Ghana's Fifth National Greenhouse Gas Inventory

2021 National Greenhouse Gas Emissions Report

May 2022

Environmental Protection Agency (EPA)

With kind support from

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Foreword

The report is Ghana's Fifth National Inventory Report (NIR5) to the United Nations Climate Change. The NIR5 updated the Greenhouse Gas (GHG) inventory results presented in Ghana's Third Biennial Update Report (BUR3) to the United Nations Framework Convention on Climate Change (UNFCCC). The GHG information reported in the NIR5 fed into the emission analysis that formed the basis of mitigation commitment in Ghana's updated Nationally Determined Contributions (NDCs). The data in the NIR5 will also serve as a benchmark for monitoring and tracking the progress and achievement of the NDCs.

Ghana continues to strengthen the national system for GHG inventory and has built on the ongoing efforts to improve data management and institutional arrangement. The Environmental Protection Agency Act 490 (1994) is undergoing review, which is expected to provide adequate legal backing for the national system for GHG inventory. Regarding data management, the online climate data hub has been repurposed to be responsive to the Modalities, Procedures, and Guidelines (MPG) requirements of the Enhanced Transparency Framework (ETF) established under the Paris Agreement.

The NIR5 covers a period of 29 years from 1990 to 2019 for the four main Intergovernmental Panel for Climate Change (IPCC) sectors: Energy, Industrial Process and Product Use (IPPU), Agriculture, Forestry and Other Land Uses (AFOLU) and Waste. The inventory has been prepared using the 2006 IPCC Guidelines covering Greenhouse Gases (GHGs) (Carbon dioxide, Methane, Nitrous oxide, Hydrofluorocarbons, Perfluorocarbons etc.), some Precursor Gases (PGs), notably non-methane volatile organic compounds, Particulate Matter, Nitrogen Oxides and Short-Lived Climate Pollutants (SLCPs) like Black carbon. Recalculations have been carried out on the 1990-2016 estimates resulting in new values for 2017 to 2019.

The national inventory report is expected to be put to several uses. First, it is a good source of information for formulating national policies for reducing greenhouse gas emissions. Secondly, it can also serve as solid reference material for users in the international and national climate change policy, research and education, climate business development, and others.

For researchers, this report provides an in-depth understanding of GHG inventory for identifiable economic sectors, linkages between emissions, development indicators, and associated drivers. It also identifies several gaps where further research would be needed. For climate planning and policymakers, this report provides an outstanding basis for identifying, developing, and prioritising climate mitigation actions and targets in sectors with high emission reduction potential and benefits to the broader Sustainable Development Goals (SDGs). It is anticipated that the necessary resources would be found for some of the programmes in the specific sectors to improve activity data collection and emission factors for future inventory preparation to achieve the ultimate objective of the Convention.

Hon. Dr. Henry Kwabena Kokofu, *Esq*
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Acknowledgement

The Environmental Protection Agency of Ghana wishes to express sincere thanks to all the individuals who, through their diligent work, led to the successful compilation of Ghana's Fifth National Greenhouse Gas Inventory Report. Special appreciation goes to the Global Environment Facility (GEF) and its implementing Agency, UN Environment, for providing financial and technical assistance for the whole greenhouse gas inventory exercise. We are particularly grateful to the UN Environment team, who helped us in diverse ways from the inventory's start to the end. It is worthy to note the signification support in terms of data provision and technical expertise to the inventory team received from the following institutions:

- Volta River Authority, Petroleum Commission
- Ghana Railways Company Limited, 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
- CSIR Forestry Research Institute
- CSIR Soil Research Institute
- Volta Aluminium Company (VALCO)
- Driver Vehicle and Licensing Authority (DVLA)

The Agency is pleased with the tireless efforts and wealth of knowledge they brought on board to enrich the quality of the report. It is also worth acknowledging the immense support the EPA received from the institutions that allowed its staff to be part of the inventory process from start to end. Our utmost appreciation also goes to the various private data generators/owners, individuals, and entities who provided the critical country-level activity data for the inventory. Finally, the EPA is immensely thankful to the various sector experts and the respective working groups for their hard work, demonstrated in the preparation and finalisation of this report.

We also wish to express our profound gratitude to all the international partners who reviewed the inventory and made invaluable comments and suggestions, which added significant value to the entire report. We also appreciate the inputs from colleagues from the Ministry of Environment, Science, Technology, and Innovation for contextualising the NIR from the policy perspective.

Mr. Ebenezer Appah-Sampong
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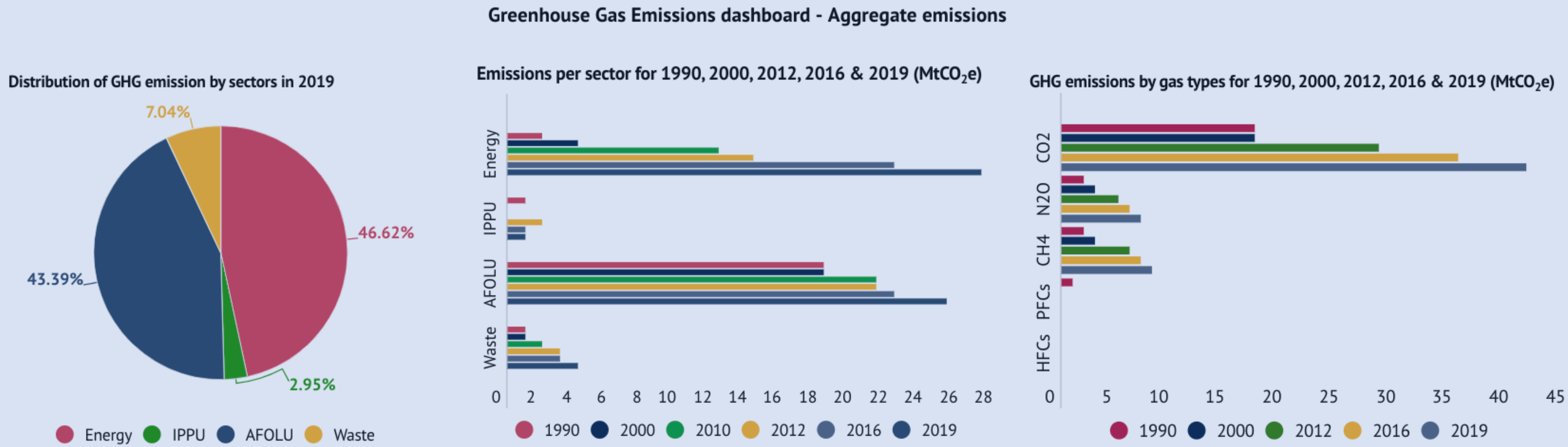
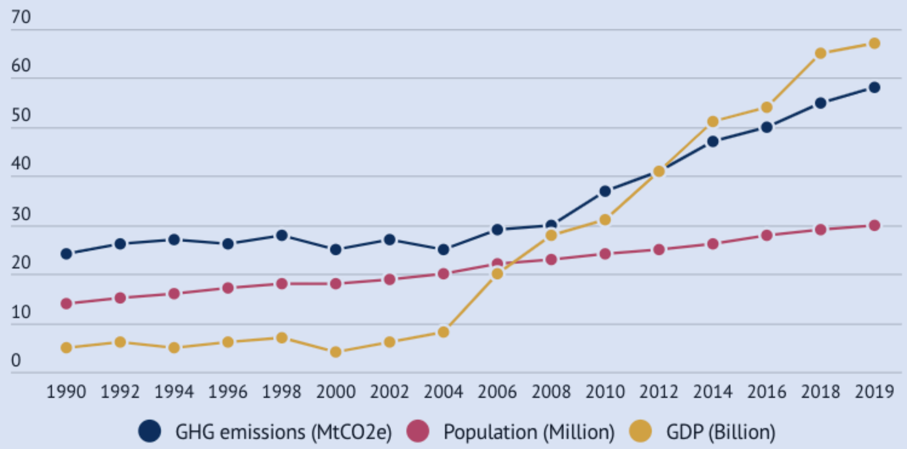
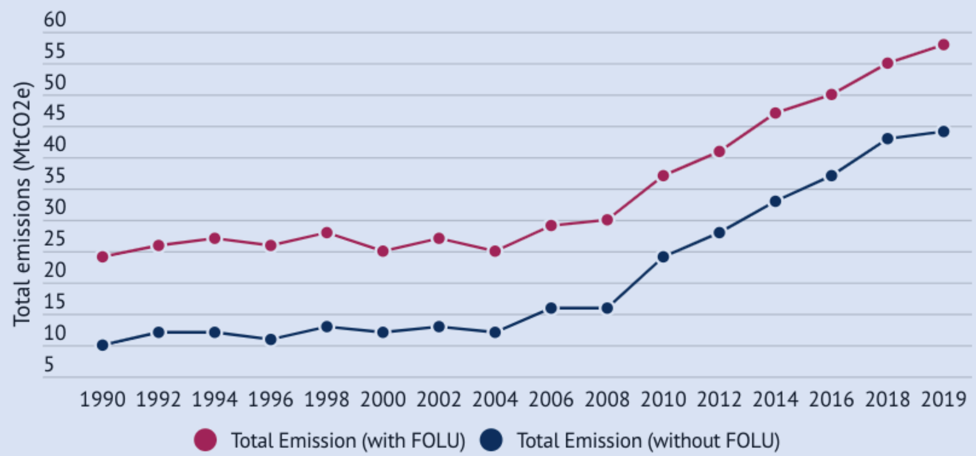
Ghana’s 2019 Greenhouse Gas Emissions Dashboard







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List of abbreviations and acronyms

AD	-	Activity Data
AFOLU	-	Agriculture, Forestry and Other Land Use
ATK	-	Aviation Turbine Kerosene
BC	-	Black Carbon
BDCs	-	Bulk Distribution Companies
BED	-	Built Environment Department
BOD	-	Biological Oxygen Demand
BOF	-	Basic Oxygen Furnace
BUR	-	Biennial Update Report
CC	-	Climate Change
CCAC	-	Coalition for Climate and Clean Air
CEL	-	Cenit Energy Limited
CERSGIS	-	Centre for Remote Sensing and Geographic Information System
CfRN	-	Coalition for Rainforest Nations
CH_4	-	Methane
CO_2	-	Carbon Dioxide
CO_2e	-	Carbon Dioxide Equivalent
COD	-	Chemical Oxygen Demand
CS	-	Country Specific
CSD	-	Crop Services Directorate
CWPB	-	Centre-worked Prebake
DFO	-	Distillate Fuel Oil
DOC	-	Degradable Organic Carbon
DVLA	-	Driver Vehicle Licensing Authority
EAF	-	Electric Arc Furnace
EC	-	Energy Commissions
EF	-	Emission Factors
EFDB	-	Emission Factor Database
EMP	-	Environmental Management Plan
EPA	-	Environmental Protection Agency
EQ	-	Environmental Quality
ETF	-	Enhanced Transparency Framework
FAO	-	Food and Agriculture Organisation
FAOSTAT	-	FAO Statistics
FOD	-	First Order Decay
FORIG	-	Forestry Research Institute of Ghana
FOLU	-	Forestry Other Land Use
FPP	-	Forest Preservation Programme
FPSO	-	Floating production storage and offloading
FREL	-	Forest Reference Emission Level
FRNR	-	Faculty of Renewable Natural Resource
FSD	-	Forest Services Division
GCARP	-	Ghana Climate Ambitious Reporting Programme
GDP	-	Gross Domestic Product
GEF	-	Global Environment Facility
Gg	-	Giga Gramme
GHG	-	Greenhouse Gas
GNGC	-	Ghana National Gas Company
GPG	-	Good Practice Guidance

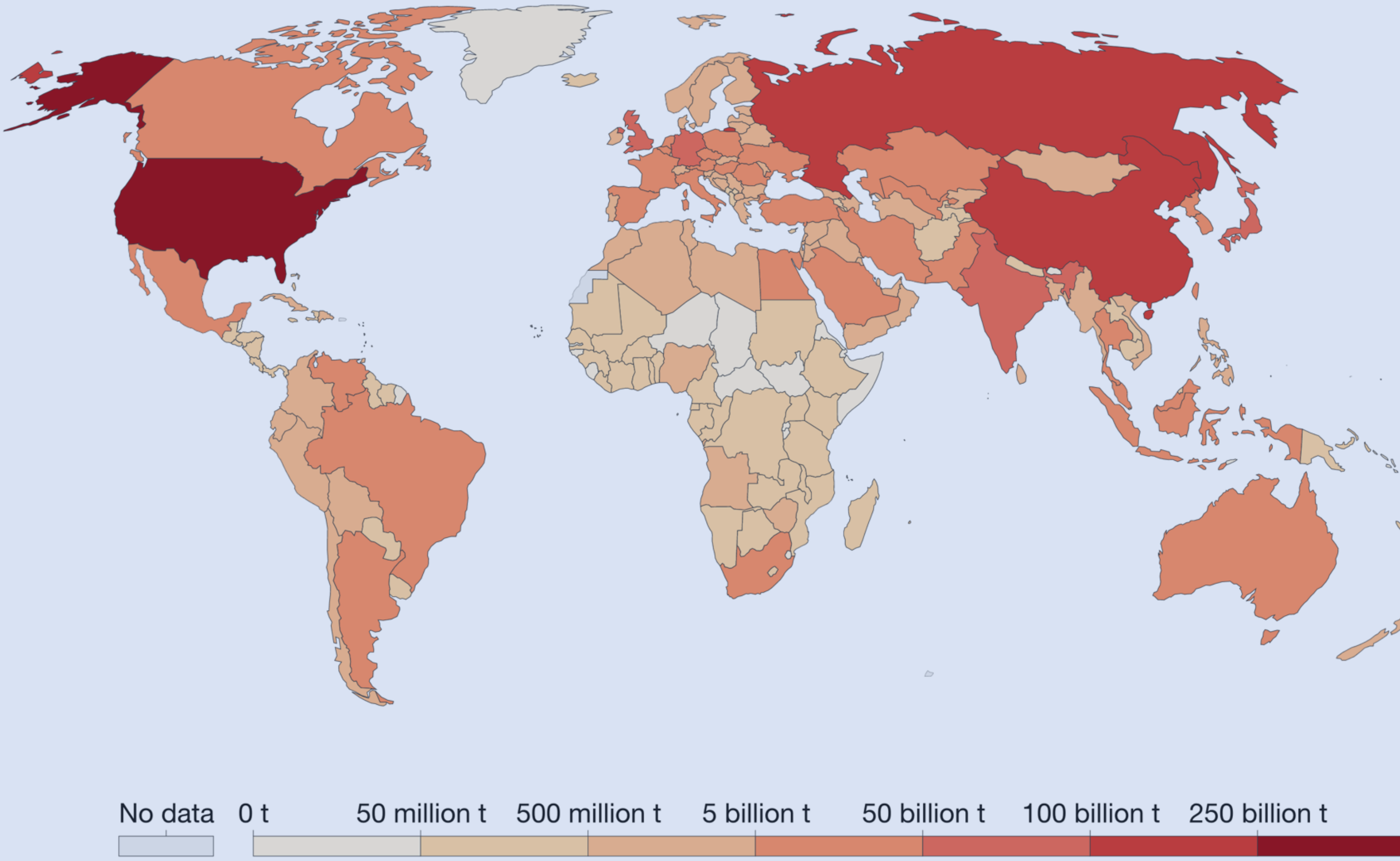
GSP	-	Global Support Programme
GSS	-	Ghana Statistical Service
GWP	-	Global Warming Potential
HFC	-	Hydrofluorocarbons
HFO	-	Heavy Fuel Oil
IEA	-	International Energy Agency
IPCC	-	Intergovernmental Panel on Climate Change
IPPU	-	Industrial Processes and Product Use
KCA	-	Key Category Analysis
KNUST	-	Kwame Nkrumah University of Science and Technology
Ktoe	-	Kilo Tonne Oil Equivalent
LCO	-	Light Crude Oil
LPG	-	Liquefied Petroleum Gas
MAC	-	Mobile Air Conditioning
MESTI	-	Ministry of Environment, Science, Technology, and Innovation
MICs	-	Multiple Cluster Indicator Survey
MID	-	Manufacturing Industry Department
MLGRD	-	Ministry of Local Government and Rural Development
MMDAs	-	Metropolitan, Municipal and District Assemblies
MODIS	-	Moderate Resolution Imaging Spectroradiometer
MOFA	-	Ministry of Food and Agriculture
MoU	-	Memorandum of Understanding
MRP	-	Mine Reverse Plant
MRV	-	Monitoring Reporting Verification
MSW	-	Municipal Solid Waste
Mtoe	-	Mega Tonne Oil Equivalent
Mt	-	Million Tonnes
MW	-	Megawatt
N_2O	-	Nitrous Oxide
NATCOMs	-	National Communications
NDC	-	Nationally Determined Contributions
NESSAP	-	National Environmental Sanitation Strategy and Action Plan
NFMS	-	National Forest Management System
NIR	-	National Inventory Report
NMVOCs	-	Non-Methane Volatile Organic Compounds
NOx	-	Nitrogen Oxide
NPA	-	National Petroleum Authority
NPK	-	Nitrogen, Phosphorus, and Potassium
ODS	-	Ozone Depleting Substances
OMCs	-	Oil Marketing Companies
PA	-	Paris Agreement
PFC	-	Perfluorocarbons
PM	-	Particulate Matter
QA/QC	-	Quality Control/Quality Assurance
RA	-	Reference Approach
REDD+	-	Reducing Emission from Deforestation and Forest Degradation+
RFCC	-	Residue Fluid Catalytic Cracker
RFO	-	Residual Fuel Oil
RMSC	-	Resource Management and Support Centre
RRR+	-	Result-based REDD+
SA	-	Sectoral Approach
SAPP	-	Sunon Asogli Power Plant
SLCP	-	Short-Lived Climate Pollutant

SNEP	-	Strategic National Energy Plan
SOC	-	Soil Organic Carbon
SOPs	-	Standard Operating Procedures
SRID	-	Statistics, Research, and information Directorate
SWDS	-	Solid Waste Disposal Sites
TACCC	-	Transparency, Accuracy, Completeness, Consistency and Comparability
TAPCO	-	Takoradi Power Company
TEN	-	Tweneboa, Enyenra, Ntomme
TICO	-	Takoradi International Company
TT2PP	-	Tema Thermal 2 Power Plant
UN-INRA	-	United Nations University, Institute for Natural Resource in Africa
UNFCCC	-	United Nations Framework Convention on Climate Change
VALCO	-	Volta Aluminum Company
VRA	-	Volta River Authority
WRI	-	World Resources Institute

Source: https://ourworldindata.org/co2-emissions

Cumulative CO2 emissions, 2020

Cumulative carbon dioxide (CO_2) emissions represents the total sum of CO_2 emissions produced from fossil fuels and cement since 1750, and is measured in tonnes. This measures CO_2 emissions from fossil fuels and cement production only – land use change is not included.



Key Messages

Executive Summary

ES.1 Background information on the GHG Inventories

Ghana's Fifth National Inventory Report (NIR5) has been prepared to primarily inform Ghana's climate change policies. The NIR5 is part of the official submission to the United Nations Framework Convention on Climate Change (UNFCCC). It contains the national greenhouse gas emission inventory estimates for 1990 to 2019. The report and the associated tables are submitted to the UNFCCC to fulfil Ghana's 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 also in compliance with the reporting requirements for the preparation of its Third Biennial Update Report (BUR3) consistent with Decision 1/CP.16 para 60(c).

The NIR has been prepared following the UNFCCC Guidelines for the preparation of national communications from non-Annex I Parties (Decision 17/CP.8) and UNFCCC Biennial Update Report Guidelines for Parties not included in Annex I to Convention (Decision 2/CP. 17, paragraph 40 and Annex III of decision 2/CP.17). Where necessary, references have been made to the previous IPCC Guidelines/guidance documents of 1996, 2000, and 2003. Ghana mainly used the 2006 IPCC Guidelines for the GHG inventory.

The methodology used for the greenhouse gas inventory has improved over time and will continue to be refined as new data and information become available and as international practices advance. The changes from the refinements to methodologies and the revisions of datasets have been reported in the recalculations section for each sector. The NIR and the preparation processes have not only helped Ghana to fulfil its international reporting obligations but have brought meaningful benefits to the efforts to raise the profile of climate issues among the line ministries as well as contributed immensely to:

- Capacity advancement for the participating institutions.
- Enhance climate policy rigour with reliable information in evaluating GHG mitigation options for increasing climate ambitions.
- Provide a meaningful basis for calibrating national emission reduction goals and feedback on the progress towards realising mitigation goals in the long run.
- Develop integrated strategies for reducing greenhouse gases and other atmospheric emissions, such as SLCPs, to simultaneously reduce air pollution while meeting mitigation goals.

The inventory covers emissions from key economic sectors in Ghana. Generally, economic growth and GHG emissions are closely related. The economic model Ghana pursues determines the consequent emission levels at any given period.

The emissions volume, either at the economy level or sector-wide, would largely depend on the ambitious sustainability-focused policy being implemented, the sectoral mitigation policy drive, and the penetration of environmentally sound technologies in the economy. All the economic activities that can generate greenhouse emissions or take carbon dioxide from the atmosphere have been categorised into four broad sectors, according to the 2006 IPCC guidelines. The IPCC sectors are: (a) Energy, (b) Industrial Process and Product Use (IPPU), (c) Agriculture, Forestry, Other Land Use and (AFOLU), and (d) Waste.

These emissions sources/removals have been further characterised into a cluster of activities according to the hierarchy below: (a) sector, (b) sub-sectors, (c) categories, (d) sub-categories, (f) activities, and (g) technologies. The Environmental Protection Agency led the inventory processes. The Agency worked with different national stakeholders to undertake the following: data management, a 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). The NIR is available on EPA's website: http://www.epa.gov.gh/epa/.

ES.2 National Greenhouse Gas Emissions/Removal Trends

ES 2.1 Greenhouse gas inventory results

In 2019, Ghana's total GHG emissions, including LULUCF, were estimated to be 59.8 million tonnes (Mt) CO_2-equivalent (CO_2e). The 2019 emissions are 16.3% higher than the 2016 levels and 139.2% above 1990 levels. When the net emissions from LULUCF are excluded from the national total, the emission estimates came down to 45.3 $MtCO_2e$ for 2019.

ES Table 1: Ghana's total greenhouse gas emissions for 1990 - 2019 categorised by sources

Sectors/ Categories	Total Emissions ($MtCO_2e$)					Percentage change (%)	
	1990	2000	2012	2016	2019	2016-2019	1990-2019
National Emissions with LULUCF	**25.0**	**26.2**	**42.6**	**51.4**	**59.8**	**16.3**	**139.2**
National Emissions without LULUCF	**10.7**	**12.8**	**29.1**	**38.0**	**45.3**	**19.1**	**323.4**
Energy	2.9	4.1	14.9	22.4	27.3	22.1	841.4
Industrial Processes and Product Use	2.0	0.9	2.0	1.7	1.7	0.0	-15.0
Agriculture, Forestry, and Other Land Use	19.0	19.5	22.6	23.7	26.6	12.2	40.0
Waste	1.1	1.6	3.1	3.6	4.1	13.9	272.7

The rising emissions trend correlates well with the continued implementation of economic transformation policies, as manifested by the impressive expansion of the national economy. The expansion in the economy, coupled with population pressures, led to remarkable increases in emissions from road transport, thermal electricity generation, biomass use for cooking, and deforestation.

ES 3 Reasons for recalculations

In line with the QA/QC procedures, Ghana has instituted the practice of systematically dealing with technical review comments and the improvement list. In addressing the technical review comments that emerged from the ICA of BUR2 and the efforts to roll out the prioritised improvement tasks, some methodological changes and revisions to datasets occurred. Consequently, recalculations were performed on most sectors' 1990-2016 estimates to ensure time-series consistency. Some of the specific changes which justified the recalculations of the previous estimates are as follows:

- Changes in activity data due to the discovery and inclusion of new datasets, revision or updates of existing activity data and inclusions of new survey results.
- Filling of time-series data gaps with international data and trend interpolation or extrapolation.
- Changes in the inconsistent use of conversion fuel factors and appropriate emission factors due to the shift from the revised 1996 IPCC Guidelines to the use of the 2006 IPCC Guidelines.
- Adoption of a new methodology for collecting new activity data and emission factors.
- Refinement in the use of expert judgment.
- Inclusion of additional pollutants for the full-time series.

The report's relevant section provides an elaborate explanation of the recalculations, their impacts on the previous estimates, and the underlying reasons for recalculations.

ES 4 GHG emissions and development indicators

Greenhouse gas emissions, population, economic and especially energy indicators are closely related. The relationship depicts how economic growth, population pressures, and energy utilisation drive GHG emissions. Generally, the results shown in Table ES 2 suggest that total emissions went alongside the rising population, GDP, and energy consumption but at varying rates. Population, GDP, and energy consumption are rising faster than emissions. The trend shows a positive sign of possible medium-effects of some mitigation policies and interventions on slowing down emission growth in the country.

ES Table 2: Macro-economy, energy and emission indicators

Indicators	1990	2000	2016	2019	Change (2016-2019) (%)	Change (1990-2019) (%)
Population (million)	14.43	18.91	28.21	30.42	7.8	110.8
GDP (Constant 2015 USD billion) *	13.17	20.01	51.07	62.47	22.3	374.3
Total primary energy supply (Mtoe)**	6.29	6.88	9.30	11.1	19.4	76.5
Total final energy consumed (Mtoe)**	4.31	5.47	7.18	8.05	12.1	86.8
Total GHG emission ($MtCO_2e$)	25.0	26.2	51.4	59.8	16.3	139.2
Total CO_2 emission ($MtCO_2$)	17.03	17.22	35.34	41.93	18.6	146.2
Total electricity generated (GWh)**	5,721	7,224	13,023	18,188	39.7	217.9
*of which is Hydroelectric (GWh)***	5,721	6,611	5,561	7,252	30.4	26.8

*of which is Oil Products (GWh)***	-	614	7,435	10,885	46.4	-
of which is Renewable (GWh)**	-	-	27	52	92.6	-
Total Electricity Consumed** (GWh)	4,462	6,889	12,528	15,232	21.6	241.4
Total energy consumed per capita (toe)	0.30	0.29	0.25	0.26	4.0	-13.3
GHG emissions per capita (tCO_2e)	1.73	1.39	1.82	1.97	8.2	13.9
CO_2 emission per capita (tCO_2)	1.18	0.91	1.25	1.38	10.4	16.9
GHG emissions per GDP unit (kg CO_2e/constant 2015 USD)	1.89	1.31	1.01	0.96	-5	-49.2
GHG emissions per GDP unit (kg CO_2/constant 2015 USD)	1.29	0..86	0.71	0.67	-5.6	-48.1

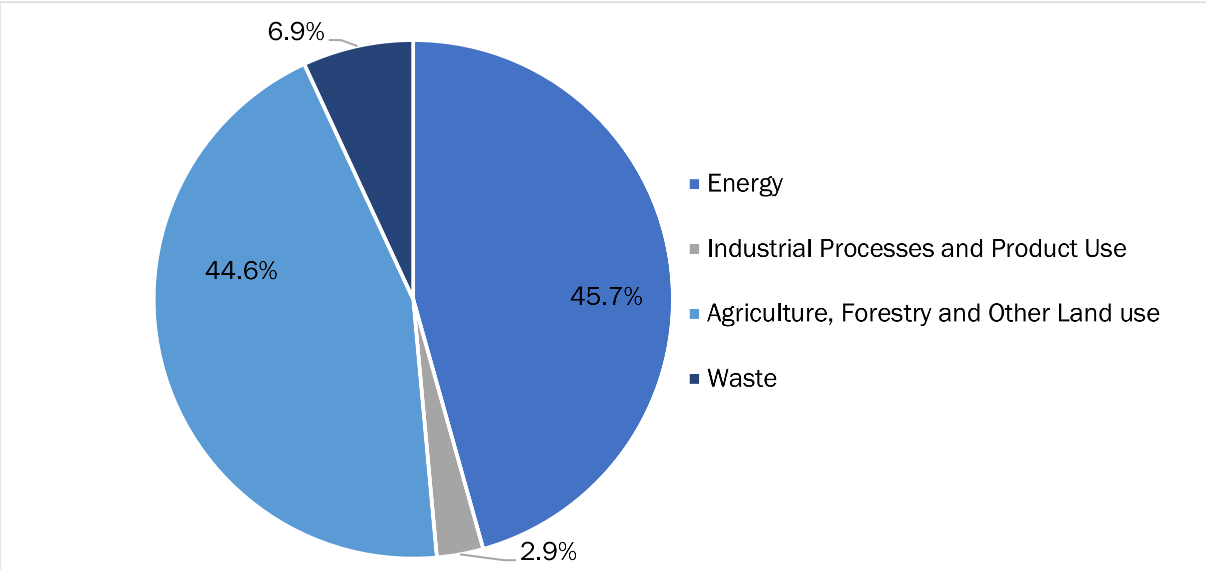
* Source: World Bank, National Account (2022),
** Source: National Energy Statistics. The figure also considers electricity export to the neighbouring countries and total hours of electricity load.

It is also worthy to note that the observed consistent decline in GHG per capita and per GDP unit reflects the influence of the decarbonisation imperatives that underpin the country's economic transformation agenda.

ES 5. Overview of sources/sinks and trends

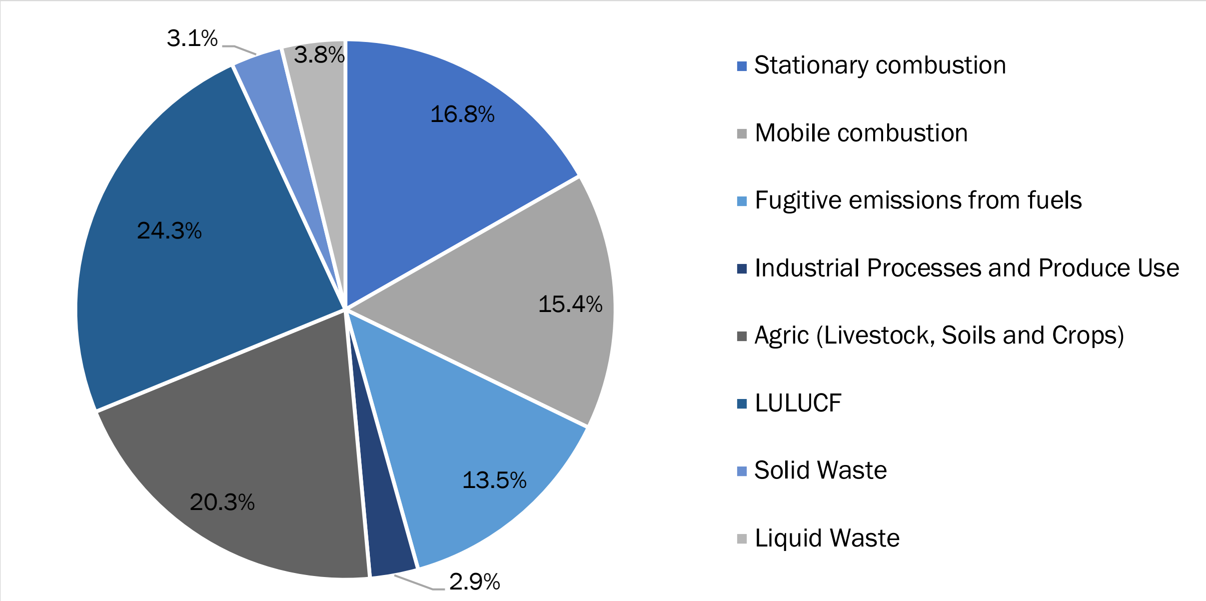
ES 5.1 Greenhouse gas inventory by source/removal

The energy sector is the major source of greenhouse emissions in 2019. It accounts for 45.7% of Ghana's total GHG emissions of 59.8 $MtCO_2e$ (ES Figure 1). The AFOLU sector occupies the second largest source, contributing 44.6% of the national emissions. The emission from the waste sector follows it is 6.9% and then by the IPPU sector of 2.9%. The total emissions recorded a growth of 16.3% between 2016 and 2019. Throughout 1990 and 2019, all the sectors have recorded emission increases except the IPPU, which has seen a decline of 11.8%. The trends of energy and waste sector emissions have shown an 853.1% and 265.1% rise over the same period.



ES Figure 1: Total emissions by source/removals in 2019

However, when the total GHG emission results are disaggregated, LULUCF and Agriculture became the two largest sources in 2019. LULUCF account for 24.3% of the 2019 total national greenhouse gas emissions, while that Agric amount to 20.3% (ES Figure 2). The emissions from land-based activities and livestock are followed by those stationary (16.8%) and mobile (15.4%) combustion sources, as well as fugitive emissions from fuels (13.5%). The rest of the emission sources are liquid waste (3.8%), solid fuel (3.1%) and industrial processes (2.9%).



ES Figure 2: Total emissions by source/removals by categories in 2019

Below is the overview of greenhouse emission trends and the underlying drivers:

For the AFOLU sector:

- The LULUCF category is the leading emissions source in the sector. Their 14.52 $MtCO_2e$ constitute 24.3% of the total national emissions in 2019. It also made up 54.5% of all AFOLU emissions in 2019, representing an 8.6% increase since 2016 due to deforestation.
- Cropland, grassland, and forestland are responsible for most emissions in the LULUCF.
- The emissions from “aggregated sources and non-CO_2 emission on land” (3C) were the second-highest in the AFOLU sector. Its levels were 7.7 $MtCO_2e$ in 2019, making 12.8% of the national emissions and representing a 19.5% rise relative to the 2016 levels.
- The “direct and indirect N_2O emissions from managed soils” formed a significant share making up 78.9% of the total 3C emissions in 2019
- Emissions from rice cultivation of 0.36 $MtCO_2e$ account for 4.6% of the total 3C GHG emissions.
- Livestock emissions of 4.44 $MtCO_2e$ make up 16.7% of the net AFOLU emissions. The emissions have grown by 13% between 2016 and 2019.

Similarly, in the energy sector:

- Stationary energy combustions are point sources in energy, manufacturing, construction, and residential/commercial industries.
- The stationary combustion emissions stood at 10.02 $MtCO_2e$ in 2019. In this category, the energy industry is the largest source and accounts for 36.7% of the energy sector emissions. The stationary combustion emissions have increased by 31.5% over the 2016-2019 period.
- Mobile combustion emissions are estimated at 9.23 $MtCO_2e$ in 2019 and account for 33.8% of the total energy emissions and 15.4% of the total national emissions.
- The 2019 transportation emissions represent an increase of 45.8% compared to the reported 2016 levels.
- Road transport was the most significant emission source within the transportation category due to growing vehicle ownership and the associated traffic congestion in the cities.

In the waste sector,

- The 2019 total emissions of 4.1 $MtCO_2e$ is 13.6% more than the 2016 figures and composed 6.9% of the total national emissions.
- Wastewater treatment and discharge and solid waste disposal were the two dominant emission sources within the waste sector.
- Wastewater treatment and discharge contributed 58.5% to all waste sector emissions, followed by solid waste disposal contributing 38.1% to the waste sector emissions.

Finally, for the IPPU sector

- The emissions were 1.73 $MtCO_2e$ for 2019, representing 2.9% of the total national emissions.
- The 2019 emissions are 3.1% more than the 2016 levels.
- HFC from product use as a substitute for ODS was the dominant emissions source, followed by emissions from the mineral industry.

ES 5.2 Emission source and removal by sink according to gases

Carbon dioxide is still the commonest greenhouse gas emission in Ghana. The 2019 levels account for 70.1% of the total net emissions. When the LULUCF emissions are excluded from the national total, CO_2 constitute 60.5% of Ghana's total emissions. The AFOLU and the energy sectors were the two most significant sources of CO_2 emissions, responsible for 97.5% of the total emissions. AFOLU was the leading source until 2011 the energy sector became a significant source.

In 2019, the energy sector generated the most CO_2 emissions of 26.38 $MtCO_2$, followed by AFOLU as the second-rated source producing 14.2 $MtCO_2$. Across the time series from 1990 to 2019, net CO_2 levels went up by 145.5%. The net CO_2 emissions have increased by 18.7% between 2016 and 2019. Forestland remaining forestland, conversion to cropland and grassland through deforestation, thermal electricity generation and; road transport drives the rising CO_2 emissions.

The second leading greenhouse gas in the country is nitrous oxide. It was estimated at 8.54 $MtCO_2e$ in 2019. It constitutes about 14.3% of the total national emissions in the same year. Between 2016 and 2019, the total N_20 levels rose by 15%, with the major sources in the AFOLU sector. The sub-category "direct N_2O emission from managed soil" is the principal source of N_2O releases into the atmosphere. The high levels of fertiliser use associated with the government fertiliser subsidy programme may account for the rising emissions. Apart from the AFOLU sector, some insignificant amounts of N_2O come from the waste (0.65 $MtCO_2e$) and energy (0.34 $MtCO_2e$) sectors (ES Table 3).

ES Table 3: Contributions from different gases to the national emissions in 2019

Sectors & Sub-sectors	Mt	Emissions $MtCO_2e$				Share of Total	
	CO_2	CH_4	N_2O	PFC	HFC	% w/ LULUCF	% w/o LULUCF
Energy	26.4	0.58	0.35	-	-	45.7	60.4
Industrial Process & Product Use	0.62	-	-	0.52	0.59	2.9	3.8
AFOLU	14.9	4.16	7.55	-	-	44.5	26.7
Waste	0.02	3.46	0.65	-	-	6.9	9.1
Total including LULUCF	41.93	8.2	8.55	0.52	0.59	100	
Total excluding LULUCF	27.42	8.2	8.55	0.52	0.59		100

Generally, methane levels also showed a rising pattern for various reasons. A significant proportion came from the AFOLU and waste sectors. Almost half (50.7%) of the total methane gas was emitted from the AFOLU sector, mostly from livestock rearing. Enteric fermentation and manure management contributed 41.7% of the total national methane emissions in 2019. The rest of the methane emissions come from the waste sector (42.2% of the total national methane emissions) through the disposal of solid waste and wastewater treatment and discharge facilities. The energy sector emitted a relatively smaller percentage of 7% of the methane from biomass for cooking and heating in the residential and commercial areas.

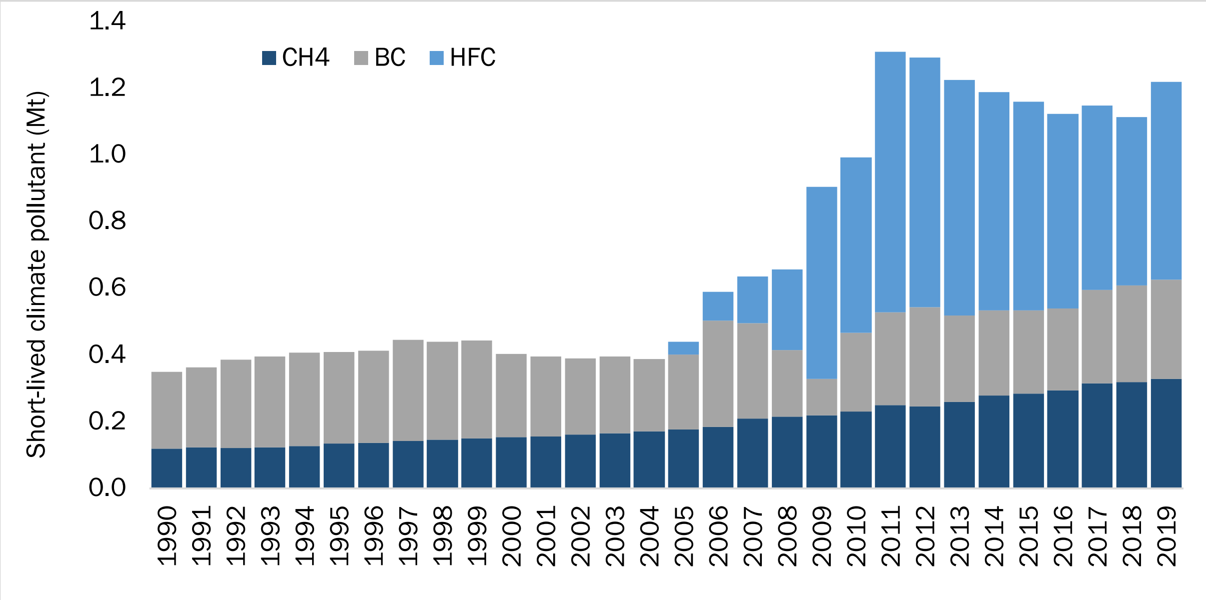
The rise in the nitrogen addition to managed soil, unmanaged waste disposal practices and wastewater treatment technologies may have contributed to the upward trends in methane emissions. The 2019 levels grew by 173.7% and 11.6% over the 1990 and 2019 levels. For the period 1990-2019, methane emissions from the waste sector recorded the highest (340.9%) growth at the fastest annual rate of 5.2% compared to the AFOLU, which increased by 105.5% at a 2.5% rate per annum. Similarly, methane emissions from the energy sector increased by 209.1% at a 4% growth rate.

PFC and HFC are the dominant industrial gases emitted exclusively from the IPPU sector. PFC emissions are associated with the Aluminium production at VALCO in the metal industry category. Its 2019 levels were estimated at 0.52 $MtCO_2e$, representing a decrease of 68.8% from 1990. PFC showed a similar decreasing trend (-23.3%) between 2016 and 2019. The reductions in PFCs attributed to the declining operation capacity of VALCO. The HFC emissions level of 0.59 $MtCO_2e$ in 2019 correlates well with the ongoing policy interventions. As a result of the national programme to phase out HFCs in the 2000s with HFC substitutes in the RAC sector. Between 2005 and 2019, HFC emissions have increased by 15 folds.

Between 2016 and 2019, HFC emissions increased by 1.6% following the efforts to promote the adoption of low-GWP HFCs. Due to the lack of activity data, SF_6 emissions are not estimated. NF3 emissions do not occur in Ghana.

ES 5.3 Precursor gases and SLCPs emissions

Precursor gases are not greenhouse gases at the point of release, but they can contribute to global warming and local and regional air pollution. There are selected GHGs, and air pollutants like methane, HFCs, black carbon, and tropospheric ozone are categorised as SLCPs because they have a relatively short life span in the atmosphere compared to carbon dioxide. They can persist for an extended period in the atmosphere. Methane, HFCs and Black Carbon (BC) are the three main SLCPs in Ghana directly emitted, while tropospheric ozone is formed photochemically in the atmosphere from primary emissions of methane, nitrogen oxides, and volatile organic compounds, and carbon monoxide.



ES Figure 3: Trend of SLCP emission between 1990 and 2019

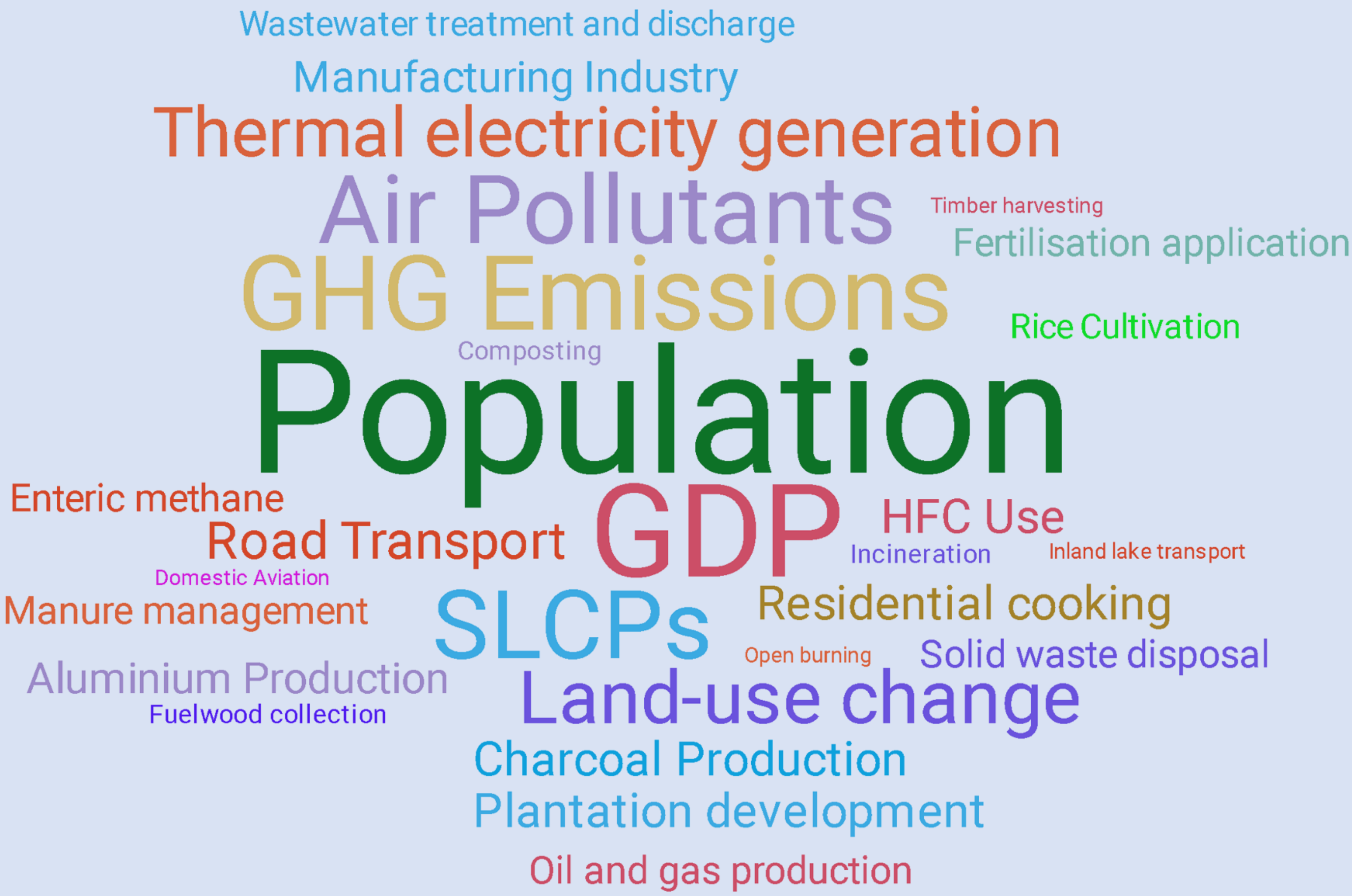
HFC is the dominant source of SLCP in Ghana and was estimated at 0.59 Mt in 2019. Methane emissions followed with a total of 0.33 Mt, while BC emissions stood at 0.3 Mt. All the three pollutants recorded increasing trends between 2016 and 2019, with BC showing the highest growth (Figure ES 3). Even though BC levels were low, they grew the most by 21% against 12% of CH_4 and 2% of HFC. HFC emissions were primarily from stationary and mobile air conditioners. The main source of CH_4 is livestock rearing, solid waste disposal and biomass use in cooking. Black carbon emissions were mainly from transport, residential cooking, and the manufacturing industry.

The NIR identified common sources of GHGs, SLCPs and air pollutants so that actions that can simultaneously reduce these substances can be developed. In addition to the SLCPs, the NIR5 also reports on the estimates of precursor gases such as Sulphur Dioxide (SO_2), Nitrogen oxides (NOx), and Carbon Monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs) and Particulate Matter ($PM_{2.5}$).

According to ES Table 4, SO_2 was the most predominant precursor gas with 18,669.19 Gg in 2019. In the same year, NOx, CO, NMVOC and PM2.5 levels were 114.9 Gg, 1,168.5 Gg, 232 Gg and 2,394.8 Gg, respectively. These emissions were significant to quantify alongside GHG emissions of GHGs and SLCPs to develop integrated strategies to reduce air pollution and greenhouse gases.

ES Table 4: Trends of precursor gas and SLCPs between 1990 and 2019

Year	(Gg NOx)	(Gg CO)	(Gg NMVOC)	(Gg BC)	(Gg, $PM_{2.5}$)	(Gg, SO_2)	(Gg, NO, N_2O)
1990	26.79	805.91	166.86	229.35	2,148.71	2,502.36	26.82
1991	27.95	839.48	174.74	239.56	2,237.51	2,409.56	27.08
1992	47.00	871.85	183.43	264.90	2,333.78	4,232.76	27.33
1993	47.41	902.67	191.07	271.79	2,400.24	4,408.32	27.59
1994	47.76	934.47	198.86	279.01	2,470.53	4,606.72	27.84
1995	34.52	960.01	203.50	274.69	2,535.83	3,432.09	28.10
1996	33.16	988.32	209.19	276.12	2,612.44	3,346.22	28.35
1997	39.89	1,024.36	216.28	304.52	2,761.96	4,321.95	28.61
1998	42.44	1,018.56	216.84	293.54	2,667.12	5,936.02	28.87
1999	39.17	1,028.00	219.78	293.52	2,698.66	5,026.52	29.12
2000	32.78	793.44	141.96	250.47	2,411.45	3,653.03	29.38
2001	33.74	768.73	138.69	239.39	2,293.98	3,916.37	29.46
2002	35.90	750.50	137.28	228.42	2,182.36	5,229.50	29.54
2003	35.61	699.27	133.15	230.12	2,093.95	5,186.04	29.62
2004	35.62	737.20	139.02	217.06	2,035.75	4,301.17	29.70
2005	39.51	835.82	175.62	223.97	2,038.23	5,296.96	29.79
2006	46.77	1,068.14	210.00	319.75	3,011.58	6,640.23	29.87
2007	52.63	955.87	200.18	285.15	2,490.16	8,105.24	29.95
2008	41.46	822.19	178.55	198.31	1,814.57	5,979.34	30.03
2009	43.55	661.26	157.12	109.86	927.32	6,782.49	30.11
2010	72.63	913.49	201.12	236.43	1,897.64	10,373.29	30.22
2011	74.07	1,088.47	231.10	277.82	2,420.09	10,900.83	30.63
2012	92.01	1,100.88	235.15	295.91	2,380.89	13,190.41	31.05
2013	88.43	1,084.23	237.01	258.14	2,097.20	12,879.47	31.47
2014	83.72	1,125.81	245.05	254.68	2,161.51	12,272.57	31.89
2015	82.68	1,121.40	244.14	248.69	2,142.79	12,541.49	32.31
2016	77.09	1,106.65	241.66	245.33	2,126.92	13,413.96	30.20
2017	94.66	1,047.85	207.98	280.31	2,319.20	16,230.53	28.08
2018	108.02	1,357.77	302.64	290.21	2,366.05	17,647.99	25.96
2019	114.96	1,168.52	232.01	297.72	2,394.83	18,669.19	23.84


Wastewater treatment and discharge
Manufacturing Industry
Thermal electricity generation
Air Pollutants
Timber harvesting
Fertilisation application
GHG Emissions
Rice Cultivation
Composting
Population
Enteric methane
GDP
HFC Use
Road Transport
Incineration
Inland lake transport
Domestic Aviation
Residential cooking
Manure management
SLCPs
Open burning
Solid waste disposal
Aluminium Production
Land-use change
Fuelwood collection
Charcoal Production
Plantation development
Oil and gas production

Chapter 1

1.0 Background to the National GHG Inventory

1.1. Context of the national emission inventory report

Ghana publishes this Fifth National Inventory (NIR5) of anthropogenic Greenhouse Gas (GHG) emissions by sources and removal by sinks in fulfilment of its obligations under Articles 4(a) and 12 (a) of the United Nations Framework Convention on Climate Change (UNFCCC)[1]. The NIR5 is a standalone follow-up to submitting the Third Biennial Update Report (BUR3) prepared under Decision 1/CP.16 paragraphs 60 (a-c) of the UNFCCC. It will also set the stage for the shift to the electronic reporting of GHG inventory and compilation of a future National Inventory Document (NID) under the Biennial Transparency Report (BTR) contained in Decision 18/CMA.1 on the modalities, procedures, and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement[2].

The NIR5 document is the product of a two-year government-led collaboration among public institutions, academia, data providers and private organisations. The preparation of the NIR5 builds on Ghana's existing technical capabilities, best available data, and support from key international partners. Global Environment Facility (GEF), through United National Environment Programme (UNEP), provided the financial grant for preparing the NIR5 as part of the funding for BUR3. The CfRN and Ghana RRR+ Phase II provided additional technical assistance to support GHG inventory for the LULUCF sector.

The NIR5 report the latest data on Ghana's Greenhouse Gas (GHG) emission inventory results from 1990 to 2019. The inventory result covers GHG estimates and trends for the Energy, Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land-Use Change and Forestry (LULUCF or Land) and Waste sectors. Ghana has compiled the NIR5 per the UNFCCC's Decision 17/CP.8[3] on Guidelines for the preparation of National Communications from non-Annex I Parties and Decision 2/CP.17, and its annexe III[4] on Biennial Update Reporting Guidelines for Parties not included in Annex I to the Convention. Ghana has prepared the NIR5 with the view to achieving the following:

- Meet its international reporting obligations under the UNFCCC.
- Continuous technical capacity development for key stakeholders in line ministries, CSOs, data providers, industry and academia.
- Assess the progress of mitigation commitment of the nationally determined contribution.
- Highlight the improvements and persistent challenges in the national sustainable greenhouse gas inventory arrangement.

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[1] https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf
[2] https://ledslac.org/wp-content/uploads/2020/09/e.-Decision-18-cma.1.pdf
[3] https://unfccc.int/files/meetings/workshops/other_meetings/application/pdf/dec17-cp.pdf
[4] http://www.ciesin.columbia.edu/repository/entri/docs/cop/FCCC_COP17_dec02.pdf

As it waits for IPCC to complete the methodology work on Short-Lived Climate Pollutants (SLCPs), Ghana has voluntarily calculated SLCPs emissions using the EMEP/CORINAIR Emission Inventory Guidebook. Ghana has prepared this GHG inventory according to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), 2019 Refinement to the 2006 IPCC Guidelines and IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). Where necessary, reference was made to the 2003 IPCC Good Practice for Land use, Land-use Change and Forestry (IPCC, 2003), mainly for the LULUCF inventory. These Guidelines made it possible to plan and undertake the estimates over a given period and ensured that the GHG emission estimates were Transparent, Complete, Consistent, Comparable and Accurate (TCCCA) through time and comparable with those inventories produced in other countries of similar national circumstances. Where Ghana has used country-specific methodology for the GHG estimation, explanations have been given in the NIR's relevant sections.

1.2. Gases covered in the national emission inventory report

The NIR5 covers information on direct GHGs emissions, SLCPs and selected local air pollutants associated with major economic activities in Ghana. Direct GHG includes Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and Fluorocarbons (F-gases). SF_6 is not reported due to a lack of country data. Including the SLCPs and selected local air pollutants in the inventory was useful because it quickly assessed their contribution to public health, agricultural productivity, and sustainable development. Consistent with UNFCCC reporting guidelines, the GHG estimates for all the GHG emissions/removals were expressed in mass units. The IPCC Fourth Assessment Report (AR4) 100-year time horizon GWPs was used to report the CO_2 equivalent of the emissions. Table 1Table 1 lists the specific GWPs values used in converting non-CO_2 GHG into a common metric.

Table 1: Global Warming Potentials of greenhouse gases reported in the NIR5

Gas	GWP
CO_2	1
CH_4	25
N_2O	298
PFC_{14} or CF_4	7,390
PFC_{116} or C_2F_6	12,200
$HFC_{32}(CH_2F_2)$,	675
HFC_{125} (CHF_2CF_3)	3,500
$HFC_{134a}(CH_2FCF_3)$	1,430
HFC_{143a} (CF_3CH_3)	4,470
SF_6	22,800

GWPs were not available for the precursor gases, so the results have been reported in mass units. The indirect GHGs have not been included in the summation of the total emissions expressed in the CO_2e at the national, sector and category levels. In addition to the GHGs, this NIR5 also provides estimates for SLCPs and some relevant air pollutants. Both CH_4 and HFCs have been captured under GHGs and SLCPs in the inventory and Black Carbon (BC), which is also not captured in the CO_2e total even though it has a warming effect on the climate. The primary local air pollutants covered in this inventory include Nitrogen Oxide (NOx), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCs) and Particulate Matter 2.5 ($PM_{2.5}$).

1.3. Emissions sources and removal by sinks covered in the inventory

The NIR5 also reports greenhouse emission estimates for five major economic activities in the country. The GHG sources/removals categories are consistent with the UNFCCC reporting guidelines in Energy, IPPU, Agriculture, LULUCF, and Waste sectors. Ghana used the methods 2006 IPCC Guidelines for estimating the GHG emissions and reported according to the UNFCCC reporting guidelines. The emission/removals have been estimated and reported at the most disaggregated levels as far as the available data permit. The results are pooled into sub-categories, categories, sectors, and national estimates for a given inventory year and across the entire period. Besides, Ghana has also identified the key category that consistently contributed most to the emission/removal levels and trends for each inventory year and throughout the time series. The NIR sector-specific section provides detailed information on the scope of the categories and methods used to assess them.

1.4. National inventory reporting years

In the NIR5, the inventory covers the period from 1990 to 2019, covering 29 years, with 2019 being the latest year. The current time series meet the N-2-year reporting requirement per the enhanced transparency framework. Where N is the year of reporting. Even though the time-series analysis will cover the entire 29-year period, particular emphasis will be on the changes that occurred after the last year of the previous NIR, 2016. The changes between 2016 and 2019 can better depict current national circumstances than the previous base years. Recalculations have been conducted on GHG emission estimates from 1990 to 2016 for selected categories as new datasets became available and changed methodological approaches.

1.5. Outline of the national inventory report

The information in the NIR5 has been organised in a systematic format consistent with the elements in 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 the Convention (Decision 2/CP.17, and its Annex III) and the user manual for the Guidelines on national communication from non-Annex I Parties. The report has also been concisely-structured to facilitate more clarity and comprehension of the NIR information and stimulate its logical flow. Real-life examples have been used to illustrate key concepts, major findings, and policy implications as much as possible. The NIR5 has four chapters, and each addresses a specific GHG inventory topic. In each chapter, detailed information on the context, methodology used, key findings and the drivers are provided below:

Chapter 1 introduces the NIR5 and highlights a wide range of cross-cutting inventory issues. The information on the cross-cutting issues seeks to establish the NIR's overall context as the foundation for the ensuing chapters. Some of the general topics that chapter 1 addresses are as follows: background information on the GHG inventory, updates in the national system, an overview of the inventory steps, methodologies, data sources and assumptions, key category analysis, quality control and quality assurance, assessment of completeness, uncertainty assessment and assessment of recalculations.

In Chapter 2, the NIR presents a broad overview of the inventory results at the national levels by providing the aggregate national emissions for 2019 and the analysis of the emissions trends for the 1990-2019 time series for each specific gas. The results have been divided according to the family of gases such as GHG, SLCPs and local air pollutants. Chapter 2 further explains emission trends and the underlying drivers.

