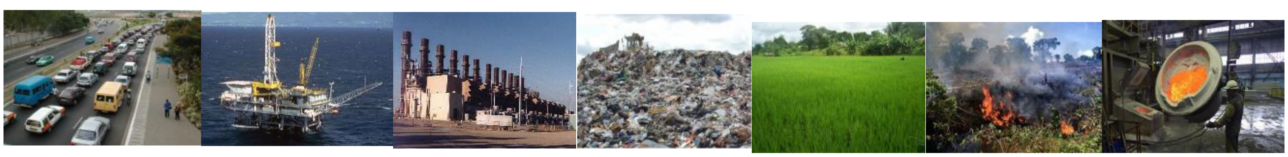
Republic of Ghana

National Greenhouse Gas Inventory Report



2014 National Carbon Accounting

Ghana Government submission to the United Nations Framework Convention on Climate Change, 2015

National Greenhouse Gas Inventory Report

July, 2015

Foreword

This is the third time Ghana has voluntarily prepared a standalone National Inventory Report (NIR) which accompany the submission of its Third National Communication and the first Biennial Update Report. The NIRs were produced during the preparation of the first and second national communication to the UNFCCC. A high quality robust national inventory estimates is the cornerstone for any functional monitoring, reporting and verification (MRV) system. It is not only about providing evidence to support climate mitigation planning, it is certainly about the building the foundation for tracking: impacts of mitigation actions; whether or not policies targets are being met; which policies or measures need further retooling.

Ghana's GHG inventory system will also play an important role in providing critical historical emission data for the formulation of Ghana's mitigation contributions and monitor the action to be undertaken to attain emission reduction objectives we will state in our intended national determined contributions (INDCs). Ghana's national system continues to improve. During this round of preparation, we introduced a number of reforms with the aim to strengthen the national system through further mainstreaming and continuous training. In this regard, we introduced a couple of innovative measures. We have established an online GHG database which is meant to host all the GHG inventory data and also make them accessible to the general public. Ghana also decentralized the inventory planning, preparation and sector reporting to key Ministries. Even as we submit this report, we have started preparing a national GHG inventory manual and QA/QC plan which is expected to guide future inventory work.

This inventory covers 20 years complete time series from 1990 and 2012 for the 4 main IPPC sectors; Energy, Industrial Process and Product Use (IPPU), Agriculture, Forestry and Other Land Uses (AFOLU) and Waste. The national accounting was done using the latest 2006 IPCC guidelines. The gases we have covered included: carbon dioxide, methane, nitrous oxide and perfluorocarbon. For the 20 year time series, recalculations were made for the period 1990-2006 and new estimates for 2007 to 2012. 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 found 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.

Daniel S. Amlalo
Executive Director
Environmental Protection Agency

Preface

The NIR was compiled by the Ministry of Environment, Science, Technology and Innovation (MESTI) and the Environmental Protection Agency (EPA) as part of the preparation of Ghana's TNC and first BUR to the United Nations Framework Convention on Climate Change (UNFCCC).

The NIR has been prepared in accordance with the 2006 IPCC guidelines and the reporting guidelines of national communication for Parties not included in Annex 1 of the convention.

The final electronic version of this report will be made available to the general on the website of MESTI (www.mest.gov.gh) and EPA (www.epa.gov.gh).

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Acknowledgments

Special thanks go to UNEP/GEF for funding the whole greenhouse gas inventory exercise. The 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 support to the inventory process.

The institutions include: Volta River Authority, Ministry of Food and Agriculture, 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 recognizes the efforts by Dr. George Manful for his support to this 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 international partners who reviewed the inventory and also for the invaluable comments and suggestions, which added great value to the entire process.

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Executive Summary

ES 1. Background information on greenhouse gas inventories

This document is Ghana's 2014 National Inventory Report (NIR), submitted to the United Nations Framework Convention on Climate Change (UNFCCC) as part of its reporting obligations. The NIR contains national greenhouse gas emission inventory (hereinafter inventory) estimates for the period 1990-2012, compiled under the UNFCCC rules for reporting. This report and the associated tables are submitted to the UNFCCC to fulfil Ghana obligations, in part, under the enhanced national communication reporting (Article 12, paragraph 1(a), of the Convention, decisions 1/CP.16 para 60 (a-b) and comply with reporting requirements in the preparation of its first biennial update report (BUR) consistent with 1/CP.16 para 60(c). This is the third time Ghana has prepared NIR, but the first NIR to be submitted to the UNFCCC under "BUR" reporting mechanism.

The NIR has been prepared in accordance with the UNFCCC guidelines for the preparation of national communications from non-Annex I Parties (decision 17/CP.8) and UNFCCC biennial update reporting guidelines for Parties not included in Annex I to Convention(decision 2/CP. 17, paragraph 40 and annex III of decision 2/CP.17). The compilation of the NIR was done using IPCC 2006 guidelines. Where necessary, references were made to the previous IPCC guidelines/guidance documents of 1996, 2000 and 2003. The methodologies used to estimate Ghana's greenhouse gas inventories have been improved over time and will continue to be refined as new data and information emerge, and international practice advances. The impacts of the changes as a result of refinements to methodologies adopted and revisions of datasets have been reported under a section dedicated to recalculation for each sector. The NIR and the preparation process is not only meant to serve the purpose of meeting international report obligations, but offers significant benefits to national development policy and capacity development, particularly, in the following respects:

- continuous capacity development among major stakeholders;
- inform policy on critical information for evaluating GHG mitigation options towards a national medium-to-long-term low carbon development pathways;
- provide basis for setting up national emission reduction targets and feedback on how GHG emission reduction goals are being met and;
- how much volumes of emissions reduction has been successfully attained, in which sector, and by which sets of policy(ies) etc.

The inventory has been conducted for key productive sectors that support Ghana's economic development. The level of emissions/removals of the various economic sectors largely depend on (a) sector mitigation policy drive (b) levels of deployment of environmentally sound technology and (c) how much sustainability underpin productivity. The emissions/removals from the economic activities have been grouped under four sectors that have been defined by the 2006 IPCC guidelines, a; (1) Energy, (2) Industrial process and product use (IPPU), (3) Agriculture, Forestry and Other Land Use and (AFOLU) and (4) Waste. These sectors represent the main economic activities that contribute to the release or capture of greenhouse gases into, or from, the atmosphere. The national emissions were derived through the characterization of emissions/removal sources into the following families of emission classes in hierarchical order: (a) activities (b) sub-categories, (c) categories, and (d) sectors. These classification was aggregated to the economy wide level.

Ghana's Environmental Protection Agency (EPA) is responsible for reporting national greenhouse gas emissions. The EPA collaborates with other stakeholders to undertake of the following; activity data management; compilation of sectoral emissions estimates' quality control and assurance; preparation of the sector reports and submission of the NIR to UNFCCC on behalf of Ghana through the Ministry of Environment Science, Technology and Innovation (MESTI).

This report is available on the EPA website at www.epa.gov.gh/tnc.

ES 2. Summary of the National Emission and Removal Related Trends

ES 2.1 Greenhouse gas inventory

In 2012, the Ghana's total greenhouse gas emissions, excluding the Agriculture, Forestry and Other Land Use (AFOLU) sector, was estimated to be 18.49 million tonnes (Mt) CO_2-equivalent (CO_2e). The 2012 emissions was 9.88 MtCO_2e higher than 2000 levels and 12.87MtCO_2e above total emissions recorded in 1990 (see table ES.1). When emissions from AFOLU were included in Ghana's total emissions, the net emissions was 33.66 MtCO_2e in 2012. Similarly, the total emissions grew by 17.34 MtCO_2e over 2000 levels and 19.44 MtCO_2e over emissions recorded 1990.

Table ES 1: Ghana's net greenhouse gas emissions by sectors under the UNFCCC

Sectors & Sub-sectors	Emissions MtCO_2e					Percent Change		
	1990	2000	2010	2011	2012	1990-2012	2000-2012	2010-2012
1. All Energy (combustion & fugitive)	**3.50**	**5.54**	**11.27**	**11.63**	**13.51**	**286.08**	**143.65**	**19.79**
(1.A1,A2&A5) Stationery energy combustion	2.03	2.73	6.48	6.22	7.05	247.28	158.10	0.09
(1.A5)Transport	1.47	2.81	4.80	5.41	6.46	339.66	129.85	34.67
(1.B) Fugitive emission	0.000	0.003	0.001	0.001	0.002	284.71	-51.74	139.35
2. Industrial Process & Product Use	**0.81**	**0.77**	**0.24**	**0.44**	**0.47**	-42.47	-39.56	**94.24**
3. AFOLU	**8.61**	**7.72**	**14.67**	**14.08**	**15.17**	**76.28**	**96.65**	**3.46**
3A Livestock	1.72	2.20	2.82	2.80	3.05	77.29	38.66	8.01
3B Land	-3.02	-4.00	1.85	1.31	1.84	-160.73	-145.86	-0.96
3C. Aggregated and Non-CO_2 emissions	9.91	9.52	9.99	9.98	10.29	3.83	8.08	3.00
4. Waste	**1.31**	**2.29**	**4.24**	**4.45**	**4.52**	**245.97**	**97.03**	**6.54**
Total emissions (excluding AFOLU)	**5.61**	**8.61**	**15.75**	**16.51**	18.49	**229.31**	**114.81**	**17.36**
Total net emissions (including AFOLU)	**14.22**	**16.32**	**30.42**	**30.60**	**33.66**	**136.69**	**106.22**	**10.66**

The observed increases in the emission trends corresponded to the on-going structural economic transformation agenda which has led to sustained growth and expansion of the national economy. The expansion in the economy has resulted in notable rise in emissions from road transport, electricity generation from crude-fired thermal plants, increasing demand for biomass use. In addition, emissions from land use change also recorded increases between 1990 and 2012 mainly due to deforestation. However, with the continuous implementation of government's national reforestation program, emissions from "land" have seen some decreases between 2010 and 2012 (see figure ES.1).

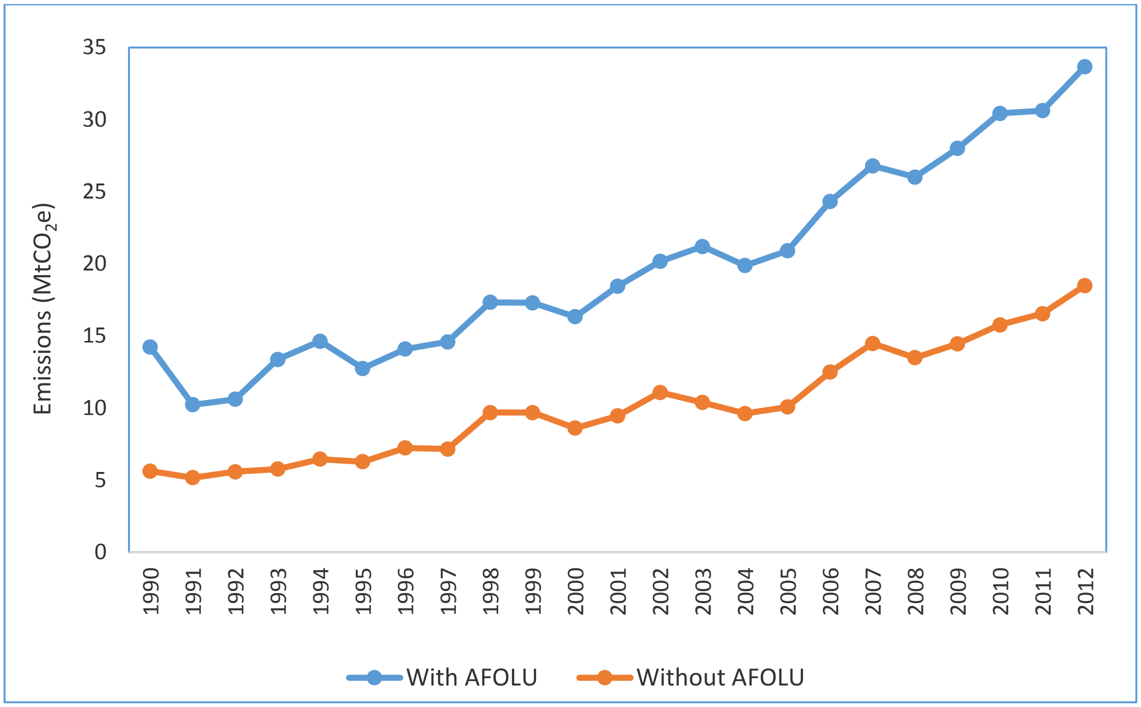

Figure ES 1: Trend of Ghana's total net emissions from 1990-2012 with and without AFOLU

ES 2.1.1 Major changes in the inventory which have resulted in recalculations

In the preparation of the inventory, the list of activities that were identified and prioritized in the improvement plan prepared in the previous inventory was given necessary attention. This led to some changes in methodological choices and revisions in datasets, consequently some recalculations were performed. Some of the changes that resulted from the recalculations of the previous estimates are listed below:

- Changes in activity data due to discovery and inclusion of new datasets, revision or updates of existing activity data and collection of new survey results;
- Filling of time series data gaps with international data sources and trend interpolation or extrapolation;
- Changes in the use of inconsistent conversion fuel factors and appropriate emission factors due to shifting from the revised 1996 IPCC guidelines to use of the 2006 IPCC guidelines;
- Adoption of new methodology for collecting new activity data and emission factors;
- Refinement in the use of expert judgments and
- Inclusion of new additional inventory activities.

ES 2.2 Emission Indictors

The impacts of population and economic growth on greenhouse gas emission trends is provided in table ES.2. The data in the ES.2 suggest that the total net emissions grow along with rising population, GDP and energy consumption. Figures ES2 also presents the trends in the relationship between emissions and GDP.

Table ES 2: Macroeconomic indicators relevant to greenhouses for Ghana

Indicators	1990	2000	2006	2010	2012	Change 1990-2012 (%)	Change 2010-2012 (%)
Population (million)	14.43	18.91	21.88	24.23	25.87	79.3	6.8
GDP (Constant 2006 USD billion)*	5.51	8.39	20.33	16.95#	16.78#	204.5	-1
TPES (Mtoe)**	5.29	7.74	9.06	9.32	11.77	122.49	26.29
Final Consumption (Mtoe)***	4.31	5.41	6.01	6.46	8.16	89.33	26.32
Total Electricity Generated (GWh) ***	5,721	7,223	8,430	10,167	12,024	110	18
*of which is Hydroelectric (GWh)****	*5,721*	*6,609*	*5,619*	*6,996*	*8,071*	41	15
*of which is Oil Products (GWh)****	*0*	*614*	*2,811*	*3,171*	*3,953*	0	25
Total Electricity Consumed*** (GWh)	4,462	6,067	7,362	8,317	9,258	107	11
GDP per capita* (Current USD thousand)	0.4	0.26	0.93	1.33	1.6	300	20.3
TPES per capita (toe)	0.37	0.41	0.41	0.38	0.45	21.62	18.42
Final Consumption per capita (toe)	0.30	0.29	0.27	0.26	0.31	3.33	19.2
GHG emissions per capita (t CO_2 e)	0.39	0.45	0.57	0.64	0.71	82.05	10.9
GHG emissions per GDP unit (kg CO_2e /2005 USD)	1.02	1.03	1.09	1.06	1.00	-1.9	–6.2
Energy Intensity (toe/2005 GDP)	0.96	0.92	0.45	0.55	0.70	-26.9	27.7

* Source: World Bank, National Account (2014), ** Source: International Energy Agency, *** Source: National Energy Statistics. This also takes in account electricity export to neighboring countries and total hours of electricity load shedding
#: Decline in GDP was the result of revision in GDP figures by Ghana Statistical Service

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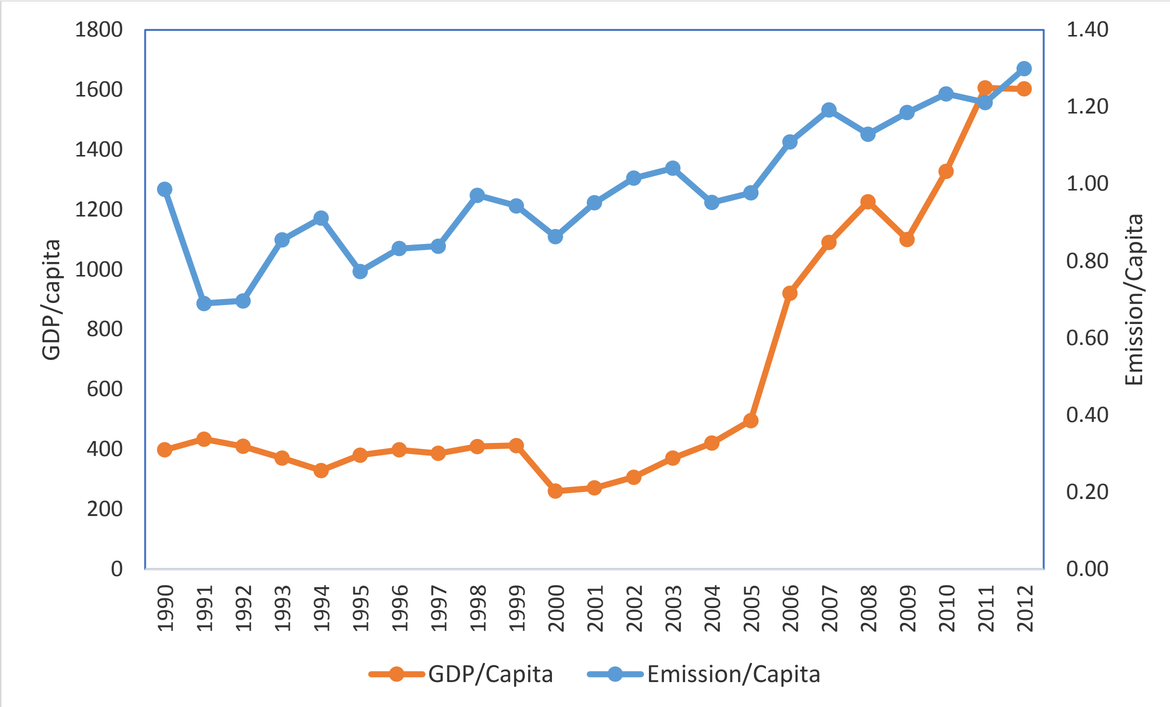


Figure ES 2: Trend of emission per capita versus GDP per capita.

ES.3 Overview of source and sink category emission estimate and trends

ES. 3.1 Greenhouse Gas Inventory

The AFOLU sector was the largest source of emissions followed by the energy sector in 2012 constituting 45.1% (15.17 $MtCO_2e$) of total net emissions. The AFOLU emissions increased by 3.46% between 2010 and 2012 (see table ES.1). The emissions from energy sector made up 40.1% of the total national emissions.

For the AFOLU sector:

- Emissions from aggregated sources and non-CO_2 emissions sources on land was the largest source of the total net emissions making up 30.6% (10.29$MtCO_2e$) and grew by 3% between 2010 and 2012.
- Livestock emissions amounted to 3.05$MtCO_2e$ which represented 9.1% of the total net emissions and increased by 8.01% between 2010 and 2012.
- Emissions from land constituted 5.5% (1.8 Mt) of the total net emissions and decreased by 0.96% between 2010 and 2012.

Similarly in the energy sector

- Stationary energy combustion *(1.A1, 1.A2 and 1.A4)* from different point sources contributed to 38.1% of the total emission excluding AFOLU and increased by 8.76% between 2010 and 2012. When are emission from AFOLU are included, stationery emission made up 20.9% of total emissions.
- Emissions from transport made up 34.9% of total national emissions, excluding AFOLU. Transport emissions recorded increases by 34.67 % between 2010 and 2012. With AFOLU emission, transport emissions accounted for 20.9%.

- Fugitive emissions from fossil fuels (0.01% total net emissions, excluding AFOLU) increased by 58.2% between 2010 and 2012.

Emission from IPPU made up 2.5% of the total emissions excluding AFOLU. The IPPU emission increased by 94.2% between 2010 and 2012. When emissions from AFOLU are added, the contribution of IPPU to the total emission reduced to 1.5%. Emissions from the waste sector is 24.4% of the total net emissions (excluding AFOLU) for 2012 and recorded increases of 6.1% between 2010 and 2012. When emissions from AFOLU are added, contributions of the waste sector accounted for 14.6% of the total net emissions.

Detailed information on the estimates according to individual sector/categories are reported under chapter 3.

ES 4 Overview of source and sink emissions by gases

In 2012, carbon dioxide (CO_2) was the dominant greenhouse gas which contributed 44% (14.81 Mt) of the total net emissions (including AFOLU) (see table ES 3). Of the total net CO_2 emission for 14.81 Mt, energy sector contributed 85% (12.59Mt), followed by AFOLU (12.6% - 1.86 Mt) and IPPU (2.4% - 0.35%). When the emissions from AFOLU are excluded from the national totals, carbon dioxide (CO_2) make up 70.1% (12.95 Mt) of the emissions in the same year. Between 2010 and 2012, the CO_2 emissions including AFOLU increased by 14.9%. Nitrous oxide (N_2O) was the second largest emission source which made up of 30.8% (10.38 MtCO_2e) of the total emissions by Methane (CH_4) (24.8% -) and PFCs (0.3%).

Table ES 3: Contribution of Basket of Gases to the National Emission in 2012

Sectors & Sub-sectors	Mt	Emissions MtCO_2e			Total	Share of total	
	Carbon Dioxide	Methane	Nitrous Oxide	PFC		%	%
1. All Energy (combustion & fugitive)	**12.59**	**0.64**	**0.27**	**0.00**	**13.51**	**73**	**40.1**
Stationery energy combustion	6.29	0.60	0.15	0.0	7.0	38	
Transport	6.30	0.04	0.12	0.0	6.5	35	
Fugitive emission	0.00	0.00	6.4E-06	0.0	0.002	0	
2. Industrial Process & Product Use	**0.35**	**0.00**	**0**	**0.11**	**0.47**	**3**	**1.4**
4. Waste	**0.00**	**4.02**	**0.49**	**0.0**	**4.5**	**24**	**13.4**
3. AFOLU	**1.86**	**3.70**	**9.62**	**0.00**	**15.17**	**100**	**45.1**
Livestock	0.00	2.13	0.9	0.0	3.0	20	
Land	1.84	0.00	0.0	0.0	1.8	12	
Aggregated and non-CO_2 emissions	**0.02**	**1.57**	**8.7**	**0.0**	**10.3**	**68**	
Total net emissions (including AFOLU)	**14.81**	**8.36**	**10.38**	**0.11**	**33.66**		**100**
Total emissions (excluding AFOLU)	12.95	4.66	0.76	0.11	18.49	100	

1.0 Background information to greenhouse gas inventories

1.1 Context of the GHG inventory report

As a Party to the UNFCCC, one of the obligations under the Convention is to develop, publish and regularly update national communication, including its national emission inventories. In addition to the reporting requirements under Article 12, paragraph 1(a), of the Convention, decisions 1/CP.16 paragraphs 60(a-c) introduced an enhanced reporting regime, which Parties not included in Annex I to the Convention are to (a) submit national communication every four years and (b) biennial update report to the Conference of Parties. Based on its current capabilities and supports received, Ghana has prepared this National Inventory Report (NIR) which contains updated accounts of net greenhouse gas (GHG) emissions estimate for the period 1990-2012 from four major economic sectors.

This report and associated tables are submitted to the UNFCCC to fulfil Ghana obligations, in part, under the enhanced national communication reporting (Article 12, paragraph 1(a), of the Convention, decisions 1/CP.16 para 60(a-b) and as part of the preparation of its first biennial update report consistent with decision 1/CP.16 para 60(c). The NIR has been prepared in accordance with the UNFCCC Guidelines for the preparation of national communications from non-Annex I Parties (decision 17/CP.8) and the UNFCCC biennial update reporting guidelines for Parties not included in Annex I to Convention (decision 2/CP.17, and its annex III). The NIR and the preparation process is not only meant to serve the purpose of meeting international report obligations; but offers significant benefits to national development policy and capacity development, particularly, in the following respects (a) continuous capacity development among major stakeholders, (b) inform policy on critical information for evaluating GHG mitigation options towards medium-to-long-term low carbon development pathways, (c) provide basis for setting up national emission ambitions and feedback on how GHG emission reduction goals are being met, (d) how much volumes of emissions reduction has been successfully attained, in which sector, and by which sets of policy(ies), etc.

The GHG emission estimates provided in this report have been compiled in accordance with the Intergovernmental Panel on Climate Change (IPCC) 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) and IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000) as reference. The purpose of using these guidelines was to ensure that the GHG emission estimates were transparent, accurate, complete, consistent and comparable (TACCC) through time and comparable with those inventories produced in other countries of similar national circumstances. The emission estimates in this report forms part of the information package contained in Ghana's first biennial update report and will be a subject of any future international technical assessment as may be required under of the international consultation and analysis (ICA) process consistent with the modalities and guidelines for international consultation and analysis, (decision 2/CP.17 and annex IV).

1.2 Basket of gases

The inventory covers sources of greenhouse gas emissions which results from anthropogenic activities for direct greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and Perfluorocarbons (PFCs) and their removals by sinks. Emissions for each of the direct greenhouse gases has been presented in carbon dioxide equivalents (CO_2e) terms using the 100-year global warming potentials (GWPs)[1] contained in the 1995 IPCC Second Assessment Report (IPCC 1996).

1.3 Key economic sectors covered

The GHG inventory has been conducted for key productive sectors that support Ghana's economic development. The level of emissions/removals of the various economic sectors largely depend on: (a) sector mitigation policy drive, (b) levels of deployment of environmentally sound technology, and (c) how much sustainability underpin productivity in each sector. The emissions/removals from the economic activities in Ghana have been grouped under four sectors that have been defined by the 2006 IPCC guidelines. The sectors are (1) Energy, (2) Industrial processes and product use (IPPU), (3) Agriculture, Forestry and Other Land Use and (AFOLU) and (4) Waste. These sectors represent the main economic activities that contribute to the release or capture of greenhouse gases into, or from, the atmosphere. The national emissions were derived through the characterization of emissions/removal sources into the following families of emission classes in a hierarchical order: (a) activities, (b) sub-categories, (c) categories and (d) sectors.

1.4 Reporting years

The reporting years of this inventory covers the period 1990 to 2012. Year 2012 is the latest reporting calendar year. The year 2000 has been selected as the base year. However, references in the emissions analysis were made to changes that happened from 2010 to 2012, as it reflects the country's current economic circumstances better than 2000. The 1990-2012 time series has been further delimited to: (a) recalculated 1990-2006 estimates, (b) 2007-2010 new estimates, and (c) 2011-2012 latest estimates.

1.5 Outline of the national inventory report

To ensure greater clarity and better understanding of the information contained in the NIR, the structure of the report has been organized, to conform to the relevant sections of the UNFCCC Guidelines for the preparation of national communications from Parties not included in Annex 1 Parties to the Convention (decision 17/CP.8), UNFCCC biennial update reporting guidelines for Parties not included in Annex I to convention (decision 2/CP.17, and its annex III) and the user manual for the guidelines on national communication from non-Annex I Parties[2]. The NIR consists of four (4) chapters. Each chapter aims at presenting sufficient information on specific topics of the GHG inventory.

- Chapter 1 is the introduction to the NIR which highlights the following key topics (a) background information on the GHG inventory, (b) information on the changes in national system, (c) description of the inventory process, (d) description of methodologies and data sources, (e) description of key categories, (f) information on quality control and quality assurance, (g) general

[1] GWPs used were: 1 = CO_2, 21 = CH_4, 310 = N_2O and 6,500 = PFC perfluoromethane.(CF4), C_2F_6 = 9,200. GWPs are not available for the indirect greenhouse gases. However they were reported but are not included in the inventory total.
[2] The user manual was prepared based on decision 17/CP.8 by the UNFCCC secretariat in 2003

assessment of completeness, (h) information on uncertainty assessment, and (i) assessment of recalculations.

- Chapter 2 presents the aggregate national GHG emissions in 2012 and establishes trends in emissions between 1990 and 2012 for each of the sectors and for the main greenhouse gases.
- Chapter 3 is a compilation of information on sector-specific GHG estimates and trends, methodologies and approaches used as well as information on crosscutting issues.
- Chapter 4 provides short discussions of the emission results, planned improvements and conclusions.

1.6 National system for sustainable inventory preparation

Ghana has a national inventory system that is capable of supporting the continuous preparation of robust national GHG inventories on a sustainable basis. For the national system to function efficiently, a number of reforms have been introduced, since 2006, as part of the long-term improvement strategies. The reforms have brought about greater improvements in the operations of the national system. Figure 1 below shows the main elements introduced in the national system.

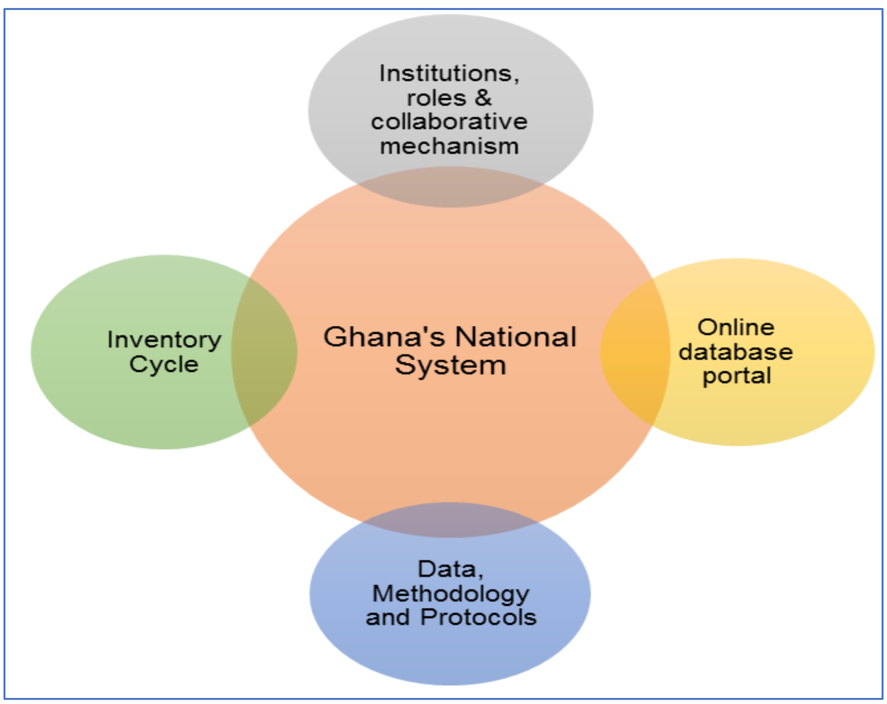


Figure 1: Elements of the national system for GHG inventory

The changes or modifications that have taken place in the national system during the preparation of this national inventory are:

a. *Strengthening national institutional arrangements* – the institutional arrangements that existed during the last inventory preparation have been transformed to include: (a) wider institutional participation, (b) decentralized roles and responsibilities, (c) revised collaborative mechanism, and (d) continuous capacity enhancement.

b. *New inventory cycle* – A two-year inventory cycle was introduced. The cycle covered a set of tasks with timelines and budget that were implemented at each stage of the inventory. The inventory stages included: planning phase, preparation phase, management phase and compilation phase.

c. *Streamlined channels for data collection* – established means for continuous data collection and updating of activity data from diverse national and international sources.

d. *New data management system* – introduced new sets of task on: (a) why we need documentation, (b) what to document, (c) how to document, (d) who to document, (e) where/how to store and retrieve. All documented inventory information are stored in an online database.

1.6.1 Description of institutional arrangements

The revised institutional arrangements involve nearly thirty experts from sixteen different public and private institutions. The roles and, responsibilities of each institution and their reporting lines are arranged to reflect the levels of interlinkages contained in the respective memorandum of understanding (see annex 1 for sample copy of MOU). The Environmental Protection Agency (EPA) is established by Act 490, 1994 and is designated as the national entity for the preparation of Ghana's national GHG inventory. The EPA functions as the "single national entity". As the "single national entity" the EPA collaborates with the inventory stakeholders to undertake management of activity data and emissions factors, compilation of emission estimates from the sectors, quality control/quality assurance, improvement planning, and preparation of the reports. The MESTI is responsible for the official approval and endorsement of NIR and onward submission to UNFCCC. Within the EPA, the UNFCCC Focal Point and Climate Change unit is the national inventory entity and is directly responsible for the management of the entire inventory process. The unit ensures that delivery of the inventory is timely, of good quality and above all meets international standards (see figure 2).

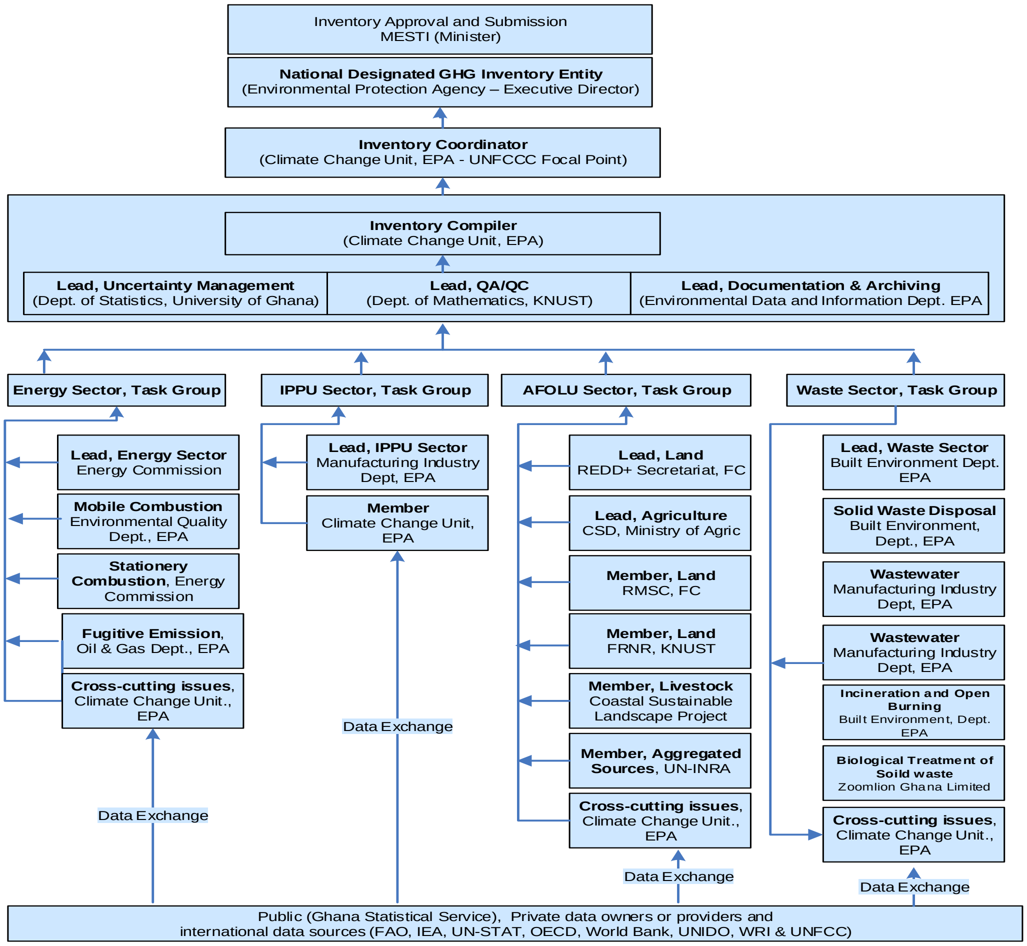


Figure 2: Institutional arrangements for preparation of national GHG inventory

The inventory complier also serve in the capacity as the generalist. The uncertainty management lead, QA/QC lead and the documentation and archiving lead are responsible for cross-cutting issues both at national and sector levels. The four working groups that were responsible for completing inventory for the four inventory sectors. Each working group has a lead. The membership is drawn from public and private organizations. In addition, there are a number of institutions that supply data to the inventory compliers. The inventory entities and their roles are provided in the table 1.

Table 1: Functional GHG Inventory entities and their roles/responsibilities

Inventory task	Lead Institution	Specific tasks
Approval and submission of inventory report	Ministry of Environment, Science, Technology and Innovation	Reviews and approves of national inventory report. Uses of inventory estimates to inform policy. Provides overall policy direction to the national inventory compilers.
Designated National Entity (DNE)	Environmental Protection Agency – Executive Director	Overall technical oversight and coordinates timely deliverables. Develops programs and strategies which will ensure long-term improvements in the inventory system. Dissemination and awareness creation on all the inventory products.
National Inventory Coordinator	UNFCCC Focal Point	UNFCCC Focal Point acts as the inventory coordinator to oversee the entire inventory on behalf of the Agency.

		Plans the preparation of the inventory and provides operational, management and technical oversight. Reports directly to the DNE for onward transmission to its Board of Governors and Ministry of Environment, Science Technology and Innovation. Manages all MoUs, contracts, and information agreements to facilitate efficient delivery of all contracts, data, tasks and agreements.
Inventory Compiler	Climate Change Unit, EPA (Lead, Mitigation Analysis and Reporting)	Reports directly to the UNFCCC focal point and works with the GHG working teams. Creates schedule based on the inventory cycle timelines and all the inventory preparation steps that need to be completed prior to, and after, the due date, taking into account the time needed to complete each of those steps. In the event of the inventory undergoing review (internal or external), the compiler will interface between reviewers and the inventory experts. Responsible for data and document management, which is critical to the long-term improvement of the inventory. Act as the receiver of inventory files from the working groups – all worksheets and text and would be responsible for putting the pieces together into one unified inventory document. Doubles as the generalist for the inventory. This implies that, the complier ensures that all the inventory activities, which border on issues such as decisions and choices to undertake recalculation, key category analysis, completeness and reporting are consistent with IPCC GPGs both at the level of the inventory and also at the sector level. Ensures new developments concerning the inventory are thoroughly discussed and implemented. The compiler works closely with the sector leaders in order to make the sector inventory internally consistent.
Lead, QA/QC	Mathematics Department, KNUST	Responsible for the planning and implementation of QA/QC activities. Together with the inventory complier design and oversee the implementation of QA/QC plan.
Lead, Uncertainty Management	Department of Statistics, University of Ghana, Legon	Design and perform tier-1 uncertainty assessment of the entire inventory and at least for the key categories. The design must be fully consistent with the 2006 IPCC. Generates simple-to-implement worksheet that inventory sectors will use with great utility, in the estimation of sector-level key category uncertainty estimation. On the basis of the 2006 IPCC, produce simple steps for the management of uncertainties in the sectors and at the inventory levels.
Lead Documentation and Archive	Environmental Data and Information Management Dept. EPA	Design and ensure complete references for all data in line with QA/QC protocols. Document all responses to internal and external review comments. Ensure all information and data are collected in a consistent manner for purposes of later reference and archived with other inventory materials. Design data storage and documentation procedures for the inventory. Implement and manage central database infrastructure that will be put in place. Ensure sector group leads complete the documentation-tracking log for onward transmission to the inventory compiler.

Lead, Sectors	Energy Commission Forestry Commission Crop Services Directorate, MoFA MID, EPA Built Environment, Dept. EPA	Conduct comprehensive assessment of GHG data requirements of the sector, identify the sources and access them with the support of the inventory coordinator/compiler using appropriate channels and document all the data and processes involved. Collect, collate, process and update all GHG and related data in the sector, and take final decisions on which processed data qualifies to be used in the inventory on the basis of agreed conditions in the QA/QC plan. Submit all processed data and any other data to the central database hosted at the Environmental Protection Agency and keep back-ups in the organization that act sectors lead. Liaise with the inventory compiler at EPA to undertake comprehensive review of available methodological choices and make sound methodological choices on the basis of its applicability to the estimation of GHG emissions. Estimate GHG emissions for all categories and gases under sectors using appropriate factors/ GWPs and ensure that the processes/assumptions for the estimation, including the software used, are consistent with the IPCC guidelines and fully documented. Conduct key category analysis for the sector and uncertainty assessment in collaboration with the generalist and the uncertainty management lead. Compile all the sector estimates in the worksheets into "detailed" and "synthesis" reports, including clearly prioritized plans for improvements to be incorporated into the national inventory report. Create and maintain hard and soft copies of all information, data, and estimates at the sector level and for onward transmission to the Environmental Protection Agency as the inventory documentation and archiving depository. Consult with the inventory compiler to discuss and agree on cost involved in activities that can be done within the quarter in the inventory year. The rate and mode for requesting funds will be discussed and agreed ahead of every inventory cycle.

1.6.2. Inventory Team

The details of the inventory team members are provided in table 2 below:

Table 2: Ghana's National GHG Inventory Team

Name	Organization	Contact Information	Role	Responsibility	Comments
Mr. Daniel S. Amlalo	Environmental Protection	Executive Director, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0302 – 664697/98 Email: support@epa.gh.gov.com	Designated National Entity	Overall coordination	Update EPA Management, Board of Director and MESTI
K.Y. Oppong-Boadi	Environmental Protection	UNFCCC Focal Point, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 020-8186958 Email: koppongboadi@gmail.com	National Inventory Coordinator	Operational and implementation oversight	Project Leader, Third National Communication
Daniel Tutu Benefor	Environmental Protection Agency	Climate Change Unit, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0246-114652	National Inventory Complier & Generalist	Manages the national inventory planning,	UNFCCC – Lead Reviewer and Energy and AFOLU Expert

		Email: daniel.benefor@epa.gov.gh		implementation and reporting	
Joseph Amankwa Baffoe	Environmental Protection Agency	Climate Change Unit, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 026-2373698 Email: jabaffoe@gmail.com	Inventory Contributor	QA/QC and Industrial process and product use	UNFCCC Reviewer – IP Expert
Kennedy Amankwa	Energy Commission	Energy Efficiency and Climate Change Unit, Energy Commission Tel: 0242-261212 Email:kenamankwah@yahoo.co.uk	Lead, Energy Sector	Manages Energy Sector Inventory	UNFCCC Reviewer – Energy Expert
Kinsley Amoako	Crop Services Directorate, Ministry of Food and Agriculture	Environment, Soil and Water Unit, Crop Services Directorate, Tel: 0207411864 Email: kingkwaw@yahoo.com	Lead, Agriculture sector	Manages Agriculture part of AFOLU sector	UNFCCC Reviewer – Agriculture Expert
William Acquah Hayfron	Environmental Protection Agency	Built Environment Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0244-633684 Email: willieacquah@yahoo.com	Lead, Waste sector	Manages Waste Sector Inventory	
Selina Amoah	Environmental Protection Agency	Manufacturing Industry Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0265-086633 Email: selamoah@yahoo.co.uk	Lead, IPPU sector	Manages IPPU inventory	
Juliana Bempah	Environmental Protection Agency	Manufacturing Industry Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0262-886872 Email: Juliabb21@yahoo.com	Alternate Lead, Waste sector	Co-Manages Waste Sector Inventory	UNFCCC – Lead Reviewer and Waste Expert
Yaw Kwakye	Forestry Commission	REDD+ Secretariat, Forestry Commission Tel: 024-4769874 Email: beemayaw@gmail.com	Lead, Land use sector	Manages the Land part of AFOLU	
Yakubu Mohammed	Forestry Commission	Manager, GIS Unit, RMSC, Forestry Commission Tel: 020-8112123 Email: myakubu89@yahoo.com	Member, AFOLU Team	Contributor, Land category	Land use mapping
Affum Baffoe	Forestry Commission	Manager, Production Unit, RMSC, Forestry Commission Tel: 020-8138662 Email: Kofi1964ba@hotmail.com	Member, AFOLU Team	Contributor, Land category. Responsible for FRA reporting	Biomass Inventory
Winston Asante (PhD)	KNUST	Faculty of Renewable Natural Resource, Tel: 024-3143375 Email: winstonasante@yahoo.com	Member, AFOLU Team	Contributor, Land category	Biomass Inventory
Nicholas Jengre	Coastal Sustainable Landscape, Project	Coastal Sustainable Landscape, Project Tel: 0243-386985 Email: nbreslyn@yahoo.com	Member, AFOLU Team	Contributor, Livestock and aggregated sources	Biomass Inventory and livestock
Kwabena Asubonteng	United Nation University	UNU-INRA, University of Ghana Tel:0244-669048 Email:Kwabena.asubonteng@gmail.com	Member, AFOLU Team	Contributor, Land category	Land use mapping and general section
Kwame Agyei	Forestry Commission	REDD+ Secretariat, Forestry Commission Tel: 0243-623235 Email: kwameagyeikyei@yahoo.com	Member, AFOLU Team	Contributor, Land category	

Larry Kotoe	Environmental Protection Agency	Oil & Gas Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0262-165575 Email: lkotoe@hotmail.com	Member, Energy Sector	Fugitive Emissions	UNFCCC Reviewer – Energy Expert
Ebenezer Fiahagbe	Environmental Protection Agency	Environmental Quality Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0267-997188 Email: eben.fiahagbe@gmail.com	Member, Energy Sector	Mobile Combustion	
Joy Ankoma Hesse	Environmental Protection Agency	Built Environment Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0246-676414 Email: ankojoyhesse@yahoo.com	Member, Waste Sector	Solid Waste Disposal Category	
Daniel Lamptey	Environmental Protection Agency	Built Environment Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0242-214111 Email: danlampteya@gmail.com	Member, Waste Sector	Incineration and open burning Category	
N.K. Frimpong	Kwame Nkrumah University of Science and Technology	Department of Mathematics, KNUST Tel: 0277-722137 Email: nkfrempong.cos@knust.edu.gh	QA/QC Lead		
Richard Minkah	University of Ghana	Department of Statistics, Tel: 0245-032266 Email: rminkah@ug.edu.gh	Uncertainty Management		
Sampson Botchwey	Environmental Protection Agency	Environmental Information and Data Management Department, Environmental Protection Agency, P. O. Box. M326, Accra – Ghana. Tel: 0243182362 Email: omarook@gmail.com	Online database archive	Manages the online GHG database	

1.6.3 Means of data acquisition and management

The lead inventory sector institution is responsible for the identification and sourcing of all datasets at the national and international levels in collaboration with the inventory compiler. As much as possible, the sector's lead institution, identifies all the data needs and the institutions where the data will be sourced. After initial contacts with the data owners/providers, the sector lead institution directly requests the data from the source with administrative help from the EPA. In case where EPA receives request from the sector lead institution, data requests are made to of relevant institutions indicating what form of data is required, covering years, data format and the main use of the data in the inventory through an official letter (see annex 2 for copy of data request letter). The EPA data request letters, especially those to industrial plants, usually make reference to the relevant provisions to the EPA, Act 490, which allows EPA access to certain level of information. The collected data goes through several steps of documentation procedures to ensure proper referencing. Initial technical and quality evaluation of the data is done before transmission to the working teams. All data are documented and stored in the online database for archiving and retrieval.

1.6.4 Information technology set-up behind inventory data management system

During the current inventory period, Ghana set up an online database system which hosts all inventory data and related information (see figure 3). The database helped in streamlining documentation and archiving of all GHG data, reports and publications. The database contains; (a) all inputs datasets from each sector; (b) datasheets for each sector; (c) emission estimates from the IPCC software for all sectors from 1990-2012, (d) IPCC 2006 software database, (f) completed QA/QC templates for sectors, and (g) all reports and documentations. The IT infrastructure of the database (server, backend database resources) is managed by the IT team of EPA. The general public and the GHG inventory team have access to the online database through this IP address 197.253.69.38 or www.epa.gov.gh/tnc. Although the general public can search for the publicly available data from the database, the GHG inventory members have access credential that allow them to (a) upload, (b) query, and (c) retrieve data from the database. Publication of data on the database is restricted to the administrator.

The IPCC software has backend database file which contains data inputs and emission results for the sectors. The software allows for different access levels giving users access to the relevant sections of the database. In this regard, one "super user log-in ID" was created for the inventory complier to allow for access to data for all the sectors. The members of the sectors were given "log-in credential" that only allowed them to access their relevant sections. When all the sector database files were completed, the sector lead institution submitted them to the inventory compilers, who created a "single inventory database file" containing all data for all the sectors for the period (1990-2012). The inventory data, individual results sheets and the database file were sent to the administrator of the online database for archiving and publication on the internet.

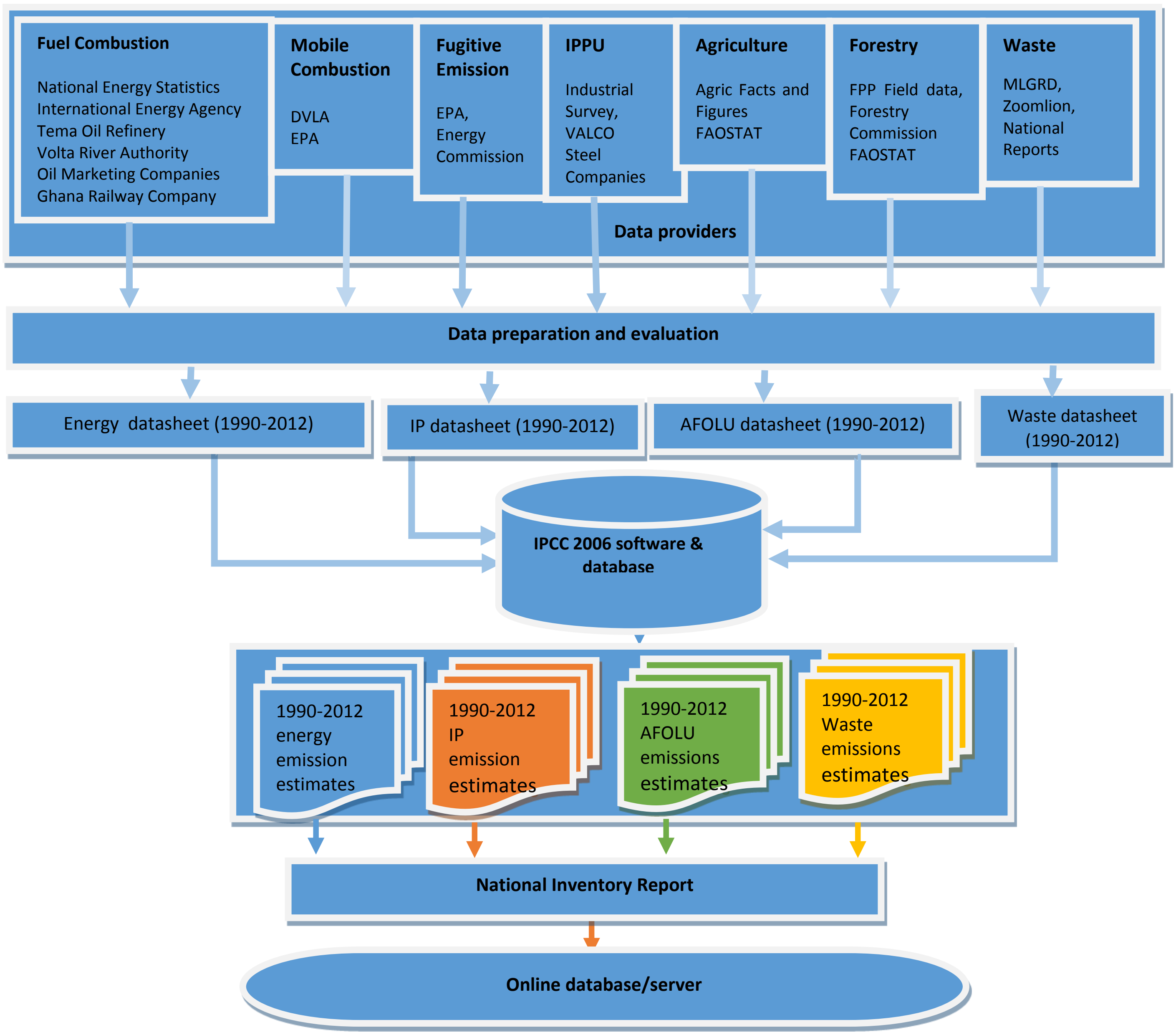


Figure 3: Inventory data structure and relationship among them

1.6.5 Brief description of inventory preparation

The planning of the main tasks for the preparation of the inventory was guided by the reporting requirements in the "UNFCCC Guidelines for the preparation of national communications from non-Annex I Parties (decision 17/CP.8) and UNFCCC biennial update reporting guidelines for Parties not included in Annex I to the convention (decision 2/CP.17, paragraph 39-42 and annex III)". The timing was determined by the UNFCCC submission timelines and availability of data and funds. Steps 000-033 (see table 3) provides an overview of the general inventory cycle. The cycle starts with review of previous emission estimation methods and estimates, identification and formation of the teams, allocation of tasks, and the data collection and evaluation for the compilation of the inventory. The cycle is completed by external independent review.

Table 3: Schedule of inventory tasks

Task ID	Task and Deliverables	Completed by Deadline	Responsible Entity (ies)
000	Review of preview estimates, procedures and improvement tasks	9-Nov	All
001	Establish Inventory protocols. The protocol will contain instructions and procedures for preparing the inventory.	11-Nov	Inventory coordinator and DoM
002	Validate and distribute protocols/instruction manuals to the teams and actors in the inventory.	31-Dec	EPA & all sectors
003	Identify and form inventory-working groups for the inventory sectors and crosscutting issues.	31-Oct	EPA
004	Formulate and sign MOU among inventory institutions. The MOU define specific functions of inventory institutions relating to estimation etc.	15-Nov	Inventory Compiler and FC, EC, MID, EQ, CSD, BED
005	Organize maiden meeting of working group	10-Nov	
006	Training for inventory teams to ensure readiness and distribute overall and sector inventory instructions, provide relevant training to teams.	10-Nov	
007	Organize kick-off meeting.	09-Jan	
008	Identification and review of data sources including choices of data, methodologies and softwares.	15-Feb	Inventory compiler and FC, EC, MID, EQ, CSD, BED
009	Data request, data review evaluation and documentation	15-Apr	
010	Set-up sector data documentation and archiving files (soft and hard) and start using them	28-Feb	All Entities
011	Create inventory web-based domain hosted at EPA website	28-Feb	Inventory Complier
012	Establish data storage server	31-Dec	EDD, GSS
013	Quarter review meeting	31-Mar	Inventory Compiler
014	GHG estimation. Work sheets and text files for each source/removal due each entity	28-May	FC, EC, MID, EQ, CSD, BED
015	All sector work sheets and documentations submitted national inventory compiler	06-Jul	
016	Compile zero order draft of composite inventory and submit to inventory coordinator	31-Jul	Inventory compiler
017	Distribute zero order draft for internal review and submit comment to inventory compiler	09-Aug	Inventory compiler and QA/QC coordinator
018	Distribute source files (worksheets) and internal review to lead institutions	09-Aug	Inventory compiler
019	Incorporate internal comments, observations and corrections	31-Aug	FC, EC, MID, EQ, CSD, BED
020	Harmonize uncertainty assessment	30-Sep	DoS, QA/QC and Inventory compiler
021	Compile second order draft of inventory and revise work sheets	15-Sep	Inventory compiler
022	Compile second order draft of composite inventory, source files and submission to inventory compiler and external reviewers (QA)	30-Sep	
023	External review of second order inventory (QA) submit	15-Nov	External reviewers
024	Comments to Inventory Compiler	29-Nov	
025	Quarter review meeting	28-Jun	Inventory coordinator

026	Incorporate external comments and revise work sheets for all sectors	29-Nov	FC, EC, MID, EQ, CSD, BED & inventory compiler
Repeat Inventory estimates, worksheets and report by 2014 and complete by September, 2014			
027	Draft improvement strategy for each sector due inventory compiler	31-Jan	FC, EC, MID, EQ, CSD, BED
028	Collect all pertinent paper and electronic source materials for archiving place in archive due national archiving and documentation institution	31-Dec	GSS, EDD & inventory compiler
029	Compile final Inventory and preparation of key category analysis	31-Dec	Inventory compiler & FC, EC, MID, EQ, CSD, BED
030	Compile inventory improvement strategy due inventory coordinator	31-Dec	
031	Compilation of National Inventory Report (NIR)	28-Jun	Inventory Coordinator and FC, EC, MID, EQ, CSD, BED
032	NIR due National Inventory Entity for incorporation into National Communication and Biennial Update Report	31-Aug	Inventory Compiler
033	Dissemination of NIR – Submission to UNFCCC, inventory is available for public release.	31-Aug	National Inventory Entity

Key: EC – Energy Commission; DoM – Dept. of Mathematics, KNUST; FC-Forestry Commission; BED – Built Environment Dept., EPA, MID – Manufacturing Industry Dept., EPA, CSD – Crop Service Directorate, MoFA; GSS – Ghana Statistical Service; EDD – Environment Info & Data Management Dept., EPA

1.6.6 Strategies for long-term improvements in the national inventory system

The reforms in the national system that have started will continue in the coming years to ensure that it operates efficiently on sustainable basis. The following specific actions will be undertaken:

a. strengthening data handling and management

- Facilitate continuous update of country-specific activity data through regular exchanges of data from the primary data providers using the online database. In this regard, selected persons from Energy Commission (responsible for publication of annual energy statistics), Ministry of Food and Agriculture (responsible for publication of Agriculture Facts and Figures), Volta River Authority, Forestry Commission etc, will be given limited right access to the online database to upload new datasets.
- Collaborate with Energy Commission, Forestry Commission, Ministry of Food and Agriculture and the Environmental Sanitation Directorate of Ministry of Local Government and Rural Development and DLVA to improve the publication of primary data for the inventory.
- Start discussions on ways to effectively incorporate GHG data collection into "facility level" environmental reporting through "Annual Report" and Environmental Management Plan" and other environmental management tools such as the Environmental Performance Rating and Public Disclosure (EPRPD -"Akoben").

b. continuous training

- Organize regular tailor made training programs for national experts, public data providers, private data owners, potential users of the GHG results and new experts who join the inventory process.
- Nominate additional experts to the UNFCCC roster of experts to allow them undertake training. The training will help to build capacity and awareness and also give opportunity

to experts from Ghana to learn-on-the-job based on the experience from the review of GHG inventories from Annex I Parties.

c. further mainstreaming

i. Identify the challenges associated with the existing institutional arrangement and where possible put in place new measures to ensure greater participation of other relevant bodies.

ii. Discuss and harmonize the relevant national statistics that are reported to international agencies such as FAO, IEA, World Bank etc

1.7 Description of methodologies and data sources

The emissions inventory has been conducted from a series of steps and using a range of data from diverse sources. The emissions were not directly measured but were estimated through the application methodologies that link emissions to data on observable economic activities in the country. The estimation of the emissions and removals used a combination of: (a) country-specific methods and data; (b) IPCC methodologies and (c) emission factors (EFs).The methods were consistent with the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC 2006) and are to the extent possible, in line with international practice. Generally, tier 1 IPCC methodology were applied, however there were selected categories such as transport (1.A3), land (3B), IPPU (2C) and solid waste disposal (4a) for which higher tier (tier 2) methodology were used.

1.7.1 Methods of estimation

On the whole, the methodology for Ghana's GHG inventory has seen some improvements towards a combination of tier 1 and tier 2 estimation methods that capture (a) new country-specific activity data; (b) a shift from the Revised 1996 IPCC guidelines to the 2006 guidelines and (c) uncertainty assessment. Detailed descriptions of methods chosen are provided in the relevant section of the report.

1.7.1.1 Selection of Methods

The estimation of emissions/removals in the categories was based on the methods described in the 2006 IPCC Guidelines. The selection of the methods was guided by the decision-tree illustrated in figure 4. Generally, tier1 IPCC methodology was applied to most of the sectors, except in cases where available national data allows adoption of a higher tier. For example, the availability of facility level data from Volta Aluminum Company (VALCO) enabled the use of tier 2 methodology for the estimation of emission from aluminum production.

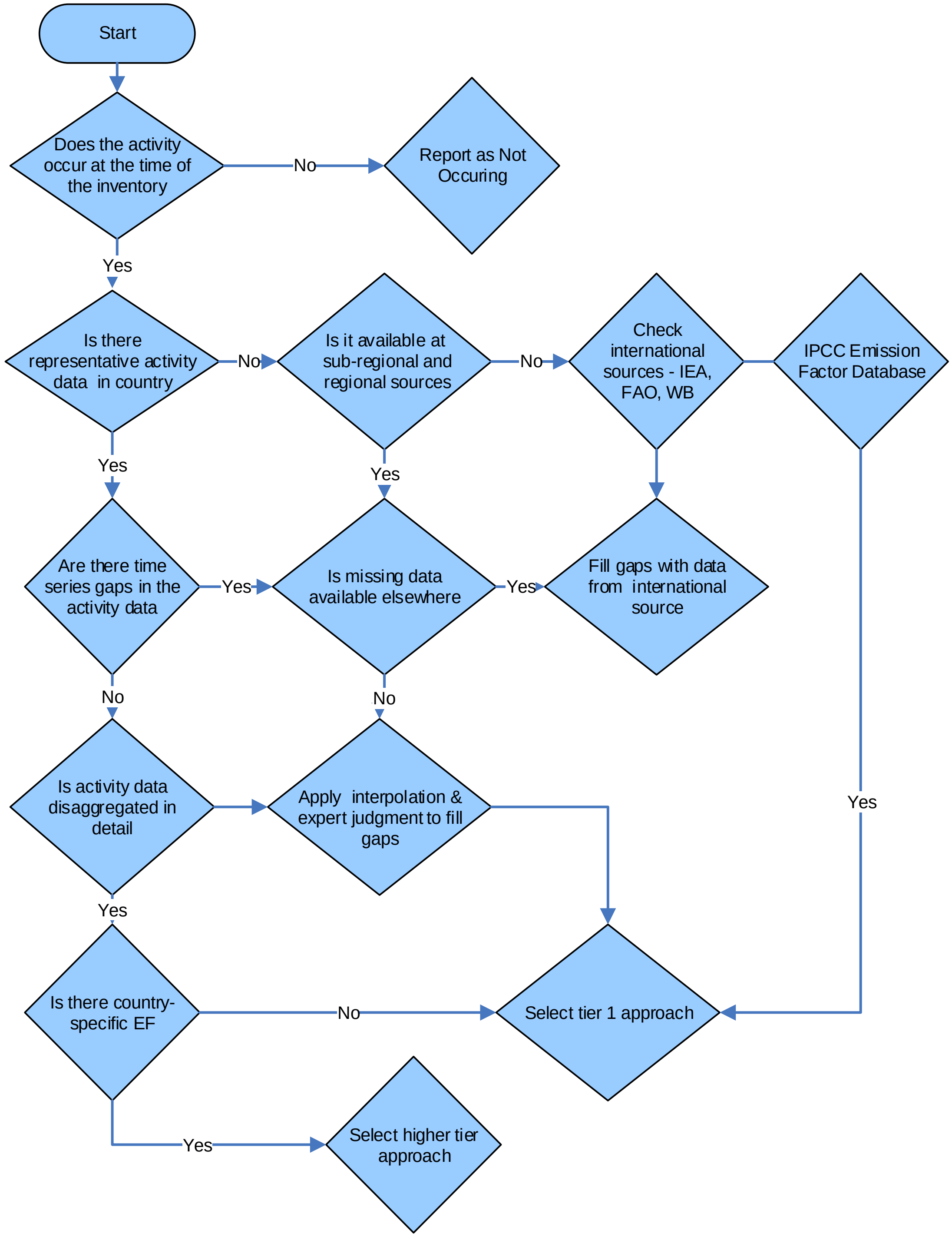


Figure 4: Decision tree for the Selection of Methods

1.7.2 Data sources

1.7.2.1 Selection of Emission Factors

Emission Factors were mainly obtained from: (a) facility-level plants; (b) country-specific or regional and international studies and IPCC Emission Factor Database (EFDB). In the selection of EFs, the following factors were considered: (a) representativeness of EFs generated at facility-level and country-specific studies and (b) applicability of the EFs generated from regional and international sources. In the inventory, default emissions factors from the IPCC EFDB were commonly used, however, in cases where country or region specific emission factors existed, priority was given to it. An overview of the methods and emission factors applied for the calculations of the emissions is presented in table 4.

Table 4: Mapping of methods and emission factors

GHG Source and Sink Categories		CO_2		CH_4		N_2O		PFC-CF_4		PFC-C_2F_6		HFCs	
		Meth	EF	Meth	EF	Meth	EF	Meth	EF	Meth	EF	Meth	EF
1.	Energy	T1, T2	D, CS	D, T1	D, CS	D, T1	D, CS						
1.A	Fuel Combustion	T1,T2	D, CS	T1,T2	D, CS	T1,T2	D, CS						
1.A1	Energy Industries	T1	D	T1	D	T1	D						
1.A2	Manufacturing Industries and Construction	T1	D	T1	D	T1	D						
1.A3	Transport	T1,T2	D, CS	T1,T2	D, CS	T1,T2	D, CS						
1.A4	Other Sectors	T1	D	T1	D	T1	D						
1.B	Fugitive Emissions			T1	D								
1.B1	Solid Fuels			NO	NO								
1.B2	Oil and Natural Gas			T1	D								
1.B3	Other Emission from Energy Production			NO	NO								
2	Industrial Process	D, PS	D, PS	NE	NE	NE	NE	T2	PS	T2	PS	NE	NE
2.A	Mineral Products	D	D	NE	NE	NE	NE						
2.B	Chemical Industry	NO	NO	NO	NO	NO	NO						
2.C	Metal Production	T2	PS	NE	NE	NE	NE	T2	PS	T2	PS		
2.D	Non-Energy Products from Fuels and Solvent Use	T1	D										
2E	Electronics Industry	NO	NO	NO	NO	NO	NO						
2.F	Product Uses as Substitutes for Ozone Depleting Substances											NE	NE
3	Agriculture, Forestry, and Other Land Use	T1,T2	D, CS	T1	D	T1	D						
3.A	Livestock			T1	D								
3.B	Land	T2	CS										
3C	Aggregate sources and non-CO2 emissions sources on land	T1	D	T1	D	TI	D						
4	Waste	T1	D	T1	D	T1	D						
4.A	Solid waste disposal			D	D	D	D						
4.B	Biological Treatment of Solid Waste			TI	D	T1	D						
4.C	Incineration and Open Burning of Waste	T1	D	TI	D	T1	D						
4.D	Wastewater Treatment and Discharge			T1	D	T1	D						

Key: *CS= Country-Specific, PS= Plant-Specific, NE = Not Estimated, NO=Not Occurring, D = Default IPCC methodology and emission factor, EF = Emission Factor, Meth=Methods, T1, T2 - Levels of Tiers*

1.7.2.2 Sources of activity data

The inventory was prepared using data from a combination of sources from national and international institutions. During data collection, priority was given to data that have been generated in the country. In cases where the required data was not available in the country, the data from international organization's such as FAO, IEA, World Bank, etc. were used. Table 5 provides an overview of the data used in the inventory.

Table 5: Description of activity data sources

Sector		Data Type	Data Source	Principal Data Providers
1. Energy Sector				
1.A1	Energy Industry	Fuel types, Fuel consumption, supply Crude oil and petroleum products production, Imports and exports	National Energy Statistics Refinery Product Balance National Energy Plan IEA Database	Energy Commission, National Petroleum Authority, Tema Oil Refinery, Ministry of Energy and Petroleum, Thermal Electricity Generation Utility Companies (VRA, Sunon Asogli, Takoradi International Company TICO and other independent power producers etc, and the IEA
1.A2	Manufacturing Industry and Construction	Fuel types, fuel consumption, supply, Feedstock, Fuels for Non-energy Use	National Energy Statistics Industry survey data, 2013 National Industry Census, 2003	Energy Commission, Manufacturing Industry Department of the Environmental Protection Agency, Manufacturing and Construction Industries, Ghana Statistical Service.
1.A3	Transport	Fuel Types, fuel Consumption by Vehicles, Aviation, Rail and Navigation, Number of Registered vehicles, Vehicle Types	Vehicle registration Database, Petroleum Product Sales Data, Railway Fuel Consumption data, Water Transport Fuel Consumption Data	Energy Commission, Environmental Quality Department of Environmental Protection Agency, Driver Vehicle Licensing Authority, Oil Marketing Companies (particularly, Shell Ghana Limited, Total Ghana Limited), Ministry of Transport, Ghana Railway Company, Volta Lake Transport Company, Ghana Bunkering Services
1.A4	Other Sectors	Fuel consumption per fuel type	National Energy Statistics National Energy Plan, National Census Report, Ghana Living Standard Survey Report	Energy Commission Ghana Statistical Service
1.B	Fugitive emissions from fuels	Gas flared, Gas produced, Gas injected and Gas consumed on site, Refinery input (crude oil)	Oil Exploration and Production Data Oil refinery data in the Energy Statistics	Ghana National Petroleum corporation Oil Exploration and Production, Companies Environmental Protection Agency Tema Oil Refinery
1. Industrial Process and Product Use				
2.A	Mineral Industry	Industrial production and Plant specific emission factors	Environmental Reports EPRPD Database Industry Survey Industrial data from facilities.	Volta Aluminum Company Limited Tema steel works, Aluworks Environmental Protection Agency
2.C	Metal Industry			
2.D	Non-Energy Products from Fuels and Solvent Use	Amount of non-energy use of diesel and kerosene		

2. Agriculture, Forestry and Other Land use				
3.A1 and 3.A2	Enteric Fermentation & Manure Management	Animal population, Fractions of manure, management practices	Agriculture Facts and Figures FAOSTAT Expert Judgment	Ministry of Food and Agriculture – Statistics Research and Information Directorate, UN Food and Agriculture Organization, AFOLU Team
3.B1	Forest land	Land use maps, land use change map, land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
		biomass estimates for 5 IPCC pools (AGB, BGB, deadwood, herb, litter and soil)		
		Climate zones, soil stratifications and ecological zone maps	IPCC database	IPCC
		Industrial round wood	RMSC, FAOSTAT	Forestry Commission, Ghana FAO
		Wood fuel production	Energy Statistics	Energy Commission
		Areas affected by fire	Expert Judgment	AFOLU Team
3.B2	Cropland	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
		biomass estimate for 5 IPCC pools (AGB, BGB, deadwood, herb, litter and soil)		
		Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
3.B3	Grassland	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
		biomass estimate for 5 IPCC pools (AGB, BGB, deadwood, herb, litter and soil)		
		Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
3.C1	Biomass burning	Areas affected by fire in cropland, forestland and grassland	Expert Judgment	AFOLU Team
		Mass fuel available for burning	Forest Preservation Program, 2012	Forestry Commission, Ghana
3.C3	Urea application	Annual Urea consumption figures	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate,
3.C4	Direct N_2O emissions from managed soils	Annual generic NPK consumption	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate,
3.C5	Indirect N_2O emissions from managed soils	Annual crop production in tonnes per annum		
3.C6	Indirect N_2O emissions from manure management	Animal population (cattle, goats, sheep, swine, donkey, poultry, horse)	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate,
		Fractions of manure management practices	Expert Judgment	AFOLU Team

3.C7	Rice cultivation	Annual rice production areas	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate
		Proportions of annual rice production area under rain fed, irrigated and upland systems	National Rice Development strategy	Ministry of Food and Agriculture
4. Waste				
4A	Solid Waste Disposal	Waste Generation, Population Figures, Composition, amounts of waste deposited, means of disposals and their various percentages	Published national reports, Ghana Statistical Services, Sanitation Directorate of MLGRD, World Bank Country Database, Private Waste Management Companies and Civil Engineering Department, KNUST, EPA	National Environmental Sanitation Strategy & Action Plan (NESSAP), Population Census Reports and Ghana Living Standards Survey 2008, Private Waste Management Companies(Zoomlion Ghana Limited, Waste care, etc.), and NGOs Academia (Civil Engineering Department, KNUST), Second National Communication Report from EPA.
4B	Biological Treatment of Solid Waste	Fraction of waste composted, number of compost plants	Private Waste Management	Private Waste Management Companies (Zoomlion Ghana Limited) and NGOs. Expert judgment by the Waste Team
4C	4C.1 Waste Incineration	Amount and types solid waste incinerated, type of incinerator including capacities and combustion efficiencies	Ghana Health Services, Ministry of Local Government and Rural Development,	National Environmental Sanitation Strategy Action Plan document and Ghana Health Service Facts and Figures, and Expert Judgment by the Waste Team
	4C.2 Open Burning of Solid Waste	Population, proportion of population burning waste, duration of burning in number of days per year, fraction of waste burnt relative to the total amount treated.	Published national reports, Ghana Statistical Services, Sanitation Directorate of MLGRD,	National Environmental Sanitation Strategy & Action Plan (NESSAP), Population Census Reports and Ghana Living Standards Survey 2008, Expert Judgment by Waste Team
4D	4D.1 Domestic wastewater treatment and discharge	Population, Wastewater Generated per year, Wastewater treated per year, Wastewater Treatment Systems and their various percentages, Protein Consumption, GDP/capita	Ghana Statistical Services, Sanitation Directorate of MLGRD, World Bank, Ghana Health Service, Ministry of Food and Agriculture	National Environmental Sanitation Strategy & Action Plan (NESSAP), Population Census Reports and Ghana Living Standards Survey 2008, Multiple Cluster Indicator Survey data World Bank Country Database, FAO Expert Judgment by Waste Team
	4D.2 Industrial wastewater treatment and discharge	Industrial coverage, Total Industry Product Quantity of wastewater generated Type of Wastewater Treatment / discharge System	Industry survey	Industrial Outputs data collected during national survey, EMPs Expert Judgment by Waste Team

1.8 Global warming potentials (GWP) Used

The IPCC Second Assessment Report (SAR) 100 year time horizon GWPs was used in inventory (see table 6).

