National Greenhouse Gas Inventory Report for 1990-2006

Volume 1: Synthesis Report

October 2011

I would like to commend the effort made by Ghana's inventory compiling team. This will be recognized prominent milestone historically, I believe.

UNFCCC Reviewer, 2010

The reviewers would like to acknowledge the efforts Ghana has made to prepare this inventory draft report and to improve the estimate of emissions of the country for a whole time series. This is absolutely remarkable, since many NAI countries have not yet developed information for so many years. This report represents a big progress from the INC submission and reflects that Ghana has the capacity to develop and improve its emission inventories. The recommendations provided below are meant to help improve the transparency, comparability, consistency, and completeness of the inventory, providing guidelines on how to report what the country has already accomplished. Data included in the Ghana report is very well presented, aggregated and synthesized.

UNDP Review Team, 2010

Acknowledgments

Special thanks goes to UNDP/GEF for funding the whole greenhouse gas inventory exercise. Environmental Protection Agency gratefully acknowledges individuals and organizations who/that contributed significantly to the successful completion of Ghana's National Greenhouse Gas Inventory. Particular mention has to be made of institutions that provided various forms of supports to the inventory process. The institutions include: **E**nvironmental **A**pplication **a**nd **T**echnology Centre (ENAPT Centre); for leading the implementation of the greenhouse gas inventory process, Energy Commission, Kwame Nkrumah University of Science and Technology, Forestry Commission, Tema Oil Refinery, Ghana Statistical Service, National Petroleum Authority, Government Ministries of Ghana, Forestry Research Institute, Soil Research Institute, Accra, Kumasi and Shama Ahanta Metropolitan Assemblies, VALCO, Driver Vehicle and Licensing Authority(DVLA), Centre for Remote Sensing and Geographic Information Systems (CERGIS) and FAO; for providing data for the inventory. Our utmost appreciation also goes to the various private data owners who provided requisite country-level activity data for the inventory.

Last but not least, the Agency highly recognises the efforts by Dr. Stephen Duah-Yentumi, Mr. William Kojo Agyemang-Bonsu[1], Mr. Kyekyeku Yaw Oppong-Boadi, Daniel Tutu Benefoh and Dr. J.K. Adu for coordinating the activities of the work from commencement to completion. Finally, the EPA likes to thank the various sector experts and the respective working groups for their work, which culminated in the preparation of this report. We also wish to thank all those, especially those from UNDP New York, UNFCCC, Bonn and ECN, Netherlands who reviewed the inventory and also for the invaluable comments and suggestion, which added great value to the entire process.

[1] William Kojo Agyemang-Bonsu coordinated Ghana's Second National Communication, for which the report forms a part, until June 2010

Foreword

Ghana has an obligation as a party to the UNFCCC to prepare a National Communication under Article 4, paragraph 1(a) and Article 12, paragraph 1(a), of the Convention. The National Communication should contain among others; a national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol, and appropriate national policies and programmes to mitigate and means to facilitate adaptation to Climate Change. It is therefore under Ghana's Second National Communication (SNC) that this Greenhouse Gas Inventory was prepared. The preparation of this NIR is also consistent with Decision 1/CP.16 of the Cancun agreement, especially paragraphs 60(a-c). This current inventory report does not necessarily cover the entire elements (i.e. information on mitigation actions, needs and support received) of the Biennial report. Those elements will be addressed in the next version of the NIR.

Ghana prepared its first Greenhouse Gas Inventory (GHGI) under the Initial National Communication (INC). Under the SNC, Ghana has expanded the initial GHGI to cover 1990 to 2006 with 2000 as the reporting year. The inventory covers five sectors, namely; Energy, Industrial Process (IP), Agriculture, Land-Use Change and Forestry (LUCF) and Waste as well as these greenhouse gases; carbon dioxide, methane, nitrous oxide, tetrafluorocarbon and hexafluoroethane. Recalculation was made for the period under the INC (1990-1996) as recommended by the Good Practice Guidelines of the IPCC. Further emission estimates have been provided from 2001 to 2006. This GHG inventory report could be put to several uses. First, it is a good source of input information for formulating national policies and measures for reducing greenhouse gas emissions. Secondly, it could be a reliable reference material for variety of users including those in international and national climate change policy, research and education, climate business development, as well as students and the general public.

For researchers, this report provides depth of understanding in the inventorying of GHGs for identifiable economic sectors, linkages between emissions, development indicators and triggers. It also identifies a number of gaps where research would be needed. With respect to climate planning and policymaking, this report provides an outstanding basis for identifying, developing and prioritizing climate mitigation actions and target at sectors that have high emission reduction potential and benefits to the broader sustainable development goals. It is hoped that necessary resources will be made available for some of the programmes in the specific sectors to improve on activity data collection and emission factors for future inventory preparation for the achievement of the ultimate objective of the Convention

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Ag. Executive Director
Environmental Protection Agency
October 2011

List of Abbreviations

CH_4	Methane
CO_2	Carbon Dioxide
DVLA	Driver Vehicle and Licensing Authority
ENAPT	Environmental Application and Technology Centre
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
Gg	Gigagrammes
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GHGIR	Greenhouse Gas Inventory
GWP	Global Warming Potential
IEA	International Energy Agency
IPCC	Inter-governmental Panel on Climate Change
KNUST	Kwame Nkrumah University of Science and Technology
LNI	Lead National Institution
LUCF	Land Use Change and Forestry
MEST	Ministry of Environment, Science and Technology
Mt	Mega Tonne
N_2O	Nitrous Oxide
NAMAs	Nationally Appropriate Mitigation Actions
NIR	National Inventory Report
NIS	National Inventory System
PFCs	Perfluorocarbons
QA/QC	Quality Assurance/Quality Control
ToR	Tema Oil Refinery
TRC	Technical Review Committee
TSPS	Transport Sector Programme Support
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

ES1: Background information on greenhouse gas inventories and climate change

The greenhouse gases that are released through human activities contribute to greenhouse effect and causing warming effect on the global weather system. This increase in the earth's temperature has adverse impacts and these impacts will need to be managed and adapted to, both now and in the future, as the climate changes. Though, developing countries like Ghana have not been necessarily responsible for the historical releases of GHGs, they are bearing the most impacts of Climate Change. As a Party to the UNFCCC, Ghana is preparing this GHG inventory as part of its Second National Communication in response Article 4 and 12 of the convention. The GHGI report is also prepared in accordance with the annex to decision 10/CP.2. In addition, the estimates, methodology and the national system for developing the inventory are consistent to the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000, 2003) according to Decision 17/CP.8.

This inventory was conducted for the following sectors: Energy, Industrial Process, Agriculture, Land use Change and Forestry and Waste covering these gases: CO_2, CH_4, N_2O, CF_4 and C_2F_6. The inventory covered 1990 to 2006 though Ghana is reporting on 2000 as stipulated by Decision 17/CP.8. IPCC tier-1 methodology was adopted for the inventory except in few cases where country-specific methodology was used, for example, in the energy sector. Generally, emissions factors were derived from IPCC emission factor database. Most of the activity data were retrieved from various national sources and complemented with international data from FAO and IEA. Recalculation was implemented in the inventory sectors and for most gases. The recalculation was done because of the availability of new datasets and methodology since the first inventory cycle. Key category analysis using the levels approach for 1990, 2000 and 2006 for applicable gases was implemented.

ES2: Overview of source and sink category emission estimates and trends

ES2.1 Overview of source and sink emissions by sectors

This NIR covers greenhouse gas emission and removal from 1990 to 2006 with 2000 as the base year. In 2000, the total direct greenhouse gas emission (including LUCF emissions) in Ghana was estimated at 12.2MtCO_2e (based on carbon dioxide, methane, nitrous oxide and perfluorocarbons). This is 173% above 1990 levels of -16.8 MtCO_2e and 96% lower than 2006 levels of 23.9MtCO_2e (figure ES 2.1). This change amounted to 242.3% increase from 1990 to 2006. If emissions from LUCF are excluded in 2000, the total GHG emissions in Ghana was estimated at 13.3MtCO_2e, which is about 49.4% above 1990 levels of 8.9MtCO_2e and approximately 38% below 2006 levels of 18.4MtCO_2e. This represented an overall increase of 107% from 1990 to 2006. Ghana's emission represents about 0.05% of the total global emissions and is ranked 108 in the world, which represents a total per capita emission of nearly 1MtCO_2e per person as of 2006.

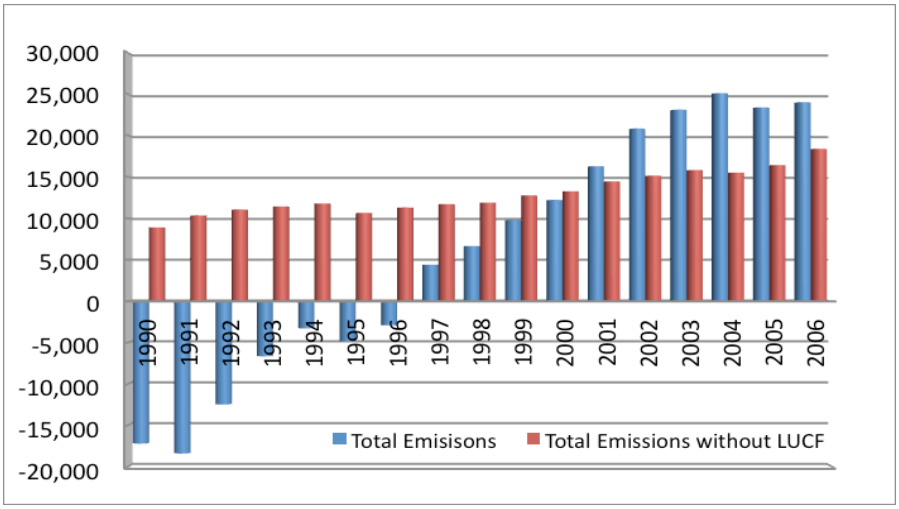

Figure ES 2.1: Trend of total GHG emissions including LUCF (in $GgCO_2e$)

Though Ghana's emissions is lower than other major developing economies, the trends clearly indicated a strong growing potential in the near to medium term horizon as the economy continues to grow and expand development to new frontiers, dominated by agriculture, forestry and oil and gas industries. The largest contribution to the total national emissions was the energy sector, accounting for 41%. Energy sector emissions increased by 32% above 1990 levels and declined marginally by 2% to 39% of the total emissions by 2006 (figure ES 2.2) Emissions from transport and residential categories were the largest emission sources within the energy sector. The general increase in emissions from the sector could be attributed to the increasing fuel consumption in the growing proportions of power generated from thermal sources, increasing fuel consumption and poor fuel efficiency in the road-transport category as well as rising biomass use in the residential sub-category.

The second largest contributor to total national emission was from the agricultural sector, amounting to approximately 38%. The general increasing trends of agricultural emissions of about 44.2% between 1990 and 2006 reflect increasing trends in livestock numbers and emissions from fertilizer application. Within the sector, emissions from agricultural soils, enteric fermentation and rice cultivation have had significant impacts on the general emission. Emissions from the waste sector constituted an average of 10% between 2000 and 2006, which is approximately 8% higher than the 1990 levels is the third largest contributor to the national emissions. The main sources of emission from this sector are from disposal of solid waste on land (particularly, waste dump site) and wastewater handling. The sector emissions were driven by the increasing per capita solid waste generation among population especially in the urban areas of Ghana. Disposal of solid waste to land with relatively deeper depth and to sanitary landfill sites is increasingly becoming common practices in urban waste management. This provides suitable conditions for the production of methane, which is not managed in any way in Ghana.

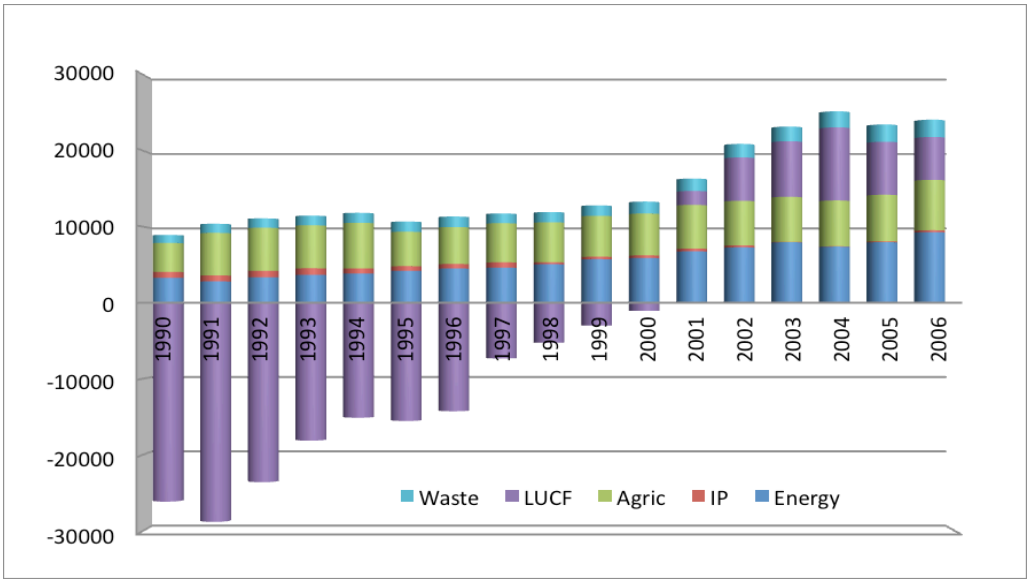

Figure ES 2.2: Trends of Total Emissions by Sectors (Gg CO_2eq.)

ES 2.2 Overview of source and sink emissions by Gases

Carbon dioxide (CO_2) emissions (including emissions from Land Use Change and Forestry, LUCF) contributed -16.3Mt, 13.3Mt and 22.9Mt of the total greenhouse gases in 1990, 2000 and 2006, respectively. Without LUCF, carbon dioxide was 9.8Mt, 15.8Mt and 18.7Mt of the total greenhouse gas emissions for the same periods respectively. In terms of reported greenhouse gas emissions, carbon dioxide was estimated at -23.9MtCO_2e in 1990 to 2.6MtCO_2e and 10.5MtCO_2e in 2000 and 2006 respectively, including LUCF. Between 1990 and 1999, CO_2 emissions contributed to net removal by sink but experienced a steady inter-annual reduction at an average rate of 24% until 1999. Beyond 1999, net CO_2 emissions increased up to 12.4MtCO_2e in 2004 and decreased marginally to 10.5MtCO_2e in 2006. This decease could be largely attributable to the net positive effect of the national afforestation programmes through the enhancement of forest biomass stocks. It similarly experienced steady increase between 1990 and 2006 but saw a slight reduction in 2004. Nitrous oxide is the third most important direct greenhouse gas during the period (1990-2006). Their levels also increased from 1990 up to 2004 and decrease afterwards. PFCs (CF_4 and C_2F_6) emissions were recorded in small quantities in the time series. Without LUCF, CO_2 emissions dominated through the time series followed by CH_4, N_2O and the PFCs.

ES3: Summary of Conclusions

The following conclusions could be drawn from the GHG inventory:

- Though Ghana's emissions are low compare to other countries, there is potential for the emissions to grow and peak across sectors considering emerging economic prospects for Ghana under business as usual.
- Carbon dioxide is the major greenhouse emissions in Ghana however; methane is predicted to contribute significantly to the national greenhouse emissions in the coming years as a result of increased activities in the oil and gas industry.
- The energy sector continues to be the largest source of greenhouse emissions as at 2006 and it is predicted to dominate over time. However, emissions from land use change and forestry have significant impact on the national emissions especially through forest and grassland conversions.
- General climate change mitigation planning in particular should prioritize mitigation interventions for emissions reductions from the energy, forestry and agriculture sector. However, other sectors like the waste becomes important because of other co-benefits associated with climate mitigation efforts.

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Table 1: List of IPCC sectors

Codes	Sectors	Categories	Sub-categories
		1. Energy	
A.1	**Fuel Combustion Activities**	**Energy Industries**	
A.1A			Public Electricity and Heat Production
A.1B			Petroleum Refinery
A.1C			Manufacture of solid fuels and other Energy
A.2		**Manufacturing Industries and construction**	
A.2A			Iron and Steel
A.2B			Non-Ferrous Metals
A.2C			Chemicals
A.2D			Pulps, Paper and Print
A.2E			Food Processing, Beverages and Tobacco
A.2F			Other
A.3		**Transport**	
A.3A			Civil Aviation
A.3B			Road Transportation
A.3C			Railways
A.3D			Navigations
A.3E			Other
A.4		**Other Sectors**	
A.4A			Commercial/Institutional
A.4B			Residential
B.	**Fugitive Emissions from Fuels**		
B.1		**Solid Fuels**	
B.1A			Coal Mining
B.1B			Solid Fuel Transformation
B.1C			Other
B.2		**Oil and Natural Gas**	
B.2A			Oil
B.2B			Natural Gas
B.2C			Venting and Flaring
2	**Industrial Process**		
2A	**Industrial Process**	**Mineral Products**	
2A.1			Cement Production
2A.2			Lime Production
2A.3			Limestone & dolomite
2A.4			Soda Ash Production & Use
2A.5			Asphalt Roofing
2A.6			Road Paving with Asphalt
2A.7			Other
2B		**Chemical Industry**	
2B.1			Ammonia Production
2B.2			Nitric Acid Production
2B.3			Adipic Acid Production
2B.4			Carbide Production
2B.5			Other
2C		**Metal Production**	
2C.1			Iron and Steel Production
2C.2			Ferroalloys Production

2C.3			Aluminum Production
2C.4			SF6 Used in Al and Mg. Foundries
2C.5			Others
2D		**Other Production**	
2D.1			Pulp and Paper
2D.2			Food and Drink
2E		**Production of Halocarbons and Sulphur Hexafluoride**	
2E.1			Refrigeration and Air Condition Eq.
2E.2			Foam Blowing
2E.3			Fire Extinguishers
2E.4			Aerosols
2E.5			Solvents
2E.6			Other
4	**Agriculture**		
4A		**Enteric Fermentation**	
4A.1			Cattle
4A.2			Buffalo
4A.3			Sheep
4A.4			Goats
4A.5			Camels and Llamas
4A.6			Horses
4A.7			Mules and Asses
4A.8			Swine
4A.9			Poultry
4A.10			Other
4B		**Manure Management**	
4B.1			Cattle
4B.2			Buffalo
4B.3			Sheep
4B.4			Goats
4B.5			Camels and Llamas
4B.6			Horses
4B.7			Mules and Asses
4B.8			Swine
4B.9			Poultry
4B.10			Anaerobic
4B.11			Liquid Systems
4B.12			Solid Storage and Dry Lot
4B.13			Other
4C		**Rice Cultivation**	
4C.1			Irrigated
4C.2			Rain fed
4C.3			Deep water
4C.4			Other
4D		**Agricultural soil**	
4E		**Prescribed Burning of Savannas**	
4F.		**Field Burning of Agricultural Residues**	
4F.1			Cereals
4F.2			Pulse
4F.3			Tuber and Root

4F.4			Sugar Cane
4F.5			Other
4G		**Other**	
5	**LUCF**		
5A		**Changes in Forest and Other Woody Biomass**	
5B		**Forest and Grassland Conversions**	
5C		**Abandonment of Managed Lands**	
5D		**CO_2 Emissions and Removals from soil**	
6	**Waste**		
6.A		**Solid Waste Disposal on Land**	
6.A1			Managed Waste Disposal on Land
6.A2			Unmanaged Waste Disposal Sites
6.A3			Other
6.B		**Wastewater Handling**	
6.B1			Industrial Wastewater
6.B2			Domestic and Commercial Wastewater
6.B3			Other
6.3		**Waste Incineration**	

Table 2: Revised 1996 IPCC gases covered and their GWPs

Gas	Particulars	GWP
CO_2	Carbon Dioxide	1
N_2O	Nitrous Oxide	320
CH_4	Methane	21
CF_4	Tetrefluromethane	6400
C_2F_6	Hexafluroethane	9200

Units and Conversions

Emissions of greenhouse gases presented in this report are given in Gigagrammes (Gg), and Million tonnes (Mt). GWP weighted emissions are also provided. To convert between the units of emissions, use the conversion factors given below.

Table 3: Prefixes and multiplication factors

Multiplication factor	Abbreviation	Prefix	Symbol
1,000,000,000,000,000	10^{15}	peta	p
1,000,000,000,000	10^{12}	tera	t
1,000,000,000	10^{9}	giga	Gg
1,000,000	10^{6}	mega	mg
1,000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	Da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000,001	10^{-6}	micro	μ

1 kilotonne (kt) =10^{3}tones =1,000 tones
1 Mega tonne (Mt) =10^{6}tones=1,000,000 tones
1 Gigagramme (Gg) = 1 kt
1 Teragramme (Tg)=1 Mt

Conversion of carbon emitted to carbon dioxide emitted
To covert emissions expressed in weight of carbon, to emissions in weight of carbon dioxide, multiply by 44/12.

Conversion of Gg of greenhouse gas emitted into Gg CO_2 equivalent
Gg (of GHG) * GWP = Gg CO_2 equivalent.

The GWP is the Global Warming Potential of the greenhouse gas. The GWPs of greenhouse gases used in this report are given in table 2.

List of authors

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Supporting Lead Author	**Kyekyeku Yaw Oppong-Boadi**
Lead Author	**J.K. Adu (PhD)**
Technical Author	**Daniel Tutu Benefoh**

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• Energy Section	Lawrence Kotoe
• Industrial Process Section	Joseph Baffoe
• Agricultural Section	J.K. Adu & Theodore E. Asimeng
• Land Use Change Forestry Section	Daniel Tutu Benefoh
• Waste Section	Juliana Boateng-Bempah (Mrs.)

[1] William Kojo Agyemang-Bonsu served as Coordinating Lead Author until end of June 2010

Overview of the GHG Inventory

The chapter provides introduction to the report by addressing the overall structure and status of the national GHGI system and processes for implementing the greenhouse gas inventory in Ghana. In addition, information on selection of methods, activity data and emission factors are provided. The chapter also deals with major crosscutting issues in the inventory such as analysis of key categories, QA/QC, completeness, recalculations and improvements.

1.1 Introduction

This is Ghana's National Inventory Report (NIR) under the second national communication. The NIR is one of the reporting elements Ghana has prepared in response to Article 4, paragraph 1(a) and Article 12, paragraph 1(a), of the Convention, which provides for each Party to report national emissions and removals to the Conference of the Parties (COP). The preparation of NIR is not part of the reporting requirements under the decision 17/CP.8, yet Ghana has prepared this report because it makes documentation of the work on the preparation of national inventory transparent and serves as a record keeping and tracking of how the inventory has been prepared, whilst listing important areas for improvements in subsequent inventory cycle. The current NIR reports GHG emissions by source and removal by sinks for five major sectors; namely: energy, industrial processes, agriculture, land use change and forestry and waste.

The major gases covered include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and Perfluorocarbons. The current GHGI builds on the previous GHGI prepared under the initial communication to ensure time series consistency and where necessary implement recalculation on relevant sectors or categories. Though, Ghana is required to report on its greenhouse gas emissions for the year 2000 under the second national communication, it has

chosen to report for the entire time series from 1990 to 2006. In some cases recalculation has been implemented for the 1990 to 1996 time series as reported in the initial national communication due to the availability of new dataset and methods. The recalculation reflected better accuracy and consistency in the emission estimates. In addition, the preparation and reporting of this national GHG inventory provides a number of other benefits to Ghana as well. These include among others:

- Provision of basic infrastructure for the development of low greenhouse gas emission growth plans
- Provision of useful information to economic development assessment and planning, such as: information on the supply and utilization of natural resources (e.g., croplands, forests, energy resources) and information on industrial demand and production.
- Provision of functional information for addressing other environmental issues (e.g., air quality, land use, waste management, etc.)
- Analysis and capturing of information on GHG emissions key category for effective prioritization and use of resources.
- Highlight and clarify national data gaps that, if filled, may be beneficial for other reasons, e.g., vehicle fleet data, national fuel consumption data, and deforestation rates data.
- Provision of basis for evaluating GHG mitigation options and based on Ghana's national circumstances and pursues cost-effective emission reduction/enhancement efforts comprehensively.

1.2 Structure of Report

This report consists of four (4) chapters, each addressing related issues on the greenhouse gas inventory. Chapter one (1) provides introduction to the report addressing the structure and status of the national system and processes for implementing the greenhouse gas inventory. In addition, information on selection of methods, activity data and emission factors are provided. The chapter also deals with major crosscutting issues in the inventory such as analysis of key categories, QA/QC, completeness, recalculations and improvements. Chapter two (2) of the report is dedicated to the analysis of national GHG emissions and trends. The analysis is done according to emissions by gases and sectors over the entire inventory period. A compilation of sector-estimates, methodologies, approaches and its associated crosscutting issues are provided in the chapter three (3). Chapter four (4) provides short discussion on the emission results, planned improvements and conclusions.

1.3 Greenhouse Gas Inventories and Climate Change

There is strong evidence that since the early twentieth century the change in the earth's climate is linked to the release of greenhouse gases (GHGs) from human activities. The greenhouse gases that are released contribute to a process known as the greenhouse effect. The greenhouse effect is a naturally occurring process, which controls the temperature of the earth. However, the release of extra greenhouse gases from human activities contributes to this process and traps extra heat within the earth's atmosphere, causing a warming effect. This increase in the earth's temperature has adverse impacts and these impacts will need to be managed and adapted to, both now and in the future, as the climate changes. Though, developing countries like Ghana have not been necessarily responsible for the historical releases of GHGs, they are bearing the most impacts of climate change. This is because they

simply lack the capacity to adequately adapt to the already climate happenings and the expected changes in human and natural systems. In Ghana, different forms of climate change effects are being observed across various sectors of economy and in typical ecological zones. In response to the threat of climate change, the United Nations Framework Convention on Climate Change - UNFCCC and Kyoto Protocol were established in 1992 and 1997 respectively. Ghana joined the global community to signing the convention and the protocol and further ratified it.

Ghana ratified the United Nations Framework Convention on Climate Change (UNFCCC) in September 1995 and the Convention came into force in December 1995. Parties to the Convention are obligated to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs). Ghana's NIR is prepared in part to respond to Articles 4 and 12 of the Convention and annex to decision 10/CP.2. In addition, the estimates, methodology and the national system for developing the inventory are consistent to the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000, 2003) and in accordance to Decision 17/CP.8.

1.4 Description of National System and Process for the Inventory Preparation

The national inventory system (NIS) in Ghana defines the institutional set-up and procedures for legitimate data collection, collation, analysis and archiving of all relevant information as input into the inventory. The institutional set-up includes; stakeholder institutions (such as government agencies, private and third party entities), their assigned roles and channels for data provision and management. Some of the major government agencies that are repository of relevant activity data for the greenhouse gas inventory are; Energy Commission, National Petroleum Authority, the District Assemblies, Forestry Commission, Ministry of Agriculture, Environmental Protection Agency, Ghana Statistical Service, Kwame Nkrumah University of Science and Technology, Volta Aluminum Company Limited and Council for Scientific and Industrial Research.