Chapters 3 to 6 are dedicated to the five IPCC sectors. Here, the detail of information on sector-specific inventory has been reported. The information covers data acquisition and processing, methodological choices and assumptions, sector-relevant cross-cutting issues (such as recalculations, key category, QA/QC), yearly emission estimates and time-series trends.

Chapter 7 uses the central messages from the emission results to briefly discuss the policy implications, mainly drawing attention to areas where the results typically demonstrate the unintended consequences between development imperatives and emissions. The chapter also provides additional information on planned improvements and conclusions.

The Annexes contain the list of mandatory reporting tables and extra information on the whole inventory.

1.6 National system for sustainable inventory preparation

In response to the call in the Bali Action Plan for countries to establish a domestic MRV system, Ghana launched the Climate Ambitious Reporting Program (CARP)[5] in 2013. The operational goal of the CARP was to establish and operate an integrated climate data management system that supports the regular preparation of credible national and international climate reports to the UNFCCC and to inform policy. The component of the CARP system includes its governance arrangement, data management and information technology, tools and methods, and capacity development and are at various stages of operationalisation. Over the last several years, Ghana has pursued reforms to institutionalise and improve the functionality of the CARP. However, the progress has not been widespread among the four GCARP system components.

1.6.1 Progress of the institutional reforms

Through the reforms, the initial ad-hoc institutional arrangement has been decentralised. The Environmental Protection Agency (EPA) transferred the GHG inventory tasks from the ad-hoc task groups, often put together to prepare climate reports to selected line ministries and agencies. As a result, the government institutions have direct responsibility for planning and preparing sector inventory reports while the EPA focuses on the overall coordination. For instance, as the coordination institution of the CARP system, the EPA signed a Memorandum of Understanding (MOU) with lead government institutions to govern the smooth workflow of climate reporting among the actors. Transferring the GHG inventory duties to the line ministries was based on the understanding that if the ministries compile their sector climate reports, it will be an incentive for continuous reporting and influence policy within their respective sectors. It would also be the surest way to get their buy-in from the line ministries to adopt climate reporting to become part of their annual plans and budget.

[5]*https://www.transparency-partnership.net/system/files/document/Good%20Practice-Ghana Climate%20Ambitious%20Reporting%20Program.pdf*

After the decentralisation, the focus is on institutionalising the GHG inventory tasks within the line ministries. Since the publication of the fourth national inventory report, the following have been achieved in institutional reforms:

- The EPA Act 490, Environmental Protection Act, 1994, which mandates the EPA to coordinate the inventory GHG inventory preparation, is under review. The review is expected to strengthen EPA legal functions to plan and manage the national system for the sustainable preparation of the GHG inventories.

- The Energy Commission has incorporated the climate reporting activities into their annual plan and approved by the management and board. The incorporation has paved the way for the Commission to allocate some of its annual budgets to support the climate reporting activities.

- As part of the CBIT project, Ghana has conducted a comprehensive study on institutional assessment for climate reporting to identify the status of institutional involvement in the GHG inventory, challenges and progress (Annex 1).

1.6.2 GHG inventory data management reforms

Timely access to good quality data for the GHG inventory continues to be a challenge for the compilers. That is why Ghana keeps on addressing data access, data storage, and sharing issues. As part of Ghana's efforts to strengthen the way the data system is relevant for GHG inventory functions, the CBIT project being implemented in Ghana supported the following:

- A comprehensive review and assessment of the methodology for preparing climate statistics in the Energy, Transport, Agriculture and Waste sectors (Annex 2).

- Re-design the climate data hub system with all the functionalities to run on an open-source platform (Annex 3).

1.6.3 Information on the institutional arrangement for the national GHG inventory

The EPA coordinates Ghana's national GHG inventory preparation, while MESTI endorses NIRs for onward submission to UNFCCC. The Climate Change unit within EPA is the national inventory entity and is directly responsible for managing the entire inventory process. The Climate change unit ensures the prompt delivery of high-quality inventory estimates and reports that satisfy international standards

As the "coordinating entity", the EPA also collaborate with several public and private institutions to plan, implement and compile the inventory (Figure 1). There are nearly thirty national experts from twenty different public and private institutions. Each institution involved in the GHG inventory has an assigned role at every stage of the inventory cycle. The EPA and the sector lead institution update the inventory tasks and capture them in the Memorandum of Understanding (MOU) (Annex 4).

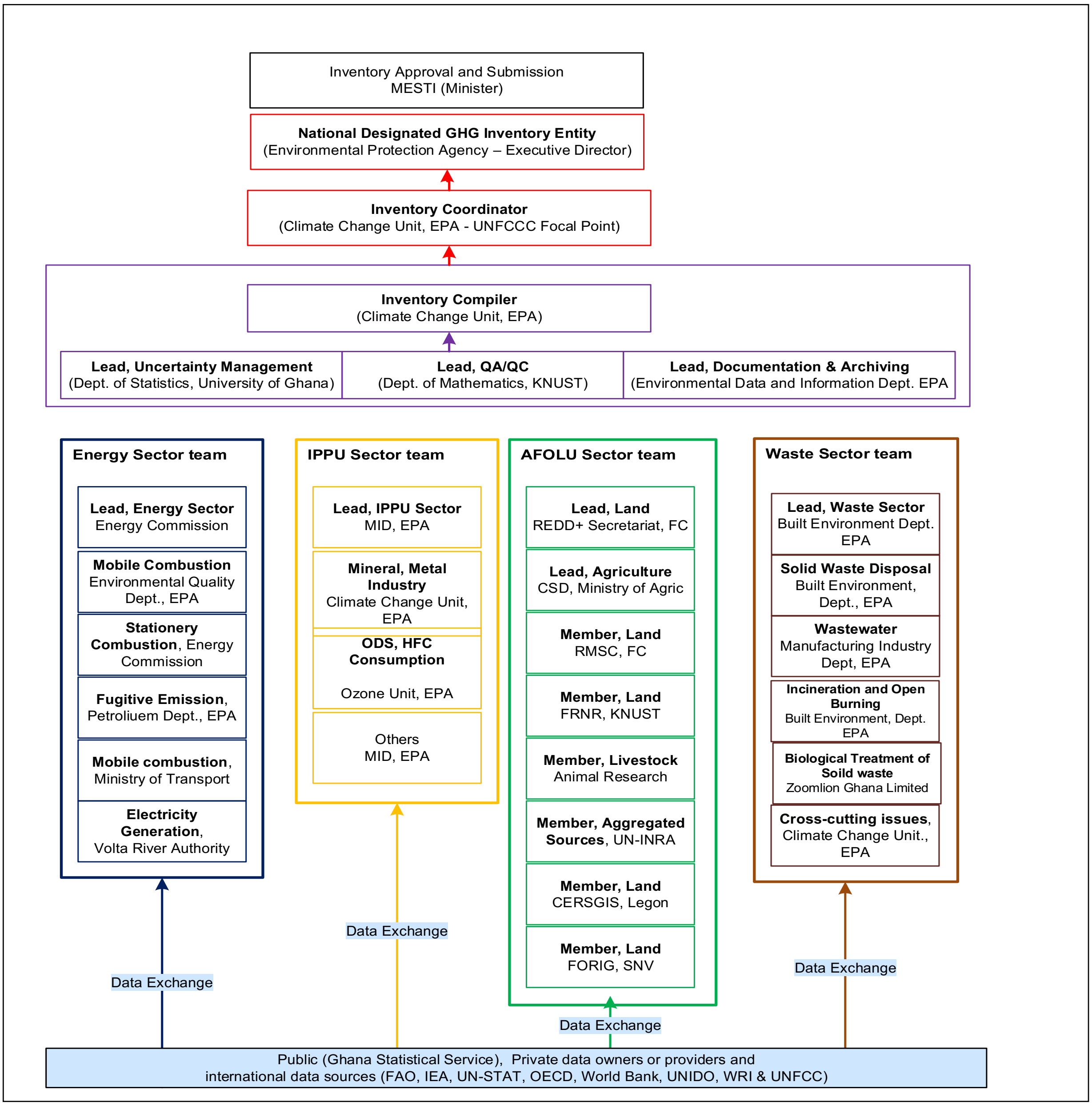

Figure 1: Institutional arrangements for the preparation of national GHG inventory[6]

The inventory compiler is also the generalist responsible for ensuring that the issues across the sectors are addressed sufficiently. Some of the generalist's issues are recalculations, ensuring the national system's responsiveness, key category analysis, managing improvements list, addressing technical review comments and leads on QA/QC and uncertainty management. The generalist also works closely with the sector experts to plan and implement QA/QC and uncertainty management protocols. There are four sector teams, and each has been assigned to one IPCC inventory sector. Each team has a lead, and the members have a specific task in the sector inventory. The members of the sector teams are drawn from public and private organisations and academia. Several institutions supply data to the inventory compilers. The inventory entities and their roles are in Table 2.

[6] Source: Ghana's GHG Inventory Manual, 2012

Table 2: Functional GHG inventory entities and their roles/responsibilities

Inventory task	Lead institution	Specific tasks
Approval and submission of the final inventory report	Ministry of Environment, Science, Technology, and Innovation *(Minister Responsible for MESTI).*	• Reviews and approves the national inventory report. • Uses inventory estimates to inform policy. • Provides policy direction to the national inventory compilers.
National Entity	Environmental Protection Agency *(Executive Director)*	• Ensures overall technical oversight and coordinates timely deliverables. • Provides strategies to guide the long-term improvements in the inventory. • Facilitate dissemination and awareness of all the inventory products.
Inventory Compiler	Climate Change Unit, EPA, *(Inventory compiler)*	• Acts as the inventory coordinator and is responsible for the general planning and execution of the inventory on behalf of the EPA. • Plans the inventory and provides operational, management and technical oversight. • Reports directly to the Executive Director for onward transmission to its Board of Governors and MESTI. • Manages all MOUs and facilitates the efficient delivery of all tasks. • Creates a schedule using the inventory cycle timelines. The schedule covers timelines for completing assignments before and after the due dates. • Facilitates national and international technical reviews of the inventory • 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 sector teams – all worksheets and text and put together into one whole inventory document. • Doubles as the generalist for the inventory and ensures that recalculations, key category analysis, and filling data gaps are consistent with IPCC GPG. • Works closely with the sector leaders to ensure internal consistency across the inventory.
Lead, QA/QC	Mathematics Department, KNUST[7]	• Responsible for the planning and implementation of QA/QC. • Together with the inventory compiler, design and oversee the QA/QC plan implementation.
Lead, Uncertainty Management	Department of Statistics, University of Ghana, Legon[8]	• Designs and performs tier-1 uncertainty assessment for the entire inventory and at least for all the key categories. The methodology for the tier-1 uncertainty assessment would be entirely consistent with the 2006 IPCC.

[7] Even though the Mathematics Department of KNUST was originally tasked to lead the QA/QC protocol there were still challenges that did not allow the full participation of the representative to function as expected. Therefore, under the new QA/QC plan, the QA/QC task has been frontloaded to the sector teams. The KNUST Mathematics still is expected to play the lead role in QA/QC in the next inventory. In this regard, the EPA will reengage KNUST to come up with a workable arrangement that will make them more active.

[8] Same comments on the QA/QC lead apply to the Uncertainty Management lead.

		• Generates a simple-to-use worksheet for the sectors team to use. • Using the 2006 IPCC, produce simple steps to manage uncertainties in the sectors and inventory levels.
Documentation and Archive	Climate change Unit, EPA	• Designs and ensures complete references for all data aligned with QA/QC protocols articulated in the QA/QC plan. • Documents all the responses to internal and external review comments and ensures that the sector team addresses outstanding comments and records them using the issue tracking template during the new inventory cycle. • Ensures all information and data are collected consistently for later reference purposes and archived with other inventory materials. • Designs data storage and documentation procedures for the inventory. • Ensures sector team leads complete the documentation-tracking log for onward transmission to the inventory compiler.
Sector Leads	Energy Commission, Forestry Commission, Crop Services Directorate, MOFA, MID, EPA Built Environment, Dept. of EPA	• Undertake a detailed review of data needs per sector, identify the sources, and access them with the inventory coordinator/compiler's support using appropriate channels and document all the data and processes used. • Collect, collate, evaluate, update all GHG and related data in each sector, and decide which data qualifies to be used in the inventory based on 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 organisations that lead the sectors. • Liaise with the inventory compiler to review options to inform methodological choices based on their applicability to GHG emissions estimation. • Estimate GHG emissions for all categories and gases under sectors using relevant factors/ GWPs and ensure that the processes/assumptions for the estimation, including the software used, are consistent with the IPCC Guidelines and thoroughly documented. • Conduct key category analysis 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 prioritised plans for improvements incorporated into the national inventory report. • Create and maintain hard and soft copies of all information, data, and estimates at the sector level and onward transmission to the Environmental Protection Agency as the inventory documentation and archiving depository.

		• Consult with the inventory compiler to discuss and agree on the cost involved in activities that can be done within the quarter in the inventory year. The rate and mode for requesting funds would be discussed and agreed upon ahead of every inventory cycle.
Data providers	All data suppliers (Energy statistics, Agricultural Facts and Figures, National Forest Monitoring System, Vehicle Statistics, Waste Statistics, Annual Environmental Reports)	• Periodically publish activity data in the energy, transport, forestry, waste, industry, and agriculture sectors. • Provides additional clarifications on the data where necessary. • Jointly agrees with the inventory compiler and the sector lead on special treatment of confidential data.

1.6.3.1 Information on the inventory team

Several national experts contributed to the inventory, and each expert has a specific role to play at each stage of the inventory. The personal contacts of the key individuals involved in the inventory and their roles are provided in Table 3.

Table 3: Contacts and roles of selected inventory team members

Name	Organisation	Contact Information	Role	Responsibility	Comments
Hon Henry Kwabena Kokofu	Environmental Protection Agency	Executive Director, P. O. Box. M326, Accra – Ghana. Tel: 0302 – 664697/98 Email: henry.Kokofu@epa.gov.gh	National Entity	Overall coordination	Regularly update EPA Management, Governing Board and MESTI
Mr Ebenezer Appah-Sampong	Environmental Protection Agency	Deputy Executive Director (Technical Services) P. O. Box M326, Accra –Ghana. Tel: 0302 – 664697/98 Email: ebenezer.sampong@epa.gov.gh	National Entity	Functional coordination	Regularly updates the Executive Director. Monitors key deliverables
Dr Daniel Tutu Benefoh	Environmental Protection Agency	Climate Change Unit P. O. Box. M326 Accra – Ghana. Tel: 0246-114652 Email: dbenefor2000@gmail.com	National Inventory Compiler & Generalist	Manages national inventory planning, implementation, and reporting	UNFCCC – Lead Reviewer. Energy Expert. Supports Energy AFOLU sector teams
Mr Joseph Amankwa Baffoe	Environmental Protection Agency	Climate Change Unit, P. O. Box. M326 Accra – Ghana. Tel: 026-2373698 Email: jabaffoe@gmail.com	Inventory Contributor	QA/QC and IPPU Sector	UNFCCC Reviewer – IP Expert. Supports Waste and IPPU sector teams
Mr Kennedy Amankwa	Energy Commission	Energy Efficiency and Climate Change Division, Energy Commission Tel: 0242-261212 Email: kenamankwah@yahoo.co.uk	Lead, Energy Sector	Manages Energy Sector Inventory	UNFCCC Reviewer – Energy Expert
Mr Salifu Addo	Energy Commission	Strategic Planning and Policy Division. Energy Commissions Tel: 0244667145 Email: salifuaddo@yahoo.com	Member, Energy Sector/ Energy Statistics	Stationery combustion	Joined the team at the beginning of this inventory cycle.
Mr Kingsley 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 as part of the AFOLU sector	UNFCCC Reviewer – Agriculture Expert

Mrs Selina Amoah	Environmental Protection Agency	Manufacturing Industry Department. P. O. Box. M326, Accra – Ghana. Tel: 0265-086633 Email: selamoah@yahoo.co.uk	Lead, IPPU sector	Manages IPPU inventory	Works closely with the IPPU sector support expert.
Emmanuel Osae Quansah	Environmental Protection Agency	Head, Climate Change and Ozone Department. P. O. Box. M326, Accra Tel: 0244-633992 Email: eosaequansah@yahoo.com	Member, IPPU sector	Contributor, ODS/HFC Category	Joined the team at the beginning of the inventory cycle
Mrs Juliana Bempah	Environmental Protection Agency	Climate Change Unit P. O. Box. M326, Accra Tel: 0262-886872 Email: Juliabb21@yahoo.com	Alternate Lead, Waste sector	Co-Manages Waste Sector Inventory	UNFCCC – Lead Reviewer and Waste Expert
Dr Ernest Foli	Forestry Research Institute of Ghana,	Forest and Climate Change Division P. O. Box UP 63 KNUST, Kumasi Tel: 0262-714148	Member, AFOLU Team	Contributor, Land category	Chairperson of the REDD+ MRV team, inventory and Forest mensuration Expert
Mr Jacob Amoako	Forestry Commission	REDD+ Secretariat, Forestry Commission Tel: 0544-988606 Email: jacobamoako2012@gmail.com	Lead, Land category	Manages the Land part of AFOLU	GIS and MRV Expert
Mr Yakubu Mohammed	Forestry Commission	Manager, GIS Unit, RMSC. Tel: 020-8112123 Email: myakubu89@yahoo.com	Member, AFOLU Team	Contributor, Land category	Land-use mapping and GIS Expert
Mr Affum Baffoe	Forestry Commission	Manager, Production Unit, RMSC. Tel: 020-8138662 Email: Kofi1964ba@hotmail.com	Member, AFOLU Team	Contributor, Land category. Responsible for FRA reporting	Biomass Inventory and also responsible for FRA Reporting.
Dr Winston Asante	KNUST	Faculty of Renewable Natural Resource Tel: 024-3143375. Email: winstonasante@gmail.com	Member, AFOLU Team	Contributor, Land category	Biomass Inventory
Mr 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
Mr Larry Kotoe	Environmental Protection Agency	Oil & Gas Department, Environmental Protection Agency, P. O. Box. M326, Accra Tel: 0262-165575 Email: lkotoe@hotmail.com	Member, Energy Sector	Fugitive Emissions	UNFCCC Reviewer – Energy Expert

Mr Daniel Essel	Ministry of Transport	Senior Planning Officer, Policy Planning & Research Department Private Mail Bag Ministries Accra- Ghana Tel: 0207-581856 Email: desseldd@hotmail.com	Member, Energy Sector	Mobile Combustion	Transport Expert
Mr Joy Ankomah Hesse	Environmental Protection Agency	Built Environment Department, P. O. Box. M326, Accra – Ghana. Tel: 0246-676414 Email: ankojoyhesse@yahoo.com	Member, Waste Sector	Solid waste disposal category	
Mr Daniel Lamptey	Environmental Protection Agency	Climate Change Unit of EPA P. O. Box. M326, Accra – Ghana. Tel: 0242-214111 Email: danlampteya@gmail.com	Member, Waste Sector	Incineration and open-burning category	
Dr Richard Minkah	University of Ghana	Department of Statistics, Tel: 0245-032266 Email: rminkah@ug.edu.gh	Uncertainty Management		Rejoined the inventory team in 2020.
Mr Sampson Botchwey	Environmental Protection Agency	Environmental Information and Data Management Department, P. O. Box. M326, Accra – Ghana. Tel: 0243-182362 Email: omarook@gmail.com	Online database archive	Manages climate change data hub	Uploads all the datasets on the database. Computer Expert
Paula Edze	Energy Commission	Renewable Energy Department Tel: 0244487403 Email- paula.edze@gmail.com	Member, Energy Sector	Contribute to the Stationery combustion section – Other sectors	A new expert joined the inventory team in 2019
Aba Amissah Gyasi	Tema Oil Refinery	Tema Oil Refinery – Environment Department Tel: 0244-050699 Email - abaamissahgyasi@gmail.com	Member, Energy Sector	Contribute to the Stationery combustion – Oil refinery	A new expert joined the inventory team in 2019
Laura Zordeh	Energy Commission	Strategic Planning and Policy Division. Energy Commissions Tel: 0201421333 Email - Lzordeh@energycom.gov.gh	Member, Energy Sector	Contribute to the Stationery	A new expert joined the inventory team in 2019

1.6.4 Data Management System

1.6.4.1 Data collection

The EPA and the sector lead institutions are responsible for identifying and sourcing activity data and emission factors. Thus, EPA updates the data mapping matrix to guide the sector and prepare detailed sector-specific data needs, institutions to obtain the data from and the means to access them (Table 4). All publicly available data is compiled into a single folder for each sector. For the data not available in the public domain, the sector lead institution directly requests the data from the source with administrative support from the EPA. Suppose the sector lead institutions asked the EPA to help access the data. In that case, an official data request is made to the relevant institutions indicating the data format, the timeframe and the primary use of the inventory via a formal letter.

The EPA data request letters, especially those to industrial plants and waste treatment facilities, usually refer to the relevant provisions of the EPA, Act 4909, which permits the EPA to access information without hindrance. A confidential data request is treated separately according to the agreement between the data provider and the EPA. The collected data then goes through screening and documentation procedures to ensure proper indexing and backup. Initial technical and quality evaluation of the data before transmission to the working teams. All the details on the acquired data were documented and stored in the online database for archiving and retrieval.

1.6.4.2 Information technology setup

Ghana, through EPA, manages a climate data hub, excel file and the IPCC database file. The climate data hub is an online database that stores, analysis, and visualises inventory data. The data hub is the storage unit of the inventory data and helps streamline documentation and archiving protocols of the activity data and emission factors, reports and relevant publications. It has three sub-portals, of which one serves as the GHG inventory database.

The database hosts the following: (a) all inputs datasets from each sector; (b) datasheets for each sector; (c) emission estimates from the IPCC software for all sectors from 1990-to 2016, (d) IPCC 2006 software database, (f) completed QA/QC templates for sectors, and (g) all reports and documentation. The database is backed by IT infrastructure (cloud server running on Microsoft SharePoint) and is managed by a webmaster at EPA. Access to the database is differentiated from open access to restrict access. The public, institutional users, and inventory team have unlimited access to the database's front end through this IP address http://climatedatahubgh.com/gh/.

The users with unlimited access can only search for publicly available data and upload files through a webmaster's trail filter. There are two levels of restricted access. General access to the backend to the inventory data and institutional users who have the permission to (a) upload, (b) query, and (c) retrieve data from the database. Access to confidential data and publication of data on the database is restricted to the administrator. In 2015, some changes were made to the database to improve the overall performance, and these are as follows:

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[9] *http://extwprlegs1.fao.org/docs/pdf/gha13234.pdf*

- Reduce downtime and ensure efficient online services; replace the standalone server with a cloud server.
- Migrated to SharePoint operating system to frontend interface.
- Reconfiguration of the backend data model to add extra functionality.
- Design the landing page of the front end and add two new sub-portals on NDCs and GCF pipeline.
- Train the webmaster and the IT team on troubleshooting and quick fixes.

With support from the CBIT project, the EPA is currently embarking on a major overhaul of the database to respond to the requirement of the transparency framework. As a result, Ghana is implementing the following:

- Re-design the climate data hub system with functionalities running on an open-source platform.
- Develop operational guidance document detailing the protocols for data flow, system management (access, security, updates, upgrades), and roles profile.
- Establish virtual interactions between the re-designed climate change data hub with existing databases (such as Energy statistics, Forestry Monitoring System, Agriculture Facts and figures etc.)

Besides, EPA also manages a large set of inventory data in excel files. All sourced raw data are in excel format and arranged in folders per sector. The raw data is cleaned, processed, and saved in excel files labelled as "datasheet" for each inventory year. All the individual annual datasheet is labelled as "combined datasheet" for the entire inventory time series. The inventory estimation is done in the excel spreadsheet and the IPCC software. EPA has created the inventory calculation steps in an excel file with all the formulae in the 2006 IPCC Guidelines. So far, the EPA has calculation sheets for the energy and LULUCF sectors. The results calculation sheets are compared with the results from the IPCC software.

Ghana also uses the IPCC software as the primary platform for calculating GHG emissions. The IPCC software has a backend database file with data inputs and emission results for the sectors. The software allows unlimited access levels for every user to the database's relevant sections but not the entire database. Therefore, one "superuser login ID" was created for the inventory compiler to access the data for all the sectors. The sectors' team members were given "log-in credentials" 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, creating a "single inventory database file" containing all the sectors' sectors for the completed time series. The inventory data, individual results sheets and the database file were sent to the online database administrator for archiving and publication on the internet. All the GHG emission results for the inventory time series are combined into a single excel file labelled as "*analysis sheet*". Further computation on the aggregate estimate for the national sector figures and trends is done in the analysis sheet.

Table 4: Overview of main data platforms relevant for the sustainable preparation of national greenhouse inventory

No	Climate reporting relevant data				Remarks
	Platform	Type	Owner	Status	
1	Energy statistics[10]	Energy balance SDG 7 indicators	Energy Commission (EC)	Published online in pdf annually.	Activity data for the energy sector GHG inventory is obtained from the Energy SE4all quarterly bulletin, published relevant data on clean cooking and productive energy use. The data in the energy statistics is not fit for reporting on energy mitigation action. Besides, the publication of the energy statistics does not include metadata to allow for calculating uncertainties. The methodology for allocating fuel consumption per sector is outdated. Energy Commission acquires energy statistics data from several energy sector players. The EC retrieves data on energy-sector mitigation actions from the sectoral annual progress report and the national budget.
2	Annual Environmental Reports (AER) for the manufacturing industry	Resource use and management data	EPA	The AERs are not published online due to the protection of industrial confidentiality.	Resource use (electricity, water, fuel and raw materials), waste generation, discharge management, and emission control. The AERs are mandatory reports the industry submits to EPA in fulfilment of their requirements under the Environmental Assessment Regulation 1999 (LI, 1652). Individual printed AER is in the archives at EPA. Some of the data are in the Akoben database. Data on intervention (pollution control or waste management, energy efficiency) are also reported in the AER, but such data are not disaggregated in detail.
3	Agriculture Facts and Figures (AFAF)	Food balance Livestock data	Ministry of Food and Agriculture (MOFA)	AFAF is published online as a pdf, and when MOFA can do so.	MOFA typically reports data in the national annual budget, sector annual progress reports, and project reports. MOFA cannot publish the facts and figures annually and on time due to funding gaps. There are issues with data quality, data gaps and non-existing metadata. AFAF does not include data relevant for reporting on agriculture mitigation measures.
5	Vehicle database	Vehicle Statistics or traffic data	DVLA	Not published online, but data is collected annually	DVLA manages the vehicle registration and roadworthy certification for private and commercial vehicles. DVLA has permitted 28 private garages nationwide to conduct registration and inspection. The garage supplies the data to DVLA for archiving. The Customs Division of the Ghana Revenue Authority collects vehicle import data that is not publicly available.

[10] *http://energycom.gov.gh/planning/energy-statistics*

					No dedicated portal for vehicle traffic data (km distance, speed, fuel consumption) and transport mitigation interventions. Such interventions are in project reports, the national annual budget, and the annual sector progress report. The data can be obtained from the GCNET or an official letter to the Customs Division.
6	National Forest Management System (NFMS)	Land-use change Biomass stocks Biomass removals	Forestry Commission	NFMS is not fully operational. The relevant departments are implementing different aspects of FC.	The FC (REDD+ and RMSC) is working on different aspects of the operationalisation of the NFMS. The FC focuses on improving the mapping and visualisation of land use maps. REDD+ secretariat has established a safeguard. There is no central location to collect forest mitigation data. The data exist in project reports, national budgets or the sector's annual progress report. The annual progress reports on national forest plantation development[11].
7	Municipal waste management	Solid waste management, Domestic wastewater discharges and treatment	Ministry of Sanitation and Water Resources	No publicly available database for municipal solid and liquid waste	Data on municipal solid and liquid waste exist at the local district assembly. The local assemblies also work with private sanitation service providers who manage the waste on behalf of the assemblies. Some private sector companies manage their final disposal site or for the local assemblies. Data on waste sector mitigation actions are reported in annual progress reports or the national budgets. UNICEF regularly publishes the multi indicator cluster survey, which is also relevant for climate reporting in the waste sector. The main challenge with access to the solid waste data is the lack of Clarity in the chain of custody of data from the district assemblies to the central location at the Sanitation Directorate of the Ministry of Sanitation and Water Resources.
8	Ghana Living Standard Survey (GLSS)	Household energy consumption and waste management data	Ghana Statistical Service	Published online every five. Access to full data and report is on request or for sale to the general public.	The publication of the GLSS depends on the availability of funds. The GLSS 7 is the latest round and contains relevant data on energy and waste management for mitigation actions and activity data for the GHG inventory for household energy and domestic wastewater discharge and treatment.

[11] https://www.fcghana.org/userfiles/files/Plantation%20Annual%20Report/FC%20AnnualReport%202016.pdf

1.6.5 Summary of the inventory steps and data flows

In Ghana, the greenhouse gas inventory activities are mapped into six steps. It starts with the identification and sourcing of activity data and emission factors. The collection strategy differs for various data sources: public, private, academia, and surveys. For much of the government sources' data, the data comes from public institutions with the legal mandate to regularly publish relevant statistics for the inventory. The recognised public institution's administrative data were the preferred source because they are considered the official government records. The EPA already collects data from industry required under the Environmental Impact Assessment (EIA) regulation as part of their Environmental Management Plans (EMPs) under Legislative Instrument (LI) 1652, 1999. Industry-specific data on energy, waste, and production was obtained from the existing Annual Environmental Report templates.

Data from published scientific literature or national reports were also used in the inventory. Going by the data documentation plan, proper source records were referenced anytime data from national reports or peer-reviewed literature were used. The purpose was to ease the retrieval of the data and correctly cite it in the NIR. The data acquired from international sources varied. The strategy was to rely on data from verifiable sources, mainly the reputable internationally-recognised organisation. We limited the sourcing of international data to already known international bodies to all third parties to authenticate data during the technical reviews.

Once all the data from the multiple sources are assembled in a single location, we evaluate and process them in a usable format. The data processing usually involved identifying outliers (inaccurate data, out-of-range data), time-series gaps, incompatible format, and indexing all selected data. The next step is the selection of applicable methods. Except for a few cases where country-specific methodology methods or models were used, most of the methods used across the inventory were tier 1. The next step, recalculating the previous years' emissions, was carried out. New estimates were calculated for the added years. After the recalculations and the new estimates, trend, key category analysis and uncertainty are performed. The datasets (activity data, emission factors, sectoral datasheets, national totals, gas-by-gas, mandatory tables) were used to prepare the draft inventory report and third-party review. Finally, the datasheet and the report are uploaded to the climate change data hub for storage (Figure 2).

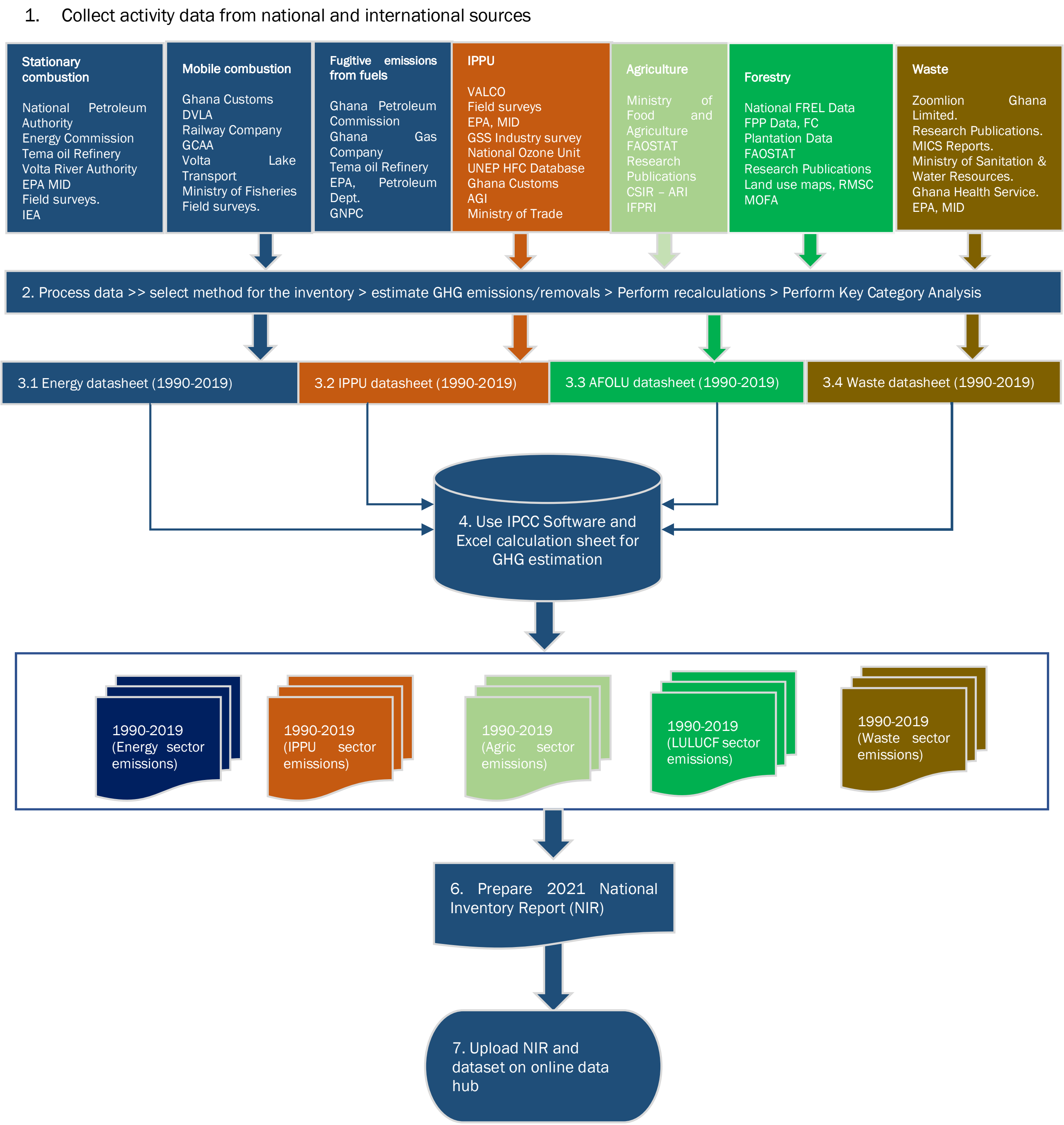

Figure 2: Summary of the inventory steps and data flows

1.6.5.1 General description of the inventory preparation steps

The inventory activities are grouped into the planning stage, the preparation stage, and the management stage. The selection of activities in each stage was informed by the guidance provided in the "UNFCCC Guidelines for the preparation of National Communications from non-Annex I Parties (Decision 17/CP.8) and UNFCCC Biennial Update Report Guidelines for Parties not included in Annex I to the convention (Decision 2/CP.17, paragraph 39-42 and Annex III)".

The submission deadline determined the scope of work, the timelines for each activity to the UNFCCC, and the number of resources allocated. The inventory activities have been summarised in the inventory cycle from the steps code 000-033 (Table 5). The inventory cycle starts with reviewing previous emission estimation methods and estimates, team formation, allocation of tasks, and the data collection and evaluation for the inventory compilation. The cycle completes with an independent external review.

Table 5: List of inventory tasks, timelines and the responsible entities

ID	Description Inventory Tasks	Timelines	Responsible entity
000	Review of preview estimates, procedures and improvement tasks.	November	All
001	Review and update the GHG Inventory Manual.	November	Inventory coordinator
002	Validate and distribute instruction manuals to the inventory team.	December	EPA & all sectors
003	Identify and form a sector team for the inventory sectors.	October	EPA
004	Formulate and sign MoU among inventory institutions.	November	Inventory Compiler and FC, EC, MID, EQ, CSD, BED
005	Organise the first meeting of the sector team.	November	
006	Train inventory teams to ensure readiness and distribute overall and sector inventory instruction.	November	
007	Organise kick-off meeting.	January	
008	Identify and review data sources, and select data, methodologies, and software.	February	Inventory compiler and FC, EC, MID, EQ, CSD, BED
009	Request data and conduct data evaluation and documentation.	April	
010	Set up sector data documentation and archiving files and start using them.	February	All Entities
011	Update the inventory website.	February	Inventory Compiler
012	Establish a data storage server.	December	CC
013	Quarter review meeting.	March	Inventory Compiler
014	Estimate GHG using datasheets, worksheets, and synthesis sheets.	May	FC, EC, MID, EQ, CSD, BED
015	All sector sheets and documentation were submitted to the national inventory compiler.	July	
016	Compile a draft inventory and submit it to the inventory coordinator.	July	Inventory compiler
017	Distribute draft inventory for internal review and submit comments to the inventory compiler.	August	Inventory compiler and QA/QC coordinator
018	Distribute source files (worksheets) and internal reviews to lead institutions.	August	Inventory compiler
019	Incorporate internal comments, observations and corrections.	August	FC, EC, MID, EQ, CSD, BED
020	Conduct the uncertainty assessment.	September	DoS, QA/QC and Inventory compiler
021	Compile the second draft of the inventory and revise worksheets.	September	Inventory compiler
022	Compile the second-order draft of composite inventory source files and submit the compiler and external reviewers to inventory.	September	
023	Submit second draft inventory for external review.	November	External reviewers
024	Submit all review comments to the inventory compiler.	November	
025	Quarter review meeting.	June	Inventory coordinator

026	Incorporate external comments and revise worksheets for all sectors.	November	FC, EC, MID, EQ, CSD, BED & inventory compiler
Repeat the process of the inventory estimates, worksheets and reports every September.			
027	Draft improvement strategy for each sector.	January	FC, EC, MID, EQ, CSD, BED
028	Collect all pertinent paper and electronic source materials from national archiving and documentation institutions for archiving archives.	December	CC & inventory compiler
029	Compile final Inventory and preparation of key category analysis.	December	Inventory compiler & FC, EC, MID, EQ, CSD, BED
030	Compile inventory improvement strategy due to inventory coordinator.	December	
031	Compilation of National Inventory Report (NIR).	December	Inventory Coordinator and FC, EC, MID, EQ, CSD, BED
032	NIR is ready for incorporation into National Communication and Biennial Update Report.	August	Inventory Compiler
033	Dissemination of NIR – Submission to UNFCCC. Make the inventory report to the public.	August	National Inventory Entity

Note: 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; CC –Climate change, EPA

1.7 Description of methodologies and data sources

The preparation of the national inventory involved a series of iterative steps from data collection, data processing, GHG estimation and reporting. The net emissions estimate relates to the activity data for key economic activities and emission factors published in scientific studies. The emissions/removals are calculated for a specific gas for a given inventory year using the Activity Data (AD) and the Emission Factor (EF). The methods are consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and in line with international best practices. Tier 1 IPCC methodology and default emission factors have been mostly used in the inventory. The current data does not allow a higher-tier or model-based method. In the current inventory, high-tier methods have been used in Land (3B), IPPU (2C), 1A and solid waste disposal (4A).

1.7.1 Methods for estimating the emissions/removals

The methodology and dataset used in the current inventory are an improvement on the previous inventories. In the NIR4, Ghana reported shifting to using the 2006 IPCC Guidelines instead of the 1996 Guidelines. As a result, Ghana has incorporated new country-specific activity data and emission factors mostly for the new inventory years and the period recalculations were performed. In the NIR5 inventory, a mixed method was adopted. It includes the use of tier 1 and tier 2 methods depending on the availability of adequate data to satisfy the level of detail for each method. A detailed elaboration of selected methods is provided under each sector of the NIR. In the coming years, Ghana will prioritise collecting additional country-specific data to enable the use of high-tier methods to estimate emissions/removals for key categories. In this NIR5, Ghana has adopted the GWP figures in the AR4 for reporting the emissions in CO_2 equivalent instead of SAR values.

1.7.1.1 Selection of methods

Estimating emissions/removals in the categories were based on the methods described in the 2006 IPCC Guidelines. The selection of the methods was guided by the decision tree illustrated in Figure 3. Generally, tier 1 IPCC methodology was applied to most sectors, except in cases where available national data allowed us to adopt a higher tier. For example, facility-level data from Volta Aluminium Company (VALCO) enabled tier 2 methodology to estimate emissions from aluminium production and solid waste disposal.

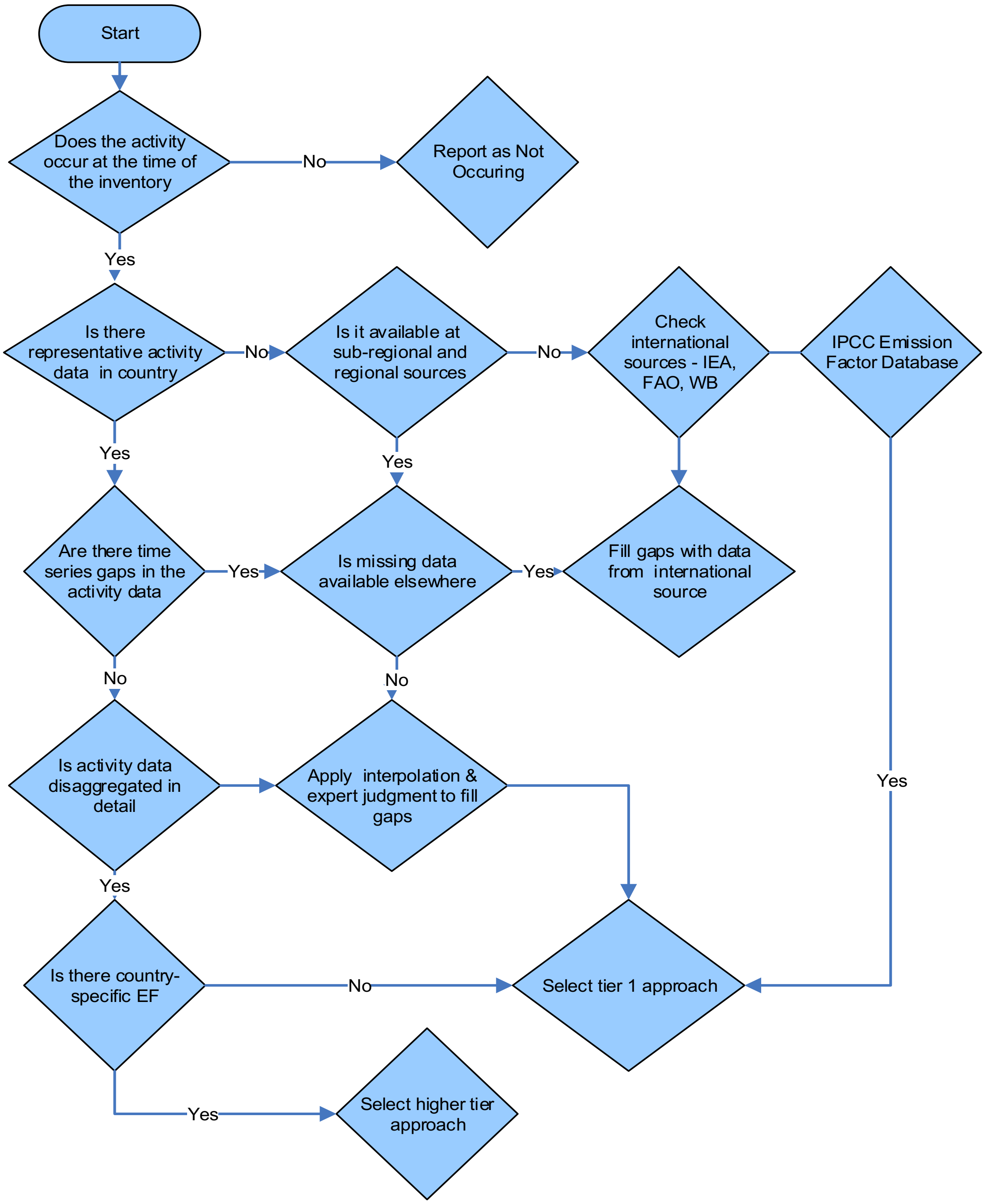

Figure 3: Snapshot of the steps followed for choosing methods for the inventory based on the modified IPCC decision tree for the selection of Methods

1.7.2 Description of Inventory Data Sources

1.7.2.1 Selection of emission factors

The emission factors have been collected from country-specific and regional/international sources. The Country-Specific (CS) EFs were from stationary industrial plants (plant-specific such as VALCO) and land categories (forestland, grassland, cropland). The default emissions factors were obtained mainly from the IPCC Emission Factor Database (EFDB)[12] and EMEP/EEA or EMEP/ CORINAIR[13] air pollutant emission inventory guidebook. We also relied on emission factors published in regional and international peer review studies. In selecting the EFs, the following factors were considered: (a) representativeness of the EFs for a set of facility-level plants, ecological zone or the production system, and (b) applicability of the regional and international EFs to the unique country conditions.

Generally, the default emissions factors from the IPCC EFDB and EMEP/EEA were commonly used in the inventory because of the non-existing country-specific emission factors. The use of the default EF per se does not render the calculated emissions/removals inaccurate but has high uncertainty. When country-specific or region-specific emission factors are available for the same activity, the country-specific factors were used instead of the IPCC default figures. The reason was that the country-specific factors tend to give a more accurate estimate of the emissions/removals associated with the activity than the global factors. Table 7 shows the overview of methodological tiers and the emission factors used according to the category and gases. The list of specific EFs used has been provided under the section on the methodology for the categories below.

Table 6: List of categories, methodological tiers and emission factors on the gas-by-gas basis

Category		CO_2		CH_4		N_2O		PFCs		SF_6		HFCs		Non-GHGs[14]	
		Meth	EF	Meth	EF	Meth	EF	Meth	EF	Meth	EF	Meth	EF	Meth	EF
1.A1	Energy Industries	T1	D	T1	D	T1	D							T1	D
1.A2	Manufacturing Industries and Construction	T1	D	T1	D	T1	D							T1	D
1.A3	Transport	T1	D	T1	D	T1	D							T1	D
1.A4	Other Sectors	T1	D	T1	D	T1	D							T1	D
1.B1	Solid Fuels			NO	NO									NO	NO
1.B2	Oil and Natural Gas			T1	D									NE	NE
2. A	Mineral Products	T1	D											NE	NE
2. B	Chemical Industry	NO	NO	NO	NO	NO	NO							NO	NO
2.C	Metal Production	T2	PS	NE	NE	NE	NE	T2	PS	NE	NE			NE	NE
2.D	Non-Energy Products from Fuels and Solvent Use	T1	D											NE	NE
2E	Electronics Industry							NO	NO	NO	NO	NO	NO	NO	NO

[12] *https://www.ipcc-nggip.iges.or.jp/EFDB/main.php*

[13] https://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

[14] *Applies to gases classified as non-GHG SLCP and indirect GHG such as Black Carbon (BC), Nitrogen Oxides (NOx), Particulate Matter (PM2.5), Carbon Monoxide (CO) and Non-methane volatile organic compounds (NMVOCs).* SO_2 *is not estimated due to the lack of appropriate factors.*

2. F	Product Uses as Substitutes for Ozone Depleting Substances											T1	D		
2. G	Other Product Manufacture and Use									NE	NE				
3.A	Livestock			T1	D										
3.B	Land	T2	CS											T1	D
3C	Aggregate sources and non-CO_2 emissions sources on land	T1	D	T1	D	TI	D							T1	D
3D	Other														
4. A	Solid waste disposal			T2[15]	D	T1	D							T1	D
4. B	Biological Treatment of Solid Waste			TI	D	T1	D							NE	NE
4. C	Incineration and Open Burning of Waste	T1	D	TI	D	T1	D							T1	D
4.D	Wastewater Treatment and Discharge			T1	D	T1	D							NE	NE

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. The ash-colour-fill cell indicates the gas emission/removal does not apply to the corresponding category.

1.7.2.2 Sources of activity data

Activity data is one of the primary data points for the inventory. It contains energy balance, supply, and consumption data for different fuels and demand sectors. They are collected from several national and international institutions and scientific literature. The majority of the AD were obtained from existing data platforms managed by government institutions such as Energy statistics (Energy Commission), Agriculture Facts and Figures (Ministry of Food and Agriculture), National Forest Management System (Forestry Commission), Vehicle statistics (Driver Vehicle and Licensing Authority - DVLA), Industry environmental statistics (EPA). The dataset format differs depending on the source and is published at varying frequencies. For instance, the energy statistics are published online on the URL address http://www.energycom.gov.gh/planning/data-center/energy-statistics.

The Energy Commission relies on data supplied by the oil refinery, electricity-producing companies, National Petroleum Authority (NPA), Petroleum Commission and the Ghana National Gas Company (GNGC). The Energy Commission also collects data from the Ghana Statistical Service (GSS) and uses survey data. The energy statistics data was the primary source of the AD for many of the sub-categories under the energy sector 1A1, 1A2, 1A3 and 1B. Data on vehicle population, car traffic, and circulation patterns were from the Ministry of Transport and DVLA.

[15] This is because country-specific activity data and some default parameters used in the inventory as recommended under section 3.2.1 and figure 3.1 (Decision tree for CH_4 emissions from Solid Waste Disposal sites) of the 2006 IPCC Guidelines.

The AD sources for the IPPU sector categories came from various sources. Most of them were sourced from the facility statistics collected through official requests. Others are obtained from the Environmental Management Plans (EMPs) and Annual Environmental Reports (AERs) companies submitted to the Environmental Protection Agency as per the Environmental Permit Conditions and Regulation 25 of LI 1652. The activity data were also retrieved from the Environmental Performance Rating and Public Disclosure Database hosted by the EPA and the Industry Survey published by the GSS and the EPA.

The IPPU inventory team collected data on HFCs consumption refrigeration air-conditioners from the national survey on HFC conducted by the National Ozone Unit at the EPA. The Ministry of Food and Agriculture's Statistics Research and Information Directorate (SRID) publishes the Agric Facts and Figures. Usually, whenever they put out figures, it covers several years other than the publication year. They make the dataset available to the public on the web[16]. The current online version of the Facts and Figures was published, covering data from 1999 to 2009. The SRID made the latest version of the facts and figures to the inventory team covering 2016 though they are not published online. The Facts and Figures is the primary activity data source for the 3A and selected categories under 3C.

The primary source of the AD for Land category (3B) is the National Forest Management System (NFMS), hosted by the REDD+ Secretariat of the Forestry Commission. Though the full version of the NFMS has not been deployed, most of the requisite data have been pulled together at a central point at the Forest Commission during the REDD+ National Forest Reference Level (FREL) preparation UNFCCC. Having the dataset at Forest Commission made access to the land representations dataset far more accessible.

The data on waste management was not well organised at a single location, and documentation is sparse. Mostly, the AD for the Waste sector was dispersed among several district assemblies. So, the waste inventory team consulted various data sources from government reports, scientific literature, data from environmental sanitation service companies and the GSS to assemble all the necessary data. Alternative reliable data from international organisations such as FAO, IEA, and the World Bank without national data were used. Table 7 presents the data used in the inventory.

[16] http://mofa.gov.gh/site/wp-content/uploads/2011/04/mofa_facts_and_figures.pdf

Table 7: Sources of activity data, format and the principal data providers

Sector		Data Type	Data Sources	Principal Data Providers	Remarks
1. Energy Sector					
1.A1	Energy Industry	Fuel types, supply, and consumption: • Crude oil production, imports, exports and use for electricity generation and as refinery inputs. • Natural gas production is processed, imported and used as fuel for electricity generation. • Production, imports, export and petroleum products production. • Auto production of selected petroleum products in the refinery, the gas processing plants, and the oil fields.	National Energy Statistics. Tema oil refinery material balance. National Energy Plan. International Energy Agency Database. Oil and Gas Production Figures. Ghana National Gas Company Data.	Energy Commission. National Petroleum Authority. Tema Oil Refinery. Thermal Electricity Generation Utility Companies (VRA, Sunon Asogli, Takoradi International Company TICO and other independent power producers. Ghana National Gas Company Limited. National Petroleum Commission. International Energy Agency.	National Energy Statistics is published online in April every year. TOR material balance is updated every year but not published. TOR data is administrative data requests through the Energy Commission. Oil and Gas Production figures are published every month by the Petroleum Commission
1.A2	Manufacturing Industry and Construction	Industrial sectors and their fuel consumption: fuel types and consumption; quantity of fuel used as feedstock; a quantity of fuels for non-energy use.	National Energy Statistics, 2018. Industry survey data, 2013. National Industry Census, 2003 IEA	Energy Commission. Manufacturing Industry Department of the Environmental Protection Agency. Ghana Statistical Service.	The fuel allocation per industry sector share is based on the fuel shares in the Energy' Commission's SNEP dataset. There are plans to survey to improve the existing data.
1.A3	Transport	Fuel, vehicle and traffic information	Vehicle registration database.	Energy Commission. Environmental Protection Agency. Driver Vehicle Licensing Authority	Yearly vehicle population figures are sourced from the yearly release of administrative data on

		Fuel types and consumption by vehicles of different years of manufacture and technology class. International and domestic Aviation Rail and Navigation, Number of Registered Vehicles, Vehicle Types	Transport sector study reports. Petroleum product sales data. Railway fuel consumption data. Water transport fuel consumption. Premix fuel consumption data.	Oil Marketing Companies (particularly Shell Ghana Limited and Total Ghana Limited). Ministry of Transport, Ghana Railway Company. Volta Lake Transport Company. Ghana Bunkering Services. Premix Committee at the Ministry of Fisheries and Aquaculture Development	vehicle registration, roadworthy certification figures from DVLA and Vehicle import figures from the GcNET under Ghana Customs. There are plans to liaise with the newly established garages involving vehicle inspections to collect additional vehicle odometer readings and measured emission figures.
1.A4	Other Sectors	Quantities of solid and liquid fuel consumption per category.	National Energy Statistics, National Energy Plan, National Census Report, Ghana Living Standard Survey Report	Energy Commission Ghana Statistical Service	The fuel allocation per industry sector is based on the fuel shares in the Energy Commission's SNEP dataset. There are plans to survey to improve the existing data.
1. B	Fugitive emissions from fuels	Quantities of wet production, quantities of reinjected, quantities of gas flared and gas consumed on site. Quantities of gas exported to Ghana National Gas Company.	Oil Exploration and Production. Gas transmission lines. Oil refinery data in the energy statistics.	Ghana National Petroleum Corporation. Petroleum Commission. Oil Production Companies. Environmental Protection Agency. Tema Oil Refinery.	Oil and Gas Production figures are published every month by the Petroleum Commission.
2. Industrial Process and Product Use Sector					
2. A	Mineral Industry	Industrial production and Plant-specific emission factors	Environmental Reports. Environmental Performance Rating and Public Disclosure Database. Industry Survey. Industrial data from facilities.	Volta Aluminum Company Limited Tema steelworks Aluworks Limited Environmental Protection Agency	No industry-specific data is published. Data are officially requested from the industry and the Environmental Impact Statements.
2.C	Metal Industry				
2.D	Non-Energy Products from Fuels and Solvent Use	Amount of non-energy use of diesel and kerosene			

2F	Product Uses as Substitutes for Ozone Depleting Substances	Quantities of different types of refrigerants imports and volumes sold per year to the refrigeration and air conditioner.	National survey on HFC consumption	National Ozone Office, Environmental Protection Agency	One-time national survey on HFCs by the Ghana EPA
3. Agriculture, Forestry and Other Land use					
3.A1 and 3.A2	Enteric Fermentation & Manure Management	Animal population, Animal attribute (age, sex and weight classes). Fractions of manure management practices.	Agriculture Facts and Figures. FAOSTAT. Expert Judgment.	Ministry of Food and Agriculture – SRID. UN FAO. AFOLU Team	Agriculture Facts and Figures is published by the Ministry of Food and Agriculture online annually. The metadata for the Agriculture Facts and Figures are not available. The team consider the lack of metadata an area for improvement.
3.B1	Forest land	Land-use maps, land-use change map, land-use change matrix.	Forest Preservation Program, 2012, National Forest Reference Level, 2017.	Forestry Commission, Ghana	Land-use maps are not published at any scheduled time. They are generally produced as part of projects.
		Biomass estimates for 5 IPCC pools (AGB, BGB, deadwood, herb, litter and soil).			Biomass estimates across all the ecological zones were produced as part of the Forest Preservation Programme in 2014. There are scheduled updates.
		Climate zones, soil stratifications and ecological zone maps.	IPCC database	IPCC Forestry Commission	One-time GIS layers for climatic zones, soil classification and ecological zones exist.
		Industrial round wood.	RMSC, FAOSTAT	Forestry Commission FAO	Industrial round wood harvest figures are available every quarter at RMSC but not published online. It is considered an administrative request via an official letter.
		Wood fuel production.	Energy Statistics	Energy Commission	Total wood fuel supply is published in the Energy Statistics every year.

		Areas affected by fires.	REDD+ National Forest Reference Level, 2017.	Forestry Commission	One-time GIS map produced by Forestry Commission when developing the REDD+ FREL
3.B2	Cropland	Land-use maps, land-use change map, land-use change matrix.	Forest Preservation Program, 2012, National Forest Reference Level, 2021.	Forestry Commission	Land-use maps are not published at any scheduled time. They are typically produced as part of projects.
		Biomass estimate for 5 IPCC pools (AGB, BGB, deadwood, herb, litter and soil).			Biomass estimates across all the ecological zones were produced as part of the Forest Preservation Programme in 2014. There are scheduled o updates
		Climate zones, soil classification and ecological zone maps.	IPCC database	IPCC	One-time GIS layers for climatic zones, soil classification and ecological zones exist.
3.B3	Grassland	Land-use maps, Land-use change map, and change matrix.	Forest Preservation Program, 2012, National Forest Reference Level, 2021.	Forestry Commission	Ditto
		Biomass estimate for 5 IPCC pools (AGB, BGB, deadwood, herb, litter and soil)			Ditto
		Climate zones, soil classification and ecological zone maps	IPCC database	IPCC	Ditto
3.C1	Biomass burning	Areas affected by fire in cropland, forestland and grassland	National Forest Reference Level, 2021.	Forestry Commission	Ditto
		Mass of fuel available for burning.	Forest Preservation Program, 2012 National Forest Reference Level, 2021.	Forestry Commission	Derived from biomass figures for each land-cover type.

3.C3	Urea application	Annual Urea consumption figures	Agriculture Facts and Figures	Ministry of Food and Agriculture – SRID	Agriculture Facts and Figures is published by the Ministry of Food and Agriculture online annually.
3.C4	Direct N_2O emissions from managed soils	Annual generic NPK consumption	Agriculture Facts and Figures	Ministry of Food and Agriculture – SRID,	Ditto
3.C5	Indirect N_2O emissions from managed soils	Annual crop production in tonnes per annum	Agriculture Facts and Figures	Ministry of Food and Agriculture – SRID	Ditto
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 – SRID	Ditto
		Fractions of manure management practices	Expert Judgment	AFOLU Team	Ditto
3.C7	Rice cultivation	Annual rice production areas	Agriculture Facts and Figures	Ministry of Food and Agriculture – SRID	Ditto
		Proportions of annual rice production area under rain-fed irrigated and upland systems	National Rice Development strategy	Ministry of Food and Agriculture - SRID	Ditto
4. Waste					
4A	Solid Waste Disposal	Waste Generation, Population Figures, Composition, amounts of waste deposited, means of disposal and their various percentages	Published national reports. Ghana Statistical Service. 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), and NGOs Academia (Civil Engineering Department, KNUST). Second National Communication Report.	Solid waste data is not at a single location. Documentation is poor. Relied on multiple reports, literature and scattered data at the assemblies. A major national survey is needed.