Table 6: 100 year time horizon GWPs

GWP	Assumption	Source
	CH_4 = 21 tonnes CO_2 N_2O = 310 tonnes CO_2	IPCC Second Assessment Report (SAR)
	PFC-14 (CF_4) = 6,500 tonnes CO_2 PFC-116 (C_2F_6) = 9,200 tonnes CO_2	

1.9 Key categories analysis

Guidance on the steps for the identification of key categories has been elaborated in the 2000 and 2003 IPCC Good Practice Guidance. The guidance explains that key category has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions or removals, the trend in emissions or removals, or both. Ghana identified the key categories for the inventory using the tier 1 level and trend assessments as recommended in the IPCC Good Practice Guidance and adopted by COP decision 13/CP9. This approach identifies sources that contribute to 95% of the total emissions or 95% of the trend of the inventory in absolute terms. The methods used for the identification of the key categories were level assessment for 1990 and 2012, and trend assessment for 2012, with respect to the base year (1990). The results of the key category analysis have been presented with and without the AFOLU sector.

1.9.1 Key category including AFOLU

The identified key categories using the level assessment approach are listed in table 6. The sum of the total emissions from the key categories amounted to 17.57 $MtCO_2e$ in the year 2012, representing 57% of Ghana's total greenhouse gas emissions (without AFOLU). On the other hand, when AFOLU emissions were included, total emissions from the key categories were 26.13 $MtCO_2e$ in 2012 which was 84.7% of the total national emissions. With the inclusion of the AFOLU sector emissions in the analysis, "land converted to cropland" and "forest land remaining forest land" were identified as the most significant of the key categories (i.e. contributing more than 45% of the emissions) in 2012 (see table 7 and table 8). When the AFOLU sector emissions was excluded from the analysis, the most, significant key categories in 2012 were, road transport (liquid fuels), wastewater treatment and discharge and public electricity generation (liquid fuel).

Table 7: Identified key categories using level assessment in 2012

IPCC Code	IPCC Categories	Gas	Cumulative Total
3.B.2.b	Land converted to cropland	CO_2	0.2
3.B.1.a	Forest land Remaining forest land	CO_2	0.5
3.B.1.b	Land converted to forest land	CO_2	0.6
3.B.3.b	Land Converted to grassland	CO_2	0.7
1.A.3.b	Road transport	CO_2	0.8
3.C.4	Direct N_2O emissions from managed soils	N_2O	0.8
4.D	Wastewater treatment and discharge	CH_4	0.8

1.A.1	Energy Industries - liquid Fuels	CO_2	0.8
3.A.1	Enteric fermentation	CH_4	0.9
3.C.1	Emissions from biomass burning	N_2O	0.9
1.A.4	Other Sectors - liquid Fuels	CO_2	0.9
4.A	Solid waste disposal	CH_4	0.9
3.C.1	Emissions from biomass burning	CH_4	0.9
1.A.2	Manufacturing Industries and Construction - liquid Fuels	CO_2	0.9
3.C.5	Indirect N_2O Emissions from managed soils	N_2O	1.0

Table 8: Identified key categories using trend assessment for the period 1990-2012

IPCC Code	IPCC Categories	Gas	Cumulative Total
3.B.1.a	Forest land remaining forest land	CO_2	0.4
3.B.1.b	Land converted to forest land	CO_2	0.7
3.C.1	Emissions from biomass burning	N_2O	0.7
3.C.1	Emissions from biomass burning	CH_4	0.8
3.B.3.b	Land converted to grassland	CO_2	0.8
1.A.3.b	Road transport	CO_2	0.9
1.A.1	Energy Industries - liquid Fuels	CO_2	0.9
3.B.2.b	Land Converted to cropland	CO_2	0.9
4.A	Solid waste disposal	CH_4	0.9
2.C.3	Aluminum production	PFCs	0.9
1.A.4	Other Sectors – biomass	CH_4	0.9
1.A.1	Energy Industries - gaseous fuels	CO_2	0.9
3.C.4	Direct N_2O emissions from managed soils	N_2O	1.0

In terms of trend assessment, CO_2 emissions/removals from “forestland remaining forestland” and “land conversions to forestland” were the key categories. This was followed by N_2O and CH_4 emissions from biomass burning (see table 8). More details on the description of the key categories are provided under each sector.

1.10 Information on Quality Assurance/Quality Control (QA/QC) Procedures

1.10.1 Description of roles and responsibilities

The sector leads were given responsibilities of ensuring that adequate QA/QC procedures were performed in the inventory, its supporting documents and spreadsheets. The EPA also doubled as the back stopper of QA/QC and focused on the following: (a) creating a checklist of QA/QC procedures, based on “EPA's Procedures template for Quality Assurance/Quality Control and Uncertainty Analysis” for the team members to follow, (b) collecting and reviewing checklists for completeness, and following up when necessary to ensure that the required QA/QC procedures were observed, (c) delivering all documentations to the online database manager, and (d) facilitating all technical reviews at the national and international levels.

1.10.2 Implementation of QC procedures

Ghana implemented the following Tier 1 QC procedures as contained in table 9:

Table 9: Summary of QC procedures followed

QC procedures	Description of tasks	Responsibility(ies)
Internal consistency	Ensured that the total GHG emissions equaled the sum of the individual emission from the sectors and categories.	Inventory compiler
	Ensured that the total GHG emissions equaled the sum of the emissions by gas.	
	Compared data in tables to calculation spreadsheets and to the text in order to ensure that all reported the same estimates.	
	Ensured that parameters used in multiple categories (e.g., population) were consistent across categories.	
	Ensured that the emissions data is reported in a manner consistent with the calculation tables in the Non-Annex 1 National Communications Reporting Guidelines	
	Ensured that the selection and application of the estimation methods were consistent with IPCC guidelines.	
Documentations	Created back-ups of all documentations in hard and soft copies and uploaded files in a central storage facility online	Inventory compilers
	Moved all files and documentations to an "online GHG database"	Database administrator
	Reviewed, approved and harmonized sector files to ensure consistency in filing.	Inventory compilers
Detailed sector QC procedures are provided under each sector		

1.10.3 External Review QA procedures

1.10.3.1 International third party review

External reviews by experts offer the opportunity to uncover technical issues related to the application of methodologies, selection of activity data, development and selection of emission factors. Based on their knowledge and experience in areas related to the inventory. The listed experts and/or organizations indicated in table 10, below were sent a draft copies of the inventory for review three months before publication. The review package that were sent to the third party reviewers included (a) data inputs, (b) inventory datasheets and results and (c) inventory report.

Table 10: List of Experts for External Review of National Greenhouse Gas Inventory

Reviewer	Affiliation/ Organization	Sector or Category	Comments
Zoltan Somogyi	EU - Hungary	AFOLU	Review was done as part of the CD-REDD Project through Rainforest Coalition with support the Germany Government.
John Watterson & Ross Hunter	Ricardo-AEA	Energy Sector	Review was done as part of the Information Matters Project through GIZ with support the Germany Government
Dominique Revet	UNFCCC	Draft NIR	Request from Ghana for informal review of draft NIR
Sabin Guendehou	Coordinator , Sustainable GHG Management Project in West Africa)	AFOLU	Review was done as part of the Sustainable Greenhouse Gas Management Project in West Africa through UNFCC with support from Australian Government

1.10.3.1 Domestic third party review

In addition, all the sector inventory results were also subjected to "internal disclosure and assessment" by the relevant Ministries, Department and Agencies (MDAs). The "internal disclosure assessment" was done through four "reality check" meetings that were held at the various MDAs to collect inputs on (a) policy implications of the sector estimates (b) practical steps that are needed to be taken to facilitate further mainstreaming of inventory in the sector and (c) how to strengthen the linkages with research. Furthermore internal technical and policy review was done by selected management members at MESTI and EPA under the overall coordination of the Executive Director, EPA. Out of the 15 people who did review, 5 of them focused on the reviewing the NIR. They are (a) Mr. Ebenezer Sampong (Deputy Executive Director, Technical –EPA); Mr. John Pwamang (Deputy Executive Director, Field Operations -EPA), Mr. Peter Dery (Deputy Director, Climate Change and Sustainable Development Unit, MESTI), Mr. K.Y. Oppong-Boadi (UNFCCC Focal Point, EPA) and Mr. Joseph Baffoe (Climate Change Unit, EPA).

1.11 General Uncertainty Assessment

The processes for estimating GHG emissions has inherent uncertainties. Generating activity data and emission factors, either through physical measurements or modeling carries certain levels of uncertainty. Datasets that are produced through such processes introduce inherent uncertainties into the inventory. In addition, use of expert judgement to inform infilling of time series data gaps for activity data, default emission factors are possible sources of uncertainties in the inventory. Managing these uncertainties, and reducing them over time, is recognized by the IPCC Good Practice reports (IPCC 2000, 2003) as an important element of the inventory preparation and development. Ghana has conducted a tier 1 uncertainty analysis across the sectors in line with the IPCC Good Practice reports (2000, 2003). However, because most of the activity data were mainly from secondary sources that hardly reported uncertainty ranges in their metadata, qualitative approach backed by experts' judgment were used to assign the uncertainty ranges based on the sources of data in a consistent and transparent manner. In addition, the uncertainty ranges associated with the IPCC emission factors were also used. Using the IPCC recommended minimum uncertainty range of ±5% for facility level activity data, the uncertainty ranges were assigned to each activity based on the source. The spread of uncertainty ranges was assumed to increase according to the level of verifiability and reliability of the source of data. Table 11 shows the uncertainty range based on input activity data.

Table 11: Range of uncertainty range input for activity data

Activity data source	Uncertainty Range		Comments
	Plus	Minus	
Facility level measurement	5%	5%	VALCO type of data
Peer reviewed literature	5%	5%	
Research results	5%	5%	
Enumeration	4%	2%	DVLA type of data
Industry archive	6.5%	6%	Ghana railway company type of data
International sources	6%	5.50%	Data from FAO, IEA, WB, etc
National reports			Including strategies, action plans etc.
• Project reports	5%	5.5%	
• Energy Statistics	6%	5.5%	
• National Census	5%	5%	
• Ghana Living Standard Survey	5%	5.5%	
Expert judgment	15%	12%	
Personal Communication	10%	10%	

At an aggregate level, using IPCC good practice tier 1 methods, the overall uncertainty surrounding the inventory estimate for 2012 was estimated at ±2.1%.

1.12 General assessment of the completeness

The assessments of completeness for each sector is provided under sector-specific description section. The general overview of completeness is as follows:

Geographic coverage

The geographic coverage is complete. The inventory covered the entire territorial boundary of the Republic of Ghana. Thus none of the 10 administrative regions in Ghana has been left uncovered by the inventory.

Sectors (sources and sinks)

All sources or removals of direct GHG gases that are associated with activities occurring in Ghana, outlined in the 2006 IPCC Guidelines, were covered in the inventory except the following activities which were considered insignificant or where there is no data:

- 1A.2a – Iron and steel
- 1A.2b – Non-ferrous metals
- 1A.2i – Mining (excluding fuel) and quarry
- 1B.2a.iii.5 – Distribution of oil products
- 2F – Product use as substitute to ozone depleting substances
- 3B.4 – Wetlands
- 3B.5 – Settlements
- 3B.6 – Other lands
- 3D.i – Harvested wood products

Gases

Majority of the direct gases have been covered under this inventory. These direct gases included CO_2, CH_4, N_2O and PFCs (CF_4 and C_2F_6). HFCs have not been considered in this inventory due to data unavailability.

Notation keys

NE (not estimated):

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

- 1A.2a – Iron and steel
- 1A.2b – Non-ferrous metals
- 1A.2i – Mining (excluding fuel) and quarry
- 1B.2a.iii.5 – Distribution of oil products
- 2F – Product use as substitute to ozone depleting substances
- 3B.4 – Wetlands
- 3B.5 – Settlements
- 3B.6 – Other lands
- 3D.i – Harvested wood products

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.

The details of the assessment of sector completeness have been provided in the relevant sections of this report.

2.0 Greenhouse Gas Emissions Trends

2.1 Aggregated Greenhouse Gas Emission Trends

Ghana's total greenhouse gas emissions were 33.66 million tonnes (Mt) carbon dioxide-equivalent (CO_2e) in 2012. This represented an increase of 10.7% on the total emissions recorded in 2010, and an increase of 106.2% and 136.7% above 2000 and 1990 levels respectively (see figure 5). The net national emissions in 2012 was 18.5MtCO_2e when emissions and removals from the AFOLU sector were excluded.

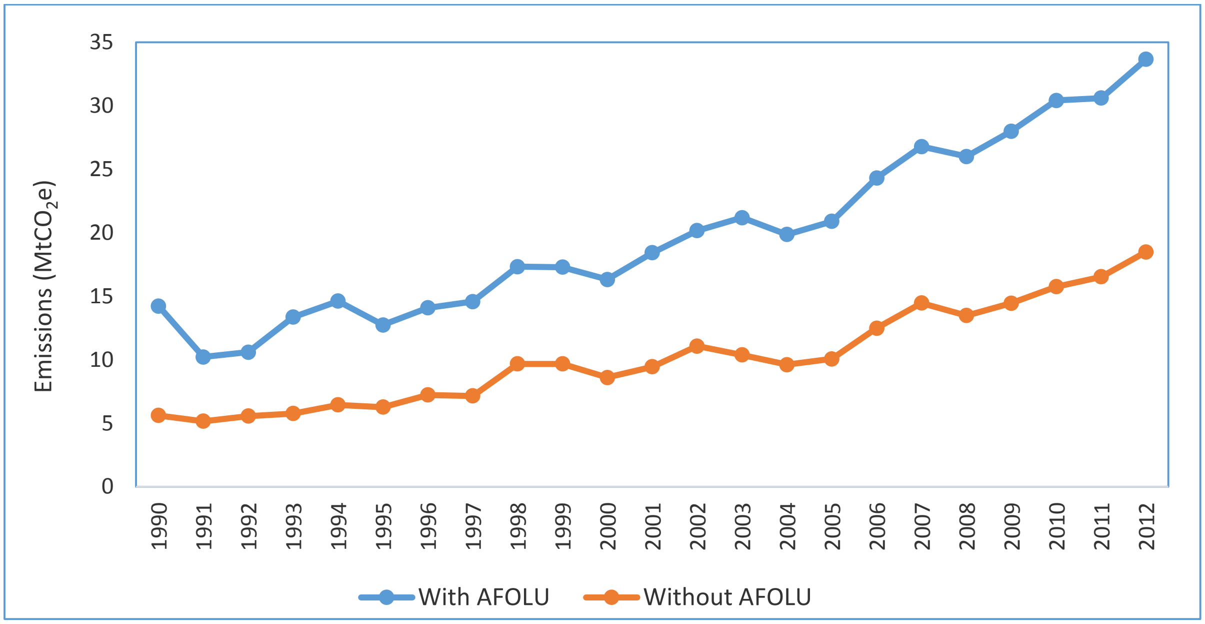


Figure 5: National emission trends with and without AFOLU

This represented an increase of 17.4% on net emissions recorded in 2010, and 114.8% and 229.3% above 2000 and 1990 levels each (see table 12). The observed increasing trends in the emissions corresponded to the structural transformation which has led to sustained growth and expansion of the national economy.

Sectors & Sub-sectors	**Emissions MtCO_2e**					**Percent Change**		
	1990	**2000**	**2010**	**2011**	**2012**	**1990-2012**	**2000-2012**	**2010-2012**
1. All Energy (combustion & fugitive)	**3.50**	**5.54**	**11.27**	**11.63**	**13.51**	**286.08**	**143.65**	**19.79**
(1.A1,A2&A5) Stationery energy combustion	2.03	2.73	6.48	6.22	7.05	247.28	158.10	0.09
(1.A5)Transport	1.47	2.81	4.80	5.41	6.46	339.66	129.85	34.67
(1.B) Fugitive emission	0.000	0.003	0.001	0.001	0.002	284.71	-51.74	139.35
2. Industrial Process & Product Use	**0.81**	**0.77**	**0.24**	**0.44**	**0.47**	-42.47	-39.56	**94.24**
3. AFOLU	**8.61**	**7.72**	**14.67**	**14.08**	**15.17**	**76.28**	**96.65**	**3.46**
3A Livestock	1.72	2.20	2.82	2.80	3.05	77.29	38.66	8.01
3B Land	-3.02	-4.00	1.85	1.31	1.84	-160.73	-145.86	-0.96
3C. Aggregated and Non-CO_2 emissions	9.91	9.52	9.99	9.98	10.29	3.83	8.08	3.00
4. Waste	**1.31**	**2.29**	**4.24**	**4.45**	**4.52**	245.97	**97.03**	**6.54**
Total emissions (excluding AFOLU)	**5.61**	**8.61**	**15.75**	**16.51**	18.49	**229.31**	**114.81**	**17.36**
Total net emissions (including AFOLU)	**14.22**	**16.32**	**30.42**	**30.60**	**33.66**	**139.69**	**106.22**	**10.66**

Table 12: Total greenhouse gas emissions by sectors

Sectors & Sub-sectors	Emissions MtCO2e					Percent Change		
	1990	2000	2010	2011	2012	1990-2012	2000-2012	2010-2012
1. All Energy (combustion & fugitive)	3.50	5.54	11.27	11.63	13.51	286.08	143.65	**19.79**
2. Industrial Process & Product Use	0.81	0.77	0.24	0.44	0.47	-42.47	-39.56	**94.24**
3. AFOLU	8.61	7.72	14.67	14.08	15.17	76.28	96.65	**3.46**
4. Waste	1.31	2.29	4.24	4.45	4.52	245.97	97.03	**6.54**
Total emissions (excluding AFOLU)	5.61	8.61	15.75	16.51	18.49	229.31	114.81	**17.36**
Total net emissions (including AFOLU)	14.22	16.32	30.42	30.60	33.66	136.69	106.22	**10.66**

In 2012, CO_2 was the dominant GHG which contributed 44% (14.81 Mt) of the total net emissions (including AFOLU). Of the total net CO_2 emissions of 14.81 Mt, energy sector contributed 85% (12.59Mt), followed by AFOLU (12.6% - 1.86 Mt) and IPPU (2.4% - 0.35%). When the emissions from AFOLU are excluded from the national totals, CO_2 make up 70.1% (12.59 Mt) of the emissions in the same year. Between 2010 and 2012, the CO_2 emissions including AFOLU increased by 14.9%. Nitrous oxide was the second largest emission source constituting 30.8% (10.38 $MtCO_2e$) of the total emissions by CH_4 (24.8% -) and PFCs (0.3%).

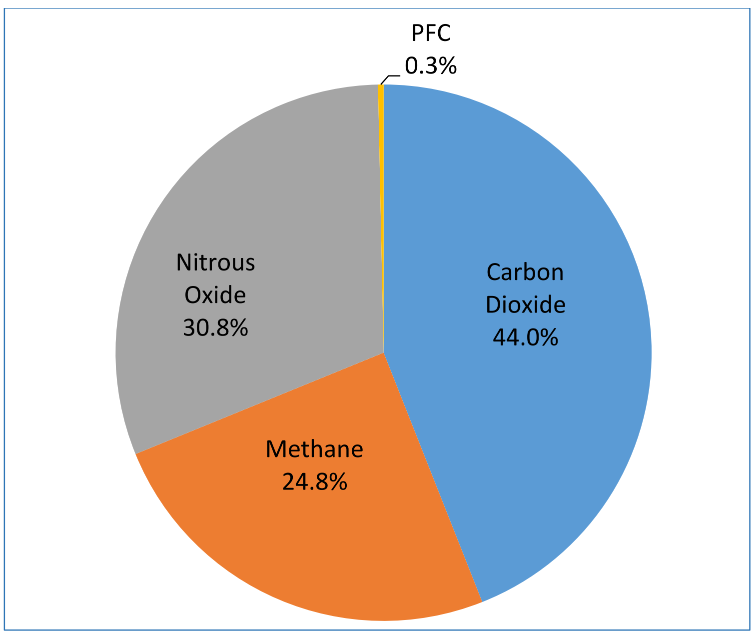


Figure 6: Emission contributions from different basket of gases to the national emissions in 2012

The energy sector was the chief source of CO_2 emissions in 2012 representing 85% of the total anthropogenic CO_2 emissions (see table 13). This was followed by AFOLU (12.6%), IPPU (2.3%) and waste (0.03%). On the other hand, for CH_4 emissions, the distribution of shares among sectors was as follows: waste sector (48.1%), AFOLU (44.2%) and energy (7.7%). For N_2O emissions. 92.7%, 2.62% and 4.7% of the total emissions were from the AFOLU, waste and energy sectors respectively (see table 13).

Table 13: Distribution of emissions contribution by sectors in 2012

Sector and sub-sectors	CO_2 [%]		CH_4 [%]		N_2O [%]	
	W/O AFOLU	With AFOLU	W/O AFOLU	With AFOLU	W/O AFOLU	With AFOLU
1. All Energy (combustion & fugitive)	**97.2**	**85.03**	**13.72**	**7.7**	**35.7**	**2.62**
Stationery energy combustion	50.0		94.4			
Transport	50.0		5.5			
Fugitive emission*	0	0	0	0	0	0
2. Industrial Process & Product Use	**2.7**	**2.39**	**0.0**	**0.0**	**0.0**	**0.00**
3. AFOLU		**12.6**		**44.2**		**92.7**
Livestock				57.5		9.58
Land		*98.7*		0		0
Aggregated and non-CO_2 emissions		*1.26*		42.5		90.4
4. Waste	0.03	**0.03**	**86.3**	**48.1**	**64.3**	**4.72**
Total net emissions (w/ AFOLU)		**100**		**100**		**100**
Total emissions (w/o AFOLU)	**100**		**100**		**100**	

* Fugitive emissions marginal and below zero percent

In 2012, the AFOLU sector was the largest of the national sources of greenhouse gas emissions representing 45.1% of the total emissions (see table 14), followed by the energy sector (40.1%), waste (13.4%) and industrial processes (1.4%). When emissions from AFOLU were excluded from the national totals, the emissions from the energy sector make up 73% of the total emissions. The remaining 24% and 3% were emissions from waste and IPPU sectors respectively.

Table 14: Net national emissions by Sectors in 2012

Sectors and Sub-sectors	Emissions						Share of Total Emissions
	Mt	$MtCO_2e$					
	CO_2	CH_4	N_2O	PFC	Total	%	%
1. All Energy (combustion & fugitive)	12.59	0.64	0.27	0.00	13.51	73	40.1
Stationery energy combustion	6.29	0.60	0.15	0.0	7.0	38	
Transport	6.30	0.04	0.12	0.0	6.5	35	
Fugitive emission	0.00	0.00	6.4E-06	0.0	0.002	0	
2. Industrial Process & Product Use	0.35	0.00	0	0.11	0.47	3	1.4
4. Waste	0.00	4.02	0.49	0.0	4.5	24	13.4
3. AFOLU	1.86	3.70	9.62	0.00	15.17	100	45.1
Livestock	0.00	2.13	0.9	0.0	3.0	20	
Land	1.84	0.00	0.0	0.0	1.8	12	
Aggregated and Non-CO_2 emissions	0.02	1.57	8.7	0.0	10.3	68	
Total net emissions (including AFOLU)	14.81	8.36	10.38	0.11	33.66		100
Total emissions (excluding AFOLU)	12.95	4.66	0.76	0.11	18.49	100	

Within the energy sector, emissions from stationery energy combustion (mainly from electricity power plants and industrial point-sources) made up 52.2% of the total emissions, which was followed by emissions from mobile combustion (transport) accounting for 47.8%. The remaining 0.01% came from fugitive emission sources in the oil and gas industry.

2.2 Emission trends by gases

Among the gases, the CO_2 emissions dominated with a total of 14.8Mt in 2012. This translated to increases of 14.9%, 92.7% and 100.7%, above the 2010, 2000 and 1990 net CO_2 emission levels respectively (see table 15). The observed increases in CO_2 emissions corresponded to the rising liquid fuel combustion in transport, electricity generation and land use change due to deforestation. On the other hand, CH_4 emissions trend recorded increases from 6.49 $MtCO_2e$ in 1990 to 7.23 $MtCO_2e$ in 2000 and peaked in 2010 with 9.24 $MtCO_2e$ before it declined to 8.36 $MtCO_2e$ in 2012. Nitrous oxide emissions recorded a steady marginal increases of 7.3%, 9%, 7.1% compared to the 2010, 2000 and 1990 levels. Aluminum production was the main source of PFCs emissions in Ghana. The PFCs emission has significantly declined by 309.7% below the 2000 levels due to reduction in Aluminum production from VALCO.

Table 15: Changes observed in the distribution of gases for the period 1990-2012

	Emissions ($MtCO_2e$)					Percent change		Share				
Year	**1990**	**2000**	**2010**	**2011**	**2012**	**2000-2012**	**2010-2012**	**1990**	**2000**	**2010**	**2011**	**2012**
Total	14.22	16.32	30.54	30.61	33.66	106.3%	10.2%	100%	100%	100%	100%	100%
CO_2	-0.11	1.08	12.27	12.60	14.81	1271.3%	20.7%	-0.8%	6.6%	40.2%	41.2%	44.0%
CH_4	6.49	6.37	8.17	8.11	8.36	31.2%	2.3%	45.6%	39.0%	26.8%	26.5%	24.8%
N_2O	7.32	8.41	9.99	9.79	10.38	23.4%	3.9%	51.5%	51.5%	32.7%	32.0%	30.8%
PFCs	0.52	0.46	0.11	0.11	0.11	-76.1%	0.0%	3.7%	2.8%	0.4%	0.3%	0.3%

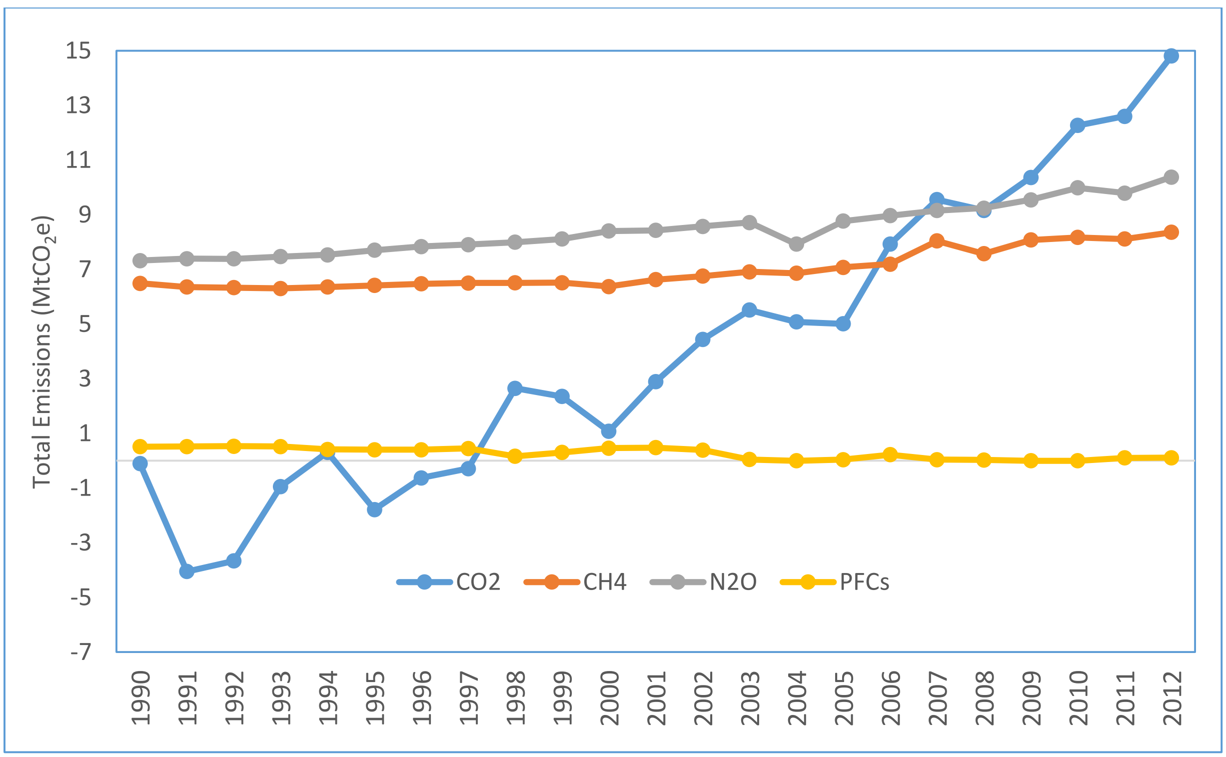


Figure 7: Trends of emissions by gases for the period 1990 to 2012

Carbon Dioxide (CO_2)

Carbon dioxide emissions increased by 100.7% from -0.11Mt in 1990 to 14.8Mt in 2012 (see figure 7). The increases in the CO_2 emission trends were mainly due to the high emissions from energy sector. The energy sector was the largest source of anthropogenic CO_2 emissions and recorded an increase of 340% in the same period. The main sources of CO_2 emissions were fossil fuel combustion and land use change. For the fuel combustion activities, road transport was the most important source. , The CO_2 emissions in the energy sector showed consistent rising trend from 2.6Mt in 1990 to 12.6Mt in 2012 (see table 16).

Table 16: Total net CO_2 emissions/removals by sectors in Mt

Year	Total	Energy	IPPU	AFOLU	Waste
1990	-0.11	2.60	0.29	-3.01	0.00509
1991	-4.05	2.23	0.30	-6.59	0.00512
1992	-3.66	2.44	0.31	-6.42	0.00513
1993	-0.94	2.57	0.31	-3.83	0.00514
1994	0.31	3.26	0.26	-3.22	0.00514
1995	-1.78	2.99	0.26	-5.04	0.00514
1996	-0.63	3.76	0.27	-4.66	0.00505
1997	-0.29	3.50	0.29	-4.08	0.00495
1998	2.65	6.38	0.13	-3.87	0.00483
1999	2.36	6.03	0.21	-3.90	0.00470
2000	1.08	4.76	0.31	-4.00	0.00457
2001	2.89	5.22	0.31	-2.64	0.00463
2002	4.44	6.78	0.27	-2.62	0.00472
2003	5.52	6.41	0.09	-0.99	0.00477
2004	5.08	5.76	0.08	-0.76	0.00487
2005	5.01	5.77	0.16	-0.92	0.00486
2006	7.92	7.70	0.28	-0.06	0.00496
2007	9.55	8.96	0.20	0.38	0.00464
2008	9.16	8.08	0.26	0.81	0.00428
2009	10.37	8.94	0.21	1.21	0.00387
2010	12.27	10.16	0.24	1.86	0.00348
2011	12.60	10.95	0.33	1.32	0.00357
2012	14.81	12.59	0.35	1.86	0.00396

Similarly, CO_2 emissions from the AFOLU recorded a rise from -3.01 Mt in 1990 to 1.86 Mt in 2012. The increase in the net CO_2 emissions from the AFOLU corresponded to the related to intensity of land use transfers among forestland, croplands and grasslands.

Methane

Methane emissions recorded steady increases of 6.49MtCO_2e in 1990 to 8.17 MtCO_2e before it declined by 0.06MtCO_2e in 2012 (see table 17). The main sources of CH_4 emissions were from discharges and treatment of liquid waste, solid waste disposal, enteric fermentation and burning of biomass. While the CH_4 emission trends in the AFOLU sector recorded steady decline between 1990 and 2012 that of waste saw increases in the same period.

Table 17: CH_4 emissions/removals by sectors in $MtCO_2e$

Year	Total	Energy	IPPU	AFOLU	Waste
1990	6.49	0.720	0.00	4.80	0.97
1991	6.36	0.593	0.00	4.74	1.02
1992	6.33	0.616	0.00	4.58	1.14
1993	6.30	0.631	0.00	4.48	1.19
1994	6.36	0.651	0.00	4.41	1.30
1995	6.42	0.682	0.00	4.37	1.37
1996	6.47	0.720	0.00	4.28	1.47
1997	6.50	0.751	0.00	4.20	1.55
1998	6.51	0.720	0.00	4.14	1.65
1999	6.51	0.739	0.00	4.04	1.74
2000	6.37	0.586	0.00	3.95	1.84
2001	6.63	0.751	0.00	3.88	1.99
2002	6.76	0.820	0.00	3.86	2.08
2003	6.91	0.885	0.00	3.82	2.21
2004	6.86	0.745	0.00	3.79	2.32
2005	7.08	0.881	0.00	3.72	2.47
2006	7.20	0.918	0.00	3.68	2.60
2007	8.05	1.251	0.00	3.62	3.17
2008	7.58	0.984	0.00	3.26	3.33
2009	8.08	1.007	0.00	3.59	3.48
2010	8.17	0.844	0.00	3.57	3.76
2011	8.11	0.485	0.00	3.67	3.96
2012	8.36	0.639	0.00	3.70	4.02

Nitrous Oxide

On the whole, nitrous oxide emissions recorded consistent increased from 7.32 $MtCO_2e$ in 1990 to 10.38 $MtCO_2e$ in 2012 (see table 18).

Table 18: N_2O emissions/removals by sectors in $MtCO_2e$

Year	Total	Energy	IPPU	AFOLU	Waste
1990	7.32	0.18	0.00	6.81	0.33
1991	7.39	0.15	0.00	6.91	0.34
1992	7.39	0.18	0.00	6.87	0.34
1993	7.47	0.18	0.00	6.94	0.35
1994	7.53	0.19	0.00	6.99	0.36
1995	7.70	0.19	0.00	7.15	0.36
1996	7.84	0.21	0.00	7.25	0.38
1997	7.91	0.20	0.00	7.31	0.40
1998	8.00	0.21	0.00	7.38	0.41
1999	8.11	0.21	0.00	7.47	0.43
2000	8.41	0.19	0.00	7.77	0.45
2001	8.43	0.23	0.00	7.75	0.45
2002	8.58	0.26	0.00	7.85	0.46
2003	8.72	0.27	0.00	7.98	0.46
2004	7.93	0.24	0.00	7.22	0.46
2005	8.77	0.28	0.00	8.03	0.46
2006	8.97	0.30	0.00	8.21	0.47

2007	9.15	0.37	0.00	8.31	0.47
2008	9.24	0.32	0.00	8.46	0.47
2009	9.55	0.34	0.00	8.74	0.47
2010	9.99	0.27	0.00	9.23	0.48
2011	9.79	0.21	0.00	9.09	0.49
2012	10.38	0.27	0.00	9.62	0.49

Perfluorocarbons (PFCs)

PFCs emissions from the Aluminum production showed a consistent decrease from 0.52MtCO$_2$e in 1990 to 0.11MtCO$_2$e in 2012 (see table 19). The general decline in the PFCs emissions coincided with the periods where the Volta Aluminum Company Limited recorded lower productivity.

Table 19: PFC emissions/removals by sectors in MtCO$_2$e

Year	Total	IPPU
1990	0.52	0.52
1991	0.52	0.52
1992	0.53	0.53
1993	0.52	0.52
1994	0.42	0.42
1995	0.40	0.40
1996	0.40	0.40
1997	0.45	0.45
1998	0.16	0.16
1999	0.30	0.30
2000	0.46	0.46
2001	0.48	0.48
2002	0.39	0.39
2003	0.04	0.04
2004	0.00	0.00
2005	0.04	0.04
2006	0.22	0.22
2007	0.04	0.04
2008	0.03	0.03
2009	0.00	0.00
2010	0.00	0.00
2011	0.11	0.11
2012	0.11	0.11

2.3 Emission trends by sources

In 2012, the total emissions of 15.2 MtCO$_2$e from the AFOLU sector constituted the largest source of GHG emissions in Ghana, which accounted for 45% of the total national emissions. The 15.2 MtCO$_2$e emissions, represented 96.5% above the share of the total emissions in 2000. Emissions from aggregated sources and non-emissions from land contributed the largest share of 67.8% and 30.6% of the total AFOLU and nation's emissions respectively. The energy sector was the second largest source of emissions making up 40.1% of the national total emissions. This share was 6.3% lower than that of 2000. A majority of the emissions in the sector were mainly from stationery fuel combustion (52%) and transport (48%) sources. The remaining 16.2% were from the waste (14.6%) and IPPU (1.5%) sectors (see table 20).

Table 20: Total emissions distribution among sectors

Sectors & Sub-sectors	Emissions $MtCO_2e$				Percent Change	Share (%)	
	1990	2000	2010	2012	2010-2012	2010	2012
1. All Energy (combustion & fugitive)	**3.5**	**5.5**	**11.3**	**13.5**	**19.5**	**37.2**	**40.1**
Stationery energy combustion	2.0	2.7	6.5	7.0	7.7		
Transport	1.5	2.8	4.8	6.46	34.6		
Fugitive emissions	0.0	0.003	0.001	0.002	100.0		
2.Industrial Process & Product Use	**0.8**	**0.8**	**0.2**	**0.47**	**135.0**	**0.7**	**1.5**
3. AFOLU	**8.61**	**7.72**	**14.67**	**15.17**	**3.4**	**48.3**	**45.0**
Livestock	1.7	2.20	2.8	3.0	7.1		
Land	-3.0	-4.00	1.9	1.8	-5.3		
Aggregated and non-CO_2 emissions	9.9	9.52	10.0	10.3	3.0		
4. Waste	**1.3**	**2.3**	**4.2**	**4.5**	**7.1**	**13.8**	**13.4**
Total emissions (w/o AFOLU)	**5.6**	**8.6**	**15.8**	**18.5**	**17.1**		
Total net emissions (W/ AFOLU)	**14.2**	**16.3**	**30.4**	**33.7**	**10.9**	**100**	**100**

Over the period 1990-2012, total emissions from most of the sectors showed increasing trends except emissions from IPPU sector which showed a slight decline (see figure 8). In terms of changes in trends, emissions from IPPU sector recorded the highest increase of 135% from 2010 to 2012 (see table 20). For the energy sector, similar increases were observed, but it was not as sharp as that of the IPPU sector. The emissions increased from 3.5 $MtCO_2e$ in 1990 to 13.5 $MtCO_2e$ in 2010, and further increased by 19.5% in 2012. Similarly, the waste sector emissions rose by 71% and 7.1% from 1990 and 2010 to 2012 respectively. The AFOLU sector also recorded a 32.7% increase in emissions between 1990 and 2012 and 5.3% from 2010 to 2012.

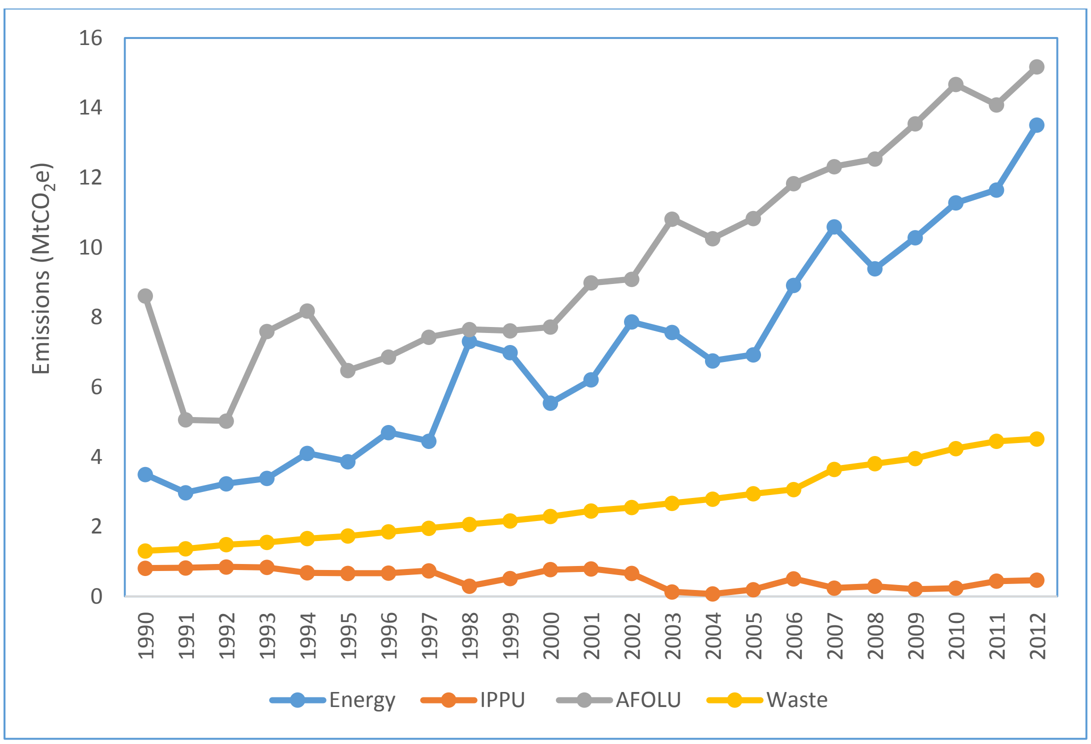


Figure 8: Trends of total emissions by sectors

The key drivers of the emission trends in the various sectors are as follows:

- **AFOLU** – The increases in emissions from AFOLU since 1990 was mainly driven by the emissions from forest land converted to cropland and grassland, biomass burning through wildfires, increases in animal populations, crop production, fertilizer use, and associated emissions.

- **Energy Sector**: The largest sectoral increase in emissions over the 1990 to 2012 period, of 52% (7 $MtCO_2e$), was from the stationary energy sector driven partly by increasing energy demand due to rising number of electrified households, expanding commercial/industrial activities and household incomes. The main driver for the increase in transport emissions was the continued growth in the number of passenger vehicles and expanding domestic aviation industry.

- **IPPU**: The decrease in emissions since 1990 is primarily driven by the declining operational capacity of the only Aluminum Plant in Ghana (VALCO).

- **Waste**: The increase in the net emissions from waste are due to growing populations, changing lifestyles and operational and management challenges at most landfill sites.

3.0 Energy Sector

3.1 Overview of the sector

In the energy sector, combustion of petroleum products and biomass through burning to produce electricity/heat/steam are the main sources of anthropogenic GHG emissions. The process of producing the heat/steam may be as a result of transformation of primary energy to secondary energy (e.g. thermal combustion of crude oil or diesel for electricity generation or conversion of biomass to charcoal). In the addition to transformation, the burning of secondary fuels such as diesel, gasoline, LPG to support stationery and mobile economic activities also generate emissions. Apart from the emissions that are generated through combustion, there are unintended emissions produced from upstream exploitation of oil and gas and petroleum refinery are also produced.

The level of emissions from the different energy activities are influenced by the following factors (a) amounts of fuels consumed or burnt; (b) rate of operations; (c) type of technology, and (d) environmental conditions. The accounting rules in the 2006 IPCC guidelines was used in the inventory to estimate the energy sector emissions. The guidelines make it possible to disaggregate activities in the energy sector that have the potential to generate emissions and categorized using codes.

3.1.1 Classification of energy sector activities

The 2006 IPCC guideline classifies the energy sector activities into combustion and fugitive sources. In the classifications of the activities the type of activity and processes through which the emissions are generated are taken into account. The level of disaggregation of the activities into the family of emission sources correspond to the various IPCC activity codes. There are two main categories under the energy sector; namely (a) fuel combustion (1.A) and (b) fugitive emission (1.B).

3.1.1.1 Fuel combustion activities (1.A)

Stationery Combustion (1.A.1, 1.A.2 and A.1.4)

Stationery combustion emissions mainly come from point source operation in power plants, industrial boilers, and refinery plants, stand-by generators, household and commercial cooking devices. Depending on the process and the type of activity, the stationery combustion sources are disaggregated into the following IPCC codes: (a) Energy industries (1.A.1) (b) Manufacturing industries and construction (1.A.2) and Other sectors (1.A.4). This classification captures most of the energy activities occurring in Ghana except in cases where such activities do not occur. Emissions from energy activities in mining, oil and gas, industry, ports etc. are already incorporated as inputs into the main activities under the categories above. Therefore having a separate emission account for the activities in the enclave industries would be a potential source of double counting.

Mobile Combustion (Transport - 1.A3)

Emissions from mobile combustion activities cover transport of passengers and freight through air, road, rail and water. The mobile fuel combustion category is further divided into (a) civil aviation (1.A.3a), (b) road transport (1.A.3b), railways (1.A.3c), water-borne navigation (1.A.3d) and other transport.

3.1.1.2 Fugitive Emission from Fuels (1.B)

In Ghana, the “fugitive emissions from fuels” occur in the offshore oil and gas industry through flaring (1.B.2.a.ii) and petroleum refining (1.B.2a.iii.4).

3.1.2 Data and methodology

3.1.2.1 Data needs and sources

The inventory was prepared using a combination of sources of activity data from national and international institutions. During the inventory preparation, considerable attention was given to proper documentation of data collection, processing and archiving. Priority was given to using data that was generated in the country (at plant or sector or economy wide levels). In cases where the data was not available in the country, the data in the databases of international organizations such as FAO and IEA were used. There were cases where comparison was done between the national and international data sources in order to detect patterns of inconsistencies and also understand the setting within which the data was generated. Country-specific activity data were mainly obtained from national energy statistics, national energy plan and the Ghana living standards survey report. Table 5 gives an overview of the main activity data datasets and their sources. Appropriate emission factors were obtained from the IPCC Emission Factor Database because of the unavailability of country-specific emissions factors.

3.1.3.2 Methodology

Description of methods and underlying assumptions

This section provides information on the methodological choices and assumptions behind the activity data and emission factors used in this inventory. The inventory was conducted in line with the methodologies contained in the 2006 IPCC Guidelines. The guidelines provided step-by-step guidance data selection, how methodology and underlying assumptions should be applied in a consistent manner. The guidelines further provided guidance on how: (a) the GHG emissions must be estimated using the AD and the EF, and (b) documentation, archiving and reporting must be done.

Activity data refers to the measure of level of intensity and/or frequency of use and/or number of the specific activities that result in emissions generation at different stages of use or production. For example, the amount of natural gas or crude oil used to produce a certain amount of electricity supplied through the national grid. Most of the country specific activity data were obtained from both primary and publicly available secondary sources. As much as possible, the data obtained covered the 1990-2012 time-series, however, where there were gaps, data from regional and international sources were used to fill the gaps. In the event that data was not available in the regional and international sources, appropriate statistical method (e.g. extrapolation, interpolation, splicing, etc.) consistent with the IPCC good practice guidance was applied to generate the missing data. Expert judgment was applied where very necessary and the underlining assumptions documented.

Emission factor is a measure of the rate at which the level, intensity, frequency of use or production will lead to specific GHG emission under defined conditions. Therefore the product of the activity data and the emission factor gives the total GHG emissions of a particular activity.

$$E = AD * EF$$

E = Emissions (unit)
AD = Activity data (unit)
EF = Emission factor

Generally, the inventory adopted a tier 1 methodology in the estimation using available data in the country. However, where sufficient data existed, tier 2 methodology was applied. Detailed descriptions of the respective methodologies or tiers are given in the specific sections of the source categories.

3.1.3 Fuel consumption patterns

3.1.3.1 Total fuel consumptions

Ghana is a net importer of crude oil and refined petroleum products. Crude oil production began in 2010 following the discovery and development of the Jubilee Field offshore in the Western Region of Ghana. Currently, the crude production level is about 2% of import requirements and it is largely exported offshore. The main secondary energy sources are from liquid, biomass and gaseous fuels. Liquid fuels consist of petroleum products, such as diesel, gasoline, LPG, kerosene, refinery fuel oil, refinery gas, petroleum coke, aviation kerosene, lubricants etc that were used for combustion, feedstock and non-energy activities. Wood fuels and charcoal were the two important sources of biomass that is used to support certain household, commercial and industrial activities. Natural gas is the main gaseous fuel used for electricity generation.

Between 1990 and 2012, Ghana consumed an average of 235.6PJ of fuel every year. In 2012 alone, the total fuel consumption amounted to 303.99 PJ which is 37.9% and 46.2% above the 2000 and 1990 levels of 188.3PJ and 163.6PJ respectively (see table 21). Additional 16.2 PJ of fuels (diesel and aviation kerosene) went into marine and aviation bunkering services in 2012. Although biomass constituted the dominant source of energy consumption, its share of the total energy consumption declined in the period 2012-1990 whereas the share of liquid fuels increased (see figure 9). The consistent decline in the biomass share of the final energy consumption from 1990 to 2012 was as a result of the growing availability of other alternative forms of fuels (liquid and gaseous fuels) through a number of government policies and technology improvement interventions. For example, the consistent promotion of LGP as alternative fuel for domestic and commercial cooking contributed to reducing biomass consumption for cooking in Ghana. As shown in figure 9, in 2012, liquid fuel constituted 53% of the total energy consumption followed by biomass (42%) and gaseous (5%).

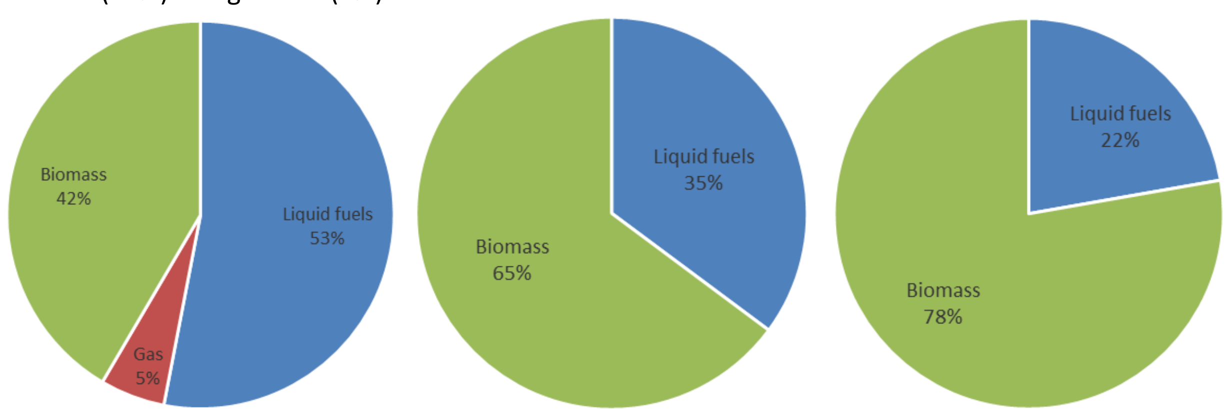


Figure 9: Percentage share of fuel consumption by type in 2012 (Left), 2000(middle), 1990(Right)

Table 21: Total fuel consumption shares

Years	Total (PJ)	Share of Liquid (%)	Share of biomass (%)	Share of Gaseous (%)
1990	163.59	22.25	77.75	
1991	139.36	22.42	77.58	
1992	155.03	21.99	78.01	
1993	159.96	22.36	77.64	
1994	173.05	26.26	73.74	
1995	175.63	23.84	76.16	
1996	193.12	27.32	72.68	
1997	185.37	26.36	73.64	
1998	218.20	40.50	59.50	
1999	216.72	38.76	61.24	
2000	188.34	35.16	64.84	
2001	229.59	31.56	68.44	
2002	264.76	35.41	64.59	
2003	273.93	32.35	67.65	
2004	235.47	34.09	65.91	
2005	265.07	30.17	69.83	
2006	298.34	35.69	64.31	
2007	369.73	33.53	66.47	
2008	317.50	35.27	64.73	
2009	333.94	37.31	62.69	
2010	299.99	43.51	51.53	4.96
2011	257.34	49.11	37.12	13.77
2012	303.99	53.04	41.54	5.42
% Change (2000-2012)	**26.81**	**28.40**	**-74.68**	**100.00**

3.1.3.2 Total fuel consumption by source activities

Liquid, biomass and gaseous fuels are the main fuel types consumed in Energy Industries, Manufacturing and Construction, Transport and Other Sectors. The total fuel consumption showed an increase from 163.59 PJ in 1990, 188.34 PJ in 2000 to 303.9 PJ in 2012. The rising energy consumption was as a result of growing demand for fuel use due to expanding economic activities in the country. The "other sectors category" was the largest source of energy consumption was followed by transport, manufacturing industry and construction and energy industry (see figure 10). The relatively high amount of biomass use in the "other sector category" explained why it dominated in the total energy consumption. For energy industries, significant levels of fuel use for thermal power generation started 1998 when the country's crude oil-fired thermal power plant became operational. Under transport, the increasing vehicle population and the expanding domestic aviation industry contributed to the steady increases in fuel consumption.

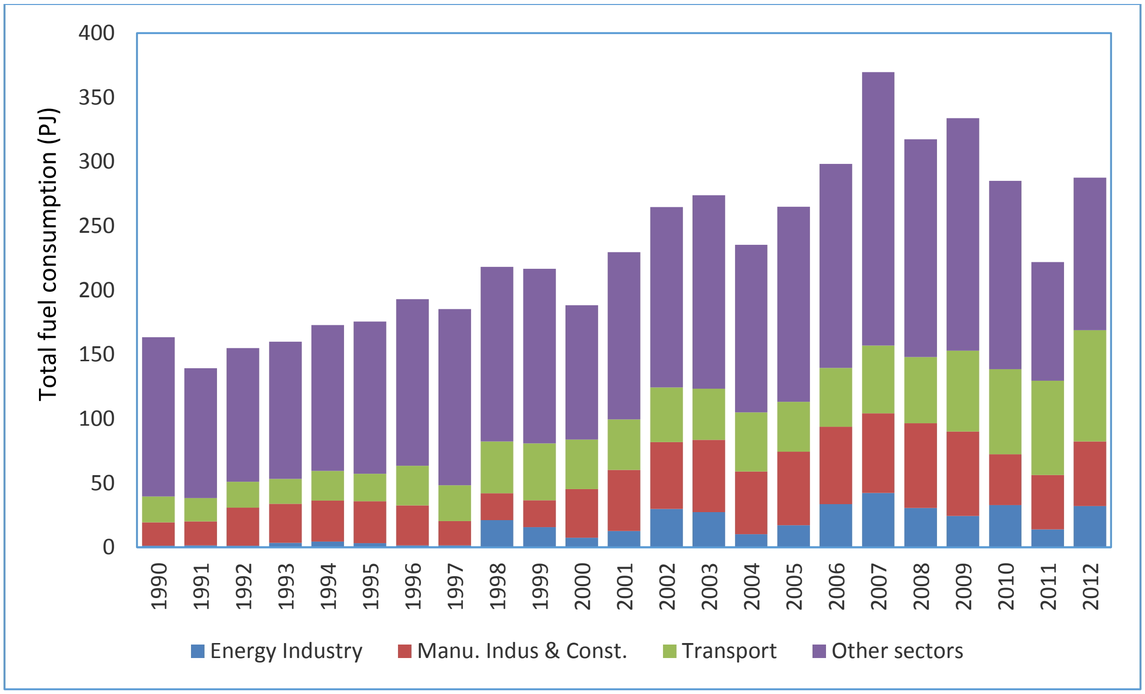


Figure 10: Trend of total energy consumption for the period 1990-2012

In 2012, the shares of liquid, biomass and gaseous fuels of the total consumption of 303.9PJ were as follows 53%, 41.5% and 5.4% (see table 22). Consumption of liquid fuel recorded 59.3% increment between 2000 and 2012 compared biomass which saw 3.3% increases in the same period. In 2010 and 2012, 14.8 PJ and 16.4 PJ of natural gas were consumed mainly for electricity generation.

Table 22: Total Fuel consumption for economic activities

Year	1990	2000	2010	2012	% change (2000-2012)
Liquid Fuel (PJ)	36.4	66.22	130.53	161.24	143.49
Gas Fuel (PJ)	-	-	14.88	16.48	100
Biomass Fuel(PJ)	127.29	122.12	154.59	126.26	3.39
Total Fuel (PJ)	163.59	188.35	299.99	303.9	61.35

3.1.3.3 Analysis of fuel consumption by types

Liquid fuels

Gasoline, diesel, RFO, kerosene, LPG, refinery gas and petroleum coke were Ghana's main liquid fuels A total 161.2PJ was consumed in 2012. The liquid fuel consumption of 161.12PJ in 2012 was 342.9% and 143.5% above 1990 and 2000 levels respectively (see table 23). As shown in table 25, in 2012, transport

(53.7%) continued to be the dominant source of liquid consumption in the country. This was followed by energy industries (19.9%), other sectors (15.3%) and manufacturing industry and construction (11.1%).

Table 23: Changes in total liquid fuel consumption among source categories

Year	1990	2000	2012	% Change (-1990-2012)	% Change (2000-2012)	Share (%) 2012
Total Liquid Fuel (PJ)	**36.4**	**66.2**	**161.2**	**342.9%**	**143.5%**	**100**
1. Energy Industries	1.2	7.6	32.1	**2575.0%**	**322.4%**	19.9
2. Manufacturing &Const.	6.2	8.6	17.9	**188.7%**	**108.1%**	11.1
3. Transport	20.2	38.4	86.6	**328.7%**	**125.5%**	53.7
4. Other Sectors	8.8	11.6	24.7	**180.7%**	**112.9%**	15.3

In terms of trends, transport consistently dominated liquid fuel consumption for the period 1990-2012 (see figure 11). Within the transport category, liquid fuel consumption in road transport was the highest followed by fuel consumption in domestic aviation, railways, inland water-navigation and other transport. The rising fuel consumption in road transport is illustrative of the impacts of the factors: (a) increased vehicle fleets in the country, (b) growing pressures from road traffic congestion, (c) inadequate alternative means of transport, and (d) lack of fuel economy or maintenance standards. On the other hand, it is important to recognize how the government deregulation policy of the petroleum sector is having positive impacts on opening of the downstream petroleum market. The opening up of the petroleum downstream market has led to the availability of a range of high grade fuels in the market which contributed to quality of fuels. The domestic aviation industry in Ghana has seen appreciable growth not just in terms of the number of active airlines operating in the country but more importantly, in terms of passenger uplifts. As at 2012, there were 4 active airlines, in the domestic aviation industry.

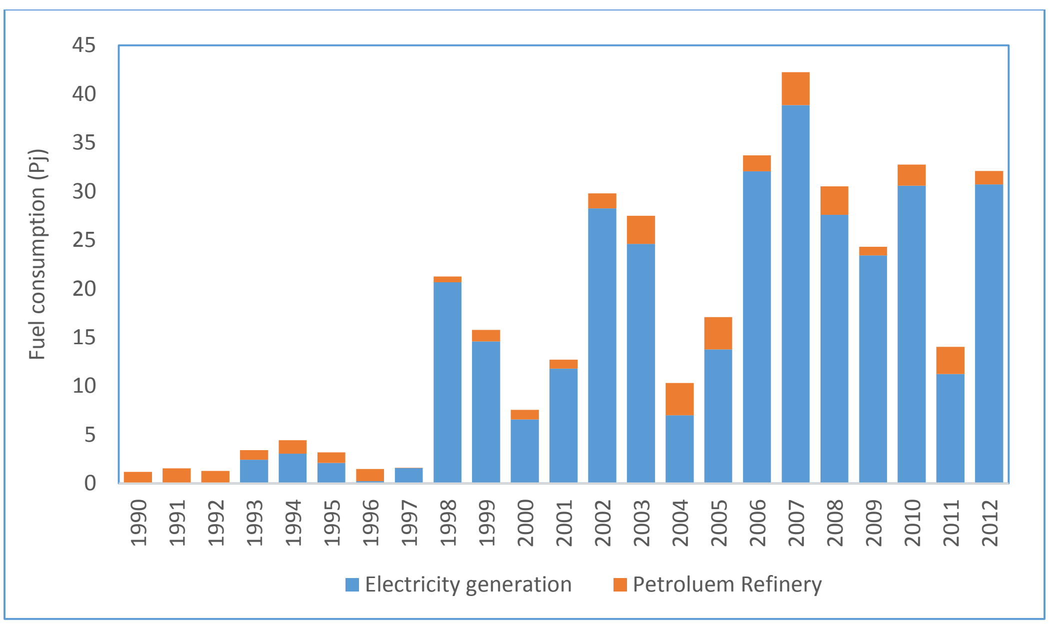


Figure 11: Trend of liquid fuel consumption by categories in fuel combustion

Electricity generation and petroleum refining are two main activities under energy industries in Ghana (see figure 11). Fuel consumption in energy industries is the second important source of liquid fuel consumption and showed notable increasing trend of 96.3% between 1990 and 2012. The rising fuel consumption patterns could be attributed to the increasing electricity generation from crude oil-fired thermal plants. Activities under "other sector category" such as commercial/institutional, residential and agriculture and forestry, was the third important source of liquid fuel consumption. The patterns of liquid fuel consumption in the other sectors category showed consistent increase since 2000. The growing use of diesel-fired and gasoline-fired stand-by generators by commercial operators and in households as a result of the frequent erratic electricity supply from the national grid was main factor driving fuel consumption in the other sectors.

Biomass Fuel

Activities in other sectors and the manufacturing industry and construction were the main sources of biomass consumption in the energy sector. In all, 126.3PJ of total biomass was consumed in both the other sectors and manufacturing industry and construction categories. The trend of biomass consumption showed marginal increase from 127.2 PJ in 1990 and peaked at 245.8 PJ in 2007 after which it declined steadily to 126.3 PJ in 2012 (see figure 12). The observed decline in biomass consumption after 2007 may be as result of the consistent implementation of the government policy on LPG promotion. In 2012, biomass consumption in other sector category accounted for 74.4% share of the total biomass consumption (see table 24). Manufacturing Industry and Construction was responsible for the remaining 25.6%. Within the other sectors category, wood fuel and charcoal were the main traditional fuel sources used for both commercial and household cooking. In manufacturing industry and construction category, wood fuel and charcoal were mainly used to produce heat to support the industrial activities.

Table 24: Biomass Consumption within the Energy Sector (PJ)

Year	1990	2000	2012	% change (1990-2012)	% change (2000-2012)	Share (%) 2012
Total Biomass	127.2	122.1	126.3	-0.7%	3.4%	100
Manufacturing & Const.	11.9	29.13	32.3	171.4%	10.9%	25.6
Other Sectors	115.2	92.98	93.9	-18.5%	1.0%	74.4

Biomass consumption in the other sector category only increased by 1% between 2000 and 2012 whereas for the same period, biomass consumption in manufacturing industry and construction recorded about 10% change.

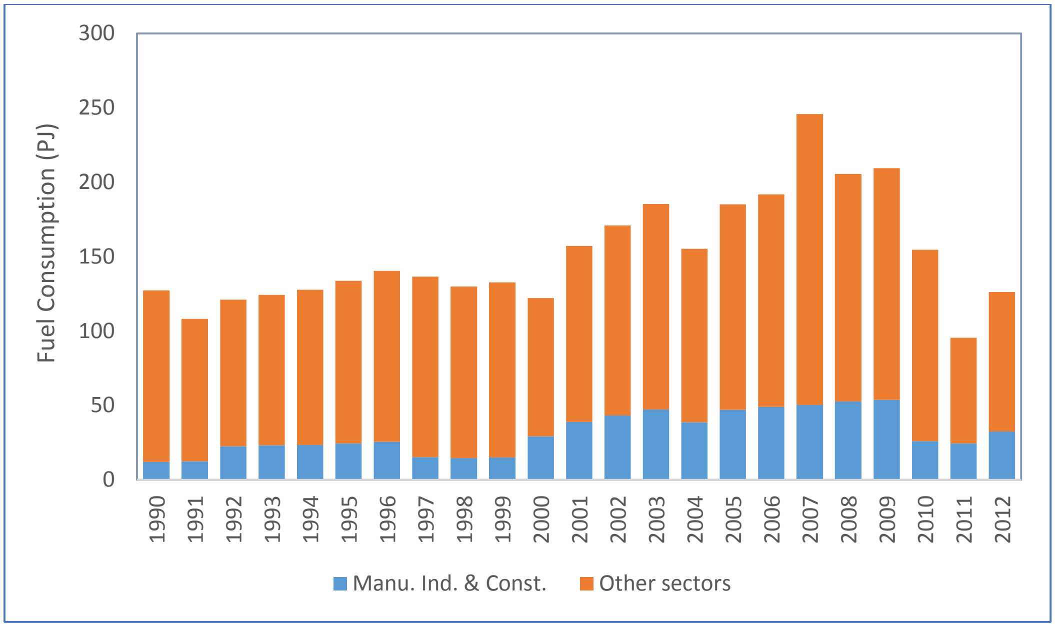


Figure 12: Trends of biomass consumption by categories

Gaseous Fuels

The use of Natural gas in thermal power generation to augment electricity generation from hydro and light crude began in 2010 following the completion of the West Africa Gas Pipeline from Nigeria. With the coming on stream of Nigeria gas, the total gas consumption for the generation of power increased by 35.4% in 2011 over the amount consumed in 2010 (see table 25). This is because, test runs and fine tuning may have contributed to the low consumption recorded for 2010. Though figures for 2012 were expected to further increase, the unfortunate destruction of a portion of the gas pipeline curtailed supplies and hence no power generation for close to eight months. Other challenge following the restoration of the pipeline was inadequate daily supply to the power producers hence the 16.5PJ for 2012.

Table 25: Natural Gas Consumption within the Energy Sector (PJ)

Year	2010	2011	2012
Total Gas Consumption in Electricity Generation	14.9	35.4	16.5

3.2 Analysis of energy sector emissions

3.2.1 Emission trends

In 2012, the total emission from the energy sector amounted to 13.51 $MtCO_2$ which constituted 43.8% of the total emissions and 85% of total anthropogenic CO_2 emissions (see table 27)e However when AFOLU emissions are excluded from the national totals, emissions from the energy sector made up 71.6% of the total emission stock. The 2012 total emissions of 13.51$MtCO_2e$ was 58.7% and 73.9% higher than 2000 and 1990 levels (see figure 13) as a result of rising emissions from transport. Out of the 13.51 $MtCO_2e$, emissions from fuel combustion made up of 99.9% whiles the remaining 0.01 came from fugitive emissions.

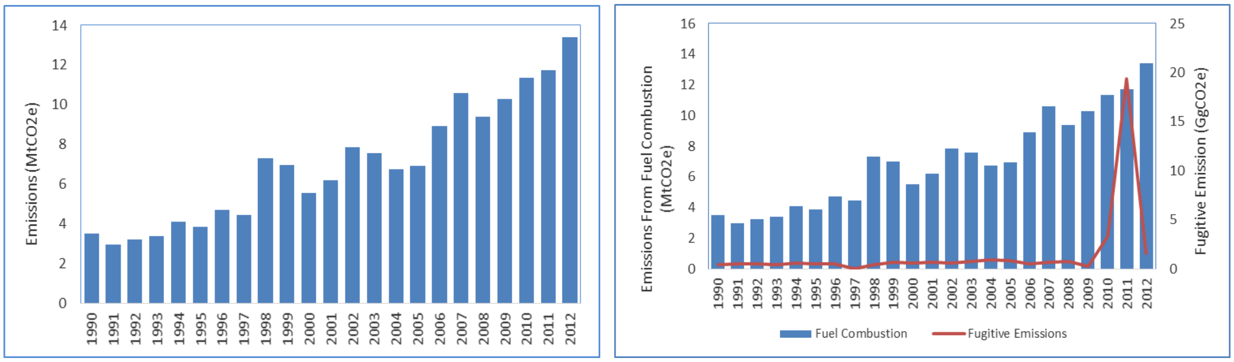


Figure 13: Trends of GHG Emissions from 1990-2012 for the energy sector

Within the energy sector, the transport category is the largest source of emissions followed by energy industries, other sectors and manufacturing industries and construction (see figure 14).

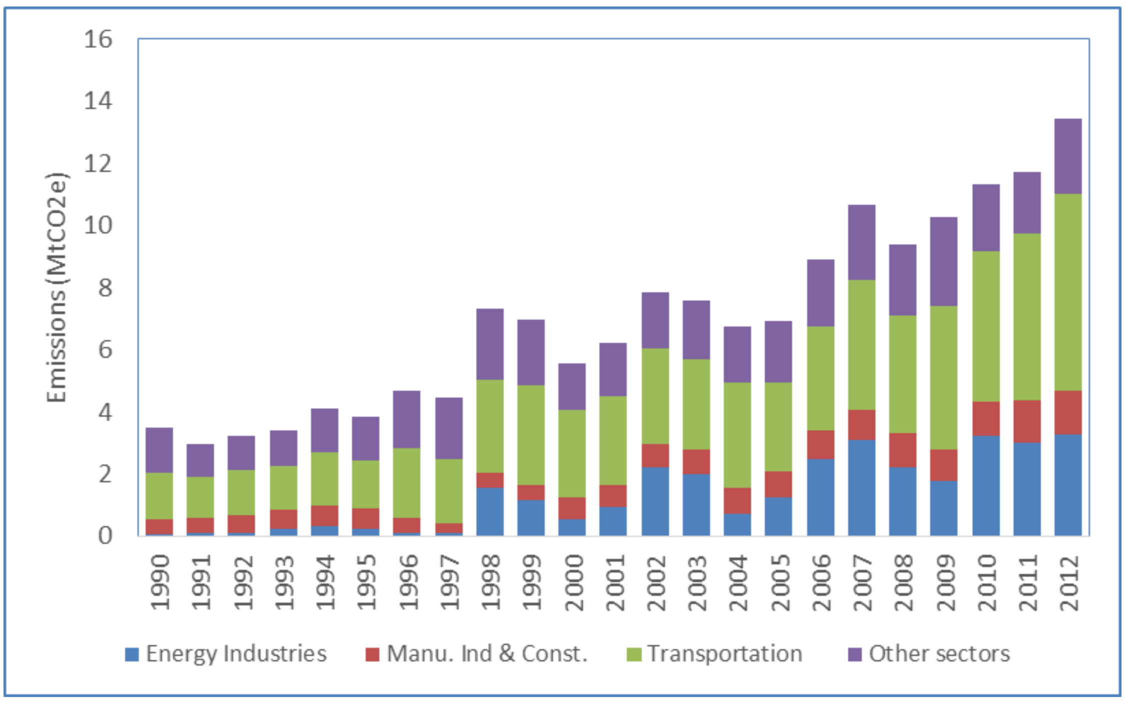


Figure 14: Contributions of fuel combustion activities to energy emissions

The shares of the total energy emission that came from transport were 42%, 51% and 47% in 1990, 2000 and 2012 respectively which illustrated the level of important transport emissions (see figure 15). The emissions from energy industries was the second largest source of emission in the energy sector. The energy industries emissions increased consistently from 2% in 1990, 10% in 2000 to 24% in 2012.The observed increase in emission in energy industry is attributed to consumption of light crude oil for thermal electricity generation. The emission contributions from other sectors showed a decrease from 42% in 1990 to 26% in 2000 and further to 18% in 2012. The decline in emission from other sector was explained by the reduction in consumption of traditional biomass.