Data were also collected from local research outputs especially from Soil Research, Forestry and Animal Research Institutes under the Council for Scientific and Industrial Research. Though, there is no specific legal regime backing data sourcing from data repositories, official arrangements exist among key data providers within the national system which offer platform for data supply on timely basis. Undoubtedly, the national system set-up would function efficiently if improvements are pursued in terms of its robustness, coordination and adaptability. In the coming years, Ghana will undertake improvements activities in the national system especially in the areas of institutional re-alignments, setting of clearer roles and responsibilities among relevant institutions, general mainstreaming of the national system, general data management and above all open-up the space for effective coordination and mainstreaming.

1.4.1 Current Institutional Arrangement for Data Acquisition and Management of the GHGI under Second National Communication

The Environmental Protection Agency (EPA) under the Ministry of Environment Science and Technology (MEST) is the Lead National Institution (LNI) coordinating all technical climate change activities including the GHGI. The Energy Resources and Climate Change (ERCC) Unit is the responsible office coordinating the GHGI process. The Climate Change Focal Point chairs a technical review committee (TRC) that has oversight over the general direction of the greenhouse gas inventory preparation and compilation. EPA has designated Environmental Application and Technology (ENAPT) Centre to coordinate the implementation of the Greenhouse Gas inventory activities, (including preparation of the inventory estimates, key source analysis, QA/QC, uncertainty management, documentation and archiving and preparation of the inventory report in Ghana.

An ad-hoc national inventory team, comprising experts from the various inventory sectors (energy, industrial process, agriculture, LUCF and waste) was setup at the centre. The working team members are drawn from the following institutions among many others: Environmental Protection Agency (EPA), Tema Oil Refinery (ToR), Ghana Statistical Service, Kwame Nkrumah University of Science and Technology (KNUST), Energy Commission, Forestry Commission, Environmental Application and Technology Centre (ENAPT Centre) and Driver and Vehicle Licensing Authority (DVLA), Ministry of Food and Agriculture, among many others. The mandate of each working team was to conduct a complete inventory of GHG emissions by sources and removals by sink according to the IPCC guidelines and guidance. Each working team has a leader who makes sure that the task of each team is undertaken in accordance with the IPCC guidelines and guidance. The table below provides information on members of the inventory management team.

Table 4: National GHG emissions inventory team

Unit/Name	Organization	Contact Information	Role	Comments
Energy Resources and Climate Change Unit/ William K. Agyemang-Bonsu	Environmental Protection Agency	P.O. Box M326 Accra, Ghana	Designated National Inventory Agency	Manages second national communication process/overall direction of the GHGI
Dr. J.K. Adu	ENAPT Centre, Accra	P .O. Box 13169 Accra	National Inventory Team Leader (NITL)	Consulting Firm and leader of national emission inventory
			Agric Sector Lead	Manages GHG in the Agric Sector
			Data and Document (Archives) Manager Coordinator	Operate portal platform for data gathering and archiving
Theodore K. Asimeng			Agric Sector Support	Provide support to Agric Sector
Lawrence Kotoe	Environmental Protection Agency	P.O. Box M326 Accra, Ghana	Energy Sector Lead	Manages GHG in the Energy Sector
Joseph Baffoe			Industrial Sector Lead	Manages GHG in the Industrial Sector
Daniel Tutu Benefoh			LUCF Sector Lead	Manages GHG in the LUCF Sector
			General section	Track GHG and IPCC process
			QA/QC Coordinators	Co-ordinate internal and external review process, Lead Compiler
Dr. J.K. Adu	ENAPT Centre, Accra	P .O. Box 13169 Accra		
Juliana Boateng-Bempah (Mrs)			Waste Sector Lead	Manages GHG in the Waste Sector
Particulars of Lead Sector Experts				
Dr. J.K. Adu	National Inventory Leader and Agriculture expert			
William Kojo Agyemang-Bonsu	UNFCCC Lead Reviewer, Generalist and Industrial Process Expert			
Daniel Tutu Benefoh	UNFCCC Reviewer on Energy and LUCF Expert			
Larry Kotoe	UNFCCC Reviewer on Energy and Energy Expert			
Joseph Baffoe	UNFCCC Reviewer Industrial Process and Industrial Process Expert			
Juliana Boateng Bempah	UNFCCC Reviewer on Waste and Waste Expert			

Leaders of the various working groups for the sectors were tasked to carry-out identification and sourcing of key inventory dataset; prepare inventory estimates with supporting documents, make important decisions such as determining the appropriate level of disaggregation for data collection, decide which variables may require collection of enhanced input data, maintain standard of work at the group level. In addition to their assigned roles, experts from whose institution's data will be obtained are given additional roles to facilitate the sourcing of the data in-house. Members of the working team conduct data and logistic needs assessment and make request through their respective leaders to ENAPT centre. The centre thus forwards the request for data and other forms of assistance from the working team to the EPA for action. Data request from EPA is made from the top management of relevant institutions indicating what form of data is required, covering years, data format and main use of the data in the GHGI.

Collected data for the inventory goes through several steps of administrative procedures for serialised documentation. Initial technical and quality evaluation of the activity data is done before transmission to the working teams. First back-up copies are also made at ENAPT centre. EPA has cordial working relationship with some of the data providers and this makes access to data not difficult though sometimes such arrangement tends to be unreliable. In cases where data providers incurred cost in generating data, the EPA is constrained in fully accessing the data. Data providers in certain cases request data protection assurance and acknowledgement of data use in any further publications. Under the Environmental Protection Agency, Act, Act 490, 1994 and the Environmental Assessment Regulation, manufacturing companies submit annual report to the EPA, this also serve as good data source for the inventory.

Final GHG emission estimates, trends and key categories are presented to EPA for final general quality control and quality assurance (QA/QC) to be carried out. The QA/QC coordinators facilitate a two-layered review process to assess general correctness of the inventory-estimates, data choices, and emission factors and the consistency with IPCC guidelines and good practice guidance. The first layer of the QA/QC evaluation is an external review of the whole GHG by a third party in the country. The third party reviewers are selected from research and the academic institutions based on their requisite experience in the sector. Feedbacks from the first round of review are incorporated into the final estimates. International experts in GHGI undertake the second layer of the review if considered necessary. The review process is crucial to maintaining rigor and quality of the estimates, background assumptions and the methodologies used. Figure 1 shows the organizational arrangement of the national system.

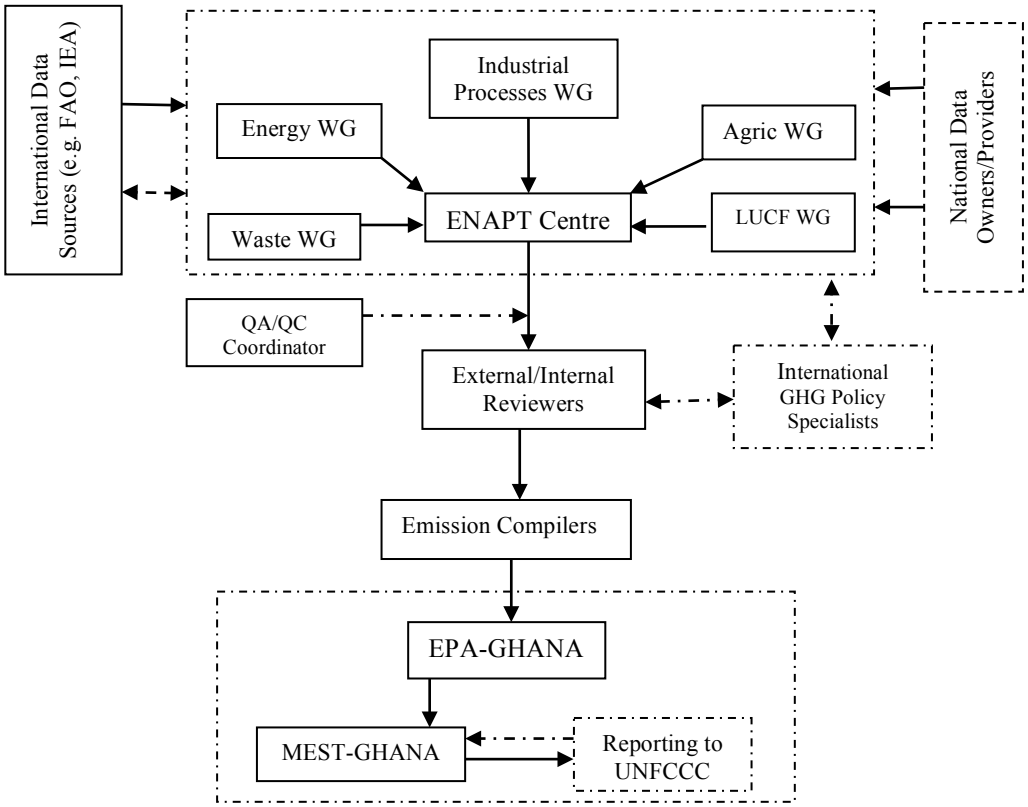

Figure 1: Institutional arrangement for the national system

The implementation of the NIS is iterative and evolving over time. One aspect that has seen major improvements over the years is the increasing institutional awareness and participation. This has contributed immensely to facilitating data access from entities that generate relevant data for the inventory. Future improvements in the NIS would, among others, seek establishment of overall legal backing or framework and general mainstreaming across sectors. The mainstreaming would to the extent possible prioritize and address issues such as funding, strategies for capacity enhancement, measures for continuous data collection, collation and archiving system.

1.4.2 Overview of Ghana's Inventory preparation

The preparation of the emissions inventory is based on the application of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, as elaborated by the IPCC good practice guidance. The compilation of the inventory is completed in four main stages: planning, preparation, management and inventory compilation

Planning stage

The EPA led the planning stage of the inventory preparation in collaboration with the Technical Review Committee (TRC). Two major tasks were implemented during the planning stage. Firstly, an inception workshop was organized for key national stakeholders

to mainly undertake the following; raise awareness, solicit institutional support for the GHGI process, form various working teams, schedule tasks and responsibilities among working teams and discuss timelines for the GHGI. Secondly, the EPA organized a two-week technical training for the working teams on the Revised 1996 IPCC National Greenhouse Gas Inventories Guidelines and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000, 2003). The time used at the planning stage is about 10% of the entire inventory timeline. The planning activities generally provided the enabling capacities among the team member to ensure effective implementation of the inventory.

Preparation stage

The preparation stage is central to the GHGI. Identification, reviewing of activity data and its sources were implemented here. This is followed by data request, data collections and evaluation of applicable source/sink categories. Quality control and quality assurance on activity data is part of the GHGI prepration activities to ensure early detection of errors. For example, where potential contradictions exist, comparison of the same or similar data from alternative data sources (e.g. Tema Oil Refinery, National Petroleum Authority and Energy Commission) is done to ensure consistency. Time series assessment is done at this stage. In cases where problems and/or inconsistencies are identified, the institution responsible for providing the data is called upon to explain the inconsistency and/or help correct the problem. Once the reliability of input data is checked and approved, emissions/removals per source/sink category are estimated using the IPCC software. The national inventory leader and the respective team leaders led this stage. The preparation stage almost took 60% of the entire inventory time cycle.

Management stage

Activities implemented at this stage, included documentation and archiving of data, such as emission estimates, emission factors, methodologies and all reports used. Final QA/QC activities are also implemented here. This includes evaluation of the emission factors used and the assessment of the consistency of the methodologies applied in relation to the provisions of the IPCC Guidelines, the IPCC Good Practice Guidance and the LUCF Good Practice Guidance. Quality control checks at this stage are related to time-series assessment as well as to the identification and correction of any errors / gaps while estimating emissions / removals. Fifteen per cent (15%) of the total inventory time is spent at this stage. The QA/QC coordinators lead this stage of the process.

Compilation stage

The inventory compilers spent 15% of the inventory time at this stage. This is the last stage of the inventory cycle and it involves the preparation of the sectoral GHGI reports, NIR and internal and external third-party review. Experts who were not directly involved in the GHGI process did the internal and external reviews. Review comments were incorporated before submission to the EPA and incorporation in the national communications. In addition, the results of the various peer reviews represent key input for the identification of possible improvements areas in the inventory. It is also important to recognize that data availability, availability of human and financial resources are equally crucial to the completion to the inventory on timely basis.

1.5 Overview of methodologies and data sources used

This section presents the methods used to estimate emissions in the various sectors. It provides a summary of emissions factors, activity data and it sources used in the inventory. Details of the methods and data sources are provided in the relevant sections of this report. The GHGs were estimated using methodologies, which mostly correspond to Tier 1 methods in the IPCC Guidelines. However, in some selected key categories such as transport (1.A3) and 5A and 5B under LUCF, country specific methods (Tier 2) were used as an improvement of the previous GHGI.

1.5.1 Selection of Emission Factors

The estimation of GHG emissions/removals per source/sink category is based on the methods described in the IPCC Guidelines, the IPCC Good Practice Guidance and the LUCF Good Practice Guidance. The emission factors used were derived from the above-mentioned methodological sources. Special attention was paid to selecting emission factors that better describe practices in Ghana. Furthermore, emission factors were obtained from the DANIDA funded transport-sector programme support (TSPS 2) project. The vehicular emission inventory component of the TSPS 2 provided country-specific emission factors for on-road transport using COPERT III model. An overview of the methods applied for the calculation of emissions/ removals is presented in Table 5.

Table 5: Methods used for the calculation of GHG emissions/removals

Greenhouse Gas Source and Sink Categories		CO_2		CH_4		N_2O		PFC-CF_4		PFC-C_2F_6	
		Methods applied	Emission Factor	Methods applied	Emission Factor	Methods applied	Emission Factor	Methods applied	Emission Factor	Methods applied	Emission Factor
1.	**Energy**	**D, T1**	**D, CS**	**D, T1**	**D, CS**	**D, T1**	**D, CS**				
A	Fuel Combustion	D, TI	D, CS	D, TI	D, CS	D, TI	D, CS				
1.	Energy Industries	D	D	D	D	D	D				
2	Manufacturing Industries and Construction	D	D	D	D	D	D				
3	Transport	D, T1, M	D, CS	D, T1	D, CS	D, T1	D, CS				
4	Other Sectors	T1	D	T1	D	T1	D				
B	**Fugitive Emissions from Fuels**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**				
1	Solid Fuels	NE	NE	NE	NE	NE	NE				
2	Oil and Natural Gas	NE	NE	NE	NE	NE	NE				
2.	**Industrial Process**	**D, PS**	**D, PS**	**NE, NO**	**NE, NO**	**NE, NO**	**NE, NO**	**D**	**D**	**D**	**D**
A	Mineral Products	D	D	NE	NE	NE	NE				
B	Chemical Industry	NO	NO	NO	NO	NO	NO				
C	Metal Production	D, PS	D, PS	NE	NE	NE	NE	D	D	D	D
F	Consumption of Halocarbons and SF6							NE	NE	NE	NE
4	**Agriculture**			**D, IE**	**D, IE**	**D, IE**	**D, IE**				
A	Enteric Fermentation			D	D	D	D				

B	Manure Management			D	D	D	D			
C	Rice Cultivation			D	D	D	D			
D	Agricultural Soils			D	D	D	D			
E	Prescribed Burning of Savannahs			IE	IE	IE	IE			
F	Field Burning of Agric Residues			D	D	D	D			
5	**Land-use & Forestry**	**D, CS**	**D, CS,**	**D**	**D, CS**	**D**	**D, CS**			
A	Changes in biomass and other woody biomass stock	D	D, CS	D	D, CS	D	D, CS			
B	Forest and Grassland Conversion	CS	D	CD	D	CD	D			
C	Abandonment of managed lands	D	D	D	D	D	D			
D	CO_2 emissions and removals from soils	D	D	D	D	D	D			
6.	**Waste**	**D**	**D**	**D**	**D**	**D**	**D**			
A	Solid waste disposal on land	D	D	D	D	D	D			
B	Waste –water handling	D	D	D	D	D	D			
C	Waste Incineration	NE	NE	NE	NE	NE	NE			

Key: CS= Country-Specific, PS= Plant-Specific, NE = Not Estimated, NA= Not Applicable, NO=Not Occurring D = Default IPCC methodology and emission factor, IE = Included Elsewhere, M = Copert III model

1.5.2 Source of Activity Data

Data collection and processing constitute the activity with the longest duration in the inventory cycle. The process of checking the data and reformatting is important to ensuring accuracy, completeness and consistency in the inventory and it is as equally relevant as emission factors. Table 6 gives an overview of the main datasets used for the estimation of GHG emissions / removals. Data retrieved from international organization's databases (such as FAO, IEA) complemented data collected from the data-providers in Ghana.

Table 6: Summary of sources of activity data used to estimate GHG emissions

Sector		Data Type	Data Source
1.A1	Energy Industry	Fuel consumption (Imports, exports)	• Energy Commission • National Petroleum Authority • Tema Oil Refinery • Ministry of Energy
1. A2	Manufacturing industry and construction	Fuel consumption	• Energy Commission • Environmental Protection Agency
1. A3	Transport	Number of vehicles, Fuel Consumption	• Energy Commission • Environmental Protection Agency • Driver Vehicle Licensing Authority

1.A4	Other Sectors (Residential/Tertiary Sector and Agriculture)	Fuel consumption	• Energy Commission • Forestry Commission
1.B	Fugitive emissions from fuels	NE	NE
2	Industrial Processes	Industrial Production	• Volta Aluminum Company Limited • Camuse Company Limited • Aluworks • Environmental Protection Agency
4	Agriculture	• Agricultural production • Livestock population • Nitrogen fertilizer use	• Ministry of Food and Agriculture • Institute for Statistical, Social and Economic Research • UN Food and Agriculture Organization • Animal Research Institute
5.	Land-use Change and Forestry	• Area and wood/biomass stocks of managed and natural forests • Harvested wood stocks • Afforestation and Deforestation areas and rates • Forest and grassland area affected by wildfires • Cultivated and fallow areas • Soil Classifications	• Inventory Compilers • Centre for Remote Sensing and GIS • Forestry Commission (Forest Service Division, Timber Industry Development Divisions • Private Sawmills • Forestry Research Institute • UN Food and Agriculture Organization • Environmental Protection Agency • Soil Research Institute
6	Waste	• Quantities - composition of municipal solid waste generated • Population • Quantities of liquid waste generated	• District Assemblies • Ghana statistical service • National consultants

1.6 Description of key categories

Key categories are defined as sources of emissions or removals that have a significant influence on the inventory as a whole, in terms of absolute level of the emissions, the trend, or both. Key categories are those which, when summed together in descending order of magnitude, add up to over 95% of total emissions (level assessment) or the trend of the inventory in absolute terms. The analysis of key categories was performed on the basis of sectoral distribution and using the Tier 1 approach for level estimates. Trends-based key category analysis was not implemented because of lack of requisite uncertainty data. Level assessment was undertaken for 1990 and 2000 (reporting year) and 2006. The LUCF sector is included in the analysis of key categories. The results of the key category analysis for 1990, 2000 and 2006 (including and excluding LUCF) are presented in Tables 7, 8, 9 and 10.

Table 7: Key categories including LUCF, 1990 (levels)

IPCC Category	Sector	Key Category	Gas	Cumulative level (%)
5A	LUCF	Changes in Forest and Other Woody Biomass	CO_2	60.2
5B	LUCF	Forest and Grassland Conversion	CO_2	76.2
5C	LUCF	Abandonment of Managed Lands	CO_2	82.0
4D	Agriculture	Direct and Indirect Emissions from Agricultural Soils	N_2O	85.1
5.D	LUCF	CO2 Emissions and Removal from Soils	CO_2	88.0
1A.3	Energy	Mobile Combustion: Road Vehicles	CO_2	90.7
4A	Agriculture	Emissions from Enteric Fermentation in Domestic Livestock	CH_4	93.2

Table 8: Key categories including LUCF, 2000 (levels)

IPCC Category	Sector	Key Category	Gas	Cumulative level (%)
5A	LUCF	Changes in Forest and Other Woody Biomass Stocks	CO_2	43.1
5B	LUCF	Forest and Grassland Conversion	CO_2	85.5
5C	LUCF	Abandonment of Managed Lands	CO_2	88.3
4D	Agriculture	Direct and Indirect Emissions from Agricultural Soils	N_2O	90.1
1A.3	Energy	Mobile Combustion: Road Vehicles	CO_2	91.8
4A	Agriculture	Emissions from Enteric Fermentation in Domestic Livestock	CH4	92.8
5B	LUCF	Forest and Grassland Conversion	N_2O	93.7
5B	LUCF	Forest and Grassland Conversion	CH_4	94.6

Table 9: Key categories including LUCF, 2006 (levels)

IPCC Category	Sector	Key Category	Gas	Cumulative level (%)
5B	LUCF	Forest and Grassland Conversion	CO_2	43.4
5A	LUCF	Changes in Forest and Other Woody Biomass Stocks	CO_2	84.8
5C	LUCF	Abandonment of Managed Lands	CO_2	87.3
5D	LUCF	Emissions and Removals from Soil	CO_2	89.4
1A.3	Energy	Mobile Combustion: Road Vehicles	CO_2	91.3
4D	Agriculture	Direct and Indirect Emissions from Agricultural Soils	N2O	92.9
4A	Agriculture	Emissions from Enteric Fermentation in Domestic Livestock	CH_4	94.0
6A	Waste	Emissions from Solid Waste Disposal Sites	CH_4	95.0

Table 10: Key categories excluding LUCF, 2000 (levels)

IPCC Category	Sector	Key Category	Gas	Cumulative level (%)
4D	Agriculture	Direct and Indirect Emissions from Agricultural Soils	N_2O	20.30
1A.3	Energy	Mobile Combustion: Road Vehicles	CO_2	39.10
4A	Agriculture	Emissions from Enteric Fermentation in Domestic Livestock	CH_4	50.20
2A	Industrial Processes	Emissions from Mineral Production	CO_2	58.60
1A.2	Energy	Emissions from Manufacturing Industries and Construction	CO_2	66.50
6A	Waste	Emissions from Solid Waste Disposal Sites	CH_4	73.80
4C	Agriculture	Emissions from Rice Production	CH_4	81.10
1A.4	Energy	Other Sectors: Residential	CH_4	87.50
6B	Waste	Emissions from Wastewater Handling	CH_4	90.70
1A.4	Energy	Other Sectors: Commercial	CO_2	93.20
1A.4	Energy	Other Sectors: Residential	CO_2	95.50

Table 11: Key categories excluding LUCF, 2006 (levels)

IPCC Category	Sector	Key Category	Gas	Cumulative level (%)
1A.3	Energy	Mobile Combustion: Road Vehicles	CO_2	22.56
4D	Agriculture	Direct and Indirect Emissions from Agricultural Soils	N_2O	40.93
4A	Agriculture	Emissions from Enteric Fermentation in Domestic Livestock	CH_4	53.49
6A	Waste	Emissions from Solid Waste Disposal Sites	CH_4	65.39
1A.4	Energy	Other Sectors: Residential	CH_4	75.73
4C	Agriculture	Emissions from Rice Production	CH_4	83.37
1A.2	Energy	Emissions from Manufacturing Industries and Construction	CO_2	90.01
1A.4	Energy	Other Sectors: Agriculture/Forestry/Fishing	CO_2	93.22

1.7 Information on the QA/QC

Quality Assurance / Quality Control (QA/QC) is a key tool for ensuring accuracy, transparency, consistency and completeness in the GHGI. The QA/QC in the national GHG inventory is implemented in two layers. ENAPT Centre and QA/QC coordinator at the EPA implemented the first layer of the QA/QC. The main objective at this stage is to proof-check all GHG estimates, data and methods used in the inventory and ensures compliance to the IPCC guidelines and the good practice guidance. The output of this review is communicated

to the sector experts for corrections to be done. At the working team level, experts and the lead group experts ensure that quality control protocols are followed rigorously and in compliance with the IPCC guidelines and the good practice guidance.

QC procedures at the working team level included data inquiry, data correctness and documentation, methodological choice in accordance with IPCC Good Practice Guidance and quality control checks for data from secondary sources and record keeping are fed into the first layer of QA/QC. In addition, all background assumptions and documentation about the data and methods are thoroughly verified for consistency. The second level of the QA/QC is mainly focused on quality assurance and it involves third party reviewers. The main activities here are related to different levels of reviews including the review of input data from experts, who are not directly involved in the GHGI, if necessary, solicit comments from stakeholders.

The NIR received extensive international third party reviews. The third-party reviews were by experts from the following international bodies: United Nations Development Programme Office (UNDP), New York, UNFCCC, Bonn and ECN, Netherlands. The UNDP expert view was coordinated by the National Communications Support Programme (NCSP) and took place from 22 October to 29 October 2010. It was conducted by María Paz Cigarán, with the support of Rocío Condor Golec, expert review for the agriculture and LUCF sectors. It was based fundamentally on the Decision 17/CP.8 -Annex I "Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention" and also in the elements from the IPCC Guidelines recommended in this decision for the preparation of the GHG emissions inventories for the Second National Communications (SNC). Tomoyuki Aizawa and R.A Rodrigo conducted the UNFCCC and ECN reviews respectively. As much as possible comments from the reviews have incorporated into the final NIR. The other comments that were not incorporated will be taken into consideration in the next inventory cycle as part of the future improvement interventions.

Apart from the international reviews, comments from nearly 50 national experts were solicited through electronic Delphi-panel method. With the support from the UNDP country office, a national GHG dissemination workshop was organized for stakeholders. The workshop afforded the opportunity to collect views and devise strategies for improving national GHG systems and the inventory process, issues on data and above all creates awareness on the inventory among key partners. Though the present QA/QC arrangements are fairly workable to an extent, it is one of the major areas of the inventory that would require improvements, especially in terms of developing an elaborative QA/QC system for the entire inventory. This will contribute to ensuring that the national system is able to function well and deliver GHG estimates that are accurate, transparent, consistent and above all repeatable.

1.8 General assessment of the completeness

An assessment of completeness for each sector may be found in the sector overview part of the corresponding sub-chapters; here is some aggregated information.

Geographic coverage

The geographic coverage is complete. No region in Ghana has been left uncovered by the inventory.

Sectors (sources and sinks)

All sources or removals of direct GHG gases, included in the IPCC Guidelines, were covered in the inventory except some completeness gaps in the following categories: Fugitive emissions from oil and gas (1.B1 and 1.B2) in the energy sector, chemical industry (2B) and other production (2D), consumption of halocarbons and sulphur hexafluoride, waste incineration (6C) and emissions estimates from Solvent and Other Product Use was not carried out for lack of data. Emissions from this sector do not adequately occur in Ghana. The general gaps in the completeness are mainly due to lack of activity data and the non-occurrence of the activity in Ghana.