4B	Biological Treatment of Solid Waste	The 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	Ditto
4C	4C.1 Waste Incineration	Amount and types of 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. Ghana Health Service Facts and Figures. Expert Judgment by the Waste Team.	Data on incineration is scanty and scattered. The inventory team relied on different data sources. A major national survey is needed.
	4C.2 Open Burning of Solid Waste	Population, the proportion of population burning waste, duration of burning in the number of days per year, and the 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	Data on open burning is not adequate. The inventory team relied on different data sources. A major national survey is needed.
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 Service. 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.	Data on domestic wastewater are scattered. The inventory team relied on different data sources. A major national survey is needed.
	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 was collected during the national survey. Environmental Management Plans. Expert Judgment by Waste team.	The quality of the survey data and the Environmental Management Plans for Industries need to be improved.

1.8 Key Categories Analysis

Ghana performed Key Category Analysis (KCA) to identify the inventory activities that significantly contribute to the emissions/removals for a given year. The 2006 IPCC Guidelines provide guidance and a mathematical approach for the KCA. The guideline emphasises that the 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. This inventory identifies key categories using the tier 1 level and trend assessments, as recommended in the 2006 IPCC Guidelines. This approach identifies sources/removals that makeup 95% of the total emissions or 95% of the inventory trend. The methods used to identify the key categories were the level assessment for 2019 and trend assessment between 2012 and 2019. The results of the key category analysis are presented with and without the LULUCF category.

1.8.1 Key category analysis results

The 2019 Level Assessment (L) produced twenty-two key categories with net emissions of 49.2 $MtCO_2e$, representing 82.3% of the total national greenhouse gas emissions. Of the twenty-two identified key categories, thirteen were sources of CO_2 emissions and contributed most to the key category emissions and followed by N_2O (four activities) and CH_4 (three activities) (Table 8). The rests were HFCs and PFCs, with one each.

Table 8: Level assessment key category list in 2019

IPCC Category	Gas	Contribution to level	Cumulative
3.B.2.b - Land Converted to Cropland	CO_2	27.33%	27.33%
1.A.3.b - Road Transportation	CO_2	12.83%	40.16%
1.B.2.b.ii - Flaring	CO_2	11.29%	51.45%
1.A.1.a.i - Electricity Generation	CO_2	8.88%	60.33%
3.C.4 - Direct N_2O Emissions from managed soils	N_2O	6.68%	67.01%
3.A.1 - Enteric Fermentation	CH_4	4.63%	71.64%
3.B.3.b - Land Converted to Grassland	CO_2	3.72%	75.36%
4.D - Wastewater Treatment and Discharge	CH_4	2.44%	77.80%
3.B.1.a - Forest land Remaining Forest land	CO_2	2.28%	80.07%
3.B.1.b - Land Converted to Forest land	CO_2	2.13%	82.20%
4.A.1 - Managed Waste Disposal Sites	CH_4	1.80%	84.00%
1.A.2 - Manufacturing Industries and Construction	CO_2	1.74%	85.74%
3.C.5 - Indirect N_2O Emissions from managed soils	N_2O	1.72%	87.46%
1.A.1.c.ii - Other Energy Industries	CO_2	1.46%	88.92%
3.B.5.b - Land Converted to Settlements	CO_2	1.03%	89.95%
2.F.1 - Refrigeration and Air Conditioning	HFC	0.85%	90.80%
4.D - Wastewater Treatment and Discharge	N_2O	0.83%	91.63%
1.A.4.b - Residential	CO_2	0.82%	92.46%
2.C.3 - Aluminium production	PFC	0.75%	93.20%
2.A.4.d - Other (please specify)	CO_2	0.71%	93.91%
3.C.3 - Urea application	CO_2	0.58%	94.50%
3.C.1 - Emissions from biomass burning	N_2O	0.56%	95.05%

There are seventeen key categories without the LULUCF category's emission, with a total emission of 41.7 $MtCO_2e$. Carbon dioxide sources dominate, with eight activities mainly in the energy sector. The largest sources of CO_2 emissions in the level key categories are road transport, flaring oil and gas production and electricity production. For trend assessment (T) KCA, twenty sources and removals have been identified in Table 9.

Table 9: List of key categories using trend assessment for the period 2016-2019

IPCC Category	Gas	Base year estimate (Ex,o)	Latest year estimate (Ex,t)	Contribution to trend (%)	Cumulative Total of trend (%)
1.B.2.b.ii - Flaring	CO_2	1,240.2	7,895.1	29.0	29
3.B.2.b - Land Converted to Cropland	CO_2	19,115.2	19,115.2	23.3	52.3
1.A.1.a.i - Electricity Generation	CO_2	3,328.7	6,209.9	9.1	61.4
3.B.1.a - Forest land Remaining Forest land	CO_2	(2,708.9)	(1,591.1)	8.4	69.8
1.A.1.c.ii - Other Energy Industries	CO_2	198.41	1,018.7	3.5	73.3
3.B.3.b - Land Converted to Grassland	CO_2	(2,600.8)	(2,600.8)	3.2	76.5
4.A.1 - Managed Waste Disposal Sites	CH_4	507.1	1,258.4	2.8	79.3
4.A.2 - Unmanaged Waste Disposal Sites	CH_4	660.4	314.6	2.4	81.7
1.A.2 - Manufacturing Industries and Construction	CO_2	1,243.3	1,217.8	1.6	83.3
2.F.1 - Refrigeration and Air Conditioning	HFC	750	593.8	1.6	84.9
3.C.3 - Urea application	CO_2	48.6	406.6	1.6	86.5
2.C.3 - Aluminium production	PFC	661.5	521.6	1.5	87.9
1.A.3.b - Road Transportation	CO_2	7,309	8,971.5	1.3	89.3
3.C.1 - Emissions from biomass burning	N_2O	505.4	389.7	1.2	90.4
3.B.1.b - Land Converted to Forest land	CO_2	(1,374.1)	(1,491.2)	1.1	91.6
3.C.1 - Emissions from biomass burning	CH_4	488.4	382.1	1.1	92.7
3.C.4 - Direct N_2O Emissions from managed soils	N_2O	3,514.4	4,670.1	1	93.7
3.A.1 - Enteric Fermentation	CH_4	2,397.4	3,239.3	0.93	94.6
3.B.5.b - Land Converted to Settlements	CO_2	719.9	719.9	0.88	95.5

In the same vein, when both L and T assessments are put together, there are seventeen sources/removals with CO_2 emission sources in the majority, followed by CH_4 and then N_2O (Table 10). Some of the key categories that emerged from L and T assessments are:

- 3.B.2.b - Land Converted to Cropland
- 1.A.3.b - Road Transportation
- 1.B.2.b.ii – Flaring
- 1.A.1.a.i - Electricity Generation
- 3.C.4 - Direct N_2O Emissions from managed soils
- 3.A.1 - Enteric Fermentation
- 3.B.3.b - Land Converted to Grassland
- 3.B.1.a - Forest land Remaining Forest land
- 4.A.1 - Managed Waste Disposal Sites
- 1.A.2 - Manufacturing Industries and Construction

Table 10: Status of level and trend key category assessment

Category	Level assessment		Trend assessment	
	L	Gas (%*)	T	Gas%**)
3.B.2.b - Land Converted to Cropland	L	CO_2 (27.3%)	T	CO_2 (23.3%)
1.A.3.b - Road Transportation	L	CO_2 (12.8%)	T	CO_2 (1.3%)
1.B.2.b.ii - Flaring	L	CO_2(11.3%)	T	CO_2 (29%)
1.A.1.a.i - Electricity Generation	L	CO_2 (8.9%)	T	CO_2 (9.1%)
3.C.4 - Direct N_2O Emissions from managed soils	L	N_2O (6.9%)	T	N_2O (1%)
3.A.1 - Enteric Fermentation	L	CH_4 (4.6%)	T	CH_4 (0.93%)
3.B.3.b - Land Converted to Grassland	L	CO_2 (3.7%)	T	CO_2 (3.2%)
4.D - Wastewater Treatment and Discharge	L	CH_4 (2.4%)		
3.B.1.a - Forest land Remaining Forest land	L	CO_2 (2.3%)	T	CO_2 (8.4%)
3.B.1.b - Land Converted to Forest land	L	CO_2 (2.1%)	T	CO_2 (1.1%)
4.A.1 - Managed Waste Disposal Sites	L	CH_4 (1.8%)	T	CH_4 (2.8%)
1.A.2 - Manufacturing Industries and Construction	L	CO_2 (1.74%)	T	CO_2 (1.6%)
3.C.5 - Indirect N_2O Emissions from managed soils	L	N_2O (1.72%)		
1.A.1.c.ii - Other Energy Industries	L	CO_2 (1.46%)	T	CO_2 (3.5%)
3.B.5.b - Land Converted to Settlements	L	CO_2 (1.03%)	T	CO_2 (0.88%)
2.F.1 - Refrigeration and Air Conditioning	L	HFC (0.85%)	T	HFC (1.6%)
4.D - Wastewater Treatment and Discharge	L	N_2O (0.83%)		
1.A.4.b - Residential	L	CO_2 (0.82%)		
2.C.3 - Aluminium production	L	PFC(0.75%)	T	PFC(1.5%)
2.A.4.d - Other (please specify)	L	CO_2 (0.71%)		
3.C.3 - Urea application	L	CO_2 (0.58%)	T	CO_2 (1.6%)
3.C.1 - Emissions from biomass burning	L	N_2O (0.56%)	T	N_2O (1.2%)
4.A.2 - Unmanaged Waste Disposal Sites			T	CH_4 (2.4%)

** percentage contribution to levels ** percentage contribution to the trends*

1.9 Quality Assurance/Quality Control Procedures

The updated information on the Quality Assurance/Quality Control (QA/QC) protocol for the inventory covers the following areas:

- QA/QC procedures across the inventory highlight its current state, institutional roles, general and specific procedures, challenges, and improvement strategies.
- Status of addressing the technical comments during the informal reviews and the ICA process.

1.9.1 Summary of QA/QC procedures

The QA/QC is an integral part of the national system, and the practices are broadly consistent with the good practices in the 2006 IPCC Guidelines. The documentation and the implementation of the QA/QC procedures are reported based on the US template EPA QA/QC measures. Inventory teams used the template to document the QA/QC activities in the inventory. The Forestry Commission has also prepared and adopted 12 Standard Operating Procedures (SOPs) to guide the land category's inventory activities. The SOPs were useful in the planning and designing of the data collection techniques for activity data and emission factors (biomass inventory)[17]. Despite some progress in the improvements of the QA/QC, there were still challenges in the areas relating to:

- insufficient data handling protocols in the treatment of incompatible data formats,
- secondary data without metadata,
- detection of data errors and outliers, and
- data restriction and confidential data.
- non-standardised application of experts' judgement,
- the use of tier 1 or default emission factors for key categories and
- the application of generic approaches to address sector-specific problems.

Ghana has also adopted a country-specific QA/QC plan and GHG inventory manual to address the challenges. The GHG plan clearly articulates the inventory steps, institutional responsibilities and timelines. The plan would also be used to inform the training of existing experts. The QA/QC manual[18] seeks to streamline and formalise existing QA/QC procedures and communicate with a clear set of objectives to the inventory team in line with the 2006 IPCC Guidelines. These procedures ensure that the inventory system and its estimates are more transparent, credible and defensible.

1.9.2 QA/QC institutional roles and responsibilities

According to the QA/QC plan, the EPA was tasked to play a facilitative role in implementing QA/QC measures and coordinates jointly with the QA/QC lead institution to ensure that the sector experts adhere to the plan. However, the Mathematics Department of KNUST could not be desirably engaged in the inventory process. Therefore, the EPA doubled as the QA/QC lead and performed the following broad functions:

- ensure that the sector teams follow the QC checklist,
- collect and review the completeness checklist submitted by the sector inventories;

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[17] http://fcghana.org/userfiles/files/REDD%2B/Ghana%20MRV%20Final%20Report%20(ID%2067024).pdf.
[18] http://www.gh.undp.org/content/dam/ghana/docs/Doc/Susdev/LECBP_QAQC%20%20Plan_Ghana_final.pdf

- facilitate all technical reviews of the inventory both in-country and at the international level,
- organise training programmes on quality-related topics.

Nevertheless, the real QA/QC measures were implemented in the sector inventories, so the sector team leads were responsible for ensuring adequate QA/QC procedures were thoroughly implemented in the inventory and backed by verifiable documentation.

1.9.3 Tier 1 QC protocols

In the inventory, Ghana implemented tier 1 QC procedures which covered checks, documentation and archiving practices the inventory compilers routinely used throughout the inventory cycle. The list of the QC procedure followed in the inventory is in Table 11.

Table 11: List of QC procedures followed in the inventory

QC Tasks	Details of QC Tasks	Responsibility
Internal consistency	Ensured that the total GHG emissions equal the sum of the individual emissions from the sectors and categories.	EPA
	Confirmed the total GHG emissions equal the sum of the emissions by gas.	EPA
	Ensured that parameters used in multiple categories (e.g., livestock population) were consistent across categories.	EPA
	Confirmed that the emissions data is reported consistently with the calculation tables in the Non-Annex 1 National Communications Reporting Guidelines.	EPA
	Confirmed that the selection and application of the estimation methods were consistent with the 2006 IPCC Guidelines.	EPA
Documentation	Created back-ups of all documentation in hard and soft copies and uploaded files to the central storage facility online.	All sectors Webmaster
	Moved all files and documentation to an "online climate change data hub".	Webmaster
Checks	Checked that assumptions and criteria for the selection of activity data and emission factors are documented	EPA
	Check that parameters and emission/removal units are correctly recorded, and appropriate conversion factors are used.	EPA
	Checked for transcription errors in data input and reference.	EPA
	Checked methodological and data changes that led to recalculations.	EPA
	Checked that emissions/removals are calculated correctly.	EPA
	Compared current inventory estimates to previous estimates, if available. If significant changes or departures from expected trends are significant, re-check estimates and explain any difference. Significant changes in emissions or removals from previous years may indicate possible input or calculation errors	EPA
	When preparing summaries, check that emissions/removals data are correctly aggregated from lower reporting levels to higher reporting levels.	EPA
	Checked that data in tables are the same as the calculation in spreadsheets and the text.	EPA
	Check if any unusual or unexplained trends are noticed for activity data or other parameters across the time series.	EPA

1.9.4 QA Procedures

Quality Assurance (QA) procedures are essential for the overall QA/QC procedures. Since QA allows the experts who have not been directly involved in the inventory to scrutinise the inventory system and the emissions to provide review comments. Ghana has undertaken extensive technical reviews of the inventory, and afterwards, the status of addressing the comments is documented with the issue-tracking template.

1.9.4.1 Third-party review of the inventory

During the preparation of the NIR4, Ghana participated in the first-ever in-country QA/QC workshop organised by the UNFCCC. QA/QC workshop produced improvement lists that Ghana included in the improvement plan. The GHG inventory chapter of the BUR was reviewed by the list of independent experts shown in Table 12. The review allowed the team to scrutinise and uncover technical issues in applying methodologies, selecting activity data, and developing and selecting emission factors by the IPCC guidelines.

Table 12: List of Experts for External Review of National Greenhouse Gas Inventory

Reviewer	Affiliation and organisation	Sector/Gas	Comments
Akyamfour Asafo Boakye Agyemang-Bonsu		All sectors	Independent expert review
Dr Chris Malley	Stockholm Environment Institute, University of York.	SLCP sectors	Under the CCAC SNAP Initiative
Brian Okoth	UNEP/UNDP Global Support Programme (GSP)	All sector	Collaboration with UNEP

All the sector inventory results were subjected to "internal disclosure and assessment" by the relevant Ministries, Department and Agencies (MDAs). The "internal disclosure assessment" was done through two "reality check" meetings that were held at the various MDAs to collect inputs on (a) policy implications of the sector estimates and (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.

1.9.4.2 Managing technical review comments

As part of the QA/QC protocol, Ghana uses the issues tracking table to document and track the progress of addressing recommendations/findings/issues identified during the review of previous NIRs. The review comments were obtained from:

- Technical Analysis of the previous BUR under the ICA consistent with Decisions/CP.17 and 20/CP/.19.
- Participation in QA/QC workshops organised by the UNFCCC secretariat.
- Informal review of the NIR5 before submission to the UNFCCC.

Technical Analysis of Ghana BUR2

Ghana submitted its second BUR on 2nd October 2018 as a stand-alone update report and resubmitted it on 19th February 2019[19].

[19] *https://unfccc.int/sites/default/files/resource/tasr2019_GHA.pdf*

The technical analysis of the BUR took place from 25th February to 1st March 2019. Table 13 presents the issues identified by the Technical Team of Experts during the Technical Analysis of Ghana's BUR2.

Table 13: Status of issues/comments identified by TTE during the ICA of BUR2

Sector	Comments from the TTE	Action taken	Status
IPPU	Reporting the F-gases on a mass basis in the summary tables.		
LULUCF	Consistency in the values reported across tables in the BUR and the NIR, especially CH_4 emissions from category 3. B		
General	The use of notation keys was not always consistent with the UNFCCC guidelines for the preparation of NCs from non-Annex I Parties		
LULUCF	Report comparable information addressing the tables included in Annex 3A.2 to the IPCC good practice guidance for LULUCF.		
IPPU	Provides additional information on the use of limestone in cement as a flux.		
General	Setting a key category threshold to 95 per cent and clearly explaining the reasons for selecting the base year for the trend analysis would facilitate a better understanding of the information reported.		

QA/QC Workshop

In March 2018, Ghana participated in the QA/QC workshop on the National Greenhouse Gas Inventory Management System and National Greenhouse Gas Inventories organised in Ghana by the UNFCCC. The workshop ended with a prioritised improvement list that would be implemented to enhance the national system's functionality. Table 14 contains the main recommendations for implementation in the BUR2 and BUR3. In the NIR4, Ghana reported progress in addressing the recommendations.

Table 14: Issues tracking table for the comments from the QA/QC Workshop in 2018

Review	Sector	Main issues	Description of issue and critical recommendations	Timelines	Actions taken	Status
Technical Analysis	Cross-cutting	Use of notation keys	Include information on other areas such as the control of consistent values, the notation key "NE" (not estimated) and the values of non-CO_2 gas emissions in units of Gg and CO_2e.	BUR2/NIR4	QA/QC has been improved to improve the checking of the use of notation keys.	Resolved in NIR4
		Use of notation keys	The transparency of the information reported could be enhanced if, following decision 17/CP.8, Annex, paragraph 22, notation keys were used where numerical data are not provided.	BUR2/NIR4	All "0" used to denote not applicable has been changed to dash.	Resolved in NIR5
		Uncertainty analysis	Provides a category-specific uncertainty assessment	BUR2/NIR4	The uncertainty assessment for the Land representation system has been provided. Uncertainty in other sectors has not been done due to the lack of requisite meta-data. Due to the lack of requisite data, there was no clear basis to assign a default range of uncertainty in the IPCC software.	Unresolved as in NIR5
		Key category analysis (KCA	Make the threshold for KCA consistent with that of the 2006 IPCC Guidelines (95%).	BUR2/NIR4	The threshold for the KCA calculation has been changed to 95%.	Resolved in NIR5
		Consistency with IPCC Guidelines	Report estimates of emissions/removals on a gas-by-gas basis and in mass units, as suggested in the UNFCCC Guidelines, to prepare national communications from non-Annex I Parties.	BUR2/NIR4	Emissions/removal has been reported on a gas-by-gas basis and in mass units (Annex 5).	Resolved in NIR4
	Energy	Reference Approach vs Sectoral Approach	Enhance the capacity of national experts to use reference and sectoral approaches.	BUR2/NIR4	Improvements in the energy balance have significantly reduced the differences in reference and sectoral approaches (section 3.6.1.1)	Resolved in NIR4
	Cross-cutting	Use of country-specific factors	Descriptions of country-or plant-specific factors are reported, where such information is not confidential	BUR2/NIR4	Detailed elaborations are provided in the NIR's relevant	Resolved in NIR4

					section, where the country or plant-specific factors have been used.	
		Completeness of source categories	Conduct regular surveys to determine the completeness of all source categories.	Long-term	A survey on missing categories has not been implemented due to a lack of financial resources.	Unsolved in the NIR5
Voluntary In-country review	Cross-cutting	Quality Control/Quality Assurance	There was an increase between 2007 and 2008 in waste sector emissions (figure 45 of the NIR of NIR3). There is a possible inconsistency in the time series because industrial wastewater emissions are estimated from 2008. Need to estimate industrial wastewater for previous years to ensure consistency (e.g. extrapolation with industrial production ratio).	BUR2/NIR4	Emissions from industrial wastewater for the years before 2007 have not been estimated due to a lack of data. Deferred to NIR5	Unresolved
	Waste		The specific country's solid waste composition in 2012 (figure 43 of the NIR3) is very different from the 2006 IPCC Guidelines composition (Vol5_Ch2_table 2.3), particularly food waste. Ghana explained that a study was carried out during the review and explained this difference. The team review recommends specifying this study about the NIR.	BUR2/NIR4	A comparison of CH_4 emissions from the use of country-specific food waste fraction and the IPCC defaults has been performed and reported in the NIR4	Resolved in NIR4
	IPPU		Lack of transparency of QA/QC information, including the use of the notation keys and QA/QC at the IPPU sector and category level	BUR2/NIR4	QA/QC has been improved to improve the checking of the use of notation keys.	Resolved in NIR5
	Waste		Ghana could compare the Solid Waste Disposal sector emissions (4A) estimated with Tier 2 and Tier 1 methodology.	BUR2/NIR4	Estimates of Tier 1 and Tier 2 emissions of solid waste disposal have been provided under the waste sector	Resolved in NIR4
	Cross-cutting	Uncertainty analysis	The uncertainty range reported in Table 11 of the NIR for all the sectors (but LULUCF to be addressed later) must be reviewed by applying the appropriate uncertainty threshold in the IPCC Guidelines.	BUR2/NIR4	The uncertainty assessment for the Land representation system has been provided. Uncertainty in other sectors has not been done due to the lack of requisite meta-data. Due to the lack of requisite	Unsolved in NIR5
			Lack of information on the level of uncertainty associated with inventory data and their underlying assumptions and the methodologies used, if any, for	BUR2/NIR4		

			estimating these uncertainties at sector and category levels.		data, there was no clear basis to assign a default range of uncertainty in the IPCC software.	
			The methodology for the estimation of uncertainty was not documented. Information on the methodology and sources of uncertainties should be provided or explained in the next national inventory report.	BUR2/NIR4 to BUR3/NIR5		
		Key category analysis	The KCA only performed with the AFOLU sector, and the country should also perform KCA without the AFOLU	BUR2/NIR4	KCA results have been presented with and without FOLU under section 1.8.1.	Resolved in NIR4
		TCCCA Principles	Fugitive emissions from natural gas and oil exploration and transport are not estimated. Need to estimate these sub-categories	BUR3/NIR5	Emissions from natural products have been estimated (section 3.7.1). Emissions from oil exploration and transport have not been estimated.	Resolved in NIR5
	Energy	Choice and updates of factors	Need to replace the EF used for flaring in oil production (1.B.2.a.ii) and need to ensure the consistency between EF specified in IPCC Guidelines and activity data used	BUR2/NIR4	Appropriate emission factors for flaring (section 3.7.1) have been selected considering Ghana's unique industry practice and consistent with the IPCC Guidelines	Resolved in NIR4
	Waste		Concerning Biological Treatment of solid waste (4B), the N_2O EF used corresponds to the old version of the 2006 IPCC Guidelines (volume 5, chapter 5, table 4.1) (0.30 g/kg), but there was an update in July 2015 where this value had been corrected (0.26 g/kg).	BUR2/NIR4	The old emission factor has been changed to 0.2g/kg	Resolved in NIR4
	IPPU	Surveys for missing source categories	Lack of regular surveys to determine the inclusion of missing category emissions reported as insignificant or non-existent; Chemical industry, Ceramics emissions (2.A.4a), Product uses as substitutes for ozone-depleting substances (2F), Other product use (2G) – SF_6 electrical equipment; N_2O for medical applications.	Long-term	A survey on missing categories has not been done due to a lack of financial resources. Emissions from 2F have been estimated from 2005 to 2016, but 2G has	Unresolved in the NIR5

	IPPU		Estimation of emission from specific categories due to lack of data in cases where emission activities are known to take place; Ceramics emissions (2.A.4a), ODS substitutes (2F)-Refrigeration and air conditioning, aerosols, fire protection, other product use (2G) – SF_6 electrical equipment; N_2O for medical applications. Lack of justification for insignificant emissions based on IPCC reporting Guidelines (e.g. lime production emissions (2.A.2); Soda Ash Use (2.A.4b), NIR page 103).	BUR2/NIR4 to BUR3/NIR5	not been conducted due to the lack of data.	
	Agriculture	Identification of outliers of animal population	Animal populations data seems to contain inconsistencies, e.g. the year 1995 for cattle, which affects associated estimates of manure management and enteric fermentation. An error in the calculation seems to have occurred in N_2O emissions from manure management for the sheep population in 2000 and 2012. It is recommended to strengthen the QC of time series, e.g. using an algorithm to identify outliers in activity data, emission factors and GHG estimates.	BUR2/NIR4	Trend analysis has been used to identify outliers in activity data, emission factors, and the livestock population's GHG estimates (section 5.1.1).	Resolved in NIR4
	Energy	Other sectors	Need to split off-road emissions (between 1.A.3.e.ii -Off-road vs 1.A.4.c.ii -Off-road Vehicles and Other Machinery, but there is no double-counting). The appropriate notation key for 1.A.4.c.ii -Off-road Vehicles and Other Machinery included elsewhere IE).	BUR2/NIR4	Off-road emission and other machinery have been separated, and an appropriate notation key was used (section 3.6.5.4).	Resolved in NIR4
	Energy	Other sectors	Need to split 1.A.4.c.i -Stationary emissions and use appropriate EF for each 1.A.4.c subcategories.	BUR2/NIR4	Split of emissions Stationary emission under 1.A.4.c is reported in Section 3.6.5.4.2	Resolved in NIR4
	Energy	Other sectors	The appropriate notation key for 1.A.4.c.iii - Fishing (mobile combustion) should be included elsewhere IE.	BUR2/NIR4	See information reported in Section 3.6.5.4.2 of the NIR	Resolved in NIR4
	Energy	1.B2a	Venting emissions are part of the emissions from flaring due to the technology used. So, the notation key for the emission category would be IE. Need to specify more explanation/evidence in the NIR about this.	BUR2/NIR4	An explanation of the use of IE has been provided under section 3.8.2	Resolved in NIR4
	LULUCF Livestock	Manure Management	Data on manure distribution among different systems were revised in 2000. It is suggested that the difference with the previous distribution (i.e. the 1990s)	BUR2/NIR4	Share of manure among different are applied	Resolved in NIR4

			is apportioned across the period to avoid inconsistencies in the time series		consistently across the time series	
		Manure Management	No removal of N excreted from total N; the 2006 EFs are applied. The calculation is performed with the 2006 IPCC software with default factors only. As a priority, the Ghanaian typical animal mass for each livestock category should be calculated and applied for calculating the Nex instead of the IPCC default.	BUR2/NIR4	Unable to access reliable data. Deferred to NIR5.	Unsolved
	AFOLU, Rice cultivation	Conditions of rice cultivation	Check whether irrigated fields are used twice a year for rice cultivation and amend Sfp accordingly. IPCC default EFs are applied. No amendments are assumed to be applied.	BUR2/NIR4	Irrigated fields are used throughout the year. Harvesting occurs once a year.	Resolved
			Rice belowground residues should not be included (bias to be corrected).	BUR2	Belowground crop residues were excluded.	Resolved
	AFOLU, Fertiliser Application	Completeness	Organic fertiliser is missing and should be estimated (no statistics available, could use expert judgment).	BUR2/NIR4	Deferred to NIR6 due to lack of data and resources to conduct studies	Unsolved in NIR5
		Fertiliser consumption	Fertiliser consumption isn't estimated. The N import is used as activity data; however, the N export isn't subtracted. Double-check export and so the net N balance. Then provide explanations for the large inter-annual variability.	NIR4	Confirmed. There are no official records of fertiliser exports. Explanations on the inter-annual variation are provided under section 3.5.2.2	Resolved in NIR4
	AFOLU, biomass burning	Activity data	Possible double counting of emissions from crop residues since a fraction of them could have been grazed, collected or burnt.	BUR2/NIR4	The effects of grazing, the amount collected or burnt on crop residues, have been considered to avoid double counting. See section 3.5.2.3	Resolved in NIR4
	AFOLU, Land	Land representation system	Although the time series of raw data doesn't start in 1971, reconstructing a consistent time series method is available from IPCC. The easiest is to assume that the same rate of change also applies to the past and future. Another viable option is to use the human population as a proxy for changes, projecting land-use changes according to trends in the human population.	BUR2/NIR4	Historical land use rates were derived from 1970 onwards. The rate was determined based on general land use drivers like peculiar population factors like policies (the structural	Resolved in NIR4

					economic programme) and the 1983 fires.	
	AFOLU, Land	Fire on Forest land	Fire emissions, although subsequent removals have not been estimated yet. Estimating C stock gains associated with forest regrowth in all forests subject to harvesting, fires, and other disturbances are recommended.	BUR2/NIR4	Check section 5.9.1.2.3.1 for carbon removal associated with regrowth	Resolved in NIR4
	AFOLU, Land	Cropland and Grassland	Different biomass stocks have been used for conversion to annual vs perennial. According to IPCC, also SOC should be different (potential overestimation of losses).	BUR2/NIR4	SOC generated from on-time field study is still in use.	Unsolved
	Waste	Solid waste disposal	Ghana does not estimate municipal solid waste generation before 1990. IPCC tool is used with first-order decay; this has the potential to underestimate the real methane emissions. Consequently, the team review strongly recommends estimating MSW generation before 1990	BUR2/NIR4	MSW generated has been derived from 1950 before the 1990 base year to be consistent with the IPCC tool and reported in the NIR4	Resolved in NIR4
	Waste	Industrial wastewater	Industrial wastewater treatment: MCF used is high (0.9). Ghana needs to have more information about the type of treatment plant used to improve the accuracy of the methane emissions for industrial wastewater	BUR2/NIR4	Information on various treatment plants in Ghana has been provided in section 6.9.4.2	Resolved
	LULUCF Livestock	Livestock characterisation	Enhance characterisation should be applied; it is recommended as a (second) priority to work on together with the Animal research institute.	BUR2/NIR4 to BUR3/NIR5	Studies on enhancing livestock characterisation have not yet started	Unsolved

1.10 General uncertainty assessment

The emission inventory figures are best estimated using standard IPCC protocols. The method used to produce the underlying datasets introduced inherent uncertainties into the inventory. For instance, physical measurements or modelling to generate activity data and emission factors carry many errors that must be accounted for in the inventory. Additionally, when expert judgments guide filling time series gaps and select default activity data and emission factors, they add to the inventory's uncertainty levels. Having recognised the possible sources of uncertainties and how to manage them, the 2006 IPCC Guidelines provide precise methods for assessing the overall uncertainties and reporting and the strategy to reduce their effects on the final emissions. The IPCC guidelines require that inventory estimates are reported with the uncertainty range using a tier 1 uncertainty analysis across the sectors. The detailed uncertainty assessment for the Land representation category has been reported under the LULUCF section.

However, Ghana cannot report on the uncertainty range for the other sectors because there is no credible basis to assign the default range of uncertainty in the IPCC software due to the absence of requisite meta-data, particularly for the country-specific activity data. The reason is that most of the activity data were from secondary sources that hardly reported uncertainty ranges in their metadata, qualitative approaches backed by experts' judgment were used to assign the uncertainty ranges based on the sources of data consistently and transparently. Although the IPCC guideline provides the methodology for uncertainty assessment and even the inventory software has a sub-menu of uncertainty values to choose from, in the case where the supplier of the activity data does not publish enough background data to allow for the quantitative calculation of the uncertainty, the assignment of the error range becomes arbitrary. In this regard, the EPA will re-engage the Mathematics Department of KNUST and the Department of Statistics to develop practical approaches to statistically quantify uncertainty levels associated with inventory and report on the progress in the next NIR6.

1.11 General assessment of inventory completeness

According to the IPCC Guidelines, assessing the inventory's completeness regarding its geographic coverage, scope (sectors and gases included, missing or non-applicable), and the time series is good practice. Therefore, each sector's completeness assessment has been reported in sections dedicated to the sectors. A list of completeness issues is in Table 15.

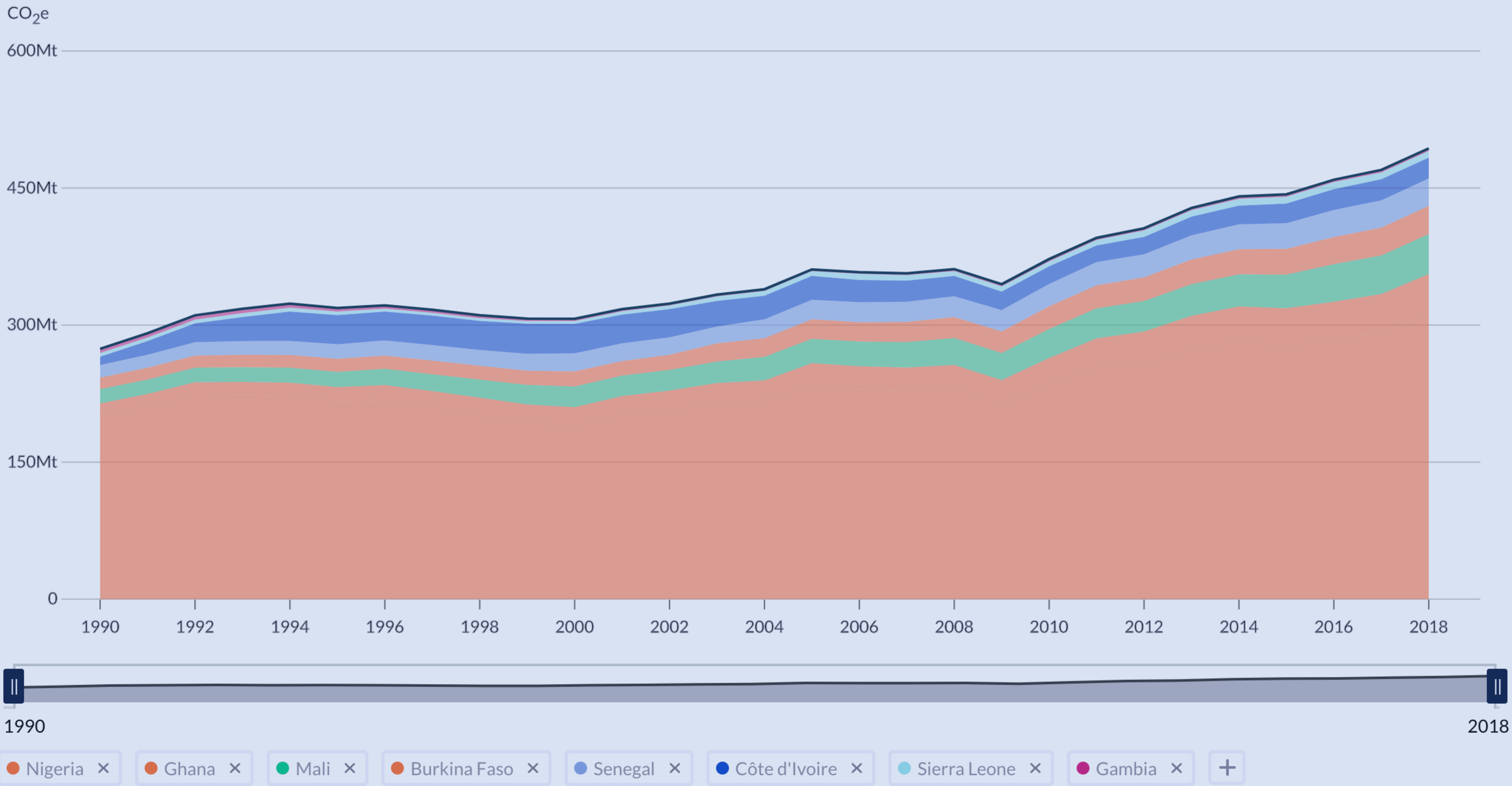
Table 15: Overview of the general assessment of completeness

Completeness parameter	Status	Comments
Geographic coverage	Nation-wide	The inventory covered the entire territorial boundary of the Republic of Ghana. Thus, none of the ten administrative regions in Ghana has been left uncovered by the inventory.
Sectors (Identified sources and sinks)	4 IPCC sectors	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 for the following activities, which were considered insignificant or where there is no data: • 1B.2a.iii.5 – Distribution of oil products • 3D. i – Harvested wood products

		• 2G – SF_6 electrical equipment; N_2O for medical applications. • 1B.2a.iii.5 - Distribution of oil products The emissions inventory does not include activities not captured in the official records published by State institutions. For example, unreported fuel use, household animals not captured in the livestock census and unaccounted for harvested wood.
Gas compounds	Direct and indirect GHGs	Direct GHG included CO_2, CH_4, N_2O and PFCs (CF_4 and C_2F_6) HFCs. Also, SLCPs and local pollutants such as BC, CO, NMVOCs, NOx and $PM_{2.5}$ have been included. SF_6 has not been considered in this inventory due to data unavailability.
Time series	26 years	Time series range – 1990 to 2019 Recalculation years – 1990 to 2016 Base year - 2010 Previous reporting year – 2016 Latest report year - 2019
Notation keys	-	Categories and gases where emissions are: • Not estimated (NE) • No occurring (NO) • Included Elsewhere (IE) • Confidential (C) • Not Applicable

Historical emissions of selected West Africa Countries

Source: https://www.climatewatchdata.org/ghg-emissions?source=CAIT



Chapter 2

2.0 Greenhouse Gas Inventory Results

2.1 Summary of the National Greenhouse Emissions

Ghana's total greenhouse gas emissions stood at 59.8 $MtCO_2e$ (million tonnes of carbon dioxide equivalent) in 2019 and are 16.3% more than the 2016 levels. Over the 29 years (1990-2019), Ghana's total emissions have recorded a 2-fold increase (representing a 139.8% rise over the same period) from 25 $MtCO_2e$ in 1990 to 59.8 $MtCO_2e$ in 2019. The Energy sector remained the most significant greenhouse emission source between 2016 and 2019 (Figure 4). In 2019, 45.7% of the total national emissions came from the Energy sector, followed by the LULUCF (24.3%), Agriculture (20.2%), Waste (6.9%) and IPPU (2.9%) sectors. When the net emissions from LULUCF are excluded from the national totals, the overall emissions were 45.3 $MtCO_2e$ in 2019, with the Energy sector as the most significant source. The emission spikes in 2011 and 2017 relate strongly to the increase in gas flaring in offshore fields. Commercial production started in 2011, and in 2017 additional gas production fields came online.

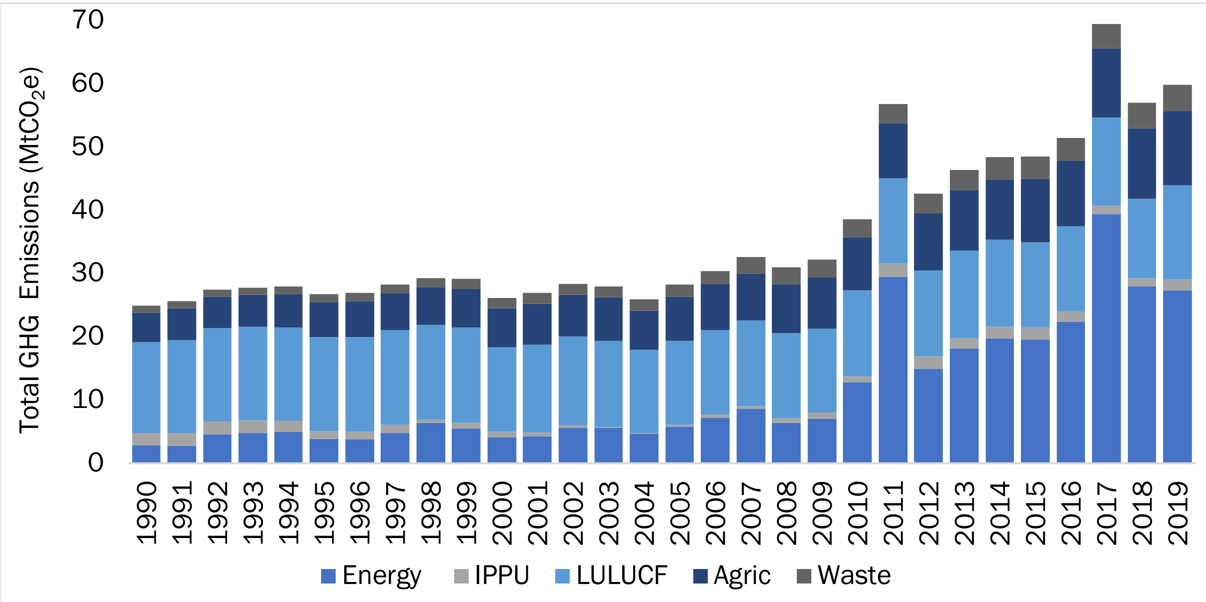


Figure 4: Total national GHG emissions trends according to sectors for the period 1990-2019

2.2 National GHG emissions, Population and GDP Trends

In the almost past three decades (1990-2019), Ghana's GHG emissions per capita have shown a consistent increase that of Gross Domestic Product (GDP) intensity declined marginally (Figure 5). The emission per capita increased from 1.7 tCO_2e per person in 1990 to 1.9 tCO_2e in 2019, representing a 16% rise. Conversely, the GDP intensity figures significant decrease of 49% from 2.1 $kgCO_2e$/GDP (at constant 2010 US$) in 1990 to 1.1 $kgCO_2e$/GDP (at constant 2010 US$) in 2019.

The overall decreases in the GDP intensity suggest a positive effect of Ghana's growth-focus and economic diversification policies in the last three decades. The current trend implies that the economy is expanding faster than the GHG emission growth rate.

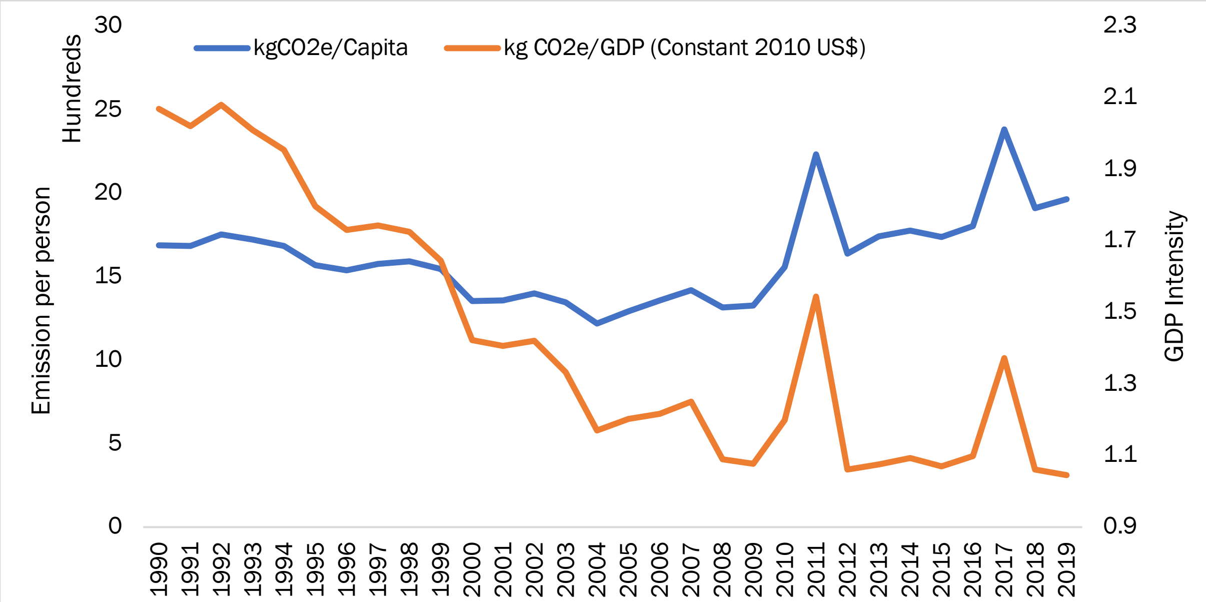


Figure 5: Emission intensity of GDP and emission per capita between 1990 and 2019

The emission per capita trend shows a rising trend. Ghana's population increased from 14.8 million in 1990 to a projected 30.4 million in 2019 at 2.5% per annum. Similarly, the GDP figures showed a consistent increase from 12 US billion in 1990 to 57.2 billion US dollars for the same period, with an annual growth rate of 5.5%. Within the same 29-year period, the GHG emissions grew from 25 $MtCO_2e$ to 59.8 $MtCO_2e$ at a 3.1% yearly growth rate.

2.3 Greenhouse gas emission trends by sectors

The LULUCF sector has consistently been the largest contributor to the national emissions from 1990 until 2011, when the energy sector became the dominant emissions source due to commercial oil production. For the 2019 total emissions of 59.8 $MtCO_2e$, the energy sector contributed 45.7% (with the breakdown as follows: stationary combustion 16.8%, mobile combustion 15.4% and fugitive emissions 13.5%) followed by LULUCF (24.3%), Agriculture (20.2%), Waste (6.9%) and IPPU (2.9%) (Figure 6). When the LULUCF emissions are excluded from the total, they represent 60% of the national emissions. The rest are Agriculture (26.8%), Waste (9%) and IPPU (4%) sectors.

All the sectors have recorded emission increases except the IPPU sector, which declined over the 29-year inventory period. But the sectoral emissions for 2016-2019 showed rising trends in all the sectors. The energy sector emissions recorded the highest increase of 22.1% and followed by the waste sector, which saw a 14% increase over the same period. The GHG emissions in the Agriculture, LULUCF and the IPPU sectors recorded a corresponding increase of 13%, 11% and 3% between 2016 and 2019.

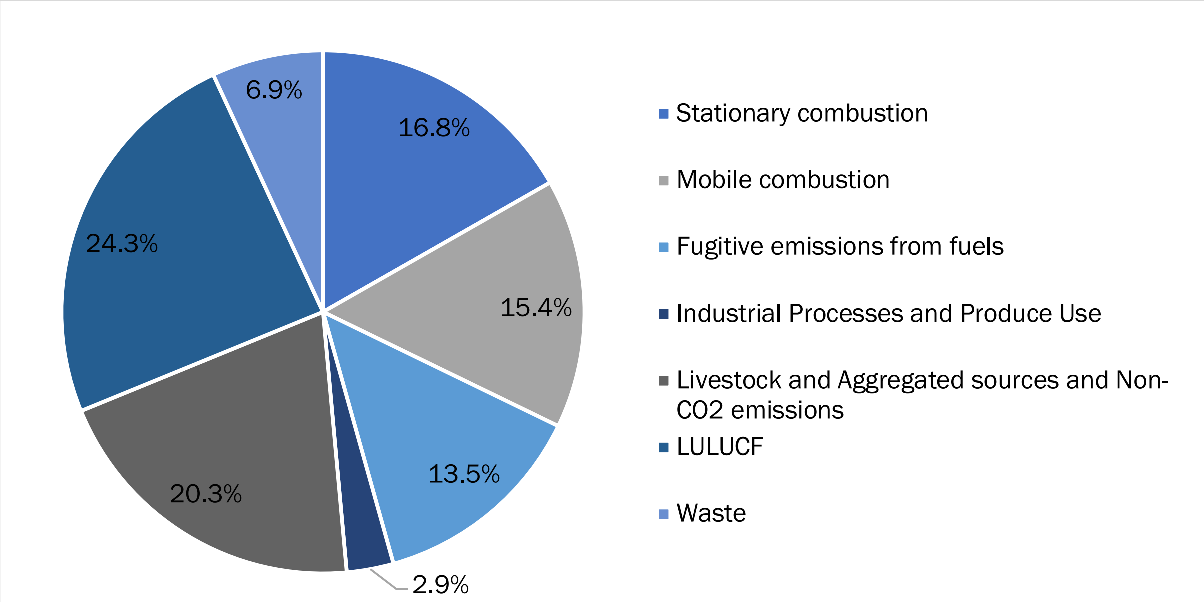


Figure 6: Share of total emissions per IPCC sector in 2019

The energy sector has been the highest source of GHG emissions in the recent period. Its percentage of the total emission increased from 11% in 1990 to 46% in 2019 (Table 16). In the same vein, the energy sector emissions increased 10-fold over the 1990-2019 period. Even though emission levels for the LULUCF sector have increased marginally by 1.5%, its contribution to the national total dropped from 57.3% in 1990 to 24.3% in 2019. Likewise, the waste sector's emissions proportion increased marginally relative to the national total. Its share of the national total grew from 4.5% in 1990 to 6.9% in 2019. Its share of the national total dropped from 7.9% in 1990 to 2.9% in 2019. The contribution of the IPPU to the total emission was the least, as it recorded a decrease of 11%.

Table 16: Sector contributions to national emissions in 1990, 2000, 2012, 2016 and 2019 and the percentage changes for the 1990-2019 and 2016-2019

Sectors/ Categories	Total Emissions ($MtCO_2e$)					Percentage change	
	1990	2000	2012	2016	2019	2016-2019	1990-2019
National Emissions with LULUCF	**25.0**	**26.2**	**42.6**	**51.4**	**59.8**	**16.3**	**139.2**
National Emissions without LULUCF	**10.7**	**12.8**	**29.1**	**38.0**	**45.3**	**19.2**	**323.4**
Energy	**2.86**	**4.07**	**14.9**	**22.4**	**27.3**	**21.9**	**854.5**
Stationery combustion)	1.2	1.7	6.1	7.6	10.0	31.6	733.3
Transport (Mobile combustion)	1.7	2.3	7.5	6.3	9.2	46	441.2
Oil and Natural Gas (Fugitive emission from fuels)	-	-	1.3	8.4	8.1	-3.6	-
Industrial Processes and Product Use	**1.96**	**0.90**	**2.01**	**1.68**	**1.73**	**3.0**	**-15**
Mineral Industry	0.01	0.04	0.52	0.35	0.53	51.4	5200
Metal Industry	1.95	0.86	0.73	0.75	0.60	-20	-69.2
Non-Energy Products from Fuels and Solvent Use	-	0.0	0.0	0.0	0.0	-1.3	-
Product Uses as Substitutes for ODS	-	-	0.75	0.58	0.59	1.7	-

Agriculture, Forestry, and Other Land Use	**19.0**	**19.53**	**22.6**	**23.73**	**26.64**	**12.3**	**40.2**
Livestock	1.94	2.37	3.28	3.93	4.44	13.0%	128.9
Land	14.3	13.3	13.52	13.37	14.52	8.6	1.5
Aggregate sources and Non-CO_2 emissions sources on land	2.75	3.85	5.80	6.43	7.68	19.4	179.3
Waste	**1.1**	**1.6**	**3.1**	**3.6**	**4.1**	**14**	**265.1**
Solid Waste Disposal	0.31	0.57	1.18	1.38	1.57	13.8	406.5
Biological Treatment of Solid Waste	0.10	0.07	0.07	0.10	0.09	-10	-10
Incineration and Open Burning of Waste	0.03	0.04	0.08	0.09	0.17	88.9	466.7
Wastewater Treatment and Discharge	0.69	0.97	1.78	2.06	2.29	11.2	231.9

The sector's contribution to the 2019 emissions is below:

Energy sector – emissions from the energy sector are associated with combustion in energy production and transformation, use and fugitive emissions. Within the energy sector, fuel combustion accounts for 32.2% of the total national emission of 58.9 $MtCO_2e$, whereas fugitive emissions contribute 13.5%. Table 16 shows that fuel combustion emissions increased by 38% and that fugitive emissions dropped by 4.2% between 2016 and 2019. Stationary and mobile combustions were the primary sources of emissions. Both sources recorded increases in the emission trend, with the mobile combustion sources slightly higher. The mobile combustion emission sources increased by 45.8% compared to the stationary sources that recorded a 31.5% increase. The fugitive emissions were slightly reduced by 4.2% from 2016 to 2019. The emission trends in the energy sector are linked to the following drivers:

- Exponential growth in vehicle population – the cumulative vehicle population has more than doubled (147%) from 2.1 million in 2016 to 5.1 million in 2019.

- Increasing shift to natural gas-based in the energy mix – In 2019, oil (38.3%) and biomass (37.8%) dominated the primary energy supply compared to natural gas of 18.2% and renewable (hydro and solar) of 5.7%. However, between 2016 and 2019, natural gas recorded the highest growth of 149%, followed by renewables of 12%, whereas oil declined by 23% and biomass remained unchanged. In terms of electricity generation, hydro share reduced from 43% to 39.9%, while the thermal and solar components increased from 57% to 59.8% and 0.2% to 0.3%, respectively. For thermal components, while fuel oil consumption declined by 48%, natural gas almost tripled over the same period.

- Consistent decline in gas flaring – the percentage of gas flared in total gas production decreased from 14% in 2016 to 4% in 2019.

IPPU sector – Emissions in the IPPU sector increased by 3.1% between 2016 and 2019. The increases are largely driven by the operations in the mineral industry, particularly in cement production. Since 2011 emission from cement production has increased by three folds. Production and ODS consumption emissions saw a minor increase of 1.6%.

Agriculture sector - The Agriculture sector emissions are included in 3A and 3C of the IPCC sources. Generally, Agriculture emissions have increased by three folds between 1990 and 2019. Most of the rising Agriculture emissions are driven by the corresponding increases in methane emission in animal rearing, rice production and fertiliser application on croplands.

LULUCF sector - The net LULUCF emissions are influenced by the land category emissions growth, especially from land converted to cropland, grassland, and forestland (forest remaining forest and land converted to forest). The high emissions associated with land conversions to cropland and grassland showed the impacts of deforestation on the growing emissions. Total Forest cover loss between 2019 and 2015 stood at 746,563 Ha per annum.

Waste sector - Emissions from unmanaged waste disposal sites and the domestic wastewater treatment and discharge determined the waste sector emission trends. The increases in the net emissions from waste were due to growing populations, operational and management challenges at most landfill sites, and the country's poor state of domestic wastewater treatment facilities.

Table 17: Emission contributions per sector and category on a gas-by-gas basis in 2019

Sector and sub-sectors	CO_2 [Mt]	CO_2 [%]		CH_4 [$MtCO_2e$]	CH_4 [%]	N_2O [$MtCO_2e$]	N_2O [%]	PFC [$MtCO_2e$]	PFC [%]	HFC [$MtCO_2e$]	HFC [%]
		w/O LULUCF	w/ LULUCF								
1. All Energy (combustion & fugitive)	**26.38**	**96.2**	**62.9**	**0.58**	**7.0**	**0.34**	**4.0**	-	-	-	-
Stationery energy combustion	*9.45*	*35.8*	-	*0.40*	*68.8*	*0.17*	*49.4*	-	-	-	-
Transport	*9.03*	*34.2*	-	*0.06*	*10.3*	*0.14*	*39.9*	-	-	-	-
Fugitive emission	*7.90*	*29.9*	-	*0.12*	*20.8*	*0.04*	*10.7*	-	-	-	-
2. Industrial Process & Product Use	**0.62**	**2.2**	**1.5**	-	-	-	-	**0.52**	**100**	**0.59**	**100**
3. AFOLU	**14.92**	**1.5**	**35.6**	**4.16**	**50.7**	**7.55**	**88.4**	-	-	-	-
Livestock	-	-	-	*3.42*	*82.3*	*1.02*	*13.5*	-	-	-	-
Land	*14.52*	-	*97.3*	-	-	-	-	-	-	-	-
Aggregated and non-CO_2 emissions	*0.41*	*100*	*2.7%*	*0.74*	*17.7*	*6.53*	*86.5*	-	-	-	-
4. Waste	**0.02**	**0.1**	**0.04**	**3.46**	**42.2**	**0.65**	**7.6**	-	-	-	-
Solid Waste Disposal	-	-	-	*1.57*	*45.4*	-	*0.0*	-	-	-	-
Biological Treatment of Solid Waste	-	-	-	*0.05*	*1.6*	*0.04*	*6.0*	-	-	-	-
Incineration and Open Burning of Waste	*0.02*	*100*	*100*	*0.13*	*3.9*	*0.02*	*3.5*	-	-	-	-
Wastewater Treatment and Discharge	-	-		*1.70*	*49.2*	*0.58*	*90.5*	-	-	-	-
Total net emissions (w/ LULUCF)	**41.93**		**100**	**8.20**		**8.54**		**0.52**		**0.59**	
Total emissions (w/o LULUCF)	**27.42**	**100**		**8.20**	**100.0**	**8.54**	**100**	**0.52**	**100**	**0.59**	**100**

2.4 Greenhouse gas emission by gases

2.4.1 Distribution of GHG emissions

Carbon dioxide continues as the most commonest greenhouse gas in Ghana and accounts for 70.1% (41.93 $MtCO_2$) of the total national emissions (including LULUCF) in 2019 and followed by nitrous oxide (14.3% of the total national emissions) and methane (13.7% of the total national emissions). The fluorinated gases (different HFCs and PFCs) were 1% and 0.9%, respectively, in 2019 (Figure 7).