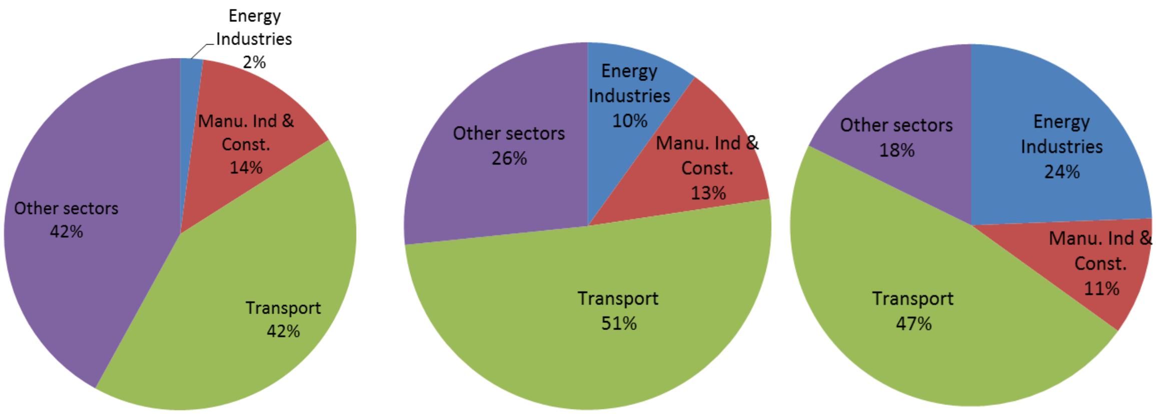


Figure 15: Contributions of emissions by sub-categories in 2012 (left), 2000 (middle) and 1990(right)

3.2.2 Emission trends by gases

Carbon dioxide was the dominant gas in the energy sector emissions constituting 93% of the total emissions. The remaining 5% and 2% were made of CH_4 and N_2O emissions respectively (see table 28). As shown by table 26, CO_2 and N_2O emissions recorded increasing trend for the period 1990-2012 whereas CH_4 emissions reduced by 13% in the same period. Although there were increases in CO_2 emissions from energy industries there were interspersed decline. ,. The increase in CO_2 in the energy sector were mainly was as a result of rise in transport and energy industries emissions.

The following specific factors contributed to the rise in CO_2 emissions; (a) traffic congestion in the urban areas, (b) crude-oil fired thermal electricity in the generation mix (c) use of stand-by generators in commercial activities during load shedding period, and (d) kerosene use in both domestic (non-electrified rural areas) and commercial (part of urban centres) lightning. Similarly there were notable increases in N_2O from activities reported under "other sectors". On the other hand, CH_4 emissions recorded consistent decline especially in the residential and commercial/institutional categories. The decrease in the CH_4 emission may be due to the impacts from the shift to efficient cooking stoves as well as the increasing penetration of LPG use may be as a result of government subsidy program.

Table 26: Trends of greenhouse gases emissions by gases for the period 1990 to 2012

Year	Carbon Dioxide [Mt]	Methane [Mt CO_2e]	Nitrous Oxide [Mt CO_2e]	Total Emissions [Mt CO_2e]
1990	2.60	0.72	0.18	3.50
1991	2.23	0.59	0.15	2.98
1992	2.44	0.62	0.18	3.23
1993	2.57	0.63	0.18	3.38
1994	3.26	0.63	0.19	4.08
1995	2.99	0.68	0.19	3.86
1996	3.76	0.72	0.21	4.70
1997	3.50	0.75	0.20	4.45
1998	6.38	0.72	0.21	7.31
1999	6.03	0.74	0.21	6.98
2000	4.76	0.59	0.19	5.54
2001	5.22	0.75	0.23	6.20
2002	6.78	0.82	0.26	7.87
2003	6.41	0.88	0.27	7.57

2004	5.76	0.74	0.24	6.75
2005	5.77	0.88	0.28	6.93
2006	7.70	0.92	0.30	8.91
2007	8.96	1.25	0.37	10.59
2008	8.08	0.98	0.32	9.39
2009	8.94	1.01	0.34	10.28
2010	10.23	0.84	0.27	11.35
2011	11.06	0.48	0.21	11.75
2012	12.51	0.64	0.27	13.42
% Change (2000-2012)	**163%**	**8%**	**42%**	**142%**

3.2.3 Emission trends by sources

Emissions from all the source categories recorded different level of increases for the period 1990-2012. The various increases were as a result of varying degree of impacts the rising fuel demand in the economy as well as changes in the fuel mix had on the emissions. For 1990-2000, transport and other sectors contributed to the majority of the emissions however, after 2000, energy industries became another major source. ., Emissions from energy industries recorded the fastest growth of 98% followed by transport (77%), manufacturing industries and construction (66%) and other sectors (38%). O Oil refinery and flaring from oil and gas activities in the Jubilee fields which started in 2010 were main sources of fugitive emission. The amount of fugitives emitted were mainly determined by the increases of CH_4 emissions (see table 27) from gas flaring which depended on the amount of gas re-injected in the wells and/or utilized on the oil rig.

Table 27: Total Energy Sector Emissions in ($GgCO_2$ equivalent) by source-category activities

Year	Energy Sector	Fuel Combustion	Energy Industry	Manu Ind. & Const.	Transport	Other Sectors	Fugitive Emissions	Oil & Gas
	1	**1.A**	**1.A.1**	**1.A.2**	**1.A.3**	**1.A.4**	**1.B**	**1.B.2**
1990	3.50	3.50	0.073	0.487	1.47	1.47	0.00042	0.00042
1991	2.98	2.98	0.097	0.501	1.31	1.06	0.00051	0.00051
1992	3.23	3.23	0.080	0.580	1.47	1.10	0.0005	0.0005
1993	3.38	3.38	0.243	0.601	1.42	1.11	0.0004	0.0004
1994	4.10	4.10	0.312	0.687	1.70	1.41	0.00056	0.00056
1995	3.86	3.86	0.224	0.664	1.56	1.42	0.00048	0.00048
1996	4.70	4.70	0.093	0.480	2.25	1.88	0.00052	0.00052
1997	4.45	4.45	0.118	0.301	2.06	1.97	0.00002	0.00002
1998	7.31	7.31	1.562	0.484	2.97	2.29	0.00043	0.00043
1999	6.98	6.98	1.155	0.471	3.23	2.13	0.00069	0.00069
2000	5.54	5.54	0.550	0.704	2.81	1.48	0.0006	0.0006
2001	6.20	6.20	0.927	0.719	2.88	1.68	0.00067	0.00067
2002	7.87	7.87	2.198	0.750	3.10	1.82	0.00063	0.00063
2003	7.57	7.57	2.012	0.763	2.91	1.88	0.00075	0.00075
2004	6.75	6.75	0.731	0.807	3.38	1.83	0.00097	0.00097
2005	6.93	6.93	1.229	0.852	2.87	1.97	0.00088	0.00088

2006	8.91	8.91	2.465	0.922	3.38	2.15	0.00051	0.00051
2007	10.59	10.59	3.081	0.965	4.19	2.43	0.00066	0.00066
2008	9.39	9.39	2.223	1.102	3.79	2.27	0.00074	0.00074
2009	10.28	10.28	1.781	0.992	4.63	2.88	0.00024	0.00024
2010	11.35	11.34	3.230	1.109	4.83	2.17	0.00334	0.00334
2011	11.75	11.73	2.997	1.386	5.36	1.99	0.01941	0.01941
2012	13.42	13.42	3.273	1.414	6.35	2.38	0.00161	0.00161
Change 2000-2012	142.2%	142.2%	495.1%	100.9%	125.9%	61.5%	168.3%	168.3%

3.2.4 Fuel Combustion activities (1.A)

This section provides information on emissions and key sources from fuel combustion activities. The information cover the following: comparison of sectoral/reference approach, feedstock/non-energy use, emission trends, methodology used, completeness, QA/QC and planned improvements.

3.2.4.1 Comparison of reference approach and sectoral approach

The Reference Approach (RA) is a top-down approach which used Ghana's total energy supply data to calculate CO_2 emissions from combustion of mainly liquid and gaseous fuels. The RA does not distinguish between different source categories within the energy sector but only estimates total CO_2 emissions from the Fuel Combustion (1A) source category. On the other, Sectoral Approach (SA) distinguished different source categories within the energy sector and estimate the emissions for the respective sources. The RA and SA often have different results because RA has no detailed information on how the individual fuels used in each category. It is therefore good practice to apply both RA and SA to estimate Ghana's CO_2 emissions from fuel combustion and compare the results of these two independent estimates. Significant differences may indicate possible problems with the activity data, net calorific values, carbon content, excluded carbon calculation. Typically, the gap between the two approaches is relatively small (5% or less) when compared to the total carbon flows involved. Therefore explanations should be provided when the difference is more than 5%.

Comparison of CO_2 emissions

The comparison and the factors that explained the differences between CO_2 emissions estimated using RA and SA have been provided below in tables 28 and 29. Figures 16 and 17 show the trends of emission estimated by RA, SA approaches and the differences between them.

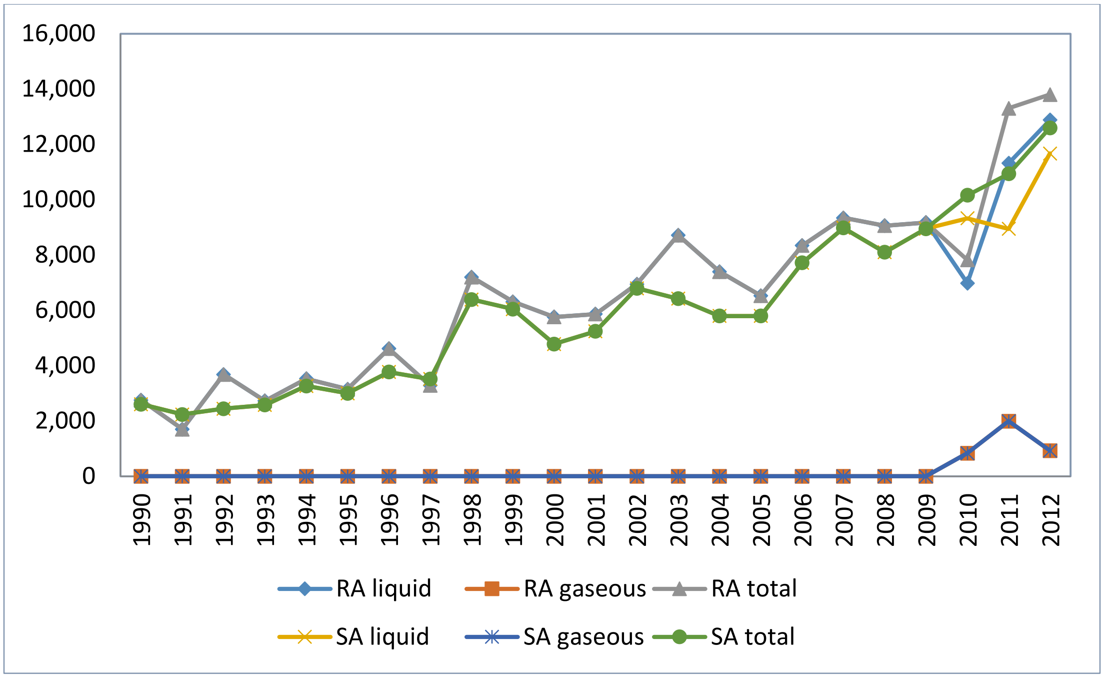


Figure 16: CO_2 emissions from reference approach and sectoral approach in $GgCO_2$ (1990 to 2012)

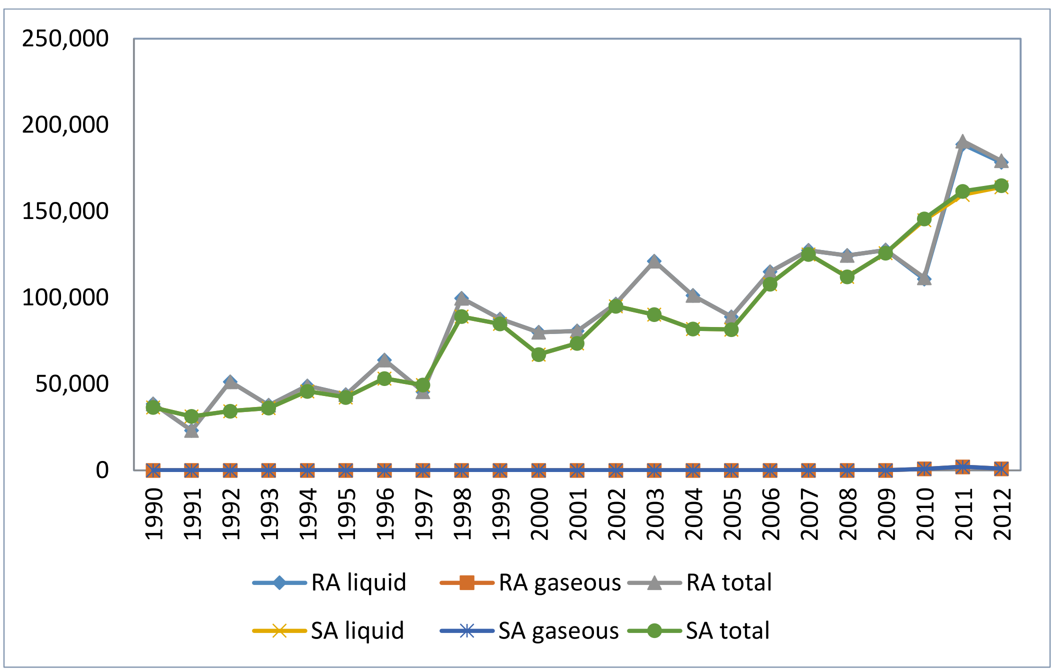


Figure 17: Energy consumption from reference approach and sectoral approach in TJ (1990 to 2012)

Table 28: Difference between CO_2 emissions reference and sectoral approach

Year	Reference Approach (RA)			Sectoral Approach (1.A) (SA)			RA/SA Difference		
	Liquid	**Gaseous**	**Total**	**Liquid**	**Gaseous**	**Total**	**Liquid**	**Gas**	**Total**
	[$MtCO_2$]	[$MtCO_2$]	[$MtCO_2$]	[$MtCO_2$]	[$MtCO_2$]	[$MtCO_2$]	%	%	%
1990	2.75	0.00	2.75	2.60	0.00	2.60	5.86		5.86
1991	1.70	0.00	1.70	2.23	0.00	2.23	-23.82		-23.82
1992	3.68	0.00	3.68	2.44	0.00	2.44	50.66		50.66
1993	2.73	0.00	2.73	2.57	0.00	2.57	5.83		5.83
1994	3.52	0.00	3.52	3.27	0.00	3.27	7.88		7.88
1995	3.15	0.00	3.15	2.99	0.00	2.99	5.18		5.18
1996	4.61	0.00	4.61	3.77	0.00	3.77	22.4		22.4
1997	3.28	0.00	3.28	3.51	0.00	3.51	-6.46		-6.46
1998	7.20	0.00	7.20	6.39	0.00	6.39	12.7		12.7
1999	6.31	0.00	6.31	6.04	0.00	6.04	4.32		4.32
2000	5.76	0.00	5.76	4.78	0.00	4.78	20.58		20.58
2001	5.86	0.00	5.86	5.24	0.00	5.24	11.94		11.94
2002	6.94	0.00	6.94	6.79	0.00	6.79	2.21		2.21
2003	8.72	0.00	8.72	6.42	0.00	6.42	35.87		35.87
2004	7.40	0.00	7.40	5.80	0.00	5.80	27.62		27.62
2005	6.53	0.00	6.53	5.79	0.00	5.79	12.66		12.66
2006	8.34	0.00	8.34	7.72	0.00	7.72	8.09		8.09
2007	9.34	0.00	9.34	8.98	0.00	8.98	4.08		4.08
2008	9.06	0.00	9.06	8.10	0.00	8.10	11.86		11.86
2009	9.17	0.00	9.17	8.95	0.00	8.95	2.53		2.53
2010	6.98	0.83	7.82	9.33	0.83	10.16	-25.13	0	-23.06
2011	11.31	1.99	13.30	8.94	1.99	10.93	26.49	0	21.67
2012	12.88	0.92	13.80	11.67	0.92	12.59	10.34	0	9.58

Negative sign indicates that SA CO_2 emissions are higher than RA CO_2 emissions

Table 29: Energy consumption from reference and sectoral approach

Year	Reference Approach (RA)			Sectoral Approach (1.A) (SA)			RA/SA Difference		
	Liquid	Gaseous	Total	Liquid	Gaseous	Total	Liquid	Gas	Total
	[PJ]	[PJ]	[PJ]	[PJ]	[PJ]	[PJ]	%	%	%
1990	38.49	0.00	38.49	36.40	0.00	36.40	5.74		5.74
1991	23.01	0.00	23.01	31.25	0.00	31.25	-26.34		-26.34
1992	51.33	0.00	51.33	34.31	0.00	34.31	49.62		49.62
1993	37.73	0.00	37.73	36.03	0.00	36.03	4.71		4.71
1994	48.90	0.00	48.90	45.75	0.00	45.75	6.88		6.88
1995	43.82	0.00	43.82	42.25	0.00	42.25	3.72		3.72
1996	63.96	0.00	63.96	53.21	0.00	53.21	20.22		20.22

1997	45.55	0.00	45.55	49.40	0.00	49.40	-7.78		-7.78
1998	99.69	0.00	99.69	89.00	0.00	89.00	12.01		12.01
1999	87.65	0.00	87.65	84.76	0.00	84.76	3.41		3.41
2000	80.00	0.00	80.00	67.11	0.00	67.11	19.2		19.2
2001	80.67	0.00	80.67	73.52	0.00	73.52	9.74		9.74
2002	96.33	0.00	96.33	95.03	0.00	95.03	1.37		1.37
2003	121.14	0.00	121.14	90.12	0.00	90.12	34.43		34.43
2004	101.28	0.00	101.28	81.87	0.00	81.87	23.71		23.71
2005	88.91	0.00	88.91	81.50	0.00	81.50	9.09		9.09
2006	114.97	0.00	114.97	107.85	0.00	107.85	6.6		6.6
2007	127.44	0.00	127.44	125.08	0.00	125.08	1.88		1.88
2008	124.46	0.00	124.46	111.98	0.00	111.98	11.14		11.14
2009	127.61	0.00	127.61	125.79	0.00	125.79	1.44		1.44
2010	110.73	0.83	111.56	144.85	0.83	145.68	-23.56	0	-23.42
2011	188.75	1.99	190.74	159.60	1.99	161.59	18.26	0	18.04
2012	178.40	0.92	179.33	164.00	0.92	164.93	8.78	0	8.73

Negative sign indicates that SA fuel consumption are higher than RA fuel consumption

Explanations of difference

The differences in CO_2 emissions between RA and SA ranges from 2.2% to 50.7% (see table 29). Generally, the RA CO_2 emissions were higher than SA CO_2 emissions, however, there were isolated years (i.e.1992, 1997, 2010) where SA CO_2 emissions were higher than the RA CO_2. The observed inconsistencies in the trends of CO_2 emissions from the two approaches may be due to the following reasons: (a) statistical difference recorded between supply and consumption of petroleum products and (b) some observed variations associated with secondary data used to derive the stock change. Specific reasons are provided below to explain the difference between CO_2 emissions for the major fuels.

Liquid Fuels

- The national energy balance was based on mass-balanced and not carbon balanced. That approach introduced inherent consistencies in the fuel balance.
- Significant statistical differences in the supply and consumption figures in the energy balance accounted for the large and inconsistent differences between the RA CO_2 and SA CO_2 within the time series.
- Data on annual stock change for liquid fuels were hardly reported in the energy balance. Therefore it was derived using production, imports, export, and consumption and ending stocks figures. Because most of the data on stock changes were not reported in the energy balance but calculated, there was possibility of overestimations or underestimations.
- *Kerosene* – RA and SA excluded CO_2 emissions from non-energy use of kerosene in industrial process.
- *Lubricants* - The RA excluded the share of lubricants used for non-energy purposes. However, in industrial processes sector, additional lubricant use was reported under 2.2D, mainly to support lubrications in stationery and mobile engines which were oxidized in small fractions (20%).

Comparison of energy consumption

The differences in energy consumption between the two approaches were due to of the following reasons:

- Transformation and distribution losses were not considered in the sectoral approach;
- High statistical difference between supply and consumption of fuels; and
- Possible overestimated stock change figures in years where they were not reported in the energy balance.

3.2.4.2 International bunker fuels

Fuels for international bunkers formed part of the original inventory estimates; but were set aside as memo item (information note) from the overall inventory results, because, the international rules for assigning the emissions are still being developed. International bunkers consisted of supply of jet kerosene and diesel fuels for international aviation and marine bunkers services. In 2012, the share of international bunkers amounted to 5.1% of the total national fuel supply which translate to 16.18 TJ. Out of the 16.18 TJ, 11.30TJ (70%) were deposited in the marine bunkers whereas the remaining 4.87 TJ (30%) went to international aviation bunkers (see table 30). The overall emissions from the international bunkers (marine and aviation bunkers) increased from 0.04 $MtCO_2e$ in 1990 to 0.34 $MtCO_2e$ in 2000 and further to 1.2 $MtCO_2e$ in 2012. Of the 1.2 $MtCO_2e$, international marine navigation accounted for 70.6% whereas the remaining 29.4% was the contributions from international civil aviation.

Methodological issues

The emissions from inland water-borne navigation (mainly Volta Lake transport) was reported separately from the international marine navigation. For the international marine navigation, diesel supply obtained from Ghana bunkering services, diesel export data reported in the national energy balance and expert judgment were used to derive the total diesel consumption for international marine navigation. In order to avoid potential double counting in the fuel balance, the total diesel supply to the Ghanaian market for consumption were separated from those meant for export. For international civil aviation, emissions were estimated based on the amounts of jet kerosene allocations to the Ghana bunkering services. However, because the domestic consumption of jet kerosene (ATK) for the local civil aviation industry were reported separately by the oil marketing companies it was possible to use bottom-up approach to split the share of international aviation from the domestic aviation. The bottom-up approach also helped to double check the quantities of ATK production from the local refinery as reported in the energy balance. IPCC default emission factors for both ATK and diesel were used in the tier 1 approach described in the 2006 IPCC guidelines to calculate the emissions. The tier 1 approach followed the international airport traffic (LTO-cycles) and international cruise traffic for IFR-flights (International Flight Rules).

Table 30: Trends of ATK and diesel Consumption and GHG emissions for international bunkers

Year	Activity (PJ)					GHG Emissions in $MtCO_2e$		
	Total Fuel Supply	Domestic Consumption	International Bunkers	Aviation Bunkers	Marine Bunkers	International Bunkers	Aviation Bunkers	Marine Bunkers
1990	164.11	163.59	0.52	0.48	0.04	0.0374	0.03452	0.00288
1991	140.28	139.36	0.92	0.88	0.04	0.0668	0.06347	0.00332
1992	156.49	155.03	1.46	1.40	0.06	0.10548	0.10072	0.00476
1993	160.67	159.96	0.71	0.67	0.04	0.05124	0.04817	0.00307
1994	174.55	173.05	1.50	1.43	0.07	0.10865	0.10304	0.00561

1995	176.58	175.63	0.95	0.95	0.07	0.06843	0.06843	0.0056
1996	195.56	193.12	2.44	2.39	0.06	0.17634	0.17208	0.00426
1997	187.87	185.37	2.49	2.48	0.02	0.17995	0.17854	0.00141
1998	221.84	218.20	3.63	3.60	0.04	0.26214	0.25941	0.00273
1999	220.73	216.72	4.01	3.98	0.04	0.28947	0.28684	0.00263
2000	193.04	188.34	4.70	4.67	0.03	0.33879	0.33687	0.00191
2001	232.39	229.59	2.80	2.76	0.04	0.20221	0.19908	0.00313
2002	267.96	264.76	3.20	3.12	0.08	0.23125	0.2252	0.00605
2003	277.18	273.93	3.25	3.10	0.15	0.23452	0.22346	0.01106
2004	239.24	235.47	3.77	3.71	0.06	0.27184	0.26726	0.00458
2005	269.24	265.07	4.17	4.12	0.06	0.30104	0.29687	0.00417
2006	305.07	298.34	6.73	3.96	2.77	0.49274	0.28542	0.20732
2007	375.87	369.73	6.14	4.24	1.90	0.44819	0.30557	0.14262
2008	324.08	317.50	6.58	4.11	2.47	0.4814	0.29662	0.18478
2009	341.45	333.94	7.51	4.30	3.20	0.55019	0.31031	0.23989
2010	307.89	299.99	7.90	3.74	4.16	0.58094	0.26975	0.3112
2011	280.67	257.34	23.33	4.67	18.66	1.73387	0.33669	1.39719
2012	320.16	303.99	16.18	4.87	11.30	1.19791	0.35162	0.84629
Change (2000-2012)	66%	61%	245%	4%	44160%	254%	4%	

3.2.4.3 Feedstock and non-energy use of fuels

Non-energy use of fuels were not considered in the national energy balance. Therefore data was sourced from the International Energy Agency (IEA) database. The feedstock and non-energy use of fuel include bitumen, some kerosene, lubricants and other fuels such as tar and grease products that were used in transport, construction and industrial activities. For example, in Ghana, Tema Lube Company produces lubricants for the oil marketing companies which are used for lubrication applications in transport and industry. For fraction of carbon stored, the IPCC default values were applied for all fuels except for lubricants use in transport and industry lubrication where only 20% was oxidized.

Lubricants

- *Manufacture of lubricants:* emissions were assumed to be included in total emissions from category 1A1.b petroleum refinery.
- *Use of lubricants:* emissions from the use of motor oil were included in CO_2 emissions from 2.2D (lubricant and solvent use) under industrial process.
- *Disposal of lubricants:* emissions from disposal of lubricant (waste oil) were not accounted for because of lack of data. The disposal was a considered non-combustible activity because significant amount were used to preserve wood products which are considered non-energy.

Bitumen

- *Manufacture of bitumen:* emissions were assumed to be included in total emissions from category 1A1.b petroleum refinery.
- *Use of bitumen:* indirect CO_2 emissions from the use of bitumen for road paving and roofing that was not reported because of lack of data.

Kerosene

- *Production of kerosene:* emissions were assumed to be included in total emissions from category 1A1.b petroleum refinery.
- *Non-energy use of kerosene:* There were no information on the emissions from non-energy use of kerosene industry (such as cleaning of aluminum sheets).

3.2.4.4 Time series consistency

In order to ensure that the emission estimates in the time series were consistent, as far as possible, the emission were calculated using similar methods and data sources in all the years. This was to avoid inconsistencies and at the same time, ensure that emission trends were neither overestimated nor underestimated. Using different methods and data could introduce bias in the emission trends. Therefore where methodological and data changes occurred or where there were time series gaps, recalculation and appropriated IPCC methods for resolving data gaps were applied. In the energy sector, recalculation was done for the previous estimate between 1990 and 2006 whereas the rest of the time series were newly estimated.

3.2.4.4.1 Description of recalculations

In general, the main reasons recalculation were done in the energy sector was as a result of the use of newly available activity data from different national and international sources. The changes in the input activity data emerged from (a) discovery of new datasets, (b) revision or updating of the energy statistics, (c) new survey results, (d) filling of time series data gaps with international data sources (mainly international energy agency), appropriate trend interpolation or extrapolation, relocation of fuels, changes in the use of inconsistent fuel conversion factors, changes in the use of appropriate emission factors between the revised 1996 and 2006 IPCC guidelines, and refinement in the use of expert judgments. Detailed descriptions of the reasons for, and impacts of recalculations have been provided under each source-specific category. Table 31 shows result of the assessment of the impacts of recalculation on the previous estimates.

Table 31: Assessment of overall impacts of recalculations in the energy sector

Year	CO_2 (Mt)			CH_4 ($MtCO_2e$)			N_2O ($MtCO_2e$)		
	PE	LE	% Change	PE	LE	% Change	PE	LE	% Change
1990	2.57	2.57	0.05	0.02912	0.03429	17.72	0.00026	0.00057	118.67
1991	2.08	3.26	56.7	0.03006	0.02823	-6.09	0.00026	0.00048	87.66
1992	2.60	2.99	15.19	0.03113	0.02931	-5.86	0.00027	0.00057	110.28
1993	2.81	3.76	33.93	0.03528	0.03002	-14.9	0.0003	0.00058	92.82
1994	2.98	3.50	17.48	0.03567	0.03099	-13.11	0.00031	0.00061	97.65
1995	3.29	6.38	93.71	0.03741	0.03245	-13.26	0.00033	0.00062	88.78

1996	3.60	6.03	67.82	0.03744	0.03425	-8.52	0.00033	0.00069	110.12
1997	3.70	4.76	28.85	0.03787	0.03578	-5.53	0.00033	0.00063	92.78
1998	4.24	5.22	23.11	0.03774	0.03425	-9.25	0.00003	0.00068	1847.15
1999	4.74	6.78	43.23	0.04061	0.03516	-13.43	0.00036	0.00069	90.7
2000	4.87	6.41	31.51	0.04166	0.02788	-33.07	0.00036	0.00061	70.43
2001	5.28	5.76	9.15	0.06141	0.03572	-41.83	0.00053	0.00076	42.95
2002	5.73	5.77	0.66	0.06385	0.03902	-38.88	0.00056	0.00085	51.24
2003	6.36	7.70	21.07	0.06611	0.04212	-36.28	0.00057	0.00089	55.57
2004	5.75	8.96	55.91	0.06763	0.03545	-47.59	0.00058	0.00079	36.18
2005	6.31	8.08	28.05	0.06791	0.04191	-38.28	0.0006	0.00089	47.87
2006	7.60	8.94	17.54	0.06846	0.04369	-36.19	0.00062	0.00095	53.75

NB: PE – Previous estimates, LE- Latest estimates

Reasons for recalculations

Recalculations were done as a result of revision of the activity data in the previous estimates and addition of new fuel data. This explained the observed decreases and increases in the emissions in table 12 above.

Natural Gas

- New dataset of 182.93TJ and 243.25TJ of natural gas were added to 2002 and 2003 respectively.
- The difference between old and new explained the increases in emission 2002 and 2003 in 1.A1

Crude Oil

- New dataset on crude oil of 208.82TJ, 16598.65TJ and 14533.22TJ in 1997, 1998 and 1999 respectively were added. This contributed to emissions in 1.A1
- Revision of previous crude oil due to changes in conversion factors (ktoe to TJ) resulted in reduction of crude oil consumption in the latest estimate by 6657.24TJ in 2000, 230.28TJ in 2001, 448.49TJ in 2002, 406.82TJ in 2003, 126.61TJ in 2004, 245.28TJ in 2005 and 575.31TJ in 2006. The revision contributed to the reduction emission in 1.A1.

Diesel

- Revision of the data on quantities of diesel consumed due to changes in conversion factors from ktoe to TJ resulted in reduction of diesel consumption.
- Discovery of new diesel consumption data sets to replace the old activity because of the changes in the national energy statistics
- Exclusion and relocation of diesel input for electricity between 1999 and 1992 to other categories.

Other Kerosene

- Reallocation of other kerosene from Manufacturing industry and construction (1.A2) to other sectors (commercial/institutional-1.A4a) between 1990 and 2006.
- Changes in total other kerosene consumption due to revision in the national energy statistics and discovery of data from international energy agency.
- Revision of the other kerosene due to changes in conversion factors from ktoe to TJ.

LPG

- Changes in total LPG consumption due to revision in the national energy statistics and discovery of data from international energy agency.

- Revision of the quantities of LPG consumption due to changes in conversion factors from ktoe to TJ.
- Relocation of LPG from 1.A2 from 2000 to 2006 as well as from 1.A3 from 1990 to 1993 to other sectors (commercial/institutional-1.A4a).

RFO

- Inclusion of new dataset of RFO into oil refinery under I.A1 from 1990 to 2006.
- Revision of the RFO due to changes in conversion factors from ktoe to TJ in 1.A2.

ATK

- Exclusion of ATK from the fuel reported in 1990.
- Inclusion of ATK consumption years 2002 to 2006 due to the picking up of the domestic aviation market in Ghana

Refinery Gas

- Inclusion of new dataset of Refinery gas into oil refinery under I.A1 from 1990 to 2006 due to discovery of new sources from Tema Oil Refinery.

Petroleum Coke

- Inclusion of new dataset of Petroleum Coke into oil refinery under I.A1 from 1990 to 2006 due to discovery of new sources from Tema Oil Refinery.

Wood fuel

- Inclusion of wood fuel consumption into 1.A2 and 1.A4 due to discovery of due data availability in the national energy statistics.

Charcoal

- Inclusion of charcoal consumption in other sectors (commercial/institutional-1.A4a) between 1990 and 2006.
- Inclusion of charcoal emissions into 1.A4 except CO_2. Previous estimate reported charcoal emissions as memo items.

3.2.4.4.2 Filling of data gaps

Data gaps identified during the inventory were filled using approved approaches prescribed in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000) and fuel balance approach which have been described in the table 32 below. The methodology used for each data gap identified depended on the types and nature of data.

Table 32: Overview of data gaps

Category	Gaps	Methodology used	Justification for methodology used	Description of approach of filling of gaps
Electricity generation (1.A1a)	Lack of time series for diesel data inputs for electricity generation plant (decommissi	overlap approach	Data gaps in the time series data and where consistent correlation or relationship existed between activity data being used	One category where this approach was used is the energy industries where a relationship was observed between the amounts of power consumed for thermal power generation and the quantum of electricity generated by a specific plant. A ratio was calculated between the amount of diesel consumed by the plant and the power generated for the years with complete data. The average of these calculated ratios was

	oned Tema Diesel plant)			applied to the power generated in the years with the data gap to obtain the quantities of diesel consumption.
ATK fuel consumption time series	Non-availability of ATK for 2000-2005, 2011-2012	Interpolation/ extrapolation	ATK consumption data were collected the beginning and ending years. Missing data in between years	Trend interpolation using the difference between the reported beginning and end year diesel consumption data. 2010 diesel consumption data was used to project 2011 and 2012 consumption.
Stock changes	Missing stock change data	Fuel balance	Used in years where both National statistics and IEA do not report on stock change	Used balance between production, import against consumption, export and ending stock.
Road Transport	Missing vehicle population data from1990 and 1995	Trend Extrapolation	Because the data gap occurred at the beginning of the time series.	Vehicle population between 1990-and 1994 was generated using annual growth of the five years of the period (1995-2000) data reported by DVLA.

3.3 Description of source-specific categories

3.3.1 Energy industries (1. A1)

Key Category: CO_2 emission - Liquid and gaseous (2012)

3.3.1.1 Energy industries emissions trends

The total emissions from energy industries amounted to 0.073 $MtCO_2e$, 0.55 $MtCO_2e$ and 3.30 $MtCO_2e$ in 1990, 2000 and 2012 respectively, representing 2%, 10% and 24%, of the total fuel combustion emissions in 1990, 2000 and 2012 (see figure 20). The observed increases in the emission trends was as a result of the influence rising levels electricity generation from the LCO-fired thermal plants. However, since 2010, the availability of the natural gas for electricity generation because of its cost effectiveness. Since 2010, natural gas consumption for electricity generation has increased from 14.88PJ, to 35.44PJ in 2011 to 16.49PJ in 2012. In 2012, the total liquid fuel consumption in energy industries accounted for 20% of the stationery combustion installations in the country. Between 1990 and 2012, the consumption of liquid fuels increased by nearly 96% from 1.18PJ in 1990 to 32.07PJ (see figure 18). While between 2000 and 2012, consumption increased by 76%, it recorded marginal decline by 5.1% from 2006 to 2012. Significant amounts of the liquid fuels in the energy industries were consumed in the electricity generation (nearly 95.7% in 2012).

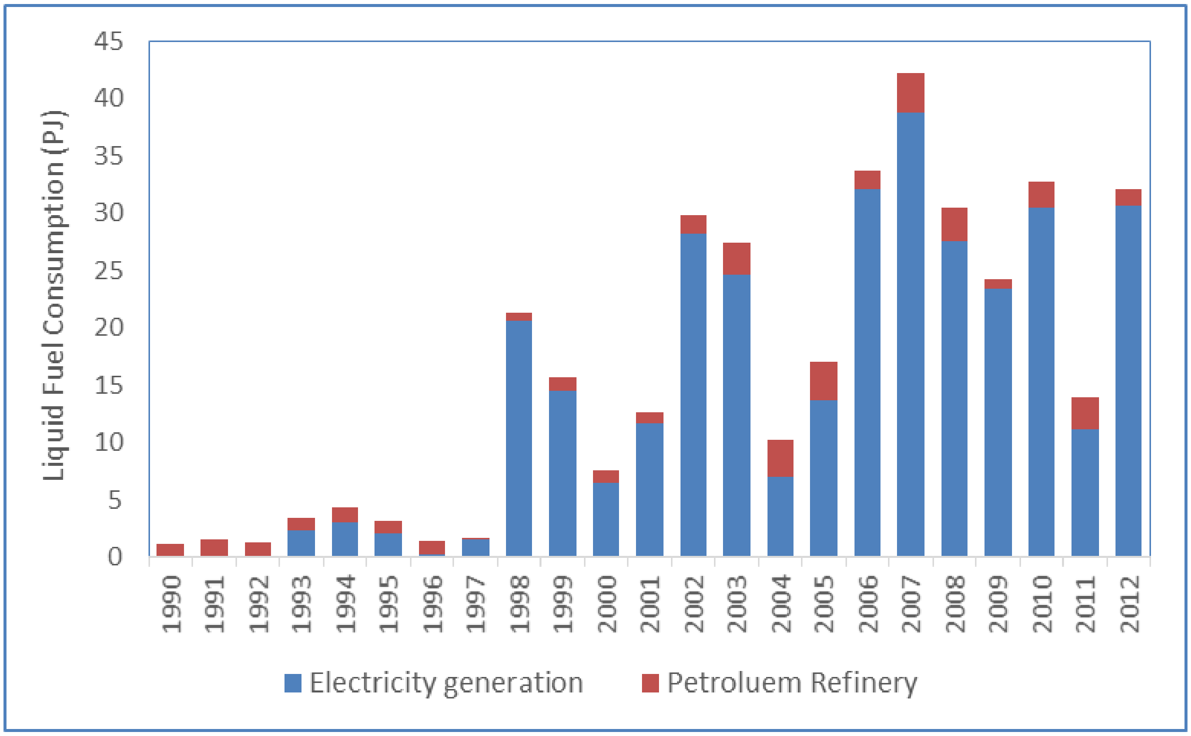


Figure 18: Trends of liquid fuel consumption in energy industries

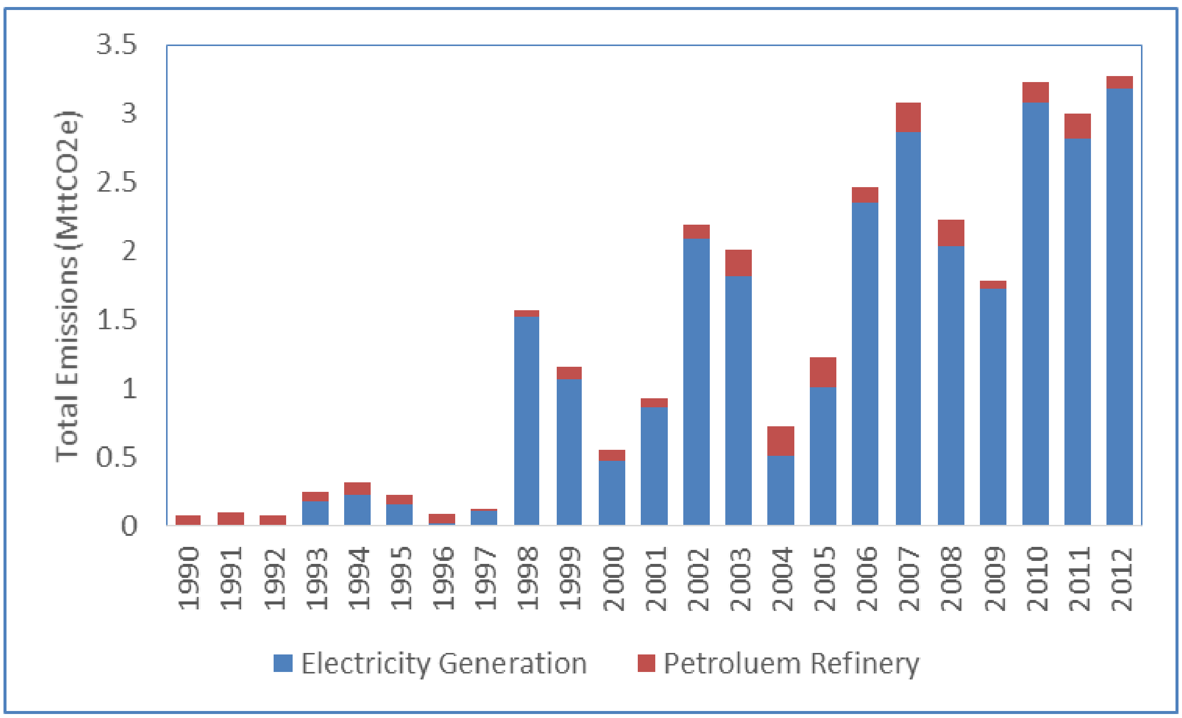


Figure 19: Trends of emissions from Energy Industries

3.3.1.2 Description of sub-sector activities

Electricity generation (1.A.1ai)

Electricity is mainly produced from hydro and thermal sources to the national electricity grid. In 2012, out of the 12,024GWh electricity generated, 67.1% was hydro whereas the remaining 32.9% was thermal sources. The thermal electricity generation was from the seven main publically and privately owned thermal plants which run on light crude oil (LCO), diesel and natural gas fuels. Out of the seven thermal plants that generated electricity to the national grid, four of them i.e. (Takoradi Power Company (TAPCO), Takoradi International Company (TICO), Cenit Energy Ltd (CEL), and Tema Thermal 1 Power Plant (TT1PP) used LCO and natural gas as input fuels. Sunon Asogli Power (Ghana) Limited (SAPP) and Tema Thermal 2 Power Plant (TT2PP) solely run on natural gas as input fuel.

The remaining thermal plants are strategic power plants which use diesel on stand-by. Between 1990 and 2012, share of electricity generation from thermal sources increased considerably because of (a) Ghana has exhausted its large hydro source of electricity generation, (b) the increasingly unreliable power generation from hydro sources and (c) increasing demand for electricity especially in peak demand periods. This has resulted in significant use of LCO, diesel and natural gas to support electricity generation. As at 2012, 64.14%, 35.17% and 0.68% of thermal electricity were produced from LCO, natural gas and diesel sources respectively. The use of LCO to generate electricity started in 1997 with 0.2PJ and increased to 30.03PJ in 2012. In addition, in 2010 the use of natural gas for electricity generation in Ghana commenced when the West Africa Gas Pipeline become operational (see table 33).

Table 33: Trends in fuel mix and emissions for the electricity sub-category

Year	LCO Inputs for Electricity Generation [TJ]	Diesel Inputs for Electricity Generation[TJ]	Natural Gas for Electricity Generation [TJ]	Total emissions [$MtCO_2e$]
1993	0.00	2422.90	0.00	0.180
1994	0.00	3042.97	0.00	0.226
1995	0.00	2091.73	0.00	0.155
1996	0.00	219.81	0.00	0.016
1997	4.99	1365.32	0.00	0.117
1998	208.92	4040.26	0.00	1.521
1999	16598.65	37.26	0.00	1.072
2000	14533.22	15.49	0.00	0.481
2001	6529.78	0.00	0.00	0.865
2002	11762.99	2512.08	182.93	2.088
2003	25707.40	2048.60	243.25	1.823
2004	22531.26	0.00	0.00	0.513
2005	6978.14	0.00	0.00	1.011
2006	13751.13	0.00	0.00	2.358
2007	32054.56	4189.31	0.00	2.859

2008	34642.59	2834.88	0.00	2.029
2009	24730.59	294.49	188.41	1.722
2010	23120.77	648.12	14875.70	3.0834
2011	29915.10	226.92	35439.59	2.815
2012	10992.44	319.87	16478.83	3.184
Totals	**304,109.14**	**26,310.01**	**67,408.70**	**2.122**

NB: The reported natural Gas in 2002 and 2003 were used in auto production on the Saltpond oil field.

In 2012, emission footprint for the electricity generation was 3.2 $MtCO_2e$. The 2012 emission level was 85% higher than the 2000 emission levels which translated into CO_2 intensity of 0.07 $GgCO_2e/GWh$ in 2000 to 0.26 $GgCO_2e/GWh$ in 2012. The changes in the emission trends correlate with the volumes of fuel consumed and the inter-annual variations in the share of the input fuel mix (light crude oil, diesel and natural gas) for electricity generation. In view of government policy of achieving 50% natural-gas based fired thermal plants by 2016, a number of initiatives are underway to (a) develop indigenous natural gas resources, (b) construct additional thermal capacity that would have duel fuel technology capability and (c) ensure reliable supply of natural gas from Nigeria through the West Gas Pipeline and (d) make improvements in efficiency thermal plant through the conversion of single cycles to combined cycles. These government initiatives are expected to have positive impacts on GHG emissions in the electricity sub-sector.

Petroleum refining (1. A.1b)

The only petroleum refining plant in Ghana is operated by the Tema Oil Refinery. The plant is among the first generation technology refineries in the ECOWAS sub-region. In 2008 a refurbishment work was done through a government Program which introduced Residue Fluid Catalytic Cracker (RFCC). The installation of the RFCC enabled the refinery to efficiently refine residual fuel oil into products such as LPG, gasoline, light cycle oil, heavy cycle oil etc. In recent times, the operations of the refinery have declined mainly due to cash flow problems which has made it less competitive in the more deregulated petroleum market. Residual fuel oil, petroleum coke and refinery gas are the main fuel sources the refinery derive energy from to support its operations and thus constitute the main source of GHG emissions in the refinery operations. In addition, the transformation process of the crude oil into other petroleum product produces methane as fugitive emissions which was accounted for under 1.B.

Table 34: Trends of Refinery inputs and emissions

Year	Total fuel (TJ)	RFO(TJ)	Refinery Gas(TJ)	Petroleum Coke(TJ)	Total emissions ($GgCO_2e$)	Implied EF ($GgCO_2e/TJ$)
1990	1178.233	260.77	917.46		73.14	0.0621
1991	1535.271	408.84	1126.43		96.69	0.0630
1992	1260.194	361.89	898.30		79.89	0.0634
1993	989.3007	304.87	684.43		63.13	0.0638
1994	1372.186	308.98	1063.21		85.29	0.0622

1995	1070.212	314.09	756.12		67.98	0.0635
1996	1244.338	231.20	1013.13		76.36	0.0614
1997	21.56244	10.68	10.88		1.46	0.0676
1998	600.7062	312.35	288.36		40.88	0.0680
1999	1187.799	730.49	457.31		83.09	0.0700
2000	1007.036	479.89	527.14		68.60	0.0681
2001	922.3332	438.20	484.13		61.94	0.0672
2002	1570.356	553.38	811.87	205.11	109.82	0.0699
2003	2893.384	545.13	2062.96	285.29	189.15	0.0654
2004	3329.102	630.70	2360.18	338.22	218.10	0.0655
2005	3325.613	562.23	2388.58	374.80	218.00	0.0656
2006	1641.911	333.14	1161.62	147.15	107.22	0.0653
2007	3397.49	504.77	2500.87	391.85	221.68	0.0652
2008	2941.047	582.90	2057.04	301.11	193.29	0.0657
2009	884.0437	193.48	596.32	94.25	58.62	0.0663
2010	2186.274	628.23	1377.38	180.67	145.85	0.0667
2011	2795.59	522.27	2029.31	244.01	181.40	0.0649
2012	1373.45	300.37	976.06	97.02	89.08	0.0649
% Change in 2000 and 2012	**26.7**	**-59.8**	**46**	**100**		

Although total GHG emissions from the refinery showed an increasing trend except that in cases where the refinery operations declined, the emission reduces correspondingly. Between 2000 and 2011(see table 34), the emissions from the refinery increased by 23%. The increases in emissions was as a result of the retrofitting of the refinery in 2008 to expand its capacity which led to optimizing refinery operations. However after 2008, the decline in the emissions was mainly due to the decreases in the level of operations of the refinery. In 1997, the refinery shut down for scheduled maintenance and that resulted in particularly low emissions and fuel consumption in the refinery. As a result more secondary fuels were imported to make up for the deficit in the refinery supply.

3.3.1.3 Methodological issues

Emissions from the energy industries category were estimated using the tier 1 approach and IPCC default emission factor. Table 35 shows the overview of methods and emission factors used in the GHG estimation.

Table 35: Overview of method used and emission factors

Categories	CO_2		CH_4		N_2O	
	Method Used	Emission Factor	Method Used	Emission Factor	Method Used	Emission Factor
1A1a Electricity generation	T1	DF	T1	DF	T1	DF
1A1b Petroleum Refining	T1	DF	T1	DF	T1	DF

Note: T1 = Tier 1, DF = IPCC Default Factors

Electricity generation

Electricity generation refers to power generated by publicly-owned and Independent Power Producers (IPPs) and evacuated to the existing national grid. Fuel (diesel) used for off-grid electricity generating systems in homes, commercial and industrial sites and the associated emissions have been accounted for under categories 1.A.4 Other Sectors and 1.A.2 Manufacturing Industries and Construction. The main fuel consumed by the grid connected thermal power generation stations were imported Light Crude Oil (LCO), natural gas, diesel and distillate fuel oil (DFO) which was for start-ups. The activity data used were LCO, natural gas, and diesel consumption figures reported by the individual power plants in national energy statistics. The sum of LCO, natural gas, and diesel consumption in each power plant in a particular year gives the total consumption of each fuel in the year. The diesel consumption in power generation was excluded from the total diesel supply used in transport, industry and other sectors to avoid double counting. The activity data on electricity generation were obtained from electricity generation companies (private and public) and Energy Commission. The collected data were evaluated to ensure internal consistency. Where there were gaps, especially fuel consumption for Tema Diesel Plant, the amount of electricity generated was used to derive the expected fuel consumption between 1993 and 1998.

Petroleum refining

Crude oil is used as feedstock or refinery input which is transformed into petroleum products during the refinery process. The transformation of the crude oil was not considered in the combustion related estimations of the refinery emissions because it does not lead to fuel combustion emissions. The portion of the crude oil lost through the transformation process as fugitive emissions was considered separately under fugitive emissions from fuels. In the refinery, fuel is burnt to generate heat/steam to support the running production process. Tema Oil Refinery uses the following fuels in their operations: refinery gas, petroleum coke and RFO. The estimation of the emissions from the refinery was based on the amounts of the fuels used in the refinery per year and the specific emission factor for each gas. The activity data were obtained from Tema Oil Refinery's energy balance and the national energy statistics which covered the 1990-2012 time series.

3.3.1.4 Source-specific recalculations (1.A.1)

The availability of new dataset and revision of existing dataset were the main reasons why recalculation was done for emissions estimates from 1990 to 2006. The recalculation resulted in the revision of the activity data which led to changes in the levels of CO_2, CH_4 and N_2O emissions. Table 36 presents the recalculation results and its impacts on the emissions.

Table 36: Results of recalculation and its impacts on emissions

Year	CO_2			CH_4			N_2O		
	PE (Gg)	LE(Gg)	% Change	PE (Gg)	LE(Gg)	% Change	PE (Gg)	LE(Gg)	% Change
1990	134.788	73.03	45.82	0.01	0.002	67.93	0.001	0.0002	77.44
1991	5.401	96.53	-1687.11	0.00	0.002	-1076.48	0.000	0.0004	0.00
1992	0.950	79.75	-8295.02	0.00	0.002	0.00	0.000	0.0003	0.00
1993	17.790	242.56	-1263.45	0.00	0.009	0.00	0.000	0.0017	0.00
1994	22.340	310.64	-1290.51	0.00	0.011	0.00	0.000	0.0021	0.00
1995	15.251	222.86	-1361.32	0.00	0.008	0.00	0.000	0.0015	0.00
1996	15.251	92.54	-506.79	0.00	0.002	0.00	0.000	0.0004	0.00
1997	15.251	117.94	-673.33	0.00	0.005	-663.78	0.000	0.0010	-662.91
1998	18.110	1556.85	-8496.57	0.00	0.063	-8421.86	0.000	0.0126	-8402.40
1999	20.590	1150.93	-5489.73	0.00	0.046	0.00	0.000	0.0092	0.00
2000	502.379	548.22	-9.1255	0.02	0.022	-8.49	0.000	0.0043	0.00
2001	889.775	924.03	-3.8499	0.04	0.037	7.28	0.010	0.0074	26.31
2002	1919.157	2190.35	-14.1310	0.08	0.088	-9.91	0.020	0.0175	12.57
2003	1684.781	2005.82	-19.0555	0.07	0.079	-12.20	0.010	0.0155	-54.77
2004	538.141	729.24	-35.5104	0.04	0.026	34.50	0.000	0.0050	0.00
2005	1038.666	1225.60	-17.9975	0.04	0.046	-16.13	0.010	0.0091	9.48
2006	2392.122	2456.64	-2.6971	0.10	0.099	1.23	0.030	0.0196	34.54

Reasons for recalculations

Natural Gas

- *New datasets were discovered in the national energy statistics* - Inclusion of natural gas for electricity generation in 2002 and 2003. Added 0.183PJ and of 0.24PJ of natural gas to energy industry activity in 2002 and 2003.

Crude Oil

- *New dataset discovered in the national energy statistics* - Inclusion of additional crude oil for electricity generation in 1997, 1998 and 1999. Addition of 0.21PJ, 1.66PJ and 14.53PJ of crude oil to energy industry in 1997, 1998 and 1997.
- *Exclusion of crude oil for electricity generation in 2000* - Excluded 6.66PJ of crude oil in energy industry. There was no electricity generation from crude oil-fired thermal plants in 2000 according to the national energy statistics.

- *Revision of crude oil inputs for energy industry from 2000 to 2006* - Crude oil reduction of 6.66PJ in 2000, 0.23PJ in 2001, 0.45PJ in 2002, 0.41PJ in 2003, 0.13PJ in 2004, 0.25PJ in 2005 and 0.58PJ in 2006. Differences are due to changes in the conversion factors from ktoe to PJ.

Diesel

- Exclusion of diesel consumption for electricity generation in the accounting from 1990 to 1992 and 2000 to 2001.
- Revision of diesel inputs for electricity generation from 1993 to 1999. The changes in diesel inputs were as follows: 2.18PJ in 1993, -2.74PJ in 1994, -1.88PJ in 1995, -0.011PJ in 1996, -1.16PJ in 1997, -3.79PJ in 1998 and 0.24PJ in 1999. The revision was as a result of discovery of new datasets from the independent power producers and changes in conversion factors from ktoe to PJ.

Refinery Fuel Oil (RFO)

- Inclusion of new datasets on RFO consumption data from 1990-2006. This was due to the discovery of new RFO dataset from Tema Oil Refinery.
- Revision of 1990 RFO consumption of 1.65PJ to 0.26PJ due to the availability of new dataset from Tema Oil Refinery.

Refinery Gas

- Inclusion of new datasets on refinery gas consumption data from 1990-2006. This is due to the discovery of new refinery gas dataset from Tema Oil Refinery.

Petroleum Coke

- Inclusion of new datasets of Petroleum Coke consumption data from 2002-2006. This is due to the discovery of new petroleum coke dataset from Tema Oil Refinery.

3.3.2 Manufacturing industry and construction (1.A.2)

Key Category: CO_2 emission - Liquid (2012)

3.3.2.1 Manufacturing industry and construction emission trends

Emissions from Manufacturing Industries and Construction category covered fuel combustion activities in the following: Pulp, Paper and print, Food processing Beverage and Tobacco, Construction, Textile and Leather. For emissions that were generated from the use of electricity from the national grid, stand by generators and "industrial processes", the accounting was done under the 1.A1a (Electricity generation), 1.A4a (Commercial/Institutional) and industrial process and solvent use (2) respectively. For 1.A.2, the emissions trend saw consistent rise from 0.49 $MtCO_2e$ in 1990, to 0.7 $MtCO_2e$ in 2000 and to 1.41 $MtCO_2e$ in 2012 (see figure 20). These increases represented more than double of the 1990 and 2000 levels. The growing emission levels were resulted from the influence of the following factors had on the underlying economic activities: (a) expansion of industrial and construction activities leading to increasing industrial productivity, (b) increasing consumption of fuels such as biomass, diesel and RFO use.

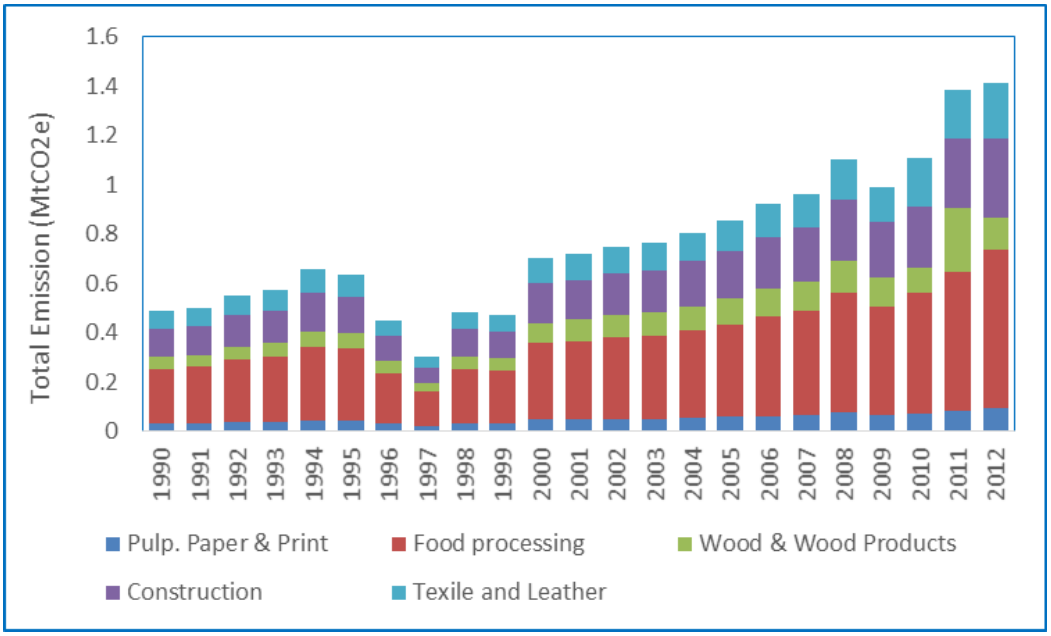


Figure 20: Emissions trend from manufacturing industry and construction

Within the Manufacturing Industries and Construction category, food processing was the dominant source of emissions followed by construction, textile and leather, wood and wood products and pulp, paper and print. The dominance of the emissions from food, beverage and tobacco industries could be explained by the growing consumption of wood and liquid fuels.

3.3.2.2 Methodological issues

In 1.A2, five sub-categories were considered. These were Pulp, Paper and Print, Food processing, Wood & wood Products, Textiles and Construction. The activity data mainly on fuel consumption were obtained from the national energy statistics. Out of the aggregated fuel consumption data, certain portions of the fuels were allotted to manufacturing industry and construction which was further divided among the industry activities. The total quantities of various fuels consumed by manufacturing industries and construction sector were disaggregated among the five sub-categories mentioned above to arrive at the quantities of fuels consumed by each sub-category.

The shares of the sub-categories were derived using the results of (a) industrial fuel consumption surveys, (b) the fuel combustion patterns of sub-categories and (c) expert judgment. The fuels considered in the estimation of the emissions in the manufacturing industries and construction were diesel, residual fuel oil, LPG, wood and charcoal. The quantity of gasoline used in this category was considered to mainly use for transport in industry and has therefore been included in category 1.A.3 (transport). LPG consumption in manufacturing industry and construction was assigned to the Food Processing industries because it was the only industry that used LPG directly to fuel its operations. There was no consumption of LPG, wood and charcoal in the construction industry hence these fuels were not considered in the estimation of emissions from that sub-category. The estimation of the emissions from each sub-category of the Manufacturing Industries and Construction sector was done using the quantities of fuels consumed by each sub-category under consideration and the applicable emission factors. The IPCC Tier 1 approach was used to estimate the emissions from this sector using the default IPCC emission factors.

3.3.2.3 Source-specific recalculations (1.A.2)

The availability of new dataset, exclusion of unreliable data and revision of existing data were the main reasons why recalculation was done for emissions estimates from 1990 to 2006 for this category. The recalculation resulted in the revision of the activity data which led to changes in the levels of CO_2, CH_4 and N_2O emissions. Table 37 presents the recalculation results and its impacts on the emissions.

Table 37: Results of recalculation and its impacts on emissions

Year	CO_2			CH_4			N_2O		
	PE (Mt)	PE (Mt)	% Change	PE (Gg)	PE (Gg)	% Change	PE (Gg)	PE (Gg)	% Change
1990	0.45736	0.46262	-1.15	0.00001	0.00001	-2878.41	0.004	0.052	-1295.82
1992	0.66197	0.52749	20.32	0.02	0.697	-3385.35	0.01	0.124	-1137.17
1993	0.68215	0.54688	19.83	0.02	0.715	-3473.58	0.01	0.127	-1167.61
1994	0.74334	0.6321	14.96	0.02	0.727	-3536.71	0.01	0.129	-1189.3
1995	0.80724	0.60643	24.88	0.02	0.76	-3699.81	0.01	0.135	-1247.43
1996	0.86698	0.42001	51.55	0.02	0.786	-3828.07	0.01	0.139	-1292.4
1997	0.88394	0.27208	69.22	0.02	0.466	-1795.51	0.007	0.063	-772.45
1998	1.00517	0.45554	54.68	0.03	0.457	-1530.67	0.008	0.062	-657.53
1999	1.12288	0.44124	60.7	0.03	0.465	-1450.43	0.01	0.063	-531.64
2000	1.06567	0.6475	39.24	0.04	0.9	-2149.62	0.01	0.122	-1117.06
2001	1.08192	0.64466	40.42	0.03	1.191	-3869.17	0.01	0.16	-1504.87
2002	1.11168	0.66677	40.02	0.03	1.325	-4316.39	0.01	0.178	-1684.36
2003	1.08847	0.67277	38.19	0.03	1.444	-4714.28	0.01	0.194	-1843.7
2004	1.22375	0.73172	40.21	0.03	1.192	-3873.57	0.01	0.161	-1509.01
2005	1.24235	0.76177	38.68	0.03	1.443	-4710.61	0.01	0.194	-1844.63
2006	0.91156	0.82729	9.24	0.03	1.501	-4903.72	0.01	0.202	-1923.61

Reasons for recalculations

Gasoline

- Gasoline consumption in manufacturing industry and construction from 1990 to 2012 was reallocated to road transport because it was considered to be used for transport activities.

Kerosene

- Significant quantities of kerosene use in manufacturing industry and construction from 1990 to 2012 were reallocated to other sectors (commercial and residential) except small amounts left for non-energy use purposes.

Diesel

- Revision of diesel consumption was as result of the discovery of new dataset from the national energy balance.
- Revision of the diesel consumption due to changes in conversion factors from ktoe to PJ.

RFO

- Revision of RFO consumption was as result of the discovery of new dataset from the national energy balance.
- Revision of the RFO consumption due to changes in conversion factors from ktoe to PJ.

LPG

- Revision of the LPG consumption due to changes in conversion factors from ktoe to PJ.
- LPG consumption was excluded from 2000 to 2006 because there was no data reported in the energy statistics.

Wood fuel

- Inclusion of wood fuel consumption from 1990-2012 due to availability of reported data in the national and IEA energy balance.

3.3.3 Transport (1.A3)

Key Category: Road Transport - CO_2 emission - Liquid (1990 and 2012)

3.3.3.1 Transport emission trends

The transport category consists of the following: civil aviation, road transport, railways and inland waterborne navigation. Emission from international and marine navigation reported as memo items was included in the overall inventory although they only for point of information and not included in the sum of emissions. In transport, total fuel consumption grew from 44.3PJ in 1990 to 86.59PJ in 2012 representing 95.7% over the 22 year period. Similarly, the corresponding emission of 6.3 $MtCO_2e$ in 2012 made up 47.3% of the total energy sector emissions. The emissions of 6.3 $MtCO_2e$ represented an increase of 55.7% of 2000 levels of 2.81 $MtCO_2e$ and 76.9% of the 1990 levels of 1.45 $MtCO_2e$. Within transport, road transport accounted for 91.6% of the emissions, followed by inland water-borne navigation, railway, civil aviation and other transport (see figure 21).

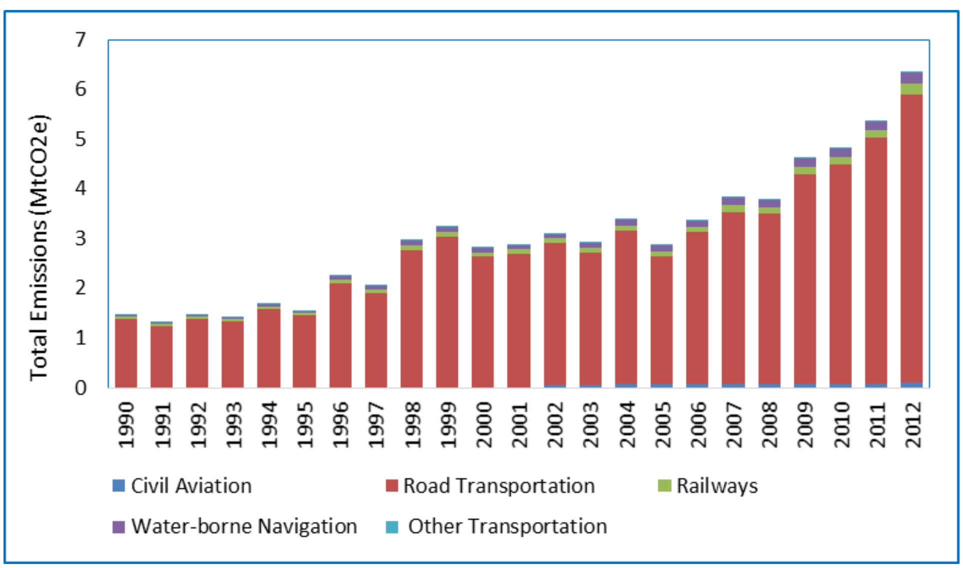


Figure 21: Trends of transport sector emissions

Road transport (cars, trucks, buses and motorcycles) accounted for over 90% of the fuels consumed in the transport category in 1990, 2000 and 2012. Fuel consumption in road transport increased by about 75.9% from 19.21PJ in 1990 to about 79.66 PJ in 2012. In the same period, there was a corresponding increase in road transport emissions from 1.39 $MtCO_2e$ in 1990 to 5.81 $MtCO_2e$ in 2012. This represented an overall increase of about 76.1% above the 1990 levels. Therefore, made cars the largest contributor to the road transport emissions. The main contributory factor for this was the rapidly increasing vehicle numbers. Between 1995 and 2012, the total number of registered vehicles increased by about 36 folds from 42,976 in 1995 to 1,532,080 in 2012 representing an increase of over 500% over the period. The following underlying factors influenced road sector emissions to varying degrees: (a) with the implementation of 10-year over-aged import duty policy, (b) general importation of fairly new vehicles, (c) implementation of government's policy on promotion of the use liquefied petroleum gas (LPG) as substitute for fuel-wood for household energy which has led to the creative and increase use of LPG as fuel in the road sector and (d) deregulation of the downstream petroleum market, certain level of efficiency has been introduced.

For domestic waterborne navigation, the rise in diesel consumption from 0.48PJ in 1990 to 2.9PJ in 2012 contributed to the high emissions. This led to increases in total emissions from 0.036 $MtCO_2e$ in 1990 to 0.22 $MtCO_2e$ in 2012. Domestic aviation became a major mode of air travel in 2002. In 2002, domestic aviation consumed nearly 0.78PJ of ATK fuel which increased to 1.22PJ in 2012. The domestic aviation experienced a corresponding increase in emissions from 0.056 $MtCO_2e$ in 2002 to 0.09 $MtCO_2e$ in 2012. The domestic aviation industry has indeed seen tremendous growth since 2002 not just in terms of the number of active airlines operating in the country but more importantly, in terms of passenger uplift. The unprecedented growth continued in 2012, with passenger uplift growing by 199% over 2011 (544,583 passengers in 2012 as against 181,863 in 2011). Diesel consumption for rail transport went up from 0.41PJ in 1990 to 2.49PJ in 2012. The total emissions from the rail sector also increased from 0.03 $MtCO_2e$ in 1990 to 0.21 $MtCO_2e$ in 2012. The drastic increases in fuel consumption and emissions in the rail transport was due to the revamping of hitherto collapsed rail infrastructure. Off-road transport (e.g. agricultural tractors) consumed 0.10PJ of fuel in 1990 which increased by about 212% to 0.32PJ in 2012. The total emissions from the off-road transport in 2012 was 0.024 $MtCO_2e$ which was more than double that of the 1990 value of 0.009 $MtCO_2e$.

3.3.3.2 Methodological issues

Emissions from transport was estimated for the following four transport modes; Civil aviation, road transport, railways and Inland water-borne navigation. Different methodological approaches were used for the different transport modes in the estimation. For civil aviation, railways and inland water-borne navigation, the tier-1 IPCC methodology was used in the estimation of the emissions. Default IPCC emission factors were used with country-specific activity data (i.e. Diesel and ATK consumption per year). For road transport, a mix of tier 1 and a simplified tier 2 approaches were used. Default IPCC emissions factors and a range of country-specific activity were used for the accounting. Details of the methodological approaches for the different transport modes are provided below:

Civil Aviation

Activity data mainly, ATK consumption was collected from three major oil marketing companies that were responsible for the supply of the bulk of the ATK to the domestic airline companies. The data collected represented the bulk ATK supply from a specific OMC. The annual ATK supply to the airlines were derived from the sum of all the supply from the individual OMCs in a year. The shares of ATK consumption of international bunkers and the domestic airlines were estimated based on the aggregated annual sale figures of the OMCs. Some of the ATK consumption figures from the OMCs had time series gaps, between 2002 and 2012, so trend interpolation was applied to fill the gaps to ensure completeness. The LTO data on domestic aviation was not readily available, therefore the IPCC tier 1 approach was used to estimate

GHG emissions using default emission factors. As part of the future improvements in the civil aviation emission estimations, efforts will be made to collect additional data that will enable the use of a tier 2 approach.

Road Transport

Estimation of emissions from road transport improved compared to the methodology used in the previous inventory although a lot remains to be done to ensure greater transparency and robustness. In the previous inventory, transport emissions was estimated using tier 1 approach whereas in the current inventory, accessibility to new data made it possible to move partly to a higher tier. Country-specific activity data on vehicle population (annual vehicle registration and road worthy certification data) was collected from the Driver Vehicle and Licensing Authority (DVLA) from 1995-2012. The missing data from 1990 to 1994 was retrieved by trend extrapolation using average annual growth rate of the five years (1995-2000) of the period DVLA provided the data. The original DVLA vehicle population data format, was further categorized into vehicle classes (passenger, light-duty, heavy-duty and motor-cycle to conform to the IPPC vehicle population classifications. The categorization of the DVLA data in the IPCC vehicle classes was based the average gross weight. Based on the 2005 survey conducted as part of the Vehicular Emission Project, the vehicle classes were further divided into technology classes based on the Euro standards. Further breakdown of the gasoline passenger and light-duty vehicles was based on the functionality of the catalytic device in the vehicles. Based on expert judgment and local industry knowledge in Ghana, 10% of the total gasoline passenger and light-duty vehicles were assumed to have functional embedded catalytic convertors.

The total amount of liquid fuels such as diesel, gasoline and LPG allocated to transport was derived from the national totals reported in the energy statistics. The allocations of fuel mix to transport and other sectors were based on the shares derived through surveys and expert judgments. Therefore the annual fuel consumption for road transport was estimated out of the overall allocation to the transport category. The remaining fuel consumption were split among non-motorized transport modes i.e. civil aviation, railways and inland water navigation. The road transport fuel consumption share was further allocated to the various vehicle classes. The amount of the fuels allocated to the vehicle classes was dependent the number of vehicles in each technology class. Because of the outdated nature of the 2005 traffic circulation data (average speed, mileage, fuel economy etc), full tier 3 methodology was not used. Instead, with the IPPC default emission factors, country-specific disaggregated vehicle classifications and its fuel allocation, the emissions for each vehicle class was estimated. In order to improve the methodology for the estimation in the future, attention will be given to the collection of data that will enable Ghana implement a tier 3 approach in the transport sector. The emission factors were obtained from the IPCC EFDB using a selection criteria that aimed at selecting emission factors were applicable to Ghana's national circumstances.

Railways

Activity data on diesel consumption was initially collected from Ghana Railway Company.. Inconsistencies were found during the preliminary assessment of the data from Ghana Railway Company, hence the annual fuel consumption data from IEA's disaggregated energy balance was used to ensure internal and time series consistency. However, efforts will be made to reconcile the two data sources and appropriately report the emissions in the next inventory. Default IPCC emission factors for CO_2, CH_4 and N_2O were used in together with the IEA activity data in order to determine the emissions.