Gases

Most direct gases were covered by the Ghanaian inventory. However, in the industrial processes sector, CO_2 and PFCs (CF_4 and C_2F_6) were covered except CH_4 N_2O and HFCs.

Notation keys

IE (included elsewhere):

Emissions (CH_4 and N_2O) from prescribed burning of savannahs (4.E) under the agriculture sector were included in forest and grassland conversion (5.B) for the sake of consistency and availability of improved spatial data in the LUCF sector. N_2O and CH_4 from biomass were included under energy instead of LUCF though the CO_2 is reported as memo items.

NE (not estimated):

There are categories reported as NE because of lack of necessary data. These sources are:

- Fugitive emissions from oil and gas (1.B1 and 1.B2)
- Chemical industry (2B)
- Consumption of halocarbons and sulphur hexafluoride (2F)
- Waste incineration (6C)

NO (not occurring)

The highest number of source categories marked with NO is found in the industrial processes sector, as most of these do not occur in the country.

1.9 Recalculations and Improvements

This section of the report summarizes recalculations and improvements made since the initial national communication was prepared. A number of recalculations have been performed since the previous inventory submission in order to improve consistency with respect to the IPCC guideline. Recalculation was implemented in the entire GHGI for the

time 1990 to 1996 series. The recalculation was in three forms: **updating** existing activity data or emission factors (in all the sectors), **expanding** the inventory by including emissions from additional sources (e.g. sub-category 5.D under LUCF sector was added to the inventory in 2000) and **extending the inventory** from 1996 to 2006.

1.9.1 Justification for recalculation

The reasons for the recalculations made, can be grouped as follows:

Changes or refinements in methods. A methodological change occurs when an inventory agency uses a different tier to estimate emissions from a source category (e.g. for key source categories) or when it moves from a tier described in the IPCC Guidelines to a national method. Methodological changes are often driven by the development of new and different data sets. A methodological refinement occurs when an inventory agency uses the same tier to estimate emissions but applies it using a different data source or a different level of aggregation. In this latest inventory, the inclusion of new sets of data in almost the sectors.

For example, in the current inventory, emissions from sectoral-approach was included to the reference-approach in the CO2 and non-CO2 emissions of the energy sector, in addition, in 5.B under LUCF, new dataset was retrieved from remote sensing imagery on the various land classes and their change matrix. The imagery also helped in picking wildfire areas. The methodology was an improvement of the previous one in the first inventory. The methodology for modeling transport emissions using COPERT III in the transport (1.A3) sub-category also contributed to the general improvement in the estimates.

- **Inclusion of new sources**. A new source is defined as a source for which estimates (all or some gases) did not exist in previous inventories either due to lack of data or because it has just been identified. Emissions from sub-category 5.D under LUCF were included in 1996to 2006 due to access of data on carbon emissions from soils. Under Energy, emissions from sub-category 1A (other sectors-residential) were added.

- **Re-allocation**. This is as a result of changes in allocation of emissions to different sectors or sources/sub-sources. In this current GHGI, emission estimates from Emissions (CH_4 and N_2O) from prescribed burning of savannahs (4E) under the agriculture sector were re-allocated to forest and grassland conversion (5B) for the sake of consistency and availability of data in the LUCF sector. This is because of availability of concise data and methodology for retrieving from satellite imagery.

- **Correction of errors**. This includes errors during calculating emissions inconsistencies resolved is also included in this category.

Table 12: Summary of recalculations in the preparation of GHG Inventory

IPCC Source/Sink Categories		*Gas*	*Explanations*	
1.A.1	Energy Industries	$CO_2/CH_4/N_2O$	AD	Updated sectoral data from electricity production to include thermal production New and updated data from Tema oil refinery
1.A.2	Emissions from Manufacturing Industries and Construction	$CO_2/CH_4/N_2O$	AD	Updated activity data
1.A.3	Mobile Combustion: Road Vehicles	$CO_2/CH_4/N_2O$	AD/EF	New activity from DVLA and EPA. Country-specific emission data was used from COPERT III
1.A.4	Other Sectors: Residential	CH_4/N_2O	AD	Added as new emission source due to availability of new datasets. Biomass use was re-allocated from LUCF sector
2.A	Mineral Products	CO_2	AD	Updated industrial production data
2.C	Metal Production	$CO_2/CF_4/ C_2F_6$	AD/EF	Updated industrial production data including EF from VALCO
4.A	Enteric Fermentation	CH_4	AD	Updated activity data
4.B	Manure Management	CH_4/N_2O	AD	
4.C	Rice Cultivation	CH_4	AD	
4.D	Agricultural Soils	N_2O	AD	
4.F	Field Burning of Agricultural Residue	CH_4/N_2O	AD	
5.A	Changes in forest and other wood biomass stocks	$CO_2/CH_4/N_2O$	AD/RF	Updated activity data and inclusion of new biomass expansion factors.
5.B	Forest and Grassland Conversions	$CO_2/CH_4/N_2O$	AD	Inclusion of updated and new activity data
5.C	Abandonment of managed lands	CO_2	AD	Updated activity data
5.D	CO2 Emissions/Removals from soil	CO_2	AD	Inclusion of new activity data
6.A	Solid waste disposal on land	CH_4	AD	Updated activity data
6.B	Wastewater treatment	CH_4	AD	Updated activity data

Key: AD – Activity Data, EF- Emission Factor, RF – Removal Factor

Analysis of Aggregated National Emissions

This chapter is presented in three main parts. The first part provides quick overview of the aggregate national estimates in terms of levels and trends over the entire time series 1990 - 2006. To assess the level of impacts of LUCF on the national estimates, emissions are also analyzed with or without LUCF. The other two parts offer trend analysis of the national aggregates in terms of gases and IPCC sectors.

2.1 Emission trends for aggregated greenhouse gas emissions

Five direct greenhouse gases namely; CO_2, CH_4, N_2O, CF_4 and C_2F_6, each with different global warming potentials were covered by this inventory. Though 2000 is the UNFCCC reporting year for the preparation of second national by non-Annex I (NAI) Parties (ref. decision 17/CP.8), Ghana has prepared a complete time series of GHG emission estimates from 1990 to 2006. The analysis of the results of the inventory will be done for the year 2000; however, other years aside the reporting year will also be covered in order to provide guidance for policy formulation, among others. In accordance with IPCC guidelines, emissions estimates for international marine and aviation bunkers were not included in the national totals, but are reported separately as memo items. Carbon dioxide (CO_2) emissions from biomass consumption were also reported as memo item in conformity with IPCC guidelines.

In 2000, the total net greenhouse gas emissions (including LUCF emissions) in Ghana is estimated as 12.2MtCO_2e. This is 173% above the 1990 levels of -16.8MtCO_2e and 97% lower than 2006 levels of 23.9MtCO_2e. The total net greenhouse gas emissions increased by

242% from 1990 to 2006 (Figure 2). If emissions from LUCF are excluded (Figure 2), in 2000, the total GHG emissions in Ghana is estimated as 13.3MtCO2e, which is about 43% above 1990 levels and 39% lower than 2006 levels. Without LUCF emissions, the total emissions increased by 107% from 9.3 MtCO2e in 1990 to 18.4MtCO2 e in 2006.

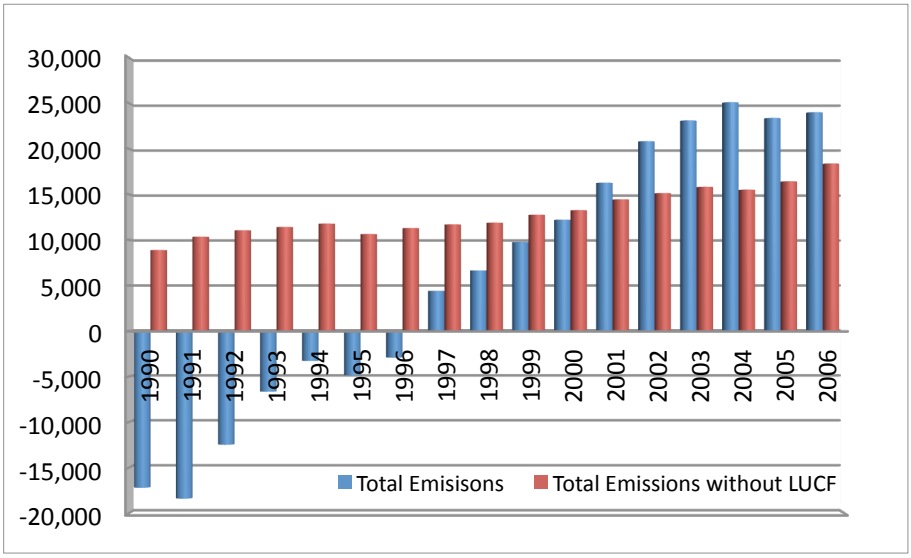

Figure 2: Trend of total GHG emissions including LUCF (in GgCO2e)

In terms of gases, carbon dioxide is estimated at 2.6MtCO2e accounting for 19% of the total GHG emissions in 2000. This level of carbon dioxide emissions was 111% and 309% below 1990 and 2006 levels respectively. Methane emission was reported at 6.2MtCO2e and forms 46% of the total national emissions in 2000 (including LUCF). This is an increase of about 83% from 1990 and nearly 28% lower than 2006 total methane emissions (Table 12). Nitrous oxide emissions recorded 4.5MtCO2e and constitute a whopping 34% of the total emissions in 2000. This is an increase of 54% from 1990 and 24% by 2006. F-gases (PFCs) emissions accounted for an average 1.5% of total GHG emissions between 1990 and 2000 and diminished below 0% in 2004 due to the closure of a major aluminum production company in Ghana.

Excluding LUCF, carbon dioxide is the highest source of emissions (6.3MtCO2e) and accounts for 44% of the total GHG emissions in 2000. This level is 120% higher than the 1990 levels and 25% below 2006 levels. This is followed by methane of 4.9MtCO2e and is 34% of the 2000 total emissions. It increased by 62% and 32% by 1900 and from 2006 respectively. Nitrous oxide accounts for 22% of the total emissions in 2000. Figure 3 shows the share of GHG among gases.

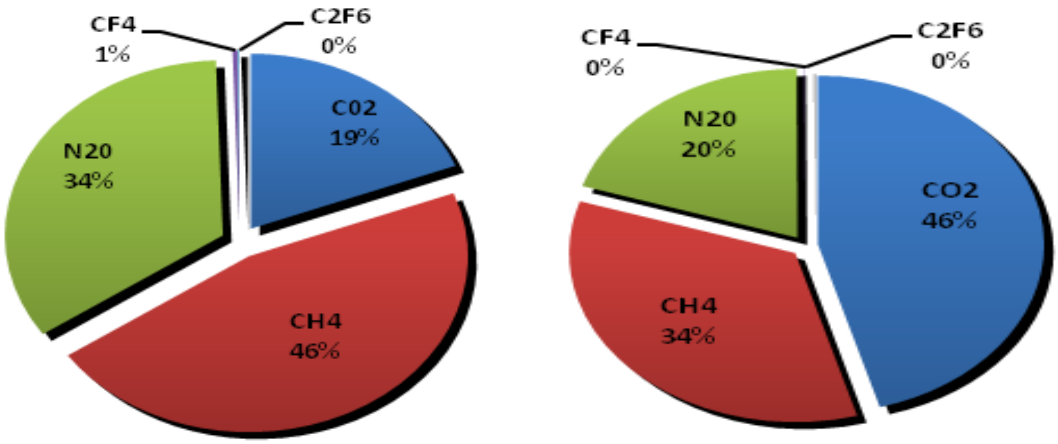

Figure 3: Share of GHG by gases with LUCF in 2000 and 2006

Table 13: Total emissions in Ghana by gases for the period 1990-2006

Total Emissions With LUCF expressed in Gg CO_2 eq.																	
Gases	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CO_2	-23,601.76	-26,740.76	-21,020.88	-15,345.41	-12,198.45	-12,311.54	-10,747.68	-5,625.21	-3,772.74	-1,175.94	2,560.25	4,683.66	8,805.84	10,845.28	12,368.34	10,302.17	10,459.43
CH_4	3,373.77	3,717.98	3,595.20	3,682.16	3,832.12	4,019.19	4,210.65	5,725.81	5,917.62	6,126.41	6,185.41	6,693.25	7,092.93	7,242.39	7,566.15	7,798.92	7,884.97
N_2O	2,944.16	2,643.07	2,592.00	2,646.40	2,691.20	2,620.17	2,799.89	4,273.23	4,393.86	4,675.20	4,544.40	4,838.19	4,878.29	5,001.26	5,146.85	5,260.75	5,624.19
CF_4	399.00	399.00	456.00	456.00	342.00	285.00	285.00	342.00	114.00	114.00	57.00	39.90	28.50	2.28	0.00	3.42	11.40
C_2F_6	83.30	83.30	95.20	95.20	71.40	59.50	59.50	71.40	23.80	23.80	11.90	8.33	5.95	0.48	0.00	1.19	2.38
Total	-16,801.53	-20,379.71	-14,833.68	-9,016.85	-5,675.13	-5,672.18	-3,737.14	4,373.83	6,538.74	9,625.66	13,290.05	16,215.10	20,777.06	23,088.92	25,081.33	23,361.84	23,968.60
Total Emissions Without LUCF expressed in Gg CO_2 eq.																	
CO_2	2,855.74	2,369.74	2,889.62	3,117.09	3,264.05	3,576.96	3,864.82	3,821.65	4,364.22	4,925.45	6,297.67	5,585.00	5,966.95	6,416.89	5,793.06	6,439.49	7,847.20
CH_4	3,005.64	3,349.85	3,227.07	3,314.03	3,463.99	3,651.06	3,842.52	4,409.53	4,502.38	4,607.94	4,870.58	5,362.05	5,703.16	5,852.62	6,100.34	6,293.48	6,419.21
N_2O	2,905.76	2,604.67	2,553.60	2,608.00	2,652.80	2,581.77	2,761.49	2,894.03	2,912.26	3,084.80	3,168.40	3,442.99	3,422.29	3,545.26	3,610.85	3,683.15	4,088.19
CF_4	399.00	399.00	456.00	456.00	342.00	285.00	285.00	342.00	114.00	114.00	57.00	39.90	28.50	2.28	0.00	3.42	11.40
C_2F_6	83.30	83.30	95.20	95.20	71.40	59.50	59.50	71.40	23.80	23.80	11.90	8.33	5.95	0.48	0.00	1.19	2.38
Total	9,249.44	8,806.56	9,221.49	9,590.32	9,794.24	10,154.29	10,813.33	11,538.60	11,916.66	12,755.99	14,405.54	14,438.27	15,126.85	15,817.53	15,504.25	16,420.73	18,368.38

2.2 Emission trends by gas

Overall, CO_2 emissions/removals constituted the dominant GHG emissions in Ghana. From 1990, CO_2 emissions including LUCF increased throughout the time series (1990-2006) from -23.9MtCO_2e in 1990 to 2.6MtCO_2e and 10.5MtCO_2e in 2000 to 2006 respectively. Between 1990 and 1999, CO_2 emissions contributed to net removals by sink but experienced steady inter-annual increase at an average rate of 24% until 1999 (Figure 4). Beyond 1999, net CO_2 emissions increased up to 12.4Mt in 2004 and decrease marginally to 10.5Mt in 2006. The trend has been driven by the changes in emissions from energy, LUCF and industrial processes.

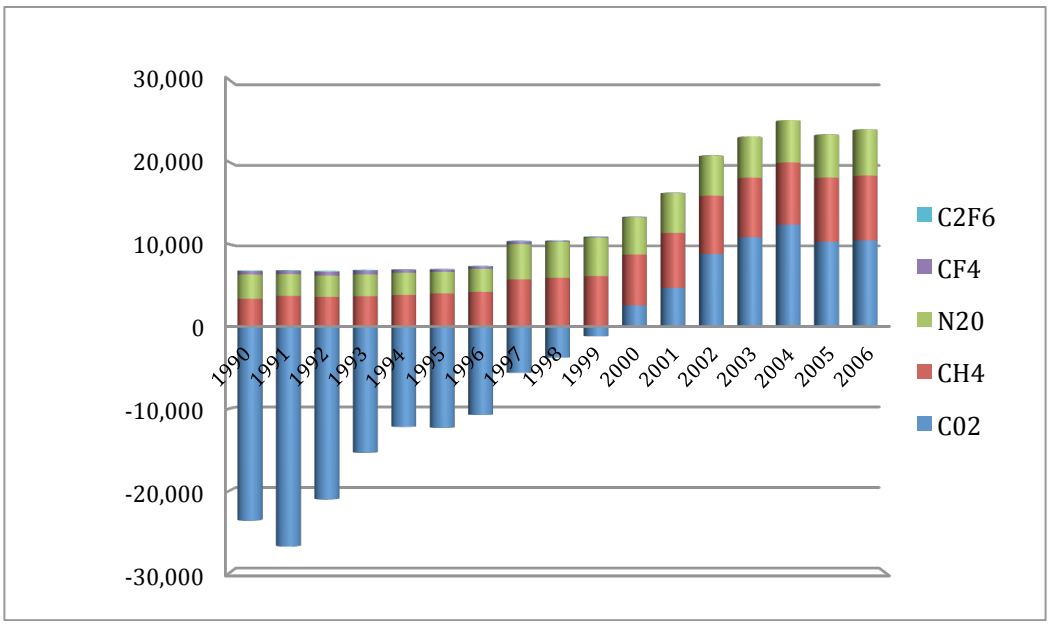

Figure 4: Trends of net CO_2 emissions by gases ($GgCO_2e$) including LUCF

Methane (CH_4) emission was the second highest direct GHG emissions constituting 33% of the total national emissions without LUCF for the year 2000. CH_4 emissions accounted for 46% with LUCF in 2000. CH_4 emissions similarly experienced steady increase over the time series. Nitrous oxide (N_2O) was the third most important direct greenhouse gas during the period (1990-2006). N_2O emissions also increased from 1990 up to 2006. PFCs (CF_4 and C_2F_6) emissions were recorded in small quantities in the time series. Without LUCF, CO_2 emissions still dominate as the largest emission throughout the time series (figure 5) followed by CH_4, N_2O and the PFCs.

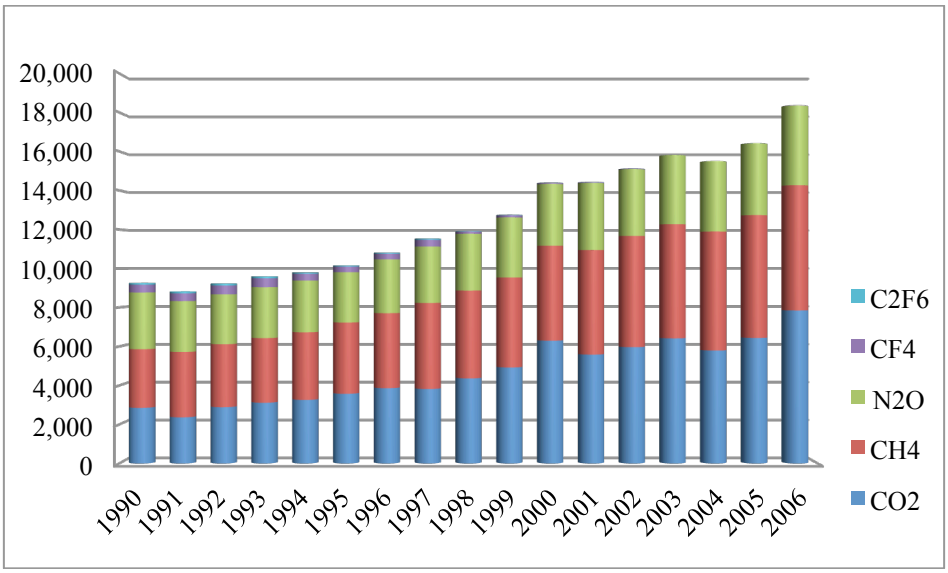

Figure 5: Trend of emissions by gases without LUCF (in $GgCO_2e$)

2.2.1 Carbon Dioxide

Levels of carbon dioxide emissions from 1990 to 2006 by source category are presented in figure 7 and table 14. The total net CO_2 emissions increased from -23.6$MtCO_2e$ in 1990 to 10.5$MtCO_2e$ in 2006 (including LUCF). In 2000, an estimated 1.4$MtCO_2e$ net CO_2 emissions were recorded from three main sectors namely; energy, LUCF and industrial process. This upward trend (from 1990 to 2006) is mainly attributed to the increases in forest and grassland conversion rates, increase fuel consumption for electricity production from thermal sources as well as increases in fuel consumption for transport. Without LUCF, the total CO_2 emissions were 2.9Mt, 5.1Mt and 7.8Mt in 1990, 2000 and 2006 respectively. In 2000, CO_2 emissions from the energy sector accounted 55% of the total net CO_2 emissions in Ghana (Figure 6) followed by 37% CO_2 removal from the LUCF sector and 14% from the industrial processes.

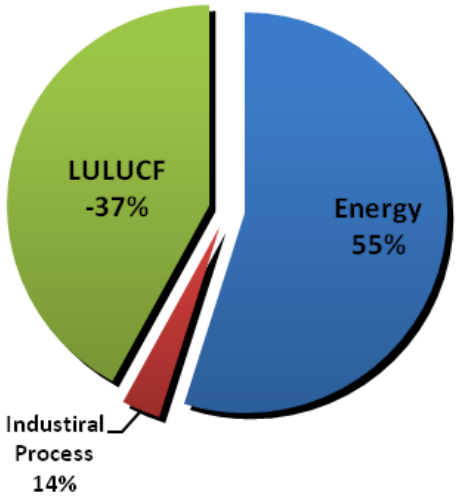

Figure 6: Share of net of CO_2 emissions by sectors in 2000

CO_2 removals from LUCF were reduced by 85.8%, from -26.5Mt in 1990 to -3.7Mt in 2000 and up to 2001 (-0.91Mt). Beyond 2001, there was observed increases in CO_2 emissions from the LUCF sector rising from 2.8Mt in 2002 and peaking in 2004 at 6.6Mt before a marginal decease to 3.86Mt and 2.6Mt net emissions for the sector in 2005 and 2006 respectively (Figure 7). The reductions in CO2 emissions are due to consistent policy on national afforestation programmes by the government of Ghana.

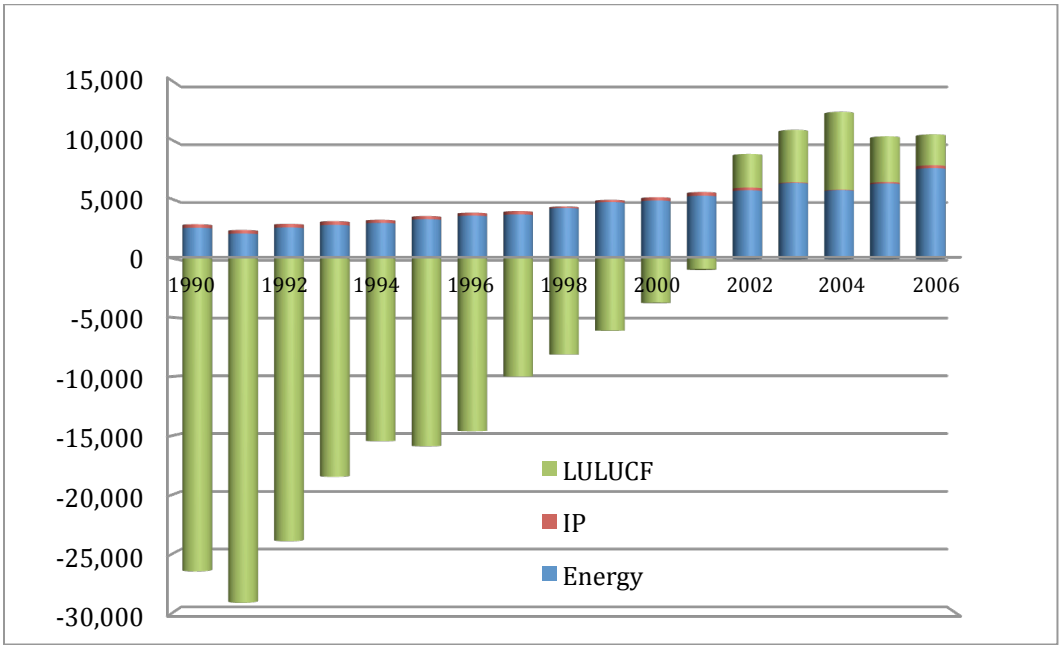

Figure 7: Trends of CO_2 emissions by sectors (in Gg)

CO_2 emissions from the energy increased from 2.6 Mt in 1990 to 4.8 Mt and 7.6Mt in 2000 and 2006 respectively, representing a total increase of 195.8% from 1990 to 2006. It also important to state that, in 2002 and beyond, both the energy and the LUCF sectors contributed to the sources of CO_2 emissions with the energy sector accounting for the most up till 2006, whereas in the LUCF, CO_2 emissions were declining. On the contrary, carbon dioxide emissions from industrial processes in 2006 decreased by 16.4% compared to 1990 levels from 0.3Mt in 1990 to 0.3Mt and 0.2Mt in 2000 and 2006 respectively. The decrease is attributed to the reduction in industrial production in mineral and metal products within the inventory period.