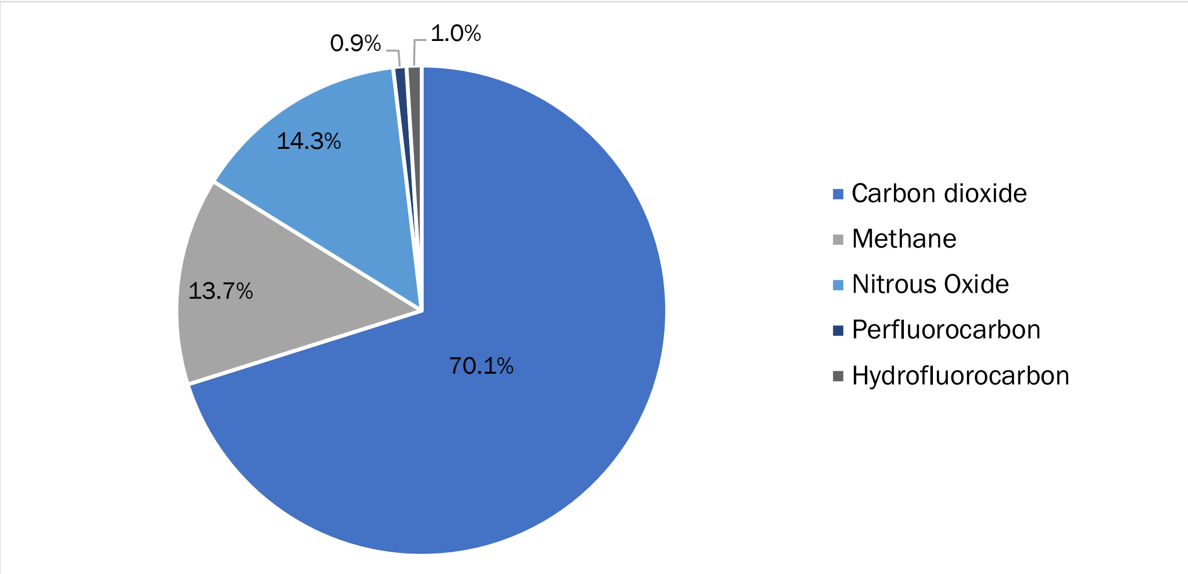


Figure 7: Distribution of types of direct greenhouse gases in 2019

When the LULUCF emissions are excluded from the national totals, CO_2 still constituted more than half (60.5% - 27.4 Mt) of the total emissions in the same year. Nitrous oxide was the second-highest GHG emission compound representing 18.9% (8.53 $MtCO_2e$) of the total emissions. Methane levels made up 18.1% (8.2 $MtCO_2e$) of all the emissions. The rest were HFCs emissions (1.3% - 0.59 $MtCO_2e$) and PFC (1.2% - 0.52 $MtCO_2e$). Carbon dioxide emissions make up the largest share (69%) of the total national emissions from 1990-to 2019. Over the 1990-2019 period, total CO_2 emissions have increased by 146%, from 17.1 Mt in 1990 to 41.9 Mt. at a 3.1% annual growth rate. From 2016 to 2019, it showed a similar upward trend of 18.7% (Figure 8). The rising trends in CO_2 emissions correspond to rising CO_2 emissions from energy industries, transport, and land-use change.

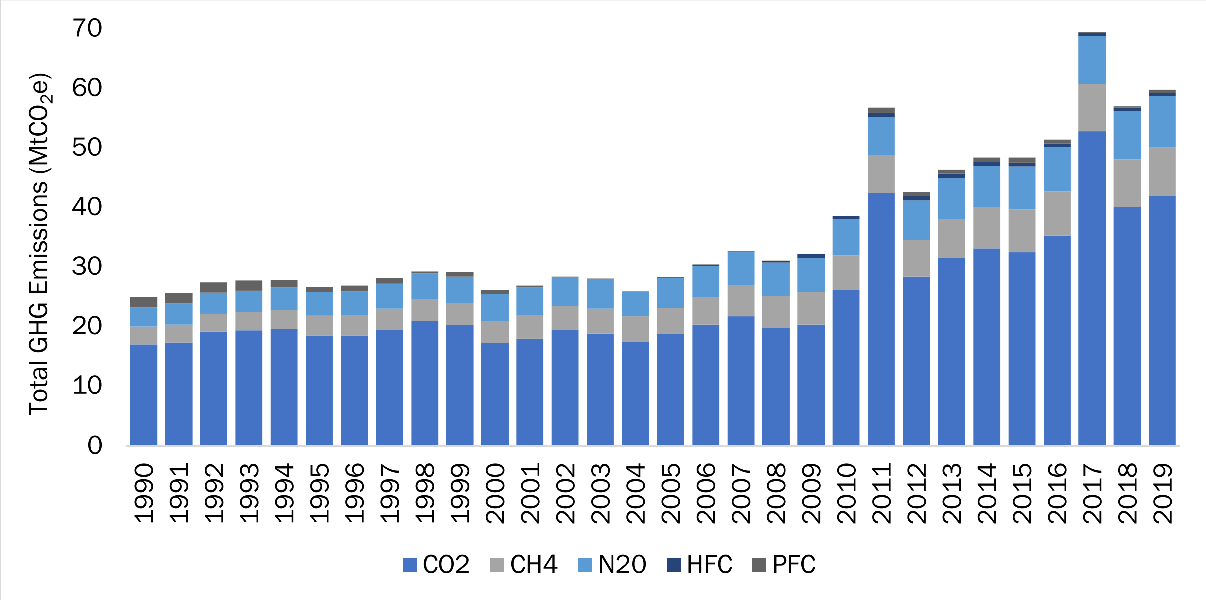


Figure 8: Trends of types of greenhouse gas emissions for the period 1990-2019

As the second-largest GHG gas, Nitrous oxide emissions exhibited a slightly higher increase trend of 166% from 1990 to 2019 at a 3.4% growth rate per annum. Compared to 2016 levels, nitrous oxide emissions increased by 15% in 2019. The drivers of N_2O emissions are the multiple sources of nitrogen accumulation in soils from the application of synthetic fertilisers, crop residues, organic fertilisers, and land-use change and management. Methane was the third largest GHG in Ghana, recording an increase of 174% at a 3.5% annual growth rate over the 1990-2019 period. Since 2016 methane levels in Ghana have grown by 12%, from 7.4 $MtCO_2e$ to 8.2 $MtCO_2e$ in 2019. Most of the CH_4 emissions came from livestock rearing (enteric fermentation and manure management), solid waste disposal and water treatment and discharge.

Perfluorocarbons are another family of greenhouses in Ghana. It mainly comes from the industrial operation operations of VALCO. PFC emission levels declined 69% at an annual rate of 3.9% from 1.7 $MtCO_2e$ in 1990 to 0. $MtCO_2e$ in 2019. The decreasing PFC levels are linked to the slowing down of the VALCO Aluminum Plant. In the 2016-2019 window, PFC emissions declined by 23%, making it the only greenhouse gas recording downward trends in Ghana. The gases used in refrigerators and air-conditioners are the primary source of HFCs. HFC imports are used in stationary and mobile air-conditioning and refrigerating appliances. In the national inventory, Ghana has reported HFC emissions from 2005 to 2019. The results showed that HFC emissions increased to 0.78 $MtCO_2e$ in 2011 before reducing to 0.59 $MtCO_2e$ in 2019. The HFCs between 2016 and 2019 increased marginally by 1.6%.

2.4.2 Analysis of emissions on the gas-by-gas basis

2.4.2.1 Carbon dioxide emissions

From 1990 to 2019, the total carbon dioxide emissions have increased 146%, from 17.1 Mt to 27.3 Mt at a 3.1% annual growth rate (Table 18). Without LULUCF, carbon dioxide emission levels increased tenfold from 2.8 Mt in 1990 to 27.4 Mt 2019 in 2019. The Energy and LULUCF sectors are the dominant sources of CO_2 emissions, mainly from fossil fuel combustion and land-use change.

While CO_2 in the energy sector recorded a significant jump, LULUCF saw a slight increase over the 29 years. In almost three past decades, the CO_2 emissions from the energy sector increased by 11 folds from 2.5 Mt to 26.4 Mt at an 8.9% annual growth rate. The CO_2 emissions in the LULUCF sector saw a modest increment of 2% over the same period.

Table 18: Trend of net carbon dioxide emission per sector for 1990-2019

Year	Million Tonnes (Mt)						
	Energy	IPPU	LULUCF	Agriculture	Waste	Total	
						(w/LULUCF)	(w/o LULUCF)
1990	2.47	0.29	14.30	0.01	0.00297	17.08	2.78
1991	2.37	0.30	14.63	0.01	0.00303	17.31	2.68
1992	4.14	0.30	14.69	0.01	0.00307	19.15	4.47
1993	4.32	0.32	14.74	0.00	0.00312	19.39	4.65
1994	4.52	0.30	14.80	0.00	0.00317	19.62	4.82
1995	3.38	0.30	14.86	0.00	0.00322	18.54	3.69
1996	3.30	0.29	14.92	0.00	0.00325	18.51	3.59
1997	4.25	0.29	14.98	0.01	0.00329	19.52	4.55
1998	5.86	0.13	14.98	0.00	0.00332	20.97	5.99
1999	4.96	0.19	15.14	0.00	0.00336	20.30	5.15
2000	3.62	0.29	13.30	0.01	0.00346	17.22	3.92
2001	3.88	0.31	13.85	0.01	0.00354	18.06	4.20
2002	5.18	0.24	14.08	0.00	0.00362	19.50	5.43
2003	5.12	0.07	13.72	0.01	0.00378	18.92	5.20
2004	4.25	0.05	13.17	0.01	0.00378	17.49	4.33
2005	5.22	0.23	13.25	0.01	0.00435	18.72	5.47
2006	6.56	0.37	13.43	0.02	0.00444	20.38	6.96
2007	7.99	0.31	13.46	0.02	0.00498	21.79	8.33
2008	5.91	0.42	13.50	0.01	0.0055	19.85	6.34
2009	6.71	0.36	13.24	0.03	0.00613	20.34	7.10
2010	12.18	0.42	13.53	0.04	0.0072	26.17	12.64
2011	28.53	0.55	13.41	0.03	0.00734	42.53	29.12
2012	14.25	0.59	13.52	0.05	0.00718	28.41	14.90
2013	17.35	0.31	13.85	0.05	0.00911	31.56	17.72
2014	18.97	0.39	13.75	0.02	0.00797	33.14	19.39
2015	18.70	0.41	13.40	0.04	0.00848	32.55	19.15
2016	21.51	0.41	13.37	0.04	0.00868	35.34	21.97
2017	38.28	0.59	13.80	0.16	0.015	52.84	39.04
2018	26.93	0.64	12.37	0.15	0.01531	40.11	27.74
2019	26.38	0.62	14.52	0.41	0.01563	41.93	27.42

2.4.2.2 Nitrous oxide emissions

Apart from the IPPU and the LULUCF sectors, Ghana has reported N_20 emissions in the Agriculture, Waste, and Energy sectors. The total N_20 emissions in Ghana have increased 166% over the entire 29-year time series, driven by the sources in the agriculture sector. The three dominant sources are managed soils, manure management, and biomass burning within the Agriculture sector. According to Table 19, N_20 emissions went up from 3.21 $MtCO_2e$ in 1990 to 8.54 $MtCO_2e$ in 2019, with the majority consistently coming from the agriculture sector. Since 2016, the N20 emissions have increased by 14.8% in 2019, most coming from managed soils. Overall, about 80% of the agriculture N_20 emissions came from managed soils, followed by manure management (15%) and biomass burning (5%).

Table 19: Trend of nitrous oxide emissions per sector for 1990-2019

Year	$MtCO_2e$					
	Energy	IPPU	Agriculture	LULUCF	Waste	Total
1990	0.21	NA	2.66	NA	0.34	3.21
1991	0.22	NA	2.99	NA	0.35	3.55
1992	0.25	NA	2.94	NA	0.35	3.55
1993	0.26	NA	3.01	NA	0.36	3.63
1994	0.27	NA	3.14	NA	0.36	3.77
1995	0.25	NA	3.31	NA	0.37	3.93
1996	0.26	NA	3.43	NA	0.38	4.07
1997	0.28	NA	3.51	NA	0.40	4.19
1998	0.28	NA	3.59	NA	0.41	4.28
1999	0.28	NA	3.70	NA	0.43	4.41
2000	0.21	NA	3.82	NA	0.45	4.48
2001	0.20	NA	3.99	NA	0.46	4.65
2002	0.19	NA	4.10	NA	0.46	4.76
2003	0.19	NA	4.26	NA	0.47	4.92
2004	0.18	NA	3.56	NA	0.47	4.21
2005	0.22	NA	4.35	NA	0.47	5.04
2006	0.28	NA	4.54	NA	0.48	5.30
2007	0.27	NA	4.67	NA	0.48	5.42
2008	0.20	NA	4.83	NA	0.48	5.51
2009	0.16	NA	5.13	NA	0.49	5.77
2010	0.26	NA	5.37	NA	0.49	6.12
2011	0.39	NA	5.53	NA	0.49	6.41
2012	0.33	NA	5.80	NA	0.49	6.62
2013	0.31	NA	6.09	NA	0.56	6.96
2014	0.32	NA	5.99	NA	0.57	6.88
2015	0.31	NA	6.36	NA	0.57	7.24
2016	0.32	NA	6.55	NA	0.58	7.44
2017	0.38	NA	7.03	NA	0.61	8.03
2018	0.38	NA	7.14	NA	0.66	8.18
2019	0.34	NA	7.55	NA	0.65	8.54

NA - Not Applicable

Besides the Agriculture sector, relatively smaller quantities of N_2O emissions came from waste and energy sectors. On average, the waste sector accounts for 9% of the N_2O emissions in Ghana. It mainly comes from the emissions linked to domestic wastewater treatment and discharge. For the energy sector, "other sectors" and road transport accounted for most emissions.

2.4.2.3 Methane emissions

The methane emissions of 8.2 $MtCO_2e$ in 2019 represent 173.7% higher than the 1990 levels of 3 $MtCO_2e$ (Table 20). Most of the methane emissions were from agriculture (51%), followed by waste (42%) and energy (7%). Between 2016 and 2019, methane levels grew by 11.6%, with Agriculture being the dominant source.

Table 20: Trend of methane emissions per sector for 1990-2019

Year	$MtCO_2e$					
	Energy	IPPU	LULUCF	Agriculture	Waste	Total
1990	0.19	NA	NA	2.02	0.79	3.00
1991	0.20	NA	NA	2.09	0.81	3.09
1992	0.21	NA	NA	2.04	0.77	3.01
1993	0.22	NA	NA	2.05	0.82	3.09
1994	0.23	NA	NA	2.11	0.85	3.18
1995	0.23	NA	NA	2.20	0.91	3.34
1996	0.24	NA	NA	2.24	0.95	3.42
1997	0.25	NA	NA	2.28	1.00	3.54
1998	0.25	NA	NA	2.35	1.06	3.66
1999	0.25	NA	NA	2.37	1.12	3.74
2000	0.25	NA	NA	2.40	1.19	3.84
2001	0.25	NA	NA	2.42	1.23	3.90
2002	0.25	NA	NA	2.50	1.27	4.02
2003	0.25	NA	NA	2.56	1.33	4.15
2004	0.26	NA	NA	2.64	1.36	4.26
2005	0.34	NA	NA	2.66	1.43	4.44
2006	0.34	NA	NA	2.72	1.52	4.59
2007	0.33	NA	NA	2.76	2.16	5.25
2008	0.30	NA	NA	2.84	2.27	5.40
2009	0.18	NA	NA	2.93	2.35	5.46
2010	0.35	NA	NA	3.02	2.40	5.77
2011	0.57	NA	NA	3.13	2.55	6.25
2012	0.33	NA	NA	3.23	2.61	6.17
2013	0.45	NA	NA	3.37	2.67	6.49
2014	0.51	NA	NA	3.50	2.97	6.98
2015	0.50	NA	NA	3.65	2.96	7.10
2016	0.53	NA	NA	3.77	3.05	7.35
2017	0.77	NA	NA	3.91	3.21	7.89
2018	0.62	NA	NA	3.98	3.36	7.96
2019	0.58	NA	NA	4.16	3.46	8.20

NA - Not Applicable

In 2019, livestock rearing accounted for 82% of the methane within the Agriculture sector, whereas re-cultivation and biomass burning accounted for 9% each. For the rest of the waste sector, most of the methane emissions were from wastewater treatment and discharge and solid waste disposal for the waste sector.

2.4.2.4 Perfluorocarbon emissions

Perfluorocarbon is industrial emissions from technology used in the primary aluminium production by VALCO during anode effects. Apart from the fact that PFCs emissions generally showed a declining trend of 69% between 1990 to 2019, 2004, 2009, and 2010 were missing because the Aluminium (VALCO) plant was not operating at all (Table 21). Since VALCO's operations have been consistent, though, on a limited capacity (running a single pot), PFC emissions decreased by 23% between 2016 and 2019 due to the corresponding low production levels of VALCO in the same years.

Table 21: Trend of perfluorocarbon emissions per sector for 1990-2019

Year		MtCO$_2$e				
	Energy	IPPU	Agriculture	LULUCF	Waste	Total
1990	NA	1.671	NA	NA	NA	1.671
1991	NA	1.681	NA	NA	NA	1.681
1992	NA	1.726	NA	NA	NA	1.726
1993	NA	1.683	NA	NA	NA	1.683
1994	NA	1.350	NA	NA	NA	1.350
1995	NA	0.902	NA	NA	NA	0.902
1996	NA	0.908	NA	NA	NA	0.908
1997	NA	1.010	NA	NA	NA	1.010
1998	NA	0.368	NA	NA	NA	0.368
1999	NA	0.683	NA	NA	NA	0.683
2000	NA	0.614	NA	NA	NA	0.614
2001	NA	0.280	NA	NA	NA	0.280
2002	NA	0.105	NA	NA	NA	0.105
2003	NA	0.003	NA	NA	NA	0.003
2004	NA	NE	NA	NA	NA	NE
2005	NA	0.010	NA	NA	NA	0.010
2006	NA	0.028	NA	NA	NA	0.028
2007	NA	0.016	NA	NA	NA	0.016
2008	NA	0.013	NA	NA	NA	0.013
2009	NA	NE	NA	NA	NA	NE
2010	NA	NE	NA	NA	NA	NE
2011	NA	0.780	NA	NA	NA	0.780
2012	NA	0.662	NA	NA	NA	0.662
2013	NA	0.630	NA	NA	NA	0.630
2014	NA	0.766	NA	NA	NA	0.766
2015	NA	0.921	NA	NA	NA	0.921

2016	NA	0.680	NA	NA	NA	0.680
2017	NA	0.108	NA	NA	NA	0.108
2018	NA	0.185	NA	NA	NA	0.185
2019	NA	0.522	NA	NA	NA	0.522

NA - Not Applicable, NE – Not Estimated

2.3.2.5 Hydrofluorocarbon emissions

Ghana reports HFC emission estimates for 2005-2019 following a national survey report on HFC. Over the 2005-2019 period, HFC emissions has increased by 15 folds from 0.04 $MtCO_2e$ to 0.59 $MtCO_2e$ (Table 22). The HFC emission trends correspond with the levels of HFC consumption over the same period. HFC emissions inched by 2% between 2016 and 2019.

Table 22: Trend of HFC emissions for 1990-2019

Year	$MtCO_2e$					
	Energy	IPPU	Agriculture	LULUCF	Waste	Total
1990	NA	NE	NA	NA	NA	NE
1991	NA	NE	NA	NA	NA	NE
1992	NA	NE	NA	NA	NA	NE
1993	NA	NE	NA	NA	NA	NE
1994	NA	NE	NA	NA	NA	NE
1995	NA	NE	NA	NA	NA	NE
1996	NA	NE	NA	NA	NA	NE
1997	NA	NE	NA	NA	NA	NE
1998	NA	NE	NA	NA	NA	NE
1999	NA	NE	NA	NA	NA	NE
2000	NA	NE	NA	NA	NA	NE
2001	NA	NE	NA	NA	NA	NE
2002	NA	NE	NA	NA	NA	NE
2003	NA	NE	NA	NA	NA	NE
2004	NA	NE	NA	NA	NA	NE
2005	NA	0.04	NA	NA	NA	0.04
2006	NA	0.09	NA	NA	NA	0.09
2007	NA	0.14	NA	NA	NA	0.14
2008	NA	0.24	NA	NA	NA	0.24
2009	NA	0.58	NA	NA	NA	0.58
2010	NA	0.52	NA	NA	NA	0.52
2011	NA	0.78	NA	NA	NA	0.78
2012	NA	0.75	NA	NA	NA	0.75
2013	NA	0.71	NA	NA	NA	0.71
2014	NA	0.65	NA	NA	NA	0.65
2015	NA	0.63	NA	NA	NA	0.63
2016	NA	0.58	NA	NA	NA	0.58
2017	NA	0.55	NA	NA	NA	0.55
2018	NA	0.51	NA	NA	NA	0.51
2019	NA	0.59	NA	NA	NA	0.59

NA - Not Applicable, NE – Not Estimated

2.5 Precursor gases and indirect greenhouse gas emissions

2.5.1 Short-Lived Climate Pollutants

Short-Lived Climate Pollutants are powerful greenhouse gases and local air pollutants emitted through similar economic activities as the GHGs. Tackling SLCPs emissions has a global climate and local air quality benefits. Therefore, Ghana continues to report the inventory of GHG and SLCPs, including Methane (CH_4), Black Carbon (BC) and Hydrofluorocarbons (HFC), for the period 1990 to 2019. Figure 9 shows the trend in SLCP emissions from 1990 to2019.

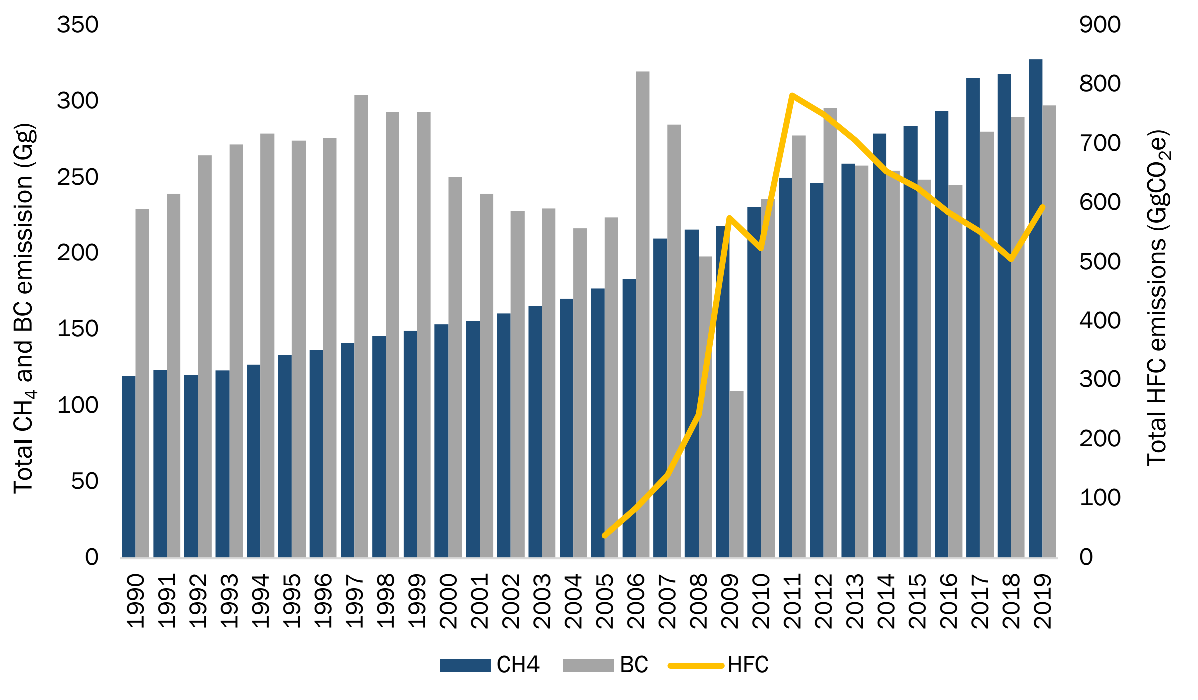


Figure 9: A chart showing SLCP emission trends between 1990 and 2019

In 2019, the methane emissions level was 327.9 Gg representing 174% and 12% higher than the 1990 and 2019 levels. Livestock, rice farming, biomass burning and waste disposal contribute most to the methane emissions. Black carbon levels increased by 30% over the same period, from 229.3 Gg in 1990 to 297.7 Gg in 2019. Residential cooking and transport are the main sources of black carbon in Ghana. For the IPPU sector, Products Uses as Substitutes for ODS were the only source of HFC emissions.

2.5.2 Precursor gases and local air pollutants

According to the IPCC guidelines, some precursor gases and local air pollutants have been estimated using national activity data and default emission factors from EMEP/EEA or EMEP/CORINAIR air pollutant emission inventory guidebook. These estimates do not replace the measured local air pollutants usually published by the Environmental Quality Department of EPA for different locations but are an essential complement. The air pollution measurements at monitoring sites estimate the concentration of air pollutants at specific locations resulting from all sources. At the same time, the NIR5 reports the emissions estimates of air pollutants from specific emission sources. Table 23 shows the trends of NOx, CO, NMVOC, BC, $PM_{2.5}$ and SO_2 emissions from 1990 to 2019. All the pollutants showed a rising pattern, with NOx and SO_2 recording the highest increases of the period. Nitrogen oxides are a group of poisonous, highly reactive gases. NOx gases form when burned at high temperatures.

Table 23: Precursor gases and local air pollutants for the period 1990-2019

Year	Gg/year					
	NOx	CO	NMVOC	BC	$PM_{2.5}$	SO_2
1990	26.8	805.9	166.9	229.3	2,148.7	74.3
1991	28.0	839.5	174.7	239.6	2,237.5	74.7
1992	47.0	871.9	183.4	264.9	2,333.8	127.7
1993	47.4	902.7	191.1	271.8	2,400.2	129.4
1994	47.8	934.5	198.9	279.0	2,470.5	134.6
1995	34.5	960.0	203.5	274.7	2,535.8	101.5
1996	33.2	988.3	209.2	276.1	2,612.4	102.8
1997	39.9	1,024.4	216.3	304.5	2,762.0	129.1
1998	42.4	1,018.6	216.8	293.5	2,667.1	139.0
1999	39.2	1,028.0	219.8	293.5	2,698.7	127.9
2000	32.8	793.4	142.0	250.5	2,411.4	82.3
2001	33.7	768.7	138.7	239.4	2,294.0	79.9
2002	35.9	750.5	137.3	228.4	2,182.4	86.8
2003	35.6	699.3	133.1	230.1	2,094.0	102.5
2004	35.6	737.2	139.0	217.1	2,035.8	86.9
2005	39.5	835.8	175.6	224.0	2,038.2	117.3
2006	46.8	1,068.1	210.0	319.7	3,011.6	132.3
2007	52.6	955.9	200.2	285.2	2,490.2	164.7
2008	41.5	822.2	178.5	198.3	1,814.6	104.3
2009	43.5	661.3	157.1	109.9	927.3	107.7
2010	72.6	913.5	201.1	236.4	1,897.6	189.4
2011	74.1	1,088.5	231.1	277.8	2,420.1	188.2
2012	92.0	1,100.9	235.1	295.9	2,380.9	234.8
2013	88.4	1,084.2	237.0	258.1	2,097.2	217.3
2014	83.7	1,125.8	245.1	254.7	2,161.5	195.3
2015	82.7	1,121.4	244.1	248.7	2,142.8	190.0
2016	77.1	1,106.7	241.7	245.3	2,126.9	191.4
2017	94.7	1,047.9	208.0	280.3	2,319.2	219.6
2018	108.0	1,357.8	302.6	290.2	2,366.1	237.0
2019	115.0	1,168.5	232.0	297.7	2,394.8	241.1

A significant amount of the precursor gases and air pollutants came from fuel and biomass combustion activities in the energy and cultivated lands. The majority of the SO_2 emissions were from road transportation (57%), household cooking (22%), manufacturing industries (13%) and thermal power generation (8%). Black carbon is a constituent of $PM_{2.5}$ produced from the incomplete burning of fossil fuels and biomass. The inventory estimates total black carbon emission in Ghana to be 297.7Gg in 2019, mainly from road transport and residential cooking activities. The 2019 BC emission is 30% higher than the 1990 levels. $PM_{2.5}$ are tiny particles with an aerodynamic diameter of 2.5 microns in the air that reduce visibility and cause haziness. It is a mixture of solid particles and liquid droplets found in the air.

Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Typically, in Ghana, $PM_{2.5}$ concentrations are measured using a gravimetric method and high-volume samplers in strategic locations along roadsides, residential, commercial and industrial areas. The $PM_{2.5}$ concentrations measured at these sites result from emissions of different pollutants, including primary PM2.5 emissions and gaseous precursors, such as nitrogen oxides, sulphur dioxide, and ammonia, which react in the atmosphere to form particles.

The estimation of primary $PM_{2.5}$ emissions based on specific activity data and emission factors is in no way replacing the measured $PM_{2.5}$ concentration monitoring figures. It complements them by providing estimated primary $PM_{2.5}$ emissions from the technology and sectoral point of view. Transport and domestic cooking and open burning are the dominant sources of primary $PM_{2.5}$ emissions in Ghana. In 2019, a total of 2,394.8 Gg of $PM_{2.5}$ was recorded in Ghana and of which 99.3 were emitted from the Energy sector through activities like road transport and domestic cooking accounted for most of them. The remaining 0.7% was open burning in the Waste sectors.

2.6 Time-series consistency

According to the 2006 IPCC Guidelines, "time series is a central component of the greenhouse gas inventory because it provides information on historical emissions trends and tracks the effects of strategies to reduce emissions at the national level. As is the case with estimates for individual years, emission trends should be neither over nor underestimated as far as can be judged. All emission estimates in a time series should be estimated consistently. The time series should be calculated using the same method and data sources in all years as far as possible. Using different methods and data in a time series could introduce bias because the estimated emission trend reflects real changes in emissions or removals and the pattern of methodological refinements."

2.6.1 Description of recalculations

Ghana has performed calculations on the 1990-2016 emission estimates. The following are the main reasons for the recalculations:

- Use of appropriate conversion factors for quantities of gas flaring.
- Inclusion of new 2015-2019 land cover matrix.
- Replacement of confirmed fuel consumption figures in the energy statistics.
- Update of a new dataset on the manufacture of charcoal.

The recalculations led to an average 2.4% decrease in the previous emissions trends, with the largest increase of 49% in 2011 and afterwards (Figure 10). Detailed descriptions of the recalculation and the underlying explanations have been provided under each sector.

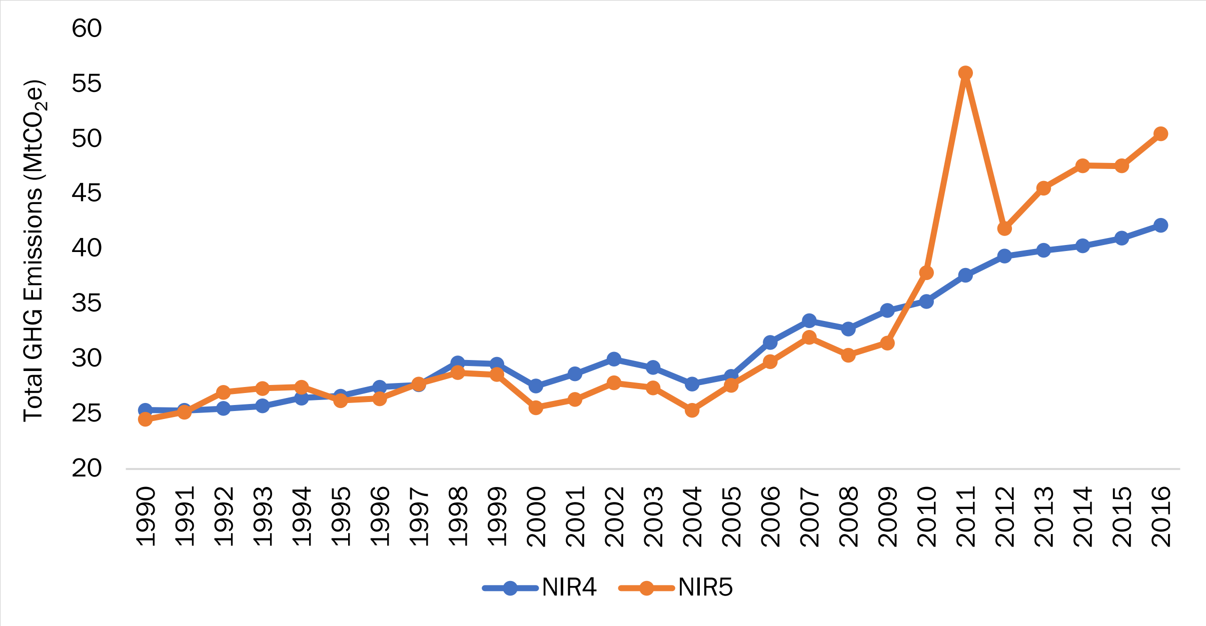


Figure 10: Comparison of differences between total national emissions in NIR4 and NIR5

2.6.2 Filling of time series gaps

In the inventory where we observed time series data gaps across the years, interpolation and extrapolation techniques were used to resolve them. Table 24 shows the list of categories of interpolation and extrapolation techniques that have been used to fill time series gaps.

Table 24: Techniques used to fill time series data gaps

Sector	Category	Activity data	Type of Technique used
LULUCF	Land – areas of land-use representations	Missing 2016 land category areas	Extrapolation
		Missing land use areas for the intervening years, 1991-1999, 2001-2011, 2013-2014	Interpolation
		Missing land use areas for 2017, 2018	Interpolation
		20-year time points	Extrapolation
	Land – areas affected by fire	1991-1999 missing, 2001-2009, 2011-2014, 2015	Interpolation
		2017, 2018, 2019	Extrapolation
	Fertiliser application	Missing years – 1991 -1994	Interpolation
	Timber harvesting	Missing 2016 activity data	Extrapolation
Waste	Solid Waste Disposal (4A)	Missing data of annual per capita solid waste generation 1950-1989, 1990-2004, 2006-2014, 2016	Trend extrapolation and interpolation
	Biological treatment of solid waste (4B)	Missing data on amount composted from 1990-1993	Extrapolation
	Wastewater discharge and treatment (4D)	Missing data income class which was derived from urban and rural population classification for 1990-1995, 1997-2004, 2006-2009 and 2011-2016	Interpolation and extrapolation
		Distribution of the share of the population in different income classes using different waste treatment facilities for 1990-1995, 1997-2004, 2006-2009 and 2011-2016	Interpolation

Energy Sector Inventory




Chapter 3

3.0 Energy sector

3.1 Summary of Energy Sector Emissions

In 2019, the total energy sector greenhouse gas emissions summed up to 27.3 $MtCO_2e$. The emission levels made the energy sector the largest source of GHG emissions, followed by LULUCF. The 2019 emissions are 46% of the total national emissions, including LULUCF and 61% without the net emissions from LULUCF.

In terms of trends, both the total GHG emissions and final energy consumption recorded steady growth between 1990 and 2019. The absolute emissions levels increased by 854.5%, from 2.86 $MtCO_2e$ in 1990 to 27.30 $MtCO_2e$ in 2019, with an annual average growth rate of 8.1%. However, beyond 2016, the energy sector emission started to decline largely due to the increasing use of natural gas for electricity generation instead of heavy fuel oils. As a result, between 2017 and 2019, total emissions for the energy sector declined from 39.42 $MtCO_2e$ to 27.30 $MtCO_2e$. Final energy consumption has correspondingly increased by 612% at an annual average growth rate of 7%, from 801.7 ktoe in 1990 to 6,416.5 ktoe in 2019.

The energy sector carbon emission levels of 26.4 Mt account for 96.2% of the total national carbon dioxide emissions without LULUCF in 2019. When the LULUCF carbon emissions are added, the energy sector makes up 63% of the total carbon emissions. Within the energy sector, the majority of the CO_2 emissions come from transport, electricity generation and gas flaring. The main leading sources of greenhouse gas emissions in the energy sector are transportation, oil and gas and energy industries. Transport has consistently been the key GHG emissions source in the energy sector, although the contribution levels have reduced from 59% to 34% for the 1990-2019 period.

On the other hand, the percentage contributions from the oil and gas and energy industries to the total energy sector emissions have seen an upward trend over the same period. While the energy sector contribution had increased from 3% in 1990 to 27% in 2019, oil and gas have sharply risen from 0% to 29% across the time series. The contributions from the manufacturing industry and construction, and other sectors saw a consistent decline. The proportion of the manufacturing industry and construction of the total energy sector emission reduced from 11% to 5% between 1990 and 2019. The emission from other sectors saw a similar decline from 27% to 5% over the 29 years.

In 2019, transport emissions made up 34% of the total energy sector emissions, followed by oil and gas (30%) and energy industries (27%) (Figure 11). 5% were from the other sectors for the rest of the emissions, and 5% were from the manufacturing industry and construction category.

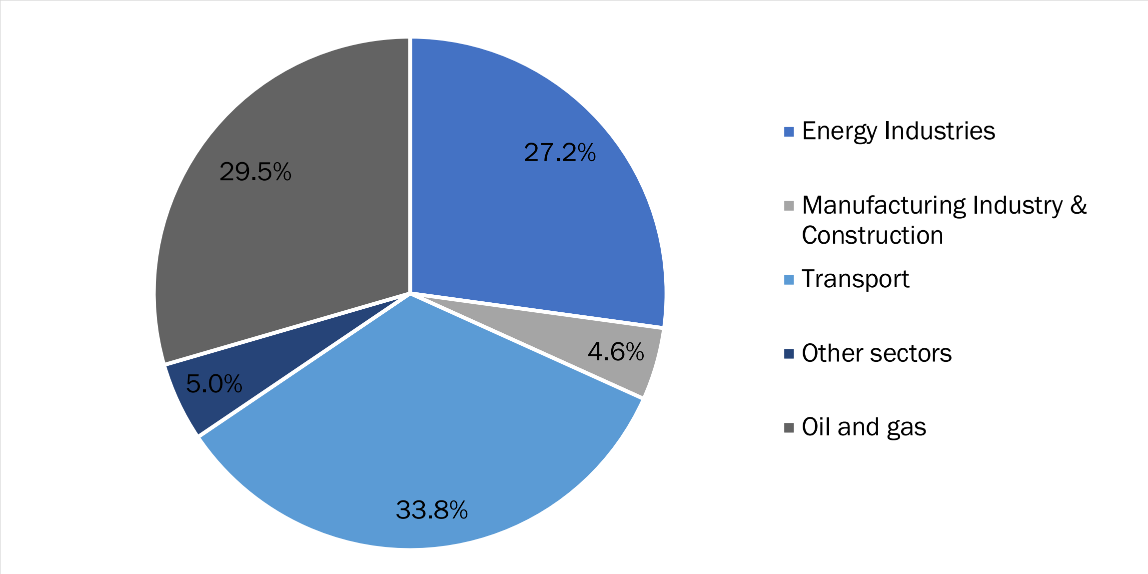


Figure 11: Energy sector emissions by category in 2019

Generally, Ghana applied the tier 1 method and the default emission factors from the IPCC 2006 guidelines to estimate the sector's greenhouse emissions. The overview of the methods and emission factors used are in Table 25.

Table 25: Overview of methods and emission factors used in the energy sector

Category	Sub-category	CO_2		CH_4		N_2O	
		Method	EF	Method	EF	Method	EF
Energy Industries	Electricity generation	T1	DF	T1	DF	T1	DF
	Petroleum Refining	T1	DF	T1	DF	T1	DF
	Manufacture of solid fuels	T1	DF	T1	DF	T1	DF
	Other energy industries	T1	DF	T1	DF	T1	DF
Manufacturing Industries and Construction	Iron and steel	T1	DF	T1	DF	T1	DF
	Chemicals	T1	DF	T1	DF	T1	DF
	Pulp, Paper and Print	T1	DF	T1	DF	T1	DF
	Food and Beverages	T1	DF	T1	DF	T1	DF
	Mining and Quarrying	T1	DF	T1	DF	T1	DF
	Construction	T1	DF	T1	DF	T1	DF
	Wood and Wood Products	T1	DF	T1	DF	T1	DF
	Leather and Textile	T1	DF	T1	DF	T1	DF
	Non-specified	T1	DF	T1	DF	T1	DF
Transportation	Domestic Aviation	T1	DF	T1	DF	T1	DF
	Cars	T1	DF	T1	DF	T1	DF
	Railways	T1	DF	T1	DF	T1	DF
	Inland navigation	T1	DF	T1	DF	T1	DF
Other sectors	Commercial/institutional	T1	DF	T1	DF	T1	DF
	Residential	T1	DF	T1	DF	T1	DF
	Agriculture/Forestry/Fishing/Fish Farms	T1	DF	T1	DF	T1	DF
Oil and gas	Oil - flaring	T1	DF	T1	DF	T1	DF
	Natural gas	T1	DF	T1	DF	T1	DF

3.2. Overview of the Energy Sector

Greenhouse gas emissions are associated with all the energy stages, from production to transformation and further to its final utilisation. The energy sector emissions are associated with the production and processing of primary energy, its transformation into secondary energy, and the final energy for economic activities. Generally, the production of electricity process heat or steam from the combustion of petroleum products and biomass often leads to anthropogenic greenhouse gas emissions. For example, the processes for producing heat/steam because of the transformation (e.g., thermal combustion or refining) of primary energy (e.g., crude oil) into secondary energy (e.g., electricity generation or diesel production) or conversion of woody biomass into charcoal. For instance, crude oil production from the Jubilee fields is considered a source of emission of methane gas because of venting, flaring, and leaks during the field equipment operations.

When the Tema Oil Refinery produces petroleum products or the Oil Market Companies (OMCs) import finished petroleum products such as diesel, gasoline, and LPG, they are typically used in stationary and mobile operations for economic activities emissions. Apart from the combustion emissions, unintended emissions are also generated from upstream oil and gas exploitation, processing, and crude oil refining. The degree to which the production, processing and utilisation of energy resources generate many operational factors that determine air emissions, the chief amongst them is:

- type, quality and quantity of fuels consumed or burnt at a given period
- installed capacity and operation hours
- technology vintage and
- environmental conditions

3.3 Categorisation of Energy Sector Activities

The 2006 IPCC guideline classifies the energy sector activities into the following categories:

- fuel combustion - 1A
- fugitive emissions from fuels – 1B
- carbon dioxide transport and storage – 1C

The classification is based on the type of activity in the energy supply chain and the operational flows through which the emissions are either released or removed from the atmosphere. The disaggregation of the energy activities into a similar emission by sources or removals by sink corresponds to the different IPCC activity codes.

3.3.1. Fuel combustion activities (1. A)

3.3.1.1 Stationary combustion (1.A.1, 1.A.2 and A.1.4)

The variety of energy activities in the stationary combustion category is a point source of emissions. Some examples of point sources are power plants, industrial boilers, crude oil refineries (e.g., Tema Oil Refinery), stand-alone electric generators, household and commercial cooking devices, and gas processing plants (e.g., Atuabo Gas Processing Plant).
The classification of the activities under the stationary combustion category was done by considering the types of operations. The classification led to three IPCC categories:

- energy industries (1.A.1)
- manufacturing industry and construction (1.A.2)
- other sectors (1.A.4).

It broadly captured most of the energy activities in Ghana that contribute to the national economy. In Ghana, emissions from energy activities in mining, oil, industry, and ports are already included in the manufacturing and construction category. Therefore, having a separate emission inventory for the enclave industries like mining alone could potentially lead to double counting. All the emissions are accounted for in the manufacturing and construction industry. Other sectors cover emissions associated with residential, commercial and forestry/fisheries/agriculture energy activities.

3.3.1.2 Mobile combustion (Transportation - 1. A3)

There is a wide range of mobile energy-combustion operations in Ghana, and most of them are covered under the mobile combustion category. These comprise on-road and off-road transport via air, road, rail, and water and are categorised into:

- air transportation (1.A.3a)
- road transportation (1.A.3b)
- railway transportation (1.A.3c)
- marine transportation (1.A.3d)
- other transportation (1.A.3f)

The IPCC Guidelines recommend that vehicles used for airport operations be treated separately. It was not possible to isolate them because of a lack of data. Therefore, off-road transport vehicles were added to the general road transportation emissions.

3.3.2 Fugitive emission from fuels (1.B)

In 2010, Ghana started producing oil in commercial quantities from the offshore Jubilee field using Floating Production Storage and Offloading (FPSO Kwame Nkrumah). Since then, two more oil and natural gas fields at TEN and Sankofa have been discovered, and production has already been ongoing. The government has put a "flaring restrictions" policy and has established the Ghana National Gas Company to process wet gas from the three oil and gas fields into lean gas, condensates, and LPG for the local market to add commercial value the natural gas. The oil from the Jubilee and TEN and recently natural gas from the Sankofa fields, the processing, and distribution of natural gas is linked to fugitive emissions. The main sources of fugitive emissions fall in the following IPCC sub-categories:

- venting (1. B.2.a.i)
- flaring (1.B.2.a.ii)
- refining (1.B.2.a.iii.4)
- natural Gas processing (1.B.2.b.iii.3)
- natural Gas Distribution (1.B.2.b.iii.5)

3.3.3 Carbon dioxide transport and storage (1C)

Activities under the category are not applicable in Ghana and were excluded from this inventory.

3.4 Data and methodology used for the Energy sector inventory

3.4.1 Description of data requirements and data sources

The energy sector inventory was conducted using activity data and emission factors obtained from various national and international sources (Table 26). In selecting the type of data for the inventory, priority was given to using country-specific data. The team prioritised them over other data sources where country-specific data were available. The reason is that country-specific data tend to give better emissions estimates with lower uncertainties than default data. In this inventory, the country-specific activity data used were from:

- Energy Commissions' national energy statistics
- Energy Commissions' Strategic national energy planning database
- Ghana National Petroleum Authority's petroleum product consumption figures
- Ghana Petroleum Commission's data on oil and gas production and export
- Ghana National Gas Company's data on natural gas production and distribution and own-fuel consumption
- Tema Oil Refinery material balance
- Driver and Vehicle Licensing Authority's vehicle registration and roadworthy figures,
- Ghana Customs vehicle imports data from GCNet
- GSS's Ghana Living Standard Survey report

In the absence of country-specific activity data and factors, data from databases of international organisations such as the IEA, FAO, UN-STAT and the World Bank were used. When there are disparities in the data from two credible sources, both were evaluated to detect patterns of inconsistencies and why there is a large difference. For example, the fuel consumption figures for selected energy demand categories in Ghana's energy statistics and the IEA were compared to assess their differences. Where there were notable differences, possible explanations were proffered to clarify possible contributing factors. The primary source of activity data for the inventory was the Energy Statistics published by the Energy Commission of Ghana. The statistics contain sectoral data on primary and secondary fuel supply and consumption for a given period. The energy statistic data used covered the multi-years below:

- 1995 Energy Statistics (1974-1994)
- 1998 Energy Statistics (1974-1997)
- 2001 Energy Statistics (2000-2008)
- 2012 Energy Statistics (2000-2011)
- 2017 Energy Statistics (2007-2016.
- 2020 Energy Statistics (2000-2019)

The new figures in the recent publication supersede the old dataset whenever previous data are updated. The preparation cycle of the energy statistics typically ends in April, after which data collection and processing start upon the completion of a previous report. The Energy Commission collects from original data owners or facility operators as stipulated by the Energy Commission Act (Act 541). Energy statistics is the primary data source for the energy inventory because they are credible official publications. Another vital energy data source is the petroleum products consumption figures. The data is published by the National Petroleum Authority (NPA). The NPA regularly updates the data and releases them online as open-source data[20].

The total fuel consumption figures in the energy statistics and energy inventory are sourced from the NPA database. Even though the energy statistics data was the primary data source for the energy inventory, the fallback is on the NPA primary data in cases where the dataset does not match or is missing. The latest NPA figures covered 1996 to 2020 and were reported monthly for each petroleum product like fuel oil, diesel (Open market, Mines and Rigs), gasoline, kerosene, LPG, premix fuel, ATK, and industrial kerosene. The National Petroleum Commission and Petroleum Department of EPA have daily and monthly oil production figures from the Jubilee, TEN and Sankofa fields. This data was also collected and used to validate what is published in the Energy Statistics. The Jubilee field data covered from November 2010 to December 2020, the TEN field from August 2016 to December 2020 and Sankofa field from May 2017 to December 2020.

Generally, the production data included raw and reconciled figures on the following variables: oil production, gas production, total water injection, gas injection, fuel gas usage, gas flared and gas exported. Refinery material balance was also collected from the three refineries in the country and used to validate the information published in the energy statistics. The materials balance contains figures on individual crude imports for each product grade, refinery input/intake, plant production, withdrawal for the internal market, transfers, imports of refined products and crude export to VRA. Natural gas processing's daily operational figures were obtained from the Ghana National Gas Company (GNGC). The figures included quantities of wet net gas imports from the oil fields, gas production at Atuabo, product (lean gas, condensate and LPG) amounts to consumers and fuel consumption at the plant.

Transport data were collected from multiple sources. Data on vehicle population, including vehicle registration and roadworthy certified vehicles, were obtained from the DVLA. The DVLA has figures on vehicle registration and roadworthy certification per region between 1995 and 2020. Data on annual vehicle imports were sourced from the Ghana Custom's GCNet database. The database has more detailed information such as the make, model, year of manufacture and chassis number of the vehicle. It also contains data on the vehicle's gross weight and fuel type. The import data is used to reconcile the DVLA data on annual vehicle registrations and roadworthy certification figures to validate vehicle population values. Ghana Bunkering Services (GBS) provided data on aviation and marine bunkers. The GBS data were used to cross-check the quantities of ATK and diesel fuel allocation for bunkering in the energy statistics. Inland water navigation relies on premix and diesel fuels collected from the Ministry of Fisheries and Aquaculture Development and the Volta Lake Transport Company.

[20] *http://www.npa.gov.gh/images/npa/documents/statistics/National_Consumption_1999-2016.xlsx*

Table 26: below gives an overview of the main activity data datasets and their sources

Category	Data Type	Data Source	Principal Data Providers
1A.1 Energy Industry			
Electricity generation	The number and installed capacities of active thermal power plants commissioned and in operation each year. Quantities of electricity generated in a year. Type and quantities of light crude oil, heavy oil and natural gas consumption per plant and the corresponding electricity production	National Energy Statistics	Energy Commission Volta River Authority Independent Power Producers Ghana Gas Company
Petroleum Refinery	Quantities of Residual Fuel Oil (RFO), Petroleum Coke and Refinery consumption per year.	National Energy Statistics	Oil refineries.
Manufacture of solid fuels	Quantities of wood fuel as input into charcoal production	National Energy Statistics. FAOSTAT. IEA Database.	National survey. FAOSTAT Ghana country data. IEA Ghana country data.
Other industries	Consumption of diesel to support the operation of Ghana National Gas Company (GNGC) and the oil fields.	National Energy Statistics Statistics on diesel consumption on-site at GNGC and on the oil rigs.	Ghana National Gas Company National Petroleum Commission National Petroleum Authority
1A.2 Manufacturing industry and construction			
Iron and steel	Quantities of RFO and Diesel consumption per year.	National Energy Statistics. National Industry Survey. Annual Environmental Report for Permitted Industries. IEA Database.	Energy Commission. Manufacturing Industry Department of EPA Ghana Statistical Service. IEA Ghana country data.
Chemicals	Quantities of RFO, diesel and wood fuel consumption per year.		
Pulp, paper and print	Quantities of diesel and LPG consumption per year.		
Food processing, Beverage and Tobacco	Quantities of RFO, diesel, LPG, Charcoal and Woodfuel consumption per year.		
Mining and Quarrying	Quantities of diesel and gasoline consumption per year		
Wood and wood products	Quantity of diesel consumption per year		
Construction	Quantity of diesel consumption per year		
Textile and Leather	Quantities of RFO and Diesel consumption per year.		
Non-specified	Quantities of RFO, diesel, LPG and Woodfuel consumption per year		

1A.3 Transport			
International aviation bunkers	Quantity of total ATK transferred to international bunkers for the consumption of international airlines.	National Energy Statistics. National Survey	Energy Commission Ghana Bunkering Services. National Petroleum Authority. Oil Marketing Companies. Ghana EPA Ministry of Transport
Domestic Aviation	Quantity of total ATK consumption by domestic airlines per annum. Data on land and take-off per flight per day (not available).		
Cars, trucks, heavy-duty vehicles, buses and motorcycle	Quantity of gasoline, diesel and LPG consumption per vehicle class and technology type. Distance and speed data on different road classes (urban roads, highways and feeder roads).		
Railways	Quantity of diesel consumption per year.	National Energy Statistics. Ghana Railways Diesel Consumption Figures	Energy Commission. Ghana Railway Development Authority.
International water-borne navigation	Quantity of total diesel transferred to international bunkers for the consumption of international ships.	National Energy Statistics.	Energy Commission
Domestic water-borne navigation	Quantity of diesel and premix consumption for inland navigation per annum.	National Energy Statistics. Volta River Lake Transport. Premix supply data	Energy Commission. Volta River Transport Company. National Petroleum Authority Ministry of Fisheries and Aquaculture Development.
Other sectors			
Commercial/Institutional and Residential	LPG, Kerosene, Charcoal and Wood fuel consumption per annum.	National Energy Statistics Strategic National Energy Plan National Census Report Ghana Living Standard Survey Report.	Energy Commission Ghana Statistical Service.
Fishing	Quantity of premix consumption for inland navigation.	Energy Statistics Premix supply data	Ministry of Fisheries and Aquaculture Development.
Stationery	Quantity of diesel consumption per year	National Energy Statistics. Strategic National Energy Plan	Energy Commission
Off-road vehicles and other machines	Quantity of gasoline and diesel consumption per year	National Energy Statistics.	Energy Commission

		Strategic National Energy Plan	
1B. Fugitive emissions			
Oil production (flaring)	Quantity of gas production The fraction of gas production exported to GNGC The fraction of gas production injected The fraction of gas production flared.	National Energy Statistics. Oil Production Figures	Energy Commission Petroleum Commission EPA
Gas Processing	Quantity of gas flared during the processing of natural gas at GNGC.	Energy Statistics GNGC production figures	Ghana National Gas Company
Refining	Quantity of throughput refinery input.	Energy Statistics Refinery's material balance	Tema Oil Refinery Platon Akwaaba
Gas distribution	Quantity of lean gas export to Aboadze thermal plant per year.	Energy Commission GNGC production figures	Ghana National Gas Company Volta River Authority

The necessary quality control procedures are introduced in the verification and analysis of data. Where discrepancies are detected in the data submitted, a follow-up meeting and discussion with the entity involved are done before data are analysed for dissemination. Energy data collection and dissemination is, as much as possible, done according to the International Recommendation of Energy Statistics (IRES) and the Energy Statistics Compilers Manual (ESCM) of the United Nations Statistics Division (UNSD) and the Energy Statistics Manual of the International Energy Agency (IEA). The Energy Commission applies the principle of official statistics by compiling and making official statistics available on an impartial basis to citizens and users, following basic procedures in disseminating energy statistics, including timeliness, confidentiality, and feedback. The flow of data is presented in Figure 12.

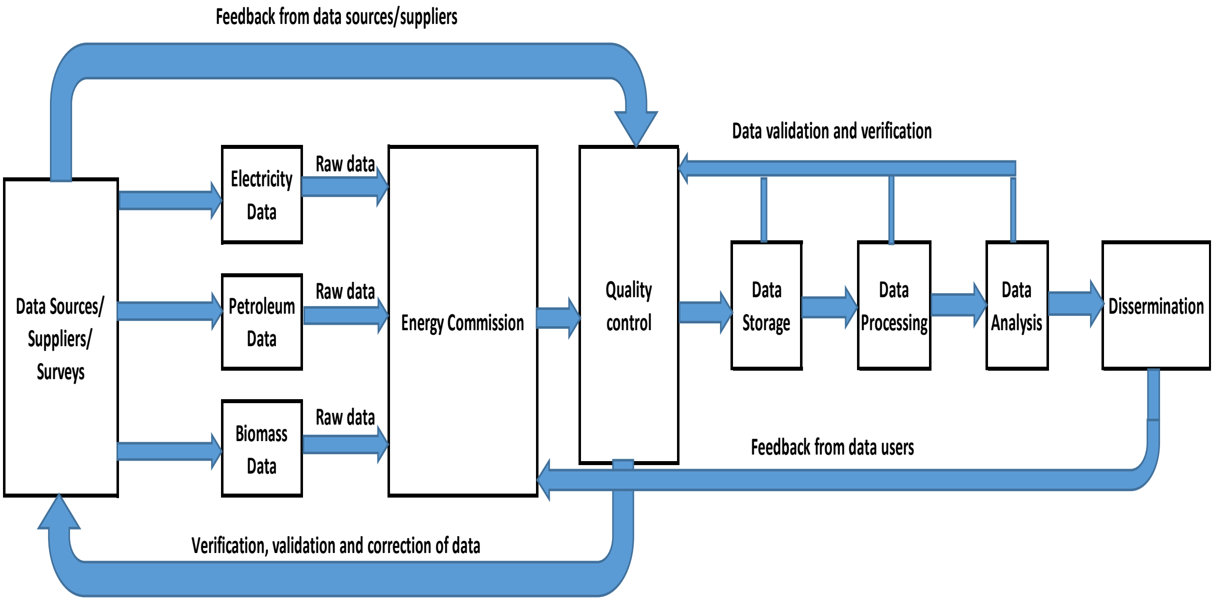


Figure 12: Overview of data flows in the energy statistics

3.4.2 Key challenges in the compilation of the Energy statistics

Some of the key challenges the Commission has encountered in the preparation of the national statistics are summarised below:

- **Inadequate financial resources**: Due to a lack of financial resources, the Energy Commission has not updated the last survey conducted in 2010 to determine the pattern and quantity of energy consumed in the various sectors of the economy. This survey normally forms the basis for the preparation of energy plans. Ideally, surveys should be conducted every 3-5 years to update energy use patterns and quantities. Currently, we rely on projections based on the 2010 study to allocate fuel shares for the various sectors of the economy based on the projections developed in the Strategic National Energy Plan (SNEP). There is, therefore, the need to undertake the necessary study to update the shares of energy use in the economy to have more accurate and reliable estimates of the energy use patterns in the various sectors of the economy.

- **Data quality**: secondary data are mainly collected from the institutions and entities in the sector. However, the Commission has minimal control over the compilation of these data and cannot guarantee the quality of data submitted by the entities involved, especially those that do not fall in the Energy Commission's regulatory arm. However, continuous work is being done with these entities by establishing a technological mechanism where the Commission can gain first-hand insight into the compiled or collected data. Some of the specific data challenges:

  - Allocation for fuel consumption for end-user sectors is based on projected fuel demand data in the LEAP model and not on empirical data.
  - Difficulty collecting data on the fraction of the total electricity generated with a specific fuel
  - Biomass supply and consumption figures are not based on empirical data but on expert judgement and outdated studies.
  - Lack of country-specific emission factors for the key categories in the energy sector.

- Inadequate capacity building process: continuous capacity building in every data collection process is essential. Continuous capacity building on new techniques and methodology in the compilation, analysis and dissemination of energy statistics would go a long way to improve the quality of data and statistics produced by the Energy Commission.