Inland water-borne navigation

The main activity data on annual diesel consumption was obtained from Volta Lake Transport Company from 2006 to 2010 to estimate GHG emissions using tier 1 approach. The missing data from 1990-2005 was collected from the IEA energy balance for Ghana. The 2011 and 2012 diesel consumption was based on the trend extrapolation using the average annual growth rate in the yearly diesel consumption. IPCC default emission factors were used for CO_2, CH_4 and N_2O.

3.3.3.3 Source-specific recalculations

The availability of new dataset, exclusion of unreliable data and revision of existing data were the main reasons why recalculation was done for emissions estimates from 1990 to 2006 for this category. The revision of the activity data led to changes in the levels of CO_2, CH_4 and N_2O emissions. Table 38 presents the recalculation results and its impacts on the emissions.

Table 38: Results of recalculation and its impacts on emissions

Year	CO_2			CH_4			N_2O		
	PE (Mt)	LE(Mt)	% Change	PE (Gg)	LE(Gg)	% Change	PE (Gg)	LE(Gg)	% Change
1990	1.54	1.43	6.82	0.3	0.461	-55.84	0.014	0.088	-540.81
1991	1.15	1.28	-11.48	0.22	0.396	-77.76	0.01	0.08	-711.87
1992	1.49	1.44	3.56	0.29	0.443	-52.67	0.01	0.089	-792.54
1993	1.64	1.39	15.45	0.32	0.411	-28.36	0.01	0.087	-772.51
1994	1.70	1.65	2.87	0.33	0.473	-43.35	0.01	0.107	-967.35
1995	1.85	1.52	17.68	0.36	0.446	-23.97	0.02	0.094	-369.54
1996	2.02	2.20	-8.91	0.39	0.559	-43.23	0.02	0.137	-584.56
1997	2.08	2.01	3.18	0.41	0.454	-11.37	0.018	0.128	-624.72
1998	2.41	2.90	-20.12	0.47	0.705	-48.9	0.021	0.183	-789.56
1999	2.75	3.16	-14.89	0.54	0.906	-67.76	0.02	0.186	-830.35
2000	2.53	2.74	-8.43	0.5	0.768	-53.57	0.02	0.164	-718.99
2001	2.54	2.81	-10.7	0.5	0.741	-48.12	0.02	0.166	-728.76
2002	1.81	3.03	-67.55	0.27	0.822	-204.54	0.02	0.183	-814.53
2003	2.60	2.85	-9.43	0.51	0.72	-41.26	0.02	0.168	-739.87
2004	2.98	3.30	-10.75	0.59	0.845	-43.25	0.03	0.201	-571.22
2005	3.01	2.81	6.71	0.59	0.589	0.2	0.03	0.176	-485.13
2006	3.10	3.30	-6.43	0.61	0.778	-27.49	0.03	0.203	-577.39

Reasons for recalculations

LPG

- Excluded LPG consumption figures in road transport from 1990 to 1993 and reallocated to other sectors.
- Inclusion of new datasets on LPG consumption from 1994 to 2012 due to discovery of new sources the national energy statistics.
- Revision of LPG consumption due to changes in conversion factors from ktoe to PJ.

Gasoline

- Allocation of the gasoline consumption from manufacturing industry and construction (1.A2) to transport (1.A3).
- Revision of the gasoline consumption due to changes in conversion factors from ktoe to PJ.

Diesel

- Inclusion of revised diesel consumption data reported in the national energy statistics.
- Revision of the diesel consumption due to changes in conversion factors from ktoe to PJ.

ATK

- Exclusion of ATK consumption data from 1990 to 2001.
- Inclusion of ATK consumption data for domestic aviation from 2002 to 2012.

3.3.4 Other sectors (1. A4)

Key Sources: Other sectors - CO_2 emissions – Liquid fuels (2012)

3.3.4.1 Other Sectors Emission Trends

Total fuel consumption in "other sectors" decreased by 5% from the 1990 levels of 124PJ to 118.6PJ in 2012. Similarly, in 2000, the total fuel consumption of 104.60PJ was 19% lower than the 1990 levels (see table 39). While biomass recorded decrease of 23% between 1990 and 2012, liquid fuels on other hand recorded an increase of 64% in the same period.

Table 39: Fuel consumption in other Sectors (PJ)

Fuel Type	Year			% Change	
	1990	2000	2012	1990-2000	1990-2012
Biomass	115.19	92.98	93.920	-24%	-23%
Liquid Fuel	8.83	11.61	24.679	24%	64%
Total Fuel	124.02	104.60	118.600	-19%	-5%

In 2012, the total fuel consumption translated into a total emissions of 2.4 $MtCO_2e$ amounting to 18% of the total energy sector emissions. This represented an increase of 38.3% compared to the 1990 emissions of 1.5 $MtCO_2e$ (see figure 22). However, there was no significant percentage change in the emission levels from 1990 to 2000. The overall increases in the total emissions were largely the result of growing consumption of liquid fuels over the period.

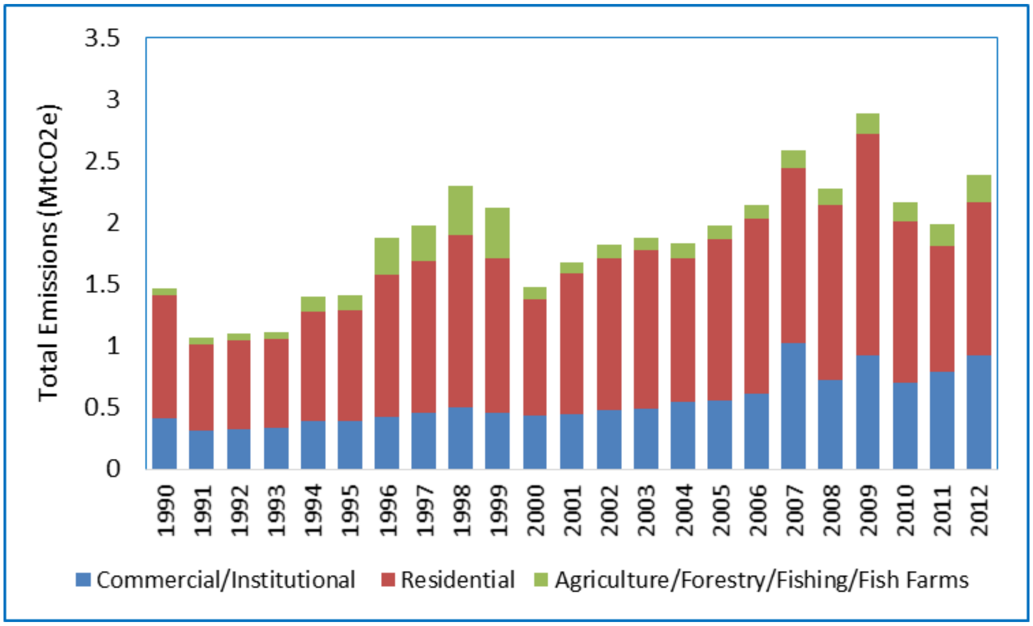


Figure 22 : Total emissions from other sectors ($MtCO_2e$)

For year 2012, CO_2, CH_4 and N_2O emissions constituted the following 1.7TMt, 0.6$MtCO_2e$ and 0.09$MtCO_2e$ respectively for other sectors. The 1.7$MtCO_2$ emissions was attributed to the expanding economic activities in commercial/institutional and residential sector. Within the other sector, residential category was the largest source of GHG emissions with 52% followed by commercial/institutional (39%) and Agriculture/forestry (9%). In 2012, total commercial/institutional emissions amounted to 0.92 $MtCO_2e$, which 56% and 53% higher than the 1990 and 2000 levels of 0.41 $MtCO_2e$ and 0.43 $MtCO_2e$ respectively. In the commercial/institutional sub-source category, the increases in the emissions was resulted from the overall impacts of growing reliance on stand-by generators especially during load shedding periods.

Whiles the trends of total CO_2 emissions increased from 1.7Mt in 1990 to 8.9Mt in 2012, the CH_4 emission trends recorded decreases from 0.2$MtCO_2e$ in 1990 to 0.03$MtCO_2e$ in 2012. The increasing CO_2 emissions is strongly influenced by the rising liquid fuel consumption, mainly diesel in commercial/institutional stand-by generators. With respect to CH_4, the reduction was attributed to decreases in biomass consumption for cooking, increasing penetration of LPG and above all the immediate impact of the promotion of efficient cooking devices. Similarly N_2O emissions recorded decreasing trends from 0.039 $MtCO_2e$ to 0.007 $MtCO_2e$ for the same period. The emissions from residential was the dominant source the totals emissions in the other sectors, the trend showed steady increase by 52% for the period 1990-2012. The increases ranged from 1.0 $MtCO_2e$ in 1990 to 0.95 $MtCO_2e$ in 2000 in 2000 to a total of 1.24 $MtCO_2e$ in 2012. The 52% increases in emissions in residential compared to the base year could be explained by the rising consumption of liquid fuels especially in generator sets coupled with the contribution from the use of biomass for cooking which is a major source of CH_4 and N_2O emissions.

In terms of gas by gas emissions, CH_4 consistently remained the dominant gas, followed by CO_2 and N_2O except in 2011 and 2012 that CO_2 emissions was the largest source. Agriculture, forestry and fisheries were the least contributors of emissions. The 2012 emission from agriculture, forestry and fisheries emissions of 0.22 $MtCO_2e$ made up 9% of the total emissions in the other sectors category. The 0.22 $MtCO_2e$ emission was 0.12 $MtCO_2e$ and 0.56$MtCO_2e$ higher than the 2000 and 1990 levels respectively. The emission trends was corresponded to the rising consumption of diesel in stationery Agriculture, forestry and fisheries activities.

3.3.4.1 Methodological issues

Emissions from other sectors was estimated for three main source activities. These were commercial/institutional, residential and agriculture/forestry/fisheries. The activities under commercial/institutional category comprised of combustion activities in the commercial and public services such as banks, schools and hospitals, and trade, retail and communication. Residential activities covered fuel consumption in household water heating and cooking. Agriculture/Forestry/Fisheries consisted stationary combustion emissions from agriculture, cattle breeding and forestry, and fuel combustion emissions from fisheries and from off-road machinery used in agriculture (mainly tractors). The methodology for estimating emissions improved compared to the previous inventory.

In the current inventory, although IPCC tier 1 approach was used, activity data were updated to reflect the changes in the national energy statistics. The IPCC default emission factors were used for all the fuel under the activities. Carbon dioxide emission from biomass was excluded from the accounting and reported as memo item. The main activity data were diesel, gasoline and biomass fuel. The activity data were obtained from national energy statistics. Although in the energy statistics, data on total national fuel supply and consumption were provided for the period 1990-2012, where there were gaps, trend interpolation and expert judgment were used to fill them. The allocation of fuel share among the activities under "other sectors" was determined using local knowledge and expert judgment. Similar, expert judgement was used for the selection of "stationery" activity under Agriculture/Forestry/Fisheries.

3.3.4.2 Source-specific recalculations

The availability of new dataset, exclusion of unreliable data and revision of existing data were the main reasons for recalculation on emissions estimates from 1990 to 2006 for this category. The revision of the activity data led to changes in the levels of CO_2, CH_4 and N_2O emissions. Table 40 presents the recalculation results and its impacts on the emissions.

Table 40: Results of recalculation and its impacts on emissions

	CO_2 Emissions			CH_4 Emissions			N_2O Emissions		
Year	PE (Mt)	PE (Mt)	% Change	PE (Gg)	LE (Gg)	% Change	PE (Gg)	LE (Gg)	% Change
1990	0.59	0.63	6.5	28.81	33.444	13.9	0.24	0.43	43.7
1991	0.37	0.38	2.5	29.82	27.439	-8.7	0.24	0.35	30.3
1992	0.44	0.40	-11.7	30.82	28.163	-9.4	0.25	0.35	29.5
1993	0.47	0.39	-18.9	34.94	28.889	-20.9	0.28	0.36	22.8
1994	0.51	0.66	22.9	35.32	29.782	-18.6	0.29	0.37	22.7
1995	0.62	0.64	2.5	37.03	31.234	-18.6	0.3	0.39	23.6
1996	0.70	1.06	34	37.03	32.902	-12.5	0.3	0.42	28
1997	0.42	1.10	62.2	37.44	34.854	-7.4	0.3	0.44	31.3
1998	0.80	1.47	45.4	37.24	33.026	-12.8	0.01	0.42	98.6
1999	0.85	1.28	34.2	40.04	33.74	-18.7	0.33	0.43	22.9
2000	0.77	0.82	6.2	41.1	26.196	-56.9	0.33	0.32	-1.9
2001	0.90	0.84	-6.6	60.84	33.755	-80.2	0.49	0.42	-15.6
2002	0.90	0.90	0.4	63.47	36.788	-72.5	0.51	0.47	-9
2003	0.98	0.88	-11.2	65.5	39.879	-64.2	0.53	0.51	-4.1

2004	1.00	0.99	-0.8	66.97	33.383	-100.6	0.54	0.42	-27.8
2005	1.02	0.98	-4.7	67.25	39.836	-68.8	0.55	0.51	-8.2
2006	1.20	1.11	-7.9	67.72	41.31	-63.9	0.55	0.53	-4.2

Reasons for recalculations

Gasoline

- Upward revision of gasoline consumption resulting in changes in activity data for gasoline due to identification of new dataset from the national energy statistics and expert judgment on the allocation on fuels.

- *Commercial* – Reduction of average gasoline consumption from an average of 0.74PJ to an average of 0.25PJ per annum in the period 1990-2012.

- *Residential* – inclusion of new gasoline consumption allocation for the entire period 1990-2012 which was excluded in the previous estimates.

- *Agriculture/Forestry/Fisheries* – revision of gasoline consumption resulting in the replacement of 3.84PJ in 2001 and 2002 in the previous estimate with 0.47PJ and 0.50PJ in 2001 and 2002 respectively due to availability new datasets from the national energy statistics and expert judgment on the allocation on fuels.

- *Agriculture/Forestry/Fisheries* – inclusion of new gasoline fuel consumption from 1990 to 2000 and 2003 to 2006 because of availability new dataset from the national energy statistics and expert judgment on the allocation on fuels.

Diesel

- Revision of total diesel consumption of an average of 3,986TJ per annum in the previous estimate to 3.84PJ in the latest estimates. However, there are cases where the annual variation differ.

- *Agriculture/Forestry/Fisheries* – revision of diesel consumption resulting in changes from 1,794TJ to 0.83PJ in 2000, 3.78PJ to 0.94PJ in 2003, 3.85PJ to 1.06PJ in 2004, 3.93 to 1.09PJ in 2005, 6.01PJ to 1.16PJ in 2006. Inclusion of new annual diesel consumption datasets from 1990 to 1999, and 2001 to 2002.

Kerosene

- Revision of total kerosene consumption of an average of 4.24PJ per annum in the previous estimate to 4.61PJ in the latest estimates. However, there are cases where the annual variation differ.
- *Commercial* – inclusion of new kerosene consumption dataset for the period 1990-2012 which was part of the previous estimates.

LPG

- Revision of total LPG consumption of an average of 1.83PJ per annum in the previous estimate to 1.82PJ in the latest estimates. However, there are cases where the annual variation differ.

- *Commercial* - revision of LPG consumption resulting in changes from 0.85PJ to 0.67PJ in 2000, 0.77PJ to 0.63PJ in 2001, 1.69PJ to 0.76PJ in 2003, 0.944PJ to 0.88PJ in 2004, 0.94PJ to 0.94PJ in

2005 and 0.94PJ to 1.31PJ in 2006. In addition, inclusion of new annual LPG consumption datasets from 1990 to 1999, and 2002.

Charcoal

- Revision of total charcoal consumption of an average of 208.81PJ per annum in the previous estimate to 16.18PJ in the latest estimates due to discovery data from the national energy statistics and IEA energy balance for Ghana. However, there are cases where the annual variation differ.
- Inclusion of 15.58PJ charcoal consumption for 1998 which not reported in the previous estimates.
- *Commercial/institutional* – inclusion of new charcoal consumption data which not reported in the previous estimates for the period 1990-2012

Wood fuel

- Inclusion new wood fuel dataset from the period of 1990-2012 for *commercial/institutional* and *residential* due to the discovery data from the national energy statistics and IEA energy balance for Ghana.

3.3.5 Fugitive emissions activities (1.B)

Fugitive emission in Ghana mainly comes from the offshore oil and gas production as well as petroleum refining. Estimates on offshore oil and gas fugitive emissions were from 2010 to 2012 because commercial production started in 2010. Estimates on fugitive emissions from oil refining, on the other hand were from much earlier years in 1990 to 2012. The level of emissions were largely influenced by the following (a) productivity level of refinery, (b) amounts of associated produced the gas field, (c) amounted of gas rejected and (d) amount gas used as fuel on site. In 2012, the total fugitive emission amounted to 0.0016 $MtCO_2e$ which constitute 0.012% of the total energy sector emissions. Of this 0.0016 $MtCO_2e$ total emissions, emissions from gas flaring contributed 83.3% whereas the remaining 16.7% were from the refinery. The 2012 total emission was 62.6% and 74% higher than the 2000 and 1990 levels respectively. For the period 1990-2009, total fugitive emission were made up of only fugitive emissions from the refinery.

3.3.5.1 Description of source-specific activities

3.3.5.1.1 Gas flaring (1.B.2.a.ii)

Gas flaring emissions trends

Total emissions resulting from gas flaring amounted to 0.0028 $MtCO_2e$, 0.0187 $MtCO_2e$ and 0.00134 $MtCO_2e$ in 2010, 2011 and 2021 respectively. The increase in 2011 emission was as a result of relatively less consumption of natural gas for onsite power generation on the field and limited gas injection in the oil wells.

Methodological issues

Based on the prevailing oil and gas production activities in Ghana, fugitive emission were estimated only for gas flaring. This was mainly because, the downstream gas processing infrastructure was under construction. The activity data covering (a) associated gas produced, (b) amount of gas used for power generation on site, (c) amounts of gas injection in the oil wells and (d) amount gas flared for the period

2010-2012 was obtained from the jubilee oil partners. Using the IPCC tier 1 methodology, the amount of methane fugitive emission was derived using the appropriate IPCC default emission factors and quantity of gas flared.

3.3.5.1.2 Petroleum refining (1.B.2a.iii.4)

Petroleum refining emissions trends

The total fugitive emission under petroleum refinery in 2012 of 0.27GgCO_2e is lower than the 2000 and 1990 levels of 0.6GgCO_2e and 0.42GgCO_2e respectively. The decreases in the emission trends could be explained by the decreasing productivity at the Tema oil refinery.

Methodological issues

Activity data was collected from the Tema Oil Refinery (TOR) which was the only refinery plant in the country. The data which covered 1990 to 2012 was from the TOR material balance. For the refinery, the fugitive emission were from the evaporations during the transformation of crude oil into secondary products. Using the IPCC tier methodology, the activity data from TOR and the IPCC default emission factors were used to estimate the total fugitive emissions from the refinery.

3.4 Cross-cutting issues

3.4.1 Comparison of AD with international data sources

This section presents the comparison of national level activity data used in the inventory preparation with the data reported for Ghana by International Energy Agency (IEA). The purpose of this comparison was to be able to assess the level of consistency between the two data sources and understand the reasons for the differences between the two data sources. The comparison which was the measure of the percentage difference of the individual input fuels from the two data sources have been provided on yearly basis (see table 41) between 1990 and 2010. This was because the IEA activity for 2011 and 2012 were not available at the time this report was put together. The negative sign indicated that the country specific data are lower than the IEA activity.

Table 41: Result of the comparison of national and international activity data (ktoe)

Year	Data Source	Crude Oil	LPG	Gasoline	Diesel	Kerosene	RFO	Primary Solid Biomass	Charcoal
1990	Ghana Data	801.72	6.57	349.55	291.33	153.58	40.3	2750.98	286.9
	IEA Data	801.17	6.78	344.55	301.99	128.68	40.33	2750.98	268.9
	Difference (%)	*0.07*	*-3.10*	*1.45*	*-3.53*	*19.35*	*-0.07*	*0.00*	*6.69*
1991	Ghana Data	981.65	7.31	296.96	285.78	75.89	46.28	2834.92	319.27
	IEA Data	979.32	10.17	316.73	285.44	80.55	40.33	2834.56	319.27
	Difference (%)	*0.24*	*-39.19*	*-6.66*	*0.12*	*-6.14*	*12.86*	*0.01*	*0.00*
1992	Ghana Data	959.78	10.65	332.29	321.51	73.49	48.59	2921.28	336.93
	IEA Data	924.35	15.82	372.37	349.56	86.83	42.25	2920.52	336.93
	Difference (%)	*3.69*	*-48.59*	*-12.06*	*-8.72*	*-18.16*	*13.06*	*0.03*	*0.00*
1993	Ghana Data	759.92	15.87	305.44	335.56	70.31	48.04	3009.8	356.05

	IEA Data	790.99	22.59	374.51	357.7	85.78	41.29	3008.88	356.05
	Difference (%)	*-4.09*	*-42.38*	*-22.61*	*-6.60*	*-22.00*	*14.05*	*0.03*	*0.00*
1994	Ghana Data	1075.78	21.92	372.09	421.23	119.55	49.12	3105.29001	375.18
	IEA Data	1072.98	31.63	356.32	417.82	93.11	43.21	3102.01	375.18
	Difference (%)	*0.26*	*-44.30*	*4.24*	*0.81*	*22.12*	*12.03*	*0.11*	*0.00*
1995	Ghana Data	849.43	68.52	346.53	381.56	80.22	50.53	3247.04	384.74
	IEA Data	919.26	37.28	378.79	469.53	104.61	46.09	3187.98	384.74
	Difference (%)	*-8.22*	*45.59*	*-9.31*	*-23.06*	*-30.41*	*8.78*	*1.82*	*0.00*
1996	Ghana Data	1014.00	82.56	422.17	516.61	154.44	48.34	3399.72	393.57
	IEA Data	1013.94	45.19	408.75	519.17	118.21	48.01	3264.49	393.57
	Difference (%)	*0.01*	*45.26*	*3.18*	*-0.50*	*23.46*	*0.69*	*3.98*	*0.00*
1997	Ghana Data	181.00	75.25	330.48	537.86	184.27	0	3557.48	403.13
	IEA Data	181.21	40.67	429.08	536.75	127.63	52.81	3339.57	403.13
	Difference (%)	*-0.12*	*45.95*	***-29.84***	*0.21*	*30.74*		*6.13*	*0.00*
1998	Ghana Data	1221.61	49.8	526.68	717.59	275.88	31.63	3430.16	413.43
	IEA Data	1221.61	41.80	475.09	692.92	142.28	48.97	3427.78	413.43
	Difference (%)	*0.00*	*16.06*	*9.80*	*3.44*	*48.43*	*-54.82*	*0.07*	*0.00*
1999	Ghana Data	1666.48	46.03	694.62	638.17	209.62	39.17	3506.7	422.26
	IEA Data	1666.48	47.45	514.68	791.17	139.14	55.69	3503.20	422.26
	Difference (%)	*0.00*	*-3.08*	***25.90***	*-23.97*	*33.62*	*-42.18*	*0.10*	*0.00*
2000	Ghana Data	1310.598	48.6	550.62	679.13	65.77	57.10	2485.00	431.82
	IEA Data	1308.14	47.45	582.10	726.01	69.05	54.73	3583.77	431.82
	Difference (%)	*0.19*	*2.37*	*-5.72*	*-6.90*	*-4.99*	*4.15*	*-44.22*	*0.00*
2001	Ghana Data	1569.58	45.9	561.855	699.38	68.39	52.00	3312.4	440.65
	IEA Data	1566.72	51.97	587.45	707.39	75.32	49.93	3659.01	440.65
	Difference (%)	*0.18*	*-13.22*	*-4.55*	*-1.15*	*-10.14*	*3.98*	*-10.46*	*0.00*
2002	Ghana Data	1816.6	54.00	598.71	732.17	74.80	51.90	3696.18	392.83
	IEA Data	1820.20	58.75	650.58	768.41	60.68	49.93	3735.83	392.83
	Difference (%)	*-0.20*	*-8.79*	*-8.66*	*-4.95*	*18.88*	*3.80*	*-1.07*	*0.00*
2003	Ghana Data	1972.48	55.00	503.79	770.42	66.74	45.70	4029.96	396.51
	IEA Data	1979.01	68.91	527.52	780.82	73.23	44.17	3734.40	396.51
	Difference (%)	*-0.33*	*-25.30*	*-4.71*	*-1.35*	*-9.73*	*3.35*	*7.33*	*0.00*
2004	Ghana Data	2016.438	63.729	604.38	865.89904	71.004	43.844	3306	400.93
	IEA Data	2035.00	79.08	633.46	879.07	78.46	43.21	3772.68	400.93

	Difference (%)	*-0.92*	*-24.09*	*-4.81*	*-1.52*	*-10.50*	*1.45*	*-14.12*	*0.00*
2005	Ghana Data	2006.85	68.385	392.49	898.03	72.07	46.37	4016.60	404.60
	IEA Data	2003.44	86.99	591.73	911.13	80.55	46.09	3811.34	404.60
	Difference (%)	*0.17*	*-27.21*	*-50.76*	*-1.46*	*-11.77*	*0.60*	*5.11*	*0.00*
2006	Ghana Data	1747.06	95.04	537.49	952.70	74.21	55.10	4173.83	409.02
	IEA Data	1743.85	107.33	563.91	966.98	82.65	54.73	3850.39	409.02
	Difference (%)	*0.18*	*-12.93*	*-4.91*	*-1.50*	*-11.37*	*0.67*	*7.75*	*0.00*
2007	Ghana Data	2094.77	100.76	571.41	1169.97	63.24	21.83	4296.28	413.43
	IEA Data	2090.99	114.10	615.27	990.77	68.00	52.81	3889.84	413.43
	Difference (%)	*0.18*	*-13.24*	*-7.68*	*15.32*	*-7.52*	*-141.96*	*9.46*	*0.00*
2008	Ghana Data	2015.32	127.01	572.25	1113.98	33.56	74.64	4491.56	417.11
	IEA Data	2011.59	143.48	616.34	940.09	37.66	48.97	3929.69	417.11
	Difference (%)	*0.19*	*-12.97*	*-7.70*	*15.61*	*-12.21*	*34.39*	*12.51*	*0.00*
2009	Ghana Data	1002.5	238.25	736.47	1305.63	89.22	0.00	4578.92	421.52
	IEA Data	998.67	249.67	750.09	1322.75	92.06	38.41	3969.93	421.52
	Difference (%)	*0.38*	*-4.80*	*-1.85*	*-1.31*	*-3.18*		*13.30*	*0.00*
2010	Ghana Data	1694.83	173.05	774.69	1297.37	50.78	29.97	2748.77	729.44
	IEA Data	1809.00	202.22	789.68	1317.57	51.26	29.76	4010.57	425.94
	Difference (%)	*-6.74*	*-16.86*	*-1.94*	*-1.56*	*-0.94*	*0.69*	*-45.90*	*41.61*

Generally the two dataset were in agreement except in few cases where major differences were observed such as biomass supply and consumption figures. The following were some examples of the cases where similarities and difference between the data set were observed:

- For crude oil, the difference between the two data sources was generally within the range of -8.22% in 1995 to 3.69% in 1992. The difference was less plus or minus 10% which is indicative of appreciable level of consistency between the two sources.
- The difference between LPG was between -48.59% in 1992 and 45% in 1995 which indicative large variations.
- The difference between gasoline data ranged between -29.8% in 1997 and 25.9% in 1997 indicating moderate variation.

These observations were expected because of the different statistical approaches used to compile the data. Where large difference were observed, further investigation was conducted to ascertain what accounted for the differences and correct them.

3.4.2 Description of notation keys and completeness information

Information on completeness and use of notation keys in the energy sector are provided below. The information on completeness include coverage of gases, categories and as well as time series completeness. Additional information is given on the status of emission estimates of all sub-categories. "E" indicates that emissions from this sub-category have been estimated. "NO" means "Not Occurring" thus indicates that the Ghana's energy balance does report energy consumption for the relevant sector and fuel category. Emissions of all sources of category 1.A Fuel Combustion have been estimated; the status of emission estimates of this category is complete. Table 42 provides the overview of subcategories of Category 1.A Fuel Combustion and status of estimation.

Table 42: Overview of subcategories of Category 1.A Fuel Combustion and status of estimation

IPCC Category	Time series Completeness												Status of Gas		
	1990-2006 (recalculations)				2007-2010 (new estimates)				2011-2012 (latest estimates)						
	Coverage of gases														
	E	NE	NO	IE	E	NE	NO	IE	E	NE	NO	IE	CO_2	CH_4	N_2O
1.A.1.a.i – Electricity Generation															
1.A.1.a Liquid Fuels	X				x				x				X	x	x
1.A.1.a Gaseous Fuels			X		x				x				X	x	x
1.A.1.a Biomass			X				x				x		NO	NO	NO
1.A.1.a Solid			X				x				x		NO	NO	NO
1.A.1.a Other fuels			X				x				x		NO	NO	NO
1.A.1.b Petroleum refining															
1.A.1.b Liquid Fuels	X				x				x				X	x	x
1.A.1.b Gaseous Fuels			x				x				x		NO	NO	NO
1.A.1.b Biomass			x				x				x		NO	NO	NO
1.A.1.b Solid			x				x				x		NO	NO	NO
1.A.1.b Other Fuels			x				x				x		NO	NO	NO
1.A.2.d Pulp, Paper and Print															
1.A.2.d Liquid Fuels	X				x								X	x	x
1.A.2.d Gaseous Fuels			x				x		x		x		NO	NO	NO
1.A.2.d Biomass	X				x				x				X	x	x
1.A.2.d Solid			x				x				x		NO	NO	NO
1.A.2.d Other Fuels			x				x				x		NO	NO	NO
1.A.2.e Food Processing, Beverages and Tobacco															
1.A.2.eLiquid Fuels	X				x								X	x	x
1.A.2.e Gaseous Fuels			x				x		x		x		NO	NO	NO
1.A.2.e Biomass	X				x				x				X	x	x
1.A.2.e Solid			x				x				x		NO	NO	NO
1.A.2.e Other Fuels			x				x				x		NO	NO	NO
1.A.2.j Wood and Wood Products															
1.A.2.j Liquid Fuels	X				x								X	x	x
1.A.2.j Gaseous Fuels			x				x		x		x		NO	NO	NO
1.A.2.j Biomass	X				x				x				X	x	x
1.A.2.j Solid			x				x				x		NO	NO	NO
1.A.2.j Other Fuels			x				x				x		NO	NO	NO
1.A.2.k Wood and Wood Products															
1.A.2.k Liquid Fuels	X				x								X	x	x
1.A.2.k Gaseous Fuels			x				x		x		x		NO	NO	NO
1.A.2.k Biomass			x				x				x		NO	NO	NO
1.A.2.k Solid			x				x				x		NO	NO	NO
1.A.2.k Other Fuels			x				x				x		NO	NO	NO
1.A.2.l Textiles and Leather															
1.A.2.l Liquid Fuels	X				x								X	x	x
1.A.2.l Gaseous Fuels			x				x		x		x		NO	NO	NO
1.A.2.l Biomass	X				x				x				X	x	x
1.A.2.l Solid			x				x				x		NO	NO	NO
1.A.2.l Other Fuels			x				x				x		NO	NO	NO

1.A.3a Civil Aviation															
1.A.3a Jet Kerosene	X				x				x				X	x	x
1.A.3b Road Transport															
1.A.3b Gasoline	X				x				x				x	x	x
1.A.3b Diesel	X				x				x				x	x	x
1.A.3b LPG	X				x				x				x	x	x
1.A.3b Natural Gas			x				x				x		NO	NO	NO
1.A.3b Biomass			x				x				x		NO	NO	NO
1.A.3b Other fuels			x				x				x		NO	NO	NO
1.A.3c Railways															
1.A.3c Diesel	X				x				x				x	x	x
1.A.3d Water-borne Navigation															
1.A.3d Diesel	X				x				x				x	x	x
1.A.3e Other transport															
1.A.3e Diesel	X				x				x				x	x	x
1.A.4a Commercial and Institutional															
1.A.4a Gasoline	X				x				x				x	x	x
1.A.4a Diesel	X				x				x				x	x	x
1.A.4Alpg	X				x				x				x	x	x
1.A.4a Natural Gas			x				x				x		NO	NO	NO
1.A.4a Biomass	x				x				x				X*	x	x
1.A.4a Other fuels			x				x				x		NO	NO	NO
1.A.4a Other Kerosene	x				x				x				x	x	x
1.A.4b Residential															
1.A.3b Gasoline	x				x				x				x	x	x
1.A.4b Diesel			x				x				x		NO	NO	NO
1.A.4Blpg	x				x				x				x	x	x
1.A.4b Natural Gas			x				x				x		NO	NO	NO
1.A.4b Biomass	x				x				x				X*	x	x
1.A.4b Other fuels			x				x				x		NO	NO	NO
1.A.4b Other Kerosene	x				x				x				x	x	x
1.A.4c Agriculture, Forestry/Fishing and Fish Farms															
1.A.3c Gasoline	x				x				x				x	x	x
1.A.4c Diesel	x				x				x				x	x	x
1.A.4c LPG			X				x				x		NO	NO	NO
1.A.4c Natural Gas			X				x				x		NO	NO	NO
1.A.4c Biomass			X				x				x		NO	NO	NO
1.A.4c Other fuels			X				x				x		NO	NO	NO

3.4.3 Key category sources

The key category sources were generated based on the steps contained in the IPCC 2006 guidelines for both trends and levels. The IPCC 2006 software was used to generate the key category sources in the energy. Table 43 presents the key source categories of 1 A Fuel Combustion Activities.

Table 43: Key category of fuel combustion activities

IPCC Category code	IPCC Category	Greenhouse gas	Key Source Assessment (Level Assessment – LA)	Key Source Trend Assessment (TA) (1990-2012)
1.A.3.b	Road Transport	CO_2	1990, 2012	TA
1.A.1	Energy Industries – Liquid Fuels	CO_2	2012	TA
1.A.4	Other Sectors – Liquid Fuels	CO_2	2012	TA
1.A.2	Manufacturing Industries and Construction – Liquid Fuels	CO_2	2012	TA
1.A.1	Energy Industries – Gaseous Fuels	CO_2		TA

Note: LA – level assessment if not specified otherwise is for 1990 and 2012 TA – trend assessment (1990 to 2012)

In the fuel combustion category, CO_2 emission from road transport emerged as the key category for both level (in 1990 and 2012) and trend assessment. The rest were (a) Energy Industries – Liquid Fuels, CO_2 (LA, 2012 and TA), (b) Other Sectors – Liquid Fuels, CO_2 (LA, 2012 and TA), (c) Manufacturing Industries and Construction – Liquid Fuels, CO_2 (LA, 2012 and TA), and Energy Industries – Gaseous Fuels, CO_2 (TA)

3.4.4 Quality control/quality assurance

Table 44 contains the information on the category-specific data generated when QA/QC procedures were carried out during the inventory. The QA/QC procedures were given serious attention to ensure greater transparency, reliability and completeness as of the improvements in the inventory.

Table 44: QA/QC procedures implemented in the energy sector

Data Type	QA/QC procedure	Remarks/Comment/Examples
Activity data check	Check for transcription, typographical errors and error transposition.	Division of task among the inventory team to ensure that one or two members of team always focus on double checking to avoid data errors associated with those described in the left column.
	Comparison with published data	Ghana's energy balance published the International energy agency, National Statistics, Data national strategic energy planning, Ghana living standard survey
	Consistency checks of categories and sub-categories with totals	Ensuring that disaggregated figures at the category and sub-categories levels add up to the overall totals.
	Identify and fix outliers in data inputs (including checking for dips and spikes in the trend)	Data that do not fall the realistic range and are suspected as inaccurate are excluded and replace with deemed appropriate from international sources or derived from expert judgment.
	Documentation of all data sources, data format and assumptions for easy reference	Keeping records of data and assumption at point use in the data sheet. This helped in easy cross-referencing.
	Ensure reduction in data clumsiness or data redundancy	Logical sequence data flow according the IPCC methodology for the GHG emission estimation was designed for: (a) easy understanding and further probing of how the final results in the IPCC software would like, (b) easy cross-referencing and avoidance of mistakes, (c) easy transmission into the IPCC software and (d) aid in better interpretation of the implication of the use of the data.
Emission factors	Check of implied emission factors (time series)	Ensure consistency check of the use of the emissions factors.
	Double Check with EFDB	To ensure that emission factors being used are the minimum range specified in the IPCC guidelines.
Calculation by the approved 2006 IPCC software	Cross-checks all steps involved in the calculation.	Ensure that steps used for determining, estimating and deriving data are accurate, transparent internally consistent.
	Documentation of sources and correct use of units.	Use of the documentation template record all data sources and assumptions.
	Check for transcription, typographical errors and error transposition.	Check mistake and blunders in the enter entry into the software

	Checked completeness of data coverage	Ensuring all the relevant gases for the specific activity were covered.
Results (emissions)	Check of recalculation differences	To identify and pinpoint changes, revision and reallocation to improve accuracy and transparency of the estimates
	Identify and fix outliers in the results	checking for dips and spikes in trends and levels
	Check of implied emission factors	Ensure consistency check of the use of the emissions factors.
Documentation	Assumptions, corrections, data and sources.	Ensure consistency, transparency, facilitate repeatability and easy retrieval
	Improvement list (internal and external findings)	Help prioritize areas that require actions.

3.4.5 Planned improvements

During the inventory certain areas were identified for future improvements. The improvements are aimed at building greater confidence in the inventory estimate and contribute reduce uncertainties in the inventory. Table 46 contains the list of identified planned improvement activities and the necessary next steps that must be taken.

Table 45: Planned improvement activities

Category	identification of planned improvement areas	prioritization of improvement activities	responsibility and next steps	Expected time to resolve
1.A4b other sector commercial/institutional	Survey on source-specific commercial/institutional generators: fuel consumption, installed capacity, population etc	KC	Energy commission and EPA	Next inventory
1.A1b – Electricity generation	Develop or request IPPs to report on their plant-specific emissions and emission factors	KC	EPA & Energy Commission	Next inventory
1.A2a	Allocate fuel share to iron and steel industry (support activities)	Non-KC	Energy team	Next inventory
All Categories	Conduct survey to update and review existing sectoral fuel consumption share	-	Energy Statistic Team. Energy Commission	Medium-long term improvement in the reporting in Energy Statistics
1.A3b – Road Transport	Survey to update the existing 2005 data on of fuels allocation to the various vehicle classes.	KC	DVLA, EPA and Energy Commission	Medium to long term bearing in mind on-going project on roadmap emission and fuel economy standards by 2020.
	Survey to improve the technology-based classification of the vehicle on based EU standards (in addition focus on separating functional catalytic device).			
	Survey to establish fuel economy baseline for different classes of fairly new vehicles (120,000 to 50,000km)		DVLA, EPA and Energy Commission, private garages	
	separate portions of the total fleet is that use for freight transport from passenger transport		Energy Team	Next inventory
1.A3a – Civil aviation	Collect additional ATK consumption, LTO of domestic airlines data from OMCs , Civil Aviation Authority, and the Airlines	Non-KC	Energy Team	Next two inventories

	Additional data collection with the aim producing tier 2 estimates – data on domestic air traffic movement (LTO),	Non-KC	Energy Team	next inventory
1.A3c Railways	Reconcile the Ghana Railway Company's and IEA diesel consumption for rail transport to ensure consistency and transparency.	Non-KC	Energy Team	next inventory
	Collect additional data from Ghana Railway Company on the following: (a) number of train in service, (b) annual distances or destinations covered and (c) technologies of the trains	Non-KC	Energy Team	next inventory
Bunkering fuels	Collect additional specific data on ATK and diesel for bunkering services	-	Energy Team	Next inventory

4. Industrial Process and Product Use (IPPU)

4.1 Sector overview

GHG emissions from industrial processes are generated from a range of often diffuse point sources. The emission are produced as by-products of primary industrial processes. These emissions are produced from industrial processes and are not directly as a result of energy consumed during the process. For example, the transformation of industry materials can result in the release of gases such as CO_2, CH_4, and N_2O. Majority of the IPPU activities that were covered in this inventory included: (a) mineral industry, (b) metal industry and (c) non-energy products from Fuels and Solvent. The rest of the activities under IPPU were excluded from the inventory because they either do not take place in Ghana or there was no sufficient data to use. For example, although certain quantities of substitute for ozone depleting substances were consumed in the country, the state of the existing data on consumption does not allow it use in the inventory (see table 47). The CO_2 and PFCs (CF_4 and C_2F_6) were the main direct GHG estimated and reported under IPPU.

4.1.1 Summary of the IPPU sector activities

The overview of IPPU sector activities and their emissions are provided in table 46. Additional information on the description of the IPPU activities that are occurring in the country has been provided in detail below.

Table 46: Overview of total emissions estimate for IPPU sector Activities for years 2010 and 2012

Greenhouse Gas Source and Sink Categories	2010					2012				
	$MtCO_2e$									
	CO_2	CH_4	N_2o	HFC/PFC/sF$_6$	Total	CO_2	CH_4	N_2o	HFC/PFC/sF$_6$	Total
2 Industrial Processes and Product Use	0.24	NO	NO	NO	0.24	0.35	NO	NO	0.113	0.47
2.A - Mineral Industry	0.21	NA	NA	NA	0.21	0.27	NA	NA	NA	0.27
2.B - Chemical Industry	NO	NO	NO	NA	NO	NO	NO	NO	NA	NO
2.C - Metal Industry	0.0084	NO	NO	NO	0.0084	0.07	NO	NO	0.113	0.18
2.D- Non-Energy Products from Fuels and Solvent	0.018	NA	NA	NA	0.018	0.02	NA	NA	NA	0.02
2.E – Electronics Industry	NA	NA	NA	NO	NO	NA	NA	NA	NO	NO
2.F – Product Uses as Substitute for Ozone Depleting Substances	NA	NA	NA	NE	NE	NA	NA	NA	NE	NE
2.G - Other Product Manufacture and Use	NA	NA	NO	NO	NO	NA	NA	NO	NO	NO

4.1.1.1 Mineral Industry (2A)

Cement Production (2.A.1)

Cement production is an energy and raw-material-intensive process that results in the generation of CO_2 from both the energy consumed in making the cement and the chemical process itself. During the cement production process, calcium carbonate ($CaCO_3$) is heated in a cement kiln at a temperature of about 1,450°C (2,400°F) to form lime (i.e., calcium oxide or CaO) and CO_2 in a process known as calcination or calcining. Next, the lime is combined with silica-containing materials to produce clinker (an intermediate product), with the earlier byproduct CO_2 being released to the atmosphere. The clinker is then allowed to cool, mixed with a small amount of gypsum and potentially other materials (e.g., slag), and used to make Portland cement. In Ghana, there are currently four cement producing plants that mainly produce Portland cement. Three of the plants import clinker where its manufacture generates significant amounts of CO_2 and is the primary step in cement production. These plants primarily mill the imported clinker with limestone and therefore the actual CO_2 emissions are from the uses of limestone which has been estimated under Other Process Uses of Carbonates (2A4). The third plant imports already produced cement and bag.

Lime Production (2.A.2)

Lime is an important manufactured product with many industrial, chemical, and environmental applications. The major uses are in steel making, flue gas desulfurization systems at coal-fired electric power plants, construction, and water purification. Lime is also used as a CO_2 scrubber. Lime actually refers to a variety of chemical compounds and include calcium oxide (CaO), or high-calcium quicklime; calcium hydroxide ($Ca(OH)_2$), or hydrated lime; dolomitic quicklime ([CaO•MgO]); and dolomitic hydrate ([$Ca(OH)_2$•MgO] or [$Ca(OH)_2$•$Mg(OH)_2$]). Lime production involves three main processes: stone preparation, calcination, and hydration. Carbon dioxide is generated during the calcination stage, when limestone—mostly calcium carbonate ($CaCO_3$)—is roasted at high temperatures in a kiln to produce CaO and CO2. The CO_2 is given off as a gas and is normally emitted to the atmosphere. No manufacturers of lime exist in Ghana. However, one company imports lime product for bagging. The only estimations were from 1991 to 2006 where data was obtained from some informal sectors. Results of emissions were quiet insignificant compared to the total emissions from the mineral industry in relation to other emissions. Extrapolation of the data has not been possible because the verification of the data source has been challenging and that there are no indications those sources still exist.

Other Process Uses of Carbonates (2A4)

Ceramics (2A4a)

Ceramics include the production of bricks and roof tiles, vitrified clay pipes, refractory products, expanded clay products, wall and floor tiles, etc. Process-related emissions from ceramics result from the calcination of carbonates in the clay, as well as the addition of additives. Carbonates are heated to high temperatures in a kiln, producing oxides and CO_2. The ceramic industry particularly for bricks and roof tiles which is common is quiet minor in Ghana. Lack of data has made it impossible to estimate emissions from sector.

Other Uses of Soda Ash (2A4b)

Some industrial facilities use soda ash such as soap and detergents. However, there are no significant uses of soda ash in Ghana. Estimation has not been possible due to insufficient data and therefore emissions are not estimated.

Limestone and Dolomite Use (2A4d)

Limestone ($CaCO_3$) and dolomite ($CaCO_3$ $MgCO_3$) are basic raw materials used by a wide variety of industries, including construction, agriculture, chemical, metallurgy, glass production, and environmental pollution control. Limestone is widely distributed throughout the world in deposits of varying sizes and degrees of purity. Deposits of limestone occur in some parts of Ghana and significant quantities are extracted for cement industrial application. For this application, limestone is heated sufficiently enough to calcine the material and generate CO_2 as a byproduct. Examples of such applications include limestone used as a flux or purifier in metallurgical furnaces, as a sorbent in flue gas desulfurization (FGD) systems for utility and industrial plants, and as a raw material for the production of glass, lime, and cement. Reported limestone use in Ghana primarily come from the cement industry. In 2010 and 2012, 485793 and 608213 metric tons of limestone was consumed in the cement industry respectively. Small amounts of dolomite have recently been used by some cement industry, however data have not been available for emission estimation. CO_2 emissions were calculated based on the IPCC 2006 Guidelines Tier 1 method by multiplying the quantity of limestone consumed by the emission factor, and converting this value to CO_2. Consumption data for 1990 through 2012 of limestone used in the cement industry (see table 47). The production capacity data for 1990 through 2012 came from two cement industries.

Table 47: Annual limestone consumption in Ghana

Year	Limestone Quantity (Tonnes)
1990	33,472.85
2005	23,9616
2006	307,467
2007	361,845.28
2008	524,097.87
2009	426,432.89
2010	485,792.65
2011	572,337.01
2012	608,212.8

4.1.1.2 Metal Industry (2C)

Emissions have only been reported under iron and steel for secondary steel/scrap recycling activities and aluminum production under the source category.

Iron and Steel Production (2C1)

In Ghana, all steel production are steel recycling activities from scrap. No primary activity with the production of pig iron occurs in the country. The majority of CO_2 emissions from the iron and steel production process come from the use of metallurgical coke in the production of pig iron and from the consumption of other process byproducts at the iron and steel mill, with lesser amounts emitted from the use of flux and from the removal of carbon from pig iron used to produce steel. Some carbon is also stored in the finished iron and steel products. Emissions from steel production in EAFs were estimated by multiplying the amount of steel produced in tons by the emission factor as applied from the Tier 1 approach for emissions from iron and steel production from the 2006 IPCC Guidelines for National

Greenhouse Gas Inventories (IPCC, 2006). The steel recycling activity does not result in fugitive emissions of CH_4, which are emitted via leaks in the primary the production equipment rather than through the emission stacks or vents of the production plants and hence not occurring. Data for steel production were obtained from the three steel producers.

Aluminum Production (2C3)

Aluminum is a light-weight, malleable, and corrosion-resistant metal that is used in many manufactured products, including aircraft, ship craft, and roofing, automobiles, bicycles, and kitchen utensils. The production of primary aluminum—in addition to consuming large quantities of electricity—results in process-related emissions of CO_2 and two perfluorocarbons (PFCs): perfluoromethane (CF_4) and perfluoromethane (C_2F_6). CO_2 is emitted during the aluminum smelting process when alumina (aluminum oxide, Al_2O_3) is reduced to aluminum using the Hall-Heroult reduction process. The reduction of the alumina occurs through electrolysis in a molten bath of natural or synthetic cryolite (Na3AlF6). The reduction cells contain a carbon lining that serves as the cathode. Carbon is also contained in the anode, which can be a carbon mass of paste, coke briquettes, or prebaked carbon blocks from petroleum coke. During reduction, most of this carbon is oxidized and released to the atmosphere as CO_2.

In Ghana, only the Centre-Worked Prebake (CWPB) alumina feed system is available with the only plant, Volta Aluminum Company Limited Company (VALCO). Primary aluminum production was not carried out in 2004, 2009 and 2010 due to unavailability of electricity. In addition to CO_2 emissions, the aluminum production industry is also a source of PFC emissions. During the smelting process, when the alumina ore content of the electrolytic bath falls below critical levels required for electrolysis, rapid voltage increases occur, which are termed "anode effects." These anode effects cause carbon from the anode and fluorine from the dissociated molten cryolite bath to combine, thereby producing fugitive emissions of CF_4 and C_2F_6. In general, the magnitude of emissions for a given smelter and level of production depends on the frequency and duration of these anode effects. As the frequency and duration of the anode effects increase, emissions increase.

4.1.1.3 Non-Energy Products from Fuels and Solvent Use (2D)

Lubricant Use (2D1)

Lubricants are mostly used in industrial and transport applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. They can be subdivided into (a) motor oils and industrial oils, and (b) greases, which differ in terms of physical characteristics (e.g., viscosity), commercial applications, and environmental fate. The use of lubricants in engines is primarily for their lubricating properties and associated emissions are therefore considered as non-combustion emissions to be reported in the IPPU Sector. It is difficult to determine which fraction of the lubricant consumed in machinery and in vehicles is actually combusted and thus directly results in CO_2 emissions, and the fraction not fully oxidized that results firstly in NMVOC and CO emissions (except for the use in 2-stroke engines, which is excluded here). For this reason, these NMVOC and CO emissions are very seldom reported by countries in the emission inventories. Therefore, for calculating CO_2 emissions the total amount of lubricants lost during their use is assumed to be fully combusted and these emissions are directly reported as CO_2 emissions. In Ghana, data from Tema Lube oil which has been operating since 1992 producing motor oils for oil marketing companies was used. Data available from the company was for the years 2004-2012. For subsequent years where CO_2 process data were not reported estimates were developed through linear extrapolation, and/or assuming representative (e.g., later reported) values. The assumption used in the estimation is that all motor oil produced by the company is consumed in the producing year. With this assumption there is likelihood that unused motor oil in a previous year is consumed in the following year since actual consumptions has not been determined.

4.1.1.4 Product Uses as Substitutes for Ozone Depleting Substances (2F)

Hydrofluorocarbons and perfluorocarbons are used as alternatives to several classes of ozone- depleting substances that are being phased out under the terms of the Montreal Protocol and the Clean Air Act Amendments of 1990.147 Ozone depleting substances—chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons (HCFCs)—are used in a variety of industrial applications including refrigeration and air conditioning equipment, solvent cleaning, foam production, sterilization, fire extinguishing, and aerosols. Although HFCs and PFCs are not harmful to the stratospheric ozone layer, they are potent greenhouse gases.

Refrigeration and Air Conditioning (2F1)

There are refrigeration and air Conditioning using HFCs (HFC-32, HFC-125, HFC-134a and HFC-143a) in Ghana. However, emission estimations have not been done due to insufficient activity data.

4.2 Analysis of IPPU emission trends

The total emissions in the IPPU sector amounted to 0.46MtCO_2e in 2012, which made up 2.5% of the national totals. When AFOLU emissions are included to the national total emissions, the IPPU emissions contributions decreased to 1.5%. The trend of the total emissions recorded a general decline between 1990 and 2012 due to notable reduction in industry productivity in the period. For the period 1990-2012, IPPU emissions decreased by 73.8% and 65.6% of the 1990 and 2000 emissions level respectively (see figure 23) compared to the 2012 levels. Not only did industrial production decline, the fall in the scale of operations of VALCO significantly pushed the emission down.

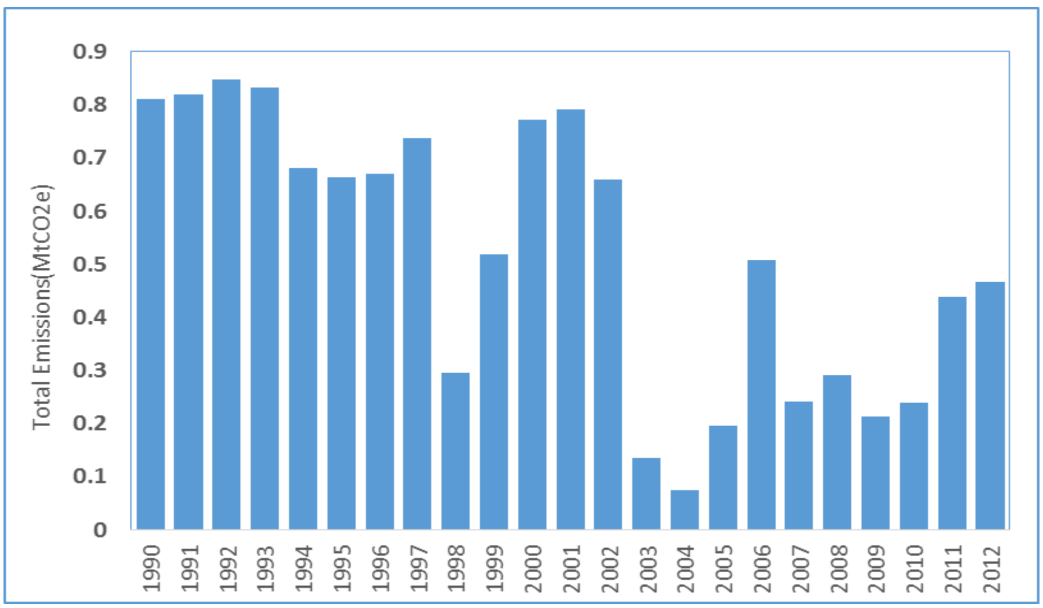


Figure 23: Declining emissions trends of the IPPU sector for the period 1990-2012

Within the IPPU, mineral industry was the largest source emissions making 58% of the total emission in 2012. This was followed by metal industry (38%) and non-energy products from fuels and solvent use (4%). However, in 1990 and 2000, emissions from the metal industry was the predominant source because in those years, the scale of operations of VALCO was relatively higher compared to 2012 (see figure 24).

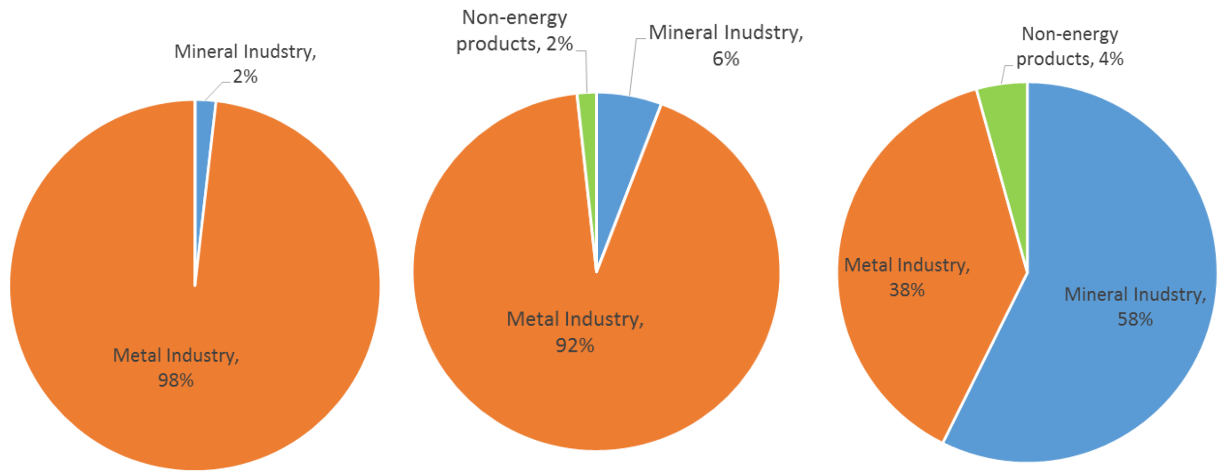


Figure 24: Share of emissions in IPPU sector 1990(Left), 2000 (Middle), 2012(Right)

Within the mineral industry, lime production and ceramics were the main sources of emissions. Of the two sources, emissions from ceramics dominated throughout the time series. Emissions from ceramics use recorded a steady rise from 1990 to 2012. Similar increases were recorded for lime production between years 1991 and 1996, however, for the rest of the years 1997 to 2012, emissions could not be estimated because of lack of sufficient data. Under non-energy products from fuels and solvent use, lubricant use was main source of emissions. The emissions from lubricant use recorded increases from 1992 and peaked at 2006 (0.023MtCO_2e) before declining to 0.020MtCO_2e in 2012.

Carbon Dioxide emissions was the largest source of greenhouse gases reported during the period 1990-2012. CO_2 from the metal industry (particularly aluminum production) constituted an average of 72.8% of total industrial emissions throughout the time series (see table 48). The remaining 27.2% share of the IPPU emissions was PFCs. For CO_2 emissions, the metal industry (aluminum production) consistently remained the dominant source until recently (2007 to 2012) that CO_2 emissions from the mineral industry (ceramics) arose to reached to significant levels (see figure 25).

Table 48: CO_2 and PFC emission trends

Year	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO_2	(Mt)	0.81	0.82	0.85	0.83	0.68	0.66	0.67	0.74	0.30	0.52	0.77	0.79
PFCs	(MtCO_2e)	0.52	0.52	0.53	0.52	0.42	0.40	0.40	0.45	0.16	0.30	0.46	0.48
Total	(MtCO_2e)	1.33	1.34	1.38	1.35	1.10	1.07	1.07	1.19	0.46	0.82	1.23	1.27
Year	**Unit**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
CO_2	(Mt)	0.66	0.13	0.08	0.20	0.51	0.24	0.29	0.21	0.24	0.44	0.47	
PFCs	(MtCO_2e)	0.39	0.04	0.00	0.04	0.22	0.04	0.03	0.00	0.00	0.11	0.11	
Total	(MtCO_2e)	1.05	0.18	0.08	0.24	0.73	0.28	0.32	0.21	0.24	0.54	0.58	

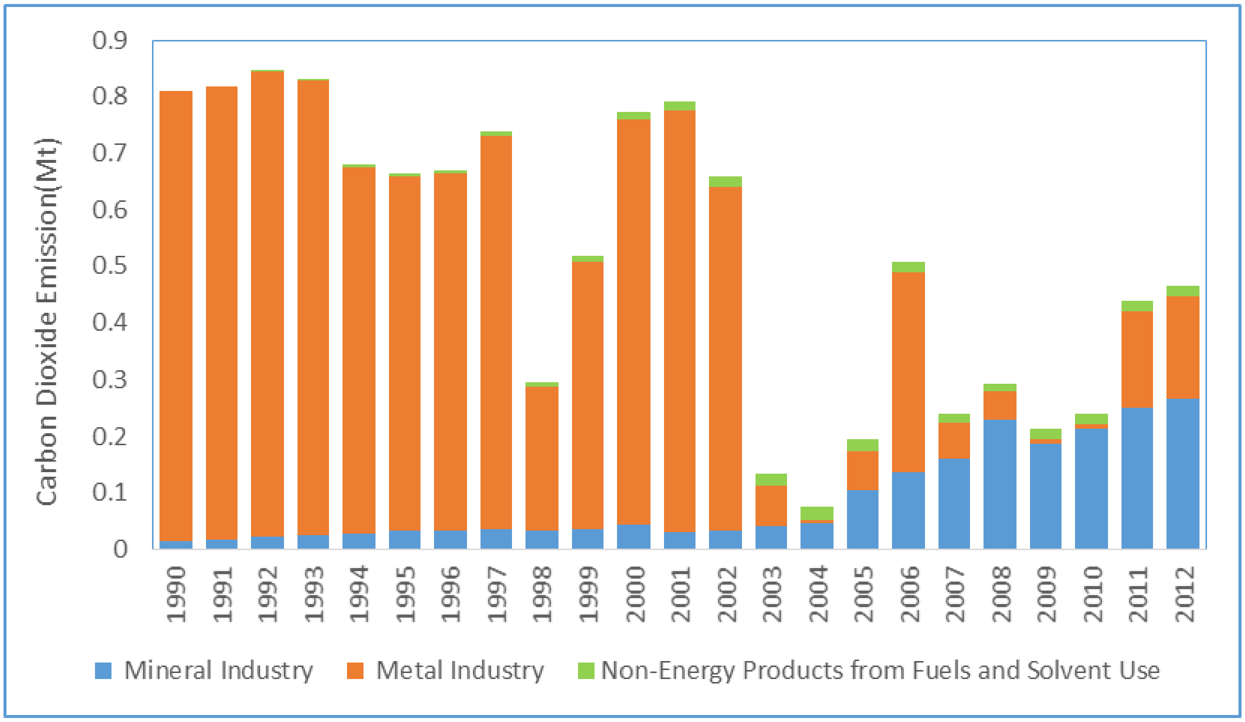


Figure 25: Declining trend of carbon dioxide emissions for the period 1990-2012 in the IPPU sector

The observed decreases in CO_2 emissions from the metal industry was associated with the consistent decline in Aluminum production at VALCO due to significant power cuts to the facility. The power cuts eventually resulted in low production activities in 2004, 2009 and 2010. Emissions form facility started picking up in 2011 following the restoration of limited electricity which enabled the plant to put one potline back into full operation.

With respect to mineral products, emissions were recorded mainly from limestone use in the cement industry. Unlike the observed decreases in CO_2 emissions in the Metal Industry, that of the mineral industry recorded remarkable increases from 0.01 $MtCO_2e$ in 1990 to 0.04 $MtCO_2e$ in 2000 and further to 0.27 $MtCO_2e$ in 2012. The high demand for limestone use in the cement industry contributed to the rise in CO_2 emissions. Limestone use have increased significantly since 1990 largely due to production of cement for infrastructural activities and the setting up of additional cement plants in country. Another source of CO_2 emissions was from industrial application of lubricant under non-energy product from fuels and solvent use. The CO_2 emissions trend saw a slight upward change from 1992 to 2012. In the case of iron and steel there is only the production steel from steel recycling plants. Together lubricant use contributed to smaller emissions with minor increments.

4.3 Methodology issues

The IPCC tier 1 methodology was applied in the IPPU 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 the plant level.

4.4 Brief description of recalculation

Recalculation was done for CO_2 emissions for both mineral industry and metal industry for 1990 - 2006. Generally, activity data for both sub-categories were updated due to the availability of new datasets from companies. The recalculation took into consideration addition of new activity under lubricant use due to availability of new datasets.

4.5 IPPU planned improvements

Significant improvements in the IPPU sector is needed in the short to the medium term. The improvements are in areas such as; (a) collecting additional data to improve completeness; (b) improvements in methodology for estimation; (c) further processing aggregated data; (d) collect data additional emission factors. Details of the planned improvements are provided below:

4.5.1 Data improvements

- Conduct industrial survey in country to identify all possible sources according to the IPCC guidelines for both formal and informal sources and ensure data is collected and sources maintained for future inventories.
- Identify, track and monitor any potential new source that would be important for inclusion in inventories according to the IPCC guidelines
- Identify additional data collection sources for lime production. Particular attention will be given to collecting enough data to fill in time series gaps.
- Collect comprehensive data on ODS substitute gas (HFCs) especially in the refrigeration and air-conditioning sectors.
- Collect data for 1990 to 2004 and include the data from a second plant established in country as the latest guidance from the IPCC on the use of facility-level data in national inventories will be relied upon.
- Collect lubricant import data from the oil marketing companies.

4.5.2 Methodological improvements

- Improvement in estimates on non-energy use and feedstock to ensure internal consistency.
- Analyze data reported for dolomite use by the cement industry and limestone use as fluxes in the steel recycling plants which would be useful to improve the emission estimates for the Limestone and Dolomite Use source category. In implementing improvements and integration of data from the plant, the latest guidance from the IPCC on the use of facility-level data in national inventories will be relied upon. Additionally, future improvements include revisiting the methodology ensure the use of tier 2 method for all years to improve emission calculations.
- Analyze data reported particularly for all three steel plants that would be useful to improve the emission estimates for the Iron and Steel Production source category. Of particular importance will be to ensure time series consistency, as the facility-level reporting data from the facilities may not be available for all Inventory years as required for this inventory. The latest guidance from the IPCC on the use of facility-level data in national inventories will be taken into account.

5. Agriculture, Forestry and Other Land use (AFOLU)

5. 1 Sector overview

Resources that are derived from the AFOLU sector are key to the socio-economic well-being of Ghanaians. The use of land to generate social and economic capital (livestock, biomass, agricultural products and waste and timber and non-timber forest products) results in the modification of the landscape. The kinds of policies, practices; technologies and their interrelationships determine the levels and quality of use of land resources. The way land resources are put to use defines whether or not the following activities will result in emissions or removals of GHG from the AFOLU sector. The activities, among others include: (a) livestock rearing and dung management (b) land use change via forest degradation and deforestation (c) conservation or sustainable forest management, (d) afforestation and reforestation, (e) wood and fuel wood harvesting, (f) wildfire disturbance (g) application of nitrogen-based fertilizers, (h) generation and disposal of crop residue and (i) rice cultivation in different eco-systems.

The rate at which emissions are emitted/removed by these activities are not only determined by the intensities of biomass removals through timber harvesting, fuel-wood collection, burning, decomposition of agricultural waste etc., but also the "coverage" of activities that restore or rehabilitate degraded lands, promote sustainable land management and enhance carbon stocks. Based on the background information provided above, emissions accounting for the AFOLU sector was conducted using the land-based approach which focused on all landscape activities that can either result in emissions or removals depending on the intensities and its "geographic spread". The 2006 IPCC guidelines was used for the estimation of emissions/removals of the AFOLU sector because it provided a more recent scientifically-robust methodologies and approaches for undertaking the inventory of GHG emissions/removals at the national level. This inventory has been done to the extent possible using country-specific data to cover the families of land-based activities occurring in Ghana as well as taking into account the need to ensure consistency with any accounting that takes place at the sub-national level and those that focus on specific set of land-based activities such as REDD+.

5.1.1 Classification of AFOLU activities under IPCC 2006 guidelines

The national inventory in AFOLU was done based on the IPCC accounting methods contained in the IPCC 2006 guidelines. The guidelines divides the AFOLU into three clusters of emission/removal categories according to land-based and non-land based activities or CO_2 and non-CO_2 activities. Each category is further disaggregated into the activities that contribute to emissions/removals. The three clusters of emission/removal categories were: livestock, land and aggregated source and non-CO_2 emission sources from land. Because the inventory was done, uniquely, at the category level using the IPCCC codes which identifies each category and the activities was possible. The code for AFOLU was prefix with the figure 3 because it is the third in the sequence of sectors covered by the national GHG accounting. The three categories and their codes are as follows: Livestock (3A), Land (3B) and Aggregated and Non-CO2 Emissions Sources (3C).

5.1.1.1 Livestock (3A)

Nitrous oxide (N_2O) and methane (CH_4) that are emitted through livestock rearing activities and are grouped under livestock (3A). The livestock rearing are further divided into enteric fermentation (3.A1) and manure management (3.A2). The emissions that are generated from enteric fermentation are influenced by factors such as animal feed intake (quantity and quality) and digestive processes (eg. Animal weight, excretion rate). On the other hand, in estimating emissions from manure management the predominance of various livestock manure management systems such as (mainly pasture/range/paddock, dry lot, liquid/slurry etc) and how their relative levels of use impact on N_2O and CH_4 emissions are considered. For the two sub-categories, the main data inputs were animal type and population (head), average mass and excretion rate.

5.1.1.2 Land (3B)

In the land category (3B), net CO_2 emissions resulting from deforestation, forest degradation, afforestation/reforestation, and sustainable forest management/conservation were estimated. The land category (3B) was divided into six land representations, namely; (3.B1 -Forest land), (3.B2 Cropland), (3.B3- Grassland), (3.B4 - Wetland), (3.B5 Settlement) and (3.B6 - Other Lands). The changes in the land representations through conversion leads to CO_2 emissions. Within each sub-categories, CO_2 emissions/removals were estimated for two main activities – (a) lands remaining same over a given period and (b) lands converted to another land use type over a given period. Depending on the degree of land use change that occur among the land types, the net CO_2 emissions could become a source or removal. The main data inputs under this category were (a) land use representations for each ecological zone and land use change matrix (transitions in land use representations (b) average carbon stocks for five biomass pools in each land representation, (c) round wood harvesting and wood fuel collection (d) areas affected by wildfire and (e) soil classification and their soil carbon stocks. All these data were made available through the Japanese Funded Forest Preservation Program (FPP), Forestry Commission and where necessary FAO.

3.1.1.3 Aggregated Sources and Non-CO_2 Emission Sources from Land (3C)

Activities that generate emissions which were neither captured under 3A nor 3B fell under "aggregated sources and non-CO_2 emission sources from land" (3C). Emissions under 3C was further divided into b these specific sources: (a) biomass burning (3C.1); (b) Liming (3C.2); (c) Urea application (3C.3), (d) Direct N_2O emissions from managed soil(3C.4); (e) Indirect N_2O emissions from managed soil(3C.5); (f) Indirect N_2O emissions from manure management(3C.6); and (g) rice cultivations(3C.7). The data input were: (a) annual yield from major stable crops, (b) areas affected by fire, (c) nitrogen fertilizer and urea consumption and mode of application, (e) rice cultivations. The main source of the data under this category was the Agriculture facts and figure published by the Ministry of Food and Agriculture.

5.1.2 Data sources and methodology

A summary of the data and the description of the methodology applied in the inventory for the AFOLU sector are provided below.

5.1.2.1 Data sources

The data used in this inventory were from different relevant national and international institutions and they occurred in different formats. Table 49 provides an overview of the data used in the inventory.

Table 49: Overview of the AFOLU categories, data and date sources in the inventory

Categories		Sub-categories	Data Type	Data Source	Principal Data Providers
3.A Livestock	3.A1	Enteric Fermentation	Animal population (cattle, goats, sheep, swine, donkey, poultry, horse	Agriculture Facts and Figures FAOSTAT	Ministry of Food and Agriculture – Statistics Research and Information Directorate,
	3.A2	Manure Management			

			Fractions of manure management practices	Expert Judgment	UN Food and Agriculture Organization AFOLU Team
3.B. Land	3.B1	Forest land	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
			biomass estimate for 5 IPCC pools (Above ground biomass, below ground biomass, deadwood, herb, litter and soil)		
			Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
			Industrial round wood	RMSC FAOSTAT	Forestry Commission, Ghana UN Food and Agriculture Organization
			Wood fuel production	Energy Statistics	Energy Commission
			Areas affected by fire	Expert Judgment	AFOLU Team
	3.B2	Cropland	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
			biomass estimate for 5 IPCC pools (Above ground biomass, below ground biomass, deadwood, herb, litter and soil)		
			Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
	3.B3	Grassland	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
			biomass estimate for 5 IPCC pools (Above ground biomass, below		

			ground biomass, deadwood, herb, litter and soil)		
			Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
	3.B4	Wetland	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
			Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
	3.B5	Settlement	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
			Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
	3.B6	Other lands	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana
			Climate zones, soil classification and ecological zone maps	IPCC database	IPCC
3.C Aggregated and non CO_2 emissions on land	3.C1	Biomass burning	Areas affected by fire in cropland, forestland and grassland	Expert Judgment	AFOLU Team
			Mass fuel available for burning	Forest Preservation Program, 2012	Forestry Commission, Ghana
	3.C3	Urea application	Annual Urea consumption figures	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate,
	3.C4	Direct N_2O emissions from manage soils	Annual generic NPK consumption	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate,
	3.C5	Indirect N_2O emissions from manage soils	Annual crop production in tonnes per annum		

	3.C6	Indirect N_2O emissions from manure management	Animal population (cattle, goats, sheep, swine, donkey, poultry, horse	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate,
			Fractions of manure management practices	Expert Judgment	AFOLU Team
	3.C7	Rice cultivation	Annual rice production areas	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate
			Proportions of annual rice production area under rain fed, irrigated and upland systems	National Rice Development strategy	

5.1.2.2 Methodology

Description of methods and underlying assumption for the estimation of emissions

This section highlights the methodological choices and assumptions behind the activity data, emission/removal factors used in estimating the emissions/removals in the AFOLU sector. The inventory shifted from the use of the revised 1996 IPCC guidelines to the 2006 IPCC guidelines. The 2006 IPCC guidelines provided a step-by-step guidance on data identification and selection, methods and application of underlying assumptions in a consistent and transparent manner. The guidelines further provided guidance on how the GHG emissions/removals must be estimated using activity data and emission/removal factors.

