatment	NA	L	PART	M	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	M	3	3
C Waste incineration	NO	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	L	0	0
D Other Wastes	NE	L	PART	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	NA	L	M	1	3
7. Other																					
International Bunkers	NE	L	NE	L	NE	L	NE	L	NE	L	NE	L	NA	L	NA	L	NA	L	L	0	0

Tanzania: National Greenhouse Gas Inventory, 1990

TABLE 8B1-1 UNCERTAINITIES DUE TO EMISSION FACTORS AND ACTIVITY DATA

UNCERTAINITIES DUE TO EMISSION FACTORS AND ACTIVITY DATA				
1	2	3	4	5
Gas of high Priority	Source Category of high Priority	Emission Factor (%) Ue	Activity Data (%) Ua	Overall Uncertainity (%) Ut
CO2	All Energy	7	10	12
CO2	Industrial Processs	7	10	12
CO2	Land Use Change and Forestry	33	60	68
CH4	Biomass Burning	40	60	72
CH4	Coal Mining and Handling Activities	55	20	59
CH4	Rice Cultivation	50	20	54
CH4	Municipal Solid Waste and Wastewaters	55	40	68
CH4	Enteric Fermentation	25	20	32
CH4	Animal Waste	20	20	28
CO2	Industrial Processes	35	40	53
N2O	Nitrogenous fertilizers	50	50	71
CH4	Burning of agricultural residues	40	60	72

Notes:
(1) These estimates are based on availability of data, quality of data, and the methods used for aggregation of data.
(2) Reference for overall Ut estimates is Volume 1 of GHG Inventory Reporting Instructions.
(3) Uncertainities in CO_2 emissions or uptake estimates range from (+-) 12% to (+-) 68% for individual sources..
(4) Uncertainities in CH_4 emission estimates range from (+-) 24% to (+-) 72% for individual sources.
(5) Uncertainities in N_2O emission estimates range from (+-) 53% to (+-) 72% for individual sources.
(7) These uncertainities correspond to (+-) 0.295Mt, (+-) 0.0031Mt, and (+-) 0.0027Mt for CO_2, CH_4 and N_2O respectively.

REFERENCES

1. CEEST, 1995; Sources and Sinks of Greenhouse Gases in Tanzania: Final Report, Revised CEEST Report No. 5/1994, CEEST, Dar es Salaam.

2. IPCC/OECD, 1995; Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, Final Version, Vol. 2 - Reporting Instruction, IPCC, London.

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