3.4.3 Energy Sector Methodology

3.4.3.1 General overview of methods and underlying assumptions

The energy sector inventory has been prepared according to volume 2 of the 2006 IPCC Guidelines. The Guidelines set out the broad systematic steps and the rationale for identifying emission sources in the energy sector, selecting methodological approaches, activity data, and factors, and formulating underlying assumptions consistently. Furthermore, the IPCC Guidelines offer good practice advice on the GHG emissions calculations using AD and the EF and strategies for documentation, archiving and reporting. The general definition is provided here for readers unfamiliar with AD and EF. Mostly, AD is a quantity that measures the intensity or frequency of a specific operation at a given rate that results in the generation of GHG emissions at different stages of the production and utilisation cycle. An example of AD could be the quantity of natural gas produced at the oil field and the fraction used by a single or multiple thermal power plant to generate electricity for the national grid.

Almost all the activity data used in the energy sector inventory were obtained from primary and publicly available secondary country sources. As much as possible, the collected AD fell within the 1990-2020 period. In a few instances where there were gaps in the country-specific AD, regional and international data were used to fill the gaps. If there is no data at the regional and international levels to fill the gap, appropriate statistical methods (e.g., extrapolation, interpolation) consistent with the IPCC good practice were applied to generate the missing data. Expert judgment was seldom applied and necessary, and the requisite underlying assumptions were documented.

An emission factor is the other variable in the GHG emission calculation. The EF is defined as measuring the rate at which the level, intensity, frequency of use or production would produce specific GHG emissions under a given condition. Most of the EFs used in the energy sector inventory were obtained from the IPCC Emission Factor Database. It is important to state that default emission factors per se in the inventory are not wrong. Nevertheless, because they are normally generated under different conditions other than what pertains to Ghana, using them to calculate the emissions comes with high uncertainty levels. The preference is to have country-specific or plant-specific factors that better represent the emissions where it was realised. Nevertheless, the EFs used in this inventory are the best available data and efforts would be made to develop country-specific factors.

The AD and the EF product are the total GHG emissions(E) of an activity [E=AD*EF]. This equation can be adapted to suit different complexities of the methodology for the emission estimates. Generally, the Tier 1 methodology was adopted to estimate the Energy sector emissions. Detailed descriptions of the respective methodologies or tiers are given in the specific sections of the source categories.

3.4.3.2 Energy sector activity data and emissions factors applied

After the collection, the AD used in the inventory was processed to identify and exclude mistakes and outliers before using them in the emission estimation with the EFs. The list of AD for 2019 and EFs are presented in Table 27 and Table 28. Except stated, all the EFs were obtained from the IPCC Emission Factor Database.

Table 27: List of activity data used in the energy sector inventory for 2019

IPCC Codes	Sub-categories	Quantity of Fuel Types (TJ)													Liquid fuel (10^m^3)	Gaseous fuel (10^6m^3)	Natural Gas (TJ)
		RFO	Crude oil	HFO	Diesel	Gasoline	LPG	DFO	Petroleum Coke	Charcoal	Wood fuel	Refinery gas	ATK	Kerose ne			
1.A1ai	Electricity generation		5,573.9	16,119.7	485.7		1,798.4										78,499.97
1.A1b	Petroleum Refining	651.8							5.49			432.75					
1.A1ci	Manufacture of solid fuel (charcoal)										51,578.5						
1.A1cii	Other energy industries				3,242.9												13,875.34
1.A2a	Iron and steel	220.2			50.6		37.13				220.16						
1.A2c	Chemicals	38.6			34.24		0.17				820.13						
1.A2d	Pulp, Paper & Print				11.24		81.13										
1.A2e	Food Processing, Beverage & Tobacco	1063.2			103.69		977.4			422.03	8,825.02						
1.A2i	Mining & Quarrying				12,387.1												
1.A2j	Wood & Wood Products				46.2												
1.A2k	Construction				961.5												
1.A2l	Textiles & Leather	299.9			18.4		1.65				1,062.7						
1.A2m	Non-specified	49.75			128.62		14.45				850.33						3,089.72
1.A3ai	International Aviation Bunkers												8,752.9				
1.A3aii	Domestic Aviation												731.9				
1.A3bi	Passenger cars				19,872.7	29,868	2,638										
1.A3bii	Light-duty truck				9,203.3	6,966.1											
1.A3biii	Heavy-duty & buses				16,939.2	4,790.3											
1.A3biv	Motorcycle				15,672.5	19,471.3											
1.A3c	Railways				37.59												
1.A3di	International water-borne navigation				308.12												
1.A3dii	Domestic water-borne navigation				42.24												
1.A4a	Commercial/ Institutional						850.8			3,918.8	1,290.6						
1.A4b	Residential						8945.2			55,949.1	51,689.5			158.74			
1.A4ci	Stationary				40.71												
1.A4cii	Off-road vehicle and other machines				1,097.6	1380.9											
1.A4ciii	Fishing				1,633.4												
1.B2aii	Oil - flaring														162,786		
1.B2biii.3	Gas Processing															1.464	
1.B2biii.5	Gas Distribution															0.01	

Table 28: Energy sector emission factors and fuel types from the 2006 IPCC Guidelines

IPCC Codes	Sub-categories	Gas		Quantity of Fuel Types (TJ)													Liquid fuel (10^m3)	Gaseous fuel (10^6 m^3)	Natural Gas (TJ)
				RFO	Crude oil	HFO	Diesel	Gasoline	LPG	DFO	Petroleum Coke	Charcoal	Wood fuel	Refinery gas	ATK	Kerosene			
1.A1ai	Electricity generation	CO_2	Kg/TJ		73,300	77,400				74,100									56,100
		CH_4			3.00	3.00				3.00									1.00
		N_2O			0.6	0.6				0.6									0.1
1.A1b	Petroleum Refining	CO_2	Kg/TJ	77,400							97,500			57,600					
		CH_4		3.00							3.00			1.00					
		N_2O		0.6							0.6			0.1					
1.A1ci	Manufacture of solid fuel (charcoal)	CO_2	Kg/TJ										112,000*						
		CH_4											30						
		N_2O											4						
1.A1cii	Other energy industries	CO_2	Kg/TJ				74,100												56,100
		CH_4					3.00												1.00
		N_2O					0.6												0.1
1.A2a	Iron and steel	CO_2	Kg/TJ	77,400			74,100												
		CH_4		3.00			3.00												
		N_2O		0.6			0.6												
1.A2c	Chemicals	CO_2	Kg/TJ	77,400			74,100						112,000*						
		CH_4		3.00			3.00						30						
		N_2O		0.6			0.6						4						
1.A2d	Pulp, Paper & Print	CO_2	Kg/TJ				74,100		63,100										
		CH_4					3.00		1.00										
		N_2O					0.6		0.1										
1.A2e	Food Processing, Beverage & Tobacco	CO_2	Kg/TJ	77,400			74,100		63,100			95,000*	112,000*						
		CH_4		3.00			3.00		1.00			1.00	30						
		N_2O		0.6			0.6		0.1			0.1	4						
1.A2i	Mining & Quarrying	CO_2	Kg/TJ				74,100	69,300											
		CH_4					3.00	3.00											
		N_2O					0.6	0.6											
1.A2j	Wood & Wood Products	CO_2	Kg/TJ				74,100												
		CH_4					3.00												
		N_2O					0.6												
1.A2k	Construction	CO_2	Kg/TJ				74,100												
		CH_4					3.00												
		N_2O					0.6												
1.A2l	Textiles & Leather	CO_2	Kg/TJ	77,400			74,100												
		CH_4		3.00			3.00												
		N_2O		0.6			0.6												

1.A2m	Non-specified	CO_2	Kg/TJ	77,400			74,100		63,100				112,000*						
		CH_4		3.00			3.00		1.00				30						
		N_2O		0.6			0.6		0.1				4						
1.A3ai	International Aviation Bunkers	CO_2	Kg/TJ												71,500*				
		CH_4													0.5*				
		N_2O													2*				
1.A3aii	Domestic Aviation	CO_2	Kg/TJ												71,500				
		CH_4													0.5				
		N_2O													2				
1.A3bia	Passenger cars with a 3-way catalyst	CO_2	Kg/TJ					69,300											
		CH_4						25											
		N_2O						8											
1.A3bib	Passenger cars without a 3-way catalyst	CO_2	Kg/TJ				74,100	69,300	63,100										
		CH_4					3.9	33	62										
		N_2O					3.9	3.2	0.2										
1.A3biia	Light-duty truck with 3-way catalyst	CO_2	Kg/TJ					69,300											
		CH_4						33											
		N_2O						3.2											
1.A3biib	Light-duty truck without 3-way catalyst	CO_2	Kg/TJ				74,100	69,300											
		CH_4					3.9	33											
		N_2O					3.9	3.2											
1.A3biii	Heavy-duty & buses	CO_2	Kg/TJ				74,100	69,300											
		CH_4					3.9	25											
		N_2O					3.9	8											
1.A3biv	Motorcycle	CO_2	Kg/TJ					69,300											
		CH_4						25											
		N_2O						8											
1.A3c	Railways	CO_2	Kg/TJ				74,100												
		CH_4					4.15												
		N_2O					28.6												
1.A3di	International water-borne navigation	CO_2	Kg/TJ				74,100												
		CH_4					7												
		N_2O					2												
1.A3dii	Domestic water-borne navigation	CO_2	Kg/TJ				74,100												
		CH_4					7												
		N_2O					2												
1.A4a	Commercial/ Institutional	CO_2	Kg/TJ						63,100			112,000*	112,000*			71,900			
		CH_4							5			200	300			10			
		N_2O							0.1			1	4			0.6			
1.A4b	Residential	CO_2	Kg/TJ						63,100			112,000*	112,000*			71,900			

		CH_4							5			200	300			10			
		N_2O							0.1			1	4			0.6			
1.A4ci	Stationery	CO_2	Kg/TJ				74,100												
		CH_4					10												
		N_2O					0.6												
1.A4cii	Off-road vehicles and other machines	CO_2	Kg/TJ				74,100	6,300											
		CH_4					10	10											
		N_2O					0.6	0.6											
1.A4ciii	Fishing	CO_2	Kg/TJ				74,100	6,300											
		CH_4					10	10											
		N_2O					0.6	0.6											
1.B2aii	Oil - flaring	CO_2	10^3 m3														0.049		
		CH_4																	
		N_2O																	
1.B2biii.3	Gas Processing	CO_2	10^6 Sm3															0.0014	
		CH_4																0.0000024	
		N_2O																0.0000024	
1.B2biii.4	Refining	CO_2	10^3 m3																
		CH_4															0.0000218		
		N_2O																	
1.B2biii.5	Gas Distribution	CO_2	10^6 m3															0.000051	
		CH_4																0.0018	
		N_2O																	

** Memo item. Emission not included in the national totals*

3.5 Analysis of fuel consumption

3.5.1 Total primary fuel consumption

Ghana is endowed with fossil hydrocarbons and biomass. It produces crude oil offshore for exports and natural gas for domestic consumption. Ghana is a net importer of refined petroleum products. Additional natural gas imports from Nigeria via the West Africa Gas Pipeline complement the domestic gas resources.

Commercial crude oil production started in 2010 on the Jubilee Field offshore in the Western Region of Ghana. Since then, operations on two additional oil fields (TEN and Sankofa fields) have started in 2016 and 2017. Almost all the crude oil produced from the oil fields is exported. The crude oil input for the refinery and electricity generation is imported from the international market. The natural gas produced from two offshore fields (Jubilee and TEN) is sent to GNGC to process lean gas, condensate, and LPG for the local market. Associated gas is produced on the Jubilee and TEN oil fields as an undesirable by-product, and fractions are injected, flared, vented, and sent to GNGC. In 2017, the Sankofa field managed by ENI/Vitol started producing non-associated gas.

Solid biomass is sourced from different parts of the country, particularly in the transition and savannah zones, as wood fuel. Some wood fuels are used as firewood, and others are converted to charcoal using inefficient kilns. Secondary fuel is produced from the transformation of primary fuel (crude oil, natural gas, and wood fuel) through refinery (crude oil to gasoline, kerosene), gas processing (wet gas to lean gas) and charcoal making (charcoal). The secondary energy is in liquid, solid and gaseous forms. Liquid fuels include petroleum products such as diesel, gasoline, LPG, kerosene, refinery fuel oil, refinery gas, and aviation kerosene. They are usually used in stationary and mobile combustion operations and as feedstock/non-energy. The secondary fuels are produced from the state-owned Tema Oil Refinery (TOR) and two privately owned refineries. The government deregulation policy of the downstream petroleum market permits the private sector to also import refined products.

Firewood and charcoal are the main sources of solid fuels. They are typically used as fuels for cooking and heating in households, commerce and industry. Firewood is solid biomass materials gathered from vegetated areas and used as fuel. They are neither processed nor seasoned before use. On the other hand, charcoal is made from the pyrolysis of wood in a dominantly earth-mound kiln. According to the Ghana Living Standard Survey (GLSS 7), 34.1% and 33.3% of households use charcoal and firewood, respectively, as their main cooking fuel.

Natural gas is the main gaseous fuel in the country. It is produced domestically by GNGC. Additional national gas is imported from Nigeria through the West Africa Gas Pipeline. Natural gas is mainly utilised in electricity generation.
Table 29 shows the total fuel consumption from 1990 to 2019. Ghana consumes an average of 5.7 million tonnes of oil equivalent to primary fuels every year. It has increased from 4.8 Mtoe in 1990 to 5.4Mtoe in 2016. In 2016 alone, the total primary fuel consumption was estimated at 5.33 Mtoe representing 12.1% and 6.1% higher than the quantities of fuel consumption reported in 1990 and 2012, respectively.

Table 29: Trends of total primary fuel consumption shares between 1990 to 2016 in ktoe

Year	Crude oil	Natural gas	Solid Biomass	Total fuel
1990	801.7	-	3,961.0	4,762.7
1991	981.7	-	4,112.0	5,093.7
1992	959.8	-	4,269.0	5,228.8
1993	759.9	-	4,434.0	5,193.9
1994	1075.8	-	4,606.0	5,681.8
1995	911.9	-	4,786.0	5,697.9
1996	989.5	-	4,974.0	5,963.5
1997	34.7	-	5,170.0	5,204.7
1998	1221.6	-	5,083.9	6,305.5
1999	1666.5	-	5,195.7	6,862.2
2000	1310.6	-	4,672.5	5,983.1
2001	1569.6	-	5,075.0	6,644.6
2002	1816.6	4.4	5,267.5	7,088.5
2003	1972.5	5.8	5,616.0	7,594.3
2004	2016.4	15.8	5,547.5	7,579.7
2005	2006.9	-	3,141.0	5,147.9
2006	1747.1	-	3,067.7	4,814.8
2007	2094.8	-	3,068.1	5,162.9
2008	2015.3	-	3,070.4	5,085.7
2009	1002.5		3,127.0	4,129.5
2010	1708.4	394	3,207.0	5,308.9
2011	1509.2	1671	3,370.7	6,551.2
2012	1332.1	389	3,409.2	5,130.6
2013	1343.7	292	3,554.9	5,190.2
2014	560.8	619	3,629.0	4,809.2
2015	339.2	1185	3,618.0	5,142.1
2016	1476.7	692	3,602.4	5,771.5
2017	169.2	1146	3,848.0	5,162.9
2018	415.8	1641	4,222.0	6,278.5
2019	898.9	1993	4,132.0	7,023.9
Change (1990-2019)	12%		4%	47%
Change (2016-2019)	-39%	188%	15%	22%

Solid biomass had consistently remained the largest primary fuel from 1990 to 2019. Solid biomass made up 72.9% of the total primary energy consumption, followed by oil (21.4%) and natural gas (5.7%). Even though biomass is still the dominant primary energy, its share of the total primary fuels recorded a consistent decline (83.2% in 1990 to 58.8% in 2019) due to the penetration of oil (16.8% in 1990 to 21% in 2019) and natural gas (0% in 1990 to 28.4% on 2019) (Figure 13). The persistent drops in biomass consumption are linked to the growing use of alternative fuels. The rapid shifting to oil reflects the national policy to diversify the reliance on biomass fuel. On a similar note, the continued implementation of Liquefied Petroleum Gas (LGP) promotion as an alternative fuel for domestic and commercial cooking contributed significantly to reducing biomass consumption in Ghana.

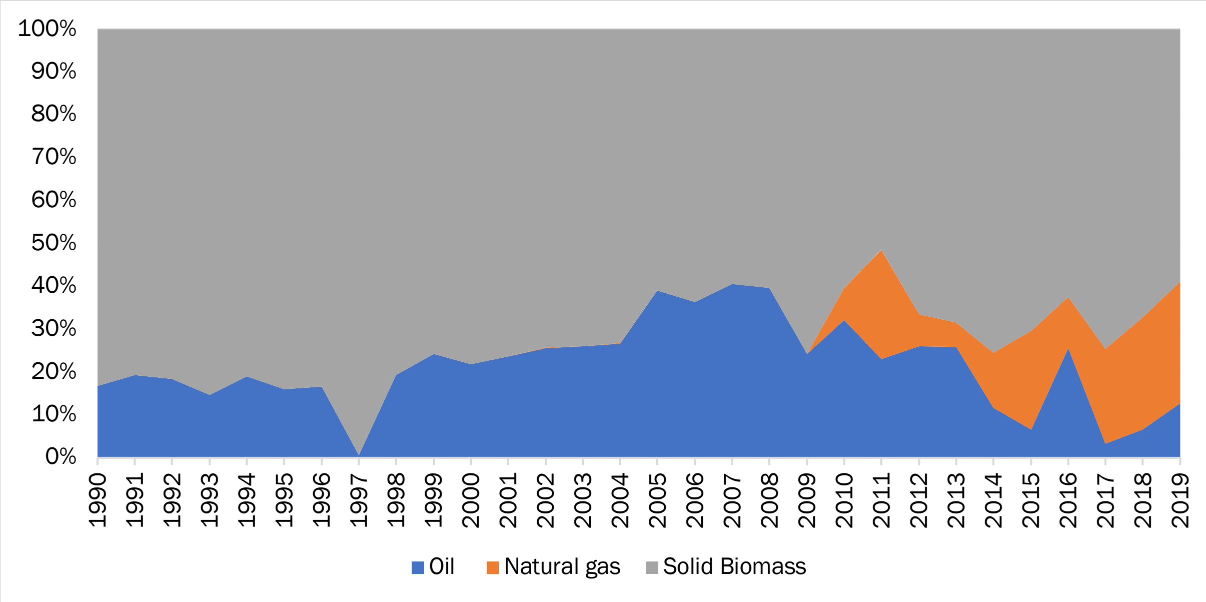


Figure 13: Percentage shares of total fuel consumption between 1990 and 2019

Figure 13 indicates a sharp increase in natural gas consumption of 187.8% between 2016 and 2019 compared to crude oil, which declined by 39% and was mostly driven by the growing use of natural gas as a substitute fuel for crude oil in electricity generation. It further revealed that solid biomass was still the dominant primary fuel (58.8%) in 2019 despite the significant transition by natural gas (28.4%).

3.5.2. Secondary fuel consumption by sources

Different forms of liquid, solid and gaseous fuels are used in energy industries, manufacturing and construction, transport and other sectors. For liquid fuels, the dominant ones are gasoline, diesel, LPG, refinery gas, refinery fuel oil, and heavy fuel oil. Petroleum coke, charcoal, firewood, and natural gas are the country's main solid and gaseous fuels. These fuels are predominantly used to fire vehicles, boilers, cooking stoves and thermal power plants. The total secondary fuel consumption increased 641% from 45.84 Petajoule (PJ) in 1990 to 339.54 PJ in 2019 (Figure 14). The consumption of gaseous fuels jumped by 178% compared to liquid fuels, which increased by 18%, as solid fuel dropped by 3% over the same period. The rising fuel consumption trend is associated with the increasing trend in energy demand due to the expanding economic activities and population pressures. Table 30 also indicates that fuel consumption trends for the various types of fuels varied. It confirms the observations of a fasting growing gas consumption against a decline in biomass fuel, particularly over 2016-2019.

Table 30: Fuel consumption and percentage change between 1990-2019

Fuel type	1990 [PJ]	2000 [PJ]	2010 [PJ]	2016 [PJ]	2019 [PJ]	Change	
						1990-2019	2016-2019
Liquid	33.83	49.32	128.02	155.21	183.36	442%	18%
Solid	161.03	157.30	157.21	181.98	176.63	10%	-3%
Gaseous	-	0.45	15.48	34.51	95.90		178%
Total	194.86	207.06	300.71	371.69	455.89	134%	23%

The analysis also showed a consistent rise in consumption of all the fuel types from 1990 to 2019. Consumption of liquid fuels recorded the highest increase of 442% relative to solid fuel, which disproportionately went up by 10%. The slow growth of solid fuels results from the policy to diversify fuel away from biomass to alternative fuels. Fuel consumption levels vary for the different emission sources in the energy sector. Generally, activities in "other sectors" and "energy industries" categories account for the largest share of the fuel consumption in the energy sector (Figure 14). On average, the "Other sectors" and "energy industries" account for 47.2% and 27% of total fuel consumption in the sector for the 29 years. The rest are transport (19.2%), manufacturing industry, and construction (6.5%).

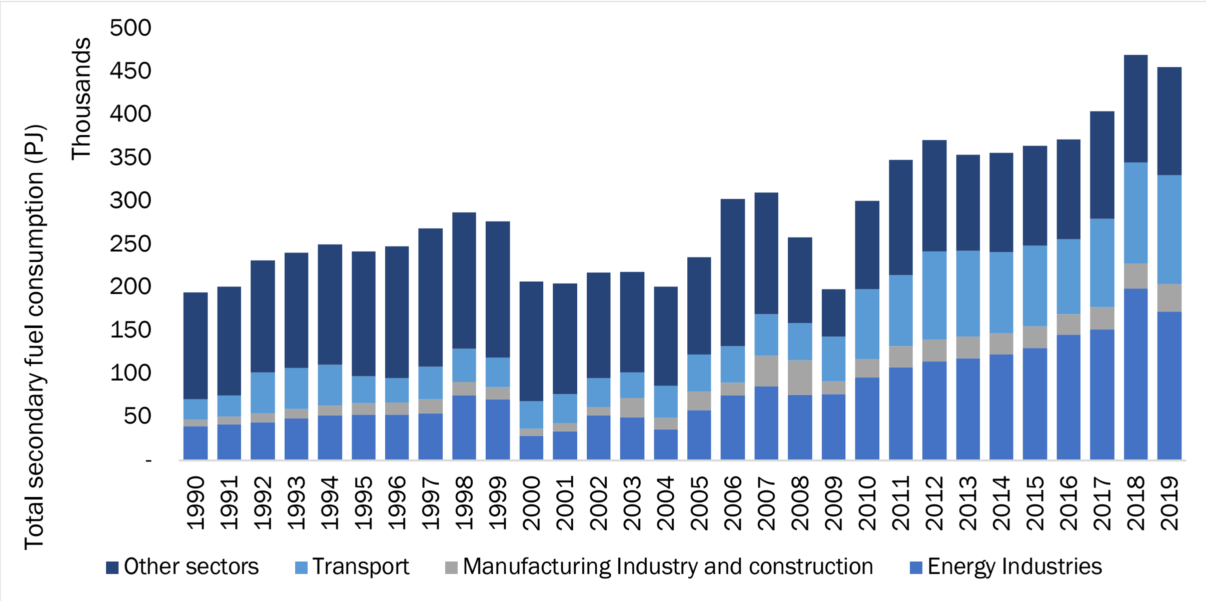


Figure 14: Trends of fuel consumption in the energy

Figure 14 shows that all the energy categories have recorded increases at different rates in terms of trends. The rate ranges from the least of 0.04% per annum for other sectors to the highest rate of 6% for transportation per annum. The transportation category recorded a sharp rise of 439% of fuel consumption at an annual growth rate of 6% for the 1990-2019 period. Total fuel consumption leapt from 39.5 PJ in 1990 to 172.3 PJ in 2019, representing a 336% increase for the energy industries category.

3.5.3 Trends in fuel consumption by types

3.5.3.1 Liquid fuels

Different types of liquid fuels are used in various energy combustion operations. Some are gasoline, diesel, kerosene, ATK, LPG, refinery gas, RFO, HFO, and DFO in electricity generation, oil refinery, lighting and transport. The predominant liquid fuels used in the Tema oil refinery are refinery gas and residual fuel oil. The commonly used liquid fuels are kerosene and diesel in the commercial and residential sectors. For instance, in the transportation category, diesel, gasoline and LPG are commonly used in road transport, whereas ATK and diesel are used in domestic aeroplanes and inland navigation by vessels and boats. Overall, the total liquid fuel consumption in the energy sector stood at 183.4 PJ in 2019, representing 442% and 18% more than the 1990 and 2016 levels.

Table 31: Changes in total liquid fuel consumption among source energy sub-categories

Categories	1990 [PJ]	2000 [PJ]	2010 [PJ]	2016 [PJ]	2019 [PJ]	Change	
						1990-2019	2016-2019
Energy Industries	-	7.07	25.20	44.50	27.87		-37%
Manufacturing Industries and construction	3.94	3.64	14.02	14.43	16.53	320%	15%
Transport	23.41	32.12	80.90	86.93	126.23	439%	45%
Other sectors	6.48	6.48	7.90	9.36	12.73	96%	36%
Total liquid fuels	33.83	49.32	128.02	155.21	183.36	442%	18%

As indicated in Table 31, in 2019, most of the liquid fuels were consumed in transport (68.8%) and followed by energy industries (15.2%), manufacturing industry and construction (9%) and other sectors (6.9%) (Figure 15). Besides being the largest consumer of liquid fuels in 2019, the transport category also recorded the highest increase of 439% between 1990 and 2019. The trend between 2016 and 2019 shows a slightly different pattern, particularly for the energy industries. Table 31 indicates a 37% decline in liquid fuel consumption in the energy industry between 2016 and 2019. The reductions in liquid fuel consumption drive the increasing utilisation of natural gas as an alternative fuel for electricity generation. Natural gas as a transition fuel is part of the Government policy to make natural gas the primary fuel source of thermal power plants.

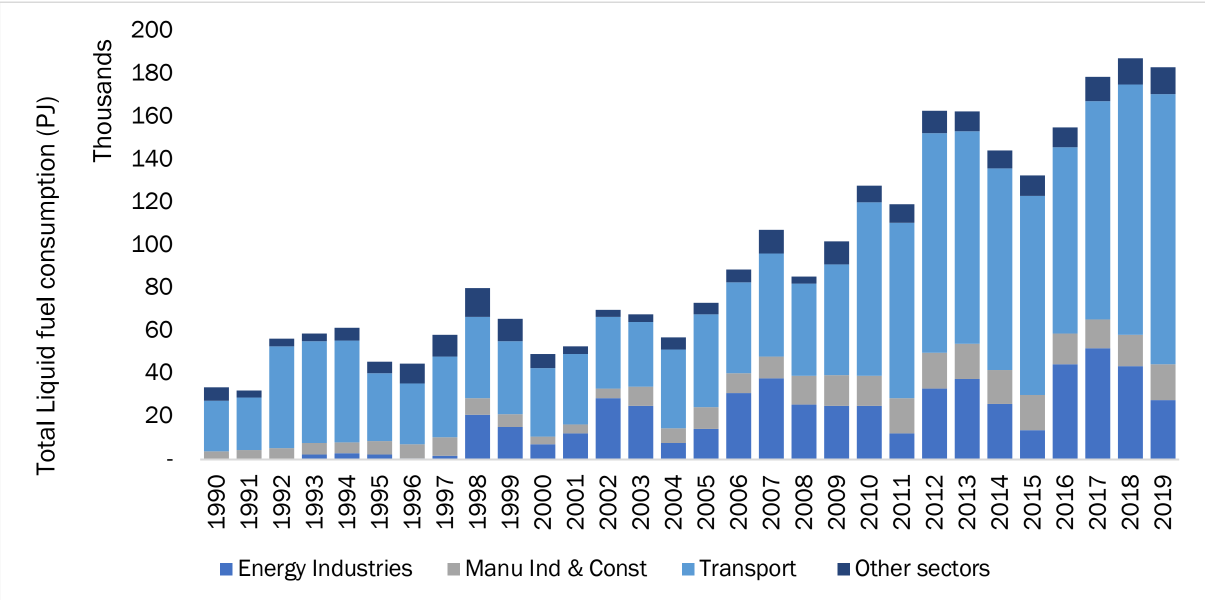


Figure 15: Liquid fuel consumption in the energy sector

In terms of trends, the transportation category was the dominant consumer of liquid fuel between 1990 and 2019 (Figure 15). Within the category, fuel consumption in road transport. Some of the underlying factors for the high fuel consumption in the road sub-category have been listed below:

- increase vehicle population and its associated traffic congestion in the major cities in the country.
- unorganised high-occupancy bus-based transport
- heavy reliance on fossil-based liquid fuels.
- inadequate non-motorised transport modes.
- non-existing fuel economy or maintenance standards.

It is also important to recognise the positive effects of the government deregulation policy on petroleum. The policy had contributed to opening the downstream petroleum market to allow more private sector participation. Oil Marketing Companies (OMCs) are now more involved in importing and retailing petroleum products. The deregulation policy had also led to the availability of a range of high-grade fuels in the market, contributing to the quality of fuels. Railways are the second-largest consumer of liquid fuels. Though the country's railway system had been operating at the desired level, its freight cargo along the Western corridor was still active. Fuel consumption in domestic aviation was rated as the third consumer of liquid fuels.

The domestic aviation industry in Ghana has seen tremendous growth not just in terms of the number of active airlines operating in the country but, more importantly, in terms of passenger uplifts. As of 2012, there were four active airlines in the domestic aviation industry, but this declined to two in 2016. The liquid fuels were consumed in the inland water-navigation sub-category involving boat and vessel use on the inland marine waters and inland freshwater transport. Premix and diesel are the main liquid fuels. The energy industry sub-category includes electricity generation, refining, manufacture of solid fuels (charcoal) and other sectors (diesel and natural gas consumption at oil fields and GNGC). For electricity generation, it involves the use of Light Crude Oil (LCO), diesel, Heavy Fuel Oil (HFO), and Distillate Fuel Oil (DFO) in a thermal power plant to produce electricity for the national grid.

In the early 1990s, most stand-by thermal power plants mostly relied on diesel until 1998, when crude oil-fired plants started kicking in during the power crises. Since then, crude oil has been the backbone fuel for thermal power plants. Recently, natural gas, HFO, and DFO fired plants have come online, resulting from the capacity expansion to boost electricity generation. Tema oil refinery is the only oil refinery in the country and consumes refinery gas, petroleum and residual fuel oil in the refinery process.

Energy industries contributed 15.2% to liquid fuel consumption in the energy sector in 2019. Liquid fuel consumption in electricity generation made up more than 90% of the energy industry in 2019. The rest was consumed in the oil refinery and other sectors. Liquid fuel consumption in energy industries showed notable increases, 294%, between 2000 and 2019. Activities under the "other sector" category are commercial/institutional, residential, agriculture, and forestry. It was the fourth important source of liquid fuel consumption, amounting to 6.9% in 2019. The patterns of liquid fuel consumption in "other sectors" increased from 1990 to 2019. The increasing use of diesel-fired and gasoline-fired stand-by generators by commercial operators and households because of the frequent erratic electricity supply from the national grid was the main factor driving fuel consumption in the other sectors.

3.5.3.2 Solid fuels

Firewood, charcoal and petroleum coke are the main solid fuels in the energy sector. They are used in refining, manufacturing solid fuels, manufacturing industry and construction, and other sectors (commercial and residential). As a by-product of the crude oil refining process, petroleum coke produces heat in multiple industrial operations. Firewood and charcoal fuels are used in the manufacturing industry, construction, and other sectors. A fraction of the wood fuel supply is used as raw material input in charcoal production. Charcoal-making is the only activity in the manufacture of solid fuel sub-category.

The solid fuel consumption amounted to 112.85 in 2019, with the most consumed commercial, residential, and manufactured solid fuels (Table 33). The consumption levels had decreased by 5% between 1990 and 2019. Consumption in energy industries (-29%) and other sectors (-4%) declined while manufacturing and construction increased by 213%.

Table 32: Share of total solid fuel consumption among the energy categories

Categories	1990 [PJ]	2000 [PJ]	2010 [PJ]	2016 [PJ]	2019 [PJ]	Change	
						1990-2019	2016-2019
Energy Industries	39.52	20.77	55.28	44.50	27.87	-29%	-37%
Manufacturing Industry & construction	3.90	4.88	7.65	9.10	12.20	213%	34%
Transport	-	-	-	-	-	-	-
Other sectors	117.61	131.64	94.27	106.21	112.85	-4%	6%
Total fuel	161.03	157.30	157.21	159.80	152.92	-5%	-4%

The "other sector" category accounted for 73.8% of solid fuel consumption. Firewood was the most common solid fuel in residential and commercial cooking within the other sector category. The charcoal's manufacture and use saw marginal increases in the residential sub-category. The second largest consumption of solid biomass was the manufacture of solid fuel (18.2%), involving the transformation of wood fuel to charcoal through pyrolysis. The remaining 8% of the solid fuel consumption was in the manufacturing industry and construction category.

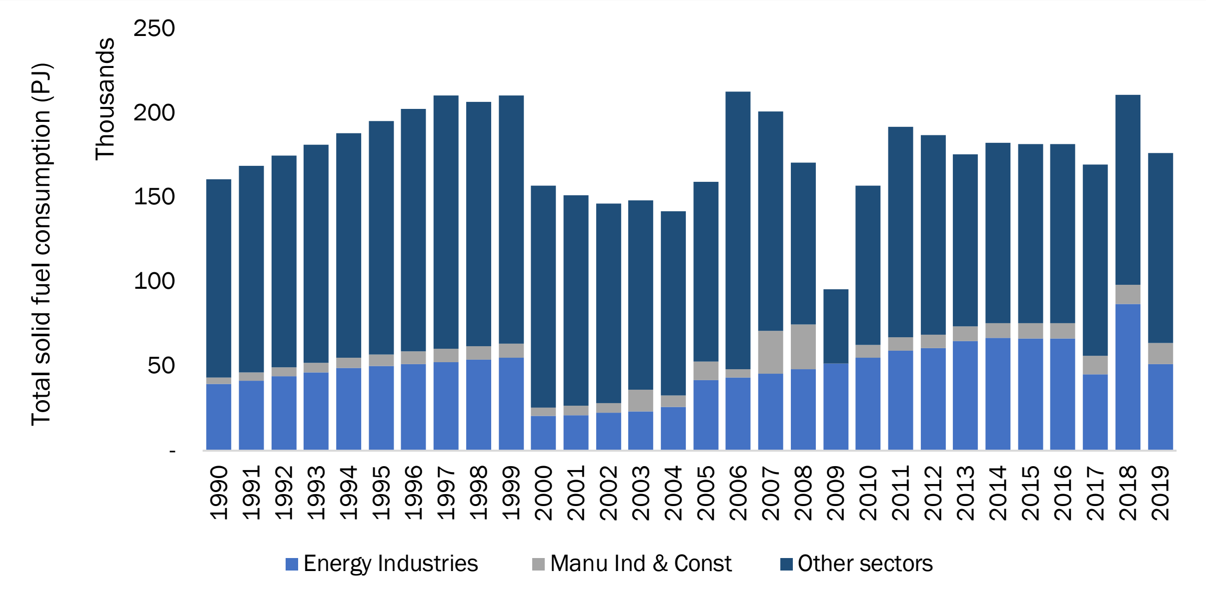


Figure 16: Trends of solid fuel consumption in the energy sector

Figure 16 also indicated a declining trend of solid fuel consumption of 5% from 161 PJ in 1990 to 152.9 in 2019. The reduction in solid fuel consumption was driven by a downward shift in firewood consumption in commercial and residential and the manufacturing industry and construction. The observed drop in solid fuel consumption could also be associated with the positive impacts of the increased LPG use through the government LPG promotion programme. Figure 16 further shows an inter-annual fluctuation in solid fuels between 2000 to 2009. The changes in the wood fuel consumption figures, especially in the firewood figures, explain the observed inter-annual variations.

Another type of solid in the energy sector is petroleum coke in refining within the energy industry category. In the crude oil refinery process, all the petroleum coke is consumed in Tema Oil Refinery (TOR).

3.5.3.3 Gaseous fuels

Natural gas and refinery gas are the main gaseous fuel in the energy sector. They are used as single-fuel or dual-fuel in thermal electricity plants and oil refineries and limited use in manufacturing. Natural gas is mainly sourced from a state-run GNGC and Nigeria through the West Africa Gas Pipeline. The Nigeria imports started in 2010 till date as a joint sub-region project. The submarine pipeline crosses Benin and Togo before getting to Ghana. There is an on-shore/off-shore tie-in pipeline in Ghana to carry the gas for distribution to the individual power plants. After 2012, GNGC commenced operations to produce domestic gas to complement the Nigeria gas imports. The GNGC wet gas is sourced from the Jubilee and Sankofa oil fields. The Tema Oil Refinery produces gas from the crude distillation process and utilises internal power generation instead of flaring.

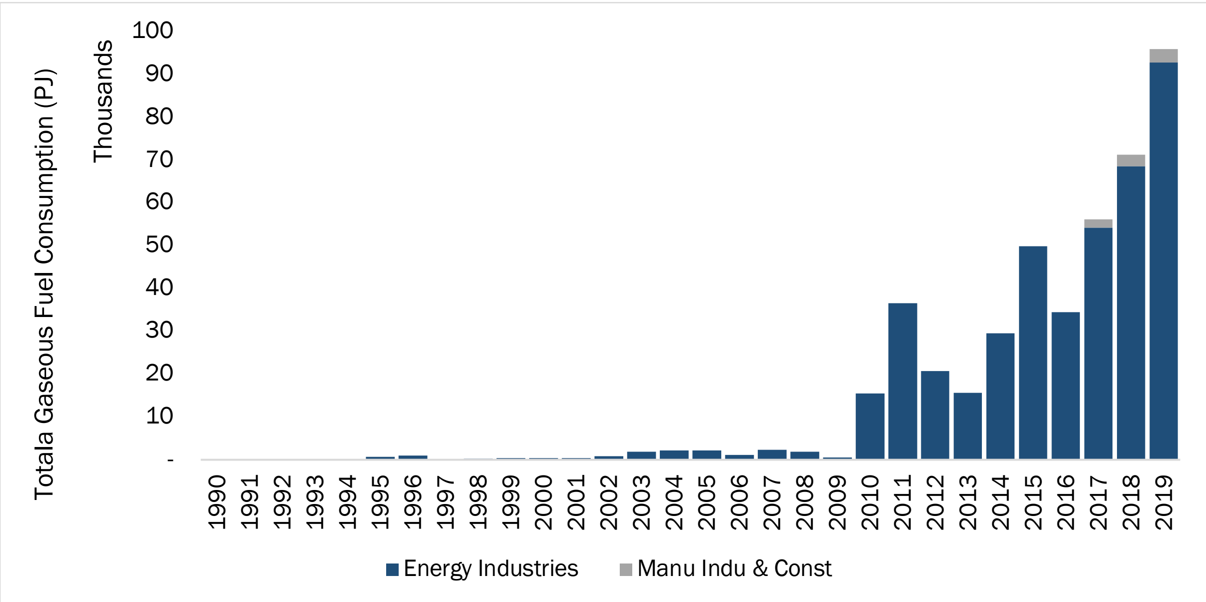


Figure 17: Gaseous fuel consumption trend from 1990 to 2019

The gas consumption trends showed inter-annual variation due to the fluctuations in the substitution of crude oil with natural gas for electricity production (Figure 17). In the first year of commercial production in 2010, natural gas consumption hovered around 36.5 PJ, suggesting a majority coming from Nigeria imports. The reason was that the new plant usually had to undergo a test run at the early stage of the commissioning, so not much natural gas may be produced from the new plants. Even if the transportation pipeline is not ready after the test run, it may not be available at the processing plant. The natural gas consumption had increased by 519%, from 15.5 PJ in 2010 to 95.8 PJ in 2019.

3.6 Analysis of energy sector emissions

The GHG emissions in the energy sector amounted to 27.30 $MtCO_2e$ in 2019, making up 45.7% of the national totals, including LULUCF. When the LULUCF emissions are excluded from the total national emissions, the energy sector emission constituted 61% of Ghana's emissions in 2019. The energy emissions showed a generally rising trend with observed peaks in 2011 and 2017. The peaks resulted from increased flaring and venting during oil and gas production and the processing and distribution of natural gas.

Furthermore, the 2019 energy emissions of 27.3 $MtCO_2e$ increased by 863% and 22.1% between 1990 and 2016. The upward trends in the energy sector emission are mainly led by the corresponding rising emissions in transport, oil and gas and electricity generation over the same period. The energy emissions correlate to final fuel consumption in the electricity and transport sectors. It also closely follows similar population and GDP growth (ES Table 2). The rising trend among total energy emissions, population and GDP firmly suggests a statistical relationship like the Kaya identity components described in Peter, 2017. Kaya identifies CO_2 as the product of population, GDP per capita, energy use per unit of GDP, and carbon emissions per energy consumed. It is used as an indicator of the driving factors of CO_2 emissions in the energy sector[21].

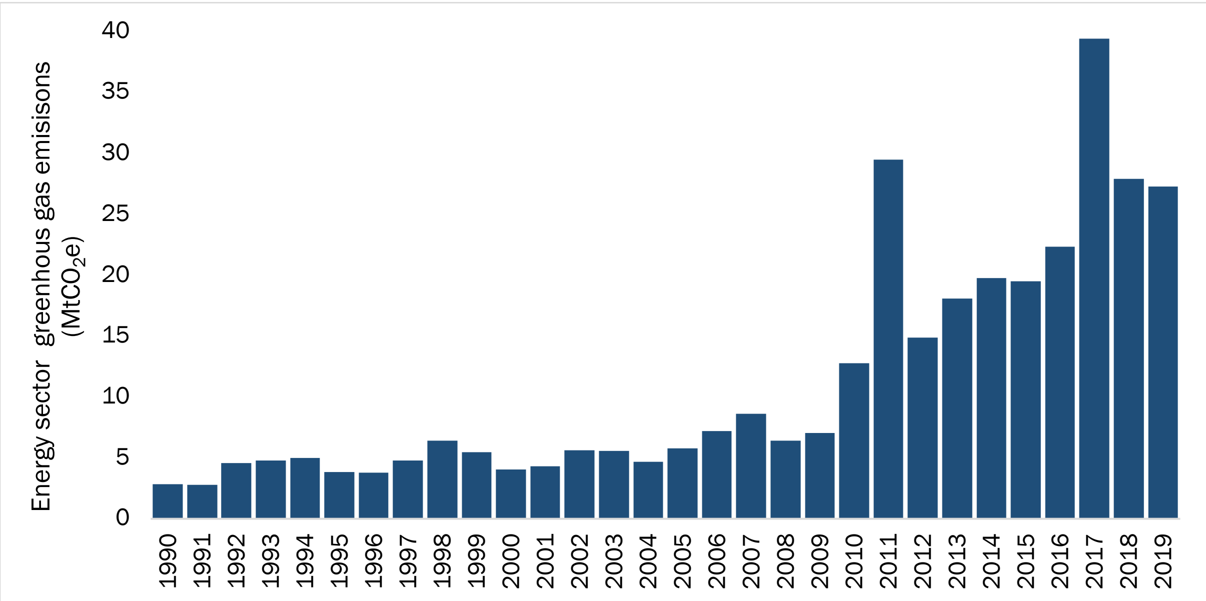


Figure 18: Trends of energy sector trends for 1990-2019

Greenhouse gas associated with fuel combustion is the dominant source of emissions in the energy sector (
Figure 19). On average, it accounted for 88.7% of the energy sector emission between 1990-2019. The remaining 11.3% come from the fugitive emissions from fuels. In 2011 and 2017, fugitive emissions from fuels topped because of increased gas flaring associated with oil production.

[21] https://sustainabilitydictionary.com/2011/03/13/the-kaya-identity access on 19th November 2021

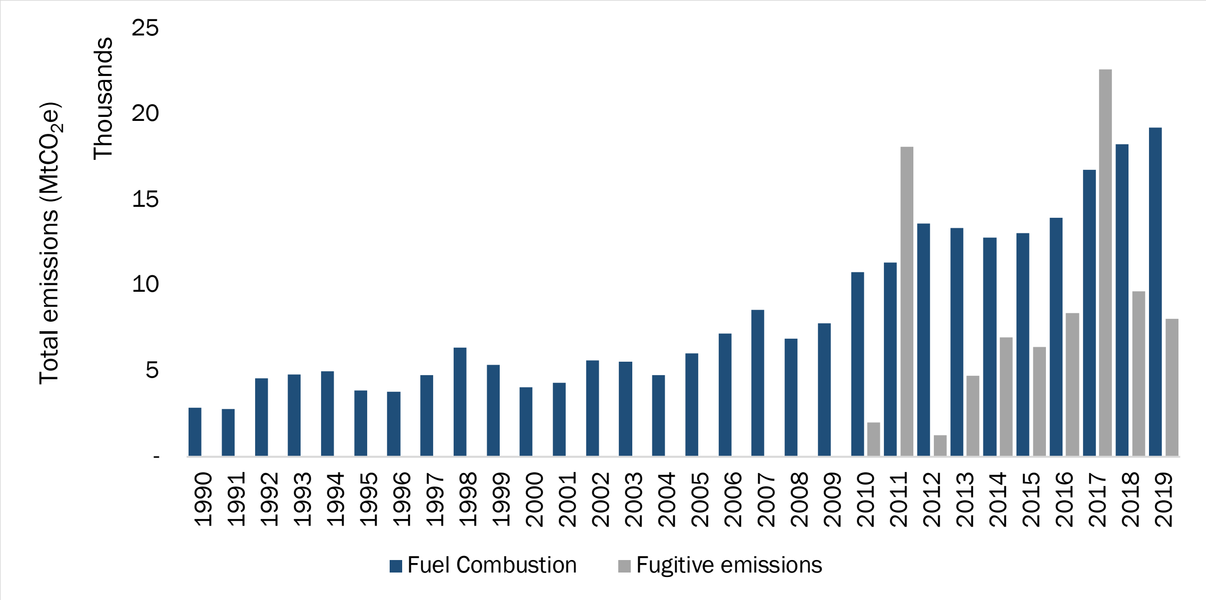


Figure 19: GHG emissions associated with fuel combustion and fugitive emissions from fuels

For the fuel combustion emissions of 19.2 $MtCO_2e$ in 2019, stationery combustion (1A.1, 1A.2 and 1A.3) contributed 52% (10 $MtCO_2e$) as against 48% (9.23 $MtCO_2e$) from the mobile combustion (1A.3). Virtually all the fugitive emissions from fuels were from venting during oil production and through the processing distribution of natural gas and oil refining. Transportation was the largest source of GHG emissions in the energy sector and was trailed by energy industries, manufacturing industries, construction, and other sectors (Figure 20). The transport sector's share of the total energy emissions reduced from 59.47% in 1990 to 47.95% in 2019. on the other hand, the energy industry's contribution to the total emissions increased from 2.68 $MtCO_2e$ in 1990 to 38.53 $MtCO_2e$ in 2019, representing an annual average growth of 15.1%

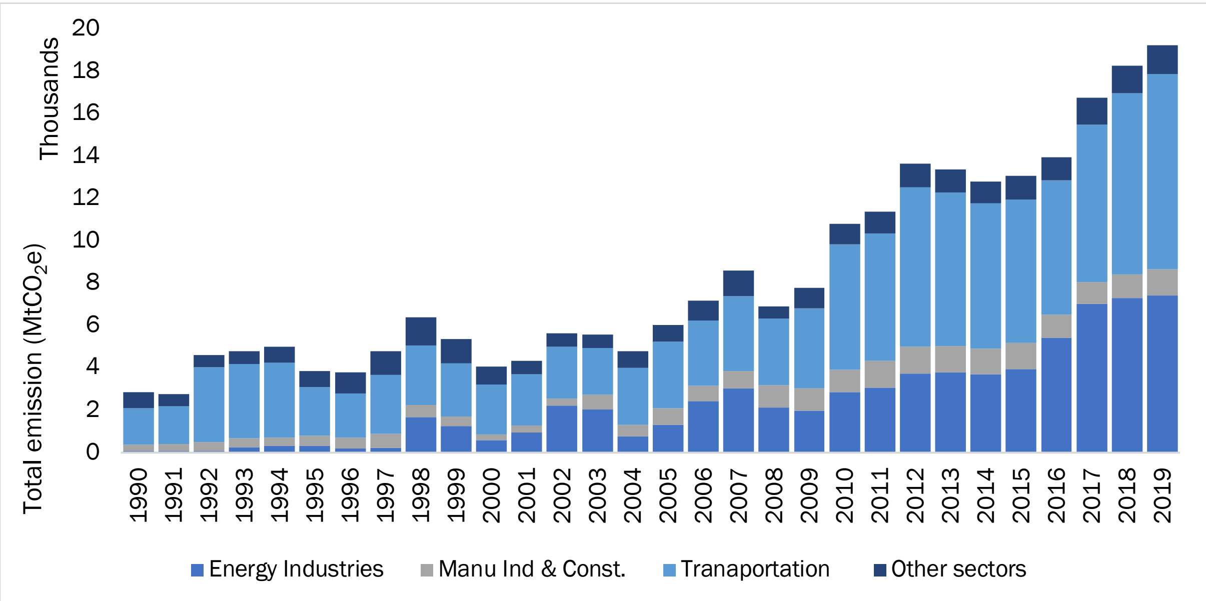


Figure 20: Share of fuel combustion activities to the energy sector emissions

3.6.1 Energy sector emissions by gases

Carbon dioxide is the most dominant greenhouse gas in the energy sector, amounting to 26.4 Mt. Of the total 2019 emissions of 27.3 $MtCO_2e$ for the sector, carbon dioxide accounted for 96.6%. The energy sector CO_2 levels made up 62.9% of the total net CO_2 emissions with LULUCF. When the CO_2 emissions from LULUCF are excluded from the national total, the energy sector's share goes up to 96.2%. Aside CO_2 emissions, methane contribute to 2.1% (0.58 $MtCO_2e$) and nitrous oxide which made up of 1.3% (0.34 $MtCO_2e$).

All three direct greenhouses exhibited rising trends at different growth rates from 1990 to 2019. Carbon dioxide emission recorded the largest percentage increase of 968% and the fastest growth rate of 9% per annum across the same period (Table 33). Similarly, from 2016 to 2019, CO_2 emissions rose by 22%. The predominance of CO_2 emissions in energy is linked to road transport and electricity generation, particularly with the growing traffic congestion in the major cities and the high carbon-intensive thermal electricity generation. LPG and kerosene use in the residential sub-categories also contributed to CO_2 emissions in the energy sector.

Table 33 : Trend of energy sector greenhouse gases for 1990-2016

Years	CO_2 (Mt)	CH_4 ($MtCO_2e$)	N_2O($MtCO_2e$)	Total ($MtCO_2e$)
1990	2.47	0.19	0.21	2.86
1991	2.36	0.20	0.22	2.78
1992	4.14	0.21	0.25	4.60
1993	4.32	0.22	0.26	4.79
1994	4.52	0.23	0.27	5.01
1995	3.38	0.23	0.25	3.86
1996	3.30	0.24	0.26	3.80
1997	4.25	0.25	0.28	4.78
1998	5.86	0.25	0.28	6.39
1999	4.82	0.25	0.28	5.35
2000	3.62	0.25	0.21	4.07
2001	3.88	0.25	0.20	4.32
2002	5.18	0.25	0.19	5.63
2003	5.12	0.25	0.19	5.57
2004	4.34	0.26	0.19	4.79
2005	5.51	0.30	0.21	6.03
2006	6.56	0.34	0.28	7.18
2007	7.99	0.34	0.27	8.60
2008	6.37	0.31	0.23	6.90
2009	7.44	0.18	0.16	7.78
2010	12.18	0.35	0.26	12.79
2011	28.53	0.57	0.39	29.48
2012	14.25	0.33	0.33	14.90
2013	17.35	0.45	0.31	18.11
2014	18.97	0.51	0.32	19.79
2015	18.70	0.50	0.31	19.50
2016	21.51	0.53	0.32	22.35

2017	38.28	0.77	0.38	39.42
2018	26.93	0.62	0.38	27.94
2019	26.38	0.58	0.34	27.30
Change (1990-2019)	968.0%	205.3%	61.9%	854.5%
Change (2016-2019)	22.64%	9.43%	6.25%	22.15%
Annual growth rate	9%	4%	2%	8%

Methane and nitrous oxide emissions also showed similar increases. Methane levels have jumped by 209.2% over the 29 years at an annual rate of 4%, mainly due to the dominant use of solid biomass fuel for residential cooking and charcoal production. The relatively slow growth rate in CH_4 emissions can be attributed to the positive influence of the gradual shift to efficient cooking stoves and penetration of LPG use.

3.6.2 Energy sector emissions by categories

The GHG emissions from the two dominant sources in “fuel combustion” and “fugitive emissions from fuel” increased in 1990 and 2019. Fuel combustion emissions generally showed steady growth over the 29-years, increasing at a rate of 8% per annum (Table 34). The fugitive emissions from fuel have also increased, registering a peak in 2011 and 2017 due to increased flaring and venting from the oil and gas production fields.

The emissions trends of activities that make up fuel combustion categories showed different patterns because of the country's growing dependence on oil products and the implementation of fuel diversification policies. The policies have largely focused on shifting reliance on solid biomass and heavy fuels to relatively cleaner oil products. Although emissions from energy industries and transport form most of the energy emissions in recent times, it is worthy to note that before 1999, the manufacturing industry and construction and other sectors dominated.

The thermal electricity diversification policy made energy industries record the fastest GHG emission growth, followed by transport, manufacturing industry, construction, and oil and gas between 1990 and 2019. In the same period, emissions from other sectors declined due to the fuel switch policy from solid biomass to LPG for cooking. The main GHG emission source was flaring and leakages in the upstream and downstream oil and gas operations. Commercial oil production started in 2010 in the Jubilee fields.

Since then, two additional fields, the TEN and Sankofa fields, started oil and gas operations in 2014 and 2016. The main emission sources in the oil and gas production stream are: (a) flaring from oil production at Jubilee and TEN fields, natural gas production at Sankofa fields; (b) natural gas transmission to the Atuabo Gas Processing Plant; (c) natural gas processing and (d) natural gas distribution from Atuabo and Aboadze Thermal Power Plants.

Table 34: Total energy sector emissions grouped into source-categories

Year	Energy	Fuel Combustion	Energy Industry	Manufacturing Industry & Construction	Transport	Other sectors	Fugitive Emissions from Fuels	Oil and gas
	1	1A	1A.1	1A.2	1A.3	1A.4	1B	1B.2
1990	2.86	2.86	0.08	0.31	1.7	0.78	-	-
1991	2.79	2.78	0.08	0.35	1.79	0.57	-	-
1992	4.6	4.6	0.09	0.43	3.51	0.58	-	-
1993	4.79	4.79	0.27	0.41	3.52	0.6	-	-
1994	5.01	5.01	0.32	0.4	3.52	0.77	-	-
1995	3.86	3.86	0.32	0.49	2.3	0.76	-	-
1996	3.8	3.8	0.19	0.51	2.08	1.01	-	-
1997	4.78	4.78	0.22	0.67	2.77	1.11	-	-
1998	6.39	6.39	1.67	0.58	2.81	1.33	-	-
1999	5.49	5.35	1.26	0.59	2.52	1.12	-	-
2000	4.07	4.07	0.59	0.29	2.33	0.87	-	-
2001	4.32	4.32	0.97	0.33	2.39	0.63	-	-
2002	5.63	5.63	2.23	0.34	2.43	0.63	-	-
2003	5.57	5.57	2.04	0.7	2.19	0.63	-	-
2004	4.7	4.79	0.78	0.45	2.68	0.79	-	-
2005	5.78	6.03	1.31	0.54	3.15	0.79	-	-
2006	7.18	7.18	2.45	0.71	3.08	0.94	-	-
2007	8.6	8.6	3.05	0.81	3.54	1.21	-	-
2008	6.4	6.9	2.12	0.55	3.15	0.58	-	-
2009	7.04	7.78	1.98	0.33	3.78	0.95	-	-
2010	12.79	10.8	2.85	1.06	5.94	0.95	1.99	1.99
2011	29.48	11.37	3.08	1.25	6.01	1.03	18.12	18.12
2012	14.9	13.64	3.74	1.26	7.52	1.11	1.26	1.26
2013	18.11	13.38	3.78	1.24	7.27	1.08	4.73	4.73
2014	19.79	12.81	3.7	1.2	6.87	1.04	6.98	6.98

2015	19.5	13.08	3.93	1.24	6.8	1.11	6.42	6.42
2016	22.35	13.95	5.44	1.09	6.33	1.09	8.4	8.4
2017	39.42	16.77	7.03	1.02	7.46	1.27	22.65	22.65
2018	27.94	18.28	7.3	1.11	8.56	1.32	9.66	9.66
2019	27.3	19.25	7.42	1.25	9.23	1.35	8.05	8.05
Change (1990-2019)	854.5%	573.1%	9175.0%	303.2%	442.9%	73.1%		
Change (2016-2019)	22.2%	37.99%	36.4%	14.68%	45.81%	23.85%	-4.17%	-4.17%
Annual growth rate	8%	7%	17%	5%	6%	2%		

3.7 Fuel combustion activities (1. A)

The energy production and consumption operations involving burning or heating are classified into fuel combustion. They have been clustered into the four IPCC sub-categories: (a) energy industries, (b) manufacturing industry, (c) transport and (d) other sectors. Under this section, the NIR reports information on the following areas:

- comparison of sectoral/reference approach
- international bunker fuels
- feedstock/non-energy use
- completeness
- source-specific emission trends
- methodology choices
- QA/QC and
- planned improvements

3.7.1 Comparison of CO_2 emissions using reference approach and sectoral approach

The Reference Approach (RA) is a top-down approach that uses Ghana's total energy supply data to calculate CO_2 emissions from the combustion of mainly liquid and gaseous fuels. The RA does not distinguish between different sources within the energy sector but estimates total CO_2 emissions from the Fuel Combustion (1A) source category. On the other hand, the Sectoral Approach (SA) distinguishes different source categories within the energy sector and estimates the emissions for the respective sources.

The RA and SA often have different results because RA has no detailed information on each category's fuels. Therefore, it is 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, and excluded carbon calculation. Typically, the gap between the two approaches is relatively small (5% or less) than the total carbon flows involved. Therefore, explanations should be provided when the difference is more than 5%.

3.7.1.1 Comparison of CO_2 emissions in the energy sector

Ghana has estimated CO_2 emissions using the Reference Approach (RA) and Sectoral Approach (SA) methods. Table 35 presents RA and SA CO_2 emissions and differences in the results over the inventory time series. The differences in CO_2 emissions between RA and SA range from 0% to 11%. Generally, RA CO_2 emissions are higher than SA CO_2 emissions in the entire time series. The observed inconsistencies in RA and SA CO_2 were due to the statistical differences among petroleum products and observed variations associated with secondary data used to derive the stock change. Since submitting the NIR4, Ghana took steps to improve fuel allocation formulae in the energy balance, which has corrected the large inconsistencies recorded in the previous report.