Table 14: CO_2 emissions removals by sectors for the period 1990-2006 (in Gg)

CO_2 emissions / removals by sector for the period 1990-2006 (in Gg)																	
Sectors	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Total (with LUCF)	-23,595.7	-26,733.4	-21,012.8	-15,338.6	-12,219.47	-12,331.8	-10,768.4	-6,008	-3,772.7	-1,178.3	1,409.2	4,683.7	8,804.3	10,839.2	12,364.7	10,293.8	10,459.4
Total (without LUCF)	2,861.8	2,377.1	2,897.7	3,123.9	3,243.03	3,556.7	3,844.1	3,977.8	4,364.2	4,925.4	5,146.6	5,585.0	5,965.4	6,410.8	5,789.4	6,431.1	7,847.2
Energy	2,570.62	2,081.33	2,595.56	2,810.61	2,981.60	3,294.33	3,595.15	3,697.33	4,239.91	4,736.55	4,872.25	5,276.88	5,733.99	6,356.12	5,748.06	6,313.27	7,603.75
Energy Industries	134.79	5.40	0.95	17.79	22.34	15.25	15.25	15.25	18.11	20.59	502.38	889.77	1,919.16	1,684.78	538.14	1,038.67	2,392.12
Manufacturing industries and construction	457.36	555.92	661.97	682.15	743.34	807.24	866.98	883.94	1,005.17	1,122.88	1,065.67	1,081.92	1,111.68	1,088.47	1,223.75	1,242.35	911.56
Transport	1,537.24	1,149.61	1,490.17	1,642.49	1,703.93	1,850.24	2,016.75	2,075.51	2,413.97	2,747.80	2,530.30	2,539.11	1,806.91	2,599.84	2,983.26	3,007.98	3,098.00
Other Sectors	441.24	370.40	442.47	468.18	511.99	621.60	696.17	722.64	802.65	845.28	773.90	766.08	896.24	983.03	1,002.91	1,024.27	1,202.07
Industrial Processes	291.17	295.79	302.14	313.24	261.43	262.41	248.92	280.50	124.31	188.90	274.37	308.13	231.43	54.73	41.31	117.87	243.45
Mineral products	14.13	16.85	21.45	23.83	26.49	32.17	32.20	33.47	32.13	35.04	34.74	29.04	30.21	32.94	41.31	92.60	129.75
Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Metal production	277.04	278.94	280.69	289.41	234.94	230.24	216.72	247.03	92.18	153.86	239.63	279.09	201.22	21.79	0.00	25.27	113.7
Agriculture																	
Enteric fermentation																	
Manure management																	
Rice cultivation																	
Agricultural soils																	
Field burning of agricultural residues																	
LUCF	-26,457.5	-29,110.5	-23,910.5	-18,462.5	-15,462.5	-15,888.5	-14,612.5	-9,985.9	-8,136.9	-6,103.8	-3,737.4	-901.3	2,838.9	4,428.4	6,575.3	3,862.7	2,612.2
Changes in forest and other woody biomass stocks	-33,719	-36,372	-31,172	-25,724	-22,724	-23,150	-21,874	-39,013.9	-39,672.1	-40,195.8	-64,290.4	-63,578.6	-63,956.6	-64,903.5	-65,927.2	-67,137.3	-66,656.2
Forest and grassland conversion	8,938	8,938	8,938	8,938	8,938	8,938	8,938	31,548	33,957.6	36,400.9	63,383.1	64,890.1	68,358.95	69,300.02	73,560.1	71,764.8	70,033.2
Abandonment of managed lands	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136	-4,136	-4,136
CO_2 emissions and removals from soil	1,615.50	1,615.50	1,615.50	1,615.50	1,615.50	1,615.50	1,615.50	1,616.00	1,713.54	1,827.08	1,305.88	1,923.20	2,572.57	4,167.90	3,078.30	3,371.25	3,371.25
Waste																	
Solid waste disposal on land																	
Waste-water handling																	

Table 15: CH_4 emissions removals by sectors for the period 1990-2006 (in Gg)

CH_4 emissions by sectors for the period 1990-2006 (in Gg)																	
Sectors	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Total (with LUCF)	160.66	177.05	171.20	175.34	182.48	191.39	200.51	272.66	281.79	291.73	294.54	318.73	337.76	344.88	360.29	371.38	375.47
Total (without LUCF)	143.13	159.52	153.67	157.81	164.95	173.86	182.98	209.98	214.40	219.43	231.93	255.34	271.58	278.70	290.49	299.69	305.68
Energy	**29.12**	**30.06**	**31.13**	**35.28**	**35.67**	**37.41**	**37.44**	**37.87**	**37.74**	**40.61**	**41.66**	**61.41**	**63.85**	**66.11**	**67.63**	**67.91**	**68.46**
Energy Industries	0.0053	0.0002	0.00	0.00	0.00	0.00	0.00	0.000624	0.00074	0.00	0.02	0.04	0.08	0.07	0.04	0.04	0.1
Manufacturing industries and construction	0.0127	0.0154	0.02	0.02	0.02	0.02	0.02	0.024576	0.02802	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Transport	0.296	0.2225	0.29	0.32	0.33	0.36	0.39	0.407206	0.47369	0.54	0.5	0.5	0.27	0.51	0.59	0.59	0.61
Other Sectors	28.81	29.818	30.82	34.94	35.32	37.03	37.03	37.44045	37.24	40.04	41.1	60.84	63.47	65.5	66.97	67.25	67.72
Industrial Processes	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Mineral products																	
Chemical industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	**88.65**	**102.44**	**95.12**	**94.06**	**97.54**	**101.72**	**109.86**	**117.88**	**119.58**	**120.84**	**122.52**	**123.69**	**130.61**	**128.03**	**130.36**	**131.83**	**137.27**
Enteric fermentation	64.80	60.60	59.05	59.25	61.59	57.68	63.70	66.62	68.1072	69.69	71.28	72.43	72.14	76.38	77.71	79.03	82.10
Manure management	3.91	3.30	3.19	3.19	3.24	3.25	3.25	3.44	3.52713	3.61	3.71	3.75	3.19	4.00	4.12	4.18	4.36
Rice cultivation	19.60	37.96	31.88	30.88	32.00	39.96	42.10	47.08	47.12	46.80	46.80	46.80	54.40	46.80	47.76	47.76	50.00
Agricultural soils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prescribed Burning of savannahs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Field burning of agricultural residues	0.35	0.59	1.00	0.74	0.71	0.84	0.81	0.74	0.83	0.74	0.73	0.71	0.88	0.86	0.76	0.85	0.81
LUCF	**17.53**	**17.53**	**17.53**	**17.53**	**17.53**	**17.53**	**17.53**	**62.68**	**67.39**	**72.31**	**62.61**	**63.39**	**66.18**	**66.18**	**69.80**	**71.69**	**69.80**
Changes in forest and other woody biomass stocks																	
Forest and grassland conversion	17.53	17.53	17.53	17.53	17.53	17.53	17.53	62.68	67.39	72.31	62.61	63.39	66.18	66.18	69.80	71.69	69.80
Abandonment of managed lands																	
CO_2 emissions and removals from soil																	
Waste	**25.35**	**27.02**	**27.42**	**28.47**	**31.74**	**34.73**	**35.68**	**54.22**	**57.07**	**57.98**	**67.75**	**70.23**	**77.12**	**84.55**	**92.51**	**96.36**	**99.95**
Solid waste disposal on land	18.72	20.25	20.80	21.45	24.54	27.38	28.17	33.98	36.65	37.37	46.95	49.23	55.90	63.12	70.84	74.21	77.80
Waste-water handling	6.63	6.77	6.62	7.02	7.20	7.35	7.51	20.24	20.42	20.61	20.81	21.00	21.21	21.43	21.66	22.15	22.15

Table 16: N_2O emissions removals by sectors for the period 1990-2006 (in Gg)

N_2O emissions by sectors for the period 1990-2006 (in Gg)																	
Sectors	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Total (with LUCF)	9.20	8.26	8.10	8.27	8.41	8.18	8.74	13.35	13.73	14.61	14.2	15.12	15.24	15.62	16.08	16.43	17.58
Total (without LUCF)	9.08	8.14	7.98	8.15	8.29	8.06	8.62	9.04	9.10	9.64	9.90	10.76	10.69	11.07	11.28	11.50	12.78
Energy	**0.26**	**0.26**	**0.27**	**0.30**	**0.31**	**0.33**	**0.33**	**0.33**	**0.03**	**0.36**	**0.36**	**0.53**	**0.56**	**0.57**	**0.58**	**0.60**	**0.62**
Energy Industries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.01	0.03
Manufacturing industries and construction	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.007	0.008	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Transport	0.014	0.01	0.01	0.01	0.01	0.02	0.02	0.018	0.021	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Other Sectors	0.242	0.241	0.25	0.28	0.29	0.3	0.3	0.304	0.006	0.33	0.33	0.49	0.51	0.53	0.54	0.55	0.55
Industrial Processes	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Mineral products																	
Chemical industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	**8.49**	**7.54**	**7.36**	**7.48**	**7.60**	**7.35**	**7.90**	**8.30**	**8.64**	**8.82**	**9.09**	**9.77**	**9.64**	**10.01**	**10.20**	**10.37**	**11.62**
Enteric fermentation																	
Manure management	0.38	0.27	0.25	0.25	0.24	0.26	0.21	0.23	0.23	0.23	0.22	0.22	0.22	0.22	0.21	0.22	0.212
Rice cultivation																	
Agricultural soils	8.1	7.25	7.09	7.21	7.34	7.06	7.66	8.05	8.39	8.57	8.85	9.53	9.39	9.76	9.96	10.12	11.38
Prescribed Burning of savannahs	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Field burning of agricultural residues	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.024
LUCF	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**0.12**	**4.31**	**4.63**	**4.97**	**4.30**	**4.36**	**4.55**	**4.55**	**4.80**	**4.93**	**4.80**
Changes in forest and other woody biomass stocks																	
Forest and grassland conversion	0.12	0.12	0.12	0.12	0.12	0.12	0.12	4.31	4.63	4.97	4.3	4.36	4.55	4.55	4.8	4.93	4.8
Abandonment of managed lands																	
CO_2 emissions and removals from soil																	
Waste	**0.33**	**0.34**	**0.35**	**0.37**	**0.38**	**0.39**	**0.40**	**0.41**	**0.43**	**0.46**	**0.45**	**0.46**	**0.49**	**0.50**	**0.50**	**0.54**	**0.54**
Solid waste disposal on land																	
Waste-water handling	0.33	0.34	0.35	0.37	0.38	0.39	0.40	0.41	0.43	0.46	0.45	0.46	0.49	0.50	0.50	0.54	0.54

2.2.2 Methane

Methane emissions are reported from activities in energy, agriculture, LUCF and waste. The trend of methane emissions from 1990 to 2006 by source category is presented in figure 9. Total CH_4 emissions increased from 3.4MtCO_2e in 1990 to 7.9MtCO_2e in 2006 (including LUCF). In 2000, estimated 6.2MtCO_2e of CH_4 emissions were recorded in Ghana. This represented 83.3% above 1990 levels and 27.5% below 2006 levels. This upward trend (from 1990 to 2006) is mainly attributed to the increases in enteric fermentation from growing numbers of domestic livestock, rising disposal of waste on deep landfills as well as increases in biomass consumption in the residential and on-site burning of biomass.

Without LUCF, the total CH_4 emissions dropped to 3MtCO_2e in 1990. This is about 62.1% below 2000 levels and nearly 31.7% below 2006 levels. The main drivers of the increases observed in the CH_4 emissions without LUCF is the mainly attributed to the increases in enteric fermentation from growing numbers of livestock, rising disposal of waste on deep landfills as well as increases in biomass consumption in the residential. In 2000, CH_4emissions from the agriculture sector accounted for the highest of 42% of the total CH_4emissions in (Figure 8) followed by 23% from the waste sector, 21% from LUCF and 14% from the energy.

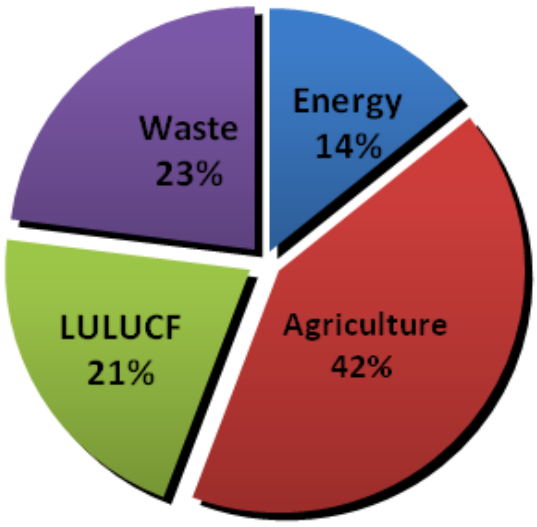

Figure 8: Share of CH_4 emissions by sectors in 2000

CH_4 emissions from the agricultural sector dominated from 1990 to 2006. It increased from 0.088Mt in 1990 to 0.12Mt and 0.14Mt in 2000 and 2006 respectively. Comparatively, methane emissions from the waste sector are lower in terms of levels considering that of agriculture, but it recorded a steady rise from 0.03Mt in 1990 to 0.07Mt in 2000 and further to 0.1Mt in 2006. Figure 9 also shows considerable increases in methane emissions from the LUCF sector. It rose by 0.045Mt above the 1990 levels (0.02Mt) in 2000 and 0.007Mt in 2006 mainly due to activities driving forest and grassland conversions.

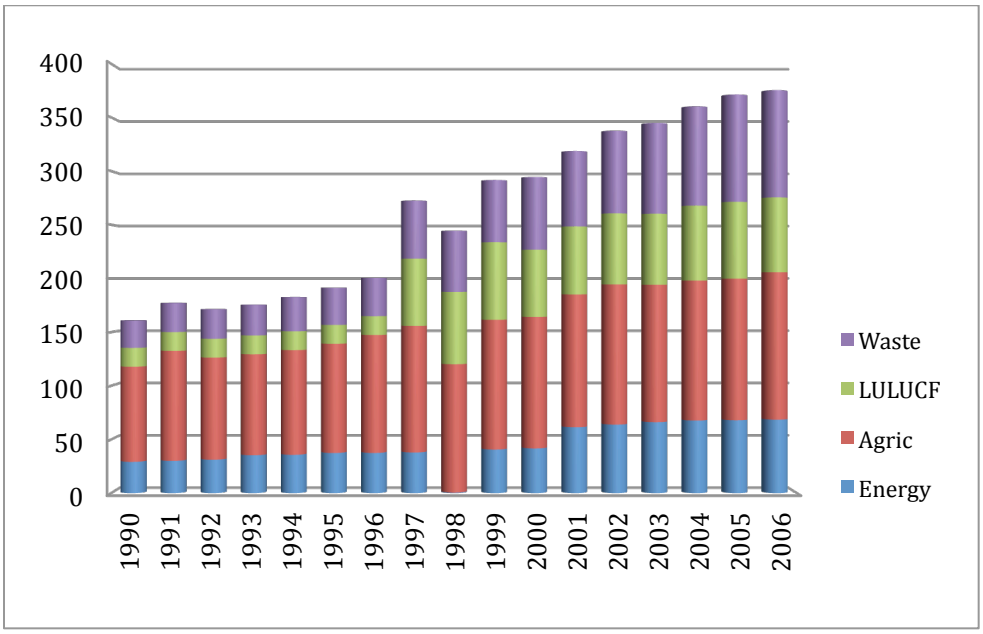

Figure 9: Total emissions by sectors over the time series (1990 to 2006)

On the contrary, methane emissions from the energy sector saw gradual increase in the entire time series from 0.029Mt in 1990 to 0.042Mt and 0.068Mt in 2000 and 2006 respectively. However, methane emission from the energy sector in 1998 was lower than the preceding year 1997 and therefore has been identified as outlier.

2.2.3 Nitrous Oxide

Nitrous oxide emissions are reported from activities in energy, agriculture, LUCF and waste with the chunk of the emissions reported from the agricultural sector (64%), LUCF (30%), waste (3%) and energy (3%) in 2000. The trend of nitrous oxide emissions from 1990 to 2006 by source category is presented in figure 10. Total N_2O emissions increased from 2.9MtCO_2e in 1990 to 5.6MtCO_2e in 2006 (including LUCF). In 2000, the total N_2O emissions amounted to 4.5MtCO_2e. This represents 54% above 1990 levels and 24% lower than 2006 levels. There were increases in N_2O emissions from 1990 to 2006, which is mainly attributable to the increases in applications of inorganic fertilizers to agricultural soils as well as increases in biomass consumption in the residential and on-site burning of biomass. The sharp increase from 1997 was the impact of the recalculation implemented in the LUCF.

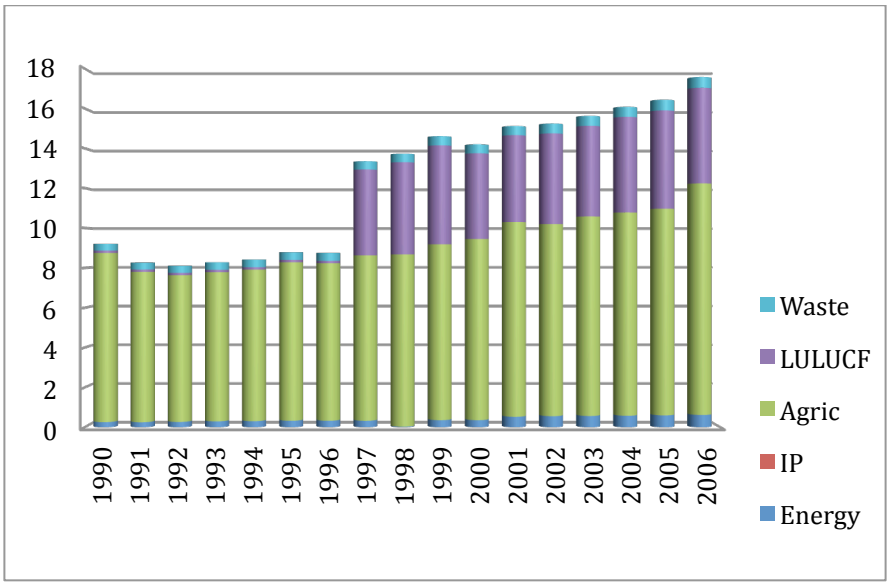

Figure 10: Trends of N_2O emissions by sectors (in Gg)

Without LUCF, total N_2O emissions dropped by 0.12Gg in 1990. This is about 49.5% below 2000 levels and nearly 84% below 2006 levels. The driving factor for the increases observed in the N_2O emissions without LUCF is mainly attributed to increases in applications of inorganic fertilizers to agricultural soils. In 2000, N_2O emissions from the agriculture sector accounted for 64% of the total N_2O emissions (figure 11) followed by LUCF sector, 30%, and waste and energy sectors, 3% each.

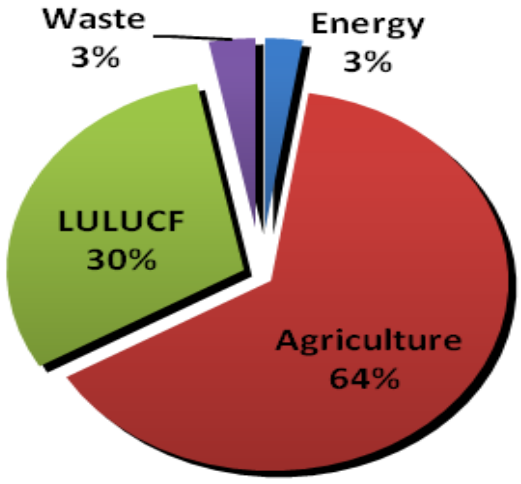

Figure 11: Share of N_2O emissions by sectors in 2000 (in Gg)

2.2.4 Perfluorocarbons (CF_4 and C_2F_6)

Carbon Tetraflouride (CF_4) and Carbon hexafluoride (C_2F_6) emissions emanate mainly from the primary metal, aluminum production industry in Ghana. The PFCs emissions constitute 1% of the national totals in 2000. The trend of CF_4 and C_2F_6 emissions from 1990 to 2006 is presented in figure 12. In general, CF_4 levels are higher than C_2F_6 throughout the time series. It is also observed that the levels of PFCs (CF_4 and C_2F_6) emissions decreased substantially from 0.5MtCO_2e in 1990 to 0.07MtCO_2e and 0.01MtCO_2e in 2000 and 2006 respectively. The main reason for the reduction in PFCs emissions is the dwindling and irregular

production levels of the primary aluminum production in Ghana as a result of decrease in energy production from the only hydro power plant from which the aluminum company has contract for the supply of energy. In 2004, the plant was shut down for lack of supply of energy and currently only one pot line is operated.

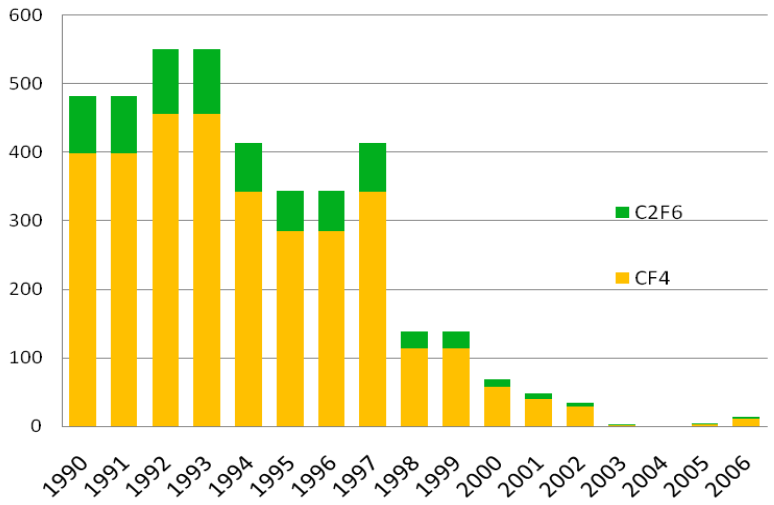

Figure 12: Trends of PFCs emissions from 1990 to 2006 (in $GgCO_2e$)

2.3 Emission trends by sectors

Total greenhouse gas emissions broken down by sectors are shown in figures 13, 14, 15 and table 16. In 2000, the largest contribution was from the energy sector, which contributed 41% of the total emissions, followed by agriculture (38%), waste (11%) and LUCF (-7%). Energy sector emissions increased from $3.3MtCO_2e$ in 1990 to $9.2MtCO_2e$ (table 16) representing a total increase of 183% energy-sector emissions between 1990 and 2006.Within this sector, the largest source is transport followed by residential. Energy Industries and manufacturing industries and construction also have a significant impact on the emissions from this sector especially in 2000 and 2006 respectively. The general rise in emissions from the sector could be attributed to the increasing fuel consumption in the growing number of thermal power generation plants, increasing fuel consumption and poor fuel efficiency in the road-transport sub-category as well as rising biomass use in the residential sub-category.

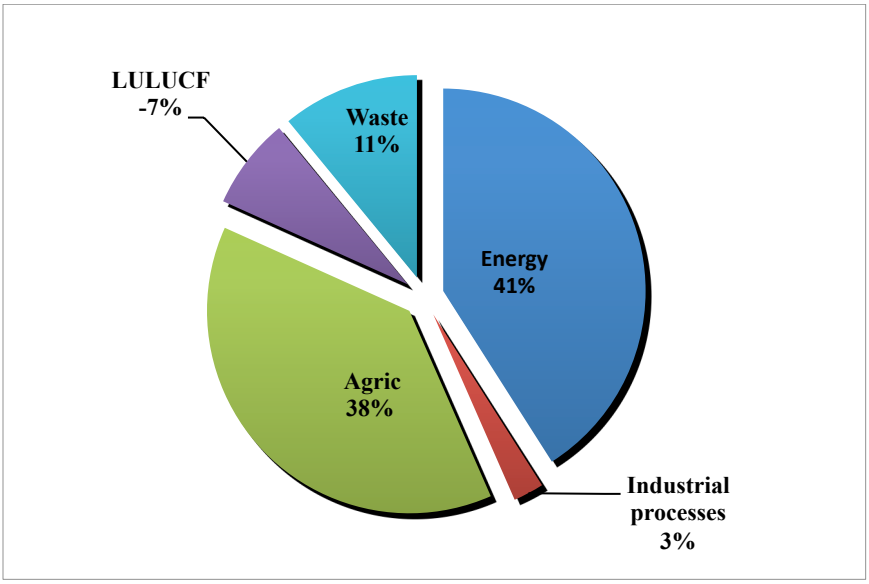

Figure 13: Share of GHG emissions by sectors in 2000 ($GgCO_2e$)

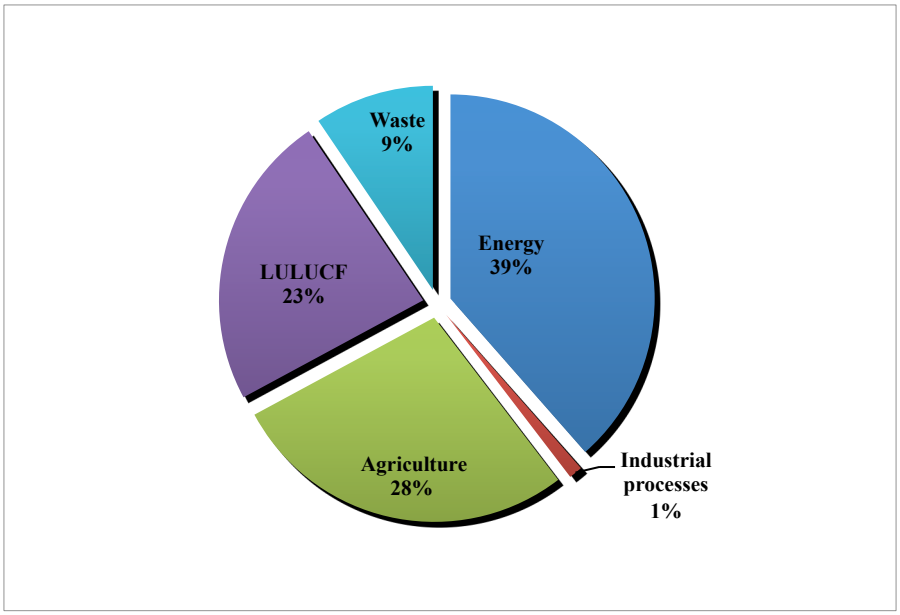

Figure 14: Share of GHG emissions by sectors in 2006 ($GgCO_2e$)

The next largest source of emissions comes from the agricultural sector. The sector contributes approximately 36% to the total emissions. The emissions from the sector have shown an overall increase of 20% in 2000 since 1990 and 44% increase from 1990 to 2006 levels. The general rising levels of agricultural emissions of about 44% between 1990 and 2006 reflects increasing trends in livestock numbers and emissions from fertilizer application. Within the sector, emissions from agricultural soils, enteric fermentation and rice cultivation have had significant impacts on the general emission (refer to the sector for more details).