Activity data refers to the measure of the level of intensity, frequency of use, or the quantity of the activity that result in the generation/removal of GHG emissions. For examples, areas of different land representations, their associated biomass and the changes in them over a given period; the annual population of livestock; annual generic NPK application etc. Emission/removal factors represent the rate at which a particular greenhouse gas (CO_2, CH_4 and N_2O) are produced or removed as a result of the use of, change of and level of intensity/frequency of use/number will produce or remove GHG emissions under defined conditions. Therefore the product of the activity data and the emission/removal factor and its global warming potential (GWP) gives the total GHG emissions of a particular activity [E=AD*EF or RF * GWP].

Generally, the inventory adopted a combination of Tier 1 and higher tier methodologies in the estimation of the emissions/removals based on the available country-specific data and data from reliable international sources. The higher tier methodology was used when sufficient country-specific data was available. Example, the use of country-generated data on land representations, associated biomass and changes in them. The purpose of striving to use country-specific data and the higher tier was to help improve the robustness and quality of the estimates as much as possible. In addition, the use of the country-specific data helped to make the results more representative of the national situation. Detailed descriptions of the methods are provided in the specific sections of the various sub-categories. As much as practicable, available country specific activity data for all the categories were used. Where country specific activity data were non-existent, data from reliable international data sources were used (see table 51). Most of these national data were either obtained from primary or publicly available secondary sources. To the extent possible, the national data obtained covered the 1990-2012 time-series, however, where gaps existed, data from credible sub-regional and international sources were used to fill the gaps. In the absence of data from the aforementioned sources to fill the gaps, appropriate statistical methods (e.g. trends extrapolation, interpolation, etc) were applied in line with the IPCC good practice guidance. In situations where there was complete absence of data at the national, sub-regional and international levels, expert judgment was applied and the underlying assumptions documented.

5.1.3 Description of notation keys and completeness information

Information on completeness and use of notation keys in the AFOLU sector are provided below. Completeness includes coverage of gases, categories as well as time series. Additional information is given on the status of emission/removal estimates of all sub-categories. Emissions/removals of all sub-categories - 3A (Livestock), 3B (Land) and 3C (Aggregated and Non-CO_2 emission source on land) have been estimated; thus the status of the AFOLU estimates is complete. Table 50 shows the overview of the completeness status of the estimations under various sub-categories.

Table 50: Overview of subcategories of AFOLU and status of estimations

IPCC Category	Time series Completeness												Status of Gas		
	1990-2006 (recalculations)				2007-2010 (new estimates)				2011-2012 (latest estimates)						
	Coverage of gases														
	E	NE	NO	IE	E	NE	NO	IE	E	NE	NO	IE	CO_2	CH_4	N_20
3.A.1.– Enteric Fermentation															
3.A.1.ai Cattle			x				x				x		NO	NO	NO
3.A.1.aii Other Cattle	x				x				x				NO	x	NO
3.A.1b Buffalo			x				x				x		NO	NO	NO
3.A.1c Sheep	x				x				x				NO	x	NO
3.A.1d Goat	x				x				x				NO	x	NO
3.A.1e Camel			x				x				x		NO	NO	NO
1.A.1.f horses	x				x				x				NO	x	NO
1.A.1.g donkey	x				x				x				NO	x	NO
1.A.1.h swine	x				x				x				NO	x	NO
3.A.2.– Manure Management															
3.A.2.ai Cattle			x				x				x		NO	NO	NO
3.A.2.aii Other Cattle	x				x				x				NO	x	NO
3.A.2b Buffalo			x				x				x		NO	NO	NO
3.A.2c Sheep	x				x				x				NO	x	NO
3.A.2d Goat	x				x				x				NO	x	NO
3.A.2e Camel			x				x				x		NO	NO	NO
3.A.2f horses	x				x				x				NO	x	NO
3.A.2.g donkey	x				x				x				NO	x	NO
3.A.2.h swine	x				x				x				NO	x	NO
3.A.2i Poultry	x				x				x				NO	x	NO
3.B.1 – Forest Land															
3.B.1a Forest land remain forest land	x				x				x				x	NO	NO
3.B.1b Other converted to forest land	x				x				x				x	NO	NO

3.B.2. Crop land															
3.B.2a Cropland remaining cropland	x				x				x				x	NO	NO
3.b.2b Other land converted to Cropland	x				x				x				x	NO	NO
3. B.3. Grassland															
3.B.3a Grassland remaining grassland	x				x				x				x	NO	NO
3.b.3b Other land converted to grassland		x			x					x			x	NO	NO
3. B.4. Wetland		x													
3.B.4a Wetland remaining wetlands		x			x					x			x	NO	NO
3.b.4b Other land converted to wetlands		x			x					x			x	NO	NO
3.B.5 Settlement															
3.B.5a Wetland remaining wetlands		x			x					x			x	NO	NO
3.b.5b Other land converted to wetlands		x			x					x			x	NO	NO
3.B. 6 Other lands															
3.B.5a Wetland remaining wetlands		x			x					x			X	NO	NO
3.b.5b Other land converted to wetlands		x			x					x			X	NO	NO
3.C.1 Emission from biomass burning															
3.C.1a biomass burning in Forest land	x				x				x				NO	x	x
3.C.1b biomass burning in cropland	x				x				x				NO	x	x
3.C.1c biomass burning in grassland	x				x				x				NO	x	x
3.C.1c biomass burning in other land		x				x				x			NO	NO	NO
3.C.2 Limning															
3.C.2 Liming			x					x				x	NO	NO	NO
3.C.3 Urea Application															
3.C.3 Urea application	x				x				x				x	x	NO
3.C.4 Direct N_2O Emissions from Managed Soils															
3.C.4 Direct N_2O Emissions from Managed Soils	x				x				x				NO	NO	x
3.C.5 Indirect N_2O Emissions from Managed Soils															

3.C.5 Indirect N_2O Emissions from Managed Soils	x				x				x				NO	NO	x
3.C.6 Indirect N_2O Emissions from Manure Management															
3.C.6 Indirect N_2O Emissions from Managed Soils	x				x				x				NO	NO	x
3.C.7 Rice Cultivations															
3.C.Rice cultivations	x				x				x				NO	x	NO

E" indicates that emissions/removals from this sub-category have been estimated.
"NO" means "Not Occurring" "NE" means "Not Estimated", "IE" means "included elsewhere"

5.1.4 Category-specific activity datasets

Data were collected from several sources for this inventory. A brief description of the datasets that were used in the AFOLU inventory have been provided in the section below:

5.1.4.1 Livestock (3A)

In order to estimate CH_4 and N_2O emissions from enteric fermentation and manure management, heads of different livestock data for each year were collected as inputs into inventory. The livestock data were obtained from Agriculture facts and figure published by MoFA and FAO. In many cases, the data from MoFA and FAO were consistent, however, where there were differences in the livestock data, MoFA was approached to provide the corrected ones.

Animal Population (3.A1 and 3. A2)

In 2012, the total national animal population was estimated at 69,501,050. Poultry only made up 57,885,000 and the remaining 11,616,050 were livestock (cattle, sheep, goat, horses, donkey and pigs). With the largest share (83.3%) of total animal population, the poultry population grew at a rate of 1.1% per annum between 2000 and 2012. The national total of 69,501,050 represented an increase of 59.8% of the animal population in 2000.The livestock population grew from 7,462,800 in 2000 to 11,616,050 in 2012 of which 46.8% were goat followed by 34.6% sheep, 13.3% cattle, 5.2% pigs, 0.12% of donkey and 0.02% of horses (see figure 1).

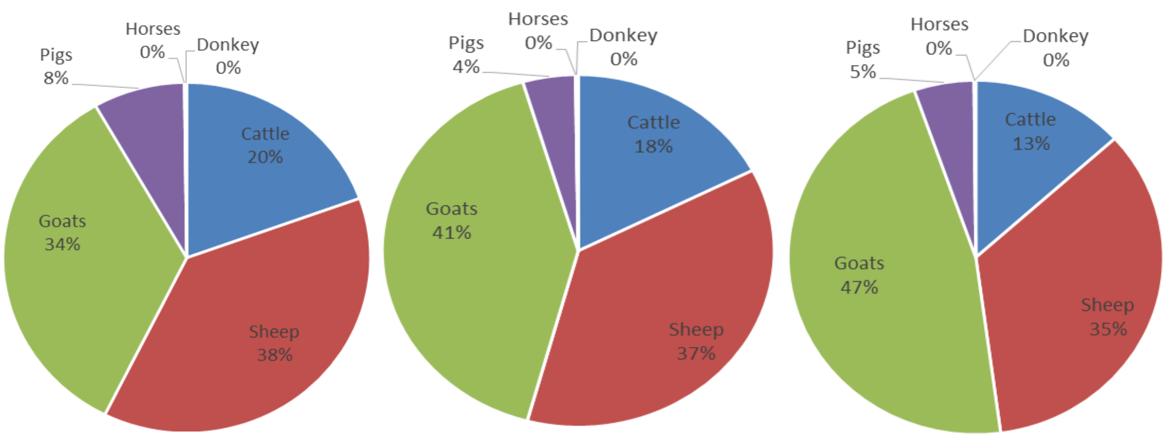


Figure 26: Share of animal population in 1990 (Left), 2000(middle) and 2012(Right)

In the period 2000-2012, the total number of goats in the country increased by 43.4% from 3,077,000 to 5,435,000 at annual average growth rate of 1.1%. With respect to sheep, the increases stood at 31.8% for the same period at annual growth rate of 1%. The cattle population increased by 15.6% from 1,302,000 in 2000 to 1,543,000 at a growth rate of 1% per annum (see table 51). Within the same period, whereas the number of pigs and donkeys increased by 46.2% and 2.4% respectively, the number of horses population decreased by 3.7%.

Table 51: Categorization of animal population (head) for the period (1990-2012) in Ghana

Year	Cattle	Sheep	Goats	Pigs	Horses	Donkeys	Poultry	Totals with Poultry	Total Without Poultry
1990	1,144,787	2,223,599	2,018,027	473,946	1,366	10,398	9,989,889	15,862,012	5,872,123
1991	1,194,633	2,162,340	2,194,372	453,877	1,302	12,042	10,572,472	16,591,038	6,018,566
1992	1,159,431	2,125,522	2,157,278	413,243	1,648	13,048	11,231,574	17,101,744	5,870,170
1993	1,168,640	2,224,974	2,124,529	408,134	1,622	11,829	12,169,523	18,109,251	5,939,728
1994	1,216,677	2,215,964	2,204,150	351,875	1,912	11,511	12,289,376	18,291,465	6,002,089
1995	1,344,106	2,010,147	2,155,938	365,339	2,200	12,000	13,247,312	19,137,042	5,889,730
1996	1,247,861	2,418,738	2,532,710	354,678	2,768	13,215	14,589,303	21,159,273	6,569,970
1997	1,261,552	2,496,111	2,580,458	365,318	2,800	13,500	15,888,000	22,607,739	6,719,739
1998	1,273,000	2,576,000	2,792,000	339,000	2,900	14,000	17,302,000	24,298,900	6,996,900
1999	1,288,000	2,658,000	2,931,000	332,000	3,000	14,300	18,810,000	26,036,300	7,226,300
2000	1,302,000	2,743,000	3,077,000	324,000	2,800	14,000	20,472,000	27,934,800	7,462,800
2001	1,315,000	2,771,000	3,199,000	312,000	2,700	13,500	22,032,000	29,645,200	7,613,200
2002	1,330,000	2,922,000	3,230,000	310,000	2,700	13,100	24,251,000	30,058,800	5,807,800
2003	1,344,000	3,015,000	3,560,000	303,000	3,000	13,500	26,395,000	34,633,500	8,238,500
2004	1,359,000	3,112,000	3,925,000	297,000	3,000	13,700	28,727,000	37,436,700	8,709,700
2005	1,373,000	3,211,000	3,923,000	290,000	3,000	13,700	28,386,000	37,199,700	8,813,700
2006	1,392,000	3,314,000	3,997,000	477,000	3,000	14,000	34,030,000	43,227,000	9,197,000
2007	1,407,000	3,420,000	4,196,000	491,000	3,050	14,100	37,038,000	46,569,150	9,531,150
2008	1,422,000	3,529,000	4,405,000	506,000	2,598	14,150	39,816,000	49,694,748	9,878,748
2009	1,438,000	3,642,000	4,625,000	521,000	2,625	14,200	43,320,000	53,562,825	10,242,825
2010	1,454,000	3,759,000	4,855,000	536,000	2653	14250	47,752,000	58,372,903	10,620,903
2011	1,498,000	3,887,000	5,137,000	568,000	2,680	14,300	52,575,000	63,681,980	11,106,980
2012	1,543,000	4,019,000	5,435,000	602,000	2,700	14,350	57,885,000	69,501,050	11,616,050
Change (2000-2012)	15.6%	31.8%	43.4%	46.2%	-3.7%	2.4%	64.6%	59.8%	35.8%

Source: Ministry of Food and Agriculture, Facts and Figures (2012)

5.1.4.2 N-fertilizer and urea application (3.C3 and 3.C4)

The estimation of direct and indirect N_2O emissions from application of nitrogen-based artificial fertilizers to soils was based on the quantities of nitrogen-based fertilizers and urea consumption in the country. Specifically, data on generic NPK, sulphate of ammonia and calcium nitrate were used in addition to urea application. In general, the yearly nitrogen-based fertilizers and urea consumption in the country saw an increase from 38,208t/year in 2000 to 346,780t/year in 2012 at an average growth rate of 1.1% per annum (see table 53).

Table 52: Quantities of nitrogen-based fertilizer and urea use from 1990 to 2012

Year	Nitrogen-based Fertilizers(t/yr)				Urea	Total
	NPK	Sulphate of Ammonia	Calcium Nitrate	Total N-based	(t/yr)	
1990	21,250	2,500	0	23,750	20,100	43,850
1991	19,375	7000	0	26,375	10050	36,425
1992	17,500	11,500	0	29,000	0	29,000
1993	10,000	7,600	0	17,600	0	17,600
1994	13,040	8,500	0	21,540	0	21,540
1995	9.3	9,000	0	9,009	4,250	13,259
1996	8,700	5,320	0	14,020	950	14,970
1997	37,080	10,700	0	47,780	1,850	49,630
1998	21,858	13,265	0	35,123	500	35,623
1999	3,602	4,800	0	8,402	0	8,402
2000	14,902	23,165	0	38,067	141	38,208
2001	49,287	22,628	0	71,915	2,500	74,415
2002	800	20,047	0	20,847	0	20,847
2003	18,890	25,715	7.35	44,612	500	45,112
2004	18,223	7,688	95,312	121,223	250	121,473
2005	38,978	15,000	157	54,135	4,540	58,675
2006	84,907	19,090	52,601	156,598	9,072	165,670
2007	87,388	17,458	52,823	157,669	4,962	162,631
2008	18,873	4,172	64,085	87,130	13,773	100,903
2009	197,631	4,616	110	202,357	25,028	227,385
2010	30,560	12,077	236,547	279,184	11,521	290,705
2011	139,128	46,222	75,292	260,642	12,363	273,005
2012	230,723	83840	267	314,830	31950	346,780
Change (2000-2012)	93.5	72.4	100.0	87.9	99.6	89.0

Source: Ministry of Food and Agriculture, Facts and Figures (2012)

The general trend in the nitrogen fertilizer and urea application showed significant changes from 2000 to 2012 in response to the government subsidy Program as part of its food security policy measures. With respects to NPK and nitrate fertilizer, the trend after 2000 was characterized by intermittent spike and dip after every other year. Relative to sulphate of ammonia (SOA) and urea application, the trend remained largely steady between 1990 and 2012 (see figure 27).

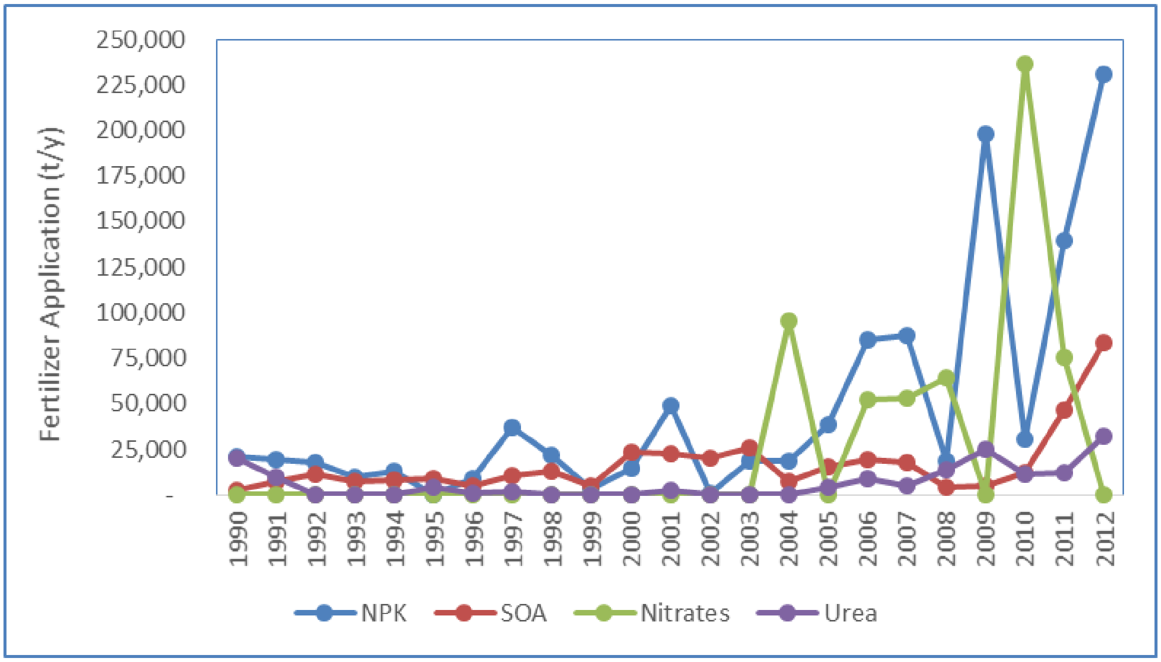


Figure 27: Trend of nitrogen-based fertilizer and urea use in Ghana

5.1.4.3 Crop Production (3.C4)

Apart from nitrogen-based fertilizers and urea application that could produce direct and indirect nitrous oxide emission, the means of disposal of crop residue after harvesting was another potential source. Data on annual production of major staple crops were used in the estimation of nitrous oxide emissions from crops residues. In 2012, the total national crop production stood at 28,903,000t/y and was 42.2% higher than the 2000 crop production (16,703,800 t/y) (see table 53).

Table 53: Quantities of crop production in t/year between 1990 and 2012

Year	Maize	Rice	Millet	Sorghum	Cassava	Cocoyam	Yam	Plantain	Total
1990	553,000	81,000	75,000	136,000	2,717,000	815,000	877,000	799,000	6,053,000
1991	931,500	150,900	112,400	241,400	5,701,500	1,296,800	2,631,900	1,178,300	12,244,700
1992	730,600	131,500	133,300	258,800	5,662,000	1,202,200	2,331,400	1,082,000	11,531,800
1993	960,900	157,400	198,100	328,300	5,972,600	1,235,500	2,720,300	1,321,500	12,894,600
1994	939,900	162,300	167,800	323,900	6,025,000	1,147,700	1,700,100	1,474,700	11,941,400
1995	1,034,200	221,300	290,000	360,100	6,611,400	1,383,200	2,125,700	1,637,500	13,663,400

1996	1,007,600	215,700	193,300	353,400	7,111,200	1,551,800	2,274,800	1,823,400	14,531,200
1997	996,000	197,100	143,500	332,600	6,999,500	1,529,800	2,407,900	1,818,400	14,424,800
1998	1,015,000	281,100	162,300	355,400	7,171,500	1,576,700	2,702,900	1,912,600	15,177,500
1999	1,014,500	209,800	159,800	302,000	7,845,400	1,707,400	3,249,000	2,046,200	16,534,100
2000	1,012,700	214,600	169,400	279,800	8,106,800	1,625,100	3,362,900	1,932,500	16,703,800
2001	938,000	253,200	134,400	279,700	8,965,800	1,687,500	3,546,700	2,073,800	17,879,100
2002	1,400,000	280,000	159,120	316,100	9,731,000	1,860,000	3,900,000	2,278,800	19,925,020
2003	1,289,000	239,000	176,000	337,700	10,239,300	1,804,700	3,812,800	2,328,600	20,227,100
2004	1,157,600	241,800	143,800	287,400	9,738,200	1,715,900	3,892,300	2,380,800	19,557,800
2005	1,171,400	236,500	154,600	299,000	9,567,200	1,685,800	3,922,800	2,791,600	19,828,900
2006	1,188,800	250,000	165,000	315,000	9,638,000	1,660,000	4,288,000	2,900,000	20,404,800
2007	1,219,600	185,300	113,000	154,800	10,217,900	1,690,100	4,376,000	3,233,700	21,190,400
2008	1,470,100	301,900	193,800	331,000	11,351,100	1,688,300	4,894,900	3,337,700	23,568,800
2009	1,619,600	391,400	245,500	350,600	12,230,600	1,504,000	5,777,900	3,562,500	25,682,100
2010	1,871,700	491,600	219,000	353,000	13,504,100	1,354,800	5,860,500	3,537,700	27,192,400
2011	1,683,000	463,000	183,000	287,000	14,240,000	1,299,000	5,855,000	3,619,000	27,629,000
2012	1,950,000	481,000	180,000	280,000	14,547,000	1,270,000	6,639,000	3,556,000	28,903,000
% Change (2000-2012)	48.07	55.38	5.89	0.07	44.27	-27.96	49.35	45.66	42.21

Source: MoFA, 2013

Out of the total food production in 2012 of 28,903,000t/y, cassava accounted for 50.33%, followed by yam (22.97%), plantain (12.3%), maize (6.75%), rice (1.66%), sorghum (0.97%) and millet (0.62%). Except cocoyam that saw a decrease in production levels, millet and sorghum increased marginally by 5.9% and 0.1% respectively, all the rest rose by 11.7% from 44.3%.

5.1.4.4 Rice Cultivations (3.C7)

In addition to the nitrous oxide emissions from the disposal of rice residue, the mode of rice cropping system (i.e. being rain fed, irrigated and upland) also emit methane. The methane emissions potential from rice cultivations depend on the percent share of the total rice cultivation areas under rain fed, irrigation and upland areas. It is also a function of the period the cultivated area is inundated. Data on annual rice cultivation areas and percentage area under different systems were obtained from the MoFA. The total area under rice cultivation in 2012 was 218,200ha. Lowland, irrigation and upland system accounted for 170,196ha (78%), 34912ha (16%) and 13,092ha (6%) respectively. The total rice cultivation areas increased by 57.1% from 93,600ha in 2000 to 218,200 in 2012 (see table 54).

Table 54: Rice Cultivation areas (Ha) from 1990 to 2012

Year	rice upland	rice lowland	rice irrigated	Total
1990	5298	68874	14128	88300
1991	5694	74022	15184	94900
1992	4782	62166	12752	79700
1993	4632	60216	12352	77200
1994	4854	63102	12944	80900
1995	5994	77922	15984	99900
1996	6318	82134	16848	105300
1997	7062	91806	18832	117700
1998	7824	101712	20864	130400
1999	6318	82134	16848	105300
2000	5616	73008	14976	93600
2001	5280	68640	14080	88000
2002	7368	95784	19648	122800
2003	7074	91962	18864	117900
2004	7164	93132	19104	119400
2005	7200	93600	19200	120000
2006	7500	97500	20000	125000
2007	6534	84942	17424	108900
2008	7968	103584	21248	132800
2009	9744	126672	25984	162400
2010	10860	141180	28960	181000
2011	11976	155688	31936	199600
2012	13092	170196	34912	218200

5.1.4.5 Land representations (3B)

Land use change constitutes a major source/removal of carbon emissions in Ghana. The main data sources were (a) areas of the six IPCC land categories per ecological zone and (b) changes (gain or loss) in each individual land category through transfers within the land categories over the inventory period. These datasets are contained in the land use matrices produced by the Forest Preservation Program implemented by the Forestry Commission in 2012. Summaries of the land representations and the transfer among them are provided in the tables 55, 56 and 57 below.

Table 55: Land use matrix for the period 1990-2010

		1990						
2010	Land categories	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	**2010 Total**
	Forest land	6,699,097	518,969	1,945,129	1,950	0	3,262	**9,168,407**
	Cropland	1,215,369	1,249,864	2,733,961	5,032	0	2,044	**5,206,270**
	Grassland	613,539	963,158	6,547,750	17,635	0	7,561	**8,149,643**
	Wetlands	11,270	27,544	92,307	743,772	0	1,336	**876,229**
	Settlements	45,695	53,797	136,003	2,691	102,288	3,570	**344,045**
	Other land	17,354	15,445	75,973	412	0	222	**109,405**
	1990 Total	**8,602,323**	**2,828,777**	**11,531,124**	**771,493**	**102,288**	**17,996**	***23,854,000***

Table 56: Land use matrix for the period 1990-2000

		1990						
2000	Land Categories	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	**2000 Total**
	Forest land	6,968,415	283,038	1,624,537	3,150	0	1,564	**8,880,704**
	Cropland	589,758	1,667,374	1,628,186	4,603	0	4,287	**3,894,209**
	Grassland	995,665	844,486	8,069,013	12,196	0	7,876	**9,929,235**
	Wetlands	9,303	3,909	26,299	750,179	0	685	**790,375**
	Settlements	13,417	22,349	62,608	286	102,288	2,302	**203,251**
	Other land	25,765	7,621	120,481	1,079	0	1,281	**156,226**
	1990 Total	**8,602,323**	**2,828,777**	**11,531,124**	**771,493**	**102,288**	**17,996**	**23,854,000**

Table 57: Land use matrix for the period 2000-2010

		2000						
2010	Land categories	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	**2010 Total**
	Forest land	6,677,708	811,029	1,653,951	4,790	0	20,929	**9,168,407**

	Cropland	1,228,723	1,786,802	2,168,497	3,776	0	18,472	**5,206,270**
	Grassland	924,543	1,205,834	5,890,984	22,930	0	105,351	**8,149,643**
	Wetlands	11,988	27,897	74,275	755,964	0	6,106	**876,229**
	Settlements	20,633	44,052	72,636	2,162	203,251	1,312	**344,045**
	Other land	17,109	18,595	68,892	753	0	4,056	**109,405**
	2000 Total	**8,880,704**	**3,894,209**	**9,929,235**	**790,375**	**203,251**	**156,226**	**23,854,000**

The land use matrices were produced for three decadal epochs; which covered, (a) 1990-2000 (b) 1990-2010 and (c) 2000-2010. The data for the individual years within each decade were generated through interpolation. Details of the interpolation have been discussed under methodological issues of land (3B)

Carbon stocks in different land representations

The relevant emission factors under the land category were derived from annual biomass increment, biomass stocks in each land representations, the reference soil organic carbon stocks and their stock change factors according to land management. For biomass stocks, data from the FPP forest inventory was used. Details of the methodology for estimation of the biomass are provided in the FPP report. Carbon stocks for the five main biomass pools (above ground biomass, dead wood, litter, herbs and soil) in the ten different ecological zones of Ghana were obtained from the FPP field data. The carbon stocks for the individual pools were averaged for each ecological zone to represent forest land, cropland and grassland. Biomass data for wetland, settlement and other lands were not available from the FPP study. Table 58 shows the biomass values used in the inventory.

Table 58: Biomass distribution in different land representations

Land cover type	Area fraction	AGB	AGB	Herb AGB	Herb AGB	Deadwood	Litter
		tC/ha	t dm/ha	tC/ha	t d.m/ha	tC/ha	tC/ha
Closed Forest							
Wet evergreen	2.56%	124.00	263.83	NA	NA	28.00	2.80
Moist evergreen	6.32%	139.00	295.74	0.50	1.06	79.50	2.60
Moist semi-deciduous (SE type)	5.95%	124.00	263.83	0.20	0.43	56.00	2.40
Moist semi-deciduous (NW type)	5.37%	40.00	85.11	0.70	1.49	10.90	2.20
Dry semi-deciduous (inner zone)	3.17%	23.00	48.94	2.10	4.47	6.00	1.30
Dry semi-deciduous (fire zone)	4.68%	15.00	31.91	0.90	1.91	NA	NA
Savannah	53.24%	18.00	38.30	0.60	1.28	NA	NA
Upland evergreen	0.22%	73.00	155.32	0.90	1.91	25.00	1.40
Coastal savannah	0.91%	11.00	23.40	0.90	1.91	2.00	2.20
Mangrove	0.00%	0.00	0.00	NA	NA	0.00	NA
Open Forest							

Wet evergreen	0.55%	30.00	63.83	NA	NA	NA	NA
Moist evergreen	1.35%	40.00	85.11	0.50	1.06	10.90	2.60
Moist semi-deciduous (SE type)	1.27%	35.00	74.47	1.20	2.55	56.00	2.20
Moist semi-deciduous (NW type)	1.15%	17.00	36.17	1.10	2.34	13.00	2.10
Dry semi-deciduous (inner zone)	0.68%	14.00	29.79	2.30	4.89	8.00	1.90
Dry semi-deciduous (fire zone)	1.00%	12.00	25.53	NA	NA	3.00	1.60
Savannah	11.37%	13.00	27.66	NA	NA	38.00	1.70
Upland evergreen	0.05%	26.00	55.32	0.40	0.85	15.00	1.10
Coastal savannah	0.19%	8.00	17.02	0.50	1.06	0.60	0.60
Mangrove	0.00%	0.00	0.00	NA	NA	NA	0.60
Average forest land		**35.8**	**76.19**	**0.57**	**1.21**	**15.34**	**0.87**
Wet evergreen	3.10%	21.00	44.68	NA	NA	6.00	3.80
Moist evergreen	7.67%	34.00	72.34	0.30	0.64	21.00	3.50
Moist semi-deciduous (SE type)	7.22%	19.00	40.43	1.60	3.40	9.00	3.60
Moist semi-deciduous (NW type)	6.52%	19.00	40.43	0.40	0.85	28.00	2.60
Dry semi-deciduous (inner zone)	3.85%	6.00	12.77	0.50	1.06	119.00	1.80
Dry semi-deciduous (fire zone)	5.68%	3.00	6.38	0.70	1.49	3.00	0.90
Savannah	64.61%	10.00	21.28	0.60	1.28	0.60	1.40
Upland evergreen	0.26%	6.00	12.77	0.30	0.64	8.00	2.00
Coastal savannah	1.10%	8.00	17.02	1.60	3.40	0.00	0.60
Mangrove	0.00%	0.00	0.00	NA	NA	NA	NA
Average cropland	**0**	**12.83**	**27.31**	**0.63**	**1.34**	**9.43**	**1.85**
Wet evergreen	3.10%	NA	NA	NA	NA	8.00	3.80
Moist evergreen	7.67%	0.00	0.00	1.90	4.04	31.00	3.50
Moist semi-deciduous (SE type)	7.22%	NA	NA	NA	NA	15.00	3.60
Moist semi-deciduous (NW type)	6.52%	1.00	2.13	NA	NA	43.00	2.60
Dry semi-deciduous (inner zone)	3.85%	NA	NA	NA	NA	178.00	1.80
Dry semi-deciduous (fire zone)	5.68%	1.00	2.13	1.00	2.13	4.00	0.90
Savannah	64.61%	9.00	19.15	1.30	2.77	1.00	1.40
Upland evergreen	0.26%	NA	NA	NA	NA	9.00	2.00
Coastal savannah	1.10%	1.00	2.13	0.40	0.85	0.00	0.60
Mangrove	0.00%	NA	NA	NA	NA	NA	NA

Average grassland		5.948	12.654	1.047	2.227	14.252	1.852

Industrial round wood supply and fuelwood production

Industrial round wood supply and fuelwood production are critical datasets for assessing the overall impacts of biomass harvesting on carbon stocks in forest land. Disaggregated data on fuelwood and round wood harvesting were not estimated for other land representation except forest land remaining forest land. Data on industrial round wood and fuelwood harvesting were obtained from the Resource Management and Support Centre of the Forestry Commission, Energy Commission (Energy Statistics) and FAOSTATS. In 2012, a total of 2,085,802m^3/yr of biomass was removed from the forest. Of the 2,085,802m^3/yr, industrial round constituted 1,454,416.8 m^3/yr whereas the remaining 631,385.2 m^3/yr were fuelwood (see table 59).

Table 59: Quantities of wood harvesting grouped according to types between 1990 and 2012

Year	Total Industrial round wood	Total Fuelwood Production (FW)	Amount of FW as parts	Amount of FW as whole tree	Total biomass removal
	m^3/year				
1990	1,656,000	610,097.3	427,068.1	183,029.2	2,266,097.3
1991	1,585,850	633,355.2	190,006.6	443,348.7	2,219,205.2
1992	1,495,000	657,537.3	197,261.2	460,276.1	2,152,537.3
1993	2,106,800	682,951.6	204,885.5	478,066.1	2,789,751.6
1994	2,143,600	709,444.1	212,833.2	496,610.9	2,853,044.1
1995	1,475,450	737,168.8	221,150.6	516,018.2	2,212,618.8
1996	1,443,250	766,125.7	229,837.7	536,288.0	2,209,375.7
1997	1,469,700	796,314.8	238,894.4	557,420.4	2,266,014.8
1998	1,411,050	783,050.1	234,915.0	548,135.1	2,194,100.1
1999	1,267,300	800,279.4	240,083.8	560,195.6	2,067,579.4
2000	1,147,700	719,686.8	215,906.1	503,780.8	1,867,386.8
2001	1,393,800	781,682.3	234,504.7	547,177.6	2,175,482.3
2002	1,269,600	811,332.4	243,399.7	567,932.7	2,080,932.4
2003	1,610,000	840,982.4	252,294.7	588,687.7	2,450,982.4
2004	1,552,500	854,459.7	256,337.9	598,121.8	2,406,959.7
2005	1,380,000	867,936.9	260,381.1	607,555.9	2,247,936.9
2006	1,499,600	894,891.5	268,467.5	626,424.1	2,394,491.5
2007	1,499,600	916,455.2	274,936.5	641,518.6	2,416,055.2
2008	1,490,452	948,800.6	284,640.2	664,160.4	2,439,253.1
2009	1,481,361	964,973.4	289,492.0	675,481.4	2,446,334.1

2010	1,472,324	986,537.0	295,961.1	690,575.9	2,458,861.4
2011	1,463,343	562,772.8	168,831.8	393,940.9	2,026,116.0
2012	1,454,417	631,385.2	189,415.6	441,969.7	2,085,802.0
Change (2000-2012)	21%	-14%			10%

The trends of total biomass removal from forest saw marginal increases at a rate of 0.98% per annum. This led to a 10% rise between 2000 and 2012. However, within the same period, whilst industrial round wood supply increased by 21%, fuel wood production decreased by 14%.

Disturbances (areas affected by fire)

Fire is another major source of greenhouse gas emissions through consumption of biomass load in forest land, cropland and grassland. The fractions of forestland, cropland and grassland affected by annual fire were estimated based on expert judgment and knowledge of the landscape. The total emissions from burning are not only a function of the area affected, but also the type and amount of fuel load available and the prevailing weather conditions. Table 60 shows the fractions of areas affected by annual fires in Ghana from 1990 to 2012.

Table 60: Fraction areas affected by burning (ha)

Year	Forest land	Crop land	Grassland
1990	3,106,167.9	494,329	4,622,510
1991	3,055,726.9	512732.7	4493599
1992	3,005,285.9	531136.8	4364688
1993	2,954,844.9	549540.9	4235777
1994	2,904,403.8	567945	4106866
1995	2,853,962.8	586349	3977955
1996	2,803,521.8	604753.1	3849044
1997	2,753,080.8	623157.2	3720133
1998	2,702,639.8	641561.3	3591222
1999	2,652,198.8	659965.4	3462311
2000	2,601,757.8	678,369	3,333,400
2001	2,558,293.2	700938.9	3220555
2002	2,514,828.6	723508.4	3107711
2003	2,471,364.0	746077.9	2994867
2004	2,427,899.4	768647.4	2882023
2005	2,384,434.8	791216.9	2769179

2006	2,340,970.2	813786.4	2656334
2007	2,297,505.6	836355.9	2543490
2008	2,254,041.0	858925.4	2430646
2009	2,210,576.4	881494.9	2317802
2010	2,167,111.8	904,064	2,204,958
2011	2,145,379.5	915349.1	2148536
2012	2,134,513.3	920991.5	2120325
Mass fuel (t.dm/ha)	**111.90**	**52.64**	**49.15**

5.1.5 Key categories

The methodology and results of the key category analysis in the AFOLU sector is presented in table 61 below.

Table 61: Result of the key Category analysis of the AFOLU sector

IPCC Category code	IPCC Category	Greenhouse gas	Key Source Assessment (Level Assessment - LA)	Key Source Assessment Trend Assessment (TA) (1990-2012)
3.B.2.b	Land Converted to Cropland	CO_2	1990, 2012	TA
3.B.1.a	Forest land Remaining Forest land	CO_2	1990, 2012	TA
3.B.1.b	Land Converted to Forest land	CO_2	1990, 2012	TA
3.C.1	Emissions from biomass burning	N_2O	1990, 2012	
3.C.1	Emissions from biomass burning	CH_4	1990, 2012	TA
3.B.3.b	Land Converted to Grassland	CO_2	1990, 2012	TA
3.C.4	Direct N_2O Emissions from managed soils	N_2O	1990, 2012	TA
3.A.1	Enteric Fermentation	CH_4	2012	

Under the land category, the 1990 and 2012 level assessment produced the following key categories for CO_2: 'land converted to cropland', 'forest land remaining forest land', 'land converted to forest' and 'land converted to grassland". Land conversions to cropland and grassland were the major contributors under the land category which are the key drivers of land use conversions in Ghana. On the other hand, government forest and national park management programs contributed to maintaining forest land over the period. These programs helped to enhance the sink capacity of the country. The national plantation program also facilitate the conversion of lands to forestland which further boosted the total carbon sinks.

The key categories for CH_4 emissions were 'emissions from biomass burning' in 1990 and 2012 and 'enteric fermentation' in 2012. Frequent fires experienced in forest and grasslands in the dry and transition zone of the country were the major sources of emissions from biomass burning'. High levels of CH_4 emissions from 'enteric fermentation' resulted from the increasing livestock populations observed over the period. For N_2O emissions, biomass burning and direct N2O emissions from managed soils were the key category sources in 1990 and 2012 respectively. In terms of trend assessment (1990-2012), the following were the key categories: 'land converted to cropland' (CO_2), 'forest land remaining forest land' (CO_2), 'land converted to forest land (CO_2)', 'emissions from biomass burning' (CH_4), 'land converted to grassland' (CO_2) and 'direct N_2O emissions from managed soils'.

5.1.6 Time series consistency

5.1.6.1 Recalculations

Recalculations was done in the AFOLU sector mainly because of the availability of new activity data and emission factors. The changes in both activity data and emission factors was as a result of (a) adoption of new methodology for generating activity data and emission factors, (b) identification and use of new datasets (c) revisions of published data from the agricultural facts and figures, (d) new field survey results from FPP, (e) filling of time series data gaps with national and international data sources (FAO), (f) changes in the use of emission factors and methodologies as a result of the shift from using the revised 1996 to 2006 IPCC guidelines, and (g) refinement in the use of expert judgments. Additional information on the descriptions of the reasons of and impacts of the recalculations has been provided under each category. The result of the assessment of recalculation and its impacts is provided in table 62.

Table 62: Assessment of the impacts of recalculation on the previous estimates

Year	CO_2(Mt)			CH_4(Mt)			N_2O(Mt)		
	PE	LE	% Change	PE	LE	% Change	PE	LE	% Change
1990	-26.46	-3.01	-779.5	0.11	1.84	94.2	0.01	0.09	90.2
1991	-29.11	-6.59	-341.7	0.12	1.81	93.4	0.01	0.09	91.3
1992	-23.91	-6.42	-272.2	0.11	1.78	93.7	0.01	0.09	91.2
1993	-18.46	-3.83	-382.1	0.11	1.75	93.6	0.01	0.08	91.1
1994	-15.46	-3.22	-380.4	0.12	1.72	93.3	0.01	0.08	90.8
1995	-15.89	-5.04	-215.2	0.12	1.69	92.9	0.01	0.08	90.9
1996	-14.61	-4.66	-213.3	0.13	1.66	92.3	0.01	0.08	90.2
1997	-9.99	-4.08	-144.6	0.18	1.63	88.9	0.01	0.08	84.3
1998	-8.14	-3.87	-110.3	0.19	1.60	88.3	0.01	0.08	83.2
1999	-6.10	-3.90	-56.6	0.19	1.57	87.7	0.01	0.08	82.3
2000	-3.74	-4.00	6.6	0.19	1.54	88	0.01	0.08	82.7
2001	-0.90	-2.64	65.9	0.19	1.52	87.7	0.01	0.08	81.5
2002	2.84	-2.62	208.5	0.20	1.49	86.8	0.01	0.08	81.2
2003	4.43	-0.99	548.8	0.19	1.47	86.8	0.01	0.07	80.5
2004	6.58	-0.76	969	0.20	1.45	86.2	0.02	0.07	78.9
2005	3.86	-0.92	518.1	0.20	1.42	85.7	0.02	0.07	78.9
2006	2.61	-0.06	4481.6	0.21	1.40	85.2	0.02	0.07	77.2

Reasons for recalculations

Recalculations led to the revision of the previous activity data and emission factors, addition of new datasets and application of new methodologies. This explains the changes in the emissions/removal illustrated in table 61 above. The reasons for the calculation are provided in table 64 below.

Table 63: Description of reasons for recalculations

Gas	Data in category	Reasons
Methane	Animal Population	Revision of animal population data in the agricultural fact and figures and replacement of animal population published in the agriculture fact and figures with data from FAOSTAT. This resulted in the following changes in animal population: • reduction by 1,058,988 in 1990, 30,447 in 1994, 51,061 in 1997, 500 in 2001, 500 in 2003 and 953,300 in 2004 and 1,350,300 in 2005 and • Increases by 2,736 in 1991, 3,096 in 1992, 101,629 in 1993, 249,842 in 1995, 336,392 in 1996, 2,413,600 in 2002 and 80,000 in 2006.
	Rice cultivations	• Introduction of new dataset on harvested rice areas in the agriculture facts and figures to replace the FAOSTATS data. The revision in the total harvested rice areas resulted in these changes (a) increases in harvested rice areas by 39,300ha in 1990 and 12,600ha in 1998 and (b) reduction in harvested rice by 11,700ha in 1999, 23,400ha in 2000, 29,000ha in 2001, 13,200ha in 2002, 900ha in 2003 and 610ha in 2005. • Changes in methodologies and emission factors for estimating methane for only one ecosystem (continuously flooded rice) to three different ecosystems (upland, rain fed and irrigation)
	Changes in area of biomass burning in grassland	• Availability of new dataset on mass of fuel for grassland (49.15td.m/ha) derived from the FPP field survey. • Revision of biomass lost in disturbance • The shift from the methodology in the LUCF to AFOLU • Changes in the areas (ha) affected by fire and forest to grassland conversions.
Carbon Dioxide	Land representations	• Changes in land category areas based on 2006 IPCC classifications. • Revision resulting in changes in new land use change matrix based on the 6 IPCC classes. • Changes in methodologies activity data and emission factors remote sensing and field data collection. • Changes in annual biomass increment for forest lands • Revision of industrial round wood and fuel wood harvest data in forest lands,
	Biomass	• New biomass (AGB, BGB, dead wood, litter and soil) datasets for five land representation categories in the different ecological zones.
Nitrous Oxide	Changes in area of biomass burning in grassland	• Availability of new dataset on mass of fuel for grassland (49.15td.m/ha) derived from the FPP field survey. • Revision of biomass lost in disturbance

		• The shift from the methodology in the LUCF to AFOLU • Changes in the areas (ha) affected by fire and forest to grassland conversions
	N_2O emission from soils	• Revision of the annual average consumption nitrogen synthetic fertilizers of 6852ton in the previous estimate to 8793.73 ton in the latest of estimates due to inclusion of new dataset from Agricultural facts and figures. Although the trend of the inter-annual variation differs year by year. • The methodology for the previous estimates accounted for fraction of animal waste whiles the latest estimates considered organic N applied as fertilizer (manure and sewage sludge). The average for former estimates has been revised from 117761.34 tons to 48722.2 tons. • The adoption of new dataset for crop harvesting. The initial estimate is averaged at 21497.9 tons and latest average estimate stand at 2657462.2 tons. • The methodological change introduced a new variable in the form of "urine and dung N deposited on pasture, range and paddock by grazing animals". This is held constant over the years. • The methodological change also introduced another new variable in the form of "N mineralization associated with loss/gain of soil organic matter resulting from land use change or management of mineral soils"

5.1.6.2 Filling of Data Gaps

Data gaps identified in the inventory were filled by using appropriate IPCC methodology for filling data gaps. The specific methods used in filling the gaps were selected based on the type of the data and nature of the gaps. Table 64 presents the data gaps and how they were filled.

Table 64: Data gaps and the method used to fill them

Category	Data Gap	Method applied	Justification for methodology used	Description of approach for filling of gaps
Enteric Fermentation and Manure Management (3.A1 and 3.A2)	Lack of data on population of mules and asses in 2012	extrapolation	Data from FAOSTATS was available up to 2011 and 2012 was lacking.	The annual average derived from the number of mules and asses the 2011 – 2006 was added to the value of 2011 to generate the number of mules and asses for 2012.
Land (3B.1-3B. 6)	Lack of data on annual changes in land representations and the changes in them between 1990-2000, 2000–2010 and further to 2012	Interpolation and extrapolation	Inter-decadal data existed for 1990, 2000 and 2010. The annual data of areas covered by the different land cover types and their transfers needed to be generated for each decade with interpolation. Extrapolation was then used to generate data for 2011 and 2012 accordingly.	Interpolation factor was generated by dividing the difference in area for each land cover category at the beginning and the end of the decade. The factor was then added from the starting year to the last year in the decade. The factor generated took into account the various assumptions behind predominant factors that drive change in the landscape

Emissions from biomass burning (3 C1)	Missing inter annual data on areas affected fires.	Interpolation and extrapolation	Inter-decadal data on areas affected by fire existed for 1990, 2000 and 2010. The annual data of areas affected by fires needed to be generated for each decade with interpolation. Extrapolation was then used to generate data for 2011 and 2012 accordingly.	Trend interpolation factor was derived by dividing the difference between the starting and ending of each decade. The difference was divided by 10 to generate interpolation factor. The interpolation factor was then added from the starting year to ending year.

5.1.7 Quality Control/Quality Assurance

The QA/QC procedures that were followed in the AFOLU sector are detailed in the table 65 below.

Table 65: QA/QC procedures implemented in the AFOLU sector

Data Type	QA/QC procedure	Remarks/Comment/Examples
Activity data check	Check for transcription, typographical errors and error transposition.	Division of task among the inventory team to ensure that one or two members of the team always focus on double checking and ensure that data errors associated with those described in the left column are avoided.
	Comparison with published data	Data on areas cultivated, animal heads and land cover areas and round wood data were compared to those published by International agencies such as FAO and ITTO and Ghana Statistical services.
	Consistency checks of categories and sub-categories with totals	Ensuring that disaggregated figures at the category and sub-categories levels add up to the overall totals.
	Identify and fix outliers in data inputs (including checking for dips and spikes in the trend)	Data that deviate unrealistically from the trends and spikes beyond ranges are suspected as inaccurate and replaced with deemed appropriate values from international sources or derived from expert judgment.
	Documentation of all data sources, data format and assumptions for easy reference	A record of all data, their sources and assumptions made in admitting the data use were kept. This helped in easy cross-referencing.
	Ensure reduction in data clumsiness or data redundancy	Logical sequence data flow according to the IPCC methodology for the GHG emission estimation was designed for: (a) easy understanding and further probing of how the final results in the IPCC software would be like, (b) easy cross-referencing and avoidance of mistakes, (c) easy transmission into the IPCC software and (d) aid in better interpretation of the implication of the use of the data.

	Improvement in accuracy of land use mapping	1,200 ground validation points for different land representations in wall-to-wall were obtained from the field and compared with remotely sensed imageries. Generation of confusion matrix indicator potential errors of commission or omission.
Emission factors	Ensure representativeness field biomass sampling in the various land cover representations.	(a) Make sure sampling design adequately covered representative land classes in each ecological zone. (b) Samples were taken at optimal intensity covering 5 biomass consistent with the IPCC guidelines.
	Reduce potential errors resulting from sampling biomass, and integrity of analysis	Adherence to sampling protocols from the design, field, lab analysis, data analysis and report writing.
Calculation by the approved 2006 IPCC software	Cross-checks all steps involved in the calculation.	Ensure that steps used for determining, estimating and deriving data are accurate, transparent and internally consistent.
	Documentation of sources and correct use of units.	Use of the documentation template to record all data sources and assumptions.
	Check for transcription, typographical errors and error transposition.	Check mistake and blunders in the data entry into the software
	Checked completeness of data coverage	Ensuring all the relevant gases for the specific activity were covered.
Emissions Results	Check of recalculation differences	To identify and pinpoint changes, revisions and reallocations to improve accuracy and transparency of the estimates
	Identify and fix outliers in the results	checking for dips and spikes in trends and levels
Documentation	Assumptions, corrections, data and sources.	Ensure consistency, transparency, facilitate repeatability and easy retrieval
	Improvement list (internal and external findings)	Help prioritize areas that require actions.

5.2 Analysis of AFOLU sector emission trends

In the year 2012, the total emissions from the AFOLU sector was 12.36 MtCO$_2$e representing 40.1% of the national total GHGs emissions. The total emissions from the sector decreased from 8.32 MtCO$_2$e in 1990 to 7.04 MtCO$_2$e in 2000 and increased to 12.36 MtCO$_2$e in 2012 (see figure 28). The observed changes in the emission trend were largely due to the reduction in biomass burning in forest and grasslands, as well as increasing emissions from land use change and livestock.

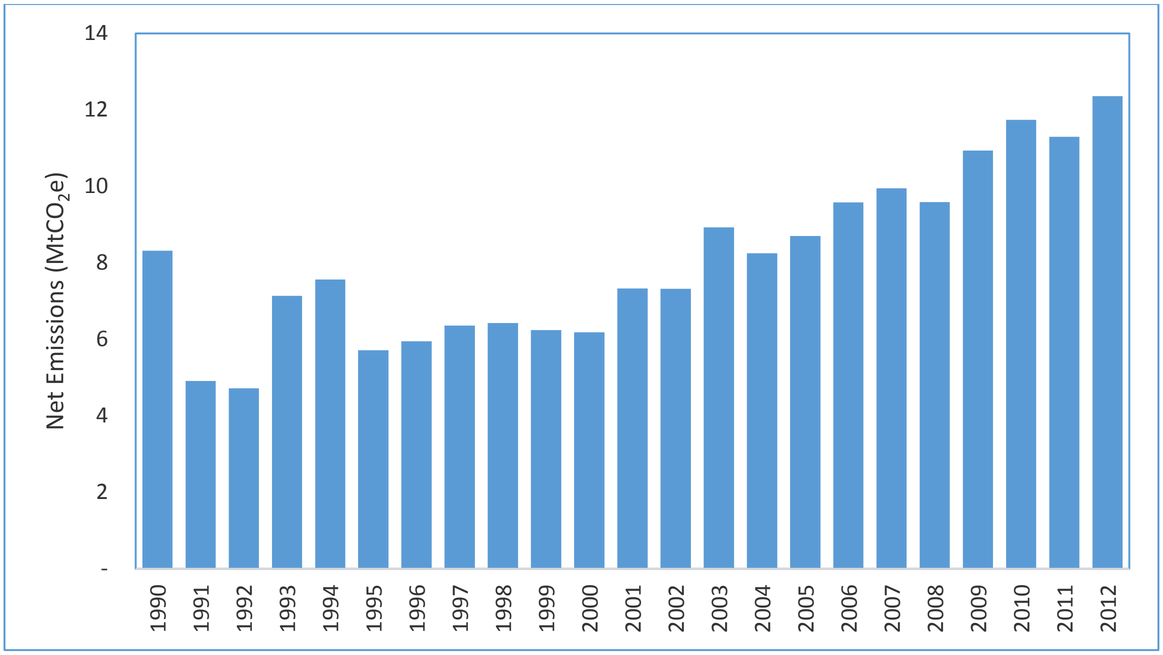


Figure 28: Total Emission trends in the AFOLU sector

Within the AFOLU sector, aggregated sources and non-CO_2 emissions source on land (3C) accounted for 60.5% of the total emissions in 2012. This was followed by livestock (24.7%) and Land (14.9%) respectively.

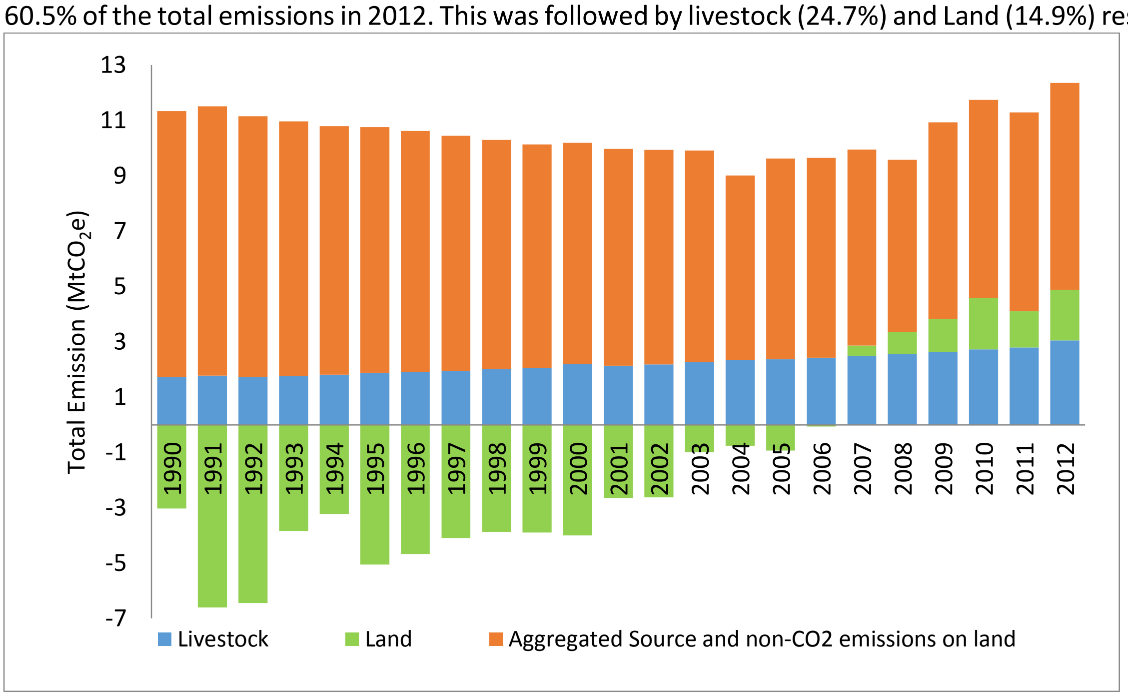


Figure 29: Total emissions trend according to sub-categories in AFOLU

In 2012, the total emission of 7.47 $MtCO_2e$ from 3C represented a decrease of 6.9% and 28.7% of 2000 and 1990 emission levels respectively. The decreases were attributed to the reductions in biomass burning in grassland and forestland following consistent with awareness creation on wildfire prevention and fire management after the 1983 country-wide wildfires. The continuous decline in biomass burning has been sustained by the positive impacts of the Wildfire Management Project (WMP) which targeted the fire-prone areas in the country. On the other hand, total emissions from livestock recorded increasing trend from 17.18 MtCO2e in 1990 to 21.98 $MtCO_2e$ in 2000 and subsequently to 30.47 $MtCO_2e$ in 2012 (see figure 29). The increases were due to the growing livestock population, particularly, cattle heads. Similarly, net carbon dioxide emissions trend from land saw a steady decline from -3.23Mt in 1990 to -4.03Mt in 2000 and leaped to 1.84Mt in 2012.

This can be attributed in part to the observed increasing forest and grassland conversion to cropland due to favourable agriculture policies. Nitrous oxide was the predominant GHG in the AFOLU sector accounting for 57% of the total emissions in 2012. This was followed by methane (38.2%) and carbon dioxide (4.8%). Between 2000 and 2012, the trends of nitrous oxides and methane emissions declined by 9% and 15% respectively. Within the same period, the carbon dioxide emissions increased by 315% (see table 66). The reductions in methane and nitrous oxide emissions were generally due to the overall effect of avoided biomass burning in forest and grassland. For CO_2, the rather high increases in the emission trends of 315% could be partly attributed to the continuous forest and grassland conversion to cropland in the same period.

Table 66: Emissions from AFOLU sector according to Gases

Year	MtCO₂e				Gg	
	Net emissions	CH_4	N_2O	Total	NOx	CO
1990	-3.01	19.95	27.23	44.18	1.50	25.05
1991	-6.59	19.67	27.18	40.26	1.48	24.60
1992	-6.42	19.30	16.36	29.23	0.83	13.84
1993	-3.83	18.98	26.32	41.48	0.82	23.71
1994	-3.22	18.69	25.92	41.40	1.40	23.27
1995	-5.04	18.44	14.20	27.60	0.12	11.41
1996	-4.66	18.14	25.29	38.77	0.80	22.38
1997	-4.08	17.84	24.91	38.67	0.79	21.94
1998	-3.87	17.56	24.53	38.23	1.29	21.50
1999	-3.90	17.25	24.19	37.54	0.77	21.05
2000	-4.00	16.94	24.04	36.98	1.24	20.61
2001	-2.64	16.68	23.65	37.69	1.21	20.25
2002	-2.62	16.48	23.39	37.26	1.19	19.88
2003	-0.99	16.25	23.16	38.43	1.17	19.52

2004	-0.76	16.05	22.03	37.32	1.15	19.16
2005	-0.92	15.80	22.48	37.35	1.13	18.79
2006	-0.06	15.58	22.29	37.82	1.11	18.79
2007	0.38	15.35	22.03	37.76	1.08	18.07
2008	0.81	15.13	21.82	37.75	1.06	17.70
2009	1.21	14.93	21.74	37.88	1.04	16.98
2010	1.86	14.75	21.54	38.15	1.02	16.98
2011	1.32	14.76	21.54	37.62	1.01	16.79
2012	1.86	14.74	21.98	38.57	1.00	16.70
% Change 2000-2012	315%	-15%	-9%	4%	-23%	-23%

Within the sector, aggregated and non-CO_2 source, in particular, activities such as biomass burning, urea and generic NPK fertilizer applied to soils are the largest sources of both nitrous oxide and methane emissions in 2012. Aggregated and non-CO_2 source contribute to 96% of the total nitrous emissions of 21.97 $MtCO_2e$ and the remaining 4% from livestock. Within aggregated and non-CO_2 sources, biomass burning accounted for 79% of the total of 21.1 $MtCO_2e$ followed by direct N_2O emissions from managed soil (16%). In 2012, methane emissions from livestock amount to 14% of the total methane emissions 14.74 $MtCO_2e$. The remaining 86% was mainly from aggregated and non-CO_2 sources through biomass burning in forestland and grasslands.

5.3 Description of source/removal categories

5.3.1 Summary of source-specific emission trends

5.3.1.1 Livestock (3A)

Key Category: CH_4 emissions - Enteric fermentation (2012)

Emissions from livestock are generated through enteric fermentation and manure management from domestic animals such as cattle, sheep, goats, swine, horses and donkeys (mules and asses). In 2012, the total emissions from livestock were 3.05 $MtCO_2e$ which represented 25% of the total AFOLU emissions. The total livestock emissions showed an increasing trend from 1.72 $MtCO_2e$ in 1990 to 2.2 $MtCO_2e$ in 2000 and further increased by 0.85 $MtCO_2e$ in 2012. The observed growing level of emissions was due to rising animal populations. For the period 1990-2012, annual total emissions from enteric fermentation and manure management were consistently on the increase. However, the annual emissions from enteric fermentation were higher than manure management (see figure 30).

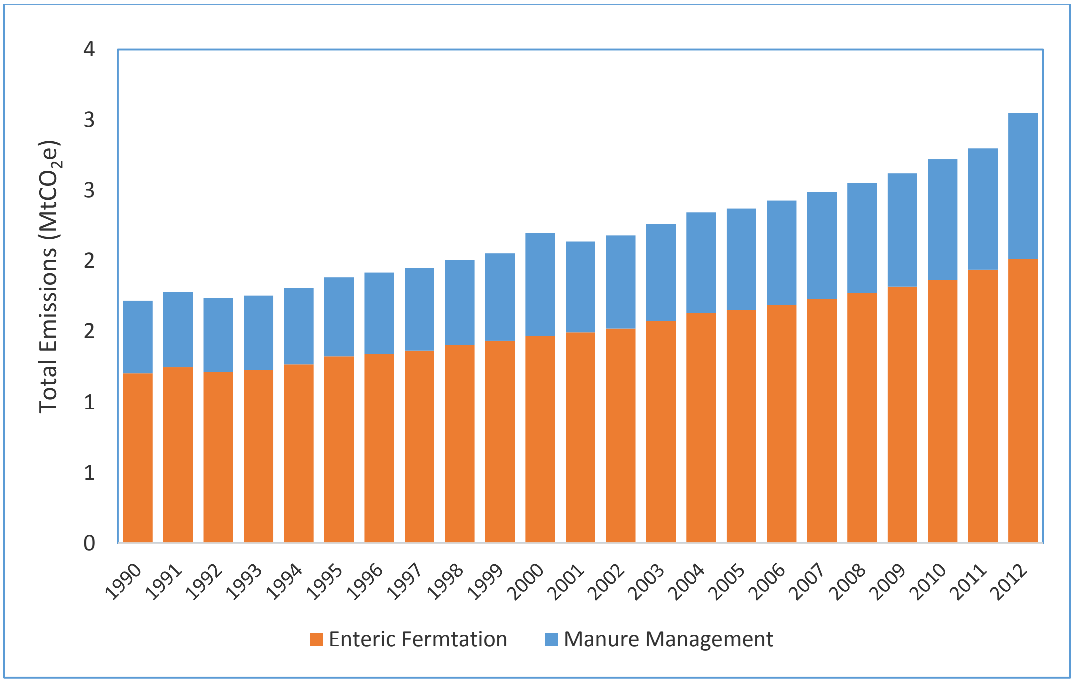


Figure 30: Emissions trend from livestock

Enteric Fermentation (3.A1)

Source Category Description

Enteric fermentation in herbivores produces methane as a by-product of digestive processes in the alimentary canal. Microbes in the animal's digestive system ferment feed ingested by the livestock which generates methane. The amount of methane produced depends on the animal's digestive system, the weight and age of the animal as well as quantity and quality of feed. Ruminant livestock are major sources of methane with moderate amounts produced by non-ruminant livestock. The total emissions attributed to enteric fermentation was 2.01 $MtCO_2e$ making up 66% of the total livestock emissions in 2012. This was 27% and 40.3% above 2000 and 1990 levels respectively (see figure 31).

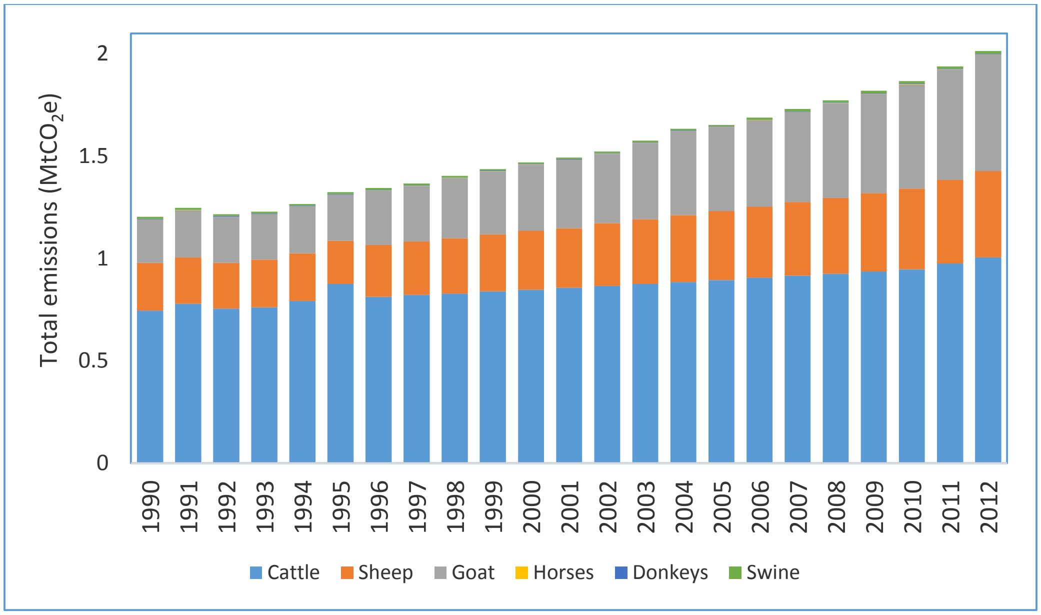


Figure 31: Total emission trend from enteric fermentation of livestock

In 2012, cattle contributed 50% of the total emissions from enteric fermentation. The rest were as follows: goat (28%), sheep (21%), swine (0.63%), donkey (0.15%) and horses (0.05%). On the whole, cattle has contributed 56% of emission for the period 1990-2012. This was followed by goat (23%), sheep (20%), and swine with 1% in the same period.

Methodological issues

Emissions from enteric fermentation were calculated using the IPCC Tier 1 methodology and default emission factors. The emissions were estimated by multiplying the individual animal population with emission factor for the respective animals (see IPCC default emission factors in tables 10.10 and 10.11 and annex 10.A1 in Vol. 4 Chapter. 10). Table 68 below provides the overview of the methodologies and emission factors applied.

Table 67: Overview of methodologies, reported emissions and emission factors used

Sector code	Source	Emissions reported	Method	EF
3.A.1.a	Cattle			
3.A.1.a.i	Dairy Cows	NO		
3.A.1.a.ii	Other Cattle	CH_4	T1	D
3.A.1.b	Buffalo	NO		
3.A.1.c	Sheep	CH_4	T1	D
3.A.1.d	Goats	CH_4	T1	D
3.A.1.e	Camels	NO		
3.A.1.f	Horses	CH_4	T1	D
3.A.1.g	Mules and Asses	CH_4	T1	D

3.A.1.h	Swine	CH_4	T1	D

NO= Not Occurring; T1= Tier 1; D= Default

The livestock population data for cattle, sheep, goats, swine and poultry were obtained from Agriculture Facts and Figures which is produced annually by the Statistics, Research and Information Directorate (SRID) of MoFA. The data presents animal population as at December 31 of every year. Data can be accessed from www.mofa.gov.gh. This was supplemented with data on horses and mules and asses from FAOSTAT (www.fao.org).

Source-specific recalculations

The acquisition of new activity data on livestock was the main reason for the recalculation of emissions for enteric fermentation. The new activity data for livestock was obtained from the latest agriculture facts and figures. Table 69 shows the percentage change in methane emissions from enteric fermentation as a result of the recalculation.

Table 68: Percentage change in methane emissions from enteric fermentation by animal type

Year	Cattle	Sheep	Goats	Horses	Mules & Asses (Donkey)	Swine	Total
1990	-4.42	-14.90	-40.40	26.79	3.83	-42.84	-13.08
1991	-3.26	0.02	0.02	0.00	16.96	-0.03	-1.99
1992	-3.19	-0.02	0.01	0.00	23.36	0.06	-1.93
1993	-3.26	4.40	-0.26	0.00	-9.90	2.73	-1.23
1994	-3.25	0.00	0.01	0.00	-12.94	-8.28	-2.11
1995	13.75	-2.98	0.00	0.00	-8.33	-20.44	8.48
1996	-3.24	-0.01	11.83	0.00	0.02	10.37	0.44
1997	-3.10	0.00	-3.04	0.00	-3.70	7.20	-2.43
1998	-3.23	0.00	0.00	0.00	0.00	0.00	-1.90
1999	-3.23	0.00	0.00	0.00	0.00	0.00	-1.88
2000	-3.23	0.00	0.00	0.00	0.00	0.00	-1.86
2001	-3.23	0.00	0.00	0.00	-3.70	0.00	-1.86
2002	-2.06	5.17	0.96	0.00	-3.05	89.94	0.46
2003	-3.23	0.00	0.00	0.00	-3.70	0.00	-1.80
2004	-3.68	0.00	8.38	0.00	-2.19	-1.01	0.11
2005	-4.13	0.00	7.42	0.00	-2.19	-5.17	-0.41
2006	-3.08	0.12	-3.08	0.00	0.00	41.30	-2.15

Reasons for recalculations

The changes in the animal population from the recalculation was due to (a) revision of animal population data in the agricultural fact and figures and (b) replacement of animal population published in the agriculture fact and figures with data from FAOSTAT for some years. The specific changes are follows:

- Declining animal population by 1,058,988 in 1990, 30,447 in 1994, 51,061 in 1997, 500 in 2001, 500 in 2003 and 953,300 in 2004 and 1,350,300 in 2005
- Increases in animal population by 2,736 in 1991, 3,096 in 1992, 101,629 in 1993, 30,447 in 1994, 249,842 in 1995, 336,392 in 1996, 2,413,600 in 2002 and 80,000 in 2006.
- Changes in methodological approaches.

Manure management (3.A2)

Source Category Description

This category refers to methane and nitrous oxide emissions from the management of livestock manure. The main manure management systems covered by this inventory were: paddock and pasture, slurry dry lot and poultry with or without litter. Ghana reports both CH_4 and N_2O emissions from manure management for cattle, sheep and goats and CH_4 emissions for horses, mules and asses, swine and poultry. Total emissions from manure management increased from 0.52 $MtCO_2e$ in 1990 to 0.73 $MtCO_2e$ in 2000 and further to 1.03 $MtCO_2e$ in 2012 (see figure 32).

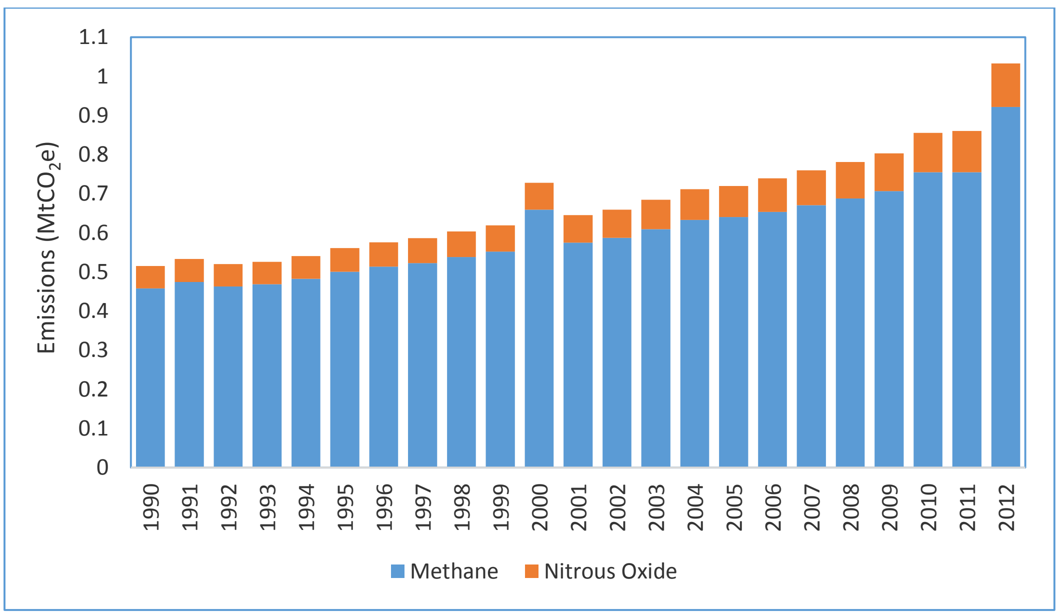


Figure 32: Methane and nitrous oxide emissions from manure management

Nitrous oxide emissions from manure management contributed a majority of the total emissions with 88.9%. The 1.1% was methane emissions. The trend of nitrous oxide and methane emissions showed steady increases for the period 1990-2012, except in 2000 and 2012 where nitrous oxide levels spiked. The increases in the emissions were as a result of growing livestock populations reported from 1990 to 2012.