Table 35: Comparison of the differences in CO_2 emissions estimated using RA and SA

Years	Reference Approach [Mt]			Sectoral Approach [Mt]			Difference [Mt]			
	Liquid	Solid	Gas	Liquid	Solid	Gas	Liquid	Solid	Gas	Total
1990	2.52	-	-	2.43	-	-	4%	0%	0%	4%
1991	2.41	-	-	2.33	-	-	3%	0%	0%	3%
1992	4.21	-	-	4.10	-	-	3%	0%	0%	3%
1993	4.22	-	-	4.17	-	-	1%	0%	0%	1%
1994	4.57	-	-	4.55	-	-	0%	0%	0%	0%
1995	3.36	-	-	3.31	-	-	2%	0%	0%	2%
1996	3.29	-	-	3.27	-	-	1%	0%	0%	1%
1997	4.34	-	-	4.21	-	-	3%	0%	0%	3%
1998	6.18	-	-	5.99	-	-	3%	0%	0%	3%
1999	5.09	-	-	4.89	-	-	4%	0%	0%	4%
2000	3.67	-	-	3.52	-	-	4%	0%	0%	4%
2001	4.08	-	-	3.79	-	-	8%	0%	0%	8%
2002	5.17	0.02	-	5.05	0.02	-	2%	0%	0%	2%
2003	5.05	0.03	-	4.98	0.03	-	2%	0%	0%	2%
2004	4.45	0.03	-	4.19	0.03	-	6%	0%	0%	6%
2005	5.40	0.04	-	5.36	0.04	-	1%	0%	0%	1%
2006	6.60	0.02	-	6.25	0.02	-	6%	0%	0%	6%
2007	7.87	0.04	-	7.69	0.04	-	2%	0%	0%	2%
2008	6.29	0.03	-	6.07	0.03	-	4%	0%	0%	4%
2009	7.31	0.01	-	7.26	0.01	-	1%	0%	0%	1%
2010	9.79	0.02	0.79	9.17	0.02	0.80	7%	0%	0%	6%
2011	8.71	0.02	1.87	8.65	0.02	1.79	1%	0%	4%	5%
2012	11.91	0.01	0.94	11.76	0.01	0.91	1%	0%	2%	4%
2013	12.15	0.01	0.68	11.68	0.01	0.66	4%	0%	3%	7%
2014	10.77	0.00	1.45	10.29	0.00	1.45	5%	0%	0%	5%
2015	9.90	0.00	2.83	9.46	0.00	2.60	5%	0%	9%	13%
2016	11.20	0.03	1.70	11.00	0.03	1.57	2%	0%	8%	10%
2017	12.92	0.00	2.78	12.27	0.00	2.62	5%	0%	6%	11%
2018	13.10	0.00	3.52	13.13	0.00	3.29	0%	0%	7%	7%
2019	13.56	0.00	4.82	13.13	0.00	4.58	3%	0%	5%	9%

Some specific explanations of the differences between CO_2 emissions for the major fuels reported in the NIR4 are still relevant as below:

- The national energy balance was based on mass-balanced and not carbon balanced. That approach introduced inherent consistencies in the fuel balance.
- Observed statistical differences in the supply and consumption figures in the energy balance contributed to some of the differences.
- Data on annual stock change for liquid fuels were hardly reported in the energy balance. Therefore, it was derived using production, imports, export, consumption and ending stocks figures. Because most of the data on stock changes were not reported in the energy balance but calculated, there was a possibility of overestimating or underestimating.
- Kerosene – RA and SA excluded CO_2 emissions from non-energy use of kerosene in the industrial process.

3.7.2 International bunker fuels

The emissions of liquid fuel consumption in international bunkers were part of the original inventory estimates. However, the emissions have been set aside as a memo item (information note) from the overall inventory results consistent with the IPCC guidelines. International bunkers supplied and used jet kerosene and diesel fuels for international aviation and marine bunkers services. In 2019, with a total of 8.75 PJ used, a corresponding total emission of 0.63 $MtCO_2e$ was recorded in the international bunkers (Table 36). Of the total marine bunker fuels of 0.31 PJ, the associated emission amounted to 0.023 $MtCO_2e$

Table 36: ATK and diesel consumption and GHG emissions for international bunkers

Year	International Bunkers					
	Fuel consumption (PJ)			GHG Emissions ($MtCO_2e$)		
	Marine Bunkers	Aviation Bunkers	Total	Marine Bunkers	Aviation Bunkers	Total
1990	0.04	0.88	0.92	0.003	0.063	0.066
1991	-	0.35	0.35	-	0.025	0.025
1992	0.06	0.34	0.40	0.005	0.025	0.029
1993	1.48	0.33	1.80	0.110	0.023	0.134
1994	1.04	0.41	1.45	0.078	0.029	0.107
1995	0.07	4.14	4.22	0.005	0.299	0.304
1996	0.43	0.54	0.98	0.032	0.039	0.072
1997	0.02	0.65	0.67	0.001	0.047	0.048
1998	2.61	0.97	3.58	0.195	0.070	0.265
1999	2.24	0.74	2.98	0.168	0.053	0.221
2000	0.03	0.54	0.57	0.002	0.039	0.041
2001	-	0.35	0.35	-	0.025	0.025
2002	0.08	0.34	0.42	0.006	0.025	0.031
2003	0.15	0.33	0.47	0.011	0.023	0.035
2004	0.06	0.41	0.47	0.005	0.029	0.034
2005	0.06	0.27	0.33	0.004	0.020	0.024
2006	2.77	0.54	3.31	0.207	0.039	0.247
2007	1.90	0.65	2.55	0.143	0.047	0.189
2008	2.44	0.97	3.40	0.182	0.070	0.252
2009	1.64	0.74	2.38	0.123	0.053	0.176
2010	0.59	4.16	4.74	0.044	0.300	0.344
2011	-	5.19	5.19	-	0.374	0.374
2012	-	5.20	5.20	-	0.375	0.375
2013	-	4.82	4.82	-	0.348	0.348
2014	0.46	4.23	4.69	0.035	0.305	0.340
2015	-	3.68	3.68	-	0.265	0.265
2016	0.10	4.74	4.84	0.008	0.342	0.350
2017	3.83	5.78	9.61	0.287	0.417	0.703
2018	0.44	7.13	7.57	0.033	0.514	0.547
2019	0.31	8.75	9.06	0.023	0.631	0.654

3.7.2.1 Methodological issues in international civil aviation and marine transport

3.7.2.1.1 International civil aviation

Generally, GHG emissions from international aviation operations were divided into landing and take-off cycles (LTO) and air operations and cruising. The parts of civil aviation that fell into this class took off from Ghana, cruised across borders and landed in other countries. So, when a plane fuels ATK in Ghana and takes off from the Kotoka International Airport, cruises for nearly hours in the international space, and land in Addis Ababa. The flight falls in the category of international bunkers because the COP has not officially adopted the methodology for allocating GHG emissions during the cruising phase.

Therefore, GHG emissions from international aviation and marine operations were estimated separately from the national totals consistent with the 2006 guidelines. Due to the lack of access to LTO and fuel use data, the tier 1 approach was used. The tier 1 methodology required the total ATK fuel allocation to the international aviation bunkers to estimate the emissions. In this inventory, the GHG emission was estimated using the quantity of ATK sent to the Ghana bunkering services and sales to the airlines and applicable IPCC default emission factors. The Ghana Bunkering Services manage ATK for civil aviation. Total ATK consumption is frequently reported in the energy statistics, but the split between domestic and international aviation was not reported in the energy balance. ATK sale figures to the local airlines were collected from the OMCs. With the OMCs data, it was possible to use a bottom-up approach to split the share of international aviation from domestic aviation.

3.7.2.1.2 International marine bunkers

Diesel was the main international marine bunker fuel in the country. Data on diesel supply was obtained from Ghana bunkering services, and diesel export data reported in the national energy balance were used to derive the total diesel consumption for international marine navigation. It was assumed that most of the reported diesel exports sent to the international were meant for the international marine bunkers. The diesel allocated to the international marine bunkers and IPCC default emission factors were used for the emission calculations under this sub-category.

3.7.3 Feedstock and non-energy use of fuels

Fuels used as non-energy and feedstock are not reported in the national energy balance. In the absence of country-specific data on feedstock and non-energy use of fuels, the data was sourced from the International Energy Agency (IEA) and some private companies that produce them locally. Some of the feedstock and non-energy use fuels are bitumen, some kerosene, lubricants and other fuels such as tar and grease products used in transport, construction and industrial activities. On average, the yearly consumption of lubricant, bitumen and kerosene is 26.83 ktoe, 5.24 ktoe and 4.22 Mtoe, respectively, per annum. The following assumptions were made:

- Emissions associated with the manufacture of lubricants, bitumen and kerosene emissions are included in category 1A1.b (petroleum refinery).
- Emissions from the use of motor oil are included in 2.2D (lubricant and solvent use).
- Emissions from waste oil disposal are not estimated due to a lack of data. Waste oil disposal is considered non-combustible because they are mainly used for wood preservation.

- Emissions from bitumen for road paving and roofing were not reported because of a lack of data.

3.7.4 Time-series consistency

The coherent use of the methods and the data helped reduce inconsistencies in the estimates and avoid overestimations or underestimations. It is good practice to ensure that the methodology used for the emission estimation and the underlying data are, as far as possible consistent throughout the time series in all the inventory years. If the method used in the inventory is not consistent throughout, biases can be introduced into the emission trends. Therefore, when changes in methods and data or time-series gaps occurred, recalculation was done, and appropriate IPCC methods for resolving data gaps were applied.

3.7.4.1 Energy sector recalculations

Recalculation has been done in the energy sector for the previous estimates for the period 1990 and 2016. The recalculations were done because of new emission sources, updates of sector fuel allocation to be consistent with the energy statistics, and newly available activity data from different national and international sources. Each source-specific category has provided detailed descriptions of the reasons for and impacts of recalculations. The changes that made the largest impact was the revision of fuel consumption share to ensure consistency with the Energy Statistic figures. Table *37* shows the results of the impacts of recalculations on the previous estimates.

Table 37: Assessment of the overall impacts of recalculations in the energy sector

Year	CO_2 (Mt)		Change (%)	CH_4 ($MtCO_2e$)		Change (%)	N_2O ($MtCO_2e$)		Change (%)	Total ($MtCO_2e$)		Change (%)
	PE	LE		PE	LE		PE	LE		PE	LE	
1990	2.52	2.47	-2	0.96	0.19	-81	0.25	0.21	-17%	3.73	2.86	-23
1991	2.03	2.36	16	0.99	0.20	-80	0.26	0.22	-17%	3.28	2.78	-15
1992	2.29	4.14	81	1.01	0.21	-79	0.26	0.25	-4%	3.56	4.60	29
1993	2.34	4.32	85	1.04	0.22	-79	0.28	0.26	-8%	3.66	4.79	31
1994	2.89	4.52	56	1.08	0.23	-79	0.29	0.27	-9%	4.26	5.01	18
1995	2.69	3.38	26	1.12	0.23	-79	0.3	0.25	-15%	4.11	3.86	-6
1996	3.21	3.30	3	1.17	0.24	-80	0.31	0.26	-16%	4.69	3.80	-19
1997	3.16	4.25	34	1.2	0.25	-79	0.32	0.28	-13%	4.68	4.78	2
1998	5.33	5.86	10	1.18	0.25	-79	0.33	0.28	-14%	6.84	6.39	-7
1999	4.81	4.82	0	1.21	0.25	-79	0.33	0.28	-15%	6.35	5.35	-16
2000	4.83	3.62	-25	0.87	0.25	-71	0.26	0.21	-21%	5.96	4.07	-32
2001	5.22	3.88	-26	0.82	0.25	-70	0.25	0.20	-21%	6.29	4.32	-31
2002	6.6	5.18	-21	0.78	0.25	-68	0.24	0.19	-19%	7.62	5.63	-26
2003	5.98	5.12	-14	0.73	0.25	-66	0.23	0.19	-16%	6.94	5.57	-20
2004	5.76	4.34	-25	0.72	0.26	-63	0.22	0.19	-15%	6.7	4.79	-29
2005	5.67	5.51	-3	0.46	0.30	-35	0.18	0.21	17%	6.31	6.03	-4
2006	7.82	6.56	-16	0.67	0.34	-49	0.23	0.28	20%	8.72	7.18	-18
2007	8.98	7.99	-11	0.69	0.34	-51	0.29	0.27	-7%	9.96	8.60	-14
2008	7.94	6.37	-20	0.45	0.31	-30	0.25	0.23	-10%	8.64	6.90	-20
2009	9.03	7.44	-18	0.45	0.18	-60	0.27	0.16	-40%	9.75	7.78	-20
2010	9.29	12.18	31	0.59	0.35	-40	0.23	0.26	14%	10.11	12.79	27
2011	10.79	28.53	164	0.62	0.57	-8	0.27	0.39	43%	11.68	29.48	152

2012	12.15	14.25	17	0.62	0.33	-47	0.3	0.33	9%	13.07	14.90	14
2013	12.24	17.35	42	0.63	0.45	-28	0.33	0.31	-6%	13.2	18.11	37
2014	12.54	18.97	51	0.65	0.51	-22	0.36	0.32	-12%	13.55	19.79	46
2015	13.14	18.70	42	0.65	0.50	-23	0.38	0.31	-19%	14.17	19.50	38
2016	13.97	21.51	54	0.66	0.53	-20	0.38	0.32	-17%	15.01	22.35	49

The energy sector recalculations led to changes in the emissions ranging from 152% to -32% compared to the estimates reported for the period 1990-2016 in the NIR4. The recalculated values for the latest estimates were generally high from 2010 to 2016, with an average 52% increase in emissions. The highest impacts of the recalculation of 152% were recorded in 2011 due to the changes in the unit conversion factor for the quantity of gas flaring in oil production. The recalculations on CO_2 emissions showed a similar impact on the total emissions. The CH_4 and N_2O emissions pattern indicated lower emissions in the latest estimates.

3.7.4.2 Filling of data gaps in the energy sector

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). The methodology used for each data gap identified depended on the types and nature of the data. Fuel balance approaches are described in Table 38.

Table 38: Data gaps in the energy sector and method for filling the gaps

Category	Gaps	Methodology used	Justification for the methodology used	Description of the approach to filling gaps
Electricity generation (1.A1a)	Lack of time series for diesel data inputs for electricity generation plant	overlap approach	Data gaps in the time series data and where consistent correlation or relationship existed between activity data being used	This approach was used in 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 applied to the power generated in the years with the data gap to obtain diesel consumption quantities.
Stock changes	Missing stock change data	Fuel balance	Used in years where both National statistics and IEA do not report on the stock change	Stock change calculation uses figures on balance between production, import against consumption, export, and ending stock.

Road Transport	Missing vehicle population data from1990 1995	Trend Extrapolation	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 (1995-2000) data reported by DVLA.

3.7.5 Description of source-specific categories in the energy sector

3.7.5.1 Energy industries (1. A1)

Key category (level and trend): (1. A.1ai) Electricity generation CO_2 emissions (liquid fuel)

3.7.5.1.1 Overall emissions and fuel consumption trends in energy industries

In 2019, the total GHG emissions in energy industries were 7.42 $MtCO_2e$, constituting 27.2% of the total energy sector emissions. Of the total emissions, the proportion of CO_2 emissions was 98.5%, N_2O emissions were 0.9%, and CH_4 was 0.6%. All the individual gases recorded upward increases, with CO_2 showing the fastest growth over the 26 years (1993-2019). The 2019 emission level is 2.68%, 27.43%, and 38.53% of the total fuel combustion emissions in 1990, 2012 and 2019. Over the 29 years, total GHG emissions in energy industries have significantly increased by 95 folds from 0.01 $MtCO_2e$ in 1990 to 7.3 in 2019 $MtCO_2e$ at an annual average growth rate of 17%. Mostly for 2016-2019, the emissions increased by 34.2% from 5.44 $MtCO_2e$ to 7.42 $MtCO_2e$ (Figure 21).

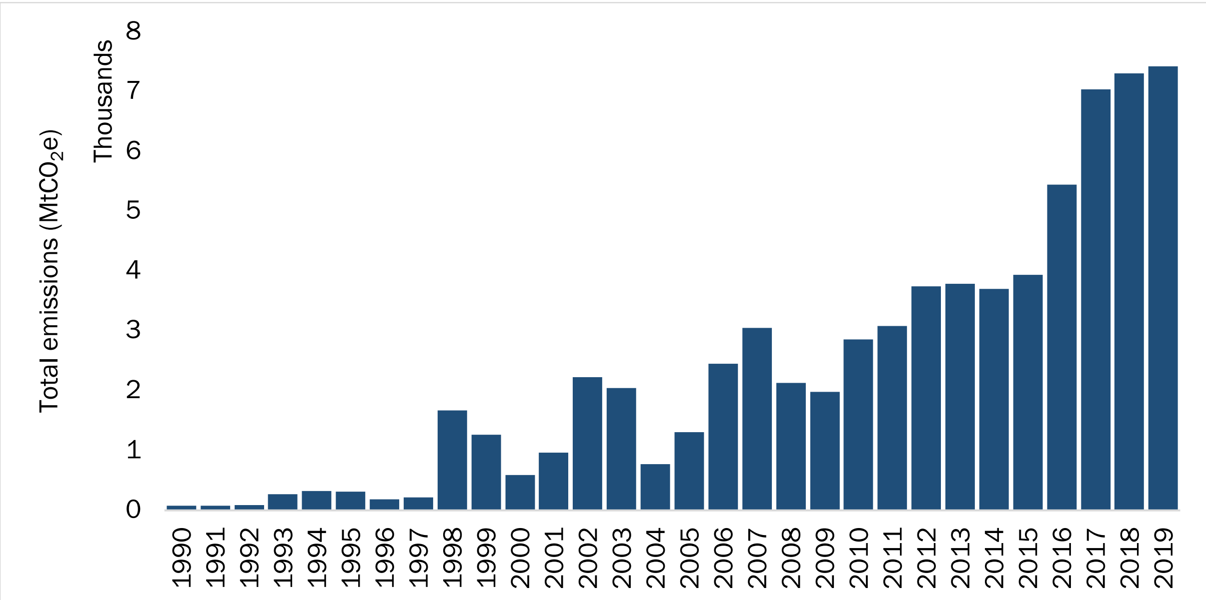


Figure 21: Trends of emissions in energy industries sub-sector for 1990-2019

Fossil fuels cause the energy industries emissions for thermal electricity generation, particularly light crude oil, natural gas, heavy fuel oil and residual fuel oil. Light crude oil was the dominant fuel for electricity generation until 2010, when natural gas became part of the fossil fuels primarily due to its cost-effectiveness. Therefore, the use of natural gas for power generation has increased significantly since 2010. Some newly commissioned thermal plants have recently run on heavy and distillate fuel oils and LPG. Emissions from the energy industries sub-sectors mainly come from four main sources, and these are:

(a) electricity generation, (b) oil refinery, (c) manufacture of solid fuels (charcoal) and (d) other energy industries. In rank, electricity generation has been the foremost source as it accounts for 83.9% of the total energy industry's emissions in 2019. The rest are spread among other energy industries (13.8%), manufacture of solid fuels (1.4%) and refinery (1.0%). Similarly, electricity generation was the largest source (84%) of the total GHG emissions from energy industries. The rest is shared among other energy industries (13.9%), the Manufacture of solid fuels (1%) and oil refining (1.0%) (Figure 22).

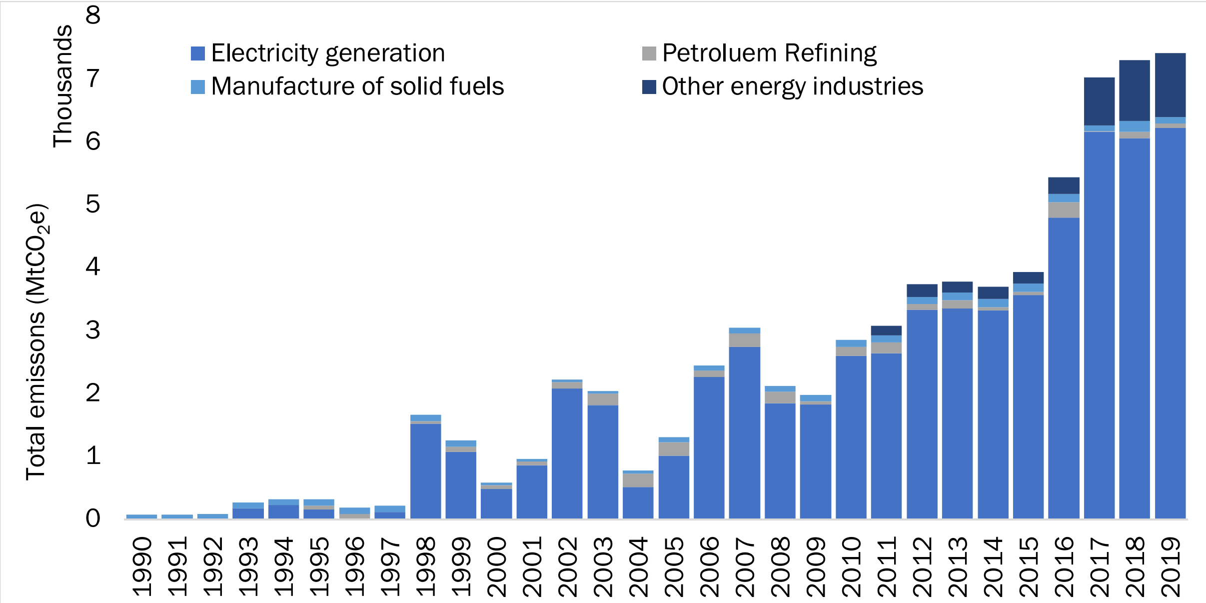


Figure 22: Trend of sources of emissions for energy industries

Under this sub-sector, the main consuming liquid fuels are light crude oil, heavy fuel oil, distillate fuel oil, refinery gas, residual fuel oil, and diesel. The solid and gaseous fuels included petroleum coke, wood fuel, and natural gas. The total fuel consumption in energy industries amounted to 172 PJ in 2019, accounting for 37.7% of the total fuel use in the energy sector. For the 1990-2019 period, the total fuel consumption increased by 335.9%, from 39.52 PJ to 172PJ at a 5.2% annual growth rate. The observed increases are mainly driven by the rising consumption of natural gas and heavy fuels in thermal electricity generation for the national grid.

Consumption of all the fuel types recorded different increases over the 29 years. Solid fuels are the most dominant fuel, accounting for 67.1%, liquid fuels (22.1%) and gaseous fuels (10.7%) of the total energy industries fuel consumption from 1990 to 2019. Over the period, natural gas consumption has 131-folds, followed by liquid fuel (12-folds) and marginally by solid (1.3-fold). The fuels also recorded different growth rates for the period 2010 -2019. While the growth rate of solid fuels was a modest 0.9% per annum, liquid and gaseous fuels grew at 9.9% and 22.5% per annum, respectively, for the same period.

In 2019, solid fuel was made up of 99.9% (51.58 PJ of wood fuel) in the manufacture of solid fuel and the remaining 0.01% (0.01 PJ of petroleum coke) in a petroleum refinery. In the same year, the total liquid fuel consumption was 22.87 PJ, of which 58% was HFO, 20% crude oil, 13% diesel, 7% LPG and 2% RFO (Figure 26).

They are mainly used in electricity generation and petroleum refineries. The use of HFO for thermal electricity generation for the national grid started in 2015 and has since increased by 29-fold from 0.55 PJ in 2015 to 16.1 PJ in 2019. Recently, the use of LPG for power generation has been on the rise since 2017. It increased from 3.72 PJ in 2017, peaked at 4.91 in 2018 and started declining in 2019 to 1.8 PJ.

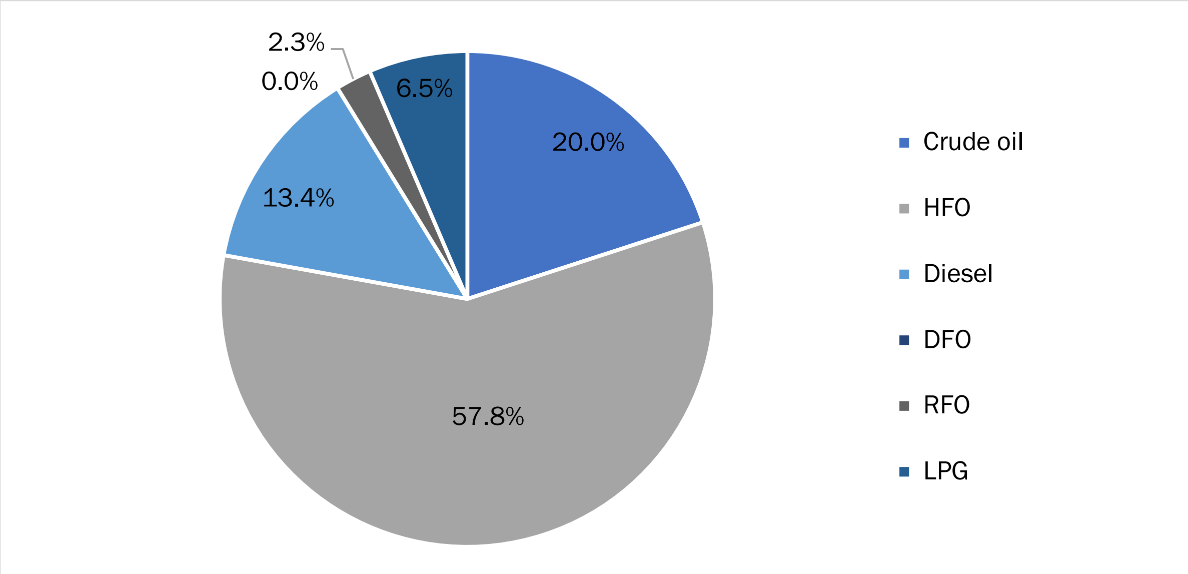


Figure 23: Breakdown of liquid fuels in energy industries for 2019

The gaseous fuels are natural gas and refinery gas. Natural gas was consumed in electricity generation and other energy industries, while refinery gas was consumed in the refinery. Natural gas consumption increased by 466%, from 19.8 PJ in 2012 to 92.4 PJ in 2019. Of the total 92.4 PJ consumed in 2019, 85% was used in electricity generation and the outstanding 15% in other energy industries (Table 39). However, refinery gas consumption decreased by 31%, from 0.71 PJ in 1995 to 0.43 PJ in 2019. When in operation, Tema Oil Refinery produces refinery gases through the distillation process and, instead of flaring the gas, recovers it to generate electricity for internal use. The decline in the refinery operations explains the 30% drop in refinery gas consumption.

Table 39: Trends of fuel consumption in the energy industries for 1990-2019

Years	Electricity generation [PJ]							Petroleum Refining [PJ]				Manufacture of solid fuels [PJ]	Other energy industries [PJ]			Total [PJ]
	Crude oil	HFO	Diesel	DFO	LPG	Natural Gas	Sub-total	RFO	Pet Coke	Refinery Gas	Sub-total	Wood	Diesel	Natural Gas	Sub-total	
1990	-	-	-	-	-	-	-	-	-	-	-	39.52	-	-	-	39.52
1991	-	-	-	-	-	-	-	-	-	-	-	41.71	-	-	-	41.71
1992	-	-	-	-	-	-	-	-	-	-	-	44.01	-	-	-	44.01
1993	-	-	2.42	-	-	-	2.42	-	-	-	-	46.51	-	-	-	48.93
1994	-	-	3.04	-	-	-	3.04	-	-	-	-	49.01	-	-	-	52.05
1995	-	-	2.09	-	-	-	2.09	0.31	-	0.71	1.02	50.26	-	-	-	53.37
1996	-	-	0.22	-	-	-	0.22	0.23	-	0.95	1.18	51.41	-	-	-	52.81
1997	0.21	-	1.37	-	-	-	1.57	0.01	-	0.01	0.02	52.66	-	-	-	54.26
1998	16.60	-	4.04	-	-	-	20.64	0.31	-	0.27	0.58	54.01	-	-	-	75.23
1999	14.53	-	0.04	-	-	-	14.57	0.73	-	0.43	1.16	55.16	-	-	-	70.89
2000	6.53	-	0.02	-	-	-	6.55	0.53	-	0.45	0.98	20.77	-	-	-	28.29
2001	11.76	-	-	-	-	-	11.76	0.44	-	0.45	0.89	21.19	-	-	-	33.85
2002	25.71	-	2.51	-	-	-	28.22	0.55	0.21	0.76	1.53	22.34	-	-	-	52.09
2003	22.53	-	2.05	0.05	-	-	24.63	0.55	0.30	1.94	2.78	23.02	-	-	-	50.44
2004	6.98	-	-	0.04	-	-	7.02	0.63	0.35	2.22	3.20	25.54	-	-	-	35.76
2005	13.75	-	-	0.04	-	-	13.79	0.56	0.39	2.24	3.20	41.41	-	-	-	58.39
2006	30.69	-	-	0.03	-	-	30.73	0.33	0.15	1.09	1.58	43.28	-	-	-	75.58
2007	33.14	-	3.88	0.24	-	-	37.26	0.50	0.41	2.35	3.26	45.44	-	-	-	85.97
2008	22.36	-	2.63	0.05	-	-	25.04	0.58	0.32	1.93	2.83	48.12	-	-	-	75.99
2009	24.72	-	-	0.08	-	-	24.79	0.19	0.10	0.56	0.85	51.49	-	-	-	77.13
2010	23.90	-	-	0.67	-	14.19	38.75	0.63	0.19	1.29	2.11	55.10	-	-	-	95.96
2011	11.53	-	-	-	-	31.93	43.46	0.52	0.26	1.91	2.68	58.95	-	2.68	2.68	107.78
2012	32.93	-	-	-	-	16.30	49.24	0.30	0.10	0.92	1.32	60.72	-	3.54	3.54	114.81
2013	36.60	-	-	-	-	11.82	48.42	0.92	0.13	0.80	1.86	64.97	-	3.03	3.03	118.28

2014	25.47	-	-	0.06	-	25.82	51.36	0.45	0.02	0.16	0.64	66.91	-	3.50	3.50	122.41
2015	12.51	0.55	-	0.04	-	46.34	59.44	0.50	0.04	0.12	0.66	66.72	-	3.34	3.34	130.16
2016	25.64	14.95	-	2.36	-	28.07	71.01	1.56	0.28	1.73	3.56	66.39	-	4.71	4.71	145.67
2017	10.56	28.03	1.32	-	3.72	44.76	88.39	0.17	0.01	0.02	0.20	45.43	3.24	9.38	12.62	146.63
2018	0.06	29.02	0.61	-	4.91	55.85	90.44	0.90	0.01	0.50	1.42	87.00	3.77	12.20	15.97	194.83
2019	5.57	16.12	0.49	-	1.80	78.50	102.48	0.65	0.01	0.43	1.09	51.58	3.24	13.88	17.12	172.26

3.7.5.1.1.1 Electricity generation (1. A1ai)

In Ghana, electricity is mainly produced from hydro and thermal sources in the national electricity grid. Emissions associated with off-grid electricity generation fall under the residential, commercial and manufacturing industry and construction categories. In 2019 a total of 18,189 GWh of electricity was generated to the national grid. 59.8% was thermal, 39.9% was hydro, and the remaining 0.3% and other renewable (solar) sources. The focus of this inventory is on emissions from the combustion of fossil fuels. Emissions from water and sun for the hydro-dam and solar are assumed to be zero. Thermal power plants run on fossil fuels to generate electricity and, in the process, produce greenhouse gas emissions. In 2019, 12 publicly and privately-owned thermal plants generated electricity for the national grid using LCO, DFO, HFO and natural gas fuels (Table 40). Two other plants, Trojan and Genser, generated power at the sub-transmission level.

Table 40: Type of fuel used by power plants in 2019

Name of Power Plant	Type of Fuel Used				
	Nat. Gas	LCO	DFO	HFO	LPG
Takoradi Power Company (TAPCO)	*				
Takoradi International Company (TICO)	*	*	*		
Tema Thermal 1 Power Plant (TT1PP)	*				
Tema Thermal 2 Power Plant (TT2PP)	*				
Kpone Thermal Power Plant (KTPP)	*		*		
Sunon Asogli Power Ltd	*	*			
Karpower plant	*			*	
CENIT	*				
CenPower	*	*	*		
AMERI Plant	*				
Amandi		*	*		
AKSA				*	
Trojan					
Genser	*				*

For the period 1990-2019, the share of thermal electricity grew because Ghana's large hydro-dams have been optimally developed, and the electricity demand was on the rise, which called for electricity generation from diversified sources. Before 1993, electricity generated into the national grid was 100% hydro. After 1993 diesel-powered generators started kicking in to complement hydro generation.

Later, as the electricity demand kept going up and there was the need to find an alternative source to produce electricity, the use of LCO kicked in 1997 at 0.21 PJ, peaked in 2013 at 36.6 PJ and declined afterwards. The drop in LCO use was due to its high cost and the availability of natural gas. In response to the government's fuel diversification agenda, other fuel alternatives, such as natural gas, featured from 2010 onwards when dual-fuel and single fuel thermal plants that use natural gas were commissioned Table 41. Natural gas supply for power generation commenced in 2010 with 14.2 PJ from the West Africa Gas Pipeline. In 2014, Ghana National Gas Company (GNGC) started the production of domestic lean gas for the Volta River Authority (VRA) thermal plant in the Aboadze power enclave in the Western Region of Ghana. Its share of the mix has grown by 180% between 2016-2019 to become the single largest consumption of 78.5 PJ in 2019.

Table 41: Trends of the fuel mix for electricity generation

Year	Crude oil	HFO	Diesel	DFO	RFO	LPG	Natural Gas	Total
1990	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-
1993	-	-	2.42	-	-	-	-	2.42
1994	-	-	3.04	-	-	-	-	3.04
1995	-	-	2.09	-	-	-	-	2.09
1996	-	-	0.22	-	-	-	-	0.22
1997	0.21	-	1.37	-	-	-	-	1.57
1998	16.60	-	4.04	-	-	-	-	20.64
1999	14.53	-	0.04	-	-	-	-	14.57
2000	6.53	-	0.02	-	-	-	-	6.55
2001	11.76	-	-	-	-	-	-	11.76
2002	25.71	-	2.51	-	-	-	-	28.22
2003	22.53	-	2.05	0.05	-	-	-	24.63
2004	6.98	-	-	0.04	-	-	-	7.02
2005	13.75	-	-	0.04	-	-	-	13.79
2006	30.69	-	-	0.03	-	-	-	30.73
2007	33.14	-	3.88	0.24	-	-	-	37.26
2008	22.36	-	2.63	0.05	-	-	-	25.04
2009	24.72	-	-	0.08	-	-	-	24.79
2010	23.90	-	-	0.67	-	-	14.19	38.75
2011	11.53	-	-	-	-	-	31.93	43.46
2012	32.93	-	-	-	-	-	16.30	49.24
2013	36.60	-	-	-	-	-	11.82	48.42
2014	25.47	-	-	0.06	-	-	25.82	51.36
2015	12.51	0.55	-	0.04	-	-	46.34	59.44
2016	25.64	14.95	-	2.36	-	-	28.07	71.01
2017	10.56	28.03	1.32	-	4.80	3.72	44.76	93.19
2018	0.06	29.02	0.61	-	4.20	4.91	55.85	94.64
2019	5.57	16.12	0.49	-	-	1.80	78.50	102.48
% Change (2016-2019	-78.3	7.8		-100			179.6	44.3

Crude oil consumption continues to slump. Especially between 2016 and 2019, crude oil significantly reduced by 78.3% as natural gas showed a consistent rise due to the deliberate government policy. New fuels in HFO and DFO were added to the fuel mix for electricity generation when the Karpower plant and Kpone Thermal Power Stations came on stream. Natural gas had the largest share of about 77% (78.5 PJ) of the total electricity generation fuel mix in 2019 and is trailed closely by HFO 16% (16.1 PJ), crude oil 5% (5.6 PJ) and LPG 2% (1.8 PJ) (Figure 24)

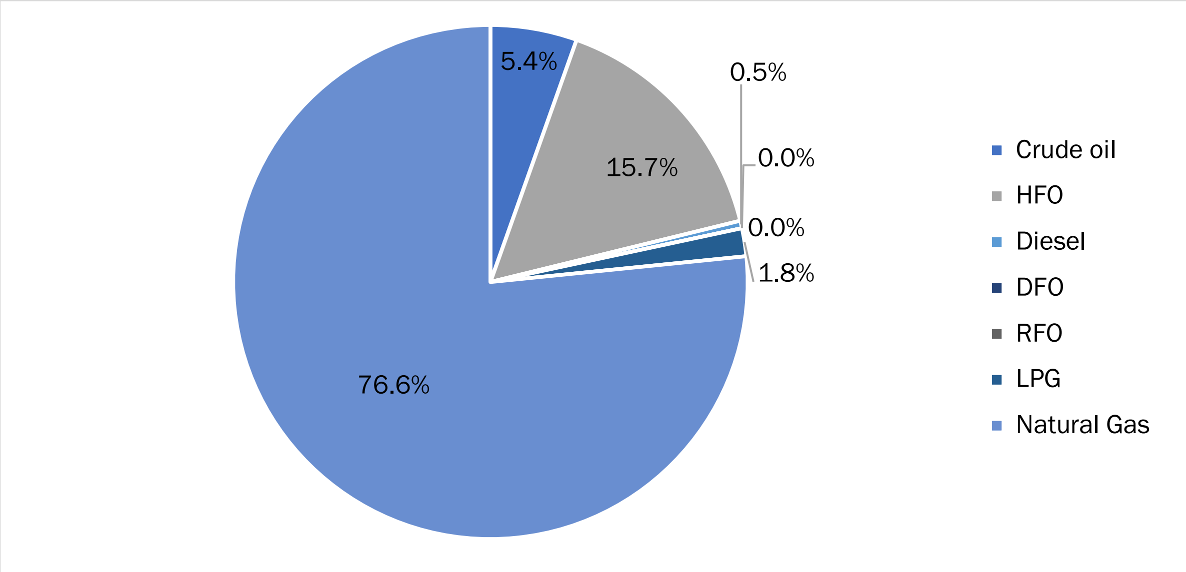


Figure 24: Shares of fuels for electricity generation in 2019

The total GHG emissions for electricity generation in 2019 were estimated at 6.23 $MtCO_2e$ representing 29.6% higher than the levels reported in 2016. The 2019 emission translate into a CO_2 intensity of 0.34 $ktCO_2e/GWh$. Since 1993 when thermal electricity kicked in, the total emissions had gone up by nearly 3353%, from a low of 0.18 $MtCO_2e$ to 6.23 $MtCO_2e$ in 2019 at a 14.6 annual growth rate. The trends compare with the quantity of fuel and the inter-annual variations in the share of the input fuel mix for electricity generation. Given the efforts to get more natural-gas based fired thermal plants, several initiatives were put in place to:

- Expand indigenous natural gas supply base. So far, natural gas production consumption has nearly doubled.
- Invest in an additional thermal capacity that would have dual-fuel technology capability.
- Ensure a reliable natural gas supply from Nigeria through the West Gas Pipeline and Ghana National Gas Company.
- Make improvements in the efficiency of thermal plants through the conversion of single cycles to combined cycles.

3.7.5.1.1.2 Petroleum Refinery (1. A1b)

The Tema Oil Refinery (TOR), established in 1963, is Ghana's only petroleum refining plant. Residual fuel oil, petroleum coke and refinery gas are the main fuel sources the refinery derives energy from to support its operations and thus constitute the main source of GHG emissions in the refinery operations. The installed capacity of the refinery is 45,000 barrels per stream day (bpsd). In 2008, a major refurbishment work was done through a government programme that added a 14,000 bpsd capacity Residue Fluid Catalytic Cracker (RFCC) to the plant. The installation of the RFCC enabled the refinery to efficiently refine residual fuel oil into products such as LPG, gasoline, light crude oil, and heavy fuel oil. Recently, the refinery operations have declined mainly due to cash flow problems that have made it less competitive in the deregulated petroleum market and the involvement of Bulk Oil Distribution Companies (BDCs) in the imports of refined oil products.

The generation of methane as fugitive emissions from the refinery has been incorporated under 1. B. The residual fuel oil was the dominant fuel consumed by the refinery in 2019 (Table 42)

Table 42: Fuel consumption at the Tema Oil Refinery and associated GHG emissions

Years	Fuel Types [ktoe]				GHG Emissions			
	RFO	Petroleum Coke	Refinery Gas	Total	CO_2 [Mt]	CH_4 [$MtCO_2e$]	N_2O [$MtCO_2e$]	Total [$MtCO_2e$]
1990	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-
1995	0.31	-	0.71	1.02	0.07	0.000041	0.000077	0.06533
1996	0.23	-	0.95	1.18	0.07	0.000041	0.000070	0.07281
1997	0.01	-	0.01	0.02	0.00	0.000001	0.000002	0.00142
1998	0.31	-	0.27	0.58	0.04	0.000030	0.000064	0.03987
1999	0.73	-	0.43	1.16	0.08	0.000066	0.000143	0.08149
2000	0.53	-	0.45	0.98	0.07	0.000051	0.000108	0.06692
2001	0.44	-	0.45	0.89	0.06	0.000044	0.000092	0.06024
2002	0.55	0.21	0.76	1.53	0.11	0.000077	0.000160	0.10794
2003	0.55	0.30	1.94	2.78	0.18	0.000112	0.000209	0.18325
2004	0.63	0.35	2.22	3.20	0.21	0.000129	0.000242	0.21141
2005	0.56	0.39	2.24	3.20	0.21	0.000128	0.000238	0.21137
2006	0.33	0.15	1.09	1.58	0.10	0.000064	0.000120	0.10384
2007	0.50	0.41	2.35	3.26	0.21	0.000127	0.000234	0.21474
2008	0.58	0.32	1.93	2.83	0.19	0.000116	0.000218	0.18748
2009	0.19	0.10	0.56	0.85	0.06	0.000036	0.000069	0.05696
2010	0.63	0.19	1.29	2.11	0.14	0.000094	0.000185	0.14187
2011	0.52	0.26	1.91	2.68	0.18	0.000106	0.000196	0.17542
2012	0.30	0.10	0.92	1.32	0.09	0.000053	0.000099	0.08611
2013	0.92	0.13	0.80	1.86	0.13	0.000099	0.000213	0.13076
2014	0.45	0.02	0.16	0.64	0.05	0.000040	0.000090	0.04682
2015	0.50	0.04	0.12	0.66	0.05	0.000043	0.000099	0.04940
2016	1.56	0.28	1.73	3.56	0.25	0.000181	0.000379	0.24760
2017	0.17	0.01	0.02	0.20	0.02	0.000014	0.000033	0.01521
2018	0.90	0.01	0.50	1.42	0.10	0.000081	0.000178	0.10016
2019	0.65	0.01	0.43	1.09	0.08	0.000060	0.000130	0.07610

Total emissions from refinery operations were 0.08 $MtCO_2e$ in 2019 and represented 1.03% of the overall energy industry emissions. In 2019, carbon dioxide contributed 99.8% of the total emissions and methane (0.003%) and nitrous oxide (0.001%). The total GHG emissions from the refinery showed an increasing trend except in cases where the refinery's operations declined, and the emissions reduced accordingly. For instance, between 2012 and 2019, the decrease in fuel consumption by 17.3% resulted in a decrease in emissions by 11.6%. In 1997, the refinery shut down for scheduled maintenance, particularly regarding low emissions and fuel consumption. As a result, more secondary fuels were imported to make up for the refinery supply deficit.

3.7.5.1.1.3 Manufacture of solid fuels (1. A1ci)

The manufacture of solid fuels converts wood to charcoal through the carbonisation process. The GHG estimates of charcoal production depend on carbonisation technology. In Ghana, the majority (99.9%) of the fraction of wood fuel converted to charcoal was considered non-renewable. The 99.9% fraction of non-renewable biomass was generated and approved for CDM projects. There are two main reasons for this assumption. Firstly, most of the wood used as feedstock was from unsustainable sources. Secondly, the efficiency of the carbonisation process (earth moulds) hovers around 10% and 25% yield. The total GHG emissions associated with charcoal-making in 2019 stood at 0.1 $MtCO_2e$, which consisted of 1.4% of the energy industry emissions. The trend indicates an increase of about 31% between 1990 and 2019 at a 4.23% average rate per annum (Table 43).

Table 43: Trend of wood fuel input for charcoal-making and related GHG emissions

Years	Fuel type [PJ]	Total GHG emission ($MtCO_2e$)		
	Wood fuel	CH_4	N_2O	Total
1990	39.52	0.0296	0.0471	0.08
1991	41.71	0.0313	0.0497	0.08
1992	44.01	0.0330	0.0525	0.09
1993	46.51	0.0349	0.0554	0.09
1994	49.01	0.0368	0.0584	0.10
1995	50.26	0.0377	0.0599	0.10
1996	51.41	0.0386	0.0613	0.10
1997	52.66	0.0395	0.0628	0.10
1998	54.01	0.0405	0.0644	0.10
1999	55.16	0.0414	0.0657	0.11
2000	20.77	0.0156	0.0248	0.04
2001	21.19	0.0159	0.0253	0.04
2002	22.34	0.0168	0.0266	0.04
2003	23.02	0.0173	0.0274	0.04
2004	25.54	0.0192	0.0304	0.05
2005	41.41	0.0311	0.0494	0.08
2006	43.28	0.0325	0.0516	0.08
2007	45.44	0.0341	0.0542	0.09
2008	48.12	0.0361	0.0574	0.09
2009	51.49	0.0386	0.0614	0.10
2010	55.10	0.0413	0.0657	0.11
2011	58.95	0.0442	0.0703	0.11
2012	60.72	0.0455	0.0724	0.12
2013	64.97	0.0487	0.0774	0.13
2014	66.91	0.0502	0.0798	0.13

2015	66.72	0.0500	0.0795	0.13
2016	66.39	0.0498	0.0791	0.13
2017	45.43	0.0341	0.0541	0.09
2018	87.00	0.0653	0.1037	0.17
2019	51.58	0.0387	0.0615	0.10
% Change (1990-2019)	30.5	30.7	30.6	25.0
% Change (2016-2019)	-22.3	-22.3	-22.3	-23.1
Annual growth rate (%)	0.9	0.9	0.9	0.8

3.7.5.1.1.4 Other energy industries (1. A1cii)

The diesel and natural gas consumption on the oil rigs and in the GNGC's processing plant started from 2011 onwards when oil production started commercially. The total fuel used on the oil rigs and the gas processing plant in 2019 was 17.12 PJ, consisting of diesel and natural gas (Table 44). The total fuel consumption had increased by 539.05%, from 2.7PJ in 2011 to 17.2PJ in 2019.

Table 44: Fuel consumption and GHG emissions under other energy industries

Years	Fuel Consumption (PJ)			GHG Emissions			
	Diesel	Natural gas	Total	CO_2 [Mt]	CH_4 [$MtCO_2e$]	N_2O [$MtCO_2e$]	Total [$MtCO_2e$]
2011	-	2.68	2.68	0.15	0.0001	0.0001	0.15
2012	-	3.54	3.54	0.20	0.0001	0.0001	0.20
2013	-	3.03	3.03	0.17	0.0001	0.0001	0.17
2014	-	3.50	3.50	0.20	0.0001	0.0001	0.20
2015	-	3.34	3.34	0.19	0.0001	0.0001	0.19
2016	-	4.71	4.71	0.26	0.0001	0.0001	0.26
2017	3.24	9.38	12.62	0.77	0.0005	0.0009	0.77
2018	3.77	12.20	15.97	0.96	0.0006	0.0010	0.97
2019	3.24	13.88	17.12	1.02	0.0006	0.0010	1.02

The total emissions have seen corresponding growth as fuel use goes up. It increased by 578.3% for the same period, from 0.15 $MtCO_2e$ in 2011 to 1.02 $MtCO_2e$ in 2019. Carbon dioxide made up 99.84% of the total 2019 emissions and rest were CH_4 (0.06%) and N_20 (0.10%). The rise in emissions is associated with the country's expanding upstream and midstream oil and gas activities. The development and operationalisation of the following facilities contributed to the increasing diesel and natural gas consumption.

- Jubilee (made of Mahogany-1 (M-1) and Hyedua-1 wells),
- Sankofa and Gye Nyame gas fields are located 60km offshore of Western Ghana in water depths ranging from 520m to 1,014m in the Tano Basin and
- Ghana Gas Processing plant

3.7.5.1.2 Methodological issues in Energy industries

Generally, the energy industries category's emissions were estimated using the Tier 1 approach and IPCC default emission factor (Table 45). shows the overview of methods and emission factors used in the GHG estimation.

Table 45: Overview of methods used for greenhouse gas estimation and emission factors

Categories	CO_2		CH_4		N_2O	
	Method Used	Emission Factor	Method Used	Emission Factor	Method Used	Emission Factor
Electricity generation	T1	DF	T1	DF	T1	DF
Petroleum Refining	T1	DF	T1	DF	T1	DF
Manufacture of solid fuels	T1	DF	T1	DF	T1	DF
Other energy industries	T1	DF	T1	DF	T1	DF

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

Methodology for estimating emissions from electricity generation

Fuels (diesel, LPG and gasoline, biofuel) 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 fuels in grid-connected thermal power stations were imported from the international markets until recently, when GNGC started to produce domestic natural gas for the Aboadze thermal power plant managed by VRA. In essence, apart from the parts of the natural gas produced by Ghana Gas, all the rest of the fuels for electricity generated are imported. Electricity is generated by publicly-owned and Independent Power Producers (IPPs) and evacuated to the existing national grid.

The quantity of LCO, natural gas, diesel, DFO, and HFO consumption figures and electricity production reported by the individual power plants in the national energy statistics were used. Since the inventory was not compiled at the individual thermal power station located mainly on the east and west coasts, fuel consumption and the corresponding electricity production have been aggregated. Therefore, the sum of LCO, natural gas, and diesel consumption in each power plant in a particular year was calculated to give the total consumption of each fuel type in the year.

The diesel consumption in the power generation was excluded from the total diesel supply used in transportation, industry and other sectors to avoid double counting. The activity data for electricity generation were obtained from electricity generation companies (private and public) and the Energy Commission. The collected data were evaluated to ensure internal consistency. The emission factors used for each fuel and a specific compound were obtained from the IPCC EFDB. This approach was opted for because there was no country-specific emission factor for the power plant as desired. The use of country-specific factors would be useful particularly for non-CO_2 GHG emissions since their levels are influenced by the type of technology in use and the plant's operations, unlike CO_2, which is largely dependent on the carbon content of the fuel in use. Since electricity generation contributes most to the energy total emissions, there are plans to carry out a study on the thermal power stations across the country to enhance the transparency and accuracy of the estimation.

Methodology for estimating emissions from petroleum refining

Crude oil is used as feedstock or as refinery input and is transformed into petroleum products during the refinery process. The crude oil transformed into petroleum products was not considered in the combustion-related estimations of the refinery emissions because it does not lead to fuel combustion emissions. In the refinery, fuel is burnt to generate steam for electricity generation and running of the production process. The portion of the crude oil lost through the transformation process as fugitive emissions were considered separately under fugitive emissions from fuels. The only refinery in Ghana, Tema Oil Refinery, uses the following fuels: refinery gas, petroleum coke and RFO. The estimation of the refinery emissions was based on the amounts of these 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 covering 1990 to 2019.

Methodology for estimating emissions from the Manufacture of solid fuels

Combustion emissions from fuel use during the manufacture of secondary and tertiary products from solid fuels include charcoal production. The dominant charcoal production technologies in Ghana are kiln and the earth mound. The majority of the informal charcoal producers use inefficient earth mounds to carbonise wood fuel into charcoal for consumption within Ghana. Formal charcoal producers mainly use wood off-cuts from sawmills as feedstock in kiln carbonisation for export to the offshore market. The emissions from the manufacture of charcoal are calculated using the fraction of the total woodfuel supply published in the Energy Commission's energy statistics.

The fraction of woodfuel supply as input into charcoal production ranged from 30.6% in 1990 to 28.9% in 2019. Expert judgement was used to estimate the percentage of woodfuel supply as charcoal production feedstock. The estimated percentage was then multiplied by the total woodfuel supply figures to derive the fraction of woodfuel as charcoal production feedstock. The dominant earth-mound charcoal production technology has an estimated efficiency of 25%. It was difficult to split wood fuel inputs into those processed with earth mounds and efficient kilns. So, all the wood fuel feedstock has been allocated to the earth mound technology. Besides, the IPCC EFDB does not provide specific factors applicable to the type of kiln used in Ghana. Even if the type of carbonisation technology separated the activity, it would not be possible to get suitable IPCC methods.

Methodology for estimating emissions from other energy industries

Under this category, emissions from own on-site fuel use have been estimated for the Jubilee and TEN oil fields and the Atuabo gas processing plant. The diesel and natural gas consumption on the oil rigs and the gas process plant were obtained from the Ghana Petroleum Commission and the Ghana National Gas Company. Both report monthly fuel consumption for the oil field and gas plant. After receiving the activity data, the monthly averages were summed for each oil field before obtaining the total fuel consumption per year.

3.7.5.1.3 Source-specific recalculations in Energy industries (1. A1)

Recalculations were done for the emission estimates from 1990 to 2016 due to the inclusion of new and revision of existing activity data, leading to changes in CO_2, CH_4, and N_2O emissions for the recalculation. Specifically, the following revisions have been introduced:

- Changes in fuel consumption figures for the oil refinery to reflect the changes in revised data from the refinery from 1995 to 2016.
- Subtraction of fraction of total woodfuel supply from 1990-2016 included as activity data on the manufacture of solid fuel,
- Revision figures on diesel and natural gas consumption for other energy industries from 2011 and 2016.

Table 46 presents the recalculation results and their impacts on the emissions.

Table 46: Energy industry recalculations and impacts on the previous emissions

Years	CO_2			CH_4			N_2O		
	PE (Gg)	LE(Gg)	% Change	PE (Gg)	LE(Gg)	% Change	PE (Gg)	LE(Gg)	% Change
1990	0.07	-	-100	0.02	0.03	30.48	0.036	0.048	31.58
1991	0.10	-	-100	0.02	0.03	29.94	0.038	0.051	32.5
1992	0.08	-	-100	0.03	0.03	29.92	0.040	0.054	32.94
1993	0.18	0.18	0	0.03	0.04	29.51	0.043	0.057	31.4
1994	0.23	0.23	0	0.03	0.04	29.82	0.045	0.060	31.06
1995	0.22	0.22	-1.67	0.03	0.04	30.14	0.047	0.060	28.04
1996	0.09	0.09	-5.41	0.03	0.04	29.52	0.047	0.063	32.41
1997	0.12	0.12	-0.04	0.03	0.04	29.51	0.049	0.063	28.83
1998	1.56	1.56	-0.09	0.03	0.04	28.34	0.053	0.069	28.64
1999	1.15	1.15	-0.18	0.03	0.04	28.89	0.053	0.069	28.56
2000	0.55	0.55	-0.41	0.01	0.02	27.74	0.020	0.027	31.96
2001	0.92	0.92	-0.25	0.01	0.02	27.38	0.022	0.027	23.97
2002	2.18	2.18	-0.07	0.02	0.02	26.04	0.026	0.033	27.61
2003	2.00	1.99	-0.35	0.02	0.02	26.23	0.026	0.033	27.46
2004	0.73	0.73	-1.06	0.02	0.02	28.25	0.025	0.033	31.58
2005	1.23	1.22	-0.61	0.03	0.03	28.74	0.041	0.051	24.54
2006	2.36	2.36	-0.17	0.03	0.03	27.17	0.045	0.057	25
2007	2.96	2.95	-0.27	0.03	0.04	26.93	0.049	0.060	22.77
2008	2.03	2.02	-0.33	0.03	0.04	27.73	0.049	0.063	28.21
2009	1.88	1.87	-0.1	0.03	0.04	28.16	0.052	0.066	26.8
2010	2.74	2.74	-0.17	0.03	0.04	27.66	0.056	0.072	28.82
2011	2.82	2.96	5.07	0.04	0.05	28.58	0.057	0.075	30.07
2012	3.42	3.61	5.7	0.04	0.05	27.8	0.062	0.077	24.64
2013	3.49	3.65	4.34	0.04	0.05	27.61	0.066	0.083	27.27
2014	3.39	3.56	5.24	0.04	0.05	27.88	0.066	0.086	31.82
2015	3.63	3.80	4.59	0.04	0.05	28.22	0.066	0.083	27.27
2016	5.10	5.30	3.9	0.04	0.05	27.06	0.069	0.089	30.43

Reasons for the recalculations

- Refinery Fuel Oil – Revision of consumption figures for RFO in the refinery from 1995 to 2016 due to the availability of a new dataset from the Tema Oil Refinery.
- Refinery Gas - Revised refinery gas consumption data of the Tema Oil Refinery from 1995 to 2016 due to a new dataset from the Oil Refinery.

- Petroleum Coke – Revised the data on refinery coke consumption of the Tema Oil Refinery from 2002 to 2016 due to a new dataset from the refinery.
- Woodfuel – Revised the woodfuel consumption data for the manufacture of charcoal from 1990 to 2016 due to the new figures in the energy balance.
- Natural Gas - Revision of natural gas consumption data by other energy industries such as the Atuabo Gas Processing Plant and Oil production rigs from 2011 to 2016 due to the availability of new data from the industry players.
- Diesel - Changes in the diesel consumption data by other energy industries such as the Atuabo Gas Processing Plant and Oil production rigs from 2011 to 2012 and from 2015 to 2016 due to the availability of new data from the industry players.

3.7.5.2 Manufacturing industry and construction (1. A2)

Key category (level and trend) – CO_2 emissions

3.7.5.2.1 Emissions and fuel consumption patterns in manufacturing industries and construction

Greenhouse gas emissions in this source-specific category cover fuel combustion activities in the manufacturing industry and construction. The industrial sectors included the following:

- Iron and steel
- Chemicals
- Pulp, Paper and Print
- Food processing, Beverage and Tobacco
- Mining and Quarrying
- Wood and Wood Products
- Construction
- Textile and Leather
- Non-specified industries

The emissions are mostly from boilers and other heating processes. Emissions from grid electricity, standby generators and "industrial processes" are accounted for under 1. A1a (Electricity generation), 1.A4a (Commercial/Institutional) and specific categories under industrial process and solvent use, respectively. The main fuels used in the manufacturing and construction sectors are diesel, RFO, wood, charcoal, LPG and gasoline. The total fuel consumption in this category was 31.82 PJ in 2019 and constituted 7% of the total energy sector fuel consumption. In 2019, mining and quarrying and food processing industrial sub-sectors consumed most of the fuels. Mining and quarrying account for 38.9% of the total fuel consumption for the manufacturing industry and construction. It is followed by food processing and beverages (35.8%), non-specified (13%), Textile and leather (4.3%), construction (3%), chemical (2.8%) and others (Figure 25). Food and beverage consume the most variety of fuels (diesel, RFO, LPG, wood and charcoal) because of the diverse nature of the operations.