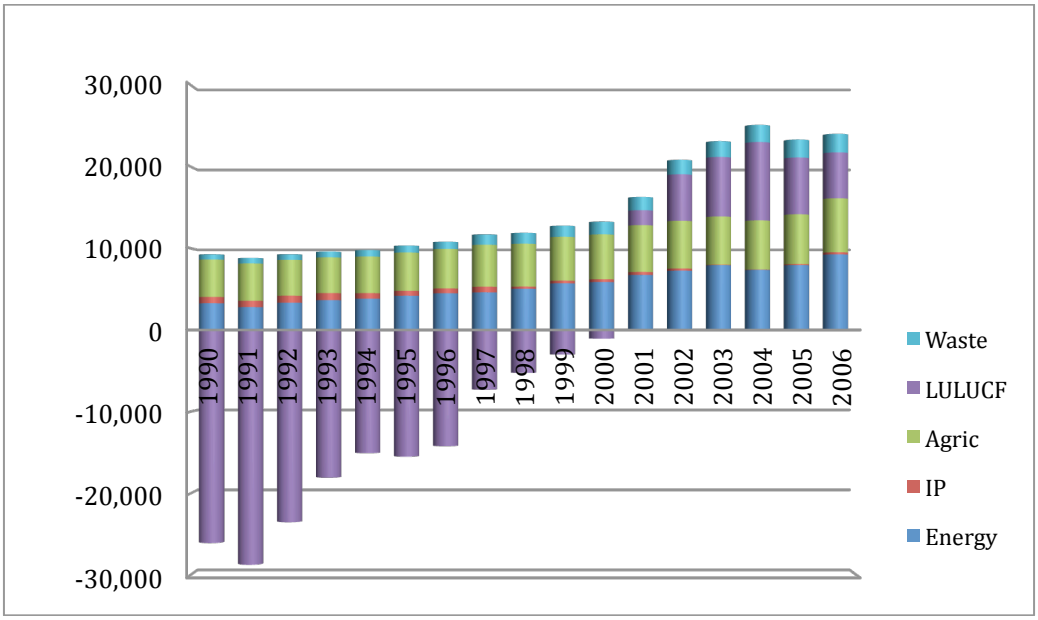

Figure 15: Trends of total emissions by sectors ($GgCO_2e$)

The LUCF sector contributed 7% net removals from the total emissions in 2000. This represented considerable decline in removals of nearly 66% of 1990 and some 32% below 2006 of the total emissions (table 17). In 2001 and beyond, net emissions from LUCF amounted to a net emission source, peaked in 2004 and started to decline in 2005 and 2006. The marginal decline in total emissions generally reflects the level of gains made in successive government's reforestation and afforestation policies and national plantation programmes as well as other sustainable forest management interventions. Within the sector, the increasing rate of forest and grassland conversions through deforestation activities is a major reason for the continuous decline in CO_2 removals from 1990 to 2004.

Emissions from the waste sector accounts for an average of 10% between 2000 and 2006, which is roughly 7% higher than the 1990 levels. The main sources of emission from this sector are from increased disposal of solid waste to deep landfill and wastewater handling systems. The increases in the sector's emissions were driven by the increasing per capita solid waste generation and population increases especially in urban areas of Ghana. Disposal of solid waste to landfills with relatively deeper depth and to sanitary landfill sites is increasingly become common practice in urban waste management. The industrial sector contributed 2%, 3% and 1% of the total emissions in 1990, 2000 and 2006 respectively. Within the sector, metal production has been a major source of the total emissions. The general reduction in emissions from industrial processes sector could be explained by the continued declined in metal production from the main aluminum smelter in Ghana.

Table 17: Total emissions / removals by sector for the period 1990-2006 (in Gg CO2 eq.)

Sectors	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total (with LULUCF)	-16,758.38	-19,852.93	-14,232.00	-8,416.49	-5,250.95	-5,321.40	-3,386.89	4,436.2	6,653.3	9,771.7	12,213.2	16,267	20,812.6	23,085.8	25,077.6	23,358.3	23,984.4
Total (without LULUCF)	9,292.59	8,851.04	9,271.97	9,639.48	9,805.02	10,160.57	10,819.08	11,726.6	11,893.4	12,766.6	13,259.8	14,441.9	15,127.9	15,811.7	15,500.6	16,412.6	18,370.4
Energy	3,265.58	2,794.20	3,335.69	3,647.49	3,829.87	4,185.54	4,486.99	4,597.95	5,043.63	5,704.56	5,862.31	6,736.09	7,254.04	7,926.83	7,353.89	7,931.38	9,239.81
Energy Industries	**135.25**	**5.41**	**0.95**	**17.79**	**22.34**	**15.25**	**15.25**	**15.30**	**18.17**	**20.59**	**502.80**	**893.81**	**1,927.24**	**1,689.45**	**538.98**	**1,042.71**	**2,403.82**
Manufacturing industries and construction	458.81	557.68	665.59	685.77	746.96	810.86	870.60	886.76	1,008.38	1,126.71	1,069.71	1,085.75	1,115.51	1,092.30	1,227.58	1,246.18	915.39
Transport	1,547.84	1,157.42	1,499.46	1,652.41	1,714.06	1,864.20	2,031.34	2,089.71	2,430.49	2,765.54	2,547.20	2,556.01	1,818.98	2,616.95	3,005.25	3,029.97	3,120.41
Other Sectors	1,123.69	1,073.70	1,169.69	1,291.52	1,346.51	1,495.23	1,569.80	1,606.18	1,586.59	1,791.72	1,742.60	2,200.52	2,392.31	2,528.13	2,582.08	2,612.52	2,800.19
Industrial Processes	**810.57**	**815.19**	**895.74**	**906.84**	**706.63**	**633.41**	**619.92**	**725.70**	**272.71**	**337.30**	**348.57**	**360.07**	**268.53**	**57.69**	**41.31**	**122.69**	**258.29**
Mineral products	14.13	16.85	21.45	23.83	26.49	32.17	32.20	33.47	32.13	35.04	34.74	29.04	30.21	32.94	41.31	92.60	129.75
Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Metal production	796.44	798.34	874.29	883.01	680.14	601.24	587.72	692.23	240.58	302.26	313.83	331.03	238.32	24.75	0.00	30.09	128.54
Agriculture	**4,578.45**	**4,564.12**	**4,391.12**	**4,368.88**	**4,480.38**	**4,680.06**	**4,835.00**	**5,131.47**	**5,242.13**	**5,359.96**	**5,481.66**	**5,723.98**	**5,827.66**	**5,891.89**	**6,001.47**	**6,086.74**	**6,600.52**
Enteric fermentation	1,360.72	1,272.55	1,240.05	1,244.25	1,293.39	1,211.19	1,337.61	1,399.11	1,399.11	1,463.49	1,496.85	1,521.04	1,515.04	1,603.98	1,631.99	1,659.71	1,724.18
Manure management	203.69	155.65	146.99	146.99	144.84	151.37	135.52	145.74	145.74	.41	148.32	149.23	137.43	154.33	153.78	158.21	159.35
Rice cultivation	411.6	797.2	669.5	648.5	672	839.2	884.1	988.7	988.7	982149.8	982.8	982.8	1,142.4	982.8	1,002.9	1,002.9	1,05
Agricultural soils	2,592.00	2,320.00	2,307.20	2,307.20	2,348.80	2,451.20	2,451.2	2,576	2,684.8	2,742.4	2,832	3,049.6	3,004.8	3,123.2	3,187.2	3,238.4	3,642.53
Field burning of agricultural residues	10.45	18.77	27.40	21.96	21.35	27.14	26.56	21.94	23.79	21.86	21.69	21.30	27.99	27.58	25.62	27.54	24.47
LULUCF	**-26,050.9**	**-28,703.9**	**-23,503.9**	**-18,055.9**	**-15,055.9**	**-15,481.9**	**-14,205.9**	**-7,290.4**	**-5,240.1**	**-2,994.9**	**-1,046.6**	**1,825.1**	**5,684.7**	**7,274.2**	**9,577.1**	**6,945.7**	**5,614**
Changes in forest and other woody biomass stocks	-33,719	-36,372	-31,172	-25,724	-22,724	-23,150	-21,874	-39,013.8	-39,672.1	-40,195.8	-64,290.4	-63,578.6	-63,956.6	-64,903.5	-65,927.2	-67,137	-66,656
Forest and grassland conversion	9,344.5	9,344.5	9,344.5	9,344.5	9,344.5	9,344.5	9,344.5	34,243.5	36,854.5	39,509.8	66,073.9	67,616.5	71,204.7	72,145.8	76,561.9	74,847.8	73,034.9
Abandonment of managed lands	-3,292	-3,292	-3,292	-3,292	-3,292	-3,292	-3,292	-4,136	-4,136	-4,136	-4,136	-4,136	-4,136	-4,136	-4,136	-4,136	-4,136
CO_2 emissions and removals from soil	1,615.5	1,615.5	1,615.50	1,615.50	1,615.50	1,615.50	1,615.50	1,616.00	1,713.54	1,827.08	1,305.88	1,923.20	2,572.57	4,167.90	3,078.30	3,371.25	3,371.25
Waste	**637.98**	**677.52**	**687.82**	**716.27**	**788.14**	**853.57**	**877.17**	**1,271.46**	**1,334.88**	**1,364.77**	**1,567.25**	**1,621.85**	**1,777.74**	**1,935.28**	**2,103.90**	**2,196.39**	**2,271.75**
Solid waste disposal on land	393.12	425.25	436.80	450.45	515.34	574.98	591.57	713.61	769.72	784.76	985.87	1,033.78	1,173.94	1,325.49	1,487.70	1,558.41	1,633.80
Waste-water handling	244.86	252.27	251.02	265.82	272.80	278.59	285.60	557.84	565.17	580.01	581.38	588.07	603.80	609.79	616.20	637.98	637.95

Analysis of Emission Estimates from Sectors

This section provides summary of analysis of various sectors and categories. It covers the overview of sector emissions in terms of sources and trends; methodologies used identification of key categories, recalculations and planned improvements. Emphasis will be placed on emissions from 2000 since it is the reporting year for the GHGI under second national communication. However, where complete time series are required, references will be made to 1990 and 2006 as well.

3.1 Energy Sector

3.1.1 Sectoral Overview

Emissions from the energy sector in Ghana represented the fastest growing source of greenhouse gas emissions. Total greenhouse gas emissions amounted to 5.9MtCO_2e in 2000. This represented an increase of 79.5% above 1990 levels and an overall increase of 182.9% between 1990 and 2006 (figure 16).

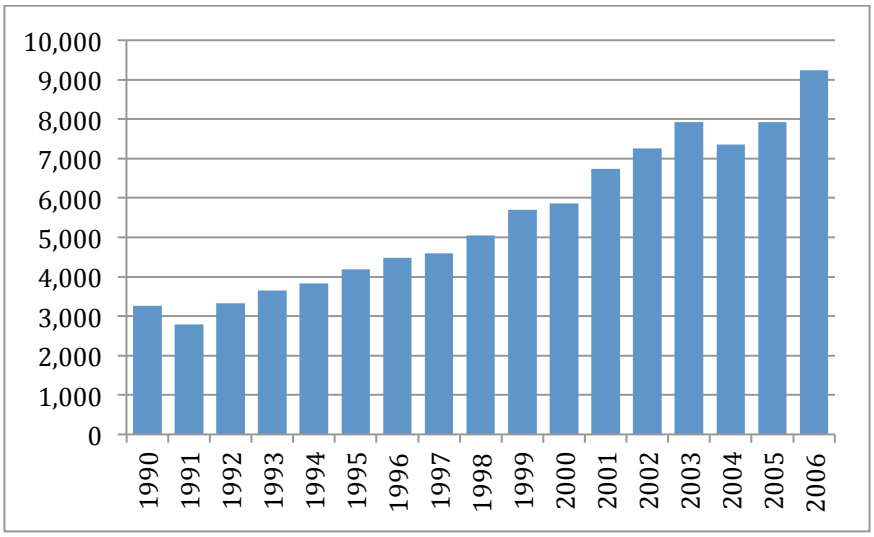

Figure 16: Trends of total emissions in the energy sector ($GgCO_2e$)

Within the energy sector, transport is the largest source of emissions. The share of emissions from transport, as fraction to the total energy sector emissions, decreased by 13% from 1990 to 2006 (Figures 17 and 18). In 2000, emissions from transport accounted for 43% of the emissions from fuel combustion, which is 4% below 1990 levels. This emissions also decreased by 11% below 1990 by 2006. The main driver of the emissions in the energy sector is the increasing amount of fuel consumption for power generation, for transport and other sectors of the economy in particular mining and agriculture. Increases in fuel consumption within the transport sector were due to increasing vehicle fleets and poor fuel efficiency in the road sector.

However, the total transport emissions reduced by 9% from 2000 to 2006. One of the reasons that accounted for this reduction is the increasing importation of fairly new vehicles into the Ghana as a result of government policy on importation of used vehicles, which imposes an import duty penalty for 10-year and over-aged vehicles. Secondly, the government's policy on the promotion of the use liquefied petroleum gas (LPG) as substitute for fuel-wood for household energy lead to the creative and increase use of LPG as fuel in the road sector. Many commercial drivers rapidly converted their gasoline-based commercial passenger vehicles to LPG-based, as this is more cost-effective.

The residential sector is the second largest contributor to the total energy emissions between 1990 and 2006, contributing to 32% of the total energy sector emissions. This is due to increasing population and subsequent increase in consumption of biomass to meet domestic energy needs. In 2000, 18% and 9% of the total energy emissions were observed in the manufacturing industries and construction and energy industries respectively. In the energy industries sub-category, emission increased by 5% from the 1990 levels and further by 17% in 2006 (an overall increase of 19% from 1990 to 2006). Increases in fuel consumption for thermal generation and for refinery operations accounts for the rising emissions in the sub-category.

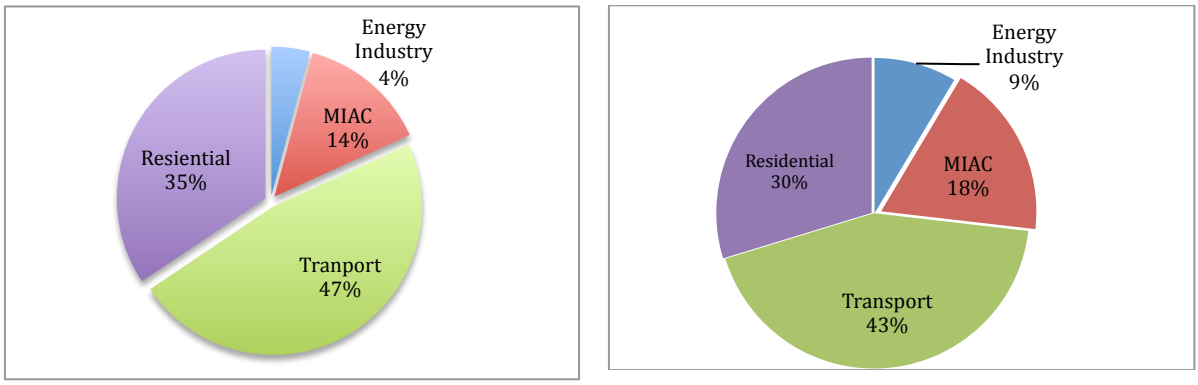

Figure 17: Emissions in the energy sector in 1990 and 2000($GgCO_2e$)

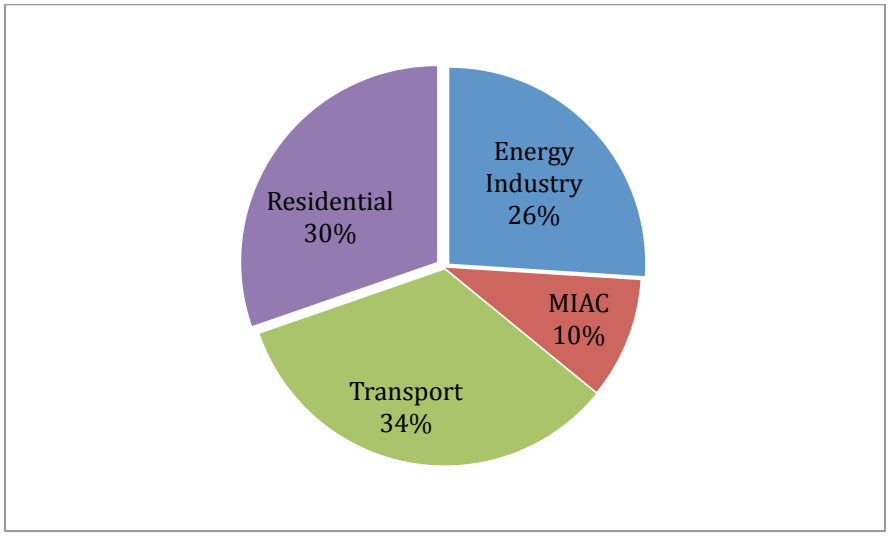

Figure 18: Share of emissions in the energy sector in 2006($GgCO_2e$)

CO_2 emissions constitutes the largest share of greenhouse emissions from the energy sector On average it accounts for 81.3% for the period 1990 to 2006 (figure 20). This is followed by methane and nitrous oxide consistently over the inventory period. In 2000, CO_2 emissions were estimated at $4.9MtCO_2e$ compared to $0.9MtCO_2e$ of methane and $0.1MtCO_2e$ of nitrous oxide. In 2000, CO_2 was 2.3Mt higher than 1990 levels and 2.7Mt in 2006 (figure 19). For CH_4, $0.9MtCO_2e$ was estimated for the 2000 and is $0.3MtCO_2e$ more than the 1990 levels and $0.6MtCO_2e$ in 2006. Nitrous oxide also observed in a similar trend.

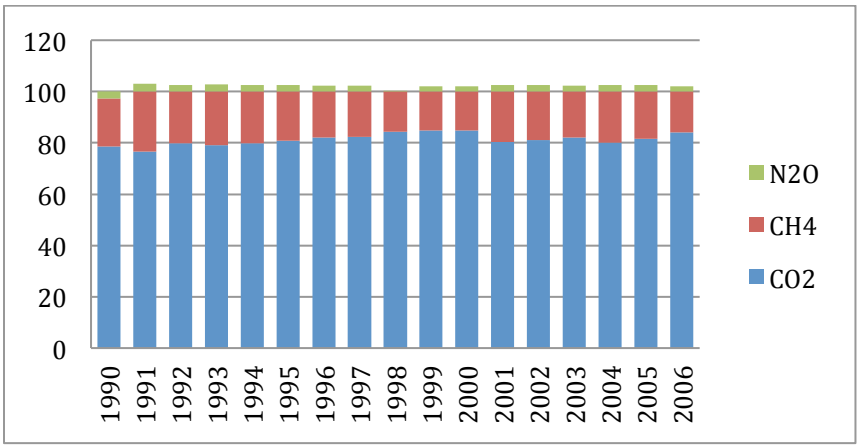

Figure 19: Percentage share of gases in the energy sector

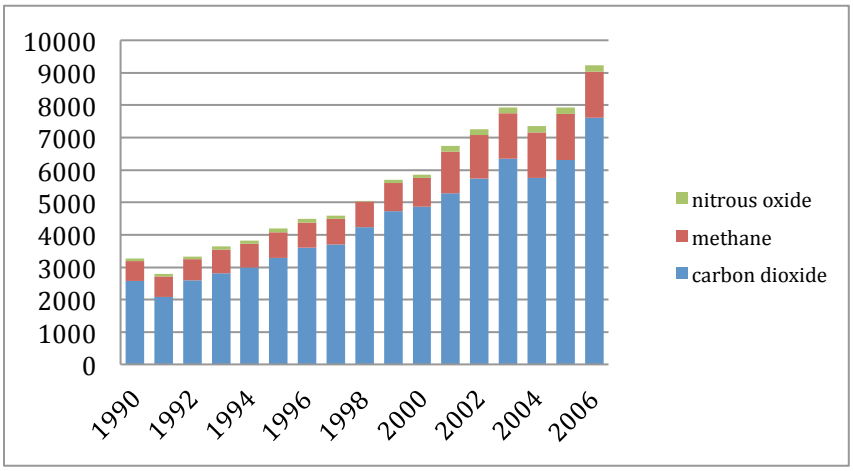

Figure 20: Comparison of gases in the energy sector ($GgCO_2e$)

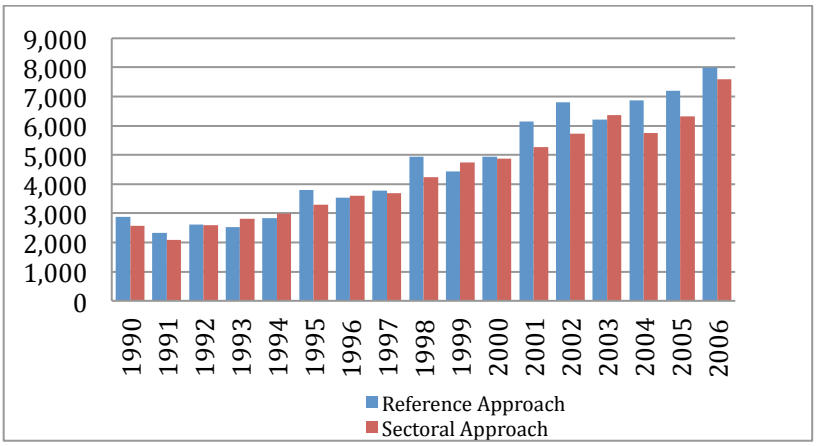

Figure 21: Comparison of trend of CO2 emissions by reference and sectoral approaches

3.1.2 Methodology

3.1.2.1 Fuel Combustion

Methodology for CO_2 estimation

IPCC methodology was used in estimating CO_2 emissions from fuel combustion. Carbon dioxide emissions were also estimated by both reference and sectoral approaches. The average differences of the two approaches yield 8.4%. The differences decreased from 10.7% in 1990 to 6.9% in 2000 and further down to 4.9% in 2006. The main reason for the differences over years is inclusion of fuels for non-energy use in the reference approach (figure 24). A description of the methodology is presented in below, and is characterized by the following steps:

Step 1. Determine total fuel consumption by fuel type and sector

Total fossil fuel consumption for each year is estimated by aggregating consumption data by end-use sector (e.g., transport, commercial, industrial, etc.), primary fuel type (e.g. petroleum, gas), and secondary fuel category (e.g. gasoline, distillate fuel oil, etc.). Petroleum activity data for Ghana were obtained directly from the Ghana Energy Commission, Tema Oil Refinery, National Petroleum Authority, Ministry of Energy and Published Energy Statistics.
Energy consumption for fuel types and categories are estimated from energy production data (accounting for imports, exports, stock changes, and losses). The resulting quantities are referred to as "apparent consumption.

2. Subtract non-energy uses in the Industrial Processes

Portions of the fuel consumption data for some fuel categories—distillate fuel, petroleum coke, natural gas, residual fuel oil, and other oil—were reallocated to the industrial processes, as they were consumed during non-energy related industrial activity.

3. Adjust for fuels consumed for non-energy uses

These are fossil fuels that are manufactured into plastics, asphalt, lubricants, or other products. Depending on the end-use, this can result in storage of some or the entire carbon contained in the fuel for a period of time. As the emission pathways of carbon used for non-energy purposes are vastly different than fuel combustion (since the carbon in these fuels ends up in products instead of being combusted), these emissions are estimated separately in the Carbon Emitted and Stored in Products from Non-Energy Uses of Fossil Fuels. Therefore, the amount of fuels used for non-energy purposes was subtracted from total fuel consumption.

4. Subtract consumption of international bunker fuels

According to the IPCC good practice guidance emissions from international transport activities, or bunker fuels, should not be included in national totals. Energy consumption statistics include these bunker fuels (e.g., distillate fuel oil, residual fuel oil, and jet fuel) as part of consumption by the transportation end-use sector, however, so emissions from international transport activities were calculated separately following the same procedures used for emissions from consumption of all fossil fuels (i.e., estimation of consumption, and determination of carbon content).

5. Determine the total Carbon content of fuels consumed.

Total carbon was estimated by multiplying the amount of fuel consumed by the amount of carbon in each fuel. This total carbon estimate defines the maximum amount of carbon that could potentially be released to the atmosphere if all of the Carbon in each fuel was converted to CO_2. The carbon content coefficients used by Ghana were obtained from IPCC default values.

6. Estimate CO_2 Emissions.

Total CO_2 emissions are the product of the adjusted energy consumption (from the previous methodology steps 1 through 4), the carbon content of the fuels consumed, and the fraction of carbon that is oxidized.

3.1.2.2 Stationary Combustion

Methodology for estimating CH_4 and N_2O

CH_4 and N_2O emissions from stationary combustion were estimated by multiplying fossil fuel and wood consumption data by emission factors (by sector and fuel type). Natural gas, and fuel oil consumption data were grouped by sector: industrial, commercial, residential, electricity generation, etc. Emission factors for the four end-use sectors were obtained from the IPCC Guidelines for National Greenhouse Gas Inventories.

3.1.3 Analysis of Key Category

In 2000 and 2006, the following sub-categories were identified as key categories in terms of levels with and without LUCF.

Table 18: Key categories in energy sector in 2000

ID	Categories	Gases
1.A.3	Mobile Combustion: Road Vehicles	CO_2
1.A.2	Emissions from Manufacturing Industries and Construction	CO_2
1.A.4	Other Sectors: Residential	CH_4
1.A.4	Other Sectors: Commercial	CO_2

Table 19: Key categories in energy sector in 2006

ID	Categories	Gases
1.A.3	Mobile Combustion: Road Vehicles	CO_2
1.A.4	Other Sectors: Residential	CH_4
1.A.2	Emissions from Manufacturing Industries and Construction	CO_2
1.A.4	Other Sectors: Agriculture/Forestry/Fishing	CO_2
1.A.4	Other Sectors: Residential	CO_2
1.A.4	Other Sectors: Commercial	CO_2

3.1.4 Brief Description of Recalculation

Recalculation of the energy sector for all gases was implemented. The impacts of the recalculation were particularly considerable on the emissions in transport (1.A3) and residential (1.4D). The recalculations in the sector included updating the existing inventory data over the entire series due to availability of new activity data especially in 1.A3 and 1.4D. New method was also available in the 1.A3 from the DANIDA-transport sector programme support project that used COPERT III to model transport emissions. The inventory in the transport sector was also expanded to include 1.4D for CH_4 and N_2O emissions due to access to biomass data from the forestry sector. The inventory from the sector also extended from 1990-1996 under the initial national communication to include 1997 to 2006.

3.1.5 Planned Improvements

The following areas under the energy sector have been identified for near to long-term improvements:

- Expanding the inventory in the sector to cover fugitive emissions from oil and gas exploitation (particularly methane) from possibly 2011 since commercial downstream operations are anticipated to commence in December 2010. This is expected to improve completeness of the inventory.
- Revise the activity data from road transport (especially on fleet population and fuel consumption to include LPG component and all gases) and also to the extent practical, move to a higher tier methodology in the inventory in accordance with the IPCC guidelines.
- Improve the estimate of data on non-energy use of fuels especially for the industrial process sector. This is expected to reflect in the next inventory cycle.
- Since non-CO_2 emissions from the residential category is key source in the sector, the plan for the long-term is to gather and collate more detailed data on biomass consumption in the country for updating the existing biomass estimate. Furthermore, it is envisaged, in the long-term, to develop country-specific emission factors for both CH_4 and N_2O.
- With the growing component of electricity generation from thermal sources, it is important to improve the existing national grid emission factor and the activity data from Energy industries (1.A.1)
- In the long-term, it is intended to develop and apply appropriate emission factors and higher tier methodology for key categories in the energy sector in order to reduce potential underestimation or overestimation.

3.2 Industrial Processes

3.2.1 Sector Overview

In this sector, emissions from mineral products (limestone use) and metal (aluminum) production were estimated for direct gases such as CO_2 and PFCs (CF_4 and C_2F_6). CO_2 emission was the largest source of GHGs reported during the period 1990-2006. CO_2 from metal production (particularly aluminum production) constituted an average of 74% of total industrial emissions throughout the time series whereas those from mineral products

(limestone use) generally formed an average of 26%. In terms of general trends, the total emissions in the sector saw irregular decline from 1990 to 2006 (figure 23) due to reduction in industrial productivity and appropriate allocation of emissions to the right emission source categories for the current inventory cycle.