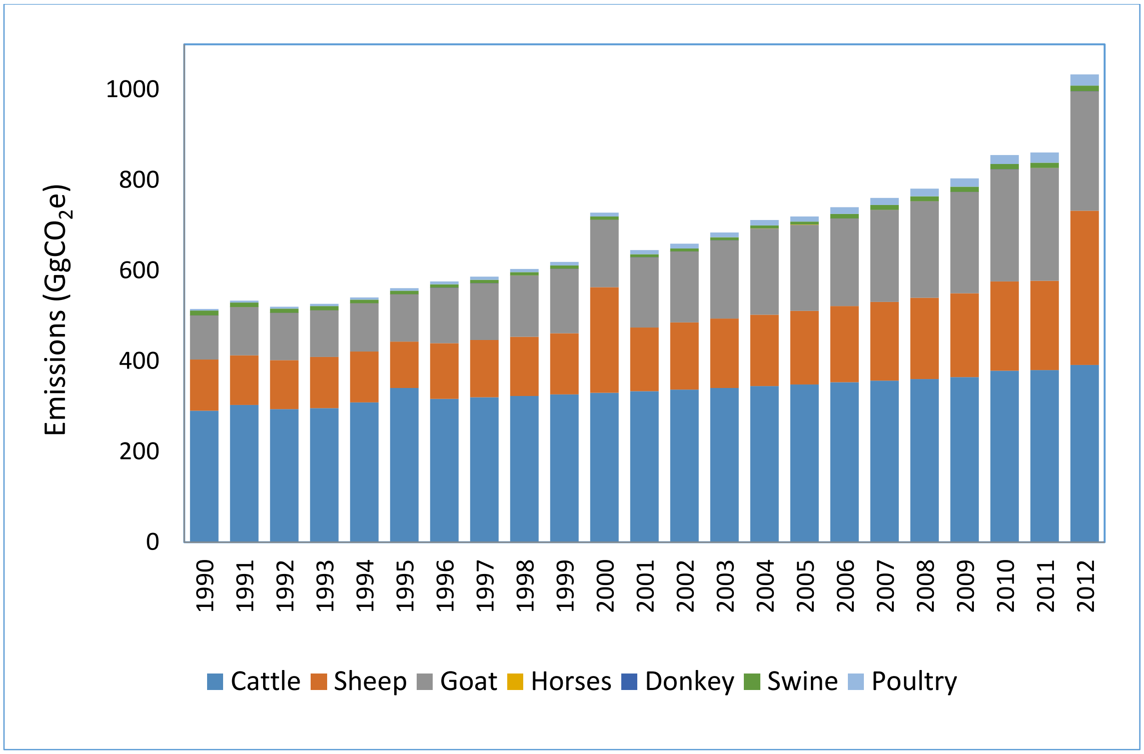


Figure 33: Emissions trend from manure management

In 2012, emissions from cattle made up 37.9% of the total emissions from enteric fermentation. The rest are as follows: goats (25.5%), sheep (33%), swine (1.2%) and Poultry (2.4%) (see figure 34). Over the period 1990-2012, cattle contributed 50% of the total emissions. This is followed by goat (24%), sheep (23%), poultry (2%) and swine (1%) in a decreasing order.

Methodological issues

The IPCC default emission factors and the tier methodology were used in the calculation of emissions from manure management. The share of the individual animal waste management systems common in Ghana were estimated by expert judgment and categorized by animal type (see table 70). Data on animal population for the period 1990-2012 were obtained from the agriculture facts and figures produced by MoFA.

Table 69: Share of Animal waste management system applied

Livestock	Manure Management systems (1990-1999)					Manure Management systems (2000-2012)				
	Pasture	Dry lot	Slurs	Poultry w/litter	Poultry w/o litter	Pasture	Dry lot	slurry	Poultry w/litter	Poultry w/o litter
Asses	100%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Cattle	40%	60%	0%	0%	0%	40%	60%	0%	0%	0%
Poultry	0%	0%	0%	65%	35%	0%	0%	0%	50%	50%
Goats	70%	30%	0%	0%	0%	70%	30%	0%	0%	0%
Horses	100%	0%	0%	0%	0%	100%	0%	0%	0%	0%

Swine	50%	0%	50%	0%	0%	50%	0%	50%	0%	0%
Sheep	60%	40%	0%	0%	0%	60%	40%	0%	0%	0%

Recalculations

The main reasons for the recalculation of emission under this sub-category were (a) availability of new activity data and changes in the shares of animal waste management systems per animal type based on expert judgment. The results of the impacts of the recalculations on the emissions are illustrated in tables 70 and 71.

Table 70: Percentage change in CH_4 manure management due to recalculation

Year	Non-dairy Cattle	Sheep	Goats	Horses	Mules & Asses	Swine	Poultry	Total
1990	-1.15	-20.65	-40.40	27.13	4.63	-185.69	-15.00	-43.88
1991	-0.03	-4.98	0.02	0.46	17.65	-100.05	-15.79	-18.15
1992	0.04	-5.02	0.01	0.46	-39.87	-99.88	-15.00	-17.43
1993	-0.03	-0.38	-0.26	0.46	-100.57	-94.54	-15.00	-15.99
1994	-0.03	-5.00	0.01	0.46	-106.11	-116.55	-15.00	-17.54
1995	16.45	-8.13	0.00	0.46	-97.71	-140.87	-13.57	-13.11
1996	-0.01	-5.01	11.83	0.46	-82.47	-79.26	-15.00	-10.02
1997	0.12	-5.00	-3.04	0.46	-2.84	-85.59	-15.00	-13.23
1998	0.00	-5.00	0.00	0.46	0.83	-100.00	-15.00	-13.39
1999	0.00	-5.00	0.00	0.46	0.83	-100.00	-15.00	-12.98
2000	0.00	-5.00	0.00	0.46	-44.08	-100.00	-15.00	-12.84
2001	0.00	-5.00	0.00	0.46	-2.84	-100.00	-15.17	-12.16
2002	1.13	0.43	0.96	0.46	-2.19	79.87	-4.48	7.26
2003	0.00	-5.00	0.00	0.46	-2.84	-100.00	-14.54	-11.45
2004	-0.44	-5.00	8.38	0.46	-1.34	-102.02	-18.97	-10.09
2005	-0.87	-5.00	7.42	0.46	-1.34	-110.34	-21.05	-11.17
2006	0.14	-4.87	-3.08	0.46	0.83	-17.40	-15.00	-5.89

Table 71: Results of impacts of recalculations on nitrous oxide emissions

Year	PE (Gg)	LE (Gg)	% change
1990	0.381	1.479	74.230
1991	0.323	1.532	78.892
1992	0.316	1.494	78.885
1993	0.307	1.512	79.660

1994	0.313	1.558	79.882
1995	0.265	1.615	83.572
1996	0.214	1.658	87.099
1997	0.226	1.687	86.592
1998	0.227	1.737	86.908
1999	0.226	1.780	87.330
2000	0.223	2.126	89.502
2001	0.219	1.855	88.216
2002	0.219	1.894	88.437
2003	0.218	1.965	88.915
2004	0.213	2.042	89.569
2005	0.221	2.068	89.296
2006	0.212	2.108	89.940

Reasons for recalculations

Revision of animal population data in the agricultural facts and figures and replacement of animal population published in the agriculture facts and figures with data from FAOSTAT for some years were the key reasons for the recalculation. The specific changes are include:

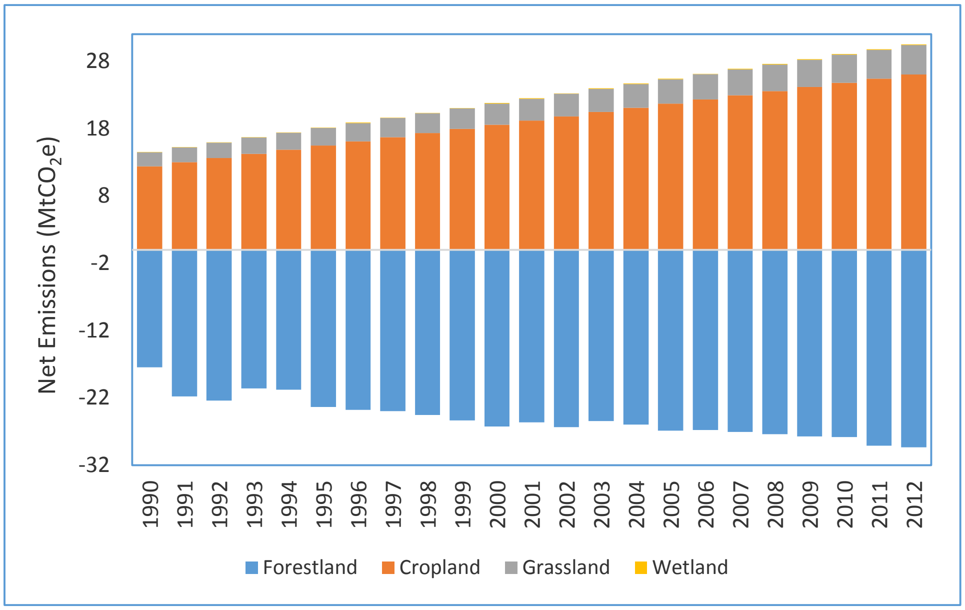
- reduction by 1,058,988 in 1990, 30,447 in 1994, 51,061 in 1997, 500 in 2001, 500 in 2003 and 953,300 in 2004 and 1,350,300 in 2005 and
- Increases by 2,736 in 1991, 3,096 in 1992, 101,629 in 1993, 30,447 in 1994, 249,842 in 1995, 336,392 in 1996, 2,413,600 in 2002 and 80,000 in 2006.
- Changes in the methodological approaches.

5.3.1.2 Land (3B)

Carbon dioxide emissions arise from human-induced modifications of landscapes which leads to land use change. The land use change is as a result of conversion of land categories among the following IPCC classes: forestland; cropland; grassland; wetlands; settlements and other lands. The estimation of the CO_2 emissions from land focused on the three dominant land categories which accounted for majority of the emissions; namely; forestland, cropland and grassland.

Emission trends from land

The total emissions from land was 1.84 $MtCO_2$ in 2012, -4 $MtCO_2$ in 2000 and -3.02 $MtCO_2$in 1990. The CO2 emissions for 2012 accounted for 14.9% of the total emissions from the AFOLU sector and made up 98.7% of net CO_2 emissions (see figure 34).



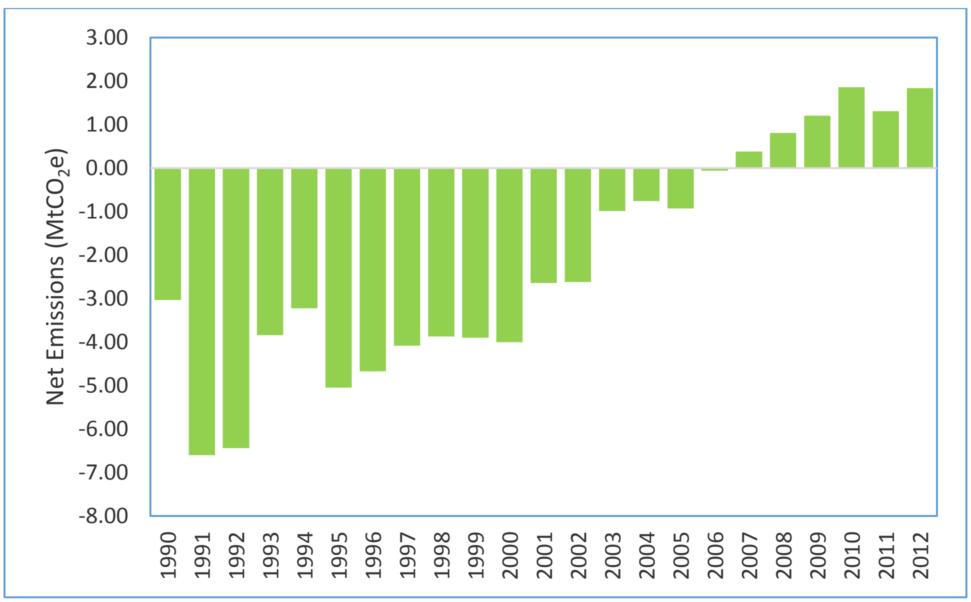


Figure 34: Net CO_2 emissions trend (b) and total emissions trend by land categories (a)

According to figure 34, the trend of CO_2 removals from land declined from 1990 to 2006 and became a source in 2007 up to 2012 due to the conversions of lands to cropland and grassland. Among the three land categories, forest remained a sink whereas grassland, and cropland were sources of emissions. The general increase in net CO_2 emissions from land could be attributed to deforestation from the following: (a) expansion of areas under cropland as part of the food security interventions, (b) forest to grassland due to fires and through cropland. On the other, the rising levels of net CO_2 removals observed in forestland was as a result of: (a) the implementation of aggressive forest plantation development program targeted at degraded forest lands, (b) implementation of the Forest and Wildlife Policy which facilitated private sector participation in sustainable forest management.

Methodological issues

Land use categorization

Country-specific emission factors and activity data were obtained from the studies conducted by the Forest Preservation Project (FPP). This was commissioned by the Forestry Commission with funding from the Japanese Government. For details of the methodology refer to www.fcghana.org. The study was undertaken by a multi-institutional team comprising the Forestry Commission, CSIR-Forestry Research Institute of Ghana, CSIR-Soil Research Institute of Ghana and PASCO Corporation of Japan as well as its local counterpart, RUDAN Engineering Limited. The 6 IPCC land use categories were obtained through the application of remote sensing and ground inventory for three (3) epochs (1990, 2000, and 2010) using a wall to wall approach. The definitions adopted for various land categories used in the study are provided in table 72:

Table 72: Land use definitions

Category	Definition
Forestland	This includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently fall below, but in situ and could potentially reach the proposed national values used to define the forest land category in Ghana as follows: • Minimum Mapping Unit (MMU) is 1.0 ha • Minimum crown cover is 15 % • Potential to reach minimum height at maturity (in situ) as 5 m
Cropland	This includes crop land (currently cropped or in fallow), including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category. This includes land where over 50% of any defined area is used for agriculture.
Grassland	This includes rangelands and pasture lands that are not considered Cropland. It also includes herbs and brushes that fall below the threshold values used in the Forest Land category such as the other wooded land following the FAO definition in Ghana: • CC < 15 % and > 10%, height > 5 m, MMU > 0.5 ha • CC 5 % - 10 %, height > 5 m, MMU > 0.5 ha • Shrubs, bushes and trees CC > 10%, Height < 5 m, MMU > 0.5 ha
Wetland	These include areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peat lands) and that does not fall into the forest land, cropland, grassland or settlements categories. It also includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions
Settlement	These include all developed land, including transport infrastructure and human settlements of any size, unless they are already included under other categories.
Other lands	This category includes bare soil, rock and all land areas that do not fall into any of the other five categories.

The satellite imagery used for the study were Landsat TM for 1990, Landsat ETM+ for 2000 and ALOS AVNIR – 2 and DMC for 2010. For the 2010, the DMC satellite data was used to fill up gaps in the ALOS AVNIR data, mainly resulting from cloud cover. The imageries were geometrically and radiometrically preprocessed. Afterwards, supervised classification was used for the delineation and estimation of the areas of the 6 land categories for the three (3) epochs using 1,100 ground data. Land use maps and land use change maps and their corresponding change matrices for the 3 epochs were generated from the analysis of the imageries. The 2010 land use map was validated using 2,213 field data points that were representative of the six land representation within the various ecological zones across the country. The previous land use (1990 and 2000) were validated using existing land use map for 2000 developed by RSMC, data from the permanent sampling plots, areas with relatively similar signatures and interviews with key informants. The forestland category was further stratified into open and closed forests based on the following factors:

- Canopy cover (CC) – Closed forests (CC > 60%); Open forest (15% < CC < 60%);
- Ecological zones;
- Primary designated use; and
- Legal management scheme

The analysis of the land representations was done for 10 and 20 years intervals i.e. 1990 – 2000; 2000 – 2010; and 1990 – 2010. In order to derive the areas of the land categories for the intervening years, for example, 1990 – 1991; the land use matrices for the three (3) epochs obtained were interpolated. The interpolation steps were as follows:

- Generated individual 20 year epochs land use matrix for the period 2010-1990, 2000-1980 and 1990-1970 based on the assumption that land use changes in the previous were generally slower than the present.
- Obtained annual land use change matrix for the individual years in each 20 year epoch.
- Extrapolated land category areas for 2011 and 2012 based on the immediate five years (2010 to 2006).

The following considerations and assumptions were made, taking into account the principle of conservativeness:

- Annual area changes were assumed to be insignificantly different from the previous years. Thus, it was assumed that area change within a year will be spatially difficult to notice.
- Annual gain/loss among forest and non-forest classes would follow a similar pattern in the intervening years. Hence for 1990, 2000 and 2010, the difference in changes between the 20 year periods was determined and the annual rate of change applied to the base year to retrieve the data for the intervening years.
- The rate of change in land categories was slower in the1980s than the 1990s and 2000s. This was because:

    i. The implementation of the policies such as the Economic Recovery Program which focused on the extractive sector e.g. surface mining, and timber harvesting influenced the changes in the landscape in 1990s. Thus land-based economic activities in the 1990s were more intense than in the 1980s.
    ii. Population growth rate was higher beyond the 1980s. Population growth and urbanization and its associated high consumptive life style influenced landscape dynamics.

  The effects of wildfire that happened in 1983 were episodic.

iii. The impacts of cocoa expansion into forest area catalysed the modification of the landscape in 1980s.

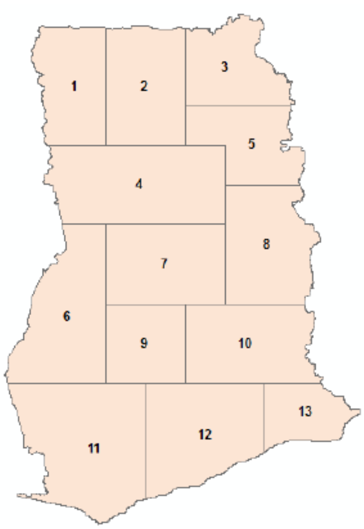
Accuracy assessment

An accuracy of the 2010 land use map was generated from an Error Matrix using the 2,213 validation points. The overall accuracy was 83.87 per cent (see table 73).

Table 73: Land use classification Error matrix

Reference data / Classified data	Forest land	Cropland	Grassland	Settlements	Wetlands	Other land	Classified Total	Users Accuracy (%)
Forestland	520	48	39	0	0	0	**607**	85.67
Cropland	57	493	48	1	0	2	**601**	82.03
Grassland	55	44	384	0	0	9	**492**	78.05
Settlements	17	13	12	283	1	5	**331**	85.50
Wetlends	0	0	1	0	152	0	**153**	99.35
Otherland	2	0	3	0	0	24	**29**	82.76
Reference Total	**651**	**598**	**487**	**284**	**153**	**40**	**2213**	-
Producer Accuracy (%)	79.88	82.44	78.85	99.65	99.35	60.00	-	**83.87**

To account for variability in the different ecological zones, the 2010 land use map was further divided into 13 relatively homogenous blocks. The classification accuracy of each block was determined (see figure 35).



Block	Overall Classification Accuracy (in %)
1	82.94
2	80.28
3	85.64
4	82.86
5	80.42
6	84.83
7	79.76
8	83.64
9	83.68
10	84.34
11	90.57
12	84.57
13	87.50

Figure 35: Homogenous blocks used in the accuracy enhancement

Biomass estimation

Biomass estimation was done using ground inventory. A pilot area within each of the nine forest ecological zones of Ghana was selected after a scoping exercise. A nested plot design in a rectangular shape, grouped in clusters was laid to delineate sampling areas for data collection. A cluster comprising 3 rectangular plots was systematically placed 500m apart. A main plot of 20m by 20m was laid to measure trees with diameter above 10cm and their corresponding heights. A sub-plot of 10m by 10m was laid within the main plot to measure the diameter and height of juveniles with diameter below 10cm in addition to dead wood encountered. Another sub-plot of 5m by 5m was laid within the 10m sub-plot to collect litter and soil samples. Destructive sampling of 10 trees per ecological zones was done and samples from the roots and stem were taken for analysis. The destructive sample results were used to develop allometric equations for the estimation of below and above ground biomass.

Recalculations

The availability of new datasets on biomass pools for the nine forest ecological zones called for the recalculation. The recalculation led to the changes in the biomass figures for the various land categories. The variation between previous CO_2 emission estimate and the latest resulting from the recalculation is provided in table 74.

Table 74: Results from recalculations and impacts on the previous emissions for the Land category

Year	CO_2 Emission (Mt)		% Change
	PE	LE	
1990	-26.46	-3.02	-761.8
1991	-29.11	-6.60	-334.7
1992	-23.91	-6.44	-265.2
1993	-18.46	-3.84	-370.3
1994	-15.46	-3.23	-366.4
1995	-15.89	-5.05	-206.7
1996	-14.61	-4.67	-204.2
1997	-9.99	-4.09	-78.3
1998	-8.14	-3.87	-35.4
1999	-6.10	-3.90	23.2
2000	-3.74	-4.00	73.9
2001	-0.90	-2.65	169.0
2002	2.84	-2.62	317.0
2003	4.43	-0.99	835.2
2004	6.58	-0.76	1360.0
2005	3.86	-0.93	848.4
2006	2.61	-0.06	8773.1

Reasons for recalculations

- Changes in land categories (in hectares) based on 2006 IPCC classifications.

- Changes in new land use change matrix based on the 6 IPCC classes.
- Changes in methodologies for the collection of activity data and emission factors using remote sensing and field data collection.
- Changes in annual biomass increment for forest lands.
- Revision of industrial round wood and fuel wood harvest data in forest lands
- New biomass (AGB, BGB, dead wood, litter and soil) datasets for the five land use categories in the different forest ecological zones.

Description of emissions from forest land

Forestland was grouped mainly into open and closed forests. The closed forests are the gazetted government reserves and national parks whereas open forests are generally forestlands outside the gazetted forests, which constitute the off-reserve forests. In addition, some gazetted forest reserves which have been degraded and are being rehabilitated were classified as open forests. In general, forestland remained a sink from 1990 to 2012. In 2012, the net CO_2 emissions from forestland accounted for -29.33 Mt which is 10% and 41% higher than the levels in 2000 and 1990 respectively (see figure 36). Within the forestland, the CO_2 removals from "lands converted to forest" contributed 67% of the total CO2 removals in 2012, the remaining 33% were from "forestland remaining forest land". In terms of the annual averages, CO_2 removals from "lands converted to forestland" were -14.4 $MtCO_2$ whereas that from "forest land remaining forestland" was -10.6 $MtCO_2$. Among land conversions to forestland, grassland contributed 76.1%, followed by, cropland (23.7%) and wetland (0.1%) in a declining order.

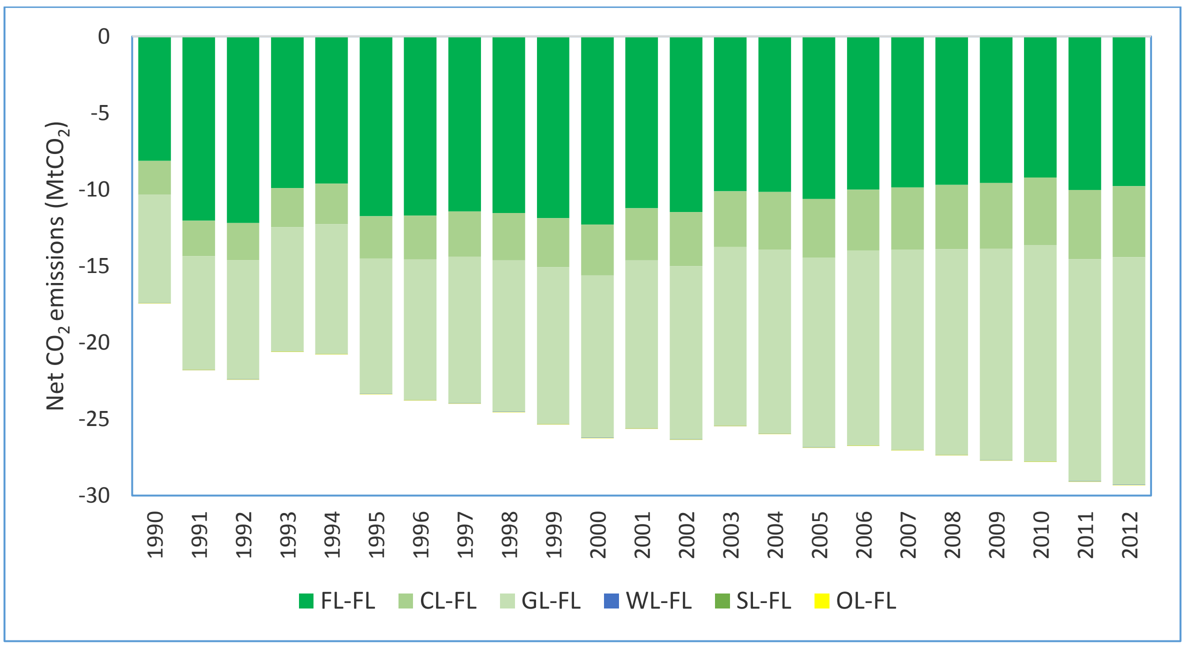


Figure 36: Net CO_2 emissions trend for forestland

The general increasing removals by forestland could be explained by the following factors: (a) the impacts of the ban on export of round logs as part of government's Program to facilitate enhancement of downstream timber processing, and (b) implementation of aggressive forest plantation development program targeted at degraded forest lands and the establishment of plantation development fund to encourage private sector plantation development.

Description of emissions from crop land

Cropland referred mainly to crop fields on which annual staple food crops are cultivated. The main land preparation methods in cropland are (a) slash and burn, (b) mechanization (c) application of weedicides and (d) a combination of the former. The conversion of forestland and grassland to cropland constitutes the sources of CO_2 emissions in cropland. In 2012, the net CO_2 emissions arising from the forest and grasslands to cropland were 22.93 $MtCO_2$. This was 28.6% and 52.4% higher than the levels recorded for 2000 and 1990 respectively (see figure 37).

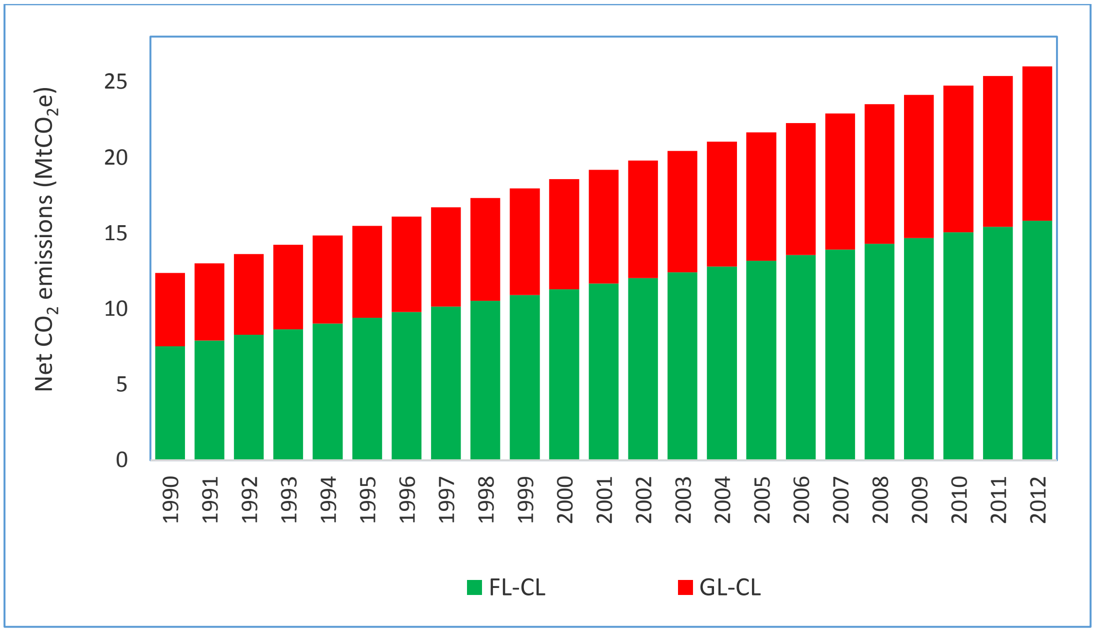


Figure 37: Net CO_2 emissions trend for cropland

Among the two sources of emission in cropland, forestland conversion to cropland has been consistently predominant for the period 1990-2012 (see figure 37). The steady growth of emissions from cropland generally resulted from the expansion of croplands at the expense of forest and grasslands.

Description of emission trend from grassland

Grasslands exist mainly in the savannah and transition zones of Ghana. The emissions from grassland largely follow the forest-to-cropland and cropland to grassland trajectory. The net CO_2 emission from grasslands was 4.38 $MtCO_2$ in 2012, 3.13 $MtCO_2$ in 2000 and 2.09 $MtCO_2$ in 1990 (see figure 38). Whereas conversion from forestland to grassland results in CO_2 emissions, cropland conversion to grassland conversely led to removal. This could be attributed to the general stability of grasses in the field as opposed to crops which are harvested annually.

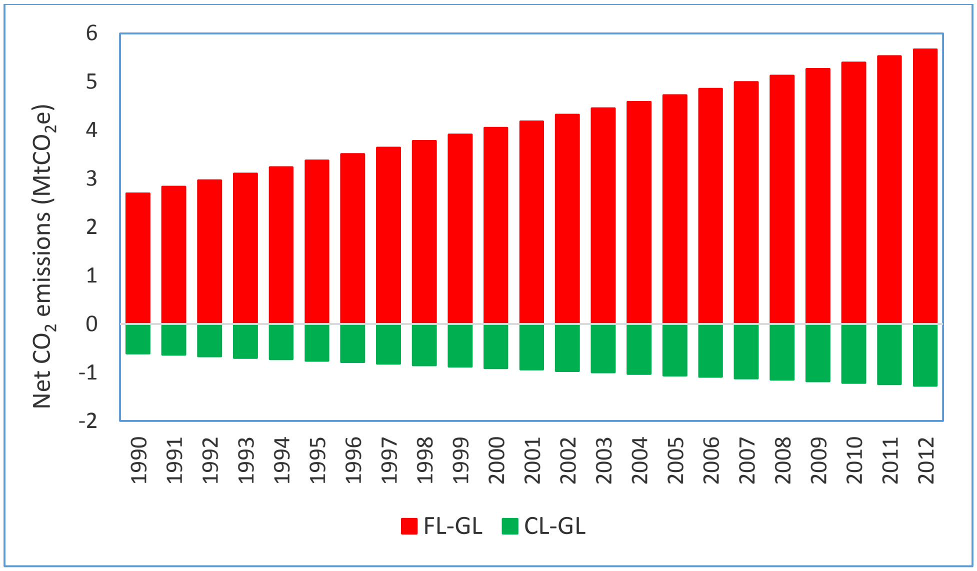


Figure 38: CO_2 emission trends in grasslands

In 2012, the forestlands to grasslands conversion accounted for 5.67 $MtCO_2$ emissions, 4.05 $MtCO_2$ in 2000 and 2.7 $MtCO_2$ in 1990. The progressive increases in emissions from the grassland are as a result of the conversion of forestland through bush fires particularly in the transition and savannah zones of Ghana.

5.3.1.3 Aggregated sources and Non-CO_2 emission sources on land (3C)

Generally, emissions under this category are CH_4 and N_2O from biomass burning, CO_2 from Urea application, direct and indirect N_2O from managed soils and indirect N2O from manure management. In 2012, the total GHG emissions from 3C were 7.47 $MtCO_2e$ representing 60% of the total AFOLU emissions. This amount was lower than those of 2000 and 1990 levels by 6.9% and 28.7% respectively. The decrease in the overall GHG emission could be explained by the decline in fire occurrence due to consistent awareness creation on fire management, particularly, in the Savannah and transition zones. In 2012, emissions from biomass burning made up 43% of the total emissions from 3C. The rest were as follows: direct N_2O emissions from managed soils (40.4%), indirect N2O emission from managed soils (12.9%) and rice cultivations (2.7%). The remaining 1% was contributed by indirect N_2O from manure management (0.7%) and urea application (0.3%). In terms of trends, biomass burning contributed an average annual emissions of 67.1% for the period 1990-2012. This was followed by direct N2O emissions from managed soils (23.6%), indirect N_2O emission from managed soils (7.3%), rice cultivations (1.4%).Urea application and indirect N_2O emission from manure contributed 0.1% and 0.5% respectively.

Description of emissions trends from biomass burning (3.C1)

The 3.C1 sub-category comprises biomass burning in forestland, cropland and grassland. The emissions estimated were CH_4 and N_2O. The total emissions decreased from 3.92 $MtCO_2e$ in 1990 to 2.51 $MtCO_2e$ in 2000 and further to 1.61 $MtCO_2e$ in 2012 (see figure 39). The reasons for the declined in the emission were attributed to the sustained public awareness on fire management in the country. In 2012, emissions from biomass burning from forest land accounted for 50% of the total emissions, whereas emissions from biomass burning from cropland and grassland were 25% each. Generally, there was a steady decline in the emission levels of the three activities.

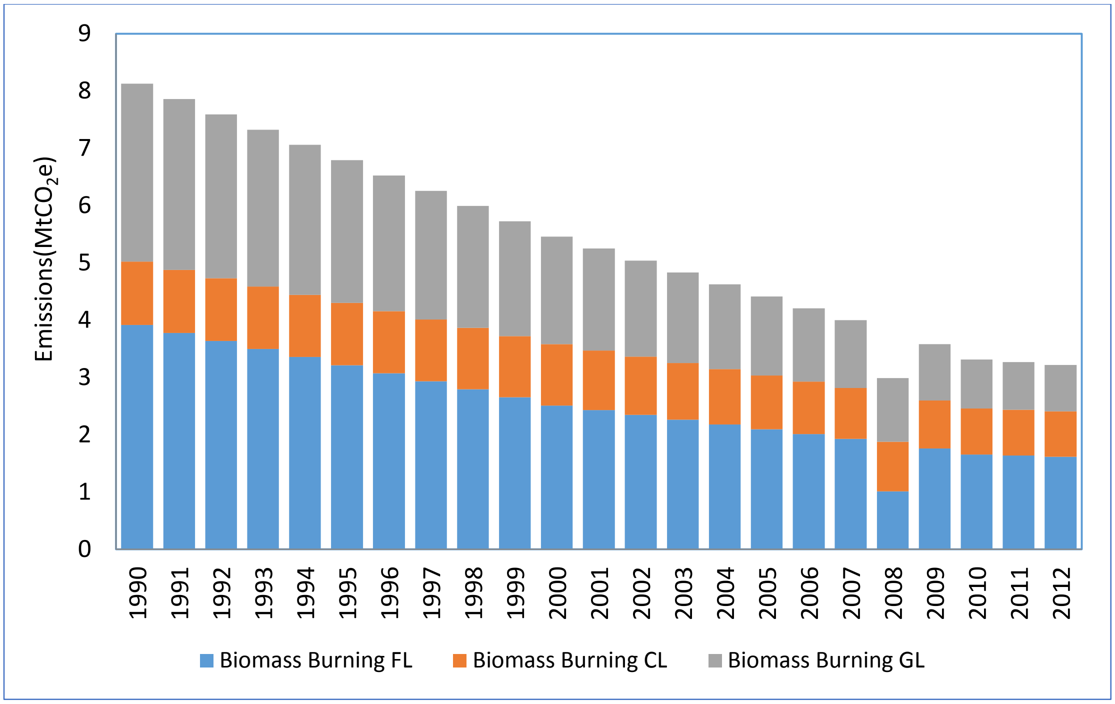


Figure 39: Emission trends in 3C according to activity types

Methodological issues

The method of estimating emissions in the IPCC 2006 guidelines and the revised 1996 IPCC guidelines differ in the way the accounting of emissions from burning are disaggregated Whilst the 1996 guidelines considered burning as part of forestland to grassland conversion, the 2006 guidelines classifies biomass burning separately under 3C. Based on the areas delineated from the land categories for each ecological zone, expert judgment was used to determine fractions of the various areas affected by fire. The actual areas affected by fire were derived from the sum of the individual areas affected by fire under each zone into the following land categories; biomass burning in forestland, cropland and grasslands. The total areas affected by burning in forestland, cropland and grassland included all forms of conversions between and within the three land categories that were due to burning. Country-specific data on mass of fuel from the FPP field survey were used to estimate total emissions from biomass burning for 1990, 2000 and 2010. In order to derive the inter-annul biomass burning estimates within each decade, trend interpolation for 1991 to 1999 and 2001 to 2009 was done. In 2011 and 2012, areas affected by fire were obtained using trend extrapolation approach based on the data generated for immediate past five years.

Description of emissions trends from urea application (3.C3)

This sub-category covers CO_2 emissions from urea application to agricultural soils. The total emissions from urea application of 14.74Gg in 1990 declined to 0.1Gg in 2000 and rose to 23.43Gg in 2012 (see table 75). The variation in the emission trends was a reflection of the factors that drive demand patterns of agricultural inputs in Ghana. The observed sharp increases from 2010 to 2012 could be attributed to the impacts of the government fertilizer subsidy program.

Table 75: Emissions from urea application

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Emission (Gg)	14.74	13.28	11.81	10.35	8.89	7.42	5.96	4.49	3.03	1.57	0.10	0.94
Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
Emission (Gg)	1.77	2.61	3.44	4.28	5.11	5.95	6.78	7.61	8.45	9.07	23.43	

Methodological issues

The IPCC tier 1 method and default emission factors were used in the calculation of the emissions from urea application. The activity data were obtained from the Agricultural facts and figures published by the Ministry of Food and Agriculture. Activity data was mainly annual urea imports into the country. Total annual imports of urea fertilizer were assumed as annul consumption because there was no data on annual stock balances or stock changes for fertilizers.

Description of emission trends from direct and indirect N_2O Emissions from Managed Soils (3.C4 and 3.C5)

Direct and indirect N_2O emissions from managed soil comprise nitrogen inputs from crop residues and application of synthetic nitrogen fertilizers. Direct N_2O emissions from managed soils increased from 1.01 MtCO2e in 1990 to 1.82 $MtCO_2e$ in 2000 and subsequently to 3.02 $MtCO_2e$ in 2012. Indirect N_2O emissions from managed soils increased from 0.36 $MtCO_2e$ in 1990 to 0.59 $MtCO_2e$ in 2000 and further to 0.96 $MtCO_2e$ in 2012 (see figure 40). The observed increasing trends of both direct and indirect N2O emissions from managed soils could also be linked to Government of Ghana's fertilizer subsidy Program.

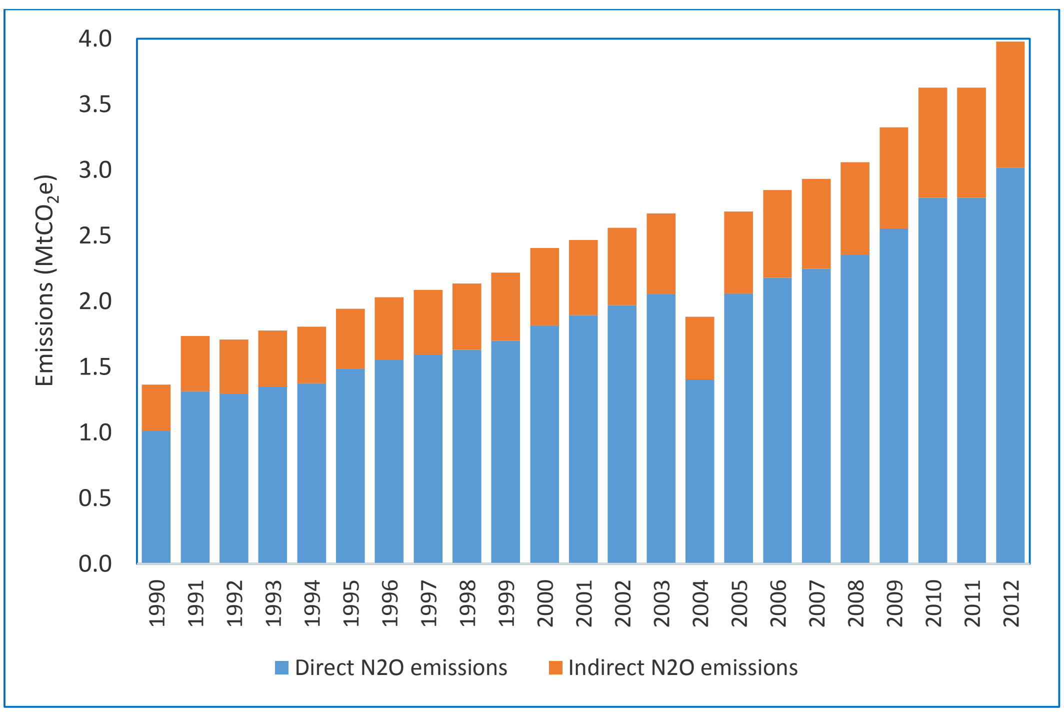


Figure 40: Trend direct and indirect N_2O Emissions from Managed Soils

Methodological issues

Direct and indirect N_2O emissions were estimated using the IPCC tier 1 and default emission factors. Country-specific activity data on annual crop production of key staples crops such as maize, yam, cassava, cocoyam, sorghum, rice and millet were obtained from the Agriculture facts and figures. Subsequently, appropriate default residue slope, residue intercept and dry matter fraction corresponding to the respective staple crops were used to retrieve the above ground biomass residue. The annual nitrogen fraction of the crop residue was obtained by applying the appropriate root-to-shoot ratio of the various crops. The individual crop residues were aggregated to form the total nitrogen fraction from the crop residue.

Data on nitrogen based fertilizers were obtained from the Agriculture facts and figures 1990-2012 which were subsequent summed up based on fraction of nitrogen content for different fertilizers published in the FAOSTAT. The percentage of nitrogen content in fertilizers was derived by multiplying total volume consumed yearly by its corresponding nitrogen fraction. The nitrogen content of the individual fertilizer types were summed to generate the annual total nitrogen input from synthetic fertilizers. Total annual N mineralization in soils was calculated based on annual soil organic matter loss and carbon-nitrogen ratio of the soil. For the annual soil organic matter, carbon stock change in mineral soils of individual land use conversion were obtained from the land use matrices and subsequently summed up to generate the annual total loss of soil organic matter per land category. The total annual nitrogen mineralization in managed soils was derived by multiplying the annual loss of soil organic matter to the carbon-nitrogen ratio. The total annual N - synthetic fertilizers, N - crop residues and N – mineralization were input for the calculation of the direct and indirect N_2O emissions from managed soils.

Recalculations

Availability of new datasets for crop production and fertilizer imports by MoFA and changes in methodological approaches between the revised 1996 and 2006 guidelines were the main reasons for the recalculations. The results of the recalculation is provided in table 76.

Table 76: Result of recalculation in 3C4 and 3C5

Year	PE (N_2O Emission -Gg)				LE (N_2O Emissions - Gg)						
	Inorganic N fertilizer application	Animal waste (FAW)	Crop residue (FCR)	Total	Inorganic N fertilizer application	Organic N applied as fertilizer (manure and sewage sludge)	Urine and dung N deposited on pasture, range and paddock by grazing animals	N in crop residues	N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils	Total	% Change
1990	0.18	1.23	0.17	1.57	0.20	0.64	0.94	0.98	1.44	4.21	62.65
1991	0.09	1.59	0.25	1.93	0.14	0.66	0.94	1.92	1.52	5.18	62.81
1992	0.09	1.70	0.23	2.02	0.08	0.64	0.94	1.87	1.59	5.12	60.56
1993	0.09	1.70	0.29	2.07	0.05	0.65	0.94	2.00	1.66	5.30	60.85
1994	0.04	1.84	0.30	2.19	0.06	0.66	0.94	1.98	1.73	5.37	59.31
1995	0.03	1.07	0.34	1.44	0.08	0.68	0.94	2.22	1.80	5.73	74.92
1996	0.04	1.15	0.33	1.51	0.04	0.71	0.94	2.37	1.88	5.95	74.54
1997	0.09	1.22	0.20	1.51	0.13	0.73	0.94	2.33	1.95	6.08	75.11
1998	0.12	1.26	0.21	1.59	0.20	0.64	0.94	0.98	1.44	4.21	62.11
1999	0.09	1.30	0.23	1.62	0.02	0.77	0.94	2.59	2.09	6.42	74.79
2000	0.10	1.33	0.24	1.67	0.11	0.94	0.94	2.64	2.16	6.79	75.41
2001	0.09	1.68	0.26	2.02	0.21	0.80	0.94	2.86	2.24	7.05	71.33
2002	0.09	1.40	0.33	1.82	0.07	0.82	0.94	3.16	2.31	7.29	75.04
2003	0.08	1.46	0.32	1.86	0.13	0.85	0.94	3.26	2.38	7.57	75.36
2004	0.08	1.50	0.28	1.87	0.30	0.89	0.94	3.09	0.25	5.47	65.83
2005	0.08	1.53	0.29	1.90	0.17	0.90	0.94	3.04	2.53	7.58	74.90
2006	0.08	2.07	0.30	2.45	0.45	0.93	0.94	3.06	2.58	7.97	69.30

Reasons for recalculation

Nitrous oxide

- Revision of annual average consumption of nitrogen synthetic fertilizers of 6,852tons in the previous estimate to 8,793.73tons in the latest of estimates due to inclusion of new dataset from agricultural facts and figures. Although the trend of inter-annual variation differs year by year.
- The methodology for the previous estimates accounted for fraction of animal waste but the latest estimates considered organic N applied as fertilizer (manure and sewage sludge). The average for the former estimates has been revised from 11, 7761.34tons to 48,722.2tons.
- The adoption of new dataset for crop harvesting. The initial estimate was averaged at 21,497.9tons and latest average estimate stand at 26, 57462.2tons.
- The methodological change introduced a new variable in the form of “urine and dung N deposited on pasture, range and paddock by grazing animals”. This was held constant over the years.
- The methodological change also introduced another new variable in the form of “N mineralization associated with loss/gain of soil organic matter resulting from land use change or management of mineral soils”

Description of emission trends from Indirect N_2O Emissions from Manure Management (3.C6)

Indirect N_2O emissions from manure management increased slightly from 34 $GgCO_2e$ in 1990 to 41 $GgCO_2e$ in 2000 and further to 50 $GgCO_2e$ in 2012 (see figure 41). The contribution of indirect N_2O emissions from manure management to the aggregated sources and non-CO_2 emission from land was 0.72% in 2012. The increases in the N_2O emissions were as a result growing livestock populations reported from 1990 to 2012.

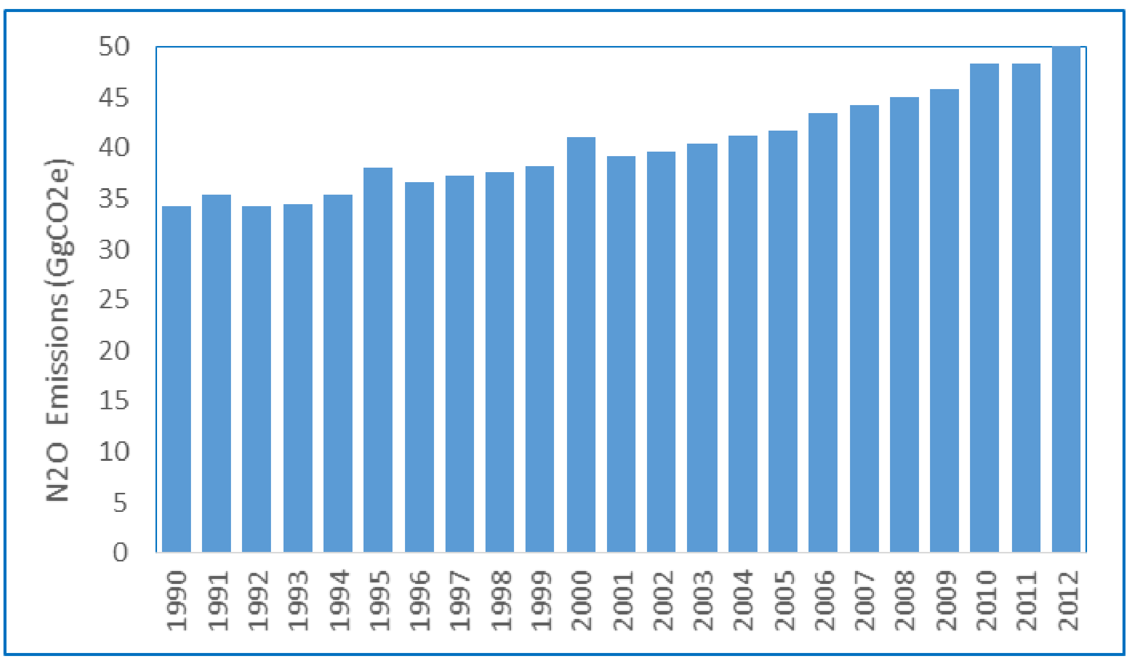


Figure 41: Indirect N_2O emission trends

Methodological issues

The IPCC default emission factors were used in the calculation of emissions from manure management. Proportions of animal waste management systems were estimated by expert judgment and categorized according to animal type.

Description of emission trends from rice cultivations (3.C7)

CH4 emissions from rice cultivations increased from 80 GgCO_2eq in 1990 to 90GgCO2eq in 2000 and further increased by 110 GgCO_2eq in 2012. The emissions from rice cultivation contributed 2.7% of the total emissions from aggregated source and non-CO_2 emissions from land (see figure 42). The rise in methane emissions could be attributed to the increasing rice production areas.

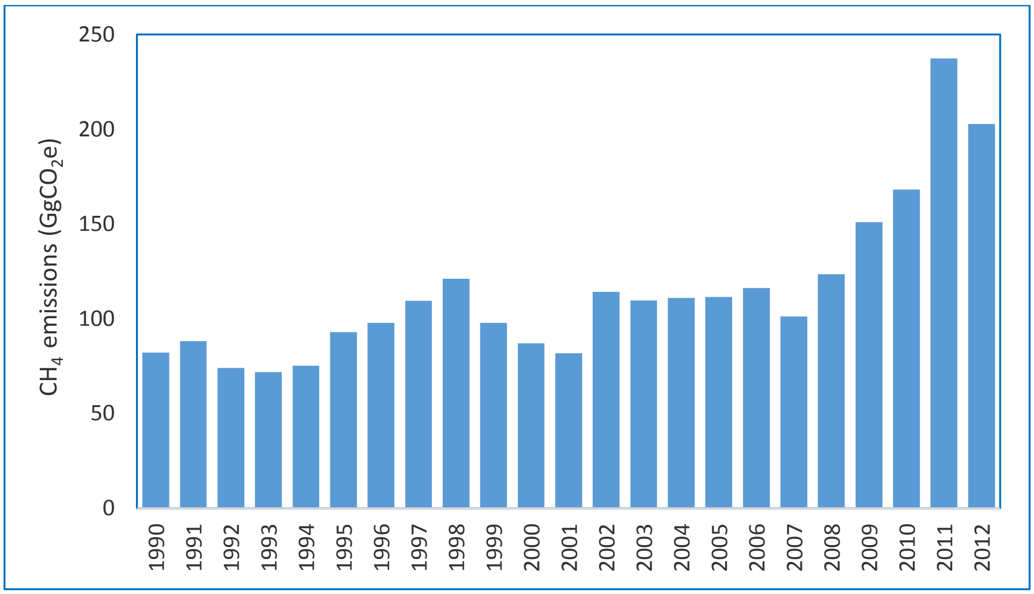


Figure 42: Emissions from Rice Cultivations

Methodological Issues

The IPCC tier 1 methodology and default emission factors for rice cultivation were used. The data on percentages of the different rice cultivation systems from the National Rice Development Strategy (MoFA, 2009) were used to derive the breakdowns of the total annual rice cultivation areas into rain-fed, upland, and irrigated systems.

Recalculations

The availability of new activity data and additional data on proportions of rice cultivation systems were the mains reasons for the recalculation of CH_4 emissions for the previous estimates. The results of the recalculations and the impacts on previous emissions is provided in table 77.

Table 77: Results of recalculation and its impacts on previous CH_4 emissions from rice cultivations

Year	PE		LE		% Change	
	Area harvested(ha)	CH4 emission(Gg)	Area harvested (ha)	CH4 emissions	Activity (Area harvested	CH_4 emissions (Gg)
1990	49000	19.60	88300	3.908	44.51	-401.58
1991	94900	37.96	94900	4.200	0.00	-803.87
1992	79700	31.88	79700	3.527	0.00	-803.87
1993	77200	30.88	77200	3.416	0.00	-803.87
1994	80900	32.36	80900	3.580	0.00	-803.87
1995	99900	39.96	99900	4.421	0.00	-803.87
1996	105250	42.10	105300	4.660	0.05	-803.44
1997	117700	47.08	117700	5.209	0.00	-803.87
1998	117800	47.12	130400	5.771	9.66	-716.53
1999	117000	46.80	105300	4.660	-11.11	-904.30
2000	117000	46.80	93600	4.142	-25.00	-1029.84
2001	117000	46.80	88000	3.894	-32.95	-1101.74
2002	136,000	54.40	122800	5.434	-10.75	-901.03
2003	117000	46.80	117900	5.218	0.76	-796.97
2004	119390	47.76	119400	5.284	0.01	-803.80
2005	119390	47.76	120000	5.310	0.51	-799.28
2006	125000	50.00	125000	5.532	0.00	-803.87

Reasons for recalculations

- Introduction of new dataset on harvested rice areas from the Agriculture facts and figures to replace the data from FAOSTATS.

- The revision in total harvested rice areas resulted in these changes (a) increases in harvested rice areas by 39,300ha in 1990, 50ha in 1996, 12,600ha in 1998, 900ha in 2003, 10ha in 2004 and 610ha in 2005 (b) reduction in harvested rice by 11,700ha in 1999, 23,400ha in 2000, 29,000ha in 2001, 13,200ha in 2002.

- Changes in methodology and emission factors for estimating methane for one ecosystem (continuously flooded rice) in the 1996 guidelines to three different ecosystems (upland, rain fed and irrigation) in 2006 guidelines.

5.4 Planned Improvements

Table 78 highlights key activities that have been planned for improving future inventories. These include efforts to generate data in categories where they are lacking and reduce the reliance on expert knowledge and associated uncertainties to an extent possible.

Table 78: List of activities for future improvements in the accounting for the AFOLU sector

Improvement tasks	Responsibility & Collaborators	Priority	Next Step	Target	Assumptions
Develop all-embracing new land representations schemes with definitions(include possibility of delineating tree crops from annual crop areas)	FC, EPA, UNU-INRA, Rudan, CERSGIS, Geomatics-KNUST, FAO, NATU-KNUST, Cocoa Board Survey department	High	Explore possibility of making a link with the FPP process as follow-up. EPA will facilitate.	Next Inventory	Funding is secured on time
Reprocess land use maps and LUC matrices	FC, AFOLU Team, CERSGIS	High	AFOLU technical team from the collaborating institutions will proceed with these activities following the initial action		
Overlay land cover maps with map of eco-zones, climate, soil and recalculate land use change maps		High			
Integrate maps on perennial crops (mainly cocoa and rubber) in land use maps and recalculate		High			
Reconsider the dealing with wetlands and eliminate some ways of change between categories.		High			
Reconsider factors that express speed of land use change in the 1970ies and 1980ies		High			
Cross-check area estimates from LUC matrices with data available at the plantation unit		High			
Fire monitoring					
Include the annual fire hotspots and overlay on the land use maps to assign disturbances to land use subcategories	FC, Ghana National Fire Service, NADMO, District Assemblies	High	Link with AGRYMET	Next Inventory	FC to initial contact with AGRYMET supported by EPA
Work on biomass inventory	FC and FORIG	High			
Include the biomass density estimates for plantations	FC and FORIG	High		Next Inventory	Contact FORIG

Remove outliers from biomass plot estimation (dead wood estimates)	FC and FORIG	High	EPA to follow-up with FC and FORIG		Contact FC for updates
Quality check deadwood calculations in inventory data	FC and FORIG	High			Contact FC
Explore possibility of surveying of non-forest trees, in settlements and communities(Measure AGB and fuel wood collections in settlements and integrate these values in the inventory)	FC and FORIG and EPA	Medium	Float call for proposal for the selection of the vendors	Next Inventory	Fund secured on time
Explore possibility of including trees in annual croplands	FC & MoFA	Medium	include in the discussions of the AFOLU collaborating team	Next Inventory	part of the activity 1
Explore possibility of reducing uncertainty associated with time series data (infilling of data gaps)	AFOLU Team	Medium	EPA to coordinate revision of existing estimates	Next Inventory	Funding is secured on time
a. biomass changes in different land representations including different pools					
b. Fuel production/supply					
d. Pools					
Other issues					
Account for the burning of crop residues beyond the burning of fields	MoFA	Low	MoFA to lead AFOLU team in the identification, collection and inclusion of data in to the inventory	Next Inventory	Funding for NC4 and BUR2 will cover this activity
Account for multiple cropping rice	MoFA and AFOLU Team	Low			
Include harvested wood products	FC	Low			
Include crop residues from plantain	MoFA and EPA	Low			
Clarify the fertilizer use in rice	MoFA and EPA	Low			

6. Waste Sector

6.1 Sector Overview

GHG emissions from the waste sector results from disposal of liquid and municipal solid waste through landfilling, compositing, incineration, opening burning and treatment of domestic and industrial liquid waste. The emissions from waste are predominantly CH_4 and CO_2 from solid waste disposal (incineration of solvents), NO_2 and CH_4 from biological treatment of solid waste, waste water treatment and discharge and decomposition of human waste. Carbon dioxide emissions from the breakdown of organic material were not reported because the carbon dioxide emitted was assumed to be reabsorbed by growth in vegetation and other organic matter in the following year. The key factors that affect emission generation in the waste sector are (a) population, (b) technology and (c) extend of emission (methane) recovery.

6.1.1 Classification of Waste Activities under IPCC 2006 Guidelines

Based on IPCC 2006 guideline, the following source categories were covered in the waste sector: Solid Waste Disposal (4A), Biological Treatment of solid waste (4B), Incineration and Open burning (4C) and Wastewater Treatment and Discharge (4D). Each major source category was divided into sub-categories that enabled allowed the inventory to take into account different waste attributes and waste management characteristics and approaches.

6.1.1.1 Solid Waste Disposal (4A)

Solid waste generation is closely linked to population, urbanization and standard of living. CH_4 and non-fossil CO_2 were the main gases associated with solid waste disposal through biological decomposition. Depending on the type of management at the disposal site, solid waste disposal activities were further divided into sub-categories managed waste disposal sites (4.A1), unmanaged waste disposal sites (4.A2) and uncategorized waste disposal sites (4.A3).

Based on the current solid waste management practices in Ghana, the estimation of methane from solid waste disposal was not disaggregated into managed, unmanaged and uncategorized. The main data input were population, waste generation per capita, solid waste streams, annual total waste generation, and fractions of waste disposed-off by different means. Methane from solid waste deposited in different site (landfill and others) were accounted for in the inventory. The data were obtained from Ghana Statistical Service, published statistics in national reports, literature and personal communication with waste experts at the AMA Waste Management Department.

6.1.1.2 Biological Treatment of solid waste (4B)

Methane and Nitrous oxide were the key emission sources from biological treatment of solid waste through compositing. The main data input were the quantities of waste composted in Ghana and the technology. The data was collected from Zoomlion Ghana Limited which was the only operator of Compost plant in Ghana.

6.1.1.3 Incineration and Open Burning of Solid Waste (4C)

Disposal of solid waste through incineration and open burning produce CO_2, CH_4 and N_2O emissions. The emission from 4C was divided into incineration (4C.1) and open burning (4.C2). Under 4C.1, emissions from municipal solid waste and clinical waste were the main sources considered using the aggregate approach. Emissions from open burning were from municipal solid waste. Data on incineration of municipal solid waste and clinical waste were obtained from the National Environmental Sanitation Strategy Action Plan document and the Ghana Health Service Facts and Figures.

6.1.1.4 Wastewater Treatment and Discharge (4D)

Methane and Nitrous Oxide are the main gases from wastewater treatment and discharge was divided into domestic (4.D1) and industrial (4.D2) wastewater treatment and discharge. Emissions 4D.1 are as a result of the different means of disposal and treatment of sewage. Emissions 4.D2 were from the 5 main industrial sectors. There were Beer and malt, Dairy Products, Fish Processing, Meat and Poultry and Organic Chemicals. The activity data were obtained from (a) Ghana Living Standard Survey, (b) Ministry of Agriculture Facts and Figures, (c) Multiple cluster Indicator Survey data, (d) National Environmental Sanitation Strategy Action Plan document and the (e) industry survey conducted by the EPA.

6.2 Data sources and methodology

The description of data sources and methodology used in the inventory for the Waste sector is provided below.

6.2.1 Data sources

The data used in this inventory were obtained from different relevant national and international sources. Table 80 provides an overview of the data used in the inventory.

Table 79: Overview of the data used in the inventory

Categories		Sub-categories	Data Type	Data Source	Principal Data Providers
4A. Solid Waste Disposal	4A	Solid Waste Disposal	Waste Generation Rate, Population Figures, Composition/Streams, amounts of waste deposited, Methods of disposals and their various percentages	Published national reports, Ghana Statistical Services, Sanitation Directorate of MLGRD, World Bank Country Database, Private Waste Management Companies and Civil Engineering Department, KNUST, EPA	National Environmental Sanitation Strategy & Action Plan (NESSAP), Population Census Reports and Ghana Living Standards Survey 2008, Private Waste Management Companies (Zoomlion) and NGOs (), Waste care, etc.), Academia, Second National Communication
4B. Biological Treatment of Solid Waste	4B	Biological Treatment of Solid Waste	Fraction of waste composted, number of compost plants	Private Waste Management	Private Waste Management Companies (Zoomlion)s and NGOs Expert judgment by Waste Team
4C Incineration and open burning	4C	4C.1 Waste Incineration	Amount and types waste incinerated, incinerator type including capacities and combustion efficiencies	Ghana Health Services Ministry of Local Government and Rural Development,	National Environmental Sanitation Strategy Action Plan document and Ghana Health Service Facts and Figures. Expert Judgment by Waste Team

		4C.2 Open Burning of Solid Waste	Population, fraction of population burning waste, duration of burning in number of days per year, fraction of waste burnt relative to the total amount treated.	Published national reports, Ghana Statistical Services, Sanitation Directorate of MLGRD,	National Environmental Sanitation Strategy & Action Plan (NESSAP), Population Census Reports and Ghana Living Standards Survey 2008 Expert Judgment by Waste Team
4D Wastewater treatment and discharge	4D	4D.1 Domestic wastewater treatment and discharge	Population, Wastewater Generated per year, Wastewater treated per year, Wastewater Treatment Systems and their various percentages, Protein Consumption, GDP/capita(income classes)	Ghana Statistical Services, Sanitation Directorate of MLGRD, World Bank, Ghana Health Service, Ministry of Food and Agriculture	National Environmental Sanitation Strategy & Action Plan (NESSAP), Population Census Reports and Ghana Living Standards Survey 2008, Multiple Cluster Indicator Survey data World Bank Country Database, FAO Expert Judgment by Waste Team
		4D.2 Industrial wastewater treatment and discharge	Industrial coverage, Total Industry Product Quantity of wastewater generated Type of Wastewater Treatment / discharge System	Industry survey.	Industrial Outputs, EMPs, waste water committees Expert Judgment by Waste Team

6.2.2 Methodology

6.2.2.1 Description of methods and underlying assumptions for the emissions estimation

The description of methodological choices and assumptions behind the activity data, emission factors used in the Waste sector are provided. The inventory adopted 2006 IPCC guidelines and GPG which provided guidance on data collection, methodological choices and the use of assumptions in a consistent and transparent way. The guidelines further provide guidance on how emissions are estimated using AD) and EF. Therefore the product of the activity data and the emission factor and its GWP gives the total GHG emissions of a particular activity [E=AD*EF * GWP].

The inventory adopted a mixture of tier 1 and tier 2 methodologies to estimate using available country-specific data and data from reliable international sources. The higher tier methodology was used because there were sufficient country-specific data was available. Example, the availability of national data on quantities of solid waste, composition, properties and disposal practices in the period 1990-2012 were used in the estimation of the emissions. As much as practicable, available country-specific activity data for all the categories were used. Where country-specific data were did not exist, data from reliable international data sources were used (see table 80). Most of these national data were either obtained from primary or publicly available secondary sources which covered the 1990-2012 time-series. However, where there were gaps, data from credible sub-regional and international sources were used. In the absence of data from the aforementioned sources to fill the gaps, appropriate statistical methods (e.g. trends extrapolation, interpolation, etc) were applied in line with the IPCC good practice guidance. In situations where there was complete absence of data for activities that occur in the country, expert judgment was used and the assumptions documented. Detailed descriptions of the respective methodologies are given in the specific sections of the various sub-categories.

6.3 Description of notation keys and completeness information

Information on completeness and use of notation keys in the Waste sector are provided below. Completeness include coverage of gases, categories and as well as time series. Additional information was given on the status of emission estimates of all sub-categories. Emissions of all sub-categories of category 4.A (Solid Waste Disposal), 4B (Biological Treatment of Solid Waste), 4C (Incineration and Opening Burning of Solid Waste) and 4D (Wastewater treatment and discharge). Table 80 shows the information on status of completeness of the estimations under various sub-categories.

Table 80: Overview of subcategories of Waste and status of estimations

IPCC Category	Time series Completeness												Status of Gas		
	1990-2006 (recalculations)				2007-2010 (new estimates)				2011-2012 (latest estimates)						
	Coverage of gases														
	E	NE	NO	IE	E	NE	NO	IE	E	NE	NO	IE	CO_2	CH_4	N_20
4.A – Solid Waste Disposal															
4.A. - Solid Waste Disposal	X				x				x				NO	x	NO
4.B– Biological Treatment of Solid Waste															
4.B– Biological Treatment of Solid Waste	X				x				x				NO	x	x
4.C – Incineration and Open Burning															
4.C1 Incineration		X			x				x				x	x	x
4.C2 Open Burning		X			x				x				x	x	x
4.D – Wastewater treatment and discharge															
4.D – Wastewater handling	X					X				x			NO	x	x
4.D1 Domestic wastewater treatment and discharge	X				x				x				NO	x	x
4.D2 Industrial wastewater treatment and discharge	X				x				x				NO	x	x

E" indicates that emissions from this sub-category have been estimated. "NO" means "Not Occurring"

6.4 Category-specific activity data inputs

The methodology used for the inventory requires that variety of activity data order to estimate the GHG emissions from a particular activity. Description of the key dataset are provided below:

6.4.1 Solid waste disposal (4A)

Emissions from municipal solid waste disposal was composed of domestic and commercial sources. The emissions were estimated taking into account population, per capita waste generation, and quantity collected and deposited in different forms of waste disposal sites. The relevant waste generation and disposal data were collected from different national sources.

6.4.1.1 Total solid waste generation and deposited

In 2012, the total MSW generated amounted 5,106.30Gg which was 41% and 59% higher than the 2000 and 1990 levels respectively (see table 81). The observed increases in the annual solid waste generation is due to growing population and change in lifestyles particularly in the urban areas. Of the 5,106.30Gg, 4085.04Gg (80%) was deposited in the solid waste disposal sites in 2012 which represented an increase from 36% in 1990 and 60% in 2000. The total of 4085.04Gg sent to SWDs had the following compositions: (a) food (73%), (b) Paper (8%), (c) Textiles (4%) and (d) Plastics and other inert (15%) (see figure 44)

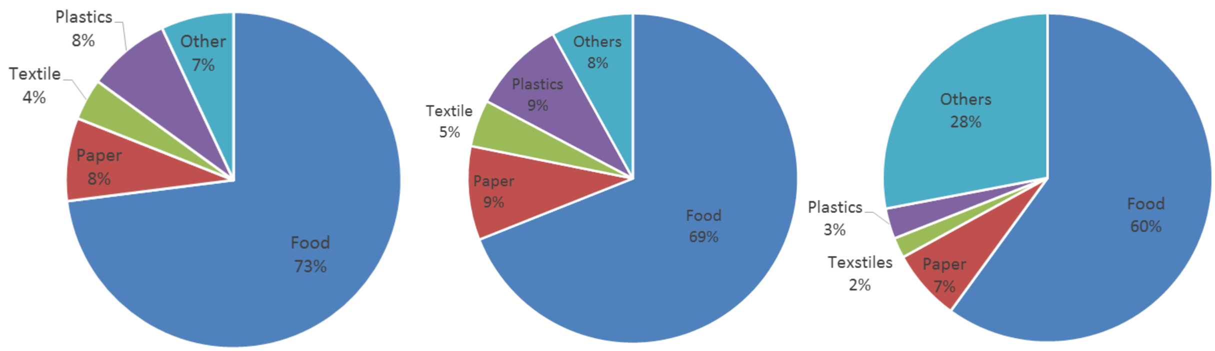


Figure 43: Solid waste composition 2012 (Left), 2000(Middle) and 1990(Right)

Table 81: Solid waste and compositions

Year	Total MSW (Gg)	% to SWDs	Total SWDs	Composition of MSW going to SWDs			
				Food	Paper	Textile	Plastic & Other Inert
1990	2106.41	36%	758.31	454.98	53.08	15.17	235.07
1991	2181.13	38%	828.83	497.30	58.02	16.58	256.94
1992	2258.35	40%	903.34	542.00	63.23	18.07	280.03
1993	2338.66	42%	982.24	589.34	68.76	19.64	304.49
1994	2421.37	44%	1065.40	639.24	74.58	21.31	330.27
1995	2506.78	46%	1153.12	691.87	80.72	23.06	357.47
1996	2594.48	49%	1266.11	759.66	88.63	25.32	392.49
1997	2686.30	52%	1386.13	831.68	97.03	27.72	429.70
1998	2780.53	54%	1512.61	907.57	105.88	30.25	468.91
1999	2877.89	57%	1646.15	987.69	115.23	32.92	510.31
2000	2991.24	60%	1794.74	1076.85	125.63	35.89	556.37
2001	3089.58	61%	1879.39	1371.96	150.35	75.18	281.91
2002	3215.19	62%	1982.49	1447.22	158.60	79.30	297.37
2003	3320.33	62%	2075.17	1514.87	166.01	83.01	311.28
2004	3428.71	63%	2171.40	1585.12	173.71	86.86	325.71
2005	3514.50	64%	2255.12	1646.23	180.41	90.20	338.27
2006	3682.42	65%	2393.57	1747.31	191.49	95.74	359.04
2007	3856.53	69%	2651.37	1935.50	212.11	106.05	397.70
2008	4037.05	73%	2926.86	2136.61	234.15	117.07	439.03
2009	4224.19	76%	3220.94	2351.29	257.68	128.84	483.14
2010	4500.24	80%	3600.19	2628.14	288.02	144.01	540.03

2011	4612.74	80%	3690.19	2693.84	295.22	147.61	553.53
2012	5106.30	80%	4085.04	2982.08	326.80	163.40	612.76
% Change (2012-2000)	41%		56%	64%	62%	78%	9%

6.4.2 Biological treatment of solid waste (4B)

The total amount of solid waste composted was 187.47 Gg in 2012 representing 3.7% of the total national solid waste generated. The 187.47 Gg is an increased from 105.43Gg in 2000 and further to 148.48Gg in 1990 at a rate 1.1% per annum (see table 82).

Table 82: Trend of solid waste composted

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Total Amt. Composted	148.48	148.95	149.24	149.40	149.35	149.10	146.31	143.20	139.65	108.53	105.43	106.63
Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
Total Amt. Composted	108.62	109.72	111.78	111.48	113.57	106.19	97.82	88.40	112.35	169.35	187.47	

6.4.3. Incineration and open burning (4C)

The disposal of municipal and clinical waste through incineration and open burning generates Carbon dioxide, methane and nitrous oxide emissions. The amount of emissions that will be generated will depend on the amount and type of waste as well as the types of incineration and open burning taking place. In all, a total of 166.32Gg of solid waste was disposed-off through incineration and open burning in 2012. Of the total 166.32Gg solid waste, 33.26Gg were incinerated whereas the remaining 133.06Gg were openly burnt (see table 83).