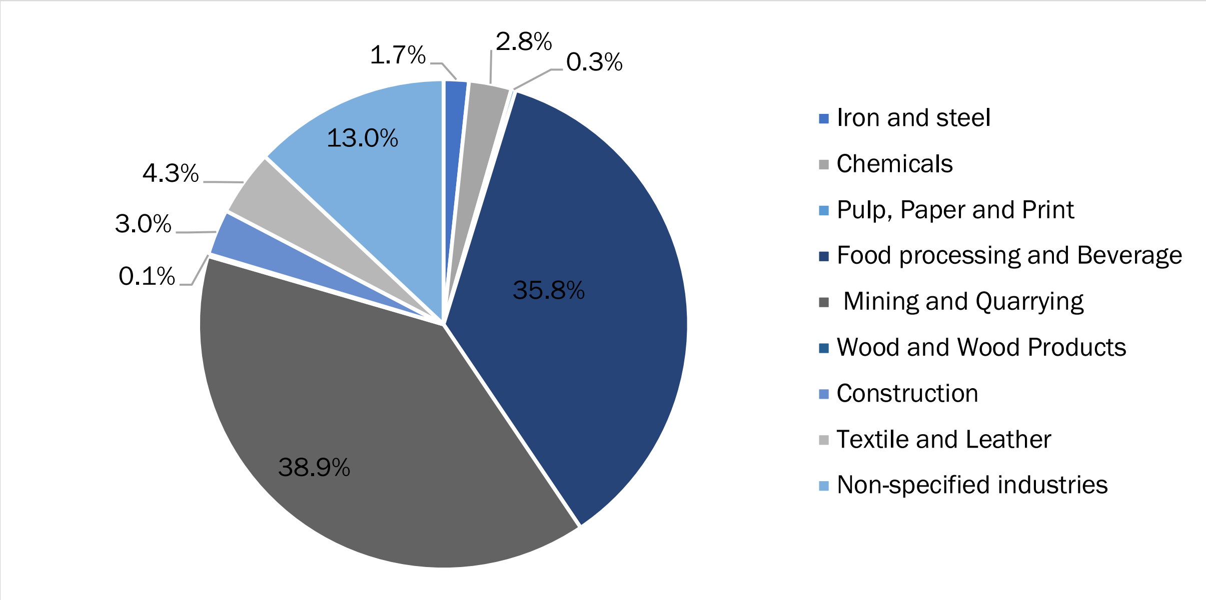


Figure 25: Source-specific category to fuel consumption in the manufacturing industry and construction sectors in 2019

Liquid fuels consistently make up 52.3% of the total fuel consumption for the manufacturing industry sub-sector. Solid fuel's shares of the total fuel consumption for the sector amounted to 46.4%, with the majority being woodfuel (averagely of 95.7%) and charcoal (averagely 4.3%). The rest of the total fuel consumption is gaseous (mainly natural gas), accounting for an average of 0.9% of the total for the sub-sector. Diesel fuels averagely constituted 74.5% over the whole time series, followed by RFO (24.3%) and LPG (1.3%).

In terms of trends, the total fuel consumption for the manufacturing industry and construction sub-sector exhibited consistent growth between 1990 and 2019. Throughout the 1990-2019 period, the total fuel consumption increased by 35.2%. Similarly, for the 2016-2019 period, the total consumption of 31.82 PJ for 2019 represented 4.9% higher than the 2016 levels. The growth in fuel consumption has been driven by the conforming rise in diesel and wood fuel consumption for heating operations in boilers and furnaces. Consumption of fuels more than doubled over the 1990-2019 period. Diesel consumption recorded the highest growth of 839% at a consistent 8% growth per annum in the same period. Mining and Quarrying account for about 90% of the diesel fuel consumption in the manufacturing industry and construction. In the same vein, the pattern of wood fuel consumption showed an upward trend. It has increased by 211% at an average of 4% for the 1990-2019 period. The majority of the woodfuel, about 75%, was consumed in the food and beverage industry sectors.

The 2019 total fuel consumption levels of 12.2 PJ represent 34.1% more than the 2016 level and a 213% rise over the 1990 fuel consumption level. Most solid fuels are used for heating in the food and beverage industries, including cooking. Firewood and charcoal are the two main solid fuels used in industry. Firewood and charcoal consumption saw more than 200% increases at a 4% annual growth rate. The industrial use of natural gas kicked in in 2017 to date. Between 2017 and 2019, the consumption levels increased by 59.4%.

The total emissions associated with the manufacturing industry and construction fuel consumption amounted to 1.25 $MtCO_2e$ in 2019, representing 4.6% of the energy sector emissions (Figure 26). The 2019 emissions for the sub-sector are made up of 97.5% carbon dioxide and 1.51%, and 0.98% of nitrous oxide and methane gas. In terms of trends, overall, the total emissions showed an over 4-fold increase, from 0.31 $MtCO_2e$ in 1990 to 1.25 $MtCO_2e$ in 2019, representing a growth rate of 4.9% per annum. The recorded growth in the emissions over the two decades is associated with the high fuel consumption in food, beverages & tobacco processing, mining and quarrying, construction and leather and textile in order of rank.

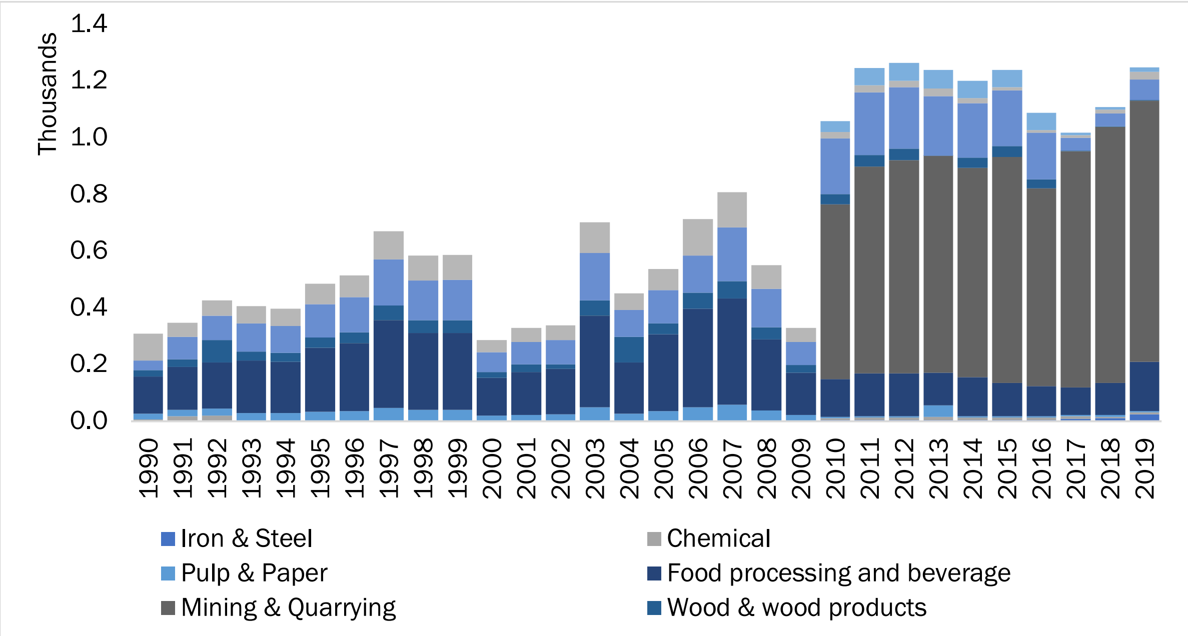


Figure 26: Emissions in the manufacturing industry and construction for 1990-2019

Food processing was the dominant energy source within the Manufacturing Industries and Construction category, followed by mining and quarrying, textile and leather, construction, non-specified industries, wood and wood products, pulp, paper and print, chemicals and iron/iron/steel. The dominant emission from the food, beverage and tobacco industries could be explained by the growing consumption of wood and liquid fuels in boilers and heating processes.

Table 47: Fuel consumption among sectors under the manufacturing industry and construction from 1990 to 2019 in PJ

Years	Iron and steel				Chemicals				Pulp, Paper and Print				Food processing and Beverage					Mining and Quarrying
	Diesel	RFO	LPG	Wood	Diesel	RFO	LPG	Wood	Diesel	RFO	LPG	Wood	Diesel	RFO	LPG	Wood	Charcoal	Diesel
1990	-	-	-	-	-	0.09	-	-	0.14	0.12	-	0.47	0.88	0.76	-	3.31	0.12	-
1991	-	-	-	-	-	0.10	-	-	0.16	0.14	-	0.47	1.03	0.87	-	3.32	0.13	-
1992	-	-	-	-	-	0.27	-	-	0.17	0.14	-	0.53	1.11	0.92	-	3.72	0.11	-
1993	-	-	-	-	-	-	-	-	0.23	0.14	-	0.57	1.45	0.91	-	3.99	0.10	-
1994	-	-	-	-	-	-	-	-	0.21	0.14	-	0.61	1.36	0.93	-	4.29	0.10	-
1995	-	-	-	-	-	-	-	-	0.29	0.15	-	0.67	1.84	0.95	0.08	4.67	0.09	-
1996	-	-	-	-	-	-	-	-	0.32	0.14	-	0.74	2.04	0.91	0.09	5.21	0.08	-
1997	-	-	-	-	-	-	-	-	0.44	0.17	-	0.76	2.80	1.09	0.08	5.33	0.08	-
1998	-	-	-	-	-	-	-	-	0.44	0.09	0.00	0.80	2.80	0.60	0.06	5.58	0.07	-
1999	-	-	-	-	-	-	-	-	0.29	0.11	-	0.85	1.85	0.74	0.04	5.94	0.06	-
2000	-	-	-	-	-	-	-	-	0.14	0.12	-	0.47	0.88	0.76	-	3.32	0.13	-
2001	-	-	-	-	-	-	-	-	0.16	0.14	-	0.53	1.03	0.87	-	3.72	0.11	-
2002	-	-	-	-	-	-	-	-	0.17	0.14	-	0.57	1.11	0.92	-	3.99	0.10	-
2003	-	-	-	-	-	-	-	-	0.50	0.13	-	1.28	3.19	0.86	-	8.93	0.10	-
2004	-	-	-	-	-	-	-	-	0.21	0.14	-	0.67	1.36	0.93	-	4.67	0.09	-
2005	-	-	-	-	-	-	-	-	0.58	0.14	-	1.10	3.71	0.87	-	7.69	0.08	-
2006	-	-	-	-	-	-	-	-	0.49	0.16	-	0.37	3.17	1.33	-	3.72	0.19	-
2007	-	-	-	-	-	-	-	-	0.65	0.06	-	2.52	4.17	0.41	-	17.63	0.07	-
2008	-	-	-	-	-	-	-	-	0.72	0.22	-	2.63	4.61	1.41	-	18.43	0.07	-
2009	-	-	-	-	-	-	-	-	0.89	0.11	-	0.01	5.70	0.74	-	0.05	0.27	-
2010	0.04	0.01	-	0.01	0.06	0.03	-	0.61	0.02	-	0.03	-	0.62	0.90	0.12	5.78	0.12	8.29
2011	0.05	0.01	-	0.01	0.07	0.04	-	0.64	0.02	-	0.03	-	0.76	0.98	0.09	6.23	0.13	9.83
2012	0.06	0.01	-	0.01	0.08	0.03	-	0.62	0.02	-	0.04	-	0.80	0.91	0.11	6.19	0.14	10.13
2013	0.06	0.01	-	0.01	0.08	0.04	-	0.63	0.52	-	0.04	-	0.14	1.09	0.10	6.39	0.15	10.29
2014	0.06	0.01	-	0.01	0.08	0.03	-	0.64	0.02	-	0.03	-	0.82	0.73	0.10	6.59	0.17	9.94
2015	0.06	0.00	-	0.00	0.09	0.01	-	0.63	0.02	-	0.04	-	0.90	0.36	0.12	6.70	0.17	10.74
2016	0.06	0.00	-	0.00	0.08	0.01	-	0.63	0.02	-	0.04	-	0.81	0.32	0.13	6.82	0.18	9.38
2017	0.03	0.06	0.03	0.06	0.08	0.01	0.00	0.77	0.01	-	0.07	-	0.06	0.27	0.87	8.23	0.23	11.19
2018	0.04	0.09	0.03	0.09	0.02	0.01	0.00	0.78	0.01	-	0.08	-	0.07	0.40	0.93	8.36	0.30	12.17
2019	0.05	0.22	0.04	0.22	0.03	0.04	0.00	0.82	0.01	-	0.08	-	0.10	1.06	0.98	8.83	0.42	12.39

Table 48: Fuel consumption selected sub-sectors under manufacturing industry and construction from 1990 to 2019 in PJ

Years	Wood and Wood Products		Construction		Textile and Leather				Non-specified industries				
	Diesel	RFO	Diesel	RFO	Diesel	RFO	LPG	Wood	Diesel	RFO	LPG	Wood	NG
1990	0.16	0.14	-	0.42	0.29	0.95	0.00	-	-	-	-	-	-
1991	0.18	0.16	0.57	0.48	0.34	0.29	-	0.95	-	-	-	-	-
1992	0.57	0.48	0.62	0.51	0.37	0.31	-	1.06	-	-	-	-	-
1993	0.26	0.16	0.80	0.50	0.48	0.30	-	1.14	-	-	-	-	-
1994	0.24	0.16	0.75	0.51	0.45	0.31	-	1.23	-	-	-	-	-
1995	0.33	0.17	1.02	0.53	0.61	0.32	-	1.33	-	-	-	-	-
1996	0.36	0.16	1.13	0.51	0.68	0.30	-	1.49	-	-	-	-	-
1997	0.50	0.19	1.55	0.61	0.93	0.36	-	1.52	-	-	-	-	-
1998	0.50	0.11	1.55	0.33	0.93	0.20	-	1.59	-	-	-	-	-
1999	0.33	0.13	1.03	0.41	0.62	0.25	-	1.50	-	-	-	-	-
2000	0.16	0.14	0.49	0.42	0.29	0.25	-	0.95	-	-	-	-	-
2001	0.18	0.16	0.57	0.48	0.34	0.29	-	1.06	-	-	-	-	-
2002	0.20	-	0.62	0.51	0.37	0.31	-	1.14	-	-	-	-	-
2003	0.57	0.15	1.77	0.48	1.06	0.29	-	2.55	-	-	-	-	-
2004	1.36	0.93	0.75	0.51	0.45	0.31	-	1.33	-	-	-	-	-
2005	0.66	0.16	2.06	0.49	1.24	0.29	-	2.20	-	-	-	-	-
2006	0.56	0.18	1.76	-	1.06	0.63	-	0.74	-	-	-	-	-
2007	0.74	0.07	2.31	0.23	1.39	0.14	-	5.04	-	-	-	-	-
2008	0.82	0.25	2.56	0.78	1.54	0.47	-	5.27	-	-	-	-	-
2009	1.01	0.13	3.16	0.41	1.90	0.25	-	0.01	-	-	-	-	-
2010	0.47	-	2.65	-	0.02	0.27	-	0.57	0.37	0.04	0.09	0.57	-
2011	0.53	-	2.98	-	0.02	0.28	-	0.65	0.49	0.21	0.12	0.61	-
2012	0.53	-	2.92	-	0.02	0.26	-	0.67	0.52	0.19	0.14	0.60	-
2013	0.02	-	2.82	-	0.02	0.30	-	0.71	0.54	0.20	0.13	0.62	-
2014	0.49	-	2.58	-	0.02	0.19	-	0.76	0.53	0.17	0.13	0.63	-
2015	0.51	-	2.65	-	0.02	0.09	-	0.79	0.58	0.09	0.15	0.64	-
2016	0.43	-	2.20	-	0.02	0.08	-	0.82	0.55	0.12	0.16	0.65	-
2017	0.03	-	0.61	-	0.01	0.07	0.00	0.99	0.09	0.02	0.01	0.79	1.94
2018	0.03	-	0.61	-	0.01	0.11	0.00	1.01	0.09	0.02	0.01	0.80	2.71
2019	0.05	-	0.96	-	0.02	0.30	0.00	1.06	0.13	0.05	0.01	0.85	3.09

3.7.5.2.2 Methodological issues under Manufacturing industry and construction

Data on fuel consumption for the applicable nine sub-categories under Manufacturing and Construction (1.A.2) were obtained from the national energy statistics. There were two levels of analysis of the fuels. First, for each fuel, out of the total consumption each year, a certain aggregate or share was allotted to the manufacturing industry and construction and further divided among the industry sectors. The sector fuel distribution was done consistently with shares reported in the energy statistics. The total quantity of various fuels consumed in manufacturing industries and construction sectors was disaggregated among the nine 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 based on the sectoral shares in the energy statistics.

Estimating 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 fuels considered in estimating the manufacturing industries and construction emissions were diesel, residual fuel oil, LPG, wood, and charcoal. LPG consumption in the manufacturing industry and construction was assigned to the Food Processing industries because it is the only industry that uses 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 to estimate emissions from that sub-category. The IPCC Tier 1 approach was used to estimate the emissions from this sector using the default IPCC emission factors.

3.7.5.2.3 Source-specific recalculations in the manufacturing industry and construction

Ghana recalculated the emissions for the category from 1990 to 2016. The recalculation was performed due to the availability of new datasets in the energy statistics, the use of the AR4 GWP and the removal of unreliable data. The recalculation mostly led to changes in the activity data and a corresponding decrease in CO_2, CH_4, and N_2O emissions levels. Table 49 presents the recalculation results and their impacts on emissions of the manufacturing industry and construction category.

Table 49: Recalculations and impacts on the manufacturing industry and construction

Years	CO_2			CH_4			N_2O		
	PE	LE	% change	PE	LE	% change	PE	LE	% change
1990	1.63	0.30	-82%	0.008757	0.0037	-57%	0.014727	0.005	-64%
1991	1.66	0.33	-80%	0.009736	0.0045	-53%	0.016496	0.007	-60%
1992	1.21	0.41	-66%	0.006114	0.0049	-19%	0.009368	0.007	-21%
1993	1.79	0.39	-78%	0.010369	0.0052	-50%	0.017593	0.008	-55%
1994	1.90	0.38	-80%	0.010592	0.0055	-48%	0.018061	0.008	-54%
1995	1.94	0.47	-76%	0.011017	0.0059	-46%	0.018725	0.009	-51%
1996	1.81	0.50	-72%	0.011295	0.0065	-43%	0.018987	0.010	-47%
1997	1.72	0.65	-62%	0.011692	0.0068	-42%	0.019472	0.011	-45%
1998	1.86	0.57	-69%	0.011432	0.0069	-40%	0.019257	0.011	-43%
1999	1.87	0.43	-77%	0.011666	0.0070	-40%	0.01962	0.011	-44%
2000	3.74	0.28	-93%	0.024843	0.0045	-82%	0.04147	0.006	-84%

2001	3.50	0.32	-91%	0.023035	0.0049	-79%	0.038502	0.007	-81%
2002	3.31	0.33	-90%	0.021385	0.0051	-76%	0.035821	0.008	-79%
2003	3.12	0.67	-78%	0.019854	0.0107	-46%	0.033308	0.017	-49%
2004	2.94	0.52	-82%	0.016489	0.0060	-64%	0.027418	0.009	-66%
2005	2.87	0.76	-73%	0.017238	0.0094	-45%	0.029126	0.015	-48%
2006	1.43	0.70	-51%	0.006218	0.0053	-15%	0.01097	0.008	-30%
2007	5.57	0.76	-86%	0.038712	0.0200	-48%	0.064346	0.032	-50%
2008	6.03	1.00	-83%	0.040649	0.0211	-48%	0.067774	0.034	-50%
2009	6.05	1.06	-82%	0.041365	0.0025	-94%	0.068882	0.003	-96%
2010	1.76	1.04	-41%	0.005605	0.0073	30%	0.011894	0.012	-3%
2011	2.01	1.23	-39%	0.006143	0.0080	30%	0.013106	0.013	-3%
2012	2.02	1.24	-39%	0.006123	0.0080	31%	0.01308	0.013	-2%
2013	2.08	1.22	-41%	0.006316	0.0082	31%	0.013481	0.013	-3%
2014	2.02	1.18	-42%	0.00641	0.0085	32%	0.013593	0.013	-2%
2015	2.07	1.22	-41%	0.006531	0.0087	32%	0.013863	0.014	-2%
2016	1.94	1.07	-45%	0.006505	0.0086	33%	0.013687	0.013	-2%

3.7.5.3 Transport (1. A3)

Key category (level and trend) – (1A3.b) Road transport CO_2 emissions (liquid fuel)

3.7.5.3.1 Overview of fuel consumption and emissions in transport

The sources of GHG emissions from the transportation category are grouped according to civil aviation, road transport, railways, and inland waterborne navigation. All emissions from the transport operations identified sources had been calculated using the IPCC recommended methodologies. But, the GHG emissions for international aviation and marine navigation are reported as memo items as the estimates have been excluded from the calculation of the national totals.

Fuel types and consumption are major determinants of emission levels in transportation. In Ghana, the predominant fuel use in the transportation sub-sector mainly includes gasoline, diesel, LPG, and ATK. Gasoline and LPG fuels are commonly used by passenger vehicles. With a relatively medium-size engine capacity of 2000cc, commercial passenger vehicles are known to use gasoline and LPG fuels because of their cost-effectiveness. On the other hand, large-size engine capacity vehicles (light-duty, heavy-duty including ships) of more than 2000cc mostly use diesel fuel. It is the preferred fuel because the large engines are designed to use diesel fuels. International and domestic planes use ATK for their operations. The computations of GHG emissions in the transport make of fuel quantity and type, travel mode, vehicle type and traffic movements.

In 2019, the total fuel consumption for transportation of 126.23PJ represented a 439% increase over 29 years (Table 50). The sharp rise in fuel consumption in transportation corresponds well with the rise in gasoline and diesel use as they respectively grew by 338% and 559% in the same period. Over the 1990-2019 period, all the fuel consumption levels recorded an upward trend, with ATK showing the highest growth. However, the fuel consumption pattern for 2016-2019 did not show a unanimous increasing trend for all the types.

It was observed that while diesel and gasoline consumption increased by 53% and 47%, that of both LPG and ATK decreased by 38% and 8%. The decline in LPG could be attributed to the policy to remove subsidies on LPG may have contributed to reducing LPG consumption, mostly in commercial passenger vehicles. Generally, the growth in the domestic aviation industry, having peaked in the mid-2000s, started to decline. The decline in domestic aviation operations may have contributed to reducing ATK consumption. Diesel is the dominant fuel in the transport sub-sector. It constituted 50.1% of all fuel consumption throughout 1990-2019, followed by gasoline (47.3%), LPG (2.3%) and ATK (0.2%). Diesel fuels are used primarily in heavy engines on roads, railways and inland navigation.

Table 50: Fuel consumption in transportation by fuel types and modes

Years	Fuel Consumption (PJ)									
	Fuel Types				Road			Domestic Aviation	Railways	Inland navigation
	ATK	Diesel	Gasoline	LPG	Diesel	Gasoline	LPG	ATK	Diesel	Diesel
1990	0.00	9.37	13.94	0.09	9.26	13.94	0.09	0.00	0.02	0.10
1991	0.00	10.47	13.94	0.10	10.35	13.94	0.10	0.00	0.01	0.11
1992	0.00	33.29	13.95	0.15	33.17	13.95	0.15	0.00	0.01	0.11
1993	0.00	33.32	13.95	0.23	33.17	13.95	0.23	0.00	0.01	0.14
1994	0.00	33.30	13.95	0.33	33.17	13.95	0.33	0.00	0.01	0.12
1995	0.00	16.50	13.95	1.03	16.32	13.95	1.03	0.00	0.01	0.17
1996	0.01	13.34	13.94	1.24	13.15	13.94	1.24	0.01	0.02	0.17
1997	0.01	22.58	13.96	1.20	22.23	13.96	1.20	0.01	0.12	0.23
1998	0.01	22.17	15.22	0.81	21.88	15.22	0.81	0.01	0.07	0.21
1999	0.01	19.47	14.00	0.77	19.06	14.00	0.77	0.01	0.21	0.20
2000	0.00	10.12	21.90	0.09	9.86	21.90	0.09	0.00	0.17	0.10
2001	0.00	10.91	21.92	0.10	10.59	21.92	0.10	0.00	0.21	0.11
2002	0.00	11.31	21.94	0.15	11.05	21.94	0.15	0.00	0.16	0.11
2003	0.00	13.96	15.78	0.23	13.65	15.78	0.23	0.00	0.17	0.14
2004	0.00	14.01	22.43	0.33	13.81	22.43	0.33	0.00	0.08	0.12
2005	0.00	19.58	22.52	1.05	19.33	22.52	1.05	0.00	0.08	0.17
2006	0.01	19.29	21.77	1.20	19.04	21.77	1.20	0.01	0.07	0.17
2007	0.01	24.94	21.82	1.59	24.64	21.82	1.59	0.01	0.07	0.23
2008	0.01	20.51	21.74	0.83	20.27	21.74	0.83	0.01	0.05	0.20
2009	0.01	24.67	26.28	0.77	24.35	26.28	0.77	0.01	0.08	0.24
2010	0.52	47.77	29.26	3.35	47.70	29.26	3.35	0.52	0.05	0.03
2011	0.68	44.12	34.03	3.29	44.03	34.03	3.29	0.68	0.05	0.04
2012	0.72	59.37	38.00	4.48	59.28	38.00	4.48	0.72	0.06	0.04
2013	0.70	52.96	41.67	4.04	52.87	41.67	4.04	0.70	0.06	0.03
2014	0.65	45.94	43.70	3.80	45.87	43.70	3.80	0.65	0.06	0.02
2015	0.59	44.93	43.41	4.30	44.85	43.41	4.30	0.59	0.06	0.02
2016	0.79	40.39	41.50	4.25	40.30	41.50	4.25	0.79	0.07	0.02
2017	0.61	50.89	47.91	2.58	50.82	47.91	2.58	0.61	0.03	0.04
2018	0.49	57.62	56.33	2.61	57.54	56.33	2.61	0.49	0.04	0.04
2019	0.73	61.77	61.10	2.64	61.69	61.10	2.64	0.73	0.04	0.04

Road transport is the highest user of all liquid fuels (Table 50). It is the biggest consumer of diesel and gasoline. In 2019, road transport consumed 125.4PJ of all liquid fuels, with diesel and gasoline, making 49.2% and 48.7% of the total, followed by LPG of 2.1%.

Within the road transport category, passenger cars consume the highest fuel. On average, it accounts for 47.3% of the total fuel usage in the transportation sub-sector. Heavy-duty and buses follow with 27.7%, motorcycles (12.6%) and light-duty vehicles (11.7%). The rest are inland navigation (0.3%), domestic aviation (0.2%) and railways (0.2%). Most passenger cars use slightly more gasoline (28.3% of the total fuel consumption for passenger cars) than diesel (16.7%) and greatly more than LPG (2.3%). Road transport constituted an important source of fuel consumption in the transport sector in which the passenger car contributes the most (Table 51). In terms of fuel types, diesel was the leading fuel in all the transport modes except domestic aviation. The rising fuel consumption levels have corresponding effects on GHG emissions in the transport sector.

Table 51: Fuel consumption trends per each transport category

Years	Total consumption (PJ)											
	Civil Aviation	Road Transport									Railway	Inland navigation
	Domestic	Passenger Cars			Light duty		Heavy-duty &buses		Motorcycle			
	ATK	Diesel	Gasoline	LPG	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Diesel
1990	0.00	0.49	9.33	0.09	0.21	2.25	8.42	-	0.15	2.37	0.02	0.10
1991	0.00	1.03	9.33	0.10	0.45	2.25	8.57	-	0.31	2.37	0.01	0.11
1992	0.00	4.35	9.33	0.15	12.03	2.25	14.69	-	2.09	2.37	0.01	0.11
1993	0.00	4.35	9.33	0.23	12.03	2.25	14.69	-	2.09	2.37	0.01	0.14
1994	0.00	4.35	9.33	0.33	12.03	2.25	14.69	-	2.09	2.37	0.01	0.12
1995	0.00	4.00	9.33	1.03	1.73	2.25	9.40	-	1.20	2.37	0.01	0.17
1996	0.01	2.72	9.68	1.24	4.40	0.05	6.03	2.36	0.00	1.86	0.02	0.17
1997	0.01	8.14	11.57	1.20	0.06	0.05	12.10	-	1.94	2.33	0.12	0.23
1998	0.01	7.40	9.56	0.81	1.47	1.26	13.01	2.47	0.00	1.93	0.07	0.21
1999	0.01	6.84	9.54	0.77	1.51	0.21	10.72	2.36	0.00	1.89	0.21	0.20
2000	0.00	3.41	14.95	0.09	1.59	0.50	4.85	3.50	0.00	2.95	0.17	0.10
2001	0.00	3.92	14.93	0.10	1.47	0.66	5.20	3.34	0.00	2.99	0.21	0.11
2002	0.00	4.21	14.88	0.15	1.76	0.85	5.08	3.18	0.00	3.03	0.16	0.11
2003	0.00	6.15	7.44	0.23	0.23	1.19	7.27	3.51	0.00	3.64	0.17	0.14
2004	0.00	5.58	13.84	0.33	0.79	1.32	7.44	3.37	0.00	3.90	0.08	0.12
2005	0.00	12.64	13.70	1.05	1.74	1.42	4.95	3.26	0.00	4.14	0.08	0.17
2006	0.01	8.57	12.70	1.20	1.59	1.57	8.88	3.15	0.00	4.35	0.07	0.17
2007	0.01	10.33	12.86	1.59	2.38	1.90	11.93	2.52	0.00	4.54	0.07	0.23
2008	0.01	9.35	11.92	0.83	2.30	1.97	8.62	3.05	0.00	4.79	0.05	0.20
2009	0.01	10.89	18.21	0.77	3.02	2.17	10.45	0.82	0.00	5.08	0.08	0.24
2010	0.52	17.92	15.11	3.35	5.46	0.67	24.31	5.41	0.00	8.06	0.05	0.03
2011	0.68	20.68	16.30	3.29	6.42	3.73	16.94	4.43	0.00	9.58	0.05	0.04
2012	0.72	21.29	19.64	4.48	7.13	3.87	19.32	4.21	11.54	10.29	0.06	0.04
2013	0.70	20.28	19.34	4.04	7.36	4.91	17.48	4.47	7.76	12.96	0.06	0.03
2014	0.65	19.04	20.64	3.80	7.41	5.15	19.41	4.63	0.00	13.28	0.06	0.02

2015	0.59	20.14	20.56	4.30	8.26	5.63	16.45	2.98	0.00	14.24	0.06	0.02
2016	0.79	17.23	18.76	4.25	7.42	5.37	15.66	4.14	0.00	13.22	0.07	0.02
2017	0.61	17.00	24.50	2.58	7.57	5.49	14.60	4.05	11.65	13.87	0.03	0.04
2018	0.49	18.82	28.12	2.61	8.60	6.47	16.24	4.59	13.88	17.15	0.04	0.04
2019	0.73	19.87	29.87	2.64	9.20	6.97	16.94	4.79	15.67	19.47	0.04	0.04

Generally, GHG emissions for the transport category for 2019 stood at 9.23 $MtCO_2e$. The 2019 transport emissions account for 33.8% of the total energy sector emissions and 15.4% of the national total GHG emissions. From 1990 to 2019, the transport emission has consistently been at a 6% annual growth from 1.7 $MtCO_2e$ to its current 9.23 $MtCO_2e$. The growth represents a 442% increase over the 29 years. A similar upward trend was observed between 2016 and 2019, where the emission grew by 45.8% from 6.33 $MtCO_2e$ in the previous inventory. Carbon dioxide was the largest emission source comprising 97.9% of the total transport GHG emissions, N_2O followed suit with 1.5% and then CH_4 with 0.6%. Of the total transportation emissions, road transportation alone accounts for 99.2%, trailed by domestic aviation, railways and inland water-borne navigation in that order (Figure 27).

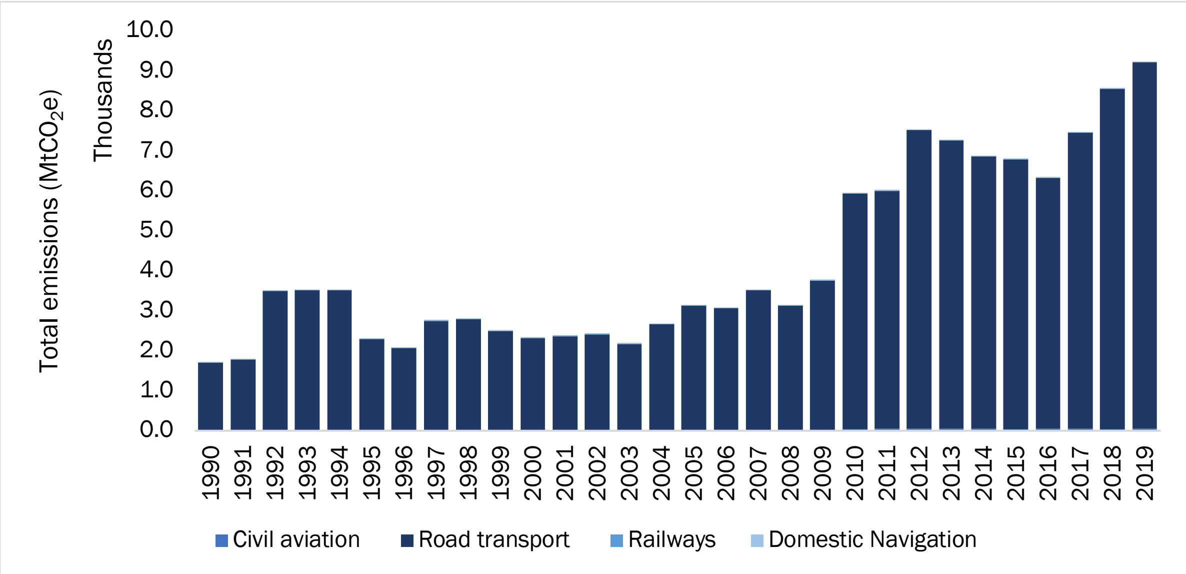


Figure 27: GHG emissions trends in the transportation sector

The road transportation category vehicular mobility on urban highways and feeder roads includes cars, trucks, buses, heavy-duty vehicles and motorcycles. The determinants of road transport emissions are mainly vehicle population, prevailing technology type, and traffic situation (distance covered and speed), affecting fuel consumption. In 2019, 125.42 PJ of fuel was used in road transport, representing a 438% increase and a 46% increase in the 1990 and 2012 fuel consumption, respectively.

The breakdown of the 2019 fuel consumption is as follows: (a) diesel – 49.2%, (b) gasoline – 48.7% and (c) LPG – 2.1%. In the same vein, the vehicle population has increased from 2,066,943 in 2016 to 2,549,472 in 2019, of which passenger cars (41%) were the majority. The rest were motorcycles (29%), heavy-duty trucks and buses (17%) and light-duty vehicles (13%). The distribution of the vehicle population contributed to the trends in the total road transport fuel consumption. Passenger cars accounted for an average of 47% of the total road transport fuel, followed by heavy-duty buses (28%), motorcycles (12%) and light-duty (11.8%). The rise in vehicle population and fuel consumption led to corresponding GHG emission increases from 1.7 $MtCO_2e$ in 1990 to 9.23 $MtCO_2e$ in 2019. Passenger cars were the most significant contributor to road transport emissions, accounting for about 47% of the total road transport emissions.

Between 1995 and 2019, the total number of registered vehicles increased by about nine folds, from 220,806 in 1995 to 2,549,472 in 2019, representing a more than 1000% increase. The main contributory factor for this was the rapid increase in vehicle numbers and associated traffic congestion. The road sector emission trends are affected by the factors below:

- implementation of a 10-year over-aged import duty policy
- increases in the importation of new vehicles
- variations in the use of LPG in vehicles
- deregulation of the downstream petroleum market
- the roll-out of the fleet renewal programme
- vehicle inspections regime

In 2019, domestic aviation became the next important source of GHG emissions within the transportation category. The domestic aviation industry has seen a gradual expansion since 2002. Indeed, the growth in the industry saw the addition of active airlines operating in the country. The expanding domestic aviation contributed to more internal flights and passenger uplift on the Accra to Kumasi, Tamale and Takoradi routes. The passenger uplift increased from 199,073 in 2011 to 687,879 in 2019. Between 1990 and 2019, the total ATK consumption increased by 267.5 folds to 0.7PJ, leading to corresponding increases in GHG emissions.

3.6.5.3.2 Methodological issues in the transport sector

GHG emissions from transportation were estimated for the following four transport modes:

- civil aviation
- road transport
- railways and
- inland water-borne navigation.

Different methods have been used to calculate the emission for the various transport modes. The IPCC tier-1 methodology was used for civil aviation, railways, and inland water-borne navigation emissions. Default IPCC emission factors were used with country-specific activity data (i.e., Diesel and ATK consumption per year). A mix of tier 1 and simplified tier 2 methods were used to estimate road transport emissions. Default IPCC emissions factors and a range of country-specific activity data were used. Details of the methodological approaches for the different transport modes are provided below:

Civil Aviation

The main activity data for estimating GHG emissions for domestic civil aviation was the quantity of ATK consumption per year. The amount of ATK for each year is a function of the number of planes in active service, the route and the number of passenger liftings. Data on ATK consumption were collected from three major OMCs responsible for supplying the bulk of the ATK to domestic airline companies. The data collected represented the bulk ATK supply from a specific OMC. The annual ATK supply to the airlines was derived from all the supplies from the individual OMCs in a year. The shares of the ATK consumption of international

bunkers and the domestic airlines were estimated based on the OMCs' aggregated annual sale figures.
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 would be made to collect additional data to use a tier 2 approach.

Road Transportation

The emission estimates for road transportation have 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 were estimated using the tier 1 approach, whereas, in the current inventory, accessibility to more data made it possible to move partially to a higher tier.

Country-specific activity data on vehicle population (i.e., annual vehicle registration and roadworthy certification data) was collected from the DVLA from 1995 to 2019. The missing data from 1990 to 1994 was retrieved by trend extrapolation using the 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 categorised into vehicle classes (passenger, light-duty, heavy-duty and motorcycle) to conform to the IPCC vehicle population classifications. The categorisation of the DVLA data in the IPCC vehicle classes was based on the average gross weight. Based on the 2005 survey conducted as part of the DANIDA Vehicular Emission Project, the vehicle classes were further divided into technology classes based on the Euro standards.

A 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 converters.

The total amounts of liquid fuels (diesel, gasoline, and LPG) allocated to transportation were derived from the national totals reported in the energy statistics. The fuel mix allocations 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 of the transportation category. The remaining fuel was split among non-motorised transport modes, i.e., civil aviation, railways and inland water navigation.

The share of road transport fuel consumption was further allocated to the various vehicle classes. The quantity of fuel allocated to the vehicle classes depended on the number of vehicles in each technology class. Because of the outdated 2005 traffic circulation data (average speed, mileage, fuel economy), the full tier 3 methodology was not used. Instead, with the IPCC default emission factors, country-specific disaggregated vehicle classifications, and fuel allocation, the GHG emissions for each vehicle class were estimated. Given the plan to improve the methodology for the estimation in the future, attention would be given to collecting data to enable Ghana to implement a higher tier approach in the transport sector. The emission factors were obtained from the IPCC EFDB using selection criteria to select emission factors applied to the prevailing transport condition in Ghana.

Railways
Activity data (diesel consumption) was initially collected from the Ghana Railway Company for the inventory period. Inconsistencies were found during the preliminary assessment of the data from Ghana Railway Company; hence the annual fuel consumption data from the Energy Statistics disaggregated energy balance was used to ensure internal and time series consistency. However, efforts would be made to reconcile the two data sources and appropriately report the next inventory emissions. Default IPCC emission factors for CO_2, CH_4 and N_2O were used with the IEA activity data to determine the emissions. The fuel allocation to railways seems to be on the high side, considering the actual passenger and freight rail transport in the last two decades. Ghana intends to investigate the diesel consumption figures from the Energy Statistics, calibrate with the actual diesel consumption figures from the Ghana Railway Corporation, and report the future inventory report's differences.

Inland water-borne navigation
The main activity data (annual diesel consumption) was obtained from the Volta Lake Transport Company from 2006 to 2019 to estimate GHG emissions using the tier 1 approach. The missing data from 1990 to 2005 was obtained from the national energy balance for Ghana. IPCC default emission factors were used for CO_2, CH_4 and N_2O.

3.6.5.3.3 Source-specific recalculations in the transport sector
Due to the availability of a new dataset and revision of fuel consumption figures, Ghana performed recalculations of the 1990 to 2016 GHG emission estimates. The recalculations led to changes in the CO_2, CH_4, and N_2O emissions figures reported in the NIR4. Table 52 presents the recalculation results and their impacts on the total transportation emissions.

Table 52: Results of impacts of recalculations on the transport emissions

Years	CO_2			CH_4			N_2O		
	PE (Mt)	LE (Mt)	Change	PE ($MtCO_2e$)	LE ($MtCO_2e$)	Change	PE ($MtCO_2e$)	LE ($MtCO_2e$)	Change
1990	1.37	1.67	22%	0.010	0.013	27%	0.028	0.024	-13%
1991	1.21	1.75	44%	0.009	0.013	49%	0.025	0.025	3%
1992	1.35	3.44	156%	0.009	0.015	58%	0.027	0.052	90%
1993	1.28	3.45	170%	0.009	0.015	72%	0.026	0.052	100%
1994	1.51	3.46	129%	0.010	0.015	52%	0.030	0.052	70%
1995	1.37	2.25	64%	0.009	0.015	58%	0.028	0.032	16%
1996	1.94	2.03	5%	0.011	0.014	31%	0.034	0.032	-6%
1997	1.94	2.72	40%	0.011	0.016	43%	0.034	0.039	15%
1998	2.27	2.75	21%	0.011	0.015	37%	0.042	0.044	5%
1999	2.37	2.46	4%	0.011	0.014	30%	0.042	0.039	-7%
2000	3.10	2.27	-27%	0.016	0.019	19%	0.055	0.038	-32%
2001	3.13	2.33	-26%	0.016	0.019	20%	0.056	0.038	-32%
2002	3.20	2.37	-26%	0.016	0.019	19%	0.057	0.038	-33%
2003	2.75	2.14	-22%	0.012	0.014	21%	0.050	0.036	-28%
2004	3.45	2.61	-24%	0.017	0.020	17%	0.062	0.042	-32%
2005	3.08	3.08	0%	0.016	0.021	33%	0.056	0.049	-13%
2006	4.05	3.01	-26%	0.018	0.021	18%	0.072	0.048	-34%

2007	4.61	3.46	-25%	0.019	0.022	19%	0.083	0.053	-36%
2008	4.27	3.08	-28%	0.019	0.021	10%	0.077	0.049	-36%
2009	5.26	3.70	-30%	0.026	0.025	-4%	0.092	0.055	-40%
2010	4.78	5.82	22%	0.025	0.033	30%	0.080	0.092	15%
2011	5.86	5.88	0%	0.029	0.037	28%	0.114	0.091	-21%
2012	6.51	7.37	13%	0.033	0.043	31%	0.142	0.112	-21%
2013	6.57	7.12	8%	0.030	0.045	52%	0.166	0.108	-35%
2014	7.13	6.72	-6%	0.036	0.046	26%	0.187	0.102	-45%
2015	7.41	6.65	-10%	0.038	0.046	23%	0.216	0.098	-54%
2016	6.92	6.19	-10%	0.035	0.044	25%	0.212	0.093	-56%

The recalculations of the previous estimate led to general net increases in the CO_2 and CH_4 emissions compared to N_2O that rather saw net reductions across the 1990-2016 time series. However, the level of changes in the emissions figures differed on a year-by-year basis for different gas types. For CO_2 emissions, the effects of the recalculations ranged from -30% in 2009 to 170% in 1993. On the contrary, recalculation impacts on methane emissions led to high emissions, as it mostly ranged from -4% in 2009 to 72% in 1993. Unlike the CO_2 and CH_4, the recalculations led to a general net reduction of 10% in N_2O emissions. In the same fashion, the highest change of 100% was recorded in 1993 compared to 3% in the preceding 1991.

Some of the specific reasons for the recalculations are listed below:

- Revision of the fuel consumption data (gasoline, diesel and LPG) for transportation due to the availability of new and updated data from the energy statistics.
- Inclusion of revised ATK consumption for domestic aviation from 1990 to 2016.
- Changes in the factors for dividing total ATK consumption into domestic and international aviation per year since the data provider does not supply disaggregated figures.
- Adjustment of the final diesel, gasoline and LPG consumption figures to be consistent with the published vehicle population figures.

3.7.5.4 Other sectors (1. A4)

Key category (level) – 1.A.4.b - Residential CO_2 emissions

3.7.5.4.1 Overview of fuel consumption and emissions in other sectors

Energy-related activities other than those captured in 1. A1, 1. A2, 1. A3 are covered under the “Other sectors” category. The inventory in this sector focuses on fuel combustion activities in commercial, residential and Agriculture/Forestry/Fishing/Fish Farms. In 2019, the other sectors category's overall fuel consumption was 125.75PJ and contributed 27.8% of the total energy sector fuel consumption in the same year (Table 53). The major fuels used in the other sectors category include LPG, kerosene, firewood, charcoal, gasoline and diesel. LPG, Kerosene, firewood and charcoal are commonly used in commercial and residential sub-categories, whereas diesel and gasoline are used in fishing, off-road vehicles and stationary operations.

Table 53: Fuel consumption trend in the "other sectors" category

Year	Fuel Consumption (PJ)							
	Kerosene	Diesel	LPG	Wood	Charcoal	Solid fuel	Liquid Fuel	Total
1990	5.83	0.47	0.18	105.72	11.89	117.61	6.48	124.10
1991	2.78	0.51	0.20	109.20	13.23	122.43	3.49	125.92
1992	2.68	0.51	0.29	111.69	14.00	125.68	3.48	129.16
1993	2.56	0.62	0.42	114.61	14.80	129.42	3.60	133.02
1994	4.70	0.54	0.57	117.76	15.61	133.37	5.81	139.18
1995	3.15	0.73	1.76	122.60	16.02	138.62	5.64	144.25
1996	6.26	0.71	2.12	127.46	16.40	143.85	9.09	152.94
1997	7.45	0.91	1.87	133.71	16.80	150.50	10.22	160.73
1998	11.13	0.91	1.22	127.67	17.24	144.91	13.26	158.17
1999	8.42	0.77	1.10	129.83	17.62	147.45	10.29	157.75
2000	5.83	0.47	0.18	105.69	25.96	131.64	6.48	138.13
2001	2.78	0.51	0.20	98.19	26.65	124.83	3.49	128.32
2002	2.68	0.51	0.29	90.44	27.95	118.38	3.48	121.87
2003	2.56	0.62	0.42	83.66	28.76	112.42	3.60	116.02
2004	4.70	0.54	0.55	77.50	31.78	109.28	5.79	115.07
2005	3.15	0.73	1.76	70.09	36.74	106.82	5.64	112.46
2006	3.61	0.71	1.87	127.59	37.24	164.84	6.19	171.03
2007	7.45	0.91	2.56	93.48	36.61	130.08	10.92	141.00
2008	1.29	0.77	1.22	58.33	37.76	96.09	3.27	99.36
2009	8.13	1.57	1.10	26.35	17.65	44.00	10.81	54.81
2010	1.82	1.51	4.57	54.87	39.40	94.27	7.90	102.17
2011	2.29	1.82	4.57	97.80	26.90	124.70	8.68	133.38
2012	1.74	1.92	6.54	89.86	28.42	118.29	10.19	128.48
2013	1.04	1.98	6.21	55.91	46.39	102.30	9.23	111.53
2014	0.36	1.94	6.03	56.29	50.57	106.86	8.33	115.19
2015	0.26	2.13	7.04	55.93	50.49	106.42	9.44	115.86
2016	0.29	1.89	7.17	55.56	50.65	106.21	9.36	115.57
2017	0.23	2.27	8.95	55.35	58.01	113.35	11.45	124.80
2018	0.20	2.58	9.38	53.03	59.70	112.73	12.16	124.89
2019	0.16	2.77	9.80	52.98	59.87	112.85	12.73	125.57

The fuel consumption in the "other sectors" sub-sector amount to 125.6 PJ, representing 7% of the total fuel consumption in the energy sector in 2019. The 2019 fuel consumption figure slightly increased by 1.2% between 1990 and 2019. Solid fuel (charcoal and woodfuel) is the main fuel for the "other sectors" sub-sector throughout the inventory period. Solid fuel formed an average of 93.7% of the total fuel consumption, and the remaining 6.3% are liquid fuels. Solid fuel consumption recorded a 4% drop over 29 years of the inventory period. The share of firewood averaged 72.4% of solid fuels, and the remaining 27.6% was charcoal. According to Table 53, the consumption trend of woodfuel showed a declining trend throughout the time series. It decreased by 50% from 105.7 PJ in 1990 to 52.9 in 2019 at 2% per annum.

On the contrary, charcoal consumption rather recorded continued increases. Over the inventory period, charcoal consumption saw a significant jump of 403% from 11.9 PJ in 1990 to 59.9PJ in 2019 at a 6% annual growth rate. Solid fuels consumption recorded a 4% decrease, and liquid fuels increased by 96%. The penetration of LPG gas drives a sharp increase in liquid fuel consumption for cooking. The preference for LPG fuel as the alternative fuel to wood fuel for cooking is linked to the consistent implementation of the National LPG Promotion Policy. In 2019, LPG had the largest share of 69.4% of the total liquid fuel consumption, followed by diesel (19.7%), gasoline (9.8%) and kerosene (1.1%).

Table 54: Fuel consumption per sub-categories in the “other sector” category

Year	Fuel Consumption (PJ)									
	Commercial/Institutional				Residential				Agric/Forestry/Fishing	
	Kerosene	Wood	Charcoal	LPG	Kerosene	Wood	Charcoal	LPG	Diesel	Gasoline
1990	0.23	2.30	0.36	0.02	5.61	103.42	11.53	0.16	0.47	0.55
1991	0.11	2.37	0.40	0.02	2.67	106.82	12.83	0.18	0.51	0.56
1992	0.11	2.51	0.56	0.02	2.57	109.17	13.43	0.26	0.51	0.57
1993	0.11	2.60	0.66	0.03	2.45	112.02	14.14	0.39	0.62	0.57
1994	0.21	2.66	0.77	0.04	4.49	115.10	14.84	0.53	0.54	0.58
1995	0.14	2.74	0.86	0.12	3.00	119.86	15.16	1.64	0.73	0.58
1996	0.30	2.79	0.95	0.15	5.96	124.66	15.44	1.97	0.71	0.59
1997	0.37	2.93	0.98	0.14	7.08	130.78	15.82	1.73	0.91	0.59
1998	0.57	2.61	1.15	0.08	10.56	125.06	16.09	1.14	0.91	0.60
1999	0.47	2.51	1.25	0.06	7.96	127.32	16.37	1.04	0.77	0.61
2000	0.23	2.37	0.40	0.02	5.61	103.31	25.56	0.16	0.47	0.81
2001	0.11	2.51	0.56	0.02	2.67	95.67	26.09	0.18	0.51	0.74
2002	0.11	2.60	0.66	0.02	2.57	87.84	27.28	0.26	0.51	0.84
2003	0.11	2.66	0.77	0.03	2.45	81.00	27.99	0.39	0.62	0.85
2004	0.21	2.74	0.86	0.03	4.49	74.76	30.91	0.53	0.54	0.87
2005	0.14	0.95	3.85	0.12	3.00	69.13	32.89	1.64	0.73	0.88
2006	0.17	2.93	2.17	0.14	3.44	124.66	35.07	1.73	0.71	0.90
2007	0.37	2.61	1.15	0.21	7.08	90.87	35.46	2.34	0.91	0.92
2008	0.06	1.25	1.92	0.08	1.22	57.08	35.84	1.14	0.77	0.50
2009	0.18	0.80	1.94	0.06	7.96	25.56	15.71	1.04	1.57	0.50
2010	0.10	0.99	2.95	0.24	1.71	53.88	36.45	4.33	1.51	1.42
2011	0.16	2.13	0.82	0.24	2.12	95.67	26.09	4.33	1.82	1.50
2012	0.09	2.02	1.14	0.40	1.64	87.84	27.28	6.14	1.92	1.50
2013	0.06	0.99	3.44	0.40	0.98	54.92	42.95	5.81	1.98	1.64
2014	0.03	0.98	3.88	0.41	0.33	55.30	46.69	5.62	1.94	1.60
2015	0.03	0.96	4.01	0.51	0.23	54.97	46.48	6.54	2.13	1.60
2016	0.04	0.95	4.14	0.54	0.25	54.61	46.51	6.63	1.89	1.42
2017	-	1.32	5.01	0.73	0.23	54.03	53.00	8.21	2.27	1.41
2018	-	1.28	4.50	0.79	0.20	51.75	55.20	8.58	2.58	1.39
2019	-	1.29	3.92	0.85	0.16	51.69	55.95	8.95	2.77	1.38

The residential category consumed most of the fuels in other sectors. It accounts for 92% of the total fuel consumed in 2019 compared to 4.8% for commercial and 3.3% for agriculture. (Table 54). Fuel consumption under agriculture/forestry/fishing and the share of fishing and off-road vehicles accounts for 99%. The fuel consumption in the residential category declined by 3.3% at an annual rate of 0.1% for the 1990-2019 period. But the trend for the individual fuel types differed across the time series. The kerosene and wood fuels continue to decline, whereas charcoal and LPG are on the ascendency. In response to the Government policy of reducing use the of Kerosene fuel, mainly for lighting in homes, its consumption levels have significantly decreased by 97% over the 29 years. In the same vein, woodfuel consumption went down by 50% relative to the 1990 levels. LPG consumption in the home continues to grow due to the combined effect of the LPG promotion programme. The consumption level has increased by 55 folds over 29 years. Charcoal is still the dominant cooking fuel for most peri-urban homes, so as the household expands, the demand for charcoal increases. That is why charcoal consumption increased by 385% between 1990-2019.

Similar fuel consumption was observed in the commercial/institutional category. Kerosene consumption has been eliminated during the inventory period, as woodfuel consumption declined by 43.8%. In the same period, charcoal and LPG consumption have risen sharply. Table 54 shows that charcoal consumption in the commercial and institutional category considerably rose by 11 folds to 3.92 PJ in 2019. It also revealed a similar consumption pattern for LPG, which recorded a significant increase of 55 folds. In 2019, the total fuel consumption translated into total emissions of 1.35 $MtCO_2e$, amounting to about 5% of the total energy sector emissions. The emissions represented a 75% rise from the 1990 emissions of 0.75 $MtCO_2e$ (
Figure 28).

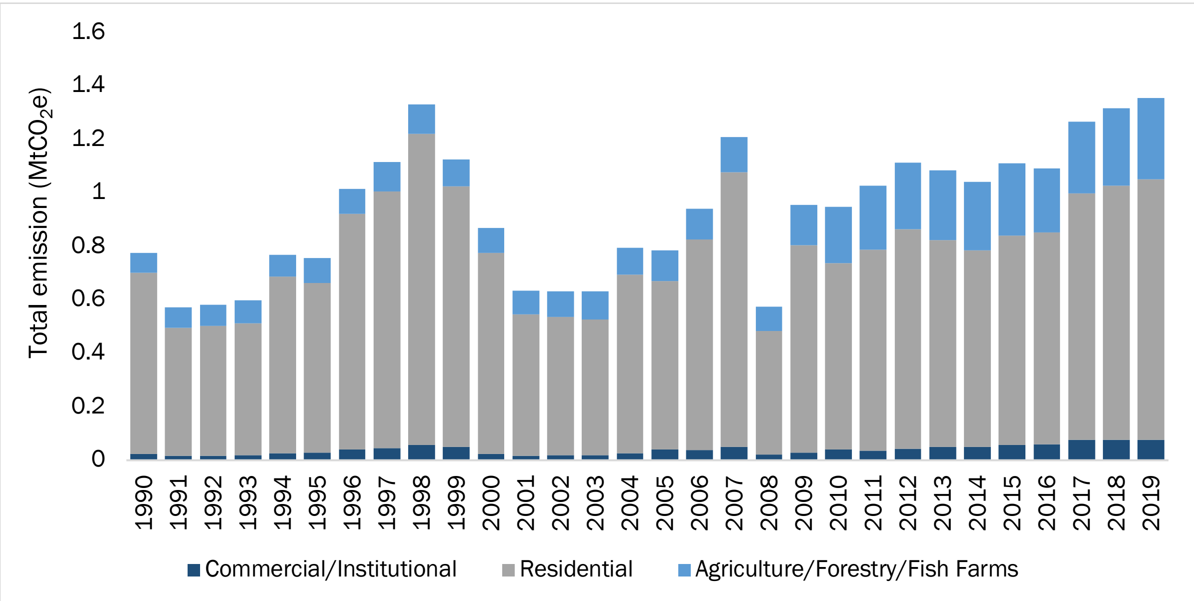


Figure 28: Total emission trends in the other sector category

In terms of gases, CO_2 was the main contributor to the emissions in other sectors, followed by CH_4 and N_2O. In 2019, the CO_2, CH_4 and N_2O emissions levels under "other sectors" were 0.93Mt, 0.34 MtCO2e, and 0.08 $MtCO_2e$, respectively. Both the total CO_2 and CH_4 levels in 2019 showed significant increases above the 1990 levels.

The trends of total CO_2 emissions in the sector increased from 0.50 Mt in 1990 to 0.93 Mt in 2019, while CH_4 emission trends recorded an increase from 0.14 $MtCO_2e$ in 1990 to 0.34 $MtCO_2e$ in 2019. However, the N_2O emissions pattern showed a visible drop of 37.26% from 0.13 $MtCO_2e$ in 1990 to 0.08 $MtCO_2e$ in 2019. The residential category (71.9%) was the largest source of GHG emissions in 2019, followed by Agriculture/forestry/fishing/fish farms (22.4%) and commercial/institutional (5.7%). The total residential sector emissions of 0.97 $MtCO_2e$ in 2019 was 44.77% and 18.29% higher than the 1990 and 2012 levels of 0.67 $MtCO_2e$ and 0.82 $MtCO_2e$ respectively. In the commercial/institutional sub-category, the total emissions increased from 0.024 $MtCO_2e$ in 1990 to 0.077 $MtCO_2e$ in 2019, representing over 200%. From 1990 to 2019, CO_2 was the dominant gas emitted, followed by CH_4 and N_2O. In 2019, CO_2 was 69.7% of the total emissions, followed by CH_4 (26,8%) and N_2O (3.54%). The 2019 Agriculture, forestry and fisheries emissions of 0.31 $MtCO_2e$ are about 309% higher than the 1990 value of 0.10 $MtCO_2e$ and 22.3% higher than the 2012 levels. The emission trends were mainly attributable to the rapid increases in diesel and gasoline consumption in stationary Agriculture, forestry and fisheries activities from 2010 onwards.