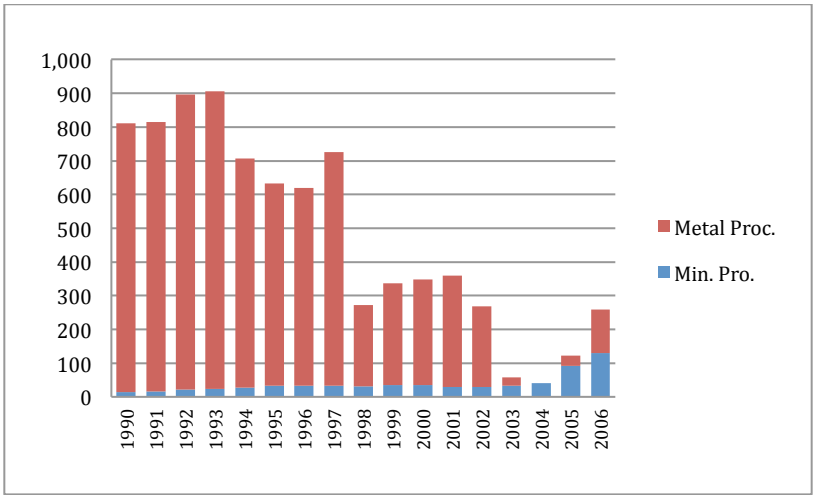

Figure 22: Trends of total emissions by categories in the industrial processes sector ($GgCO_2e$)

From figure 22, emissions from metal production (aluminum) decreased from about 0.79Mt CO_2e in 1990 to 0.3MtCO_2e in 2000 and further to 0.13MtCO_2e in 2006. This represented an overall reduction of 89.5% by 2006 compared to 1990 levels. This was attributed to the steady reduction in aluminium production from particularly 2003 and 2005 where the only primary aluminium production plant operated only single pot line and its eventual closure in 2004. The year 2004 has the minimum CO_2 emissions for the industrial processes since emissions came only from limestone use and because there was no production of aluminium due to unavailability of electrical power. On the contrary, total emissions from limestone use under mineral products saw slight but gradual increase through the time series. In 2000, a total of 34.7$GgCO_2e$ emissions from lime use were estimated. This amounts to 145.8% above 1990 levels and 273.5% increase in 2006 compared to 1990 levels. The rise in limestone use in Ghana has accounted for this change in trends.

3.2.2 Methodology

The IPCC tier 1 methodology was applied in this sector. Emission factors used for calculation of emissions, in most cases, default factors taken from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, and Good Practice Guidance and Uncertainty Management in National GHG Inventories, mainly due to a lack of country-specific emission factors. However, plant-specific emission factors for aluminum production were estimated by collecting the actual data at plant level.

3.2.3 Brief Description of Recalculation

Recalculation was done for CO_2 emissions for both mineral products and metal production for 1990 - 1996. Generally, activity data for both sub-categories was updated due to the availability of new datasets from companies. Furthermore, additional inventory years were added to expand the inventory from 1990-1996 to 2006. The recalculation took into consideration proper allocation of the emission estimates in the industrial processes sector to the right categories in energy sector. For example, in the initial national communication CO_2 emission from energy use in cement production was included in the industrial processes

sector. Current CO_2 emissions from energy use in cement production, which is not process related emissions have been included in Emissions from Manufacturing Industries and Construction (1.A.2). This is important as it also avoids double counting.

3.2.4 Planned Improvements

A number of areas require improvements over the near, medium to long-term time. These include:

- Improvement in activity data on other industrial operations in Ghana to enhance completeness
- Accounting for emission from consumptions from HFCs especially in the refrigeration and air-conditioning sectors.
- Improvement in estimates on non-energy use and feedstock to ensure transparency

3.3 Agriculture Sector

3.3.1 Sector Overview

In this sector, methane and nitrous oxide emissions from animal enteric fermentation (4.A), manure management (4.B), rice cultivation (4.C), agricultural soils (4.D) and field burning of agricultural residues (4.F) were estimated from 1990 to 2006. Nitrous oxide emissions were the largest greenhouse gas from the agricultural sector followed by methane. Total emissions from the agricultural sector increased steadily from nearly 4.6GgCO_2e in 1990 to 5.5GgCO_2e in 2000 and slightly further to 6.68GgCO_2e in 2006. This represented an increase of 44% of the whole time series (1990 to 2006) and an increase of some 20% from 1990 to 2000 (figure 23).

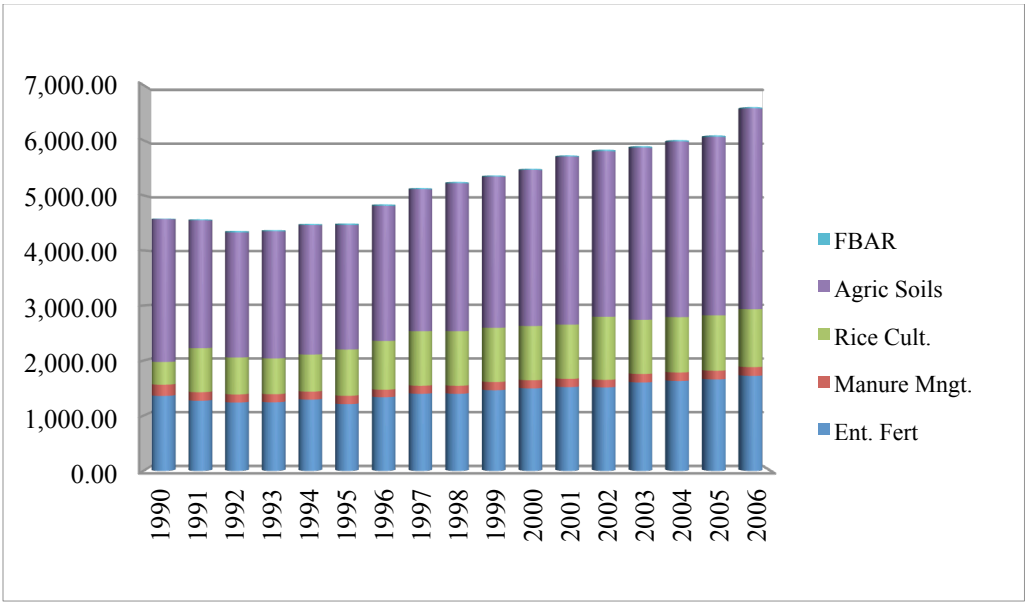

Figure 23: Trends of total emissions by categories in the agriculture sector (GgCO_2e)

Within the sector, the largest source of emissions comes from Agricultural soils throughout the time series. This is primarily due to the increases in the applications of artificial fertilizers for agricultural production and from pasture, rangelands and grazing. The next largest contributor of agricultural emissions comes from enteric fermentation of domestic livestock. The emission levels maintained a continuous but gradual increase from 1990 to 2006. This is followed by emissions from rice cultivation and manure management respectively and similarly increased marginally over the time series (figure 24). It is noteworthy that, emissions from field burning of agricultural residue are negligible compared to the other sub-sectors throughout the time series.

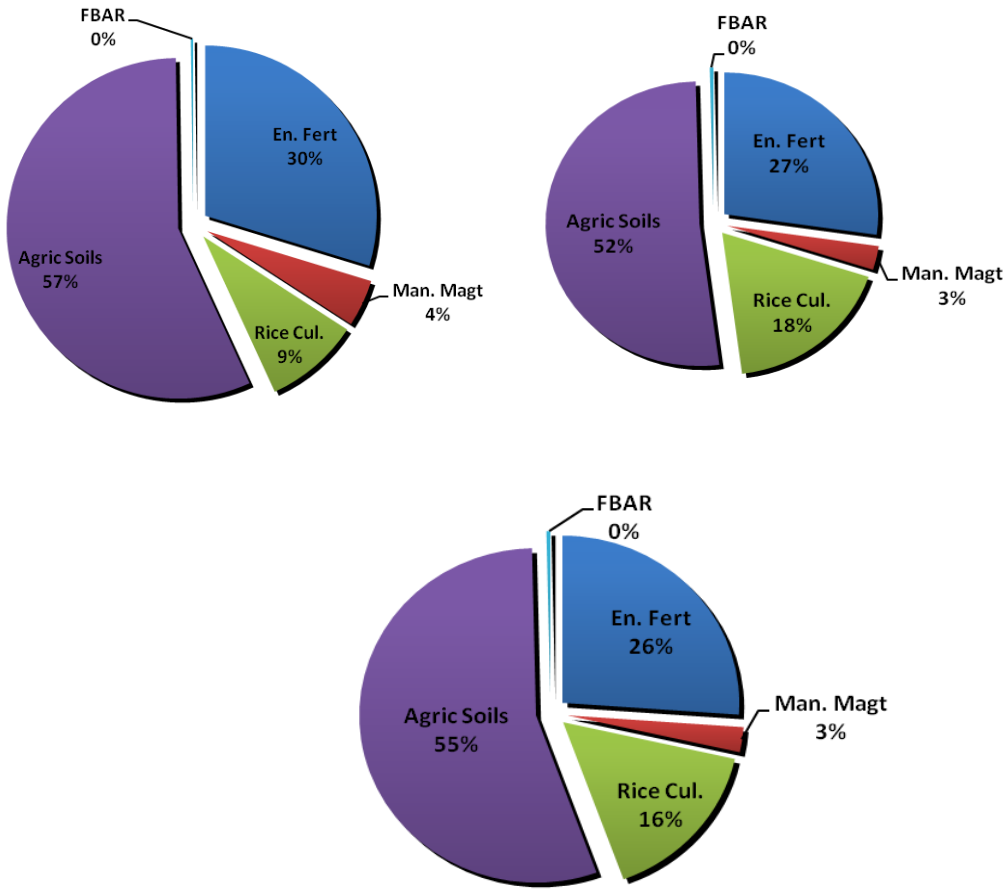

Figure 24: Contributions from sector categories to total agricultural emissions in 1990, 2000 and 2006.

In terms of gases, N_2O is the largest from the agricultural sector compared to CH_4 throughout the time series. Between 1990 and 2000, N_2O emissions increased steadily by nearly 19.7% and in the overall, N_2O emissions increased by 44.1% from 1990 to 2006 (figure 25).

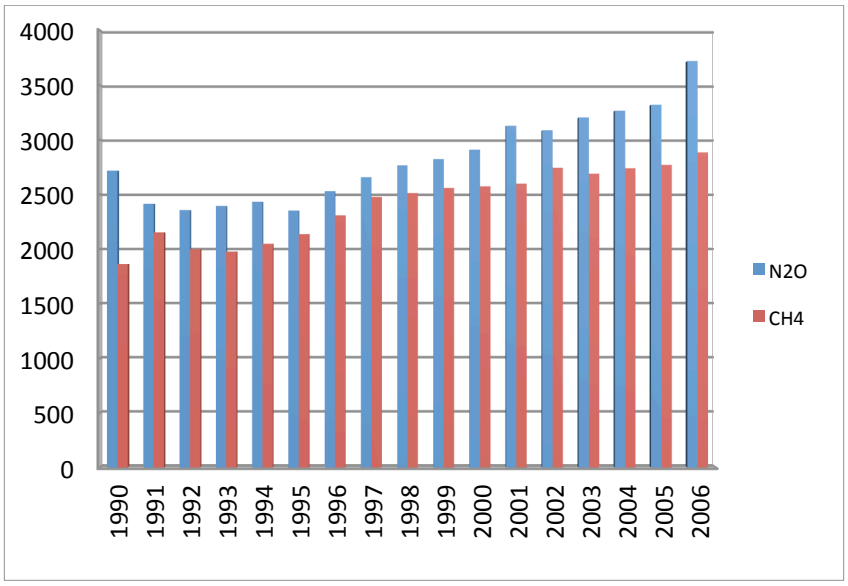

Figure 25: Trends of N_2O and CH_4 in the agricultural sector ($GgCO_2e$)

Agricultural soils are the largest source of nitrous oxide emissions for the period 1990 to 2006. Total nitrous oxides (N_2O) ranged from 2.9$MtCO_2e$ in 1990 to 4.5$MtCO_2e$ in 2000 and 5.6$MtCO_2e$ in 2006. Contribution from burning of Agricultural residues was significantly very low. Values of emissions from manure management were next to the values of the soils (figure 26), though on the very low side with the highest percentage value of about 6% in 1990. The emissions from manure management followed a consistent downward trend and reduced from 121.6$GgCO_2e$ in 1990 to 64$GgCO_2e$ (47.4% reduction) in 2006.

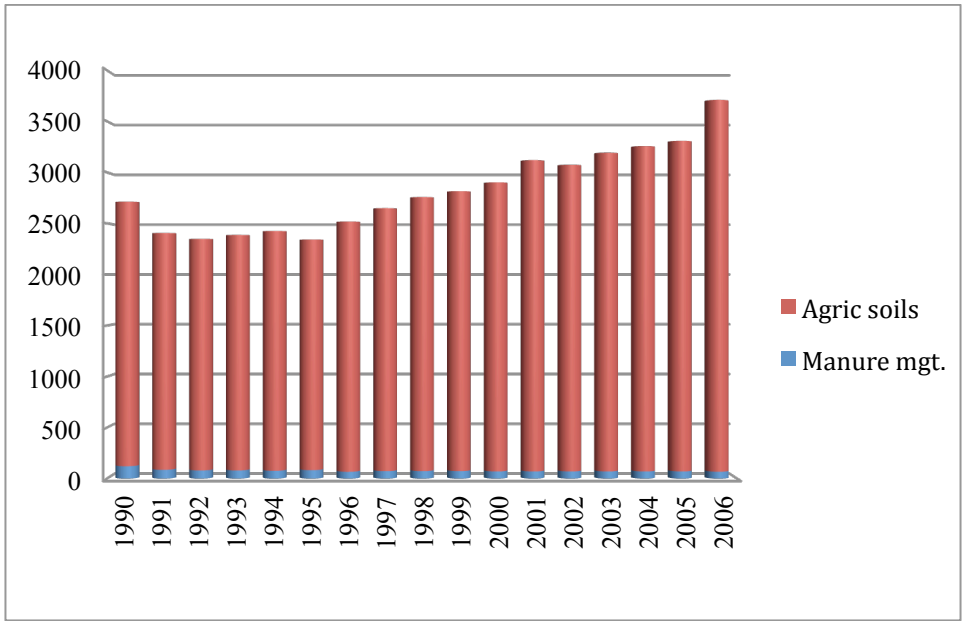

Figure 26: Trend of sources of N_2O in the Agricultural sector (Gg)

Methane emissions were recorded from these the categories; Enteric Fermentation, Manure Management, Rice Cultivation and Field Burning of Agricultural Residues in the agricultural sector with enteric fermentation from domestic livestock being the largest source. In 2000 methane emissions from the sector was estimated as 2.6GgCO_2e, thus representing 38.2% above 1990 levels and 16.6% below 2006 level. Overall methane emissions increased by 54.9% from 1990 to 2006. Enteric fermentation from domestic livestock is the largest contributor of methane in the agricultural sector during the period 1990 to 2006 (figure 27).

This is mainly due to the increasing numbers of domestic livestock such as ruminant animals. Specifically, non-dairy cattle were the major contributors with the values ranging from 54% in 2006 to 63% in 1996. Contributions from sheep and goats appear to be similar from 1990 to 1997, with values ranging from 17-20% for sheep and 17-22% for goats. However, percent contributions of goats from 1998 to 2006 were higher than those of sheep for all the years. Although the difference between the two was only 1% in 2000, this difference had risen to 6% by the year 2006. These differences were due to the differential increases in animal population over the years. Contributions from Horses, Asses and Swine were insignificant. Methane from rice cultivation is the second largest source of emissions from the agricultural sector. Emissions are mainly from rice cultivation in flooded fields and increased by nearly 138% between 1990 and 2000 and by 155% for the period between 1990 and 2006. This result supports the claim of increase in local production in rice especially for the time series. Methane emissions from both manure management and field burning of agricultural residues are minimal throughout the time series.

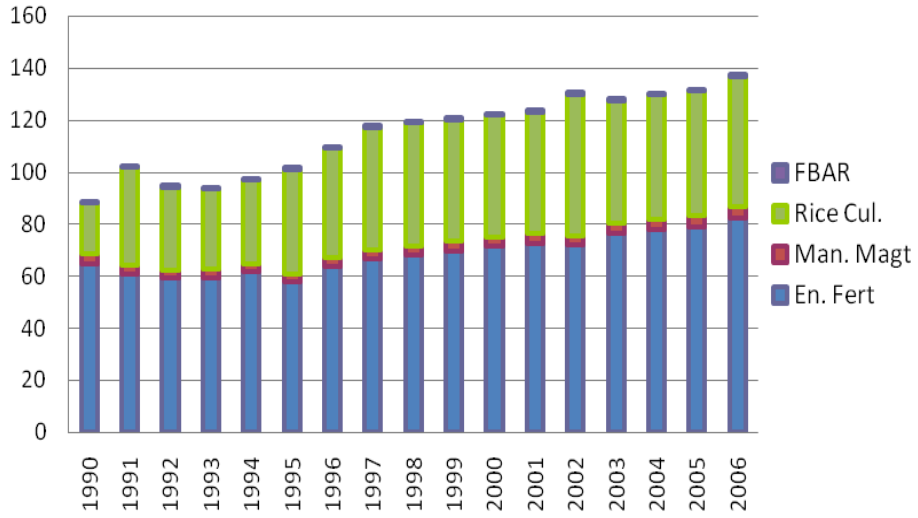

Figure 27: Trends of CH_4 emissions in the Agriculture sector

3.3.2 Methodology

IPCC tier 1 methodology was adopted for the estimation of emissions from the agriculture mainly due to lack of detailed activity data and emission factors. Activity data sources were mainly from Ghana and completed with data from FAO. In addition, emission factors used were mainly default from IPCC.

3.3.3 Analysis of Key Category

In 2000 and 2006, the following sub-categories were identified as key categories in terms of levels with and without LUCF.

Table 20: Key categories in the agricultural sector in 2000

ID	Sub-categories	Gases
4.D	Direct and Indirect emissions from Agricultural Soils	N_2O
4.A	Emissions from Enteric Fermentation in Domestic Livestock	CH_4
4.C	Emissions from Rice Production	CH_4

Table 21: Key categories in the agricultural sector in 2006

ID	Sub-categories	Gases
4.D	Direct and Indirect Emissions from Agricultural Soils	N_2O
4.A	Emissions from Enteric Fermentation in Domestic Livestock	CH_4
4.C	Emissions from Rice Production	CH_4

3.3.4 Brief Description of Recalculation

Recalculation was implemented from 1990-1996, as new reliable data were available for the preparation of the inventory. The data made available included; animal population, crop production, and nitrogen fertilizer consumption figures. Recalculation was done in the following sub-categories: enteric fermentation, agricultural soils and burning of crop residues for both CH_4 and N_2O. Emission from burning of savannah was estimated under LUCF during the GHGI cycle due to availability of GIS data and also to avoid double counting.

3.3.5 Planned Improvements

The following areas in agricultural sector have been identified for near to long-term improvements:

- Improving activity data coverage for production of pulses and consumption synthetic Nitrogen fertilizer especially for transparency and completeness purposes.
- In the long-term, develop and apply appropriate emission factors and higher tier methodology for key categories in the agricultural sector in order to reduce potential underestimation or overestimation.

3.4 Land Use Change and Forestry

3.4.1 Sector Overview

Between 1990 and 2000, net GHG removals from LUCF decreased nearly by 96% from -26.1GgCO_2e to -1.04GgCO_2e. It further decreased to 5.6GgCO_2e in 2006. Net emissions from LUCF constituted sink from 1990 but steadily depleted to 7% in 2000. After 2000, the sector contributed to emission sources, peaked in 2004 and reduced marginally in 2005 and 2006. Forest and grassland conversion category was the main source of emissions in the period between 1990 and 2006. It increased steadily from 20% of the LUCF emissions/removal in 1990 to 49% in 2000 and further to 50% in 2006 (Figures 28). Net emissions/removal from changes in forest and other woody biomass stocks category has been responsible for removals. This category constituted -70% of the total net emission/removal from the LUCF sector in 1990 to -47% in 2000 and -45% in 2006.

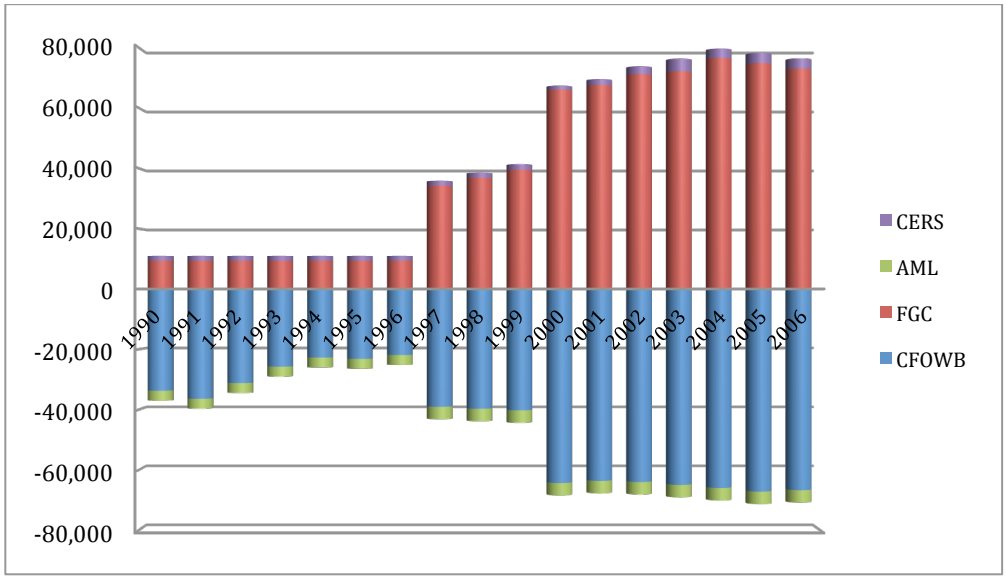

Figure 28: Trends of total emissions by categories (GgCO_2e)

Forest and grassland conversion through deforestation activities has been the major cause for the declined in CO_2 removal capacity (sinks) and increases emissions in the sector. Some of the activities included, agricultural intensification predominantly in the middle deciduous eco-zones in the country, illegal logging, expansion of settlements, expansion of surface mining activities, and regular field burning. Though, the trends of contribution of emissions from the sector increased from 2000, it is important to recognize that increased government and private sector plantation (under managed areas) initiatives grossly impacted positively on the increases in the CO_2 removals in Ghana. In addition, other government policies on sustainable forest management and forest conservation contributed to managing and enhancing carbon stocks in natural and managed areas. This has generally aided in reducing net emissions from the sector since 2004.

Removals of GHG through abandonment of managed lands decreased from -7% in 1990 to -3% and -3% in 2000 and 2006 respectively, even though this constituted a marginal portion of the total of the LUCF emission/removals. The CO_2 emissions from soil averagely made up 3% to 2% of the total LUCF emissions between 1990 and 2000.

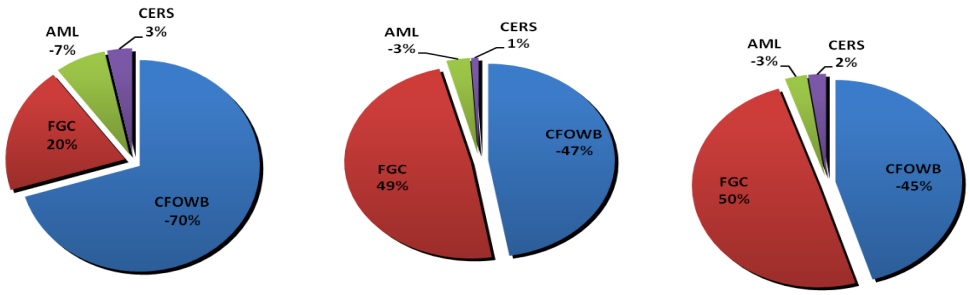

Figure 29: Contributions of emission from LUCF activities

CO_2 is the major source of greenhouse gas emission/removal from the LUCF sector compared to CH_4 and N_2O respectively. In 1990, it constituted -97% (-26.7Mt) of the total LUCF emissions/removals and decreased by 39% to -3.7Mt and further to 2.6Mt. Though the remaining gases (i.e. CH_4 and N_2O) represented small amounts of the LUCF emissions in 1990, they subsequently increased sharply in 2000 to 21% and further 26% in 2006 (figure 30).

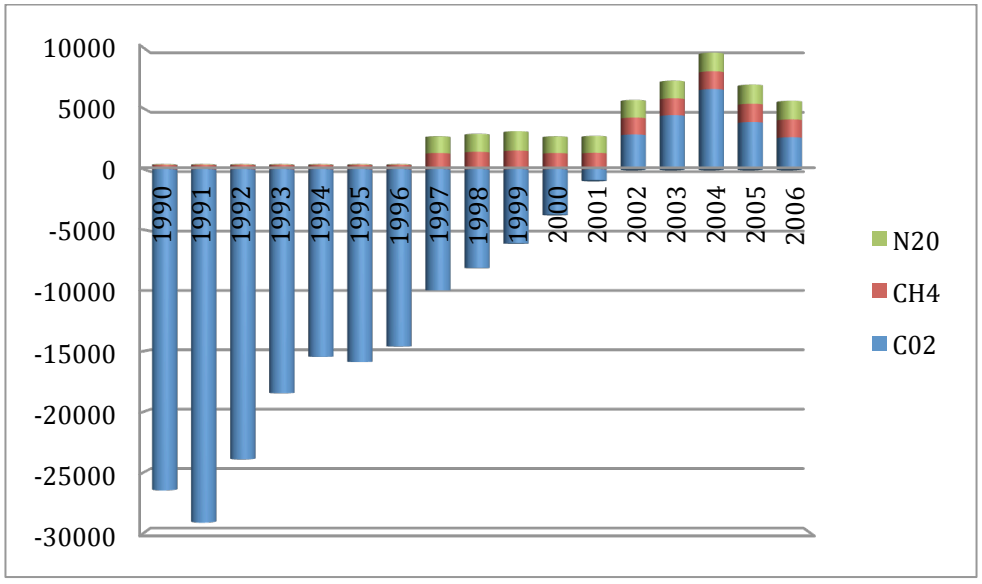

Figure 30: Trends of emissions by gases in the LUCF sector ($GgCO_2e$)

Overall, CO_2 is the dominant emissions/removals in the LUCF throughout the inventory period (1990 to 2006), followed by CH_4 and N_2O. Whiles CO_2 emissions increased sharply over the years from -97% in 1990 to 47% in 2006, CH_4 and N_2O on the other hand recorded marginal increase from 1990 until 1997 after which it increased to 26% in 2006. Figure 30 also shows the steady reduction in CO_2 removals up to 2001 at annual average of 9.6%, subsequent to which CO_2 contributed to the source emissions of the sector. The two major important drivers of the trend in the CO_2 emissions have been the net increases in forest or woody biomass and growing rates of forest and grassland conversions. Figure 29 also shows that categories under forest and grassland conversions and CO_2 emissions from soil,

respectively constituted the main sources of CO_2, CH_4 and N_2O emissions in the LUCF over the inventory period with the former dominating. Whereas categories such as changes in forest and woody biomass and abandonment of managed lands constitute the major source of CO_2 removals from the sector.