Table 83: Solid waste disposal by incineration and open burning

	Incineration			Open Burning	Total
Year	MSW [Gg]	Clinical Waste [Gg]	Total [Gg]	MSW [Gg]	
1990	41.71	2.20	43.91	175.64	219.55
1991	41.54	2.51	44.05	176.19	220.23
1992	41.32	2.81	44.13	176.54	220.67
1993	41.06	3.12	44.18	176.72	220.90
1994	40.74	3.43	44.17	176.66	220.83
1995	40.37	3.72	44.09	176.36	220.45
1996	39.32	3.95	43.27	173.07	216.34
1997	38.19	4.16	42.35	169.39	211.74
1998	36.96	4.34	41.30	165.19	206.49
1999	35.63	4.49	40.12	160.48	200.60
2000	34.34	4.63	38.97	155.89	194.86
2001	34.46	4.96	39.42	157.67	197.09

2002	34.82	5.33	40.15	160.60	200.75
2003	34.90	5.66	40.56	162.23	202.78
2004	35.27	6.05	41.32	165.28	206.60
2005	34.89	6.32	41.21	164.84	206.05
2006	35.25	6.73	41.98	167.92	209.90
2007	32.69	6.56	39.25	157.02	196.27
2008	29.87	6.29	36.16	144.64	180.80
2009	26.77	5.91	32.68	130.71	163.39
2010	23.81	5.51	29.32	117.26	146.58
2011	24.20	5.85	30.05	120.19	150.24
2012	26.61	6.65	33.26	133.06	166.32
% Change (2000-2012)	**-29.0%**	**30.3%**		**-17.2%**	

Out of the 33.26Gg solid waste incinerated, 26.61Gg were municipal solid waste and the other 6.65Gg were clinical waste in 2012. The total amount of 26.61Gg municipal waste incinerated was 29% lower than the 2000 levels. The observed reduction in the total amount of incinerated MSW could be the result of the declining incineration capacity at the local government level. On the other hand, the 6.65Gg clinical waste incinerated was an increase of 30.3% of the 2000 levels.

6.4.4. Wastewater treatment and discharge (4D)

Domestic and industrial water treatment and discharge are sources of methane and nitrous oxide. For domestic wastewater, total population, biological oxygen demand (BOD), type of treatment systems and the amount of protein intake per person per year were the main input data for the estimation of the emissions. Table 84 illustrates the rising trend of the national population and BOD per person and a decline in the protein intake per person.

Table 84: Trend of population, BOD per/capita and protein intake/capita

Year	Population (mil)	BOD (kg/ person/ year)	Protein intake (kg/ person/ year)
1990	14.43	11.33	31.6
1991	14.82	11.56	31.38
1992	15.22	11.79	31.16
1993	15.63	12.02	30.94
1994	16.05	12.26	30.72
1995	16.48	12.49	30.5
1996	16.93	12.72	31.14
1997	17.39	12.95	31.78
1998	17.85	13.18	32.42
1999	18.34	13.41	33.06
2000	18.91	13.65	33.7
2001	19.38	13.88	33.1
2002	19.87	14.11	32.5

2003	20.37	14.34	31.9
2004	20.88	14.57	31.3
2005	21.40	14.80	30.7
2006	21.93	15.04	30.1
2007	22.48	15.27	29.5
2008	23.04	15.50	28.9
2009	23.62	15.73	28.3
2010	24.66	15.96	27.7
2011	25.28	16.19	27.1
2012	25.91	16.43	26.5
% Change (2000-2012	**37**	**20.4**	**-21.4**

Centralized, aerobic, septic systems, latrines, sea, river and lake discharge and stagnant sewer were the main domestic treatment and discharge facilities in the country. In 2012, among the five treatment and discharge systems, latrine facility is the most commonest among the populace, followed by sea, river and lake discharge, septic systems, centralized aerobic and stagnant sewer facilities (table 85)

Table 85: Type of wastewater treatment and discharge facilities

Year	Treated wastewater									Untreated wastewater					
	Centralized, aerobic treatment plant			Septic systems			Latrines			Sea, river and lake discharge			Stagnant sewer		
	Urban high income	Urban low income	Rural	Urban high income	Urban low income	Rural	Urban high income	Urban low income	Rural	Urban high income	Urban low income	Rural	Urban high income	Urban low income	Rural
1990	2.86	1.54	1.50	1.90	1.30	0.90	43.82	38.08	60.90	2.94	2.56	36.80	2.68	2.33	0.05
1991	2.79	1.57	1.44	2.12	1.46	0.92	43.63	37.93	61.00	3.06	2.66	36.72	2.56	2.22	0.06
1992	2.72	1.60	1.38	2.35	1.61	0.94	43.45	37.77	61.10	3.18	2.76	36.64	2.44	2.12	0.07
1993	2.65	1.63	1.32	2.57	1.77	0.96	43.27	37.61	61.20	3.30	2.86	36.56	2.32	2.02	0.08
1994	2.58	1.66	1.26	2.80	1.92	0.98	43.09	37.45	61.30	3.41	2.97	36.48	2.20	1.92	0.09
1995	2.49	1.71	1.20	3.02	2.08	1.00	42.91	37.29	61.40	3.53	3.07	36.40	2.09	1.81	0.10
1996	2.42	1.74	1.14	3.17	2.31	1.02	42.73	37.13	61.50	3.65	3.17	36.32	1.97	1.71	0.11
1997	2.35	1.77	1.08	3.31	2.55	1.04	42.54	36.98	61.60	3.77	3.27	36.24	1.85	1.61	0.12
1998	2.28	1.80	1.02	3.46	2.78	1.06	42.36	36.82	61.70	3.88	3.38	36.16	1.73	1.51	0.13
1999	2.21	1.83	0.96	3.60	3.02	1.08	42.18	36.66	61.80	4.00	3.48	36.08	1.62	1.40	0.14
2000	2.14	1.86	0.90	3.75	3.26	1.10	42.00	36.50	61.90	4.12	3.58	36.00	1.50	1.30	0.15
2001	2.06	1.89	0.84	4.42	4.16	1.12	40.37	36.59	62.00	4.14	3.78	35.92	1.36	1.22	0.16
2002	2.00	1.91	0.78	5.10	5.07	1.14	38.73	36.69	62.10	4.16	3.98	35.84	1.22	1.14	0.17
2003	1.94	1.94	0.72	5.77	5.97	1.16	37.10	36.78	62.20	4.17	4.19	35.76	1.09	1.05	0.18
2004	1.88	1.96	0.66	6.45	6.88	1.18	35.47	36.87	62.30	4.19	4.39	35.68	0.95	0.97	0.19
2005	1.82	1.98	0.60	7.12	7.78	1.20	33.84	36.96	62.40	4.21	4.59	35.60	0.81	0.89	0.20
2006	1.76	2.00	0.54	7.61	8.87	1.22	32.37	36.89	62.50	4.20	4.82	35.52	0.70	0.78	0.24
2007	1.70	2.02	0.48	8.10	9.96	1.24	30.90	36.82	62.60	4.19	5.05	35.44	0.59	0.67	0.28
2008	1.64	2.04	0.42	8.59	11.05	1.26	29.43	36.75	62.70	4.18	5.28	35.36	0.48	0.56	0.32
2009	1.58	2.06	0.36	9.08	12.14	1.28	27.96	36.68	62.80	4.17	5.51	35.28	0.37	0.45	0.36

2010	1.51	2.09	0.30	9.58	13.22	1.30	26.50	36.60	62.90	4.16	5.74	35.20	0.25	0.35	0.40
2011	1.44	2.12	0.24	10.08	14.30	1.32	25.04	36.52	63.00	4.15	5.97	35.28	0.13	0.25	0.44
2012	1.37	2.15	0.18	10.58	15.38	1.34	23.58	36.44	63.10	4.14	6.20	35.36	0.01	0.15	0.48

For latrine facilities, while the fraction of the urban high population that use generally declined from 42% in 2000 to 23.6% and dependence by the rural communities largely remained unchanged at an average of 60%. The use of septic systems recorded increases among urban high incomes (10.6%) and low income (15.4%) population. In the rural areas of the country, significant fraction of the population depend on latrines and sea, river and lake discharge (see table 87). Datasets on total industry products, COD and BOD levels, wastewater generated and the fraction treated for five main industrials sectors were obtained through a survey. The survey was conducted by the Manufacturing industry Department, EPA. The survey covered about 20% of the industrial capacity in the country. In 2012, industry products from food processing and chemical industries constituted 79.5% of the industries and followed by dairy product (11.8%), fish processing (5.8%), meat and poultry (2.5%) and Beer and Malt (0.4) (see table 86).

Table 86: Trend of total Industry Product

Year	Total Industry product (t/yr)				
	Beer and Malt	Dairy Products	Fish Processing	Meat and Poultry	Organic Chemicals
2000				393	
2001		10,882		1,570	
2002		14,128		67	
2003		16,465		879	
2004		24,002		912	
2005		23,973		995	
2006		22,045	36,174	1,144	
2007	3,405	27,001	31,979	13,644	538,021
2008	3,600	28,275	46,677	11,215	921,757
2009	3,420	39,701	37,494	11,752	506,468
2010	3,300	41,514	42,367	14,772	571,702
2011	3,600	35,552	43,542	27,692	622,285
2012	3,000	95,225	46,317	20,285	639,470

6.5 Key Categories

The methodology and results of the key category analysis in the waste sector is presented in table 87 below.

Table 87: Result of the key Category analysis of the Waste sector

IPCC Category code	IPCC Category	Greenhouse gas	Key Source Assessment(Level Assessment – LA)	Key Source Assessment Trend Assessment (TA)(1990-2012)
4.D	Wastewater Treatment and Discharge	CH_4	2012	TA
4.A	Solid Waste Disposal	CH_4	2012	TA

Methane emissions from both solid waste disposal and wastewater treatment and discharge were the key categories in terms levels (2012) and trends (1990-2012) for the waste sector. The levels of methane emissions from solid waste disposal and wastewater treatment and discharge were as result of the following (a) rising population especially in the major cities, (b) shift in the waste collection and disposal in cities, (c) no methane recovery in the landfills, (d) poor state of existing treatment systems and (e) discharge pathways.

6.6 Time series consistency

6.6.1 Recalculations

Recalculations have been done for the waste sector due to the following reasons (a) changes in both activity data and emission factors as a result of (a) changes in methodological approaches due to switch to 2006 guidelines, (b) identification and use of new datasets (c) filling of time series data gaps with national and international data sources and (g) refinement in the use of expert judgments. Detail information on the descriptions of the reasons of, and impacts of the recalculations have been provided under each category. The result of the assessment of recalculation and its impacts are shown in table 88

Table 88: Assessment of the impacts of recalculation on the previous estimates

	CO_2			CH_4			N_2O		
Year	PE	LE	% Change	PE	LE	% Change	PE	LE	% Change
1990	0.00	5.09	100	25.35	46.19	82.2%	0.33	1.07	222.8%
1991	0.00	5.12	100	27.02	48.68	80.2%	0.34	1.09	215.3%
1992	0.00	5.13	100	27.42	54.13	97.4%	0.35	1.11	215.9%
1993	0.00	5.14	100	28.47	56.90	99.9%	0.37	1.13	204.4%
1994	0.00	5.14	100	31.74	61.92	95.1%	0.38	1.15	201.9%
1995	0.00	5.14	100	34.73	65.10	87.4%	0.39	1.17	201.1%
1996	0.00	5.05	100	35.68	69.99	96.2%	0.40	1.22	205.5%
1997	0.00	4.95	100	54.22	73.73	36.0%	0.41	1.30	213.4%
1998	0.00	4.83	100	57.07	78.61	37.7%	0.43	1.33	212.7%
1999	0.00	4.70	100	57.98	82.65	42.6%	0.46	1.38	200.5%
2000	0.00	4.57	100	67.75	87.52	29.2%	0.45	1.45	221.2%
2001	0.00	4.63	100	70.23	94.91	35.1%	0.46	1.46	217.7%
2002	0.00	4.72	100	77.12	99.10	28.5%	0.49	1.50	202.4%
2003	0.00	4.77	100	84.55	105.23	24.5%	0.50	1.48	196.4%
2004	0.00	4.87	100	92.51	110.63	19.6%	0.50	1.49	195.2%
2005	0.00	4.86	100	96.36	117.82	22.3%	0.54	1.50	177.0%
2006	0.00	4.96	100	99.95	123.60	23.7%	0.54	1.50	178.4%

Reasons for recalculations

Recalculations led to the revision of the previous activity data and emission factors, addition of new datasets and application of new methodologies. This explains the changes in the emissions illustrated in table x. The reasons for the calculation are provided in table 89.

Table 89: Reasons for recalculations according to gases

Gases	Data in category	Reasons behind recalculations
Carbon Dioxide	Incineration (total solid waste incinerated)	• Inclusion of incineration sub-category • Introduction of new dataset on fraction of total solid waste incinerated from 1990-2012 due to discovery of new data from Ghana Health Service
	Open burning (total solid waste burnt)	• Inclusion of open burning sub-category • Introduction of new dataset on fraction of total solid waste openly burnt from 1990-2012 due to discovery of new data based on expert judgment
Methane	Solid waste disposal	• Changes in MCF, DOCf due to switch to new methodology in the 2006 IPCC guidelines as well as from the changes from bulk or aggregate to component approach. • Changes activity data (total municipal solid waste generation) due to revision of per capita waste generation. • Revisions in the percentages of MSW deposited in Solid waste disposal sites.
	Domestic wastewater discharge and treatment	• Changes in the activities from 1990-2012 due to revision of population figures from 5 cities to cover the entire national level. • Changes in aggregated MCF/EF due to switch to new methodology in the 2006 IPCC guidelines • Disaggregation of treatment systems from only anaerobic system to 5 treatment systems (septic, centralized system, latrine, Sea River, stagnant water).
	Biological treatment of solid waste (total solid waste composted)	• Inclusion of open burning sub-category • Introduction of new dataset on fraction of total solid waste composted from 1990-2012 due to discovery of new data based on data Zoomlion and expert judgment
	Incineration (total solid waste incinerated)	• Inclusion of incineration sub-category • Introduction of new dataset on fraction of total solid waste incinerated from 1990-2012 due to discovery of new data from Ghana Health Service
	Open burning (total solid waste burnt)	• Inclusion of open burning sub-category • Introduction of new dataset on fraction of total solid waste openly burnt from 1990-2012 due to discovery of new data based on expert judgment
Nitrous Oxide	Biological treatment of solid waste (total solid waste composted)	• Inclusion of open burning sub-category • Introduction of new dataset on fraction of total solid waste composted from 1990-2012 due to discovery of new data based on data Zoomlion and expert judgment
	Incineration (total solid waste incinerated)	• Inclusion of incineration sub-category • Introduction of new dataset on fraction of total solid waste incinerated from 1990-2012 due to discovery of new data from Ghana Health Service

	Open burning (total solid waste burnt)	• Inclusion of open burning sub-category • Introduction of new dataset on fraction of total solid waste openly burnt from 1990-2012 due to discovery of new data based on expert judgment
	Domestic wastewater discharge and treatment	• Changes in the activities from 1990-2012 due to revision of population figures from 5 cities to cover the entire national level. • Changes in aggregated MCF/EF due to switch to new methodology in the 2006 IPCC guidelines • Disaggregation of treatment systems from only anaerobic system to 5 treatment systems (septic, centralized system, latrine, Sea River, stagnant water).
		• Revision in per capita protein intake due to availability of new dataset from Fact and Figures published by the Ministry of Food and Agriculture.

6.6.2 Filling of data gaps

The data gaps that were identified in the inventory were filled by adopting the appropriate IPCC methodology for filling such gaps. The specific methods used in filling the gaps were selected based on the type of the data and nature of the gaps. Table 90 presents the data gaps and how they were filled.

Table 90: Data gaps and the method used to fill them

Category	Data Gap	Method applied	Justification for methodology used	Description of approach for filling of gaps
Solid Waste Disposal (4A)	Missing data of annual per capita solid waste generation 1991-1999, 2000-2004 and 2006 and 2010	Trend interpolation	National sources data from Ministry of Local Government and Rural Development, literature and study reports.	The annual per capita solid was generation was derived from the difference between two known and divided by the number interval years. The annual average difference was applied to the preceding known figure in order to generate the missing annual data
Waste water discharge and treatment	Missing data income class which was derived from urban and rural population classification. For 1991-2009 and 2011 and 2012	Interpolation and extrapolation	Urban and rural population share were obtained from the Ghana Statistical Service for 1990 and 2010	Based on the available 1990 and 2010 urban, rural population share, interpolation factor was derived by finding the difference between the share for 1990 and 2010 and dividing by the difference between 1990 and 2010.
	Distribution of the share of population in different income classes using different waste treatment facilities. Missing data from 1990 to 2004, 2007-2010 and 2012	Interpolation	Data on population using different treatment systems were obtained from the Multiple Cluster Indicator Survey data for 2011, 2005, 2006	Fraction of population using different treatment system was derived each 5 years in the time series. For each five years, interpolation was made using average interpolation factor. The factor derived from the difference between the two known years and divided by the difference in the intervening years.

6.7 Quality control/quality assurance

The QA/QC procedures that were followed in the Waste sector is detailed in table 91.

Table 91: QA/QC procedures implemented in the Waste sector

Data Type	QA/QC procedure	Remarks/Comment/Examples
Activity data check	Check for transcription, typographical errors and error transposition.	Division of task among the inventory team to ensure that one or two members of team always focus on double checking and ensure that data errors associated those described in the left column are avoided.
	Comparison with published data/literature	Data on per capita solid waste generation, fraction of waste composted and incinerated were cross-checked with published the Ghana statistical services, different local government authorities, industry (Zoomlion Ghana Limited) and Ghana Health Service.
	Consistency checks of categories and sub-categories with totals	Ensuring that disaggregated figures at the category and sub-categories levels add up to the overall totals.
	Identify and fix outliers in data inputs (including checking for dips and spikes in the trend)	Data that deviate unrealistically from the trends and spikes beyond ranges are suspected as inaccurate and replace with from expert judgment.
	Documentation of all data sources, data format and assumptions for easy reference	A record of all data, their sources and assumptions made in admitting the data use were kept. This helped in easy cross-referencing.
	Ensure reduction in data clumsiness or data redundancy	Logical sequence data flow according the IPCC methodology for the GHG emission estimation was designed for: (a) easy understanding and further probing of how the final results in the IPCC software would like, (b) easy cross-referencing and avoidance of mistakes, (c) easy transmission into the IPCC software and (d) aid in better interpretation of the implication of the use of the data.
Calculation by the approved 2006 IPCC software	Cross-checks all steps involved in the calculation.	Ensure that steps used for determining, estimating and deriving data are accurate, transparent internally consistent.
	Documentation of sources and correct use of units.	Use of the documentation template record all data sources and assumptions.
	Check for transcription, typographical errors and error transposition.	Check mistake and blunders in the enter entry into the software
	Checked completeness of data coverage	Ensuring all the relevant gases for the specific activity were covered.
Results (emissions)	Check of recalculation differences	To identify and pinpoint changes, revision and reallocation to improve accuracy and transparency of the estimates
	Identify and fix outliers in the results	checking for dips and spikes in trends and levels
Documentation	Assumptions, corrections, data and sources.	Ensure consistency, transparency, facilitate repeatability and easy retrieval
	Improvement list (internal and external findings)	Help prioritize areas that require actions.

6.8 Analysis of waste sector emission trends

In 2012, total emissions from the Waste sector was 4.52 $MtCO_2e$ which represented 14.6% of the national totals. When emissions from AFOLU are excluded from the national totals, the contributions from waste sector made up of 24.4% of the national emissions. The total emissions from the sector has recorded consistent rise from 1.3 $MtCO_2e$ in 1990 to 2.3 $MtCO_2e$ in 2000 and further to 4.52 $MtCO_2e$ in 2012 (see figure 44).

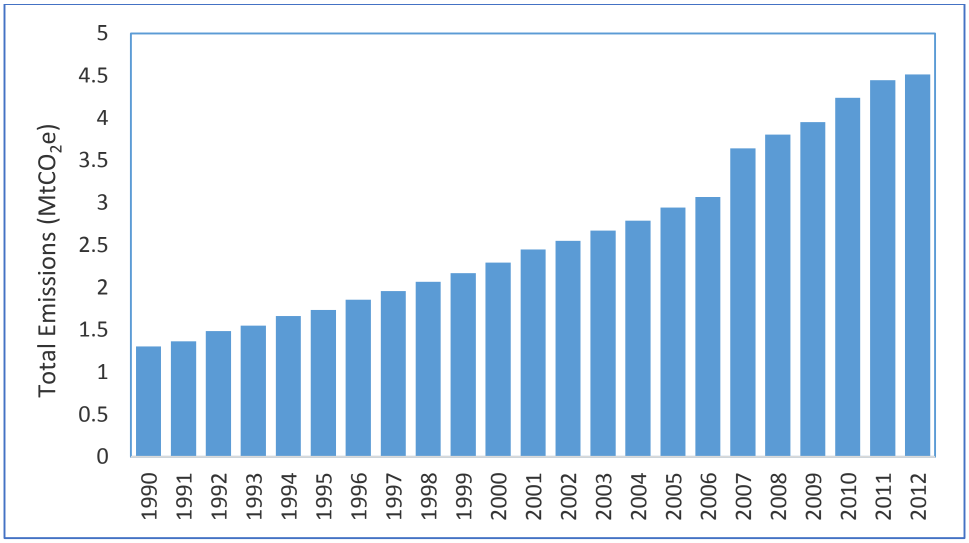


Figure 44: Total emission trends in the waste sector

The observed changes in the emission trend corresponded to the rising emissions from wastewater treatment and discharge as well as solid waste disposal. In the waste sector, wastewater treatment and discharge (4D) contributed largest emissions making up 66.8% of the total emissions in 2012. This was followed by solid waste disposal (31.9%), biological treatment of solid waste (0.7%) and incineration and open burning of waste (0.6%) (see figure 45)

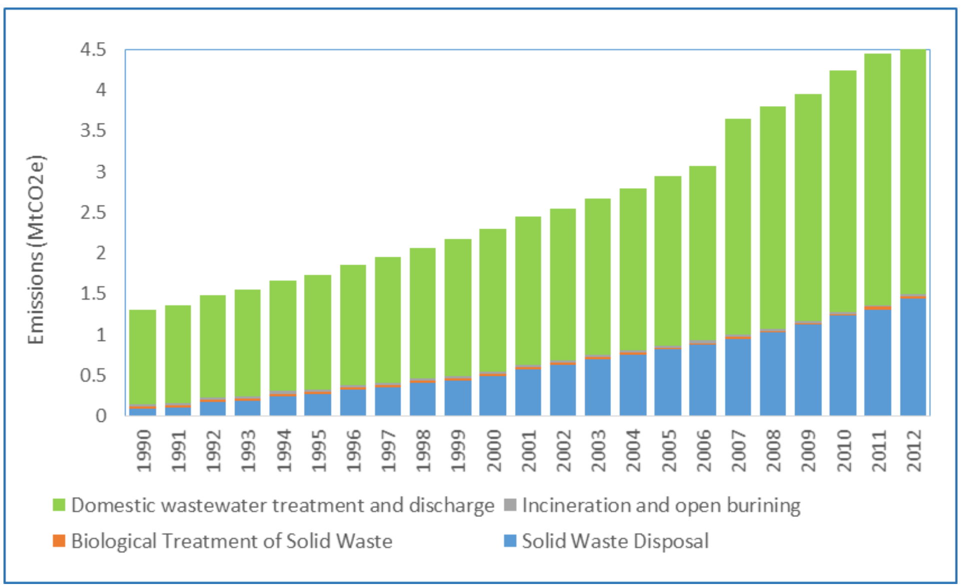


Figure 45: Total emissions trend according to sub-categories in waste sector

In 2012, the total emissions of 3.01 $MtCO_2e$ represented an increase of 61.8% and 42.1% above the 1990 and 2000 levels. The trend is attributed to the following drivers: (a) rising domestic and industrial wastewater generation as a result of increasing population and expansion of industrial production; (b) inadequate wastewater treatment facilities; and (c) significant amount of untreated wastewater particularly from households. Emissions from solid waste disposal recorded similar trends. It rose steadily from 0.09 $MtCO_2e$ in 1990 to 0.5 $MtCO_2e$ in 2000 and further to 1.44 $MtCO_2e$. The observed emissions trends was linked to the growing population, changing lifestyles due to improving socio-economic conditions in the country particularly in the large cities, increases fraction of solid deposited on solid waste disposal sites and non-existing landfill management program in the country. The rest of the waste sector emissions came from biological treatment of solid waste, compositing, and incineration and open burning. While the emissions from biological treatment of solid waste recorded increases that of incineration and opening burning decreased.

Methane was the most important gas in the waste sector. It constituted 89.1% of the total emissions from the waste sector in 2012 (see table 93). Within the waste sector, wastewater treatment and discharge (4D) was the dominant sources of methane (63.3%) followed by solid waste disposal (35.8%). The remaining 1% were emitted from incineration and opening (4C) and biological treatment of solid waste (4B) in 2012. Nitrous oxide emission was the next important greenhouse gas making up 10.8% of the total emissions from the waste sector. Wastewater treatment and discharge (4D) accounted for the most nitrous oxide emissions making up 95.5% of the total nitrous oxide emission in the waste sector in 2012 (see table 92). The rest of the waste sector emission was carbon dioxide accounting 0.1% of the total waste sector emissions.

Table 92: Waste Sector emissions

Year	CO_2	CH_4 ($GgCO_2e$)					N_2O ($GgCO_2e$)			
	4C	4A	4B	4C	4D	Total	4B	4C	4D	Total
1990	5.09	93.36	12.47	24.16	839.91	969.91	13.81	5.50	310.93	330.24
1991	5.12	101.75	12.51	24.28	883.68	1022.22	13.85	5.53	317.10	336.48
1992	5.13	174.85	12.53	24.28	925.02	1136.69	13.88	5.53	323.38	342.78
1993	5.14	189.93	12.55	24.30	968.16	1194.95	13.89	5.53	329.77	349.19
1994	5.14	250.45	12.54	24.30	1012.96	1300.25	13.88	5.53	336.26	355.68
1995	5.14	271.13	12.52	24.26	1059.10	1367.01	13.87	5.46	342.87	362.20
1996	5.05	326.87	12.29	23.81	1106.92	1469.89	13.61	5.42	359.51	378.54
1997	4.95	354.71	12.03	23.32	1158.34	1548.40	13.32	5.31	384.40	403.02
1998	4.83	408.46	11.73	22.72	1207.85	1650.77	12.99	5.17	394.78	412.94
1999	4.70	442.99	9.12	22.07	1261.55	1735.72	10.09	4.95	413.44	428.49
2000	4.57	497.90	8.86	21.44	1309.75	1837.94	9.80	4.88	434.66	449.35
2001	4.63	580.87	8.96	21.69	1381.62	1993.14	9.92	4.86	437.60	452.37
2002	4.72	634.47	9.12	22.09	1415.41	2081.10	10.10	5.03	448.54	463.67
2003	4.77	705.24	9.22	22.31	1473.04	2209.81	10.20	5.08	443.08	458.37
2004	4.87	757.23	9.39	22.74	1533.90	2323.25	10.40	5.08	445.62	461.10
2005	4.86	818.51	9.36	22.67	1623.62	2474.16	10.37	5.16	448.00	463.53
2006	4.96	875.15	9.54	23.10	1687.85	2595.65	10.56	5.26	450.23	466.05
2007	4.64	953.46	8.92	21.60	2187.15	3171.12	9.88	4.92	452.29	467.08
2008	4.28	1031.07	8.22	19.90	2272.09	3331.27	9.10	4.43	454.16	467.69
2009	3.87	1125.51	7.43	17.98	2330.43	3481.34	8.22	4.09	455.85	468.17
2010	3.48	1231.41	9.44	16.13	2498.21	3755.19	10.45	3.67	465.84	479.96
2011	3.57	1310.72	14.23	16.53	2614.50	3955.98	15.75	3.76	467.14	486.66
2012	3.96	1441.15	15.75	18.30	2546.68	4021.87	17.44	4.17	468.22	489.82

6.9 Description of source categories

6.9.1 Summary of source-specific emission trends

6.9.1.1 Solid waste disposal (4A)

Key Category: CH_4 emissions (TA)

Methane emissions from solid waste disposal is the product of the manner waste disposal to managed site take place. The nature of the management practice at the final solid waste disposal site determine aerobic conditions which produce methane. Solid waste are disposed-off and treated by unmanaged sites (dump sites) and few managed sites (landfills). Currently most of the disposal sites are unmanaged dump sites and only four well engineered landfills which are not properly managed. Over the years, it has been observed that the amount of waste deposited keeps increasing due to increase in waste generated which is influenced by population increase. In all, for the period of 1990-2012, total Municipal Solid Waste (MSW) generation increased. Similarly the fraction of solid waste collected for deposition at solid waste disposal site also recorded increases.

The total of 5.11 Mt of MSW generated in 2012 represented 58.7% and 35% higher than the 1990 and 2000 MSW respectively. Similarly, the fraction MSW collected and deposited for the period 1990-2012 increased from 36% in 1990, 60% in 2000 and 80% in 2012 (see figure 46). The increasing trend in waste collection in Ghana is due to Policy shift in Public Private Partnership (PPPs) arrangements (private sector to collect 80% of waste). Notwithstanding the increase in the waste collection there has not been any policy introduced to ensure the collection of methane from the final disposal site.

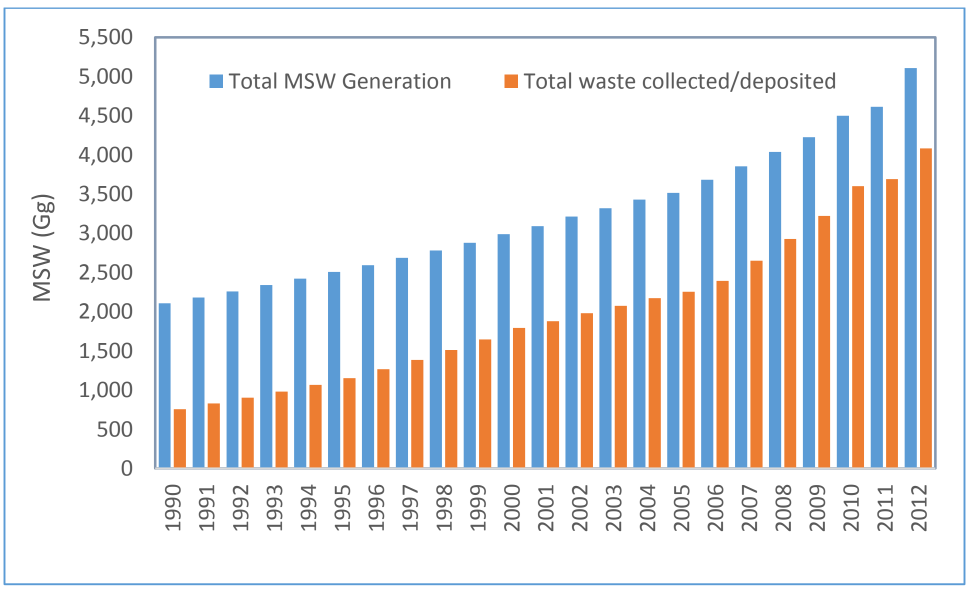


Figure 46: Comparison of the trend of total MSW generation and fraction deposited

Between 1990 and 2012, food waste dominated the waste stream in the country constituting 73% of the total MSW, followed by plastics (8%), paper (8%), others including ash, inert, metals and nappies (7%) and textile (4%). The increasing MSW generation and fractions deposited on solid waste disposal sites translated to similar patterns of total GHG emissions (see figure 47). In 2012, the emission of 1.41 $MtCO_2e$ attributed to solid waste disposal was 93.5% and 65.5% above 1990 and 2000 emission levels respectively.

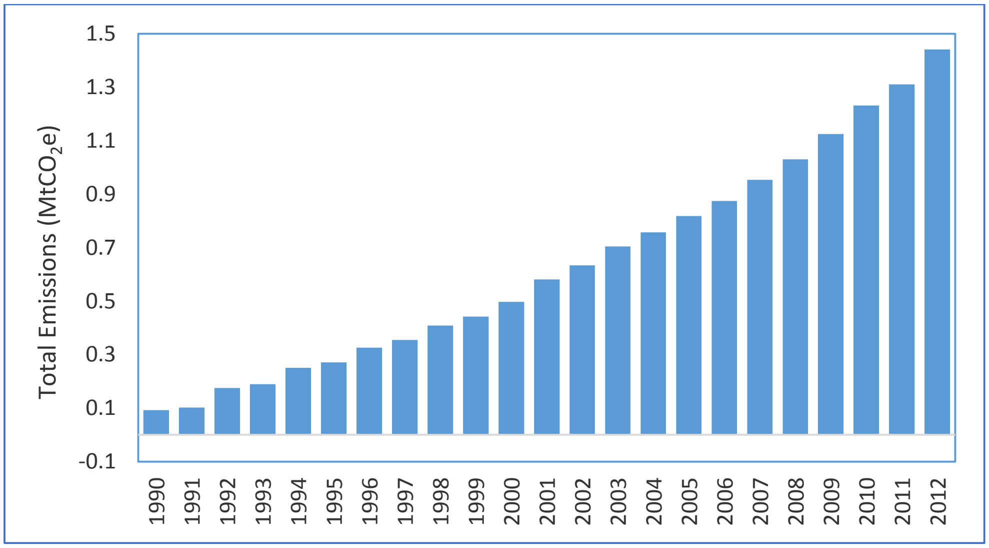


Figure 47: Total emission trends from solid waste disposal

It was observed that CH_4 emissions increases with the amount of waste collected and disposed increases throughout for the period 1990-2012. The increase trend in the amount of waste collected and disposed reiterates the afore mention policy shift, over the years, in solid waste service provision from central government to sole provision by local governments and now the involvement of private sector in the country. Historically, in the early 1990s, there was policy shift towards private sector-led development, led to contracting out and franchising the solid waste collection services to the private sector in Accra and Tema. The shift helped to increase the amount of waste collected and deposited for treatment on landfill sites. Although the policy that allowed private sector participation yielded some level of efficiency in waste collection and disposal, not much have been done to improve management of waste disposal sites. In addition, the existing policy does not offer clarity on landfill gas management.

Methodological issues

The key parameters needed for calculating the emission were (a) the amount of MSW generated (b) fraction of MSW deposited according to streams at the various sites and the amount of methane recovered at these sites over the years. The total amount of MSW generated was obtained from the products of annual national population trend and per capita solid waste generation. The national population data were obtained from national population census for 1984, 2000 and 2010. The population for the intervening years were derived from using the inter-census population growth rate published by the Ghana Statistical Service. From various studies and consultation with the waste management department of the Accra Metropolitan Area various solid waste generation rates for some specific years were obtained. The waste generation rates for other years were interpolated or were based on exert judgments (see table 93). After estimation of the amount of waste generated, the waste deposited were calculated with the various percentage estimates from each year. The fraction of MSW collected and deposited were obtained from number interviews of experts from Accra Metropolitan Assembly, Zoomlion Ghana Limited and the data published in the Ghana Living Standard Survey in 2008.

Table 93: Overview of amount of waste collected and deposited

Year	population (mil)	MSW Generation rate (kg/per/year)	total MSW generation (tonnes)	total MSW generation (Gg)	% Waste deposited at SWDS	Waste collection/Deposited (Gg)
1990	14,427,443	146.00	2,106,407	2,106.41	36.0%	758.31
1991	14,816,984	147.20	2,181,127	2,181.13	38.0%	828.83
1992	15,217,043	148.41	2,258,346	2,258.35	40.0%	903.34
1993	15,627,903	149.65	2,338,659	2,338.66	42.0%	982.24
1994	16,049,856	150.87	2,421,369	2,421.37	44.0%	1065.40
1995	16,483,203	152.08	2,506,780	2,506.78	46.0%	1153.12
1996	16,928,249	153.26	2,594,483	2,594.48	48.8%	1266.11
1997	17,385,312	154.52	2,686,299	2,686.30	51.6%	1386.13
1998	17,854,715	155.73	2,780,531	2,780.53	54.4%	1512.61
1999	18,336,792	156.95	2,877,893	2,877.89	57.2%	1646.15
2000	18,912,079	158.17	2,991,237	2,991.24	60.0%	1794.74
2001	19,384,881	159.38	3,089,580	3,089.58	60.8%	1879.39
2002	19,869,503	161.82	3,215,193	3,215.19	61.7%	1982.49
2003	20,366,241	163.03	3,320,327	3,320.33	62.5%	2075.17
2004	20,875,397	164.25	3,428,708	3,428.71	63.3%	2171.40
2005	21,397,282	164.25	3,514,503	3,514.50	64.2%	2255.12
2006	21,932,214	167.9	3,682,419	3,682.42	65.0%	2393.57
2007	22,480,519	171.55	3,856,533	3,856.53	68.8%	2651.37
2008	23,042,532	175.2	4,037,052	4,037.05	72.5%	2926.86
2009	23,618,595	178.85	4,224,186	4,224.19	76.3%	3220.94
2010	24,658,823	182.50	4,500,235	4,500.24	80.0%	3600.19
2011	25,275,294	182.50	4,612,741	4,612.74	80.0%	3690.19
2012	25,907,176	197.10	5,106,304	5,106.30	80.0%	4085.04

In Ghana, there are no methane recovery at the various landfill and thus methane recovery was assumed as zero throughout the time series. The composition of waste available for Ghana was normally for the total municipal waste. The general composition of municipal waste in the country is shown in the table 94. The composition of waste in Ghana was predominantly made of biodegradable materials and a high percentage of inert materials as well. The inert material was mostly made of wood ash, sand and charcoal. The food waste ranges from 60-73%, paper from 7 -8%, textile 2-4%, plastics 3-8% and others 7-28% for the various waste streams. Most of the garden and wood waste were combined with the food waste and also nappies are included to other waste. It should be noted that the composition of waste streams of what was generated is similar if not the same as what was deposited.

Table 94: Waste Composition Deposited at SWD Sites

Food	Garden	Paper	Wood	Textile	Nappies	Plastics	Others	total
(60- 73%)	IE	(7- 8%)	IE	(2-4%)	IE	(3-8%)	(28-7%)	
454.98	IE	53.0814	IE	15.1661	IE	22.75	212.33	758.31
497.29	IE	58.0180	IE	16.5766	IE	24.86	232.07	828.83
542.00	IE	63.2337	IE	18.0668	IE	27.10	252.93	903.34
589.34	IE	68.7566	IE	19.6447	IE	29.47	275.03	982.24
639.24	IE	74.5782	IE	21.3080	IE	31.96	298.31	1065.40
691.87	IE	80.7183	IE	23.0624	IE	34.59	322.87	1153.12
759.66	IE	88.6275	IE	25.3222	IE	37.98	354.51	1266.11
831.68	IE	97.0291	IE	27.7226	IE	41.58	388.12	1386.13
907.56	IE	105.8826	IE	30.2522	IE	45.38	423.53	1512.61
987.69	IE	115.2308	IE	32.9231	IE	49.38	460.92	1646.15
1076.85	IE	125.6320	IE	35.8948	IE	53.84	502.53	1794.74
1371.96	IE	150.3513	IE	75.1757	IE	150.35	131.56	1879.39
1447.22	IE	158.5990	IE	79.2995	IE	158.60	138.77	1982.49
1514.87	IE	166.0137	IE	83.0068	IE	166.01	145.26	2075.17
1585.12	IE	173.7120	IE	86.8560	IE	173.71	152.00	2171.40
1646.23	IE	180.4093	IE	90.2047	IE	180.41	157.86	2255.12
1747.31	IE	191.4858	IE	95.7429	IE	191.49	167.55	2393.57
1935.49	IE	212.1093	IE	106.0547	IE	212.11	185.60	2651.37
2136.61	IE	234.1490	IE	117.0745	IE	234.15	204.88	2926.86
2351.29	IE	257.6753	IE	128.8377	IE	257.68	225.47	3220.94
2628.14	IE	288.0151	IE	144.0075	IE	288.02	252.01	3600.19
2693.84	IE	295.2154	IE	147.6077	IE	295.22	258.31	3690.19
2982.08	IE	326.8035	IE	163.4017	IE	326.80	285.95	4085.04

In estimating the methane emissions from the various disposal sites the “tier 2” methodology based on national data on waste quantities, composition, properties and disposal practices was used. The first-order decay (FOD) methodology for calculating the methane generation was used. This method assumed that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly throughout a few decades, during which CH_4 and CO_2 were formed. Only the methane remaining after subtraction of methane recovered is available for oxidation. In the Ghana’s case there was no Methane recovery. Mass units used are Giga grams (Gg, 10^9 grams): one Gg is equivalent to one kilotonne. In the generation of the methane by the guidelines, the FOD model is built on an exponential factor that describes the fraction of degradable material which each year is degraded into CH_4 and CO_2. One key input in the model is the amount of degradable organic matter (DOCm) in waste disposed into SWDS. This is estimated based on information on disposal of different waste categories (municipal solid waste (MSW), sludge, industrial and other waste) and the different waste types/material (food, paper, wood, textiles, etc.) included in these categories, or alternatively as mean DOC in bulk waste disposed. Information is also needed on the types of SWDS in the country and the parameters. With "Tiers 2" some country-specific activity data and/or country-specific parameters were used. The CH_4 potential that is generated throughout the years was estimated on the basis of the amounts and composition of the waste disposed into SWDS and the waste management practices at the disposal sites. The simple FOD spreadsheet model was used in the estimation of the methane. This takes into account all what has been stated above.

Choice of Emission Factors and Parameters

Degradable organic carbon (DOC) is the organic carbon in waste that is accessible to biochemical decomposition, and should be expressed as Gg C per Gg waste. The DOC in bulk waste is estimated based on the composition of waste and can be calculated from a weighted average of the degradable carbon content of various components (waste types/material) of the waste stream. Based on the lack of data from the waste management sectors and time constraints the IPCC default values were used. Fraction of degradable organic carbon which decomposes (DOCf) is an estimate of the fraction of carbon that is ultimately degraded and released from SWDS, and reflects the fact that some degradable organic carbon does not degrade, or degrades very slowly, under anaerobic conditions in the SWDS. The recommended IPCC default value for the Western Africa by weight fraction on wet basis which is dissimilated 0.5 (DOCf of 0.5) was used. The methane generation rate constant (k) for the Moist and Wet Tropical region (regions with temperatures greater than 20^oC) for the IPPC default range were used. Also the IPCC default values for the MSW were used as the Methane Correction Factors (MCF). Other IPCC default values that were used for the estimation includes; (a) 6 months delay time; that is the average time before anaerobic decay begins, (b) fraction of Methane (F) in developed gas as 0.5, (c) Convection factor C to CH_4 of 1.33 and (d) oxidation Factor (OX) of Zero (0).

6.9.1.2 Biological Treatment of Solid Waste (4B)

Composting is the major biological treatment of solid waste in Ghana. Methane and Nitrous oxide were the key emission sources from biological treatment of solid waste through composting. In the past, composting was mostly practiced in a form of back-yard farming in urban households. However, in recent times treatment of solid waste through composting has declined because of the following reasons: a) space b) market for the product c) lack of policy direction on composting. The historical trend on PPPs has resulted in the participation of the private sector in the compost market. For example the establishment of the Accra Compost and Recycling Plant by Zoomlion Ghana Limited and the partnership venture between CHF International and Jekora Ventures has resulted in increase in composting in Ghana. In 2012, the total amount of solid waste composted amounted to 187.47Gg representing an increase of 43.8% and 20.8% above 2000 and 1990 respectively (see figure 48).

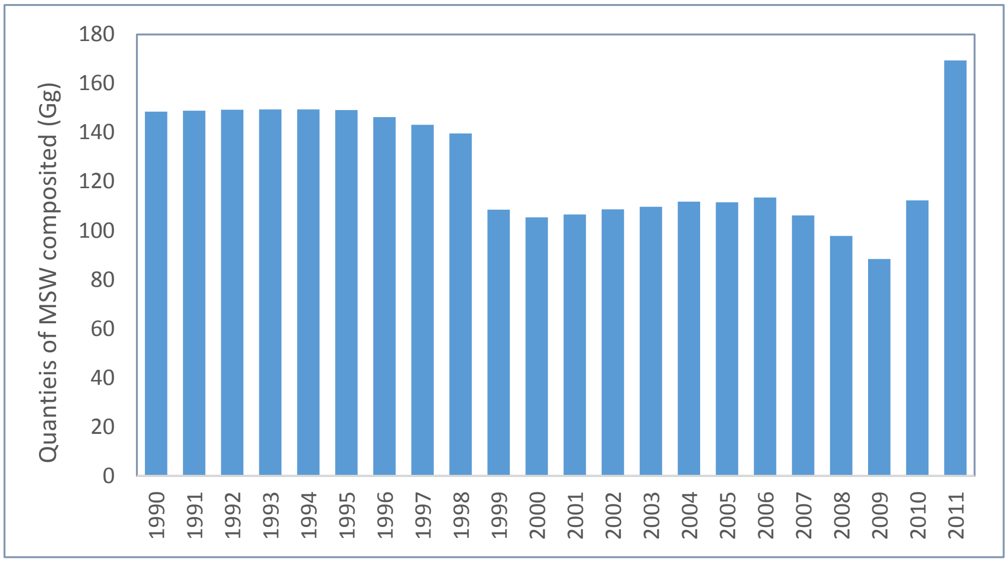


Figure 48: Trend of fraction of MSW composted

This translated into a total GHG emissions of 5.7MtCO_2e in 2012. This is 1.96MtCO_2e higher than 2000 levels and 0.64MtCO_2e above 1990 emissions. The observed increases in emission from composting could be explained by systematic shift from back-yard composting to commercial composting facilities with significant financial injection from the private sector.

Methodological issues

The main data input was based on the amount of waste composted in Ghana and the type of technology used. The input data were derived from the fraction of solid waste treated. The amount of solid waste treated through composting although was derived as a fraction of solid waste treated, the data was compared with the actual existing operating composting capacity in the country provide Zoomlion Ghana Limited.

6.9.1.3 Incineration and open burning (4C)

In Ghana, fraction of MSW and clinical waste accounts for the proportions of wastes that are treated and disposed of through incineration. It consists of a mix of combustible and non-combustible materials, such as paper, plastics, food waste, glass, wood and other non-hazardous materials. Wastes from healthcare or medical facilities are also incinerated. Most senior high schools have installed incinerators used to treat (controlled burning) and reduce volumes of municipal waste generated in these institutions. Furthermore, a large portion of the incinerators have been installed across the country in almost all District, and Regional as well as Teaching Hospitals. Few manufacturing companies incinerate their waste generated onsite in order to meet regulatory standards but hardly keep records on the volumes incinerated. It is also important to state that these incinerator plants are of small capacities hence supplied in batches in small quantities. This accounted for increases in the frequency of start-up of these incinerators. These incinerators are operated with the sole aim of converting waste materials into ash. In the early 1980's, almost every household had an area demarcated for this purpose. This practice was predominant in low income areas and rural areas.). With the advent of these strategies and actions, some households moved towards operating 'backyard' dumps or composts. Even though, open burning of waste has been criminalized, open burning is still ongoing due to various reasons such as high collection fees (of polluter pays principle).

Open burning practices have changed considerably and will continue to change due to the enforcement of regulations and through education of the general public. From table 95, the total amount of solid waste that is incinerated and openly burnt is on the decline showing a reduction in the capacity to undertake open burning and incineration. Generally there was a decline in the trends for both incineration and open burning of waste from 1990 to 2012. Even though, there was an increase in the capacity to incinerate waste due to policies which allowed all district, regional and teaching hospitals to install incinerators over the period, it is not shown in the trends.

Table 95: Solid waste disposal by incineration and open burning

	Incineration			Open Burning	Total
Year	MSW [Gg]	Clinical Waste [Gg]	Total [Gg]	MSW [Gg]	
1990	41.71	2.20	43.91	175.64	219.55
1991	41.54	2.51	44.05	176.19	220.23
1992	41.32	2.81	44.13	176.54	220.67
1993	41.06	3.12	44.18	176.72	220.90
1994	40.74	3.43	44.17	176.66	220.83
1995	40.37	3.72	44.09	176.36	220.45
1996	39.32	3.95	43.27	173.07	216.34
1997	38.19	4.16	42.35	169.39	211.74
1998	36.96	4.34	41.30	165.19	206.49
1999	35.63	4.49	40.12	160.48	200.60
2000	34.34	4.63	38.97	155.89	194.86
2001	34.46	4.96	39.42	157.67	197.09
2002	34.82	5.33	40.15	160.60	200.75
2003	34.90	5.66	40.56	162.23	202.78
2004	35.27	6.05	41.32	165.28	206.60
2005	34.89	6.32	41.21	164.84	206.05
2006	35.25	6.73	41.98	167.92	209.90
2007	32.69	6.56	39.25	157.02	196.27
2008	29.87	6.29	36.16	144.64	180.80
2009	26.77	5.91	32.68	130.71	163.39
2010	23.81	5.51	29.32	117.26	146.58
2011	24.20	5.85	30.05	120.19	150.24
2012	26.61	6.65	33.26	133.06	166.32
% Change (2000-2012)	-29.0%	30.3%		-17.2%	

Out of the 33.26Gg solid waste incinerated, 26.61Gg were municipal solid waste and the other 6.65Gg were clinical waste in 2012. The total amount of 26.61Gg municipal waste incinerated was 29% lower than the 2000 levels. The observed reduction in the total amount of incinerated MSW could be the result of the declining incineration capacity at the local government level. On the other hand, the 6.65Gg clinical waste incinerated was an increase of 30.3% of the 2000 levels. The disposal of municipal and clinical waste through incineration and open burning generates Carbon dioxide, methane and nitrous oxide emissions.

The amount of emissions that will be generated depends on the amount and type of waste, the capacity and the combustion efficiency of the incinerators and open burning taking place. Emissions from municipal solid waste and clinical waste were the main source considered using the aggregate approach. Emissions from open burning were from municipal solid waste. In Ghana, solid waste from industries is collected as part of the MSW which may is sometimes incinerated as part of MSW. Few industries separately treat their waste through on-site incineration generated but records are not kept on amounts incinerated. Data on incineration of municipal solid waste and clinical waste were obtained from the National Environmental Sanitation Strategy Action Plan document and the Ghana Health Service Facts and Figures. In all, a total of 166.32Gg of solid waste was disposed-off through incineration and open burning in 2012. Of the total 166.32Gg solid waste, 33.26Gg were incinerated whereas the remaining 133.06Gg were openly burnt. The total amount of waste disposed-off through incineration and open burning resulted in a total emission of 0.026 $MtCO_2e$ in 2012 which represented 0.6% of the total waste sector emissions. Of the total emission, 92.7% came from open burning and the rest from incineration. The 2012 emission of 0.026 $MtCO_2e$ represented 12.8% and 23.9% lower than emissions in 2000 and 1990 respectively (see figure 49).

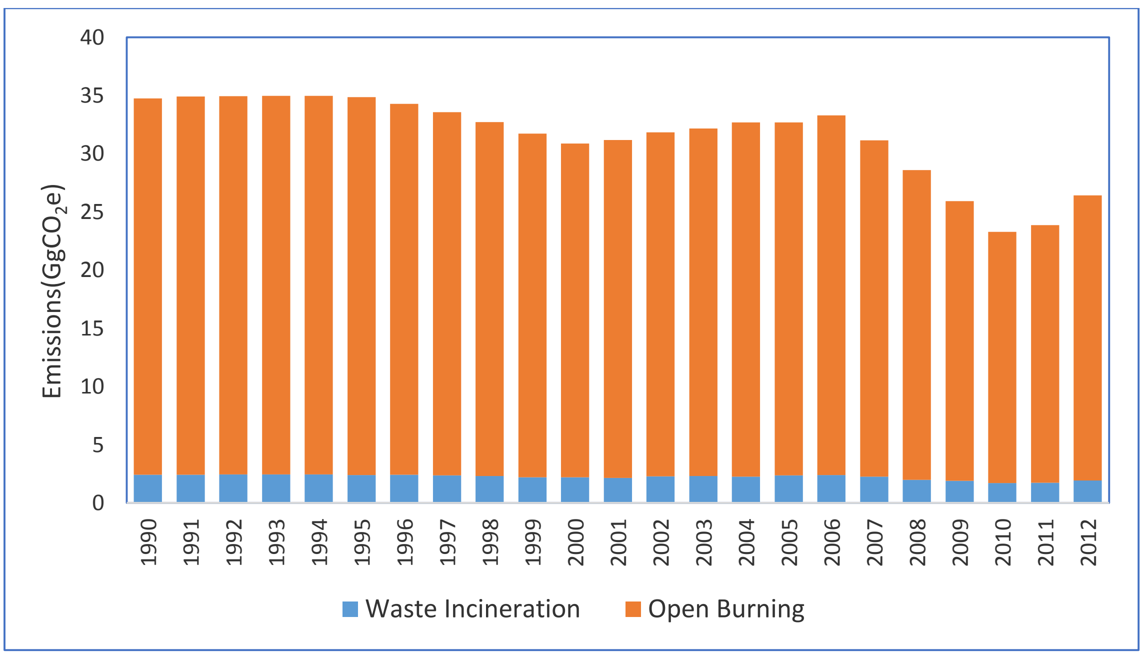


Figure 49: Trend of GHG emissions from burning

Methodological issues

The total amount of MSW open-burned and the amount of MSW and clinical waste incinerated was an important activity data required to undertake the emission calculations. The amount MSW opened-burned was obtained using the equation below;

$$MSW = P \times P_{frac} \times MSW_P \times B_{frac} \times 365 \times 10^{-6}$$

Where;

MSW = Total amount of municipal solid waste open-burned, Gg/yr
P = population (capita)
Pfrac = fraction of population burning waste, (fraction)
MSWP = per capita waste generation, kg waste/capita/day
Bfrac = fraction of the waste amount that is burned relative to the total amount of waste treated,
10-6 = conversion factor from kilogram to gigagram

Based on our national circumstances a plant by plant basis as well as various waste categories could not be obtained. The tier 1 Approach was used for estimation because of reasons earlier stated. For incineration, the subcategories where estimation was conducted were from MSW and clinical waste. Hazardous and industrial waste could not be estimated due to lack of data. The methods for estimating CO_2, CH_4 and N_2O emissions from incineration and open burning of waste vary because of the different factors that influence emission levels. This tier 1 Approach requires the use of activity data and default emission factors from IPCC, 2006 for MSW and clinical waste. The calculation of CH_4 and N_2O emissions was based on the amount of waste incinerated or open-burned and on the related emission factor. The amount of waste used is consistent with the activity data used for CO_2 calculation and default CH4 emission factors (IPPC, 2006). To determine the amount of waste that is incinerated and openly burnt, the percentage of MSW not collected was distributed among the various other means of disposal (recycling, reuse and salvaging). The percentage distribution among the various means of disposal was based on expert judgment. The table below shows the amount of waste opened burnt, the fraction of population burning waste and fraction of MSW treated (see table 96).

Table 96. Trend of amount of waste openly burnt

Year	Amount of waste open burnt (Gg)	fractions of population Burning	fractions of total MSW treated
1990	175.64	0.083	0.467
1991	176.19	0.081	0.467
1992	176.54	0.078	0.467
1993	176.72	0.076	0.467
1994	176.66	0.072	0.467
1995	176.36	0.070	0.467
1996	173.07	0.067	0.467
1997	169.39	0.063	0.467
1998	165.19	0.059	0.467
1999	160.48	0.056	0.508
2000	155.89	0.052	0.508
2001	157.67	0.051	0.508
2002	160.60	0.049	0.508

2003	162.23	0.049	0.508
2004	165.28	0.048	0.508
2005	164.84	0.047	0.508
2006	167.92	0.046	0.508
2007	157.02	0.041	0.508
2008	144.64	0.036	0.508
2009	130.71	0.031	0.508
2010	117.26	0.026	0.444
2011	120.195	0.026	0.369
2012	133.056	0.026	0.369

To prevent double counting of emissions reported, it is important that emphasis is placed on the fact that heat is not recovered from any of the incineration processes reported under waste sector. This is because in Ghana, there is no form of energy recovered in the incineration of waste. Furthermore, it is important to add that Agricultural residue openly burnt was reported under AFOLU.

6.9.1.4 Wastewater treatment and discharge (4D)

Key Category: CH_4 emissions

Wastewater originates from domestic, commercial and industrial sources. In Ghana, these may either be treated on site (uncollected) or, channeled to a centralized point (collected) or disposed of in a near-by water body, (National Environmental Sanitation Strategy Action Plan, 2010). Domestic wastewater is mainly water from household water use, while industrial wastewater is from industrial process water only. The kind of treatment practiced also differs for people living in the rural and urban areas and for those in urban high income and urban low-income areas. Taking this into consideration, the type of treatment and discharge pathway or system was categorized into untreated system equivalent to unimproved facilities (i.e. sea, river and lake discharge and stagnant water) and treated system also equivalent to improved facilities (i. e. centralized, aerobic treatment plant, septic system and latrine), (Reference MICs 2011, page 89). It is important to note that treatment systems are not final disposal points or sites. They are usually considered as intermediary treatment infrastructure since they ultimately end up in the sea or river but not in its raw state. Domestic wastewater includes human sewage mixed with other household water. In Ghana, after this effluent is processed, it is directly discharged into water bodies generating N_2O during both Nitrification and denitrification of the nitrogen present. Industrial Wastewater treatment and discharge sources are estimates noted to be the major contributor to Wastewater treatment and discharge emissions while domestic and commercial wastewater treatment and discharge is a minor contributor. This was rather the reverse in Ghana since wastewater coming from most industries end up in commercial wastewater streams.

Industrial wastewater may be treated on-site or released directly into domestic sewer system. Usually most industries treat processed water in order to meet regulatory standard before discharge. The historical trend indicates that, the provision of public toilet facility was free for users before 1982. The service providers and their supervisors were poorly motivated and this led to the poor management and deterioration of sanitary conditions within the major cities. The situation improved due to the formation of the Committees for the Defense of the Revolution (CDRs) who charged minimal fees to manage the facilities. In 1989, following the implementation of the National Decentralization Program, the management of the public toilets were reverted to the Municipal Government now termed Metropolitan Assemblies. The sanitary facilities (public toilets) were managed under the franchise agreement with the payment of not less than 20% of gross revenue to the Assembly (Ayee and Crook, 2003). In the 1990's and thereafter came into being the Public Private Partnerships (PPPs) through franchising and contracting out and encouraging more community based participation in the provision of local cleaning and sanitation services. The period of 2000 to date manifest that most environmental sanitation services are provided by the private sector including NGOs and community based organizations and supervised by public agencies (especially the MMDAs) with the appointment of MMDA Chief Executives. Over the years, it has been observed that the amount of domestic wastewater generated keeps increasing due to increase in population and access to improved treatment systems such as flush to pipe sewer systems and flush to septic tanks as shown in the table below (MICS, 2006 and 2011) (see table 97).

Table 97: Distribution of population and the dominant treatment system

Treatment systems		2006		2011	
		urban	Rural	urban	Rural
improved facilities	**Systems**	%	%	%	%
	flush to pipe sewer systems	3.8	0.6	3.6	0.3
	flush to septic tanks	14.9	1.2	22.8	1.3
	flush to pit (latrine)	5.3	0.6	2.3	0.5
	flush don't know where			0.3	0.0
	VIP latrine			40.0	21.6
	Pit latrine with slab	12.0	23.8	10.7	19.6
	Composting toilets			0.0	0.0
unimproved facilities	Pit latrine without slab/open pit	7.0	19.0	9.7	21.2
	flush to somewhere else			0.1	0.0
	Bucket	1.7	0.2	0.5	0.4
	hunging toilet, hunging latrine			0.0	0.0
	mobile toilet			0.0	0.0
	Other			0.1	0.0
	Open defecation (No facility/bush/field)	8.7	35.5	9.9	35.2

For industrial wastewater, it has been observed over the period that industrial wastewater output keeps increasing due to the increasing number of industries in the country. A survey conducted by the Manufacturing Industries Department of the EPA revealed that industrial outputs in terms of products has been increasing over the years. The data that was obtained from the survey was from year 2000 to 2012 but there are still gaps for some industry categories for some years. The Table 98 indicates the percentage change in industrial product output as per IPCC, 2006 categorization.

Table 98: Share industrial productivity

Year	Total Industry product (t/yr)				
	Beer and Malt	Dairy Products	Fish Processing	Meat and Poultry	Organic Chemicals
2000				393	
2001		10,882		1,570	
2002		14,128		67	
2003		16,465		879	
2004		24,002		912	
2005		23,973		995	
2006		22,045	36,174	1,144	
2007	3,405	27,001	31,979	13,644	538,021
2008	3,600	28,275	46,677	11,215	921,757
2009	3,420	39,701	37,494	11,752	506,468
2010	3,300	41,514	42,367	14,772	571,702
2011	3,600	35,552	43,542	27,692	622,285
2012	3,000	95,225	46,317	20,285	639,470
% Change	0.4%	11.8%	5.8%	2.5%	79.5%

The trends of emissions from wastewater treatment and discharge shows a steady increase from 1990 to 2012. It was observed that emissions from 1990 amounted to 114,026.1 GgCO_2eq, 1,622,505.5 GgCO_2eq in 2000 and 198628.6 GgCO_2eq in 2012. Within the sub-category 98.33% of the emissions were from Domestic wastewater treatment and discharge (4.D.1) while 1.67% of the emissions were from Industrial wastewater treatment and discharge (4.D.2) for 2012. The contribution of industrial wastewater treatment and discharge to the total wastewater treatment and discharge started in 2006 due unavailability of data as shown in figure 50.

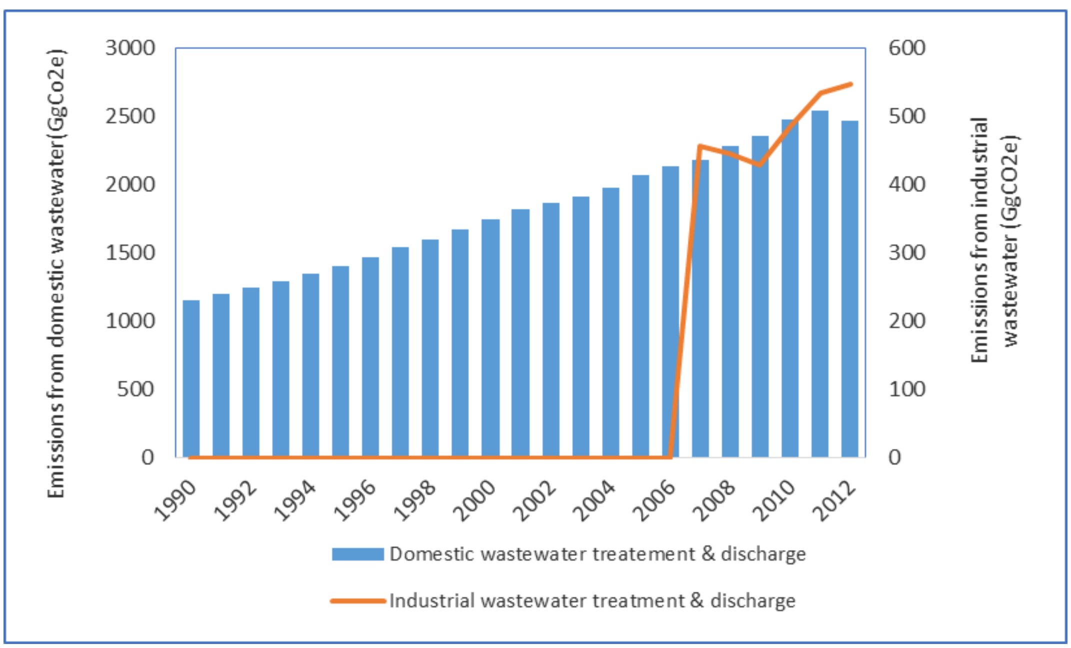


Figure 50: Trends of emission from wastewater treatment and discharge

Emissions of CH_4 and N_2O from wastewater have increased steadily during 1990-2012 inventory estimates. The emission trend for this period is shown below. The increase in emissions from domestic wastewater treatment and discharge is mainly due to the kind of treatment systems and discharge pathways being used in Ghana.

Methodological issues

The methodology used to estimate emissions from wastewater treatment and discharge management activities require country-specific knowledge on wastewater generation, population country-specific BOD, per capita protein intake and management practice. Waste management activities in Ghana are generally inadequately organized and this results in the lack and inconsistency of data. Therefore, effort was done in order to evaluate and compile data coming from different sources and adjust them to recommended Intergovernmental Panel on Climate Change (IPCC, 2006) methodology which is used for GHGs emissions estimation. Estimation of emissions for the wastewater treatment and discharge was commenced from 1990- 2012. The method used to calculate methane CH_4 and nitrous oxide N_2O emissions for wastewater water treatment and discharge was adopted from the 2006 IPCC guidelines and the Good Practice Guidance (GPG). The guideline provided guidance on exactly how to use activity data (AD) and emission factors (EF) in other to attain estimate of emissions. According to the Tier 2 key category analysis emissions of CH4 from waste water handling are key category in level and trend in 1990 - 2012.

Methane emissions from Domestic/Commercial Wastewater Treatment and Discharge

Generally in estimating CH_4 emissions from wastewater treatment and discharge, for this sub-category, the total population (24,915,550) of the country (GSS, 2010). The household size of four and the number of households (5,599) were also used for the estimation (World Bank Country Data). As per the 2006 IPCC Guideline, the population in the urban, rural and different income classes (urban high, urban low and rural) were also taken into consideration. These income classes are equivalent to metro-urban, peri-urban and rural in Ghana. For the urban population, data on the sum of improved facilities (treated system) and unimproved facilities (untreated) as well as the rural population for 2010 was obtained from 2005 and 2010 survey data from the MICS. The fraction of the urban population was divided into metro-urban (42% and 47.8%) and peri-urban (58% and 52.2%) using the population share of 2005 and 2010 respectively (see figure 98). Figures for 1990, 1995 and 2000 were derived from extrapolations from the 2005 and 2010 survey from the MICS and interpolations was done for the other in between years in order to get the fraction of the population whose wastewater are either treated or untreated by a particular system (see table 99).

Table 99: Treatment systems and distribution of population using them

Year	Centralized, aerobic treatment plant			Septic systems			Latrines			Sea, river and lake discharge			Stagnant sewer		
	Urban high income	Urban low income	Fraction of rural	Urban high income	Urban low income	Fraction of rural	Urban high income	Urban low income	Fraction of rural	Urban high income	Urban low income	Fraction of rural	Urban high income	Urban low income	Fraction of rural
1990	2.86	1.54	1.50	1.90	1.30	0.90	43.82	38.08	60.90	2.94	2.56	36.80	2.68	2.33	0.05
1991	2.79	1.57	1.44	2.12	1.46	0.92	43.63	37.93	61.00	3.06	2.66	36.72	2.56	2.22	0.06
1992	2.72	1.60	1.38	2.35	1.61	0.94	43.45	37.77	61.10	3.18	2.76	36.64	2.44	2.12	0.07
1993	2.65	1.63	1.32	2.57	1.77	0.96	43.27	37.61	61.20	3.30	2.86	36.56	2.32	2.02	0.08
1994	2.58	1.66	1.26	2.80	1.92	0.98	43.09	37.45	61.30	3.41	2.97	36.48	2.20	1.92	0.09
1995	2.49	1.71	1.20	3.02	2.08	1.00	42.91	37.29	61.40	3.53	3.07	36.40	2.09	1.81	0.10
1996	2.42	1.74	1.14	3.17	2.31	1.02	42.73	37.13	61.50	3.65	3.17	36.32	1.97	1.71	0.11
1997	2.35	1.77	1.08	3.31	2.55	1.04	42.54	36.98	61.60	3.77	3.27	36.24	1.85	1.61	0.12
1998	2.28	1.80	1.02	3.46	2.78	1.06	42.36	36.82	61.70	3.88	3.38	36.16	1.73	1.51	0.13
1999	2.21	1.83	0.96	3.60	3.02	1.08	42.18	36.66	61.80	4.00	3.48	36.08	1.62	1.40	0.14
2000	2.14	1.86	0.90	3.75	3.26	1.10	42.00	36.50	61.90	4.12	3.58	36.00	1.50	1.30	0.15
2001	2.06	1.89	0.84	4.42	4.16	1.12	40.37	36.59	62.00	4.14	3.78	35.92	1.36	1.22	0.16
2002	2.00	1.91	0.78	5.10	5.07	1.14	38.73	36.69	62.10	4.16	3.98	35.84	1.22	1.14	0.17
2003	1.94	1.94	0.72	5.77	5.97	1.16	37.10	36.78	62.20	4.17	4.19	35.76	1.09	1.05	0.18
2004	1.88	1.96	0.66	6.45	6.88	1.18	35.47	36.87	62.30	4.19	4.39	35.68	0.95	0.97	0.19
2005	1.82	1.98	0.60	7.12	7.78	1.20	33.84	36.96	62.40	4.21	4.59	35.60	0.81	0.89	0.20
2006	1.76	2.00	0.54	7.61	8.87	1.22	32.37	36.89	62.50	4.20	4.82	35.52	0.70	0.78	0.24
2007	1.70	2.02	0.48	8.10	9.96	1.24	30.90	36.82	62.60	4.19	5.05	35.44	0.59	0.67	0.28
2008	1.64	2.04	0.42	8.59	11.05	1.26	29.43	36.75	62.70	4.18	5.28	35.36	0.48	0.56	0.32
2009	1.58	2.06	0.36	9.08	12.14	1.28	27.96	36.68	62.80	4.17	5.51	35.28	0.37	0.45	0.36
2010	1.51	2.09	0.30	9.58	13.22	1.30	26.50	36.60	62.90	4.16	5.74	35.20	0.25	0.35	0.40
2011	1.44	2.12	0.24	10.08	14.30	1.32	25.04	36.52	63.00	4.15	5.97	35.28	0.13	0.25	0.44
2012	1.37	2.15	0.18	10.58	15.38	1.34	23.58	36.44	63.10	4.14	6.20	35.36	0.01	0.15	0.48

The IPCC methodology for estimation of methane emissions from Domestic/ commercial Waste water treatment and discharge is given by standard IPCC Equations below:

$$CH_4 \text{ Emissions} = \{\sum_{i,j} (U_i * T_{i,j} * EF_j)\} (TOW - S) - R$$

Where:

CH_4 emissions= CH_4 emissions in inventory year, kg CH_4/yr

TOW = Total organics in wastewater in inventory year, kg BOD/year

S = organic component removed as sludge in inventory year, kg BOD/year

U_i = Fraction of population in income group I in inventory year

$T_{i,j}$ = degree of utilization of treatment/discharge pathway or system, j, for each income group fraction I in inventory

i = income group: rural, urban high income and urban low income

j = each treatment/discharge pathway or system

EF_j = emission factor, kg CH4/kg BOD

R = amount of CH4 recovered in inventory year, kgCH4/yr

The emission factor used for estimation of emissions was based on the equation below:

$$EF_j = Bo * MCF_j$$

Where:

EFj = emission factor, kg CH_4/kg BOD

j = each treatment/discharge pathway or system

Bo = Maximum CH4 producing capacity, kg CH4/kg BOD (Default value was used For estimation)

MCFj = Methane correction factor (Default value was used for estimation)

The activity data for this source category is the total amount of organically degradable material in the wastewater. The parameters in the equation below were used for estimation.

$$TOW = P * BOD * 0.001 * I * 365$$

Where:

TOW = total organics in wastewater in inventory year, kg BOD/yr

P = country population in inventory year

BOD = country-specific per capita BOD in inventory year, g/person/day

0.01 = conversion from grams BOD to kg BOD

I = correction factor for additional industrial BOD discharged into sewers

Industrial Wastewater treatment and discharge

In the estimation of emissions from industrial wastewater handling, oxygen-deficient water bodies were considered (anaerobic wastewater handling system). IPCC default values of 0.1 and 0.9 were used as emission factors for fraction of wastewater treated by the handling system and methane conversion factor respectively.