3.7.5.4.2 Methodological issues in other sectors

GHG emissions from the other sectors were estimated for three main source activities: commercial/institutional, residential and agriculture/forestry/fisheries/fish farms. Activities under the commercial/institutional category comprise combustion activities in the commercial and public services such as (banks, schools and hospitals, trade, retail and communication). Residential activities cover fuel consumption by household heating and cooking, and Agriculture/Forestry/Fisheries/Fish Farms comprise stationary combustion emissions from agriculture, cattle breeding, and forestry, and fuel combustion emissions from fisheries and off-road machinery used in agriculture (mainly tractors). The methodology for estimating emissions improved compared to the previous inventory.

Although the IPCC tier-one approach was used in the current inventory, the 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. In residential and commercial/institutional use, carbon dioxide emission from biomass was excluded from the inventory emission and reported as a memo item. The main activity data are LPG, kerosene, diesel, gasoline, and biomass fuel (firewood and charcoal). The activity data were obtained from national energy statistics. Although in the energy statistics, data on total national fuel supply and consumption are provided for the period 1990-2019, where there were gaps, trend interpolation was used to ensure time-series consistency.

3.7.5.4.3 Source-specific recalculation in other sectors

The availability of a new dataset, exclusion of unreliable data, and revision of existing data are the main reasons this category was recalculated for emissions estimates from 1990 to 2016. The recalculation resulted in t changes in CO_2, CH_4, and N_2O emissions levels.

Table 55 presents the recalculation results and their impacts on the other sector's previously reported emissions.

Table 55: Results of recalculation and its impacts on emissions for other sectors.

Years	CO_2 Emissions			CH_4 Emissions			N_2O Emissions		
	PE (Mt)	LE (Mt)	% Change	PE ($MtCO_2e$)	LE ($MtCO_2e$)	% Change	PE ($MtCO_2e$)	LE ($MtCO_2e$)	% Change
1990	0.56	0.50	-10.7	1.07	0.14	-86.9	0.16	0.13	-20
1991	0.35	0.29	-16.6	1.11	0.15	-86.6	0.17	0.13	-21.1
1992	0.35	0.29	-17.8	1.14	0.15	-86.4	0.18	0.14	-22
1993	0.35	0.30	-16.2	1.17	0.16	-86.3	0.18	0.14	-20
1994	0.53	0.45	-13.9	1.21	0.17	-86.1	0.18	0.15	-21
1995	0.49	0.43	-11.5	1.26	0.17	-86.2	0.19	0.15	-21.5
1996	0.75	0.68	-9.9	1.31	0.18	-86.3	0.20	0.16	-20.9
1997	0.82	0.76	-7.4	1.37	0.19	-86.4	0.21	0.17	-21.1
1998	1.05	0.99	-6.1	1.32	0.19	-86	0.20	0.16	-20.6
1999	0.86	0.77	-9.6	1.35	0.19	-86	0.21	0.16	-21.7
2000	0.54	0.52	-3.1	0.94	0.21	-77.7	0.14	0.13	-2.2
2001	0.52	0.30	-42.5	0.89	0.21	-76.6	0.13	0.13	-2.3
2002	0.56	0.31	-44.7	0.84	0.21	-75	0.12	0.12	-2.5
2003	0.56	0.32	-43.8	0.79	0.21	-73.6	0.11	0.11	0.0
2004	0.57	0.47	-17.7	0.75	0.22	-71	0.10	0.10	0.0
2005	0.60	0.45	-24.9	0.44	0.24	-46.1	0.05	0.10	77.8
2006	0.71	0.49	-30.6	0.72	0.28	-60.5	0.10	0.16	71.9
2007	0.66	0.83	26.0	0.69	0.26	-62.7	0.09	0.13	35.5
2008	0.63	0.26	-58.9	0.40	0.23	-41.7	0.06	0.08	42.1
2009	0.97	0.81	-16.8	0.41	0.11	-72.9	0.06	0.04	-31.6
2010	0.73	0.63	-13.9	0.61	0.24	-60.7	0.08	0.08	0.0
2011	0.83	0.69	-16.7	0.64	0.21	-67	0.08	0.13	55.6
2012	0.96	0.78	-18.6	0.64	0.21	-66.8	0.08	0.12	44.4
2013	0.91	0.73	-19.6	0.65	0.28	-57.8	0.08	0.08	0.0
2014	0.83	0.66	-20.6	0.68	0.30	-56.2	0.08	0.08	0.0
2015	0.88	0.73	-16.4	0.67	0.30	-56.1	0.08	0.08	0.0
2016	0.88	0.71	-19.3	0.67	0.30	-55.9	0.08	0.08	0.0

Recalculations of the previous GHG emissions of the “other sector” sub-sector led to the reduction of CO_2 and CH_4 emissions and increases in N_2O emissions. Generally, the CO_2 emission for the other sector sub-sector was reduced by 18.6% due to recalculations. The recalculation impacts the previous estimate different for each year. It ranged from -58.9% in 2008 to 26% in 2007. Methane emissions also showed a similar reduction effect of an average of 71.9% ranging from -86.9% in 1990 to 41.7% in 2008. Unlike CO_2 and CH_4, the recalculation led to a marginal average increase of 2.9% in N_2O emissions in the latest estimates. The highest change of 77.8% was recorded in 2008 compared to -31.6% in 2009.

Reasons for recalculations

- Revision of LPG consumption figures from 2000 to 2006 and 2008 to 2009 for the residential sector due to the availability of new data.
- Revision of kerosene consumption figures from 2000 to 2007 and 2009 for the residential sector due to the availability of new data
- Revision of woodfuel consumption figures from 2005 to 2009 and 2011 to 2012 for the residential sector due to the availability of new data
- Revision of Charcoal consumption figures for 2005, 2007, 2008, 2011 and 2012 for the residential sector due to the availability of new data

- Revision of Wood consumption figures from 1990 to 2009 and 2011 to 2012 for the commercial sector due to the availability of new data
- Revision of charcoal consumption figures from 1990 to 2005, 2007 to 2008 and 2011 to 2012 for the commercial sector due to the availability of new data
- Revision of gasoline, diesel and LPG consumption figures from 1990 to 2016 for off-road vehicles and other machinery under other sectors due to the availability of new data
- Revision of gasoline and diesel consumption figures from 1990 to 2016 for the fishing under other sectors due to the availability of new data

3.8 Fugitive emissions from fuels (1.B)

3.8.1 Overview of sources of Fugitive emissions

The main sources of fugitive emissions fuels in the country are oil and gas production, gas processing distribution, and petroleum refining. Ghana started reporting fugitive emissions from flaring in oil and gas production in 2010 when commercial production from the Jubilee field commenced. Since then, operations in two additional fields (TEN and Sankofa) have commenced in 2016 and 2017. Since the commencement of oil and gas commercial production, Ghana has produced 390.2 million barrels of crude oil with an annual average of 39 million barrels. In the same period, a cumulative total of 623,538 MMscf of natural gas was produced at an average of 62,354 MMscf per year (Table 56).

Table 56: Oil and gas production statistics

Year	Crude oil production [thousand barrels]	Natural gas statistics [MMscf]					
		Gas Production	Own use	Injection	Export to Atuabo Plant	Gas Flared	Statistical Difference
2010	1,365	2,655.71	-	-	-	1,484.00	1171.709
2011	23,833	30,620.35	2,386.19	14,741.29	-	13,493.87	-1
2012	28,937	32,970.16	3,150.49	28,877.77	-	942.06	-0.16
2013	36,859	47,430.22	2,702.85	41,203.27	-	3,524.08	0.02
2014	37,299	55,758.14	3,121.15	45,526.15	1,910.07	5,200.75	0.02
2015	37,458	52,549.19	2,975.85	20,553.04	24,236.01	4,784.27	0.02
2016	32,298	44,952.49	4,192.22	12,921.63	21,579.60	6,259.08	-0.04
2017	58,658	78,264.26	8,355.37	22,199.84	30,816.31	16,873.70	19.04
2018	62,135	108,725.86	10,871.93	56,373.75	33,831.15	7,193.31	-107.48
2019	71,440	169,611.61	12,360.02	96,458.14	53,932.63	5,997.35	856.26

Production of natural gas went up at the same rate. It moved from 2,655.71 MMscf in 2010 to 44,952.49 in 2016 and further up by 277% to 169,611.61 MMscf. Of the total natural gas production, 55% are re-injected into the oil well, 27% is transferred to Ghana National Gas Company for further processing, 8% is used as their fuel on the rig and 11% is flared. On the other hand, natural gas for further downstream processing has increased from 3% of the total national gas production in 2014 to 36% in 2019. The considerable reductions in gas flaring were due to gas injection to reduce environmental impacts and the increased downstream processing in response to the government's national gas development policy. Fugitive emissions were also reported from the Atuabo gas processing.

The Ghana National Gas processing plant treats the wet gas from the oil and gas fields as flares isopentane into the atmosphere. Since 2014, the Atuabo Gas Plant has processed an aggregate of 166,305.77 MMscf of wet gas into lean gas, condensate and LPG. Gas flaring from Tema Oil Refinery has not been estimated due to the lack of data at the plant.

3.8.1 Description of source-specific activities

3.8.1.1 Emissions from Oil and Natural gas (1.B2)

The total emissions from the upstream and downstream oil and gas operations were estimated at 8.1 $MtCO_2e$ in 2019. This value represented 29.5% of the total energy sector emissions of 27.3 $MtCO_2e$ in the same year. The emissions increased by 304% from 1.9 $MtCO_2e$ in 2014 to 8.1 $MtCO_2e$ in 2019 (Table 57).

Table 57: Greenhouse gas emissions trend in the Oil and Gas category

Years	GHG Emissions ($MtCO_2e$)			
	Conventional oil production(flaring)	Gas Processing	Gas Distribution	Total
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	-	-	-	-
2005	-	-	-	-
2006	-	-	-	-
2007	-	-	-	-
2008	-	-	-	-
2009	-	-	-	-
2010	1.9924	-	-	1.9925
2011	18.1169	-	-	18.1172
2012	1.2648	-	-	1.2648
2013	4.7314	-	-	4.7315
2014	6.9825	0.000	0.00000	6.9827
2015	6.4234	0.000	0.00002	6.4235
2016	8.4034	0.000	0.00002	8.4036
2017	22.6546	0.000	0.00002	22.6551

2018	9.6577	0.000	0.00002	9.6579
2019	8.0520	0.000	0.00004	8.0522

3.8.1.2 Methodological issues in the oil and gas category

The activity data were from the Ghana Petroleum Commission, Environmental Protection Agency and the Ghana National Gas Company. The Petroleum Commission's monthly oil and gas production figures for the three oil fields were reconciled with the energy balance figures. Generally, the figures are matched except for the venting data. The rig and production platforms venting is currently not accurately monitored and reported. So, emissions from venting would have to be improved in the next inventory circle. The activity data on gas processed and gas distribution was collected from Ghana Gas. The monthly data on gas processing and distribution covered the period the plant has been in operation. The total fugitive emissions were estimated using the IPCC tier methodology, the activity data, oil refining, oil production, gas processing and distribution, and the IPCC default emission factors.

3.9 Cross-cutting issues in the Energy sector

3.9.1 Comparison of Activity data with international data sources

The section compares activity data used in the inventory with Ghana's International Energy Agency (IEA) data. The comparison aims to assess the extent of consistency of the two data sources to understand the reasons behind the difference between the two data sources. The comparison, which measures the percentage difference of the individual input fuels from the two data sources, has been provided yearly (Table 58) between 1990 and 2019. The negative sign indicates that the country-specific activity data is lower than the IEA activity.

Table 58: Comparison of Activity Data to International Energy Agency Data

Year	Data Source	Crude Oil [ktoe]	LPG [ktoe]	Gasoline [ktoe]	Diesel [ktoe]	Kerosene [ktoe]	RFO [ktoe]	Solid Biomass [ktoe]
1990	Ghana Data	801.72	6.57	349.55	291.33	153.58	40.3	2750.98
	IEA Data	801.17	6.78	344.55	301.99	128.68	40.33	2750.98
	Difference (%)	0.07	-3.20	1.43	-3.66	16.21	-0.07	0.00
1991	Ghana Data	981.65	7.31	296.96	285.78	75.89	46.28	2834.92
	IEA Data	979.32	10.17	316.73	285.44	80.55	40.33	2834.56
	Difference (%)	0.24	-39.12	-6.66	0.12	-6.14	12.86	0.01
1992	Ghana Data	959.78	10.65	332.29	321.51	73.49	48.59	2921.28
	IEA Data	924.35	15.82	372.37	349.56	86.83	42.25	2920.52
	Difference (%)	3.69	-48.54	-12.06	-8.72	-18.15	13.05	0.03
1993	Ghana Data	759.92	15.87	305.44	335.56	70.31	48.04	3009.8
	IEA Data	790.99	22.59	374.51	357.7	85.78	41.29	3008.88
	Difference (%)	-4.09	-42.34	-22.61	-6.60	-22.00	14.05	0.03
1994	Ghana Data	1075.78	21.92	372.09	421.23	119.55	49.12	3105.29
	IEA Data	1072.98	31.63	356.32	417.82	93.11	43.21	3102.01
	Difference (%)	0.26	-44.30	4.24	0.81	22.12	12.03	0.11
1995	Ghana Data	849.43	68.52	346.53	381.56	80.22	50.53	3247.04
	IEA Data	919.26	37.28	378.79	469.53	104.61	46.09	3187.98
	Difference (%)	-8.22	45.59	-9.31	-23.06	-30.40	8.79	1.82
1996	Ghana Data	1014	82.56	422.17	516.61	154.44	48.34	3399.72
	IEA Data	1013.94	45.19	408.75	519.17	118.21	48.01	3264.49

	Difference (%)	0.01	45.26	3.18	-0.50	23.46	0.68	3.98
1997	Ghana Data	181	75.25	330.48	537.86	184.27	35.6	3557.48
	IEA Data	181.21	40.67	429.08	536.75	127.63	52.81	3339.57
	Difference (%)	-0.12	45.95	-29.84	0.21	30.74	-48.34	6.13
1998	Ghana Data	1221.61	49.8	526.68	717.59	275.88	31.63	3430.16
	IEA Data	1221.61	41.8	475.09	692.92	142.28	48.97	3427.78
	Difference (%)	0.00	16.06	9.80	3.44	48.43	-54.82	0.07
1999	Ghana Data	1666.48	46.03	694.62	638.17	209.62	39.17	3506.7
	IEA Data	1666.48	47.45	514.68	791.17	139.14	55.69	3503.2
	Difference (%)	0.00	-3.08	25.90	-23.97	33.62	-42.18	0.10
2000	Ghana Data	1310.60	48.6	550.62	679.13	65.77	57.1	2485
	IEA Data	1308.14	47.45	582.1	726.01	69.05	54.73	3583.77
	Difference (%)	0.19	2.37	-5.72	-6.90	-4.99	4.15	-44.22
2001	Ghana Data	1569.58	45.9	561.855	699.38	68.39	52	3312.4
	IEA Data	1566.72	51.97	587.45	707.39	75.32	49.93	3659.01
	Difference (%)	0.18	-13.22	-4.56	-1.15	-10.13	3.98	-10.46
2002	Ghana Data	1816.6	54	598.71	732.17	74.8	51.9	3696.18
	IEA Data	1820.2	58.75	650.58	768.41	60.68	49.93	3735.83
	Difference (%)	-0.20	-8.80	-8.66	-4.95	18.88	3.80	-1.07
2003	Ghana Data	1972.48	55.00	503.79	770.42	66.74	45.70	4029.96
	IEA Data	1979.01	68.91	527.52	780.82	73.23	44.17	3734.40
	Difference (%)	-0.33	-25.29	-4.71	-1.35	-9.72	3.35	7.33
2004	Ghana Data	2016.44	63.73	604.38	865.90	71.00	43.84	3306.00
	IEA Data	2035.00	79.08	633.46	879.07	78.46	43.21	3772.68
	Difference (%)	-0.92	-24.09	-4.81	-1.52	-10.50	1.45	-14.12
2005	Ghana Data	2006.85	68.39	392.49	898.03	72.07	46.37	4016.60
	IEA Data	2003.44	86.99	591.73	911.13	80.55	46.09	3811.34
	Difference (%)	0.17	-27.21	-50.76	-1.46	-11.77	0.60	5.11
2006	Ghana Data	1747.06	95.04	537.49	952.70	74.21	55.10	4173.83
	IEA Data	1743.85	107.33	563.91	966.98	82.65	54.73	3850.39
	Difference (%)	0.18	-12.93	-4.92	-1.50	-11.37	0.67	7.75
2007	Ghana Data	2094.77	100.76	571.41	1169.97	63.24	21.83	4296.28
	IEA Data	2090.99	114.10	615.27	990.77	68.00	52.81	3889.84
	Difference (%)	0.18	-13.24	-7.68	15.32	-7.53	-141.91	9.46
2008	Ghana Data	2015.32	127.01	572.25	1113.98	33.56	74.64	4491.56
	IEA Data	2011.59	143.48	616.34	940.09	37.66	48.97	3929.69
	Difference (%)	0.19	-12.97	-7.70	15.61	-12.22	34.39	12.51
2009	Ghana Data	1002.50	238.25	736.47	1305.63	89.22	34.34	4578.92
	IEA Data	998.67	249.67	750.09	1322.75	92.06	38.41	3969.93
	Difference (%)	0.38	-4.79	-1.85	-1.31	-3.18	-11.85	13.30
2010	Ghana Data	1694.83	192.67	774.69	1297.37	50.78	29.97	2748.77
	IEA Data	1809.00	202.22	789.68	1317.57	51.26	29.76	3207.00
	Difference (%)	-6.74	-4.96	-1.93	-1.56	-0.95	0.70	-16.67
2011	Ghana Data	1231.00	192.67	586.20	1176.90	64.27	36.40	3370.70
	IEA Data	1069.00	201.00	545.00	1160.00	59.00	36.00	3370.00
	Difference (%)	13.16	-4.32	7.03	1.44	8.20	1.10	0.02
2012	Ghana Data	1233.69	268.49	957.08	1761.14	47.00	33.50	3409.20
	IEA Data	1163.00	273.00	957.00	1596.00	48.00	33.00	3408.00
	Difference (%)	5.73	-1.68	0.01	9.38	-2.13	1.49	0.04
2013	Ghana Data	1446.40	251.76	1030.40	1618.70	28.62	38.10	3554.90

	IEA Data	1653.00	230.00	1050.00	1629.00	29.00	37.00	3553.00
	Difference (%)	-14.28	8.64	-1.90	-0.64	-1.33	2.89	0.05
2014	Ghana Data	706.30	260.90	1306.30	1765.90	9.30	26.00	3629.00
	IEA Data	646.00	267.00	1331.00	1790.00	53.00	26.00	3628.00
	Difference (%)	8.54	-2.34	-1.89	-1.36	-469.89	0.00	0.03
2015	Ghana Data	441.40	218.30	1212.76	2045.00	34.90	13.00	3618.00
	IEA Data	461.00	224.00	1254.00	2225.00	49.00	12.00	3618.00
	Difference (%)	-4.44	-2.61	-3.40	-8.80	-40.40	7.69	0.00
2016	Ghana Data	612.29	280.82	1152.83	1605.50	21.90	12.60	3602.40
	IEA Data	1,820	173.00	1,032.00	1603.00	32.00	12.00	3600.00
	Difference (%)	-33.6	61.6	5.5	0.16	-46.12	4.76	0.07
2017	Ghana Data	252.32	387.64	1144.21	1575.97	5.6	10.46	3903.30
	IEA Data	237.89	312.60	1221.33	1718.32	5.85	10.36	2758.26
	Difference (%)	6.1	24.0	-6.3	-8.3	-4.3%	1.0	41.5
2018	Ghana Data	1.43	428.56	1345.39	1843.49	4.86	15.14	4192.12
	IEA Data	1.39	325.74	1403.66	1899.52	5.23	34.33	2723.96
	Difference (%)	2.9	31.6	-4.2	-2.9	-7.1	-55.9	53.9
2019	Ghana Data	133.13	366.49	1459.25	1951.40	3.79	39.93	4218.48
	IEA Data	133.1	338.44	1970.78	1970.78	3.98	39.78	2901.56
	Difference (%)	0.0	8.3	-26.0	-1.0	-4.8	0.4	45.4

3.9.2 Description of notation keys and completeness information

The information on completeness includes coverage of gases, categories, and 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 indicating that Ghana’s energy balance does report energy consumption for the relevant sector and fuel category. Emissions of all relevant sources of greenhouse gases under the fuel combustion category have been estimated. As much as possible, Ghana has reported emissions of all relevant sources and gases under this category for the 1990-2019 period. Table 59 provides an overview of fuel combustion sub-categories and the types of greenhouse gas calculations.

Table 59: Subcategories of Fuel Combustion Activities

IPCC categories	Time series completeness										
	1990-2016 (recalculations)				2017-2019 (Latest estimates)				Gases Covered		
	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 Crude oil	x				x				x	x	x
1.A.1.a HFO					x				x	x	x
1.A.1.a Diesel	x								x	x	x
1.A.1.a DFO							x		x	x	x
1.A.1.a RFO			x		x				x	x	x
1.A.1.a Natural gas	x				x				x	x	x
1.A.1.a LPG			x		x				x	x	x
1.A.1.a Biomass			x				x		NO	NO	NO
1.A.1.a Solid			x				x		NO	NO	NO
1.A.1.b Petroleum refining											
1.A.1.b Refinery gas	x				x				x	x	x

1.A.1.b Residual fuel oil	x				x				x	x	x
1.A.1.b Gaseous Fuels			x				x		NO	NO	NO
1.A.1.b Biomass			x				x		NO	NO	NO
1.A.1.b Petroleum coke	x				x				x	x	x
1.A1ci, Manufacture of solid fuel											
1.A.1ci Liquid Fuels			x				x		NO	NO	NO
1.A.1ci Gaseous Fuels			x				x		NO	NO	NO
1.A.1ci Woodfuel	x				x				IE	x	x
1.A.1ci Solid			x				x		NO	NO	NO
1.A1cii. Other energy industries											
1.A.1cii Diesel	x				x				x	x	x
1.A.1cii Natural gas	x				x				x	x	x
1.A.1cii Biomass			x				x		NO	NO	NO
1.A.1cii Solid			x				x		NO	NO	NO
Manufacturing industry and construction											
1.A.2a Iron and steel											
1.A.2.a Diesel	x				x				x	x	x
1.A.2.a RFO	x				x				x	x	x
1.A.2.a Gaseous Fuels			x				x		NO	NO	NO
1.A.2.a Biomass			x				x		NO	NO	NO
1.A.2.a Solid			x				x		NO	NO	NO
1.A.2c Chemicals											
1.A.2.c Diesel	x				x				x	x	x
1.A.2.c RFO	x				x				x	x	x
1.A.2.c Gaseous Fuels			x				x		NO	NO	NO
1.A.2.c Biomass			x				x		NO	NO	NO
1.A.2.c Solid			x				x		NO	NO	NO
1.A.2.d Pulp, Paper and Print											
1.A.2.d LPG	x				x				x	x	x
1.A.2.e Diesel	x				x				x	x	x
1.A.2.d Gaseous Fuels			x				x		NO	NO	NO
1.A.2.d Biomass			x				x		NO	NO	NO
1.A.2.d Solid			x				x		NO	NO	NO
1.A.2.e Food Processing, Beverages and Tobacco											
1.A.2.e Diesel	x				x				x	x	x
1.A.2.e LPG	x				x				x	x	x
1.A.2.e RFO	x				x				x	x	x
1.A.2.e Gaseous Fuels			x		x				NO	NO	NO
1.A.2.e Woodfuel	x				x				IE	x	x
1.A.2.e Charcoal	x				x				IE	x	x
1.A2i. Mining & Quarrying											
1.A.2.e Gasoline	x				x				x	x	x

1.A.2.e Diesel	x				x				x	x	x
1.A.2.e Gaseous Fuels			x				x		NO	NO	NO
1.A.2.e Biomass			x				x		NO	NO	NO
1.A.2.e Solid			x				x		NO	NO	NO
1.A.2.j Wood and Wood Products											
1.A.2.j Diesel	x				x				x	x	x
1.A.2.j Gaseous Fuels			x				x		NO	NO	NO
1.A.2.j Biomass			x				x		NO	NO	NO
1.A.2.j Solid			x				x		NO	NO	NO
1.A.2.k Construction											
1.A.2.k Diesel	x				x				x	x	x
1.A.2.k Gaseous Fuels			x				x		NO	NO	NO
1.A.2.k Biomass			x				x		NO	NO	NO
1.A.2.k Solid			x				x		NO	NO	NO
1.A.2.l Textiles and Leather											
1.A.2.l Diesel	x								x	x	x
1.A.2.l RFO	x								x	x	x
1.A.2.l Gaseous Fuels			x		x		x		NO	NO	NO
1.A.2.l Woodfuel	x				x				IE	x	x
1.A.2.l Solid			x				x		NO	NO	NO
1.A.2.m non-specified											
1.A.2.l Diesel	x								x	x	x
1.A.2.l RFO	x								x	x	x
1.A.2.l LPG	x								x	x	x
1.A.2.l Gaseous Fuels			x		x		x		NO	NO	NO
1.A.2.l Woodfuel	x				x				IE	x	x
1.A.2.l Solid			x				x		NO	NO	NO
Transportation											
1.A.3a Civil Aviation											
1.A.3a Jet Kerosene	x				x				x	x	x
1.A.3b Road Transportation											
1.A.3b Gasoline	x				x				x	x	x
1.A.3b Diesel	x				x				x	x	x
1.A.3b LPG	x				x				x	x	x
1.A.3b Natural Gas			x				x		NO	NO	NO
1.A.3b Biomass			x				x		NO	NO	NO
1.A.3c Railways											
1.A.3c Diesel	x				x				x	x	x
1.A.3d Water-borne Navigation											
1.A.3d Diesel	x				x				x	x	x
1.A.4a Commercial and Institutional											
1.A.4a Kerosene	x				x				x	x	x
1.A.4A LPG	x				x				x	x	x
1.A.4a Natural Gas			x				x		NO	NO	NO

1.A.4a Woodfuel	x				x				IE	x	x
1.A.4a Charcoal	x				x				IE	x	x
1.A.4b Residential											
1.A.4b Kerosene	x				x				x	x	x
1.A.4Blpg	x				x				x	x	x
1.A.4b Natural Gas			x				x		NO	NO	NO
1.A.4b Woodfuel	x				x				IE	x	x
1.A.4b Charcoal	x				x				IE	x	x
1.A.4c Agriculture, Forestry/Fishing and Fish Farms											
1.A.3c Gasoline	x				x				x	x	x
1.A.4c Diesel	x				x				x	x	x
1.A.4c LPG			x				x		NO	NO	NO
1.A.4c Natural Gas			x				x		NO	NO	NO
1.A.4c Biomass			x				x		NO	NO	NO
1.A.4c Other fuels			x				x		NO	NO	NO
1B2aOil production flaring									x	x	x
1B2a.iii.4_Refining									NE	NE	NE
1B2biii.5Gas distribution									x	x	NA
1B2b.iii3Gas processing									x	x	NA

3.9.3 Energy sector key categories

The key category sources were generated based on the IPCC 2006 Guidelines' steps for both trends and levels. Ghana followed methods described in the IPCC 2006 guideline to identify the key category sources in the energy sector. Table 60 presents the key source categories of 1A Fuel combustion activity.

Table 60: Key category results for fuel combustion under the Energy sector

IPCC Category code	IPCC Category	Greenhouse gas	Key Source Assessment (Level Assessment – LA - 2019)	Key Source Assessment Trend Assessment (TA) (2012-2019)
1.A.3.b	Road Transport	CO_2	2012, 2019	LA, TA
1.A.1.a.i	Electricity Generation	CO_2	2012, 2019	LA, TA
1.B.2.b. ii	Oil production - Flaring	CO_2	2012, 2019	LA, TA
1.A.2	Manufacturing Industries and Construction – Liquid Fuels	CO_2	2012, 2019	LA, TA
1.A.1.c.ii	Other Energy Industries	CO_2	2019	LA, TA

Note: LA–level assessment, if not specified otherwise, is for 2019. TA–trend assessment (2012 to 2019)

3.9.4 Quality Control/Quality Assurance Procedures in the Energy Sector

Table 61 contains the information on the category-specific QA/QC carried out during the inventory. The QA/QC procedures were given serious attention to ensure greater transparency, reliability, and completeness regarding the improvements in the inventory.

Table 61: QA/QC procedures implemented in the Energy sector

Data type	QA/QC procedure	Remarks/comments/examples
Activity data check	Check for transcription, typographical errors and error transposition.	Division of tasks among the inventory team ensures that one or two team members always focus on double-checking and avoid data errors associated with those described in the left column.
	Comparison with published data	Ghana's energy balance is published by the International Energy Agency, Ghana National Energy Statistics, Strategic National Energy Plan for Ghana, and Ghana Living Standard Survey reports.
	Consistency checks of categories and subcategories with totals	Ensuring that disaggregated figures at the category and subcategories levels add 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 in the realistic range and are suspected as inaccurate are excluded and replaced with deemed appropriate from international sources or derived from expert judgment.
	Documentation of all data sources, data format and assumptions for easy reference	Keeping a record of data and assumptions at the point used in the datasheet 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: • Easy understanding and further probing of the final IPCC software results. • Easy cross-referencing and avoidance of mistakes. • Easy transmission into the IPCC software. • Aid in better interpretation of the implication of the use of the data.
Emission factors	Check of implied emission factors (time series)	Ensure the 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 and internally consistent.
	Documentation of sources and correct use of units.	Use of the documentation template records all data sources and assumptions.
	Check for transcription, typographical errors and error transposition.	Check mistakes and blunders in data entry data 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, revisions and reallocation to improve the 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 the consistency check of the use of the emissions factors.
Documentation	Assumptions, corrections, data and sources.	Ensure consistency and transparency, facilitate repeatability and easy retrieval
	Improvement list (internal and external findings)	Help prioritise areas that require action.

3.9.5 Planned improvements in the Energy sector

During the inventory, certain areas were identified for future improvements to ensure building greater confidence in the inventory estimate by reducing uncertainties to the extent possible. Table 62 contains the list of identified planned improvement activities and the necessary next steps that must be taken.

Table 62: Planned improvement activities in the Energy sector

Category	Identification of planned improvement areas	Priority of improvement list	Responsibility and next steps	Expected time to resolve or comments
1.A1b – Electricity generation	Develop or request IPPs to report on their plant-specific emissions and emission factors or conduct a study.	KC	EPA and Energy Commission.	Ghana is looking for funding to implement this activity.
All Categories	Survey to update and review the existing pattern and share of fuel consumption in all sectors of the economy	-	Energy Statistic Team. Energy Commission.	Medium-long term improvement in the reporting in Energy Statistics
1.A3b – Road Transportation	Survey to update the existing 2005 data on fuel allocation to the various vehicle classes.	KC	DVLA, EPA and Energy Commission.	Medium to long-term, bearing in mind the project on roadmap emission and fuel economy standards by 2024.
	Survey to improve the vehicle's technology-based classification based on EU standards (besides focusing on separating the functional catalytic device).			
	Survey to establish fuel economy baseline for different classes of vehicles		DVLA, EPA and Energy Commission, Private garages.	
	Separate portions of the total fleet are used 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 inventory
	Additional data collection to produce 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 trains in service, (b) annual distances or destinations covered and (c) technologies of the trains	Non-KC	Energy Team	Next inventory
1.B2a.iii.4	undertake a study to assess the quantities of gas flaring at the refinery when funding is made available to the team	Non-KC	Energy Team	When funds are available

Industrial Process and Product Use Inventory

Chapter 4

4.0 Industrial Process and Product Use sector

4.1 Overview of the IPPU sector

Emissions from industrial processes are generated from several practices and a range of often diffuse sources. It is produced as the by-products of various non-energy-related industrial activities. These emissions are produced from industrial processes and are not directly due to the energy consumed. For example, material transformation can result in the release of gases such as CO_2, CH_4, and N_2O. The majority of the IPPU activities that were covered included those relating to:

- mineral industry
- metal industry
- non-energy products from fuels and solvent use
- the product uses as a substitute for ozone-depleting substances and
- Other products manufactured and Used.

Emissions from Other Products Manufactured and used were reported by a Power company for 2015 to 2019 and have not been included in the estimates since they are considered negligible. The rest of the activities under IPPU have not been included in the inventory because those activities do not take place in Ghana. The CO_2, PFCs (CF_4 and C_2F_6) and HFCs were the main direct greenhouse gases estimated and reported.

4.1.1 Summary of IPPU Sector Activities

The overview of IPPU sector activities and their emissions are provided in Table 63. Additional information on the IPPU activities occurring in the country has been provided in detail below.

Table 63: Overview of total emissions estimate for IPPU sector Activities

Greenhouse Gas Source Categories	2016					2019				
	CO_2	CH_4	PFC	HFC	SF_6	CO_2	CH_4	PFC	HFC	SF_6
Mineral Industry	0.345	NA	NA	NA	NA	0.532	NA	NA	NA	0.532
Chemical Industry	NO	NO	NA	NA	NA	NO	NO	NA	NA	NO
Metal Industry	0.07	NO	0.68	NA	NA	0.08	NO	0.68	NA	0.76
Non-Energy Products from Fuels and Solvent	0.0021	NA	NA	NA	NA	0.002	NA	NA	NA	0.002
Electronics Industry	NA	NA	NO	NA	NE	NA	NA	NO	NA	NE
Product Uses as Substitutes for Ozone Depleting Substances	NA	NA	NA	0.58	NA	NA	NA	NA	0.59	NA
Other Product Manufacture and Use	NA	NA	NE	NA	NE	NA	NA	NO	NA	NE

4.2 Overview of Emissions for the IPPU sector

4.2.1 Aggregate IPPU sector emissions trend

The total greenhouse gas emissions for the IPPU sector were 1.73 $MtCO_2e$ in 2019 and 1.68 $MtCO_2e$ in 2016. The current levels represent an increase of 3.1% in emissions between 2016 and 2019. PFC emissions from "Metal Industries" were the most important GHG in the IPPU inventory, followed by CO_2 emissions from the "Mineral Industries" category were the most important GHG in the IPPU inventory. Of the total 2019 emissions, CO_2 accounts 0.62 $MtCO_2e$ followed by HFCs with 0.59 $MtCO_2e$ and PFCs with 0.52 $MtCO_2e$. The trend constitutes 35.6% of CO_2, 34.3% of HFCs and 30.1% of PFC of the total emissions in 2019. There was a total emission increase in the sector of 3.1% from 2016 to 2019. Of the individual greenhouse gases, emissions of CO_2 increased by 48.4%, a decrease of 23.3% for PFC and an increase of 1.6% for HFCs between 2016 and 2019.

4.3.2 Emission trends by sources and gases

4.3.2.1 Overall IPPU sector emission trends

The total GHG emissions for the IPPU sector were 1.73 $MtCO_2e$ in 2019 and 1.68$MtCO_2e$ in 2016, representing an increase of 3.1% emissions recorded for the year. The emissions trend exhibited a downward trend from 1990 to 2019 by 11.84% (Figure 29). PFC emissions from "Metal Industries" were the most important GHG in the IPPU inventory, followed by CO_2 emissions from the "Mineral Industries" category. Of the total emissions as of 2019, CO_2 emissions was 0.62 $MtCO_2e$ followed by HFCs with 0.59 $MtCO_2e$ and PFCs with 0.52 $MtCO_2e$. It comprises 35.6% of CO_2, 34.30% of HFCs and 30.1% of PFC of the total emissions in 2019. There was a total emission increase in the sector of 3.1% from 2016 to 2019. Of the individual greenhouse gases, emissions of CO_2 increased by 48.4%, a decrease of 23.3% for PFC and an increase of 1.6% for HFCs between 2016 and 2019.

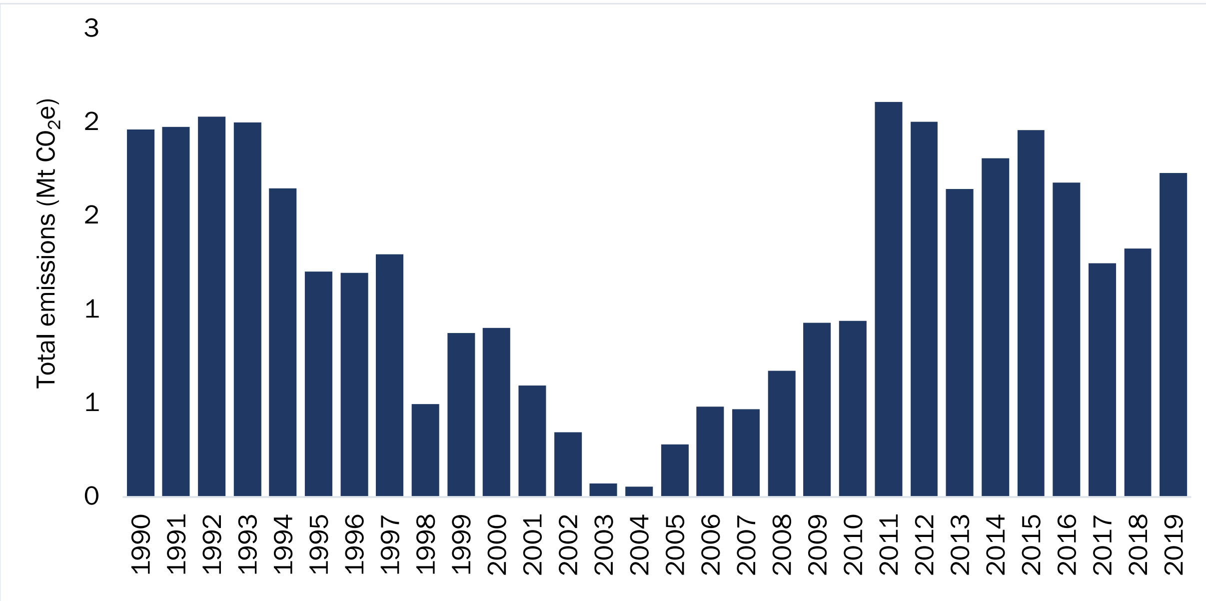


Figure 29: Emissions trends of the IPPU sector for the period 1990-2019

As of 2019, the Mineral product category was the major contributor to CO_2 emissions, mainly from limestone use, followed by cement production. Carbon dioxide emissions from the metal industry subcategory mainly from aluminium production. Generally, CO_2 emissions increased largely from 2005 due to limestone use by the cement industry. For aluminium production, CO_2 emissions generally decreased due to the power availability challenges with the plant. Stationary air conditioners are the major source of HFC emissions, followed by mobile air conditions, whilst PFCs emissions are mainly from Aluminium production. Product use as a substitute for the category of the Ozone-depleting substance contributed 34.3%, with 30.7% from the mineral industry, 34.9% from the metal industry and 0.12% from non-energy products. Compared to 1990 emissions, 99.3% and 0.8% were from metal and mineral industry categories, respectively. SF_6 emissions from electrical equipment, mainly from closed pressure transformers, were not estimated due to a lack of data.

The mineral industry observed increases from 14.76 $GgCO_2e$ in 1990 to 531.73 $GgCO_2e$ in 2019. Within the industry, limestone use, soda ash use, and cement production were the main sources of emissions. Of the three sources, emissions from limestone use dominated throughout the time series. Emissions generally recorded increases from 1990 (0.014 $MtCO_2e$) to 2018 (0.55 $MtCO_2e$) dropped in 2013 and in 2019 (0.53 $MtCO_2e$). The high demand for limestone use in the cement industry contributed to the rise in CO_2 emissions. Limestone use has increased significantly since 1990, largely due to the production of cement for infrastructural activities and the setting up of additional cement plants in the country. Similar increases were recorded for Soda ash use even though emissions were minimal between 1999 and 2008, which decreased in 2019. Emissions from cement production increased from 2011 to 2019. Carbon dioxide is the main gas in this category.

Emissions from the metal production category were dominated by aluminium production, followed by steel production, mainly from steel recycling plants. Emissions from Aluminium production decreased from 1990 to 2003, rising slightly until after 2016, when emissions decreased to 2019. The decreases in CO_2 emissions are mainly due to significant power cuts to the facility. The power cuts eventually resulted in no production activities in 2004, 2009 and 2010. Emissions from the facility started picking up in 2011 following the restoration of limited electricity, which enabled the plant to be operational. In 1990, 1.95 $MtCO_2e$ emissions were from Aluminium production, whiles iron and steel contributed only 0.0048 $MtCO_2e$, whilst in 2019, 0.59 $MtCO_2e$ and 0.012 $MtCO_2e$ were from Aluminium and steel production, respectively.

Under non-energy products from fuels and solvent use, lubricant use the was main source of emissions. The emissions from lubricant use recorded increases from 1992 and peaked at 2004 (0.03 $MtCO_2e$) before declining to 0.021 $MtCO_2e$ in 2019. Emissions from refrigeration and AC subcategories dominated HFC emissions, followed by Mobile AC. Emissions peaked at 0.78 $MtCO_2e$ in 2011 and gradually decreased to 0.59 $MtCO_2e$ in 2019. PFC emissions from Aluminium production were the largest source of greenhouse gas reported from 1990 to 2002, followed by CO_2 emissions from the mineral industry from limestone use. From 2005 onwards until 2019, emissions were largely dominated by HFC emissions, followed by CO_2 emissions from the mineral industry and then PFC from aluminium production. For CO_2 emissions, the metal industry (aluminium production) consistently remained the dominant source until 2003, when CO_2 emissions from the mineral industry (Limestone use) rose to high levels (Table 64).

Table 64: Total emission trends according to different gases

Year	CO_2 ($MtCO_2e$)	PFCs ($MtCO_2e$)	HFC ($MtCO_2e$)	Total ($MtCO_2e$)
1990	0.292	1.671	0.000	1.964
1991	0.297	1.681	0.000	1.978
1992	0.305	1.726	0.000	2.031
1993	0.318	1.683	0.000	2.000
1994	0.298	1.350	0.000	1.648
1995	0.302	0.902	0.000	1.204
1996	0.289	0.908	0.000	1.197
1997	0.285	1.010	0.000	1.295
1998	0.128	0.368	0.000	0.496
1999	0.194	0.683	0.000	0.877
2000	0.289	0.614	0.000	0.904
2001	0.314	0.280	0.000	0.594
2002	0.240	0.105	0.000	0.345
2003	0.069	0.003	0.000	0.072
2004	0.054	0.000	0.000	0.054
2005	0.234	0.010	0.038	0.283
2006	0.371	0.028	0.085	0.484
2007	0.312	0.016	0.140	0.468
2008	0.417	0.013	0.243	0.673
2009	0.357	0.000	0.575	0.932
2010	0.415	0.000	0.524	0.940
2011	0.547	0.780	0.782	2.109
2012	0.594	0.662	0.750	2.005
2013	0.307	0.630	0.707	1.644
2014	0.390	0.766	0.654	1.810
2015	0.411	0.921	0.626	1.958
2016	0.415	0.680	0.584	1.679
2017	0.589	0.108	0.552	1.249
2018	0.635	0.185	0.505	1.326
2019	0.616	0.522	0.594	1.731

4.3.2.2 General IPPU emissions trend by gases and categories

The mineral product category was the major contributor to CO_2 in 2019. The emissions were mainly from "limestone use" and cement production. Carbon dioxide emissions from the metal industry sub-category are mainly from Aluminium production. Generally, CO_2 emissions increased largely from 2005 due to increased limestone use by the cement industry. An additional increase is seen with the emissions from cement production from 2011 with clinker production from one cement plant established to produce clinker. For Aluminium production, CO_2 emissions generally decreased across the time series due to the power availability challenges with the plant. Stationary air conditioners are the major source of HFC emissions, followed by mobile air conditioners, whilst PFCs emissions are mainly from Aluminium production. The observed annual increases in the emissions for each category were driven by HFC use in the refrigeration and stationery air-conditioning sector after 2005. Before 2005, PFC from Aluminium production under the Metal Industry category drove emissions.

Between 2005 and 2011, HFC emissions increased largely due to high imports of HFCs-based refrigerants equipment and gas due to the Hydrochlorofluorocarbon (HCFCs) phased out management programme until 2011 decreased after that until 2019. The decrease was mainly due to the conversion of HFC based ACs to hydrocarbon-based air conditioners in 2012, which was necessitated by the phase-down schedules of HCFCs under the Montreal protocol and initiated by the national ozone office. Additionally, with the high imports of HFCs based refrigerants equipment and gas, most of them were not completely utilised, and these served as stocks in subsequent years whilst imports and consumption reduced.

For CO_2 emissions, the metal industry (aluminium production) consistently remained the dominant source until 2003, when CO_2 emissions from the mineral industry (Limestone use) increased significantly (Figure 30): Emissions trends of the IPPU sector for the period 1990-2019). Limestone use in the cement industry gradually increased from 1990 as production grew in 2004, and emissions increased until 2019. From 2013 to 2016, mineral production emissions from cement production also contributed to increases in the subcategory. Changes in steel production, lubricant use, and soda ash use are minor (Figure 30). HFC emissions were the largest source of greenhouse gases reported during the 2008-2014 period. It is followed by CO_2 emissions from the mineral industry and PFC from aluminium production.

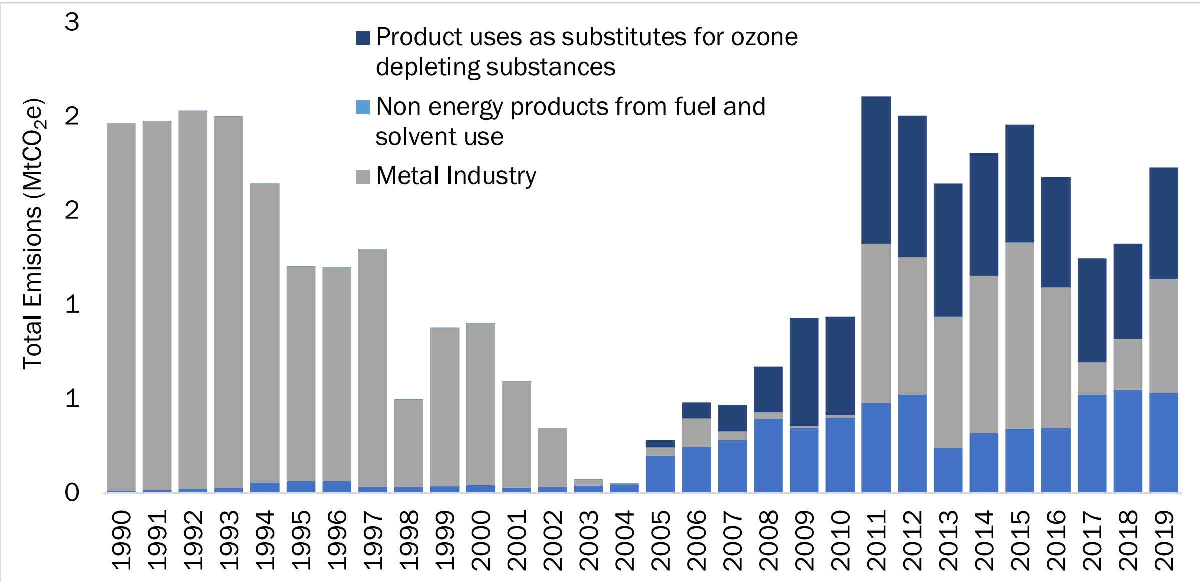


Figure 30: Share by sub-category of the total IPPU emissions

4.3 IPPU sector data sources

The description of data sources and methodology used in the inventory for the IPPU sector is provided below. The data used in this inventory were obtained from different relevant national sources. Table 65 provides an overview of the data used in the IPPU sector inventory. It covers data from major industrial sector operations in the country. The main industrial activities occur in major cities. The majority of the process industries in the mineral, metal and non-energy products are located in Tema, Accra and Takoradi, which are the coastal cities in the country. A relatively small number of the process industry is found in the rest of Ghana's regional capitals.

Table 65: Overview of the data used in the IPPU sector

Category	Sub-categories		Data Type		Source
2A Mineral Industry	2A1 Cement Production		Mass of Clinker produced, Type of clinker	Data collected from plant	Savannah Diamond Cement (plant-specific)
	2A4 Other Process Uses of Carbonates	2A4b Other Uses of Soda Ash	Amount of carbonate consumed	Soda ash use data from plants	Private Companies
		2A4d Other (Limestone Use in Cement Production)	Amount of carbonate consumed	Cement Plants	GHACEM, Savannah Diamond Cement plants
2C Metal Industry	2C1 Iron and Steel Production		Amount of steel produced	Steelmaking plants	
	2C3 Aluminum Production		Amount of Aluminum produced, plant EF CO_2, CF_4, C_2F_6, Anode	Aluminum Plant	Volta Aluminum Company
2D Non-Energy Products from Fuels and Solvent Use	2D1 Lubricant Use		Lubricant consumption	Lubricant plant	Plant Data
2F Product Uses as Substitutes for Ozone Depleting Substances	2F1 Refrigeration and Air Conditioning	2F1a Refrigeration and Stationary Air Conditioning	F-gas imports	EPA	National Ozone Unit at EPA, Customs

4.4 Description of notation keys and completeness information in IPPU

Information on completeness and notation keys in the IPPU sector is provided below. Completeness includes coverage of gases, categories and as well as time series. Additional information is given on the status of emission estimates of all sub-categories. Table 66 contains information on the completeness status of the estimations under various sub-categories.

Table 66: Notation keys and status of emission estimations in the IPPU sector

IPCC Category	Time series Completeness								Status of Gas				
	1990-2016 (recalculations) 2013-2019 (latest)												
	IE	E	NE	NO	IE	E	NE	NO	CO_2	CH_4	N_2O	PFC	HFC
Cement Production				x		x				x	NO	NO	NA
Other Process Uses of Carbonates		x				x				NO	NO	NO	NA
Iron and Steel Production		x				x				x	NO	NA	NA
Aluminum Production		x				x				x	NA	NA	x
Lubricant Use		x				x				x	NA	NA	NA
Refrigeration and Air Conditioning		x				x				NA	NA	NA	NA

4.5 Description of source-specific emission trends

4.5.1 Mineral Industry (2A)

Emissions from the mineral industry are mainly process-related carbon dioxide emissions resulting from carbonate as raw materials in the production and use of various mineral industry products. Two main pathways release CO_2 from carbonates: calcination and the acid-induced release of CO_2. In Ghana, the primary process resulting in the release of CO_2 is the calcination of carbonate compounds, during which, through heating, a metallic oxide is formed. Under the mineral industry, the use of carbonates as basic raw materials having commercial applications in industries where carbonates are consumed in metallurgy is also key (e.g., iron and steel), agriculture, construction and environmental pollution control (e.g., flue gas desulphurisation.

Four broad source categories are considered under carbonate use, and these include ceramics, other uses of soda ash, non-metallurgical magnesia production, and other uses of carbonates. Soda ash use in industry has been considered, whilst lack of data has not made it possible to estimate emissions under ceramics. Limestone use under cement production and reducing agents in the steel industry have been reported in their respective sources under other carbonates. From Figure 31, emissions from mineral production marginally increased from 1990 until 2005 when there were substantial increases until 2012, after which there was a sharp drop in 2013 and a subsequent increase until 2019. The increase has mainly been due to limestone use in cement production. It also applies to the reduction from 2013 to 2016, where cement production decreased. Emissions from cement production with the clinker production have been estimated from 2011 to 2019 from one cement producing plant.

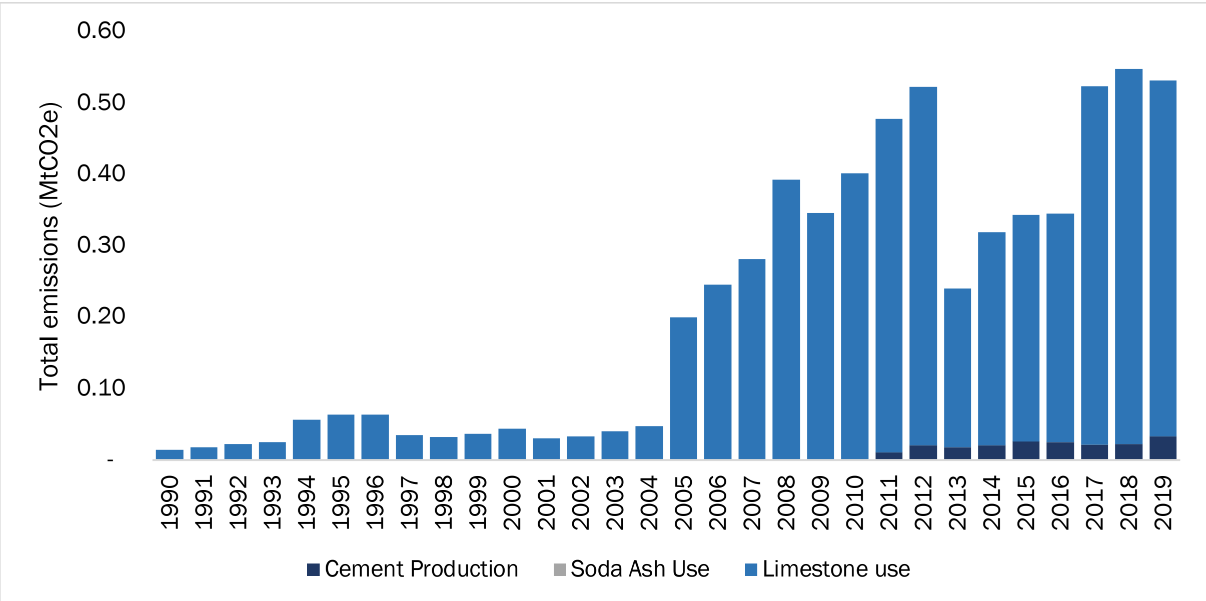


Figure 31: Mineral industry category emissions

In 1990, limestone use in the cement industry contributed 99.7% of emissions under the mineral industry, followed by Soda ash use with 0.3%. In 2019 Limestone use contributed 93.82% of emissions, followed by cement production with 6.17%, and lastly, soda ash use with 0.01% (Figure 31).

4.5.2 Cement production (2.A.1)

Portland cement was produced in Ghana from four cement producing plants. Cement manufacture is an energy-intensive process where CO_2 is produced during the production of clinker, an intermediate product which is then finely ground, alongside a small proportion of calcium sulfate (gypsum ($CaSO_2O$) or anhydrite ($CaSO_4$), into Portland cement. 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.

Two plants import clinker, where its manufacture generates significant 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 estimated under Other Process Uses of Carbonates (2A4). One plant only imports already produced cement for bagging. Beginning in 2011, one plant started the production of clinker for its use in the country. Emissions from cement production increased from 2011 to 2019. In 2019, 0.033 $MtCO_2e$ was emitted from the manufacture of cement (Figure 32)

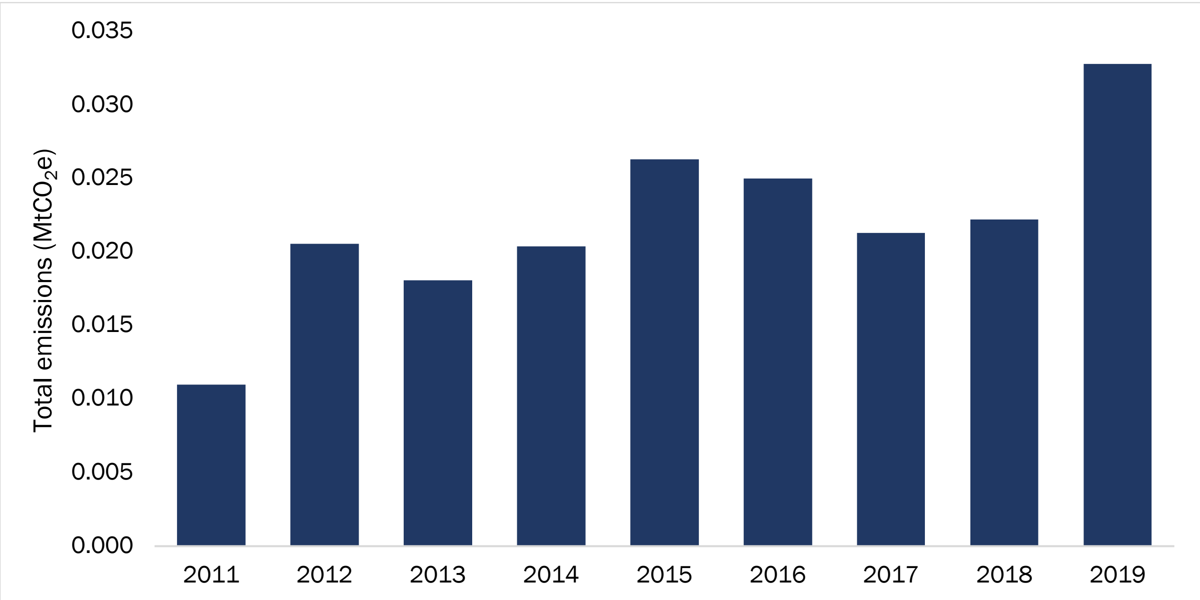


Figure 32: Cement production emissions

4.5.3 Other process uses of carbonates (2A4)

4.5.3.1 Ceramics (2. A4a)

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. Carbonates are heated to high temperatures in a kiln, producing oxides and CO_2. The ceramic industry is particularly for bricks and roof tiles which is quite common in Ghana. However, because of a lack of data, emissions have not been estimated from the subcategory. An initial survey conducted on the use of clay in the Ashanti Region revealed the clay type used as kaolin.

4.5.3.2 Other Uses of Soda Ash (2. A4b)

Soda ash is used in various applications such as glass production, soaps and detergents, flue gas desulphurisation, chemicals, pulp and paper and other common consumer products. Soda ash production and consumption (including sodium carbonate and Na_2CO_3) results in the release of CO_2 emissions. Soda ash consumption has been reported for industrial undertakings such as soap, detergents, and the textile industry. In 2019, emissions from the sub-category were 0.057 $GgCO_2e$, above the 1990 level of 0.044 $GgCO_2e$. Emissions from soda ash consumption increased gradually from 1990 to 2008, after which they decreased gradually until 2016 and after that increased again in 2019. The observed increase was due to the increase in the productive use of soda ash. On the hand, the reduction in the emission between 2008 and 2016 was because some beverage industries that relied on Soda Ash stopped using the product (Figure 33). There has also been a decrease in use by the textile industry.