3.4.2 Methodology

In general, IPCC tier 1 methodology and emission or removal factors were used in the accounting of emissions in the LUCF sector. However, there were some categories, particularly, forest and grassland conversion, where higher tier methodologies based on remote sensing were used for the retrieval of land cover units and the changes in them. Locally developed allometric equation especially for selected planted species (teak species) was also employed. Activity data were also retrieved from various local sources and complemented by data from FAO. The LUCF inventory data have been compiled from various sources including:

- References contained in books, journals and reports;
- Data stored in digitized formats or hard copies in state and private institutions;
- Default values as contained in the Revised 1996 IPCC Guidelines for GHG Inventories (Work book, Reporting Instructions, Reference Manual);
- Professional/expert best assumptions
- Remote sensing and GIS geo-databases
- Peer reviewed scientific publication and
- The initial national communication

Data on land-use change and forestry activities in the country existed in varying forms and quality. Data inaccuracies and inconsistencies have constrained the inventory to a large extent. In most cases, data were unreliable, un-updated and full of gaps. The Forestry Commission of the Ministry of Lands and Natural Resources has a fairly adequate data on harvesting and planting activities.

However, those of private companies, other government organizations, individuals and groups were hard to access. Sourcing and accessing of data from state and private institutions was undertaken through EPA, personal visits and where necessary, identified data gaps were filled from files found in company archives. Data analysis and compilation were in conformity with the Revised 1996 Guidelines for GHG Inventories Workbook, Reference Manual and Reporting Instructions and the 2003 IPCC good practice guidance. Units of measurements of main inventory tables are as contained in the IPCC Guidelines. Data and information were accessed from the following sources:

- Ghana Rubber Estate Limited (GREL) at Agona Nkwanta and Takoradi
- The Plantation Unit of the Forestry Services Divisions in Kumasi
- The GIS and Remote Sensing Unit of the Forestry Services Divisions in Kumasi
- Ashanti Goldfields Company (AGC) at Obuasi
- Subri Industrial Plantation Limited (SIPL) at Daboase near Takoradi
- Swiss Lumber Company at Wassa Amenfi in the Western Region
- Pioneer Tobacco Company (PTC) at Techiman, Wenchi, Takoradi
- Bonsunvonberg at Somanya in the Eastern Region
- Samartex Company Limited
- Savanna Agricultural Research Institute (SARI) at Tamale

- Forestry Research Institute of Ghana (FORIG) in Kumasi
- Institute of Renewable Natural Resources (IRNR) of the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi
- Soil Research Institute of the Council for Scientific and Industrial Research in Accra and Kumasi
- FAO Forest Resources Assessment Report 1990, 1996, 2000, 2005
- Timber Industry Development Division, Kumasi and Takoradi
- FAO Yearbook Production (1986, 1989-92, 1994)
- World Bank - Staff Appraisal Report, Ghana Forest Resources Management Project, 1988. Report No. 7295 – GH
- Environmental Protection Agency, State of the Environment Report, 2006
- GIS Unit, Environmental Protection Agency
- CERGIS, Legon, University of Ghana, Legon
- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (Work book, Reporting Instructions, Reference Manual).
- SEMCO Report (EPA Ghana and Pennsylvania State University).

Data Requirements under LUCF
Data reported under this sub-category were generally retrieved from national institutions that are responsible for collecting data on the inputs below. The aggregate value of all the data below gives a sense of annual harvest of biomass from both natural and planted forest areas both for export and internal use.

Roundwood
Roundwood figures are given in solid volume of roundwood (or roundwood equivalent) without bark. It comprises all wood obtained from removals, i.e. the quantities removed from forests and from trees outside the forest, including wood recovered from natural, felling and logging losses within the year. Commodities included are sawlogs, veneer logs, poles, including other industrial roundwood (pitprops, wood residues, chips), fuelwood and wood converted into charcoal. The statistics include recorded volumes, as well as estimated unrecorded volumes using conversion defaults as indicated in the notes. The main data were mainly from the timber exports quarterly reports produced TIDD and complemented by the FAO country data on Ghana sourced from the Internet.

Industrial Roundwood
The commodities included are sawlogs and veneer logs. These data are primarily collected by the respective sawmills and subsequently transmitted to the TIDD for quarterly reporting. The Timber Industry Development Division and FAO were the main sources of this data.

Other Industrial Roundwood
The commodities included are wood chips, poles, and wood residues eg. Sawmill rejects, slabs, edgings and trimmings, veneer log cores, veneer rejects, sawdust, bark (excluding briquettes), residues from carpentry and joinery production, etc. The Timber Industry Development Division and FAO were the main sources of this data.

Fuelwood and Charcoal
The statistics include the roundwood equivalent of charcoal and harvested fuel essentially for commercial purposes. However, those harvested for domestic activities (cooking, heating etc) are excluded because of lack of official data though the amount growingly substantial. Apart

from the data from FAO, national data from the Energy Commission's strategic energy plan and the production unit of the Forestry Service Division complemented the use of data on Fuelwood and charcoal in the inventory.

Area of Forest/Biomass Stocks (thousand hectares)

Stock data provide indication of existing biomass stocks in different ecological zones in Ghana and its annual growth rate. The key data are areas covered by the different types of forest or biomass stocks in hectares. The data on different forest types and changes in them were collected from remote sensing data processed by the inventory compilers and scaled to cover the previous time series. This was complemented by the land cover maps for Ghana developed in 2000 by CERGIS, land cover data reported in the Spatially Explicit Modeling for Soil Organic Carbon (SEMSOC) project by EPA-Ghana and Pennsylvania State University and Forest Assessment Reports in 1990, 1995, 2000 and 2005. The GIS and Remote Sensing Unit of the Forestry Commission also provided secondary data on the forest extent in the country.

Mean Annual Increment (cubic meter per hectare per year)

This represents the annual growth rate in solid volume of biomass per hectare per year for each species or a combination of species. Growth rates were obtained from menstruation data of the Forestry Commission (Production Unit, Kumasi), Forestry Research Institute of Ghana (FORIG) and the IPCC guidelines. Total annual volume of biomass (thousand cubic meters per year) is thus a product of the area of forest/biomass stocks and the mean annual increment.

Forest and Grassland and Conversion

Land use/land cover conversions and burning of biomass through in-situ fires are the main sources of emissions through permanent transfer of forestlands and grasslands to other less-biomass cover types. The major sources of data on different forest types were collected from remote sensing imagery, which was processed by the inventory team. This was complemented by the land cover maps for Ghana developed in 2000 by CERGIS, land cover data reported in the SEMSOC project and Forest Assessment Reports in 1990, 1995, 2000 and 2005. The GIS and Remote Sensing Unit of the Forestry Commission also provide data on the forest extent in the country.

Deforestation Rate

The deforestation data were primarily retrieved from processing remote sensing images on decade basis and other data from EPA, CERGIS and Forestry Commission. The inventory compliers in consultation with other national institutions such as CERCGIS, FORIG, EPA and the Forestry Commission settled on using decade basis for determining average annual deforestation rates at the national level because; the available remote sensing data (Landsat, MODIS and Aster) could yield better results in tandem on wide temporal scale; the actual cycle of forest and grassland conversion may be effectively manifested in five years and above. Thus deforestation rates at the national and ecological zone scales were determined using remote sensing data for 1970, 1980, 1990 and 2000.

Burnt Areas

For consistency and transparency purposes, all burnt areas including the savannah areas were reported under LUCF instead of the Agriculture Sector. The land cover map produced by CERGIS for 2000 was the main source of data under this sub-category.

Abandonment of Managed Lands
Data under abandonment of managed lands had several sources. The data gives an idea of the extent of CO_2 removal resulting from land fallowing for different number of years. Removals resulting from the abandonment of managed lands include: cultivated lands (arable land used for the cultivation of crops) and pasture (land used for grazing animals). No specific statistics were available for the high forest and savannah areas. Extensive discussions among key national experts especially those in the agricultural sector assisted in deriving data on abandonment of managed lands. The FAO yearly reports on Agriculture for Ghana also complemented. Relevant data from the initial national communication were also drawn upon.

CO_2 emissions and removals from soil
This emission from this category was not reported in the inventory during the initial national communication because of lack of requite data. The availability of a national soil map from the soil research institute and the FAO, data could be derived for estimating CO2 emission from soil.

3.4.3 Analysis of Key Category
In 2000 and 2006, the following sub-categories were identified as key categories in terms of levels with LUCF.

Table 22: Key categories in the LUCF sector in 2000

ID	Sub-categories	Gases
5.A	Changes in Forest and Other Woody Biomass Stocks	CO_2
5.B	Forest and Grassland Conversion	CO_2
5.C	Abandonment of Managed Lands	CO_2
5.B	Forest and Grassland Conversion	N_2O
5.B	Forest and Grassland Conversion	CH_4

Table 23: Key categories in the LUCF sector in 2006

ID	Sub-categories	Gases
5.B	Forest and Grassland Conversion	CO_2
5.A	Changes in Forest and Other Woody Biomass Stocks	CO_2
5.C	Abandonment of Managed Lands	CO_2
5.D	CO2 Emissions and Removals from Soil	CO_2
5.B	Forest and Grassland Conversion	N_2O
5.B	Forest and Grassland Conversion	CH_4

3.4.4 Brief Description of Recalculation

Recalculation was done on all categories namely: 5A, 5B, 5B and 5D from 1997 to 2006 for CO_2, CH_4 and N_2O. The entire LUCF inventory was extended from 1997 to 2000 and to 2006 and also updated with new available data. Whiles 5A and 5B updated and extended from 1997 to 2006, emissions from 5D was expanded from 1990 to 2006. This is due to the following reasons: availability of new remote sensing data and methodology to delineate and reclassify land cover units according to IPCC guidelines; methodology for the estimation of new deforestation rates; identification of new dataset on spatial and temporal burnt areas in Ghana, inclusion of new dataset on soil use classes and changes in them. The recalculation in general resulted in sharp increases in the emissions from forest and grassland conversion category especially from 1997 to 2006 resulted (Figure 30).

3.4.5 Planned Improvements

The following areas in the LUCF sector have been identified for near to long-term improvements:

- Improvements in activity data especially on forest and grassland conversion category (5B) from 1990 and 1997 to complete the recalculation. This will reduce potential underestimation or overestimation in removals/emissions
- In the long-term, develop and apply appropriate emission or removal factors and higher tier methodology for key categories in LUCF to reduce potential underestimation or overestimation and improve accuracy.
- Collect more country-specific data on lands under abandonment across the country and at also at eco-zones.
- Collect more data on non-forest trees especially avenue or village trees. In this inventory data on avenue trees are not captured.
- Develop or adopt appropriate methodology for estimating emissions from wetland including the potential methane emissions from the Akosombo dam. This is a potential source of underestimation.

3.5 Waste Sector

3.5.1 Sector Overview

Methane and Nitrous oxide emissions were reported in the following activities in the waste sector; (6A) Solid waste disposal: methane (CH_4) emissions and (6B) Wastewater handling: methane (CH_4) and nitrous oxide (N_2O). Total emissions from the waste sector were 0.64, 1.6 and 2.3GgCO_2e in 1990, 2000 and 2006 respectively. This was 2%, 10% and 10% of the total greenhouse gas emissions in Ghana for the years 1990, 2000 and 2006 respectively (figure 33). Overall, emissions increased by nearly 115% from 1990 to 2006 whereas in between 1990 and 2000, the emission increased by some 49%. Growing rates of per capita waste generation especially in urban areas due to population increases and urbanization were generally driving the emission increases. Over the years, city authorities have increasingly shifted towards disposing solid waste in deep lands (crude dumping or sanitary landfills) without any policy of methane capture.

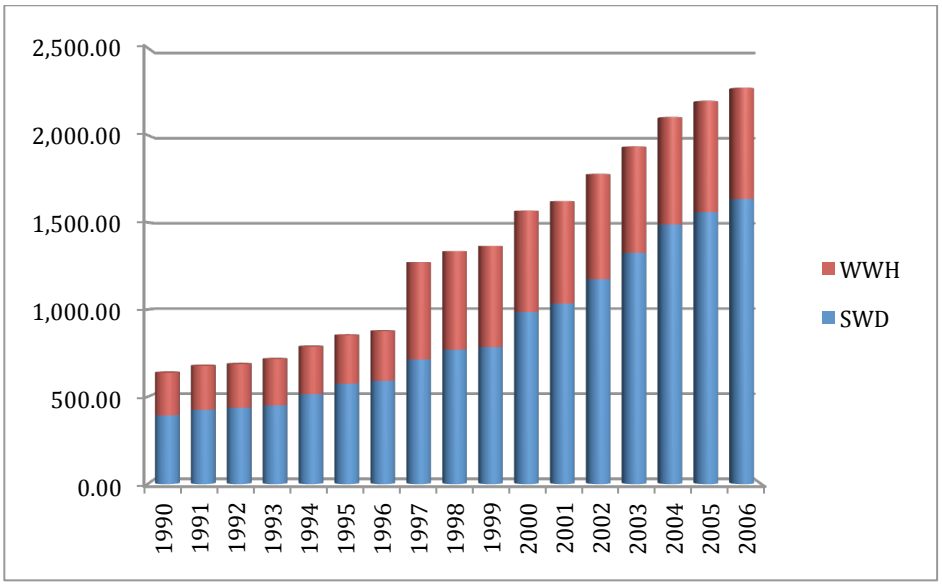

Figure 31: Trends of total emissions by categories in the waste sector ($GgCO_2e$)

Within the sector, solid waste disposal on land was the largest source of emissions throughout the period. In 2000, $1.0MtCO_2e$ emission was estimated from solid waste disposal on land. This was about 150.8% above 1990 levels and nearly 65.7% lower than 2006 levels. Emissions from wastewater handling sharply increased by 137% between 1990 and 2000 and further by nearly 10% in 2006. This trend of emissions could be generally attributed to increases in commercial and liquid waste and the lack of proper systems for management. Methane emissions were recorded in both 6A and 6B. In 1990, $0.5MtCO_2e$ of methane was estimated, which is nearly $0.89MtCO_2e$ and $1.6MtCO_2e$ below 2000 and 2006 levels respectively (figure 32). Within the sector, solid waste disposal on lands was the largest source of methane followed by wastewater handling throughout the time series (figure 32).

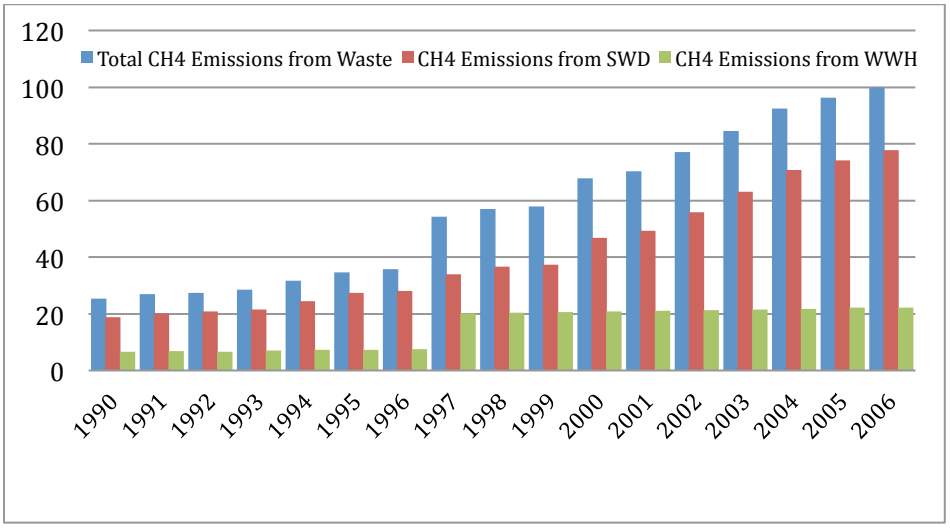

Figure 32: Methane emissions by categories in the waste sector ($GgCO_2e$)

The reasons for the high percentage of methane from solid waste disposal on land and wastewater handling are similar to the reasons given above. On the other hand wastewater handling was a singular source of nitrous oxide emissions in the waste sector. It increased by almost 50% from 1990 to 2000 and further nearly 20% in 2006 (figure 33). The levels of nitrous oxide emissions have been considerably influenced by the poor waste disposal practices of domestic and commercial liquid waste especially in the urban areas.

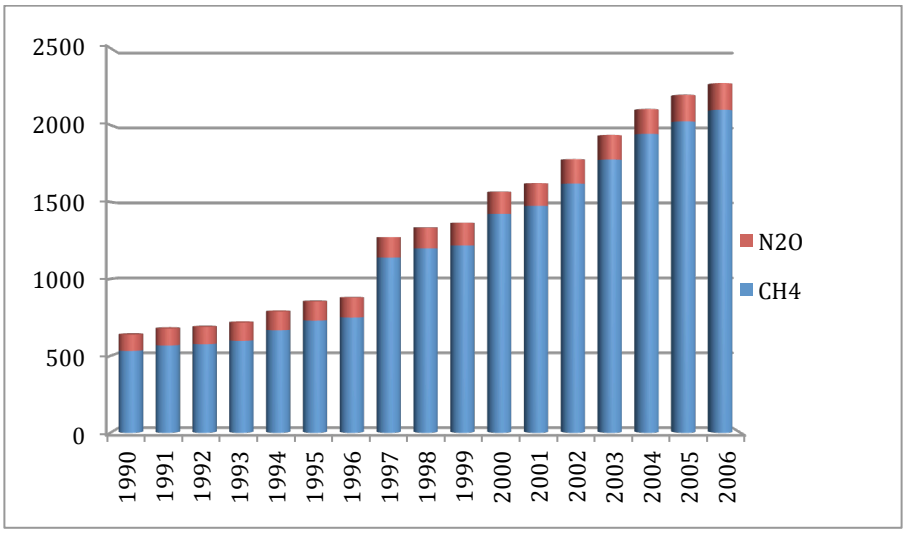

Figure 33: Trends of emissions by gases ($GgCO_2e$)

3.5.1 Methodology

Generally, tier 1 method in 1996 revised IPCC guidelines and default emission factors were used. Activity data were mainly obtained from local sources especially the Urban Waste Management Departments in various district assemblies in Ghana. References were also made to the inventory data under the initial national communication. The methodology used to estimate emissions from waste management activities requires local knowledge on waste generation, composition and management practice. The fact that waste management activities in Ghana are generally inadequately organized and implemented results in the lack and inconsistency of data. Therefore, effort was done in order to evaluate and compile data coming from different sources and processed them to meet recommended IPCC methodologies.

3.5.2 Analysis of Key Category

In 2000 and 2006, the following sub-categories were identified as key categories in terms of levels with the waste sector.

Table 24: Key category in the waste sector in 2000

ID	Sub-categories	Gases
6.A	Methane emissions from solid waste disposal on land	CH_4

Table 25: Key category in the waste sector in 2006

ID	Sub-categories	Gases
6.A	Methane emissions from solid waste disposal on land	CH_4

3.5.3 Brief Description of Recalculation

Recalculation was conducted for the entire time series for both 6A and 6B of CH_4 and N_2O. The recalculation included updating the activity of the both 6A and 6B and also extending the inventory from 1990-1997 to 2006. This was largely due to the availability of new data in the sector.

3.5.4 Planned Improvements

The following areas in the waste sector have been identified for near to long term improvements:

- In the long-term, develop and apply appropriate emission factors and higher tier methodology for key categories in the waste sector to reduce potential underestimation or overestimation and improve accuracy.
- For completeness and potential underestimation purposes, gather request activity data on waste incineration and industrial wastewater handling for fill the gap in the waste inventory.

Brief Discussion of Results and Planned Improvements

This section is in three parts. The first part presents brief discussion on the national GHG estimates in the context of global, continental and sub-regional emissions situations. It also highlights on the driving factors of the emission trends and the linkages with the socio-economic dynamics of Ghana. It also draws on the major potential economic sectors that are likely to have significant impacts on the total emissions in near future. The second part provides insights into the areas of the inventory, which require improvements over the various time scales. The last part of this section draws important conclusions from the entire inventory process.

4.1 Brief Discussion of Overall Results

The national GHG aggregates represent the best possible estimates of emissions/ removals from various socio-economic activities based on available methodology, activity data and emissions factors. The total net emissions of 23.9MtCO_2e for 2006 are consistent to the World Resource Institute's global emission data on CO_2, CH_4, N_2O and PFCs of 21.3MtCO_2e at 2005. This emission represents about 0.05% of the total global emissions and rank 108 on the world. Using the 2000 population census figures, the total per capita emission is nearly 1tCO_2e per person as at 2006 and 0.7tCO_2e per person as at 2000. At the continental level, Ghana is rank at par with Senegal and Mali at the 21st most GHG emitting country in Africa trailing behind Nigeria, South Africa, and Egypt etc. At the level of ECOWAS, Nigeria and Cote d'Ivoire are rank are ahead of Ghana.

Though Ghana's emissions appears relatively low compare to other major developing economies, the trend in total national emissions clearly indicates a strong increasing potential in the near to medium term horizon as the economy of Ghana continue to grow and expand to development frontier dominated by agriculture and oil and gas production. The increasing trends of the national emissions are also indicative of level of growth of the Ghanaian economy, which is mainly led by the agricultural and related sectors and driven on energy. In terms of GHG intensity of the economy (loosely expressed as net GHG per unit GDP), 813.5tCO_2e/Million dollars (CAIT, 2009) is reported for Ghana in 2005. Between 1990 and 2006, Ghana recorded a total growth in GDP of 107.3% (CAIT, 2009) in millions dollars, emissions of 106.8% (according to this emissions estimates) without LUCF in MtCO_2e. This result revealed close linkages between the performance of the Ghanaian economy and the levels of emissions.

The emissions in Ghana are predicted to grow and peak in the medium to long term horizon as the economy of Ghana also expands especially in the agriculture and other related sectors such as forestry and energy. The flagship agriculture policy (FASDEP 2) of Ghana thrust on enhanced and efficient agriculture-led economic development; the growth pole component of the policy seeks to achieve increases in agricultural production to ensuring food sufficiency. The policy drift though laudable in terms of achieving food security targets, it also comes with associated agricultural emissions, particularly, methane and nitrous oxide that are likely to significantly impact on the total national emissions.

Another important sector, which is expected to impact strongly on the national emissions, is the energy sector. Fugitive emissions from the oil and gas production are expected to reflect as a major source of methane emissions as commercial oil and gas exploitation comes on stream by the end of 2010. The other triggers in the energy sector that are likely to impact significantly on the emissions are the likely increases in the light crude consumption in thermal energy generation; as percentage of hydro power generation dwindles over time due to decreased surface flows as a result of impact of climate change on the water resources, duration and quantities of peak-hour energy demand are grows. Consumption of biomass for domestic and commercial heating, lighting and cooking is also expected to grow. Waste-related emissions may not be that much as compare to other sectors, however, solid waste disposal on land (in the form of landfill and crude dumping) is predicted to grow substantially especially in the urban areas and impact strongly on the national emissions since methane management is clearly lacking in the waste policies in Ghana.

4.2 Planned Improvements

The inventory system of Ghana has experienced considerable improvements since the initial national communication. Yet, more need to be done to achieve substantial rigor and robustness in the inventory. The planned improvements are to be implemented in phases over time. The broad areas identified for improvements over and above those identified in the sectors include:

- Developing relevant higher-tier methodology and emission factors of major key categories by levels and incorporate them appropriately in the subsequent inventories. This would ultimately improve accuracy and reduce potential underestimation.
- Conduct tier-1 uncertainty assessment using IPCC methodology for the entire inventory, all the sectors and in particular key categories in the next inventory. This will also improve transparency of the inventory.

- Conduct and incorporate key category analysis by trends using inputs from the uncertainty analysis.
- Within the national system, effective data management systems strategies (data collection, storage and archiving) will be pursued in the upcoming inventory cycle. In addition, institutional roles and responsibilities among stakeholders will be clearly implemented and incentivized.
- Data generation and archiving in-between national communications is important to the sustainability of the inventory process. Ghana will vigorously follow this agenda.
- Develop and implement a comprehensive QA/QC plan for the next inventory cycle.

4.3 Conclusions

From the 2000-inventory year, Ghana current total national emission is 12.2MtCO_2e for five direct greenhouse gases namely CO_2, CH_4, N_2O, CF_4, and C_2F_6. It increased to 23.9MtCO_2e in 2006, which is of 0.05% of global emissions. This emission levels indicated a 243% increase from the 1990 levels. The energy sector is the major GHG emissions source followed by land use change and forestry and agriculture. The current emissions are predicted to increase in the near to medium term horizon considering the economic development prospects of Ghana. Though, Ghana's total net emissions are relatively small compare to the global average emissions; it has great potential to double in the next decade. The coming to stream of the oil and gas industry, potential of increasing GHG-intensive food production and the increasing rates of forest conversions are likely to impact significantly on the future emissions of Ghana. This result will also serve as a practical basis for developing and prioritizing GHG mitigation interventions for Ghana.

The emission results will also guide Ghana in formulating its nationally appropriate mitigation actions (NAMAs) by exhaustive emission reduction potential analysis of each GHG source or removal sectors and in particular within the key categories within the context of sustainable development enabled by provision of finance and development and transfer of appropriate technologies and support for capacity development. This NIR will also help Ghana to conduct further emissions modeling studies based on the available data in order to develop future emissions scenarios base on the socio-economic development outlook for Ghana. The benefits of these interventions are that, Ghana will be put in place relevant domestic plans, policies and programmes to mitigation climate change and contribute to the global effort of mitigating future climate change. The result will also serve as further basis for future GHG inventories.