Indirect Nitrous oxide emissions from human sewage estimation

The estimation of nitrous oxide emissions from human sewage was mainly based on the per capita protein consumption from FAO statistics, and population of the country. The emission factors were obtained from the Revised 2006 IPCC Guidelines.

Per capita protein consumption

The per capita protein consumption (protein in kg/person/yr) was obtained from the FAO Statistics, 1995. Table 100 below shows the range of years and their respective per capita protein consumption values.

Table 100 : Trend of per capita protein consumption

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
BOD (kg/ person/ year)	11.33	11.56	11.79	12.02	12.26	12.49	12.72	12.95	13.18	13.41	13.66	13.87
Protein intake	31.6	31.38	31.16	30.94	30.72	30.5	31.14	31.78	32.42	33.06	33.7	33.1
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
BOD (kg /person /year)	14.11	14.34	14.57	14.80	15.04	15.27	15.49	15.73	15.96	16.19	16.42	
Protein intake	32.5	31.9	31.3	30.7	30.1	29.5	28.9	28.3	27.7	27.1	26.5	

Sludge Handling System

There was no estimation of sludge handling system since there was no sludge removal data for the entire time series.

6.10 planned improvements

Table 101 highlights key activities that have been planned for improving future inventories. These include efforts to generate data in categories where they are lacking and reduce the reliance on expert knowledge and associated uncertainties to an extent possible.

Table 101: List of activities for future improvements in the accounting for the Waste sector

Improvement tasks	Responsibility & Collaborators	Priority	Next Step	Target	Assumption
Solid waste disposal					
Collect additional data on solid waste generation rate and waste classification	Built Environment Department, EPA, Civil Engineering Department, KNUST, MLGRD, AMA, KMA, STMA, TMA	medium	Contact relevant institutions to include data need into yearly surveys and research	next inventory	Funding is secured on time
Revise solid waste generation rates and waste stream fractions with new datasets	Waste inventory team	high	EPA to coordinate revision of existing estimates	next inventory	
Separate solid disposal further to managed, unmanaged and uncategorized	Waste inventory team	medium	EPA to coordinate	next inventory	Availability of new solid waste dataset
Revise fraction of solid waste biologically treated through composting	Built Environment Department, EPA and Zoomlion Ghana Limited	medium	EPA and Zoomlion to take lead	next inventory	

Revision of the fraction of solid waste incinerated and openly burnt	Built Environment Department, EPA	medium	EPA to contact Ghana Health Service and Ghana Education Service to include in their survey	next inventory	
Wastewater and treatment					
Update existing survey data on industrial and domestic waste	Manufacturing Industry Department, EPA	high	EPA to initiative review of industrial survey	next inventory	Funding is secured on time

Annex 1: Sample Copy of MOU

Work-Package Memorandum of Understand (WP-MoU) Between Environmental Protection Agency and National Greenhouse Gas Inventory Entities in Ghana

What does the WP-MoU seeks to do?

1. The vision of the new greenhouse gas inventory in Ghana is to, first, become more relevant to government policies and national planning and secondly, be able to meet present and future international reporting requirements. The GHG inventory system must be integrated to the extent that it will become responsive to any future international mechanism intended to subject the inventories to either "facilitative" or "technical" reviews, which may be required of the country. In order to ensure that Ghana's ability is strengthened to undertake the GHG inventory on regular basis and to make it relevant to decision-making, an improved National System for GHG Inventory is to be implemented under the Third National Communication (TNC).

2. The National System for GHG inventory is mainly defined by a framework, which contains a set of institutions, their roles and responsibilities and above all, the collaborative mechanisms, which underpin them. As part of the efforts to establish a national system under the NC3, new institutional arrangement has been put in place. The institutions have been identified; their roles and responsibilities defined and reporting channels have been delineated. The various organization (GHG inventory entities) were selected on the basis of their competence and relevance to the GHG inventory sectors.

3. Considering the national circumstances of Ghana, the "state of progress of Ghana's inventory system and what the inventory system is envisaged to be in the coming years, the Environmental Protection Agency has in consultation with the key stakeholders, adopted the "Work-Package MoU" option. This is considered to be practical and suitable as the practical working guidance document between Environmental Protection Agency and all the inventory entities.

4. This WP-MoU therefore seeks to establish a set of common understanding GHG inventory tasks, which will be undertaken by the inventory entities during the latest inventory cycle. The list of activities that would be undertaken by the inventory entities will be designed to become consistent with the timeframe of the inventory and the available budget for the sector, bearing in mind that, the administrative and technical bottlenecks that are likely to hamper the smooth delivery of the activities within a reasonable time-frame will be progressively managed.

5. As much as possible, the activities that are to be undertaken by the inventory entities will be dependent on the overall satisfaction of all conditions precedent on the part of the Environmental Protection Agency and the said entity. Because the intention of the Agency is to ensure that the efficiency of the National System is progressively improved and become more integrated, the WP-MoU will be reviewed at the beginning and end of every inventory and reporting cycle. The purpose of the review is to help improve upon the overall efficiency of the national system and to make it more responsive to the lessons learnt in the previous inventory cycle.

Preamble

The Environmental Protection Agency being the Designated National GHG inventory Entity and in collaboration with "National Entity A"; recognizes that:

1. *WHEREAS* there is an urgent need to have the national GHG inventories processes mainstreamed into the activities of the various inventory entities and making it relevant for national development and international reporting;

2. Strengthening the capacities of GHG inventories entities is fundamental to the ability of Ghana to meet the increasing demand for reporting on GHG emissions on a regular basis;

3. Making GHG inventories relevant to sector planning and development, would facilitate the assessment of impacts of Ghana's policies and measures and support its received on GHG mitigation and development in general;

4. A fully-fledge GHG national system in Ghana that is operational would help prepare Ghana for any potential review of our national GHG inventory system in country or by any international body;

Responsibilities of Entity A

The Entity will be responsible for undertaking the following GHG inventories activities in the Energy sector with support from the Environmental Protection Agency.

i. Conduct comprehensive assessment of GHG data requirements of the Energy sector, identify the sources and access them with the support of the inventory coordinator using appropriate channels and document all the data and processes involved.

ii. Collect, collate, process and update all GHG and related data in the Energy sector, and take final decisions on which processed data qualifies to be used in the inventory on the basis of agreed conditions in the QA/QC plan.

iii. Submit all processed data and any other data to the central database hosted at the Environmental Protection Agency and keep back-up in your organization.

iv. Liaise with the inventory coordinator at EPA to undertake comprehensive review of available methodological choices and make sound methodological choices on the basis of its applicability to the estimation of GHG emissions.

v. Estimate GHG emissions for all categories and gases under your sector using appropriate factors/ Global Warming Potentials (GWPs) that are occurring in Ghana and ensure that the processes/assumptions for the estimation including the software used are consistent with the Inter-governmental Panel on Climate Change (IPCC) guidelines and fully documented.

vi. Conduct key categories analysis for the energy sector and uncertainty assessment, where appropriate and to the extent possible, in collaboration with the generalist and the uncertainty management lead.

vii. Compile all the Energy sector estimates in the worksheets into "detail" and "synthesis" reports including clear prioritized plans for improvements to be incorporated into the national inventory report.

viii. Create and maintain hard and soft back-up copies of all information, data, and estimates at the sector level and for subsequent onward transmission to the Environmental Protection Agency and Ghana Statistical Services as the inventory documentation and archiving depository.

ix. Consult with the inventory coordinator to discuss and agree on cost involved in activities that can be done within the quarter in the inventory year. The rate and mode for requesting funds will be discussed and agreed ahead of every inventory cycle.

x.

Timelines

5. The activities listed above must be prioritized and implemented Not only on the basis of the sequence of activities, but in a manner that is realistic and achievable within the overall timeframe of the inventory cycle.

This WP-MoU has been done between Environmental Protection Agency and the GHG Inventory Entity on

........date.......

For: Environmental Protection Agency	*For: Entity A*
(National Inventory Entity)	*(Energy Sector, Lead)*
Executive Director	*Executive Secretary*

Annex 2: Sample Data Request

Tel: (0302) 664697 / 664698,
662465 / 667524
Fax: 233 (0302) 662690

Email: support@epaghana.org

Environmental Protection Agency
P. O. Box M 326
Ministries Post Office
Accra, Ghana

19th April, 2013

Operations/Distribution Manager
Total Ghana Limited
Accra – Ghana

Dear Sir,

REQUEST FOR NATIONAL DATA ON AVIATION FUEL SUPPLY TO UPDATE GHANA'S GREENHOUSE GAS INVENTORY ESTIMATES

The Environmental Protection Agency (EPA) is undertaking the Third Round of National Greenhouse Gas (GHG) Inventory. The inventory exercise will enable the Agency undertake compilation of the levels and trends of dominant sources of greenhouse gas emissions and removals by sink from five productive economic sectors. The five economic sectors that will cover under the inventory are; (1) Energy (electricity, industry, transport, commercial and residential, oil and gas), (2) Industrial Processes, (3) Agriculture, (4) land use change and forestry and (5) Waste.

The inventory exercise will culminate in a National Inventory Report which will help facilitate exchange of information on Ghana GHG emissions footprint among the international community. Above all, the national inventory estimates and the report will serve as useful reference source of information for any sustainable development planning or initiative by public, research and private actors.

The inventory estimation requires the use of activity data in the five sectors to establish productivity patterns. We consider your institution as a major depository of activity data on domestic and international aviation fuel supply. We are therefore writing to request for the national data on international and domestic aviation fuel supply covering 1990 to present. In order to make the data compilation less cumbersome, we have attached the data format sheet in the annex 1 for your easy reference.

This is a continuous national exercise and so we respectfully request your maximum cooperation.

Thank you.

Yours faithfully,

Annex 3: Summary Tables

Full list of tables submitted electronically together with this report

Table A Summary Table

Inventory Year: 2012

	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)				
Categories	**Net CO2 (1)(2)**	**CH4**	**N2O**	**HFCs**	**PFCs**	**SF6**	**Other halogenated gases with CO2 equivalent conversion factors (3)**	**Other halogenated gases without CO2 equivalent conversion factors (4)**	**NOx**	**CO**	**NMVOCs**	**SO2**
Total National Emissions and Removals	14811.73	398.05	24.39	0.00	112.71	0.00	0.00	0.00	110.57	1842.80	0.00	0.00
1 - Energy	12594.78	30.45	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A - Fuel Combustion Activities	12593.46	30.44	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1 - Energy Industries	3239.88	0.11	0.02						0.00	0.00	0.00	0.00
1.A.2 - Manufacturing Industries and Construction	1320.79	2.44	0.14						0.00	0.00	0.00	0.00
1.A.3 - Transport	6300.43	1.69	0.40						0.00	0.00	0.00	0.00
1.A.4 - Other Sectors	1732.36	26.20	0.32						0.00	0.00	0.00	0.00
1.A.5 - Non-Specified	0.00	0.00	0.00						0.00	0.00	0.00	0.00
1.B - Fugitive emissions from fuels	1.32	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.1 - Solid Fuels	0.00	0.00	0.00						0.00	0.00	0.00	0.00
1.B.2 - Oil and Natural Gas	1.32	0.01	0.00						0.00	0.00	0.00	0.00
1.B.3 - Other emissions from Energy Production	0.00	0.00	0.00						0.00	0.00	0.00	0.00
1.C - Carbon dioxide Transport and Storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.C.1 - Transport of CO2	0.00								0.00	0.00	0.00	0.00
1.C.2 - Injection and Storage	0.00								0.00	0.00	0.00	0.00
1.C.3 - Other	0.00								0.00	0.00	0.00	0.00
2 - Industrial Processes and Product Use	353.64	0.00	0.00	0.00	112.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A - Mineral Industry	267.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2.A.1 - Cement production	0.00								0.00	0.00	0.00	0.00
2.A.2 - Lime production	0.00								0.00	0.00	0.00	0.00
2.A.3 - Glass Production	0.00								0.00	0.00	0.00	0.00
2.A.4 - Other Process Uses of Carbonates	267.44								0.00	0.00	0.00	0.00
2.A.5 - Other (please specify)	0.00	0.00	0.00						0.00	0.00	0.00	0.00
2.B - 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
2.B.1 - Ammonia Production	0.00								0.00	0.00	0.00	0.00
2.B.2 - Nitric Acid Production			0.00						0.00	0.00	0.00	0.00
2.B.3 - Adipic Acid Production			0.00						0.00	0.00	0.00	0.00
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			0.00						0.00	0.00	0.00	0.00
2.B.5 - Carbide Production	0.00	0.00							0.00	0.00	0.00	0.00
2.B.6 - Titanium Dioxide Production	0.00								0.00	0.00	0.00	0.00
2.B.7 - Soda Ash Production	0.00								0.00	0.00	0.00	0.00
2.B.8 - Petrochemical and Carbon Black Production	0.00	0.00							0.00	0.00	0.00	0.00
2.B.9 - Fluorochemical Production				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.10 - 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
2.C - Metal Industry	66.05	0.00	0.00	0.00	112.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.C.1 - Iron and Steel Production	5.29	0.00							0.00	0.00	0.00	0.00
2.C.2 - Ferroalloys Production	0.00	0.00							0.00	0.00	0.00	0.00
2.C.3 - Aluminium production	60.76				112.71			0.00	0.00	0.00	0.00	0.00
2.C.4 - Magnesium production	0.00					0.00		0.00	0.00	0.00	0.00	0.00
2.C.5 - Lead Production	0.00								0.00	0.00	0.00	0.00
2.C.6 - Zinc Production	0.00								0.00	0.00	0.00	0.00
2.C.7 - 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
2.D - Non-Energy Products from Fuels and Solvent Use	20.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D.1 - Lubricant Use	20.15								0.00	0.00	0.00	0.00
2.D.2 - Paraffin Wax Use	0.00								0.00	0.00	0.00	0.00
2.D.3 - Solvent Use									0.00	0.00	0.00	0.00

2.D.4 - Other (please specify)	0.00	0.00	0.00						0.00	0.00	0.00	0.00
2.E - Electronics 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
2.E.1 - Integrated Circuit or Semiconductor				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.E.2 - TFT Flat Panel Display					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.E.3 - Photovoltaics					0.00			0.00	0.00	0.00	0.00	0.00
2.E.4 - Heat Transfer Fluid					0.00			0.00	0.00	0.00	0.00	0.00
2.E.5 - 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
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F.1 - Refrigeration and Air Conditioning				0.00				0.00	0.00	0.00	0.00	0.00
2.F.2 - Foam Blowing Agents				0.00				0.00	0.00	0.00	0.00	0.00
2.F.3 - Fire Protection				0.00	0.00			0.00	0.00	0.00	0.00	0.00
2.F.4 - Aerosols				0.00				0.00	0.00	0.00	0.00	0.00
2.F.5 - Solvents				0.00	0.00			0.00	0.00	0.00	0.00	0.00
2.F.6 - Other Applications (please specify)				0.00	0.00			0.00	0.00	0.00	0.00	0.00
2.G - Other Product Manufacture and Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.G.1 - Electrical Equipment					0.00	0.00		0.00	0.00	0.00	0.00	0.00
2.G.2 - SF6 and PFCs from Other Product Uses					0.00	0.00		0.00	0.00	0.00	0.00	0.00
2.G.3 - N2O from Product Uses			0.00						0.00	0.00	0.00	0.00
2.G.4 - 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
2.H - Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.H.1 - Pulp and Paper Industry	0.00	0.00							0.00	0.00	0.00	0.00
2.H.2 - Food and Beverages Industry	0.00	0.00							0.00	0.00	0.00	0.00
2.H.3 - Other (please specify)	0.00	0.00	0.00						0.00	0.00	0.00	0.00
3 - Agriculture, Forestry, and Other Land Use	1859.36	176.09	21.93	0.00	0.00	0.00	0.00	0.00	110.57	1842.80	0.00	0.00
3.A - Livestock	0.00	101.22	2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.A.1 - Enteric Fermentation		95.90							0.00	0.00	0.00	0.00
3.A.2 - Manure Management		5.33	2.97						0.00	0.00	0.00	0.00
3.B - Land	1835.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.1 - Forest land	-29325.89								0.00	0.00	0.00	0.00
3.B.2 - Cropland	26038.99								0.00	0.00	0.00	0.00
3.B.3 - Grassland	4382.43								0.00	0.00	0.00	0.00
3.B.4 - Wetlands	101.41		0.00						0.00	0.00	0.00	0.00
3.B.5 - Settlements	681.89								0.00	0.00	0.00	0.00
3.B.6 - Other Land	-42.90								0.00	0.00	0.00	0.00
3.C - Aggregate sources and non-CO2 emissions sources on land	23.43	74.86	18.96	0.00	0.00	0.00	0.00	0.00	110.57	1842.80	0.00	0.00
3.C.1 - Emissions from biomass burning		65.21	5.95						110.57	1842.80	0.00	0.00
3.C.2 - Liming	0.00								0.00	0.00	0.00	0.00
3.C.3 - Urea application	23.43								0.00	0.00	0.00	0.00
3.C.4 - Direct N2O Emissions from managed soils			9.73						0.00	0.00	0.00	0.00
3.C.5 - Indirect N2O Emissions from managed soils			3.10						0.00	0.00	0.00	0.00
3.C.6 - Indirect N2O Emissions from manure management			0.17						0.00	0.00	0.00	0.00
3.C.7 - Rice cultivations		9.66							0.00	0.00	0.00	0.00
3.C.8 - Other (please specify)		0.00	0.00						0.00	0.00	0.00	0.00
3.D - Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.D.1 - Harvested Wood Products	0.00								0.00	0.00	0.00	0.00
3.D.2 - Other (please specify)	0.00	0.00	0.00						0.00	0.00	0.00	0.00
4 - Waste	3.96	191.52	1.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.A - Solid Waste Disposal	0.00	68.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.B - Biological Treatment of Solid Waste	0.00	0.75	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.C - Incineration and Open Burning of Waste	3.96	0.87	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.D - Wastewater Treatment and Discharge	0.00	121.27	1.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.E - 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
5 - Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.B - 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
Memo Items (5)												
International Bunkers	1186.17	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3.a.i - International Aviation (International Bunkers)	348.54	0.00	0.01						0.00	0.00	0.00	0.00
1.A.3.d.i - International water-borne navigation (International bunkers)	837.62	0.08	0.02						0.00	0.00	0.00	0.00
1.A.5.c - Multilateral Operations	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B Short Summary Table (National Totals 2012)

Categories	Emissions (Gg)			Emissions CO2 Equivalents (Gg)				Emissions (Gg)				
	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
Total National Emissions and Removals	14811.73	398.05	24.39	0	112.71	0.00	0.00	0.00	110.57	1842.80	0.00	0.00
1 - Energy	12594.78	30.45	0.88	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A - Fuel Combustion Activities	12593.46	30.44	0.88						0.00	0.00	0.00	0.00
1.B - Fugitive emissions from fuels	1.32	0.01	0.00						0.00	0.00	0.00	0.00
1.C - Carbon dioxide Transport and Storage	0.00								0.00	0.00	0.00	0.00
2 - Industrial Processes and Product Use	353.64	0.00	0.00	0	112.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A - Mineral Industry	267.44	0.00	0.00						0.00	0.00	0.00	0.00
2.B - Chemical Industry	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.C - Metal Industry	66.05	0.00	0.00	0	112.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.D - Non-Energy Products from Fuels and Solvent Use	20.15	0.00	0.00						0.00	0.00	0.00	0.00
2.E - Electronics Industry	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F - Product Uses as Substitutes for Ozone Depleting Substances				0	0.00			0.00	0.00	0.00	0.00	0.00
2.G - Other Product Manufacture and Use	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.H - Other	0.00	0.00	0.00						0.00	0.00	0.00	0.00
3 - Agriculture, Forestry, and Other Land Use	1859.36	176.09	21.93	0	0.00	0.00	0.00	0.00	110.57	1842.80	0.00	0.00
3.A - Livestock		101.22	2.97						0.00	0.00	0.00	0.00
3.B - Land	1835.93		0.00						0.00	0.00	0.00	0.00
3.C - Aggregate sources and non-CO2 emissions sources on land	23.43	74.86	18.96						110.57	1842.80	0.00	0.00
3.D - Other	0.00	0.00	0.00						0.00	0.00	0.00	0.00
4 - Waste	3.96	191.52	1.58	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.A - Solid Waste Disposal		68.63							0.00	0.00	0.00	0.00
4.B - Biological Treatment of Solid Waste		0.75	0.06						0.00	0.00	0.00	0.00
4.C - Incineration and Open Burning of Waste	3.96	0.87	0.01						0.00	0.00	0.00	0.00

4.D - Wastewater Treatment and Discharge		121.27	1.51						0.00	0.00	0.00	0.00
4.E - Other (please specify)	0.00	0.00	0.00						0.00	0.00	0.00	0.00
5 - Other	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3			0.00						0.00	0.00	0.00	0.00
5.B - Other (please specify)	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Memo Items (5)												
International Bunkers	1186.17	0.08	0.03	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3.a.i - International Aviation (International Bunkers)	348.54	0.00	0.01						0.00	0.00	0.00	0.00
1.A.3.d.i - International water-borne navigation (International bunkers)	837.62	0.08	0.02						0.00	0.00	0.00	0.00
1.A.5.c - Multilateral Operations	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 1 - Energy Sectoral Table (Sheet 1 of 1)

Inventory Year: 2012

Categories	Emissions (Gg)						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1 - Energy	12594.779	30.452	0.878	0	0	0	0
1.A - Fuel Combustion Activities	12593.459	30.438	0.878	0	0	0	0
1.A.1 - Energy Industries	3239.8754	0.1098	0.02	0	0	0	0
1.A.1.a - Main Activity Electricity and Heat Production	3150.9463	0.1076	0.02	0	0	0	0
1.A.1.a.i - Electricity Generation	3150.9463	0.1076	0.02	0	0	0	0
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				0	0	0	0
1.A.1.a.iii - Heat Plants				0	0	0	0
1.A.1.b - Petroleum Refining	88.929144	0.0022	3E-04	0	0	0	0
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries				0	0	0	0
1.A.1.c.i - Manufacture of Solid Fuels				0	0	0	0
1.A.1.c.ii - Other Energy Industries				0	0	0	0
1.A.2 - Manufacturing Industries and Construction	1320.7947	2.4371	0.137	0	0	0	0
1.A.2.a - Iron and Steel				0	0	0	0
1.A.2.b - Non-Ferrous Metals				0	0	0	0
1.A.2.c - Chemicals				0	0	0	0
1.A.2.d - Pulp, Paper and Print	88.326404	0.0612	0.006	0	0	0	0
1.A.2.e - Food Processing, Beverages and Tobacco	626.8015	0.4274	0.038	0	0	0	0
1.A.2.f - Non-Metallic Minerals				0	0	0	0
1.A.2.g - Transport Equipment				0	0	0	0
1.A.2.h - Machinery				0	0	0	0
1.A.2.i - Mining (excluding fuels) and Quarrying				0	0	0	0
1.A.2.j - Wood and wood products	100.94446	0.5806	0.053	0	0	0	0
1.A.2.k - Construction	315.45144	0.0127	0.003	0	0	0	0
1.A.2.l - Textile and Leather	189.27087	1.3552	0.037	0	0	0	0
1.A.2.m - Non-specified Industry				0	0	0	0
1.A.3 - Transport	6300.4333	1.6889	0.4	0	0	0	0
1.A.3.a - Civil Aviation	87.136004	0.0006	0.002	0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers) (1)							
1.A.3.a.ii - Domestic Aviation	87.136004	0.0006	0.002	0	0	0	0

1.A.3.b - Road Transport	5790.2696	1.6564	0.319	0	0	0	0
1.A.3.b.i - Cars	2818.2026	1.0204	0.136	0	0	0	0
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	151.13344	0.0545	0.017	0	0	0	0
1.A.3.b.i.2 - Passenger cars without 3-way catalysts	2667.0692	0.9658	0.118	0	0	0	0
1.A.3.b.ii - Light-duty trucks	1260.9788	0.2471	0.098	0	0	0	0
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts	56.523709	0.0269	0.003	0	0	0	0
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	1204.4551	0.2201	0.095	0	0	0	0
1.A.3.b.iii - Heavy-duty trucks and buses	433.29329	0.0228	0.023	0	0	0	0
1.A.3.b.iv - Motorcycles	1277.7949	0.3662	0.063	0	0	0	0
1.A.3.b.v - Evaporative emissions from vehicles				0	0	0	0
1.A.3.b.vi - Urea-based catalysts	0			0	0	0	0
1.A.3.c - Railways	184.22172	0.0103	0.071	0	0	0	0
1.A.3.d - Water-borne Navigation	214.92534	0.0203	0.006	0	0	0	0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.3.d.ii - Domestic Water-borne Navigation	214.92534	0.0203	0.006	0	0	0	0
1.A.3.e - Other Transport	23.880593	0.0013	0.001	0	0	0	0
1.A.3.e.i - Pipeline Transport				0	0	0	0
1.A.3.e.ii - Off-road	23.880593	0.0013	0.001	0	0	0	0
1.A.4 - Other Sectors	1732.3556	26.202	0.321	0	0	0	0
1.A.4.a - Commercial/Institutional	887.54384	1.32	0.023	0	0	0	0
1.A.4.b - Residential	630.80792	24.853	0.297	0	0	0	0
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	214.00381	0.0294	0.002	0	0	0	0
1.A.4.c.i - Stationary	214.00381	0.0294	0.002	0	0	0	0
1.A.4.c.ii - Off-road Vehicles and Other Machinery				0	0	0	0
1.A.4.c.iii - Fishing (mobile combustion)				0	0	0	0
1.A.5 - Non-Specified				0	0	0	0
1.A.5.a - Stationary				0	0	0	0
1.A.5.b - Mobile				0	0	0	0
1.A.5.b.i - Mobile (aviation component)				0	0	0	0
1.A.5.b.ii - Mobile (water-borne component)				0	0	0	0
1.A.5.b.iii - Mobile (Other)				0	0	0	0
1.A.5.c - Multilateral Operations (1)(2)							
1.B - Fugitive emissions from fuels	1.319685	0.0136	2E-05	0	0	0	0
1.B.1 - Solid Fuels	0	0		0	0	0	0
1.B.1.a - Coal mining and handling	0	0		0	0	0	0

1.B.1.a.i - Underground mines	0	0		0	0	0	0
1.B.1.a.i.1 - Mining	0	0		0	0	0	0
1.B.1.a.i.2 - Post-mining seam gas emissions	0	0		0	0	0	0
1.B.1.a.i.3 - Abandoned underground mines				0	0	0	0
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2	0	0		0	0	0	0
1.B.1.a.ii - Surface mines	0	0		0	0	0	0
1.B.1.a.ii.1 - Mining	0	0		0	0	0	0
1.B.1.a.ii.2 - Post-mining seam gas emissions	0	0		0	0	0	0
1.B.1.b - Uncontrolled combustion and burning coal dumps				0	0	0	0
1.B.1.c - Solid fuel transformation				0	0	0	0
1.B.2 - Oil and Natural Gas	1.319685	0.0136	2E-05	0	0	0	0
1.B.2.a - Oil	1.319685	0.0136	2E-05	0	0	0	0
1.B.2.a.i - Venting	0	0		0	0	0	0
1.B.2.a.ii - Flaring	1.319685	0.0008	2E-05	0	0	0	0
1.B.2.a.iii - All Other	0	0.0128	0	0	0	0	0
1.B.2.a.iii.1 - Exploration				0	0	0	0
1.B.2.a.iii.2 - Production and Upgrading				0	0	0	0
1.B.2.a.iii.3 - Transport				0	0	0	0
1.B.2.a.iii.4 - Refining	0	0.0128		0	0	0	0
1.B.2.a.iii.5 - Distribution of oil products				0	0	0	0
1.B.2.a.iii.6 - Other				0	0	0	0
1.B.2.b - Natural Gas				0	0	0	0
1.B.2.b.i - Venting				0	0	0	0
1.B.2.b.ii - Flaring				0	0	0	0
1.B.2.b.iii - All Other				0	0	0	0
1.B.2.b.iii.1 - Exploration				0	0	0	0
1.B.2.b.iii.2 - Production				0	0	0	0
1.B.2.b.iii.3 - Processing				0	0	0	0
1.B.2.b.iii.4 - Transmission and Storage				0	0	0	0
1.B.2.b.iii.5 - Distribution				0	0	0	0
1.B.2.b.iii.6 - Other				0	0	0	0
1.B.3 - Other emissions from Energy Production	NE	NE	NE	0	0	0	0
1.C - Carbon dioxide Transport and Storage	0			0	0	0	0
1.C.1 - Transport of CO2	0			0	0	0	0
1.C.1.a - Pipelines	0			0	0	0	0

1.C.1.b - Ships	0			0	0	0	0
1.C.1.c - Other (please specify)	0			0	0	0	0
1.C.2 - Injection and Storage	0			0	0	0	0
1.C.2.a - Injection	0			0	0	0	0
1.C.2.b - Storage	0			0	0	0	0
1.C.3 - Other	0			0	0	0	0

Energy Sectoral Table (Memo and Information Items)

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
Memo Items (3)							
International Bunkers	1186.1661	0.0816	0.032	0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers) (1)	348.54402	0.0024	0.01	0	0	0	0
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	837.62205	0.0791	0.023	0	0	0	0
1.A.5.c - Multilateral Operations (1)(2)				0	0	0	0
Information Items							
CO2 from Biomass Combustion for Energy Production	14141.608						

Table 1.1 - Energy Background Table (1.A1 -1.A2)

Inventory Year: 2012

2006 IPCC Categories	Activity (TJ)			Emissions Liquid Fuel (Gg)			Emissions Gas (Gg)			Emissions Biomass (Gg)		Emissions Total (Gg)			Information Items (Gg)	
	Liquid Fuel	Gas	Biomass	CO2	CH4	N2O	CO2	CH4	N2O	CH4	N2O	CO2	CH4	N2O	CO2 Amount Captured	Biomass CO2 emitted
1.A - Fuel Combustion Activities	162627.52	16478.83	126264.35	11668.99	2.05	0.44	924.46	0.016	0.002	28.38	0.44	12593.46	30.44	0.878	0	14141.60782
1.A.1 - Energy Industries	31744.9	16478.83		2315.41	0.09	0.019	924.46	0.016	0.002			3239.86	0.11	0.02	0	
1.A.1.a - Main Activity Electricity and Heat Production	30371.46	16478.83		2226.48	0.09	0.018	924.46	0.016	0.002			3150.95	0.11	0.02	0	
1.A.1.a.i - Electricity Generation	30371.46	16478.83		2226.48	0.09	0.018	924.46	0.016	0.002			3150.95	0.11	0.02	0	
1.A.1.a.ii - Combined Heat and Power Generation (CHP)												0	0	0		
1.A.1.a.iii - Heat Plants												0	0	0		
1.A.1.b - Petroleum Refining	1373.45			88.93	0.002	3E-04						88.93	0.0022	3E-04	0	
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries												0	0	0		
1.A.1.c.i - Manufacture of Solid Fuels												0	0	0		
1.A.1.c.ii - Other Energy Industries												0	0	0		
1.A.2 - Manufacturing Industries and Construction	17902.68		32343.76	1320.79	0.05	0.01				2.39	0.13	1320.79	2.44	0.137	0	3622.500701
1.A.2.a - Iron and Steel												0	0	0		
1.A.2.b - Non-Ferrous Metals												0	0	0		
1.A.2.c - Chemicals												0	0	0		
1.A.2.d - Pulp, Paper and Print	1187.75		1309.12	88.33	0.004	7E-04				0.057	0.005	88.33	0.06	0.006	0	146.6218256
1.A.2.e - Food Processing, Beverages and Tobacco	8570.37		9163.86	626.80	0.02	0.005				0.40	0.034	626.80	0.43	0.038	0	1026.352779
1.A.2.f - Non-Metallic Minerals												0	0	0		
1.A.2.g - Transport Equipment												0	0	0		
1.A.2.h - Machinery												0	0	0		

1.A.2.i - Mining (excluding fuels) and Quarrying												0	0	0		
1.A.2.j - Wood and wood products	1357.43		13091.2344	100.94	0.004	8E-04				0.58	0.052	100.94	0.58	0.053	0	1466.218256
1.A.2.k - Construction	4241.96			315.45	0.013	0.003						315.45	0.01	0.003	0	
1.A.2.l - Textile and Leather	2545.17		8779.53428	189.27	0.008	0.002				1.35	0.035	189.27	1.35	0.037	0	983.3078397
1.A.2.m - Non-specified Industry												0	0	0		

Table 1.1 - Energy Background Table (1.A3 -1.A5)

Inventory Year: 2012

2006 IPCC Categories	Activity (TJ)		Emissions Liquid Fuel (Gg)			Emissions Biomass (Gg)		Emissions Total (Gg)		
	Liquid Fuel	Biomass	CO2	CH4	N2O	CH4	N2O	CO2	CH4	N2O
1.A.3 - Transport	88300.413		6300.433	1.689	0.4			6300.433	1.6889	0.4
1.A.3.a - Civil Aviation	1218.6854		87.136	6E-04	0.002			87.136	0.0006	0.002
1.A.3.a.i - International Aviation (International Bunkers) (2)										
1.A.3.a.ii - Domestic Aviation	1218.6854		87.136	6E-04	0.002			87.136	0.0006	0.002
1.A.3.b - Road Transport	81372.853		5790.27	1.656	0.319			5790.27	1.6564	0.319
1.A.3.b.i - Cars	40075.927		2818.203	1.02	0.136			2818.203	1.0204	0.136
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	2180.8577		151.1334	0.055	0.017			151.1334	0.0545	0.017
1.A.3.b.i.2 - Passenger cars without 3-way catalysts	37895.069		2667.069	0.966	0.118			2667.069	0.9658	0.118
1.A.3.b.ii - Light-duty trucks	17545.606		1260.979	0.247	0.098			1260.979	0.2471	0.098
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts	815.63794		56.52371	0.027	0.003			56.52371	0.0269	0.003
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	16729.968		1204.455	0.22	0.095			1204.455	0.2201	0.095
1.A.3.b.iii - Heavy-duty trucks and buses	5847.4128		433.2933	0.023	0.023			433.2933	0.0228	0.023
1.A.3.b.iv - Motorcycles	17903.907		1277.795	0.366	0.063			1277.795	0.3662	0.063
1.A.3.b.v - Evaporative emissions from vehicles										
1.A.3.b.vi - Urea-based catalysts (3)								0		
1.A.3.c - Railways	2486.1231		184.2217	0.01	0.071			184.2217	0.0103	0.071
1.A.3.d - Water-borne Navigation	2900.4769		214.9253	0.02	0.006			214.9253	0.0203	0.006
1.A.3.d.i - International water-borne navigation (International bunkers) (2)										

1.A.3.d.ii - Domestic Water-borne Navigation	2900.4769		214.9253	0.02	0.006			214.9253	0.0203	0.006
1.A.3.e - Other Transport	322.27521		23.88059	0.001	0.001			23.88059	0.0013	0.001
1.A.3.e.i - Pipeline Transport								0	0	0
1.A.3.e.ii - Off-road	322.27521		23.88059	0.001	0.001			23.88059	0.0013	0.001
1.A.4 - Other Sectors	24679.521	93920.599	1732.356	0.212	0.011	25.99	0.31	1732.356	26.202	0.321
1.A.4.a - Commercial/Institutional	12095.999	4083.5043	887.5438	0.119	0.007	1.201	0.016	887.5438	1.32	0.023
1.A.4.b - Residential	9638.9431	89837.095	630.8079	0.064	0.003	24.789	0.294	630.8079	24.853	0.297
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	2944.5789		214.0038	0.029	0.002			214.0038	0.0294	0.002
1.A.4.c.i - Stationary	2944.5789		214.0038	0.029	0.002			214.0038	0.0294	0.002
1.A.4.c.ii - Off-road Vehicles and Other Machinery								0	0	0
1.A.4.c.iii - Fishing (mobile combustion)								0	0	0
1.A.5 - Non-Specified								0	0	0
1.A.5.a - Stationary								0	0	0
1.A.5.b - Mobile								0	0	0
1.A.5.b.i - Mobile (aviation component)								0	0	0
1.A.5.b.ii - Mobile (water-borne component)								0	0	0
1.A.5.b.iii - Mobile (Other)								0	0	0
1.A.5.c - Multilateral Operations (5)										

Memo Items

2006 IPCC Categories			Emissions Liquid Fuel (Gg)			Emissions Biomass (Gg)		Emissions Total (Gg)		
	Liquid Fuel	Biomass	CO2	CH4	N2O	CH4	N2O	CO2	CH4	N2O
International Bunkers	16178.683		1186.166	0.082	0.032			1186.166	0.0816	0.032
1.A.3.a.i - International Aviation (International Bunkers) (2)	4874.7415		348.544	0.002	0.01			348.544	0.0024	0.01
1.A.3.d.i - International water-borne navigation (International bunkers) (2)	11303.941		837.6221	0.079	0.023			837.6221	0.0791	0.023
1.A.5.c - Multilateral Operations (5)								0	0	0

Table 1.1 - Energy Background Table (1.3 -1.B)

2006 IPCC Categories	Activity Data			Emissions (Gg)			Information Item: Amount Captured (2) (Gg)
	Description	Unit (1)	Value	CO2	CH4	N2O	CO2
1.B - Fugitive emissions from fuels				1.32	0.014	2E-05	
1.B.1 - Solid Fuels				0	0		
1.B.1.a - Coal mining and handling				0	0		
1.B.1.a.i - Underground mines				0	0		
1.B.1.a.i.1 - Mining	coal produced	ktonnes		0	0		
1.B.1.a.i.2 - Post-mining seam gas emissions	coal produced	ktonnes		0	0		
1.B.1.a.i.3 - Abandoned underground mines	number of mines	number	0				
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2	gas flared	10^6 Sm3	0	0	0		
1.B.1.a.ii - Surface mines				0	0		
1.B.1.a.ii.1 - Mining	coal produced	ktonnes		0	0		
1.B.1.a.ii.2 - Post-mining seam gas emissions	coal produced	ktonnes		0	0		
1.B.1.b - Uncontrolled combustion and burning coal dumps	solid fuel combusted	ktonnes	0				
1.B.1.c - Solid fuel transformation							
1.B.2 - Oil and Natural Gas				1.32	0.014	2E-05	
1.B.2.a - Oil				1.32	0.014	2E-05	
1.B.2.a.i - Venting	total gas vented from oil production	10^6 Sm3	0	0	0		
1.B.2.a.ii - Flaring	gas flared from oil production	10^3 m3	27.21	1.32	8E-04	2E-05	
1.B.2.a.iii - All Other				0	0.013	0	
1.B.2.a.iii.1 - Exploration	wells drilled	number					
1.B.2.a.iii.2 - Production and Upgrading	oil produced	10^3 m3					
1.B.2.a.iii.3 - Transport	crude oil transported	10^3 m3					
1.B.2.a.iii.4 - Refining	refinery crude oil throughput	10^3 m3	589.26	0	0.013		
1.B.2.a.iii.5 - Distribution of oil products	amount distributed	10^3 m3					
1.B.2.a.iii.6 - Other							
1.B.2.b - Natural Gas							

1.B.2.b.i - Venting	total gas vented from natural gas production	10^6 Sm3					
1.B.2.b.ii - Flaring	gas flared from natural gas production	10^6 Sm3					
1.B.2.b.iii - All Other							
1.B.2.b.iii.1 - Exploration	wells drilled	number					
1.B.2.b.iii.2 - Production	gas produced	10^6 Sm3					
1.B.2.b.iii.3 - Processing	amount of gas processed at facilities	10^6 Sm3					
1.B.2.b.iii.4 - Transmission and Storage	amount transported and stored	10^6 Sm3					
1.B.2.b.iii.5 - Distribution	amount of gas distributed	10^6 m3					
1.B.2.b.iii.6 - Other							
1.B.3 - Other emissions from Energy Production				0	NE	NE	

Table 2 – Industrial Processes Sectoral Table (Sheet 1 of 1)

Inventory Year: 2012

Categories	(Gg)			CO2 Equivalents(Gg)				(Gg)
	CO2	CH4	N2O	HFCs	PFCs	SF6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)
2 - Industrial Processes and Product Use	353.64	0	0	0	112.71	0	0	0
2.A - Mineral Industry	267.44	0	0	0	0	0	0	0
2.A.1 - Cement production	0.0							
2.A.2 - Lime production	0.0							
2.A.3 - Glass Production	0.0							
2.A.4 - Other Process Uses of Carbonates	267.43	0	0	0	0	0	0	0
2.A.4.a - Ceramics	0.0							
2.A.4.b - Other Uses of Soda Ash	0.0							
2.A.4.c - Non Metallurgical Magnesia Production	0.0							
2.A.4.d - Other (please specify) (3)	267.44							
2.A.5 - Other (please specify) (3)								
2.B - Chemical Industry	0.0	0	0	0	0	0	0	0
2.B.1 - Ammonia Production	0.0							
2.B.2 - Nitric Acid Production			0					
2.B.3 - Adipic Acid Production			0					
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			0					
2.B.5 - Carbide Production	0.0	0						
2.B.6 - Titanium Dioxide Production	0.0							
2.B.7 - Soda Ash Production	0.0							
2.B.8 - Petrochemical and Carbon Black Production	0.0	0	0	0	0	0	0	0
2.B.8.a - Methanol	0.0	0						
2.B.8.b - Ethylene	0.0	0						
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer	0.0	0						
2.B.8.d - Ethylene Oxide	0.0	0						
2.B.8.e - Acrylonitrile	0.0	0						
2.B.8.f - Carbon Black	0.0	0						

2.B.9 - Fluorochemical Production	0.0	0	0	0	0	0	0	0
2.B.9.a - By-product emissions (4)				0				
2.B.9.b - Fugitive Emissions (4)								
2.B.10 - Other (Please specify) (3)								
2.C - Metal Industry	66.05	0	0	0	112.7137	0	0	0
2.C.1 - Iron and Steel Production	5.29	0						
2.C.2 - Ferroalloys Production	0.00	0						
2.C.3 - Aluminium production	60.76				112.7137			
2.C.4 - Magnesium production (5)	0.0					0		
2.C.5 - Lead Production	0.0							
2.C.6 - Zinc Production	0.0							
2.C.7 - Other (please specify) (3)								
2.D - Non-Energy Products from Fuels and Solvent Use (6)	20.15	0	0	0	0	0	0	0
2.D.1 - Lubricant Use	20.15							
2.D.2 - Paraffin Wax Use	0							
2.D.3 - Solvent Use (7)								
2.D.4 - Other (please specify) (3), (8)								
2.E - Electronics Industry	0	0	0	0	0	0	0	0
2.E.1 - Integrated Circuit or Semiconductor (9)				0	0	0		0
2.E.2 - TFT Flat Panel Display (9)					0	0		0
2.E.3 - Photovoltaics (9)					0			
2.E.4 - Heat Transfer Fluid (10)					0			
2.E.5 - Other (please specify) (3)								
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	0	0	0	0	0
2.F.1 - Refrigeration and Air Conditioning	0	0	0	0	0	0	0	0
2.F.1.a - Refrigeration and Stationary Air Conditioning				0				
2.F.1.b - Mobile Air Conditioning				0				
2.F.2 - Foam Blowing Agents				0				0
2.F.3 - Fire Protection				0	0			
2.F.4 - Aerosols				0				0
2.F.5 - Solvents				0	0			0
2.F.6 - Other Applications (please specify) (3)				0	0			0
2.G - Other Product Manufacture and Use	0	0	0	0	0	0	0	0
2.G.1 - Electrical Equipment	0	0	0	0	0	0	0	0

2.G.1.a - Manufacture of Electrical Equipment					0	0		
2.G.1.b - Use of Electrical Equipment					0	0		
2.G.1.c - Disposal of Electrical Equipment					0	0		
2.G.2 - SF6 and PFCs from Other Product Uses	0	0	0	0	0	0	0	0
2.G.2.a - Military Applications					0	0		
2.G.2.b - Accelerators					0	0		
2.G.2.c - Other (please specify) (3)					0	0		
2.G.3 - N2O from Product Uses	0	0	0	0	0	0	0	0
2.G.3.a - Medical Applications			0					
2.G.3.b - Propellant for pressure and aerosol products			0					
2.G.3.c - Other (Please specify) (3)			0					
2.G.4 - Other (Please specify) (3)								
2.H - Other	0	0	0	0	0	0	0	0
2.H.1 - Pulp and Paper Industry								
2.H.2 - Food and Beverages Industry								
2.H.3 - Other (please specify) (3)								

Table 2.1 - IPPU Background Table

Inventory Year: 2012

Categories	Activity Data			Emissions		
	Production/Consumption Quantity			CO2 (Gg)	CH4 (Gg)	N2O (Gg)
	Description (1)	Quantity	Unit (2)	Emissions (3)	Emissions (3)	Emissions (3)
2.A - Mineral Industry				267.43725	0	0
2.A.1 - Cement production				0		
2.A.2 - Lime production				0		
2.A.3 - Glass Production				0		
2.A.4 - Other Process Uses of Carbonates (7)				267.43725	0	0
2.A.4.a - Ceramics				0		
2.A.4.b - Other Uses of Soda Ash				0		
2.A.4.c - Non Metallurgical Magnesia Production				0		
2.A.4.d - Other (please specify)	Carbonate consumed	608212.8	t	267.43725		
2.A.5 - Other (please specify) (8)						
2.B - Chemical Industry				0	0	0
2.B.1 - Ammonia Production				0		
2.B.2 - Nitric Acid Production						0
2.B.3 - Adipic Acid Production						0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production	Caprolactam; Glyoxal; Glyoxylic Acid	0	t			0
2.B.5 - Carbide Production	Calcium Carbide Used in Acetylene Production	0	t	0	0	
2.B.6 - Titanium Dioxide Production	Titanium Slag; Synthetic Rutile; Rutile TiO2	0	t	0		
2.B.7 - Soda Ash Production				0		
2.B.8 - Petrochemical and Carbon Black Production				0	0	0
2.B.8.a - Methanol				0	0	
2.B.8.b - Ethylene				0	0	
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer				0	0	
2.B.8.d - Ethylene Oxide				0	0	
2.B.8.e - Acrylonitrile				0	0	
2.B.8.f - Carbon Black				0	0	
2.B.10 - Other (Please specify) (8)						

Table 2.2 - IPPU Background Table

Inventory Year: 2012

Categories	HFC-23	Total HFCs
SAR GWPs (100 year horizon) Conversion Factor (1)	11700	
Emissions in original mass unit (tonne)		
2.B.9 - Fluorochemical Production	0	
2.B.9.a - By-product emissions (3)	0	
(information) Reduced amount (4)		
2.B.9.b - Fugitive Emissions (3)		
(information) Reduced amount (4)		
2.B.10 - Other (Please specify) (5)		
Emissions in CO2 equivalent unit (Gg CO2)		
2.B.9 - Fluorochemical Production	0	**0**
2.B.9.a - By-product emissions	0	**0**
2.B.9.b - Fugitive Emissions		
2.B.10 - Other (Please specify) (5)		

Table 2.3 – IPPU Background Table

Inventory Year: 2012

Categories	Activity Data			Emissions						
	Production/Consumption Quantity			CO2 (Gg)			CH4 (Gg)		N2O (Gg)	
	Description (1)	Quantity	Unit (2)	Emissions (3)	Information Item Captured and Stored (4)	(memo) Other Reduction (5)	Emissions (3)	Information Item Reduction (6)	Emissions (3)	Information Item Reduction (6)
2.C - Metal Industry				66.05136	0	0	0	0	0	0
2.C.1 - Iron and Steel Production	Electric Arc Furnace	66116	t	5.28928			0			
2.C.2 - Ferroalloys Production				0			0			
2.C.3 - Aluminium production	Prebake; CWPB	113928.9	t	60.76208						
2.C.4 - Magnesium production				0						
2.C.5 - Lead Production				0						
2.C.6 - Zinc Production				0						
2.C.7 - Other (please specify)										

Table 2.4 – IPPU Background Table

Inventory Year: 2012

Categories	CF4	C2F6	Total PFCs	SF6
SAR GWPs (100 year time horizon) Conversion Factor (1)	6500	9200		23900
Emissions in original mass unit (tonne)				
2.C.3 - Aluminium production (3)	15.19052	1.519052		
(information) Reduced amount (4)				
2.C.4 - Magnesium production (3)				0
(information) Reduced amount (4)				
2.C.7 - Other (please specify) (5)				
(information) Reduced amount (4)				
Emissions in CO2 equivalent unit (Gg CO2)				
2.C.3 - Aluminium production	98.73838	13.9752784	**112.71366**	
2.C.4 - Magnesium production				0
2.C.7 - Other (please specify)				

Table 2.5 – IPPU Background Table

Inventory Year: 2012

Categories	Activity Data			Emissions		
	Production/Consumption Quantity			CO2	CH4	N2O
	Description	Quantity	Unit	(Gg)	(Gg)	(Gg)
2.D - Non-Energy Products from Fuels and Solvent Use				20.15376	0	0
2.D.1 - Lubricant Use	Lubricant Consumed	1374.12	t	20.15376		
2.D.2 - Paraffin Wax Use				0		
2.D.3 - Solvent Use						
2.D.4 - Other (please specify)						

Table 3 – AFOLU Sectoral Table

Inventory Year: 2012

Categories	(Gg)				
	Net CO2 emissions / removals	Emissions			
		CH4	N2O	NOx	CO
3 - Agriculture, Forestry, and Other Land Use	1859.36	176.09	21.93	110.57	1842.80
3.A - Livestock	0	101.22	2.97	0	0
3.A.1 - Enteric Fermentation	0	95.90	0	0	0
3.A.1.a - Cattle	0	47.83	0	0	0
3.A.1.a.i - Dairy Cows		0		0	0
3.A.1.a.ii - Other Cattle		47.83		0	0
3.A.1.b - Buffalo		0.00		0	0
3.A.1.c - Sheep		20.10		0	0
3.A.1.d - Goats		27.18		0	0
3.A.1.e - Camels		0.00		0	0
3.A.1.f - Horses		0.05		0	0
3.A.1.g - Mules and Asses		0.14		0	0
3.A.1.h - Swine		0.60		0	0
3.A.1.j - Other (please specify)		0		0	0
3.A.2 - Manure Management (1)	0	5.33	2.97	0	0
3.A.2.a - Cattle	0	1.54	1.16	0	0
3.A.2.a.i - Dairy cows		0	0	0	0
3.A.2.a.ii - Other cattle		1.54	1.16	0	0
3.A.2.b - Buffalo		0.00	0	0	0
3.A.2.c - Sheep		0.80	1.05	0	0
3.A.2.d - Goats		1.20	0.77	0	0
3.A.2.e - Camels		0.00	0	0	0
3.A.2.f - Horses		0.01	0	0	0
3.A.2.g - Mules and Asses		0.02	0	0	0
3.A.2.h - Swine		0.60	0	0	0
3.A.2.i - Poultry		1.16	0	0	0
3.A.2.j - Other (please specify)		0	0	0	0
3.B - Land	1835.93	0	0	0	0

3.B.1 - Forest land	-29325.89	0	0	0	0
3.B.1.a - Forest land Remaining Forest land	-9789.75			0	0
3.B.1.b - Land Converted to Forest land	-19536.14	0	0	0	0
3.B.1.b.i - Cropland converted to Forest Land	-4637.47			0	0
3.B.1.b.ii - Grassland converted to Forest Land	-14864.27			0	0
3.B.1.b.iii - Wetlands converted to Forest Land	-12.87			0	0
3.B.1.b.iv - Settlements converted to Forest Land	0.00			0	0
3.B.1.b.v - Other Land converted to Forest Land	-21.53			0	0
3.B.2 - Cropland	26038.99	0	0	0	0
3.B.2.a - Cropland Remaining Cropland	0.00			0	0
3.B.2.b - Land Converted to Cropland	26038.99	0	0	0	0
3.B.2.b.i - Forest Land converted to Cropland	15815.78			0	0
3.B.2.b.ii - Grassland converted to Cropland	10200.72			0	0
3.B.2.b.iii - Wetlands converted to Cropland	17.69			0	0
3.B.2.b.iv - Settlements converted to Cropland	0.00			0	0
3.B.2.b.v - Other Land converted to Cropland	4.80			0	0
3.B.3 - Grassland	4382.43	0	0	0	0
3.B.3.a - Grassland Remaining Grassland	0.00			0	0
3.B.3.b - Land Converted to Grassland	4382.43	0	0	0	0
3.B.3.b.i - Forest Land converted to Grassland	5670.37			0	0
3.B.3.b.ii - Cropland converted to Grassland	-1272.34			0	0
3.B.3.b.iii - Wetlands converted to Grassland	-4.84			0	0
3.B.3.b.iv - Settlements converted to Grassland	0.00			0	0
3.B.3.b.v - Other Land converted to Grassland	-10.76			0	0
3.B.4 - Wetlands	101.41	0	0	0	0
3.B.4.a - Wetlands Remaining Wetlands	0.00	0	0	0	0
3.B.4.a.i - Peatlands remaining peatlands	0.00		0	0	0
3.B.4.a.ii - Flooded land remaining flooded land				0	0
3.B.4.b - Land Converted to Wetlands	101.41	0	0	0	0
3.B.4.b.i - Land converted for peat extraction			0	0	0
3.B.4.b.ii - Land converted to flooded land	101.41			0	0
3.B.4.b.iii - Land converted to other wetlands				0	0
3.B.5 - Settlements	681.89	0	0	0	0
3.B.5.a - Settlements Remaining Settlements	0.00			0	0
3.B.5.b - Land Converted to Settlements	681.89	0	0	0	0

3.B.5.b.i - Forest Land converted to Settlements	487.38			0	0
3.B.5.b.ii - Cropland converted to Settlements	5.62			0	0
3.B.5.b.iii - Grassland converted to Settlements	185.80			0	0
3.B.5.b.iv - Wetlands converted to Settlements	3.09			0	0
3.B.5.b.v - Other Land converted to Settlements	0.00			0	0
3.B.6 - Other Land	-42.90	0	0	0	0
3.B.6.a - Other land Remaining Other land				0	0
3.B.6.b - Land Converted to Other land	-42.90	0	0	0	0
3.B.6.b.i - Forest Land converted to Other Land	113.98			0	0
3.B.6.b.ii - Cropland converted to Other Land	-30.42			0	0
3.B.6.b.iii - Grassland converted to Other Land	-126.92			0	0
3.B.6.b.iv - Wetlands converted to Other Land	0.46			0	0
3.B.6.b.v - Settlements converted to Other Land	0.00			0	0
3.C - Aggregate sources and non-CO2 emissions sources on land (2)	23.43	74.86	18.96	110.57	1842.80
3.C.1 - Emissions from biomass burning	0	65.21	5.95	110.57	1842.80
3.C.1.a - Biomass burning in forest lands		32.73	2.99	55.51	925.09
3.C.1.b - Biomass burning in croplands		16.13	1.47	27.35	455.86
3.C.1.c - Biomass burning in grasslands		16.34	1.49	27.71	461.84
3.C.1.d - Biomass burning in all other land		0.00	0.00	0.00	0.00
3.C.2 - Liming	0			0	0
3.C.3 - Urea application	23.43			0	0
3.C.4 - Direct N2O Emissions from managed soils (3)			9.73	0	0
3.C.5 - Indirect N2O Emissions from managed soils			3.10	0	0
3.C.6 - Indirect N2O Emissions from manure management			0.17	0	0
3.C.7 - Rice cultivations		9.66		0	0
3.C.8 - Other (please specify)				0	0
3.D - Other	0	0	0	0	0
3.D.1 - Harvested Wood Products	0			0	0
3.D.2 - Other (please specify)				0	0

Table 3.1 – AFOLU Background Table 3.A

Inventory Year: 2012

Categories	Activity Data	Emissions	
	Number of Animals	CH4 (Gg)	N2O (Gg)
3.A.1 - Enteric Fermentation	11616050	95.8971	0
3.A.1.a - Cattle	1543000	47.833	0
3.A.1.a.i - Dairy Cows		0	
3.A.1.a.ii - Other Cattle	1543000	47.833	
3.A.1.b - Buffalo		0	
3.A.1.c - Sheep	4019000	20.095	
3.A.1.d - Goats	5435000	27.175	
3.A.1.e - Camels		0	
3.A.1.f - Horses	2700	0.0486	
3.A.1.g - Mules and Asses	14350	0.1435	
3.A.1.h - Swine	602000	0.602	
3.A.1.j - Other (please specify)		0	
3.A.2 - Manure Management (1)	69501050	5.325333	2.972703178
3.A.2.a - Cattle	1543000	1.543	1.157500892
3.A.2.a.i - Dairy cows		0	0
3.A.2.a.ii - Other cattle	1543000	1.543	1.157500892
3.A.2.b - Buffalo		0	0
3.A.2.c - Sheep	4019000	0.8038	1.046461134
3.A.2.d - Goats	5435000	1.1957	0.768741152
3.A.2.e - Camels		0	0
3.A.2.f - Horses	2700	0.005913	0
3.A.2.g - Mules and Asses	14350	0.01722	0
3.A.2.h - Swine	602000	0.602	0
3.A.2.i - Poultry	57885000	1.1577	0
3.A.2.j - Other (please specify)		0	0

Table 3.2 – AFOLU Background Table 3.B – (Sheet 1 of 2)

Inventory Year: 2012

Categories	Activity Data	Net carbon stock change and CO2 emissions						Net CO2 emissions (Gg CO2)
		Biomass			Dead organic matter		Soils	
	Total Area (ha)	Increase (Gg C)	Decrease (Gg C)	Net carbon stock change (Gg C)	Carbon stock change (Gg C)	Net carbon stock change (Gg C)	Net carbon stock change in mineral soils (2) (Gg C)	
3.B - Land	22978132.00	2029.81	2150.19	-120.38	-103.16	-103.16	-249.51	1734.51
3.B.1 - Forest land	9168407.00	6722.28	2150.19	4572.09	1182.18	1182.18	2243.71	-29325.89
3.B.1.a - Forest land Remaining Forest land	6574088.00	4820.12	2150.19	2669.93		0.00		-9789.75
3.B.1.b - Land Converted to Forest land	2594319.00	1902.15	0.00	1902.15	1182.18	1182.18	2243.71	-19536.14
3.B.1.b.i - Cropland converted to Forest Land	545242.00	399.77	0.00	399.77	226.33	226.33	638.66	-4637.47
3.B.1.b.ii - Grassland converted to Forest Land	2043601.00	1498.37	0.00	1498.37	950.48	950.48	1605.04	-14864.27
3.B.1.b.iii - Wetlands converted to Forest Land	2049.00	1.50	0.00	1.50	2.01	2.01	0.00	-12.87
3.B.1.b.iv - Settlements converted to Forest Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.1.b.v - Other Land converted to Forest Land	3427.00	2.51	0.00	2.51	3.36	3.36	0.00	-21.53
3.B.2 - Cropland	5206271.00	-3236.15	0.00	-3236.15	-1252.44	-1252.44	-2612.95	26038.99
3.B.2.a - Cropland Remaining Cropland	1049571.00	0.00	0.00	0.00		0.00	0.00	0.00
3.B.2.b - Land Converted to Cropland	4156700.00	-3236.15	0.00	-3236.15	-1252.44	-1252.44	-2612.95	26038.99
3.B.2.b.i - Forest Land converted to Cropland	1276897.00	-2286.39	0.00	-2286.39	-531.32	-531.32	-1495.68	15815.78
3.B.2.b.ii - Grassland converted to Cropland	2872368.00	-948.18	0.00	-948.18	-725.27	-725.27	-1108.56	10200.72
3.B.2.b.iii - Wetlands converted to Cropland	5287.00	-1.58	0.00	-1.58	2.94	2.94	-6.19	17.69
3.B.2.b.iv - Settlements converted to Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.2.b.v - Other Land converted to Cropland	2148.00	0.00	0.00	0.00	1.21	1.21	-2.52	4.80
3.B.3 - Grassland	8149644.00	-1220.38	0.00	-1220.38	161.69	161.69	-136.52	4382.43
3.B.3.a - Grassland Remaining Grassland	6466655.00			0.00		0.00	0.00	0.00
3.B.3.b - Land Converted to Grassland	1682989.00	-1220.38	0.00	-1220.38	161.69	161.69	-136.52	4382.43
3.B.3.b.i - Forest Land converted to Grassland	644599.00	-931.52	0.00	-931.52	-108.68	-108.68	-506.27	5670.37
3.B.3.b.ii - Cropland converted to Grassland	1011918.00	-292.47	0.00	-292.47	248.93	248.93	390.54	-1272.34
3.B.3.b.iii - Wetlands converted to Grassland	18528.00	0.87	0.00	0.87	15.00	15.00	-14.55	-4.84

3.B.3.b.iv - Settlements converted to Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.3.b.v - Other Land converted to Grassland	7944.00	2.74	0.00	2.74	6.43	6.43	-6.24	-10.76
3.B.4 - Wetlands (3)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.5 - Settlements	344405.00	-169.82	0.00	-169.82	-194.58	-194.58	178.43	681.89
3.B.5.a - Settlements Remaining Settlements	90409.00			0.00		0.00		0.00
3.B.5.b - Land Converted to Settlements	253996.00	-169.82	0.00	-169.82	-194.58	-194.58	178.43	681.89
3.B.5.b.i - Forest Land converted to Settlements	48008.00	-85.95	0.00	-85.95	-46.97	-46.97	0.00	487.38
3.B.5.b.ii - Cropland converted to Settlements	56521.00	-35.86	0.00	-35.86	-31.88	-31.88	66.21	5.62
3.B.5.b.iii - Grassland converted to Settlements	142889.00	-47.17	0.00	-47.17	-115.73	-115.73	112.23	185.80
3.B.5.b.iv - Wetlands converted to Settlements	2827.00	-0.84	0.00	-0.84	0.00	0.00	0.00	3.09
3.B.5.b.v - Other Land converted to Settlements	3751.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.B.6 - Other Land	109405.00	-66.12	0.00	-66.12	0.00	0.00	77.82	-42.90
3.B.6.a - Other land Remaining Other land	135.00							
3.B.6.b - Land Converted to Other land	109270.00	-66.12	0.00	-66.12	0.00	0.00	77.82	-42.90
3.B.6.b.i - Forest Land converted to Other Land	17367.00	-31.08	0.00	-31.08		0.00	0.00	113.98
3.B.6.b.ii - Cropland converted to Other Land	15457.00	-9.81	0.00	-9.81		0.00	18.11	-30.42
3.B.6.b.iii - Grassland converted to Other Land	76033.00	-25.10	0.00	-25.10		0.00	59.72	-126.92
3.B.6.b.iv - Wetlands converted to Other Land	413.00	-0.13	0.00	-0.13		0.00	0.00	0.46
3.B.6.b.v - Settlements converted to Other Land	0.00	0.00	0.00	0.00		0.00	0.00	0.00

Table 3.3 – AFOLU Background Table 3.B (Sheet 2 of 2)

Inventory Year: 2012

Categories	Activity Data	Emissions		
	Area (ha)	CO2 (Gg)	CH4 (Gg)	N2O (Gg)
3.B.4 - Wetlands	6958	101.4127209	0	0
3.B.4.a - Wetlands Remaining Wetlands	0	0	0	0
3.B.4.a.i - Peatlands remaining peatlands		0		0
3.B.4.a.ii - Flooded land remaining flooded land				
3.B.4.b - Land Converted to Wetlands	6958	101.4127209	0	0
3.B.4.b.i - Land converted for peat extraction				0
3.B.4.b.ii - Land converted to flooded land	6958	101.4127209		
3.B.4.b.iii - Land converted to other wetlands				

Table 3.4 – AFOLU Background Table 3.C (sheet 1 of 4)

Inventory Year: 2012

Categories	Activity Data							Information item: Carbon emitted as CH4 and CO (5)	
	Description (2)	Unit (ha or kg dm)	Value	CH4 (4) (Gg) Biomass	N2O (Gg)	CO (4) (Gg) Biomass	NOx (Gg)	Biomass (C Gg)	DOM (C Gg)
3.C - Aggregate sources and non-CO2 emissions sources on land				65.21	5.95	1842.80	110.57	838.67	0
3.C.1 - Emissions from biomass burning				65.21	5.95	1842.80	110.57	838.67	0
3.C.1.a - Biomass burning in forest lands				32.73	2.99	925.09	55.51	421.02	0
Area burned				32.73	2.99	925.09	55.51	421.02	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires	Area burned	ha	231249	32.73	2.99	925.09	55.51	421.02	0
Amount burned				0	0	0	0	0	0
Controlled Burning				0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
3.C.1.b - Biomass burning in croplands				16.13	1.47	455.86	27.35	207.47	0
Area burned				0	0	0	0	0	0
Biomass Burning in Cropland Remaining Cropland				16.13	1.47	455.86	27.35	207.47	0
Controlled Burning	Area burned	ha	133230	16.13	1.47	455.86	27.35	207.47	0
Wildfires				0	0	0	0	0	0
Biomass burning in Forest Land Converted to Cropland				0	0	0	0	0	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
Biomass Burning in Non Forest Land Converted to Cropland				0	0	0	0	0	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
Amount burned				0	0	0	0	0	0
Controlled Burning				0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
3.C.1.c - Biomass burning in grasslands				16.34	1.49	461.84	27.71	210.19	0
Area burned				0	0	0	0	0	0

Burning in Grassland Remaining Grassland				16.34	1.49	461.84	27.71	210.19	0
Controlled Burning				0	0	0	0	0	0
Wildfires	Area burned	ha	195355	16.34	1.49	461.84	27.71	210.19	0
Burning in Forest Land Converted to Grassland				0	0	0	0	0	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
Burning in Non Forest Land Converted to Grassland				0	0	0	0	0	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
Amount burned				0	0	0	0	0	0
Controlled Burning				0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
3.C.1.d - Biomass burning in all other land				0	0	0	0	0	0
Area burned				0	0	0	0	0	0
Biomass Burning in Other Land Remaining All Other Land				0	0	0	0	0	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
Biomass Burning in Forest Land Converted to All Other Land				0	0	0	0	0	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
Biomass Burning in Non Forest Land Converted to All Other Land				0	0	0	0	0	0
Controlled Burning	Area burned	ha	0	0	0	0	0	0	0
Wildfires				0	0	0	0	0	0
Amount burned				0	0	0	0	0	0
Controlled Burning				0	0	0	0	0	0
Wildfires				0	0	0	0	0	0

Table 3.5 – AFOLU Background Table 3.C (sheet 1 of 5)

Categories	Activity Data			Emissions
	Limestone CaCO3 (Mg / yr)	Dolomite CaMg(CO3)2 (Mg / yr)	Total amount of lime categories applied (Mg / yr)	CO2 (Gg)
3.C.2 - Liming	0	0	0	0
Forest Land	0	0	0	0
Cropland	0	0	0	0
Grassland	0	0	0	0
Wetlands	0	0	0	0
Settlements	0	0	0	0
Other Land	0	0	0	0

Table 3.6 – AFOLU Background Table 3.C (sheet 2 of 5)

Categories	Activity Data	Emissions
	Annual Average Population (Mg / yr)	CO2 (Gg)
3.C.3 - Urea application	31950	23.43
Forest Land	0	0
Cropland	31950	23.43
Grassland	0	0
Wetlands	0	0
Settlements	0	0
Other Land	0	0

Table 3.7 – AFOLU Background Table 3.C (sheet 3 of 5)

Categories	Activity Data		Emissions
	Total amount of nitrogen applied (Gg N / yr)	Area (ha)	N2O (Gg)
3.C.4 - Direct N2O Emissions from managed soils	425910153.1	192700033	9.72101721
Inorganic N fertilizer application	66214535		1.040514121
Organic N applied as fertilizer (manure and sewage sludge)	86048564.07		1.352191721
Urine and dung N deposited on pasture, range and paddock by grazing animals	0		0
N in crop residues	273647054		4.300167991
N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils		192700033	3.028143376
Drainage/management of organic soils (i.e., Histosols)			0

Table 3.8– AFOLU Background Table 3.C (sheet 4 of 5)

Categories	Activity Data	Emissions
	Total amount of nitrogen applied / excreted (Gg N / yr)	N2O (Gg)
3.C.5 - Indirect N2O Emissions from managed soils		3.101578201
From atmospheric deposition of N volatilized from managed soils from agricultural inputs of N (synthetic N fertilizers; organic N applied as fertilizer; urine and dung N deposited on pasture, range and paddock by grazing animals (2); N in crop residues (3); and N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (3))	231.5905496	0.623804601
From N leaching/runoff from managed soils (i.e. from synthetic N fertilizers; organic N applied as fertilizer; urine and dung N deposited on pasture, range and paddock by grazing animals (2); N in crop residues (3); and N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (3))	700.7844526	2.4777736
3.C.6 - Indirect N2O Emissions from manure management	21.95637279	0.172514358

Table 3.9– AFOLU Background Table 3.C (sheet 4 of 5)

Categories	Activity Data	Emissions	
	Area (ha)	CH4 (Gg)	N2O (Gg)
3.C.7 - Rice cultivations	218200	9.656240256	
3.C.8 - Other (please specify)		0	0

Table 4 – Waste Sectoral Table

Inventory Year: 2012

Categories	Emissions [Gg]						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
4 - Waste	3.956152262	191.5178308	1.580070482	0	0	0	0
4.A - Solid Waste Disposal	0	68.6259576	0	0	0	0	0
4.A.1 - Managed Waste Disposal Sites				0	0	0	0
4.A.2 - Unmanaged Waste Disposal Sites				0	0	0	0
4.A.3 - Uncategorised Waste Disposal Sites				0	0	0	0
4.B - Biological Treatment of Solid Waste		0.749896	0.0562422	0	0	0	0
4.C - Incineration and Open Burning of Waste	3.956152262	0.871609701	0.013439921	0	0	0	0
4.C.1 - Waste Incineration	1.284668557	0.0066528	0.0016632	0	0	0	0
4.C.2 - Open Burning of Waste	2.671483705	0.864956901	0.011776721	0	0	0	0
4.D - Wastewater Treatment and Discharge	0	121.2703675	1.510388361	0	0	0	0
4.D.1 - Domestic Wastewaster Treatment and Discharge		95.16878432	1.510388361	0	0	0	0
4.D.2 - Industrial Wastewater Treatment and Discharge		26.10158322		0	0	0	0
4.E - Other (please specify)				0	0	0	0

Table 4.1 – Background Table CO_2

Inventory Year: 2012

Categories	Type of Activity Data	Unit	Emissions [Gg]		
			CO2 (Gg)	CH4 (Gg)	N2O (Gg)
4.A - Solid Waste Disposal (1)			0	68.6259576	0
4.A.1 - Managed Waste Disposal Sites	79.24983808	Gg		1.331343577	
4.A.2 - Unmanaged Waste Disposal Sites	3268.03456	Gg		54.90076608	
4.A.3 - Uncategorised Waste Disposal Sites	737.7588019	Gg		12.39384794	
4.B - Biological Treatment of Solid Waste	187.474	Gg		0.749896	0.0562422
4.C - Incineration and Open Burning of Waste (2)			3.956152262	0.871609701	0.013439921
4.C.1 - Waste Incineration	33.264	Gg	1.284668557	0.0066528	0.0016632
4.C.2 - Open Burning of Waste	133.0702924	Gg	2.671483705	0.864956901	0.011776721
4.D - Wastewater Treatment and Discharge			0	121.2703675	1.510388361
4.D.1 - Domestic Wastewaster Treatment and Discharge			0	95.16878432	1.510388361

CH4 Emissions (3)	425525365.8	kg		95.16878432	
N2O Emissions (4)	192231245.9	kg			1.510388361
4.D.2 - Industrial Wastewater Treatment and Discharge			0	26.10158322	0
CH4 Emissions (3)	131851921	kg		26.10158322	
N2O Emissions (4)					
4.E - Other (please specify)			0	0	0

Table 4.2 – Background Table CH_4

Inventory Year: 2012

Categories	CH4 [Gg]
	Flared / Energy Recovered
4.A - Solid Waste Disposal	0
4.B - Biological Treatment of Solid Waste	0
4.D - Wastewater Treatment and Discharge	0
4.D.1 - Domestic Wastewaster Treatment and Discharge	0
4.D.2 - Industrial Wastewater Treatment and Discharge	0
4.E - Other (please specify)	

Table 4.3 – Background Table (Long term storage)

Inventory Year: 2012

Categories	C [Gg]
Information Items (2)	
Long-term storage of carbon in waste disposal sites	
Annual change in total long-term storage of carbon stored	15.39634874
Annual change in long-term storage of carbon in HWP waste (3)	3.260643015