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Annexes

Annex 1: Disaggregated National Emissions/Removals As Presented in 17CP.8 Table for Reporting Year 2000

National greenhouse gas inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol and greenhouse gas precursors								
Greenhouse gas source and sink categories	**CO_2 emissions (Gg)**	**CO_2 removals (Gg)**	**CH_4 (Gg)**	**N_2O (Gg)**	**NO_x (Gg)**	**CO (Gg)**	**NMVOCs (Gg)**	**SO_x (Gg)**
Total national emissions and removals	**6297.67**	**-3737.42**	**294.55**	**14.22**	**205.63**	**2246.99**	**35.08**	**0.50**
1. Energy	**4872.25**	**0.00**	**41.66**	**0.37**	**49.21**	**1621.61**	**35.07**	**0.00**
A. Fuel combustion (sectoral approach)	4872.25		41.66	0.37	49.21	1621.61	35.07	0.00
1. Energy Industries	502.38		0.02	0.00	1.38	0.10	0.03	0.00
2. Manufacturing industries and construction	1065.67		0.04	0.01	0.00	0.00	0.00	0.00
3. Transport	2530.30		0.50	0.02	24.47	183.79	34.64	0.00
4. Other sectors	773.90		41.10	0.33	23.37	1437.71	0.39	0.00
5. Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00
B. Fugitive emissions from fuels	0.00		0.00		0.00	0.00	0.00	0.00
1. Solid fuels			0.00		0.00	0.00	0.00	0.00
2. Oil and natural gas			0.00		0.00	0.00	0.00	0.00
2. Industrial processes	**1425.42**	**0.00**	**0.00**	**0.00**	**0.00**	**62.24**	**0.01**	**0.50**
A. Mineral products	1185.79				0.00	0.00	0.00	0.36
B. Chemical industry	0.00		0.00	0.00	0.00	0.00	0.00	0.00
C. Metal production	239.63		0.00	0.00	0.00	62.24	0.00	0.14
D. Other production	0.00		0.00	0.00	0.00	0.00	0.01	0.00
E. Production of halocarbons and sulphur hexafluoride								
F. Consumption of halocarbons and sulphur hexafluoride								

G. Other (please specify)	0.00		0.00	0.00	0.00	0.00	0.00	0.00
3. Solvent and other product use	**0.00**			**0.00**			**0.00**	
4. Agriculture			**122.52**	**9.10**	**0.84**	**15.29**	**0.00**	**0.00**
A. Enteric fermentation			71.28					
B. Manure management			3.71	0.22			0.00	
C. Rice cultivation			46.80				0.00	
D. Agricultural soils				8.85			0.00	
E. Prescribed burning of savannahs			0.00	0.00	0.00	0.00	0.00	
F. Field burning of agricultural residues			0.73	0.02	0.84	15.29	0.00	
G. Other (please specify)			0.00	0.00	0.00	0.00	0.00	
5. Land-use change and forestry [1]	**0.00**	**-3737.42**	**62.61**	**4.30**	**155.58**	**547.85**	**0.00**	**0.00**
A. Changes in forest and other woody biomass stocks	0.00	-64290.38						
B. Forest and grassland conversion	63383.08	0.00	62.61	4.30	155.58	547.85		
C. Abandonment of managed lands		-4136.00						
D. CO_2 emissions and removals from soil	1305.88	0.00						
E. Other (please specify)	0.00	0.00	0.00	0.00	0.00	0.00		
6. Waste			**67.75**	**0.45**	**0.00**	**0.00**	**0.00**	**0.00**
A. Solid waste disposal on land			46.95		0.00		0.00	
B. Waste-water handling			20.81	0.45	0.00	0.00	0.00	
C. Waste incineration					0.00	0.00	0.00	0.00
D. Other (please specify)			0.00	0.00	0.00	0.00	0.00	0.00
7. Other (please specify)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Memo items								
International bunkers	**335.01**		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Aviation	315.00		0.00	0.00	0.00	0.00	0.00	0.00
Marine	20.01		0.00	0.00	0.00	0.00	0.00	0.00
CO_2 emissions from biomass	**0.00**							

[1] If you have completed the LUCF section of Table 7As, these data will appear here automatically. If, however, you have used the IPCC Good Practice Guidance and Categories therein, apply the mapping back procedure for this sector and insert the corresponding numbers here manually.

Annex 2: Short Summary of Total National Emissions (Gg CO_2 equivalent)

National greenhouse gas inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol

Customized National Summary of CO_2 Equivalent of Direct GHG Trends Over Years (1990-2006)

Greenhouse gas source and sink categories	Net CO_2 Emissions (Gg CO_2 equivalent)																	Change (1990-2000)	Char (199 200
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	(%)	(%
Total national emissions and removals including LUCF	-16,795.5	-19,890.0	-14,236.0	-8,458.9	-5,282.7	-5,155.9	-3,413.4	4,403.7	6,642.6	9,761.06	12,207.9	16,263.3	20,809.9	23,085.6	25,077.6	23,358.1	23,983.3	172.7	24
Total national emissions and removals without LUCF	9,255.5	8,813.9	9,267.9	9,597.1	9,773.2	10,326.1	10,792.6	11,694.8	11,882.6	12,755.9	13,254.5	14,438.3	15,125.3	15,811.5	15,500.6	16,412.4	18,369.3	43.2	9
Energy	3,265.6	2,794.2	3,335.7	3,647.5	3,829.8	4,185.5	4,486.9	4,597.9	5,043.6	5,704.56	5,862.31	6,736.1	7,254.0	7,926.8	7,353.9	7,931.4	9,239.8	79.5	18
Industrial processes	773.5	778.09	853.3	864.4	674.8	606.9	593.4	693.9	262.1	326.70	343.27	356.4	265.9	57.4	41.31	122.5	257.2	55.6	6
Agriculture	4,578.5	4,564.1	4,391.1	4,368.9	4,480.4	4,680.1	4,835	5,131.5	5,242.1	5,359.96	5,481.7	5,723.9	5,827.6	5,891.9	6,001.5	6,086.7	6,600.5	19.7	4
Land-use change and forestry	-26,0501	-28,704	-23,504	-18,056	-15,055.9	-15,481.9	-14,205.9	-7,291.1	-5,240.1	-2,994.9	-1,046.6	1,825.1	5,684.6	7,274.2	9,577.1	6,945.7	5,614	95.9	12
Waste	637.98	677.52	687.8	716.27	788.1	853.6	877.2	1,271.46	1,334.9	1,364.77	1,567.25	1,621.85	1,777.7	1,935.3	2,103.9	2,196.4	2,271.8	15.6	25

Annex 3: Long Summary of Total National Emissions (Gg CO_2 equivalent)

Years		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total national emissions and removals with LUCF		**-16,758.38**	**-19,852.93**	**-14,193.60**	**-8,416.49**	**-5,250.95**	**-5,129.40**	**-3,386.89**	**4,436.20**	**6,653.23**	**9,771.66**	**12,213.20**	**16,267.04**	**20,812.63**	**23,085.84**	**25,077.64**	**23,358.31**	**23,984.37**
Total national emissions and removals without LUCF		**9,292.59**	**8,851.04**	**9,310.37**	**9,639.48**	**9,805.02**	**10,352.57**	**10,819.08**	**11,726.58**	**11,893.35**	**12,766.59**	**13,259.79**	**14,441.98**	**15,127.97**	**15,811.69**	**15,500.56**	**16,412.59**	**18,370.36**
Energy		**3,265.58**	**2,794.20**	**3,335.69**	**3,647.49**	**3,829.87**	**4,185.54**	**4,486.99**	**4,597.95**	**5,043.63**	**5,704.56**	**5,862.31**	**6,736.09**	**7,254.04**	**7,926.83**	**7,353.89**	**7,931.38**	**9,239.81**
	Energy Industries	135.25	5.41	0.95	17.79	22.34	15.25	15.25	15.30	18.17	20.59	502.80	893.81	1,927.24	1,689.45	538.98	1,042.71	2,403.82
	Manufacturing industries and construction	458.81	557.68	665.59	685.77	746.96	810.86	870.60	886.76	1,008.38	1,126.71	1,069.71	1,085.75	1,115.51	1,092.30	1,227.58	1,246.18	915.39
	Transport	1,547.84	1,157.42	1,499.46	1,652.41	1,714.06	1,864.20	2,031.34	2,089.71	2,430.49	2,765.54	2,547.20	2,556.01	1,818.98	2,616.95	3,005.25	3,029.97	3,120.41
	Other Sectors (Residential)	1,123.69	1,073.70	1,169.69	1,291.52	1,346.51	1,495.23	1,569.80	1,606.18	1,586.59	1,791.72	1,742.60	2,200.52	2,392.31	2,528.13	2,582.08	2,612.52	2,800.19
Industrial processes		**810.57**	**815.19**	**895.74**	**906.84**	**706.63**	**633.41**	**619.92**	**725.70**	**272.71**	**337.30**	**348.57**	**360.07**	**268.53**	**57.69**	**41.31**	**122.69**	**258.29**
	Mineral products	14.13	16.85	21.45	23.83	26.49	32.17	32.20	33.47	32.13	35.04	34.74	29.04	30.21	32.94	41.31	92.60	129.75
	Chemical industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Metal production	796.44	798.34	874.29	883.01	680.14	601.24	587.72	692.23	240.58	302.26	313.83	331.03	238.32	24.75	0.00	30.09	128.54
	Other production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Production of halocarbons and sulphur hexafluoride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Consumption of halocarbons and sulphur hexafluoride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture		**4,578.45**	**4,564.12**	**4,391.12**	**4,368.88**	**4,480.38**	**4,680.06**	**4,835.00**	**5,131.47**	**5,242.13**	**5,359.96**	**5,481.66**	**5,723.98**	**5,827.66**	**5,891.89**	**6,001.47**	**6,086.74**	**6,600.52**
	Enteric fermentation	1,360.72	1,272.55	1,240.05	1,244.25	1,293.39	1,211.19	1,337.61	1,399.11	1,399.11	1,463.49	1,496.85	1,521.04	1,515.04	1,603.98	1,631.99	1,659.71	1,724.18
	Manure management	203.69	155.65	146.99	146.99	144.84	151.37	135.52	145.74	145.74	149.41	148.32	149.23	137.43	154.33	153.78	158.21	159.35
	Rice cultivation	411.60	797.16	669.48	648.48	672.00	839.16	884.10	988.68	988.68	982.80	982.80	982.80	1,142.40	982.80	1,002.88	1,002.88	1,050.00
	Agricultural soils	2,592.00	2,320.00	2,307.20	2,307.20	2,348.80	2,451.20	2,451.20	2,576.00	2,684.80	2,742.40	2,832.00	3,049.60	3,004.80	3,123.20	3,187.20	3,238.40	3,642.53
	Prescribed burning of savannahs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Field burning of agricultural residues	10.45	18.77	27.40	21.96	21.35	27.14	26.56	21.94	23.79	21.86	21.69	21.30	27.99	27.58	25.62	27.54	24.47
	Other (please specify)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Land-use change and forestry		**-26,050.97**	**-28,703.97**	**-23,503.97**	**-18,055.97**	**-15,055.97**	**-15,481.97**	**-14,205.97**	**-7,290.39**	**-5,240.12**	**-2,994.92**	**-1,046.59**	**1,825.06**	**5,684.65**	**7,274.15**	**9,577.08**	**6,945.72**	**5,614.00**
	Changes in forest and other woody biomass stocks	-33,719.00	-36,372.00	-31,172.00	-25,724.00	-22,724.00	-23,150.00	-21,874.00	-39,013.87	-39,672.05	-40,195.82	-64,290.38	-63,578.62	-63,956.64	-64,903.54	-65,927.16	-67,137.32	-66,656.21
	Forest and grassland conversion	9,344.53	9,344.53	9,344.53	9,344.53	9,344.53	9,344.53	9,344.53	34,243.48	36,854.39	39,509.82	66,073.91	67,616.48	71,204.72	72,145.78	76,561.94	74,847.79	73,034.96
	Abandonment of managed lands	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-3,292.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00	-4,136.00
	CO_2 emissions and removals from soil	1,615.50	1,615.50	1,615.50	1,615.50	1,615.50	1,615.50	1,615.50	1,616.00	1,713.54	1,827.08	1,305.88	1,923.20	2,572.57	4,167.90	3,078.30	3,371.25	3,371.25
Waste		**637.98**	**677.52**	**687.82**	**716.27**	**788.14**	**853.57**	**877.17**	**1,271.46**	**1,334.88**	**1,364.77**	**1,567.25**	**1,621.85**	**1,777.74**	**1,935.28**	**2,103.90**	**2,196.39**	**2,271.75**
	Solid waste disposal on land	393.12	425.25	436.80	450.45	515.34	574.98	591.57	713.61	769.72	784.76	985.87	1,033.78	1,173.94	1,325.49	1,487.70	1,558.49	1,633.80
	Waste-water handling	244.86	252.27	251.02	265.82	272.80	278.59	285.60	557.84	565.17	580.01	581.38	588.07	603.80	609.79	616.20	637.98	637.95

Annex 4: Short Summary of Net CO_2 Emissions (Gg CO_2 equivalent)

Greenhouse gas source and sink categories		Net CO_2 Emissions (Gg)																
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total national emissions and removals (With LUCF)		-23,595.7	-26,733.8	-21,012.8	-15,338.6	-12,219.7	-12,331.7	-10,768.3	-5,469.	-3,772.7	-1,175.9	1,409.0	4,683.6	8,804.3	10,839.2	12,364.6	10,293.8	10,459.4
Total national emissions and removals (Without LUCF)		2,861.7	2,377.1	2,897.7	3,123.8	3,243.	3,556.7	3,844.1	3,977.8	4,364.2	4,925.4	5,146.2	5,585	5,965.4	6,410.8	5,789.4	6,431.1	7,847.4
Energy		2,570.6	2,081.3	2,595.5	2,810.2	2,981.6	3,294.3	3,595.2	4,237.1	4,239.9	4,738.9	4,872.5	5,276.8	5,733.9	6,356.1	5,748.1	6,313.2	7,603.7
% Difference Between Reference and Secoral Approach		3.07	2.51	0.23	2.77	1.45	5.04	0.53	0.77	6.98	3.1	0.63	8.62	10.63	1.42	11.18	8.8	3.94
Energy	Reference Approach	2,877.31	2,332.45	2,618.17	2,533.75	2,837.07	3,797.91	3,542.33	3,774.53	4,937.76	4,431.51	4,935.13	6,139.03	6,796.97	6,214.12	6,866.00	7,195.60	7,997.58
	Fuel combustion (sectoral approach)	2,570.62	2,081.33	2,595.56	2,810.61	2,981.60	3,294.33	3,595.15	3,697.34	4,239.91	4,736.55	4,872.25	5,276.88	5,733.99	6,356.12	5,748.06	6,313.27	7,603.75
Industrial processes		291.17	295.79	302.14	313.24	261.43	262.41	248.92	280.50	124.31	188.90	274.37	308.13	231.43	54.73	41.31	117.87	243.45
Agriculture																		
Land-use change and forestry		-26,457.50	-29,110.50	-23,910.50	-18,462.50	-15,462.50	-15,888.50	-14,612.50	-9,986.56	-8,136.95	-6,103.79	-3,737.42	-901.34	2,838.89	4,428.38	6,575.28	3,862.68	2,612.24
Waste																		
Memo items																		
International bunkers		125.53	108.94	132.06	115.36	146.66	186.37	201.45	193.54	281.99	1131.77	335.01	248.4	294.17	291.16	349.09	387.91	372.76

Annex 5: Short Summary of CH_4 Emissions (Gg)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Total national emissions and removals (With LUCF)	160.66	177.05	171.20	175.34	182.48	191.39	200.51	272.65	244.55	291.73	294.54	318.73	337.76	344.88	360.38	371.38	375.47
Total national emissions and removals (Without LUCF)	143.13	159.52	153.67	157.81	164.95	173.86	182.98	209.97	177.16	219.43	231.93	255.34	271.58	278.70	290.58	299.69	305.68
Energy	29.12	30.06	31.13	35.28	35.67	37.41	37.44	37.87	0.50	40.61	41.66	61.41	63.85	66.11	67.63	67.91	68.46
Industrial processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	88.65	102.44	95.12	94.06	97.54	101.72	109.86	117.88	119.58	120.84	122.52	123.69	130.61	128.03	130.45	131.83	137.27
Land-use change and forestry	17.53	17.53	17.53	17.53	17.53	17.53	17.53	62.68	67.39	72.31	62.61	63.39	66.18	66.18	69.80	71.69	69.80
Waste	25.4	27.02	27.42	28.47	31.74	34.74	35.68	54.22	57.07	57.97	67.75	70.23	77.12	84.56	92.51	96.36	99.95

Annex 6: Short Summary of N_2O Emissions (Gg)

Greenhouse gas source and sink categories	Years																
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total national emissions and removals (With LUCF)	9.2	8.3	8.2	8.3	8.4	8.8	8.7	13.4	13.7	14.6	14.2	15.1	15.2	15.6	16.1	16.4	17.6
Total national emissions and removals (Without LUCF)	9.1	8.1	8.1	8.2	8.3	8.7	8.6	9.0	9.1	9.6	9.9	10.8	10.7	11.1	11.3	11.5	12.8
Energy	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.6
Industrial processes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	8.5	7.5	7.4	7.5	7.6	7.4	7.9	8.3	8.6	8.8	9.1	9.8	9.6	10.0	10.2	10.4	11.6
Land-use change and forestry	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4.3	4.6	5.0	4.3	4.4	4.6	4.6	4.8	4.9	4.8
Waste	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Annex 6: Total Greenhouse Gas Emissions Distribution with LUCF between 1990 and 2006

Gigagrammes																		Change (1990-2000)	Change (1990-2006)
GHGs	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	(%)	(%)
CO_2	-23,601.76	-26,740.76	-21,020.9	-15,345.4	-12,198.5	-12,311.5	-10,747.68	-5,625.2	-3,772.74	-1,175.94	2,560.25	4,683.66	8,805.84	10,845.28	12,368.34	10,302.17	10,459.43	110.85	144.32
CH_4	160.66	177.05	171.2	175.3	182.48	191.4	200.51	272.66	281.79	291.73	294.54	318.73	337.76	344.88	360.29	367.79	375.47	83.34	133.71
N_20	9.20	8.26	8.10	8.27	8.41	8.19	8.75	13.35	13.73	14.61	14.20	15.12	15.24	15.63	16.08	16.44	17.58	54.35	91.03
CF4	0.07	0.07	0.08	0.08	0.06	0.05	0.05	0.06	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	-85.71	-97.14
C2F6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-85.71	-97.14
Total CO2	-23,431.83	-26,555.38	-20,841.49	-15,161.71	-12,007.5	-12,111.9	-10,538.37	-5,339.1	-3,477.19	-869.58	2,869.00	5,017.51	9,158.85	11,205.78	12,744.71	10,689.99	10,852.49	-112.24	-146.32
CO2 eq. Gigagrammes																			
CO_2	-23,601.76	-26,740.76	-21,020.9	-15,345.4	-12,198.5	-12,311.5	-10,747.68	-5,625.2	-3,772.74	-1,175.94	2,560.25	4,683.66	8,805.84	10,845.28	12,368.34	10,302.17	10,459.43	110.85	144.32
CH_4	3,373.77	3,717.98	3,595.2	3,682.2	3,832.1	4,01.2	4,210.65	5,725.8	5,917.62	6,126.41	6,185.41	6,693.25	7,092.93	7,242.39	7,566.15	7,723.59	7,884.97	83.34	133.71
N_20	2,944.16	2,643.07	2,592.0	2,646.4	2,691.2	2,620.2	2,799.89	4,273.2	4,393.86	4,675.20	4,544.40	4,838.19	4,878.29	5,001.26	5,146.85	5,260.75	5,624.19	54.35	91.03
CF4	399.00	399.00	456.0	456.0	342.0	285.00	285.00	342.00	114.00	114.00	57.00	39.90	28.50	2.28	0.00	3.42	11.40	-85.71	-97.14
C2F6	83.30	83.30	95.20	95.2	71.4	59.5	59.50	71.40	23.80	23.80	11.90	8.33	5.95	0.48	0.00	1.19	2.38	-85.71	-97.14
Total C02	-16,801.53	-20,379.71	-14,833.7	-9,016.9	-5,675.1	-5,672.2	-3,737.14	4,373.8	6,538.74	9,625.66	13,290.05	16,215.10	20,777.06	23,088.9	25,081.33	23,361.84	23,968.60	179.10	242.66

Total Greenhouse Gas Emissions Distribution without LUCF between 1990 and 2006

Gigagrammes																		Change (1990-2000)	Change (1990-2006)
GHGs	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	(%)	(%)
C02	2,855.74	2,369.74	2,889.62	3,117.1	3,264.1	3,576.96	3,864.82	3,821.6	4,364.22	4,925.45	6,297.67	5,585.00	5,966.95	6,416.89	5,793.06	6,439.49	7,847.20	120.53	174.79
CH4	143.13	159.52	153.67	157.8	164.9	173.86	182.98	209.9	214.40	219.43	231.93	255.34	271.58	278.70	290.49	296.1	305.68	62.05	113.57
N20	9.08	8.14	7.98	8.15	8.29	8.07	8.63	9.04	9.10	9.64	9.90	10.76	10.69	11.08	11.28	11.51	12.78	9.04	40.69
CF4	0.07	0.07	0.08	0.08	0.06	0.05	0.05	0.06	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	-85.71	-97.14
C2F6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-85.71	-97.14
Total CO2 eq.	3,008.02	2,537.47	3,051.4	3,283.1	3,437.5	3,758.95	4,056.48	4,040.7	4,587.74	5,154.54	6,539.51	5,851.11	6,249.23	6,706.67	6,094.83	6,750.69	8,165.65	117.40	171.46
CO2 eq. Gigagramme																			
C02	2,855.74	2,369.74	2,889.62	3,117.09	3,264.05	3,576.96	3,864.82	3,821.6	4,364.22	4,925.45	6,297.67	5,585.00	5,966.95	6,416.89	5,793.06	6,439.49	7,847.20	120.53	174.79

CH4	3,005.64	3,349.85	3,227.07	3,314.03	3,463.99	3,651.06	3,842.52	4,409.5	4,502.38	4,607.94	4,870.58	5,362.05	5,703.16	5,852.62	6,100.34	6,218.1	6,419.21	62.05	81.98
N20	2,905.76	2,604.67	2,553.60	2,608.00	2,652.80	2,581.77	2,761.49	2,894.0	2,912.26	3,084.80	3,168.40	3,442.99	3,422.29	3,545.26	3,610.85	3,683.15	4,088.19	9.04	43.71
CF4	399.00	399.00	456.00	456.00	342.00	285.00	285.00	342.00	114.00	114.00	57.00	39.90	28.50	2.28	0.00	3.42	11.40	-85.71	-90.00
C2F6	83.30	83.30	95.20	95.20	71.40	59.50	59.50	71.40	23.80	23.80	11.90	8.33	5.95	0.48	0.00	1.19	2.38	-85.71	-90.00
Total CO2 eg.	9,249.44	8,806.56	9,221.49	9,590.32	9,794.24	10,154.29	10,813.33	11,538.6	11,916.66	12,755.99	14,405.54	14,438.27	15,126.85	15,817.53	15,504.25	16,420.73	18,368.38	55.75	63.95

Proposed Projects for Improvements

Project Title:

Building Efficient Data Management System for Improved National Greenhouse Gas Inventory for Ghana

Project Rationale

Robust data management system is an important pillar for developing an efficient GHG Inventory. Data management system must function in nexus from generation, collection, archiving, storage and backed by a clearly defined legal regime, which ensures data protection, data confidentiality and above all data integrity. The current data management in the national system is generally ad-hoc, unsustainable and does not support readily retrieval at the right scale. This affects the ability of the national system to deliver good quality inventory in terms of timeliness, accuracy and transparency.

Building effective data management system will ultimately inure efficiency in the national system and bring quality in the delivery of the GHG inventory and the NIR. This project will strongly contribute to enabling Ghana meeting paragraph 60(c) of the Cancun Agreement, which indicates that *"Developing countries, consistent with their capabilities and the level of support provided for reporting, should also submit biennial update reports, containing updates of national greenhouse gas inventories including a national inventory report and information on mitigation actions, needs and support received.*

Project Objective

The main objective of the project is to build and manage efficient GHG data management system that is able to provide timely, accurate and reliable data in a transparent manner. This is will be achieved by providing support (technical and capacity) for public and private data owners.

Project Activities

The following are summaries of the proposed project activities:

- Conduct an inventory of data generation and archiving capabilities of key data providers. This will assist in focusing technical and capacity interventions and activating existing channels for data flow on sustainable basis.
- Provide hand-on and skilled training programmes for dedicated persons at the respective institutions.
- Provide and install seamless and central GHG electronic portal at a designated national statistical office that is able to receive, store and archive all GHG and related data from public and private.
- Initiate and develop a framework for GHG data management that ensures data integrity, data protection and above all incentives to generate and exchange data on sustainable basis.
- Develop relevant higher-tier methodology and emission factors of major key categories by levels and incorporate them appropriately in the subsequent inventories.
- Conduct tier-1 uncertainty assessment using IPCC methodology for the entire inventory, all the sectors and in particular key categories.
- Develop a comprehensive QA/QC plan for the GHGI

Stakeholders
The major stakeholders of the project are: Ghana Statistical Services, Kwame Nkrumah University of Science and Technology, Energy Commission, Forestry Commission, Council Scientific Industrial and Industrial Research, University of Ghana etc.

Project Duration
The project will last for 4 years and will be implemented in phases

Project Estimated Cost: 1.15Million Dollars

Project Title:

Development of Emission Factors for Estimating Methane Emission from Enteric Fermentation in Domestic Livestock

Rationale:
Greenhouse gas emission from domestic livestock sector comes mainly as methane. Methane emission from the Agriculture sector alone was 42% of the total national GHG emission in the form of methane in 2000.An important component estimating methane emission from the livestock is the Emission Factor. Lack of country-specific emission factors in Ghana has contributed to high uncertainty in values of GHG levels in the absence of appropriate emission factors there has been a need for reliance on IPCC default values during the preparation of the Initial National Communication as well as the Second National Communication and this has not helped in producing reliable GHGI.

It will be appropriate to have specific and reliable emission factors locally so as to be able to develop reliable GHGI for the country. For the purpose of Good Practice, availability of country-specific emission factors will also assist in improving the methodology of estimation, and the quality of the inventory results, by using a Tier2 approach instead of Tier 1 approach.

Objectives:
To develop appropriate country-specific Emission Factors for different types of animals in the Livestock sub-category.

Project Description
The project will involve identification of data gaps for relevant data needed for estimating Emission data for enteric fermentation for ruminants (cattle, sheep and goats). Trials will then be carried out to determine parameters, such as growth rate, milk yield performance, feed intake, feed digestibility, draught power(with special reference to cattle where the necessary data may be lacking).This will be done in collaboration with CSIR-ARI and Faculties of Agriculture of the Universities.

Expected outputs
The project will assist to get the necessary data in estimating emission factors for enteric fermentation. Improved quality in Greenhouse gas inventory with the use of country-specific data on emission factors.

Planned activities
- Gather available data from existing research publications
- Identify data gaps
- Carry out the necessary trials to determine various data (not yet available locally)
- Analyze data and estimate Emission factors.

Indicative Cost: US$ 350,000

Duration: 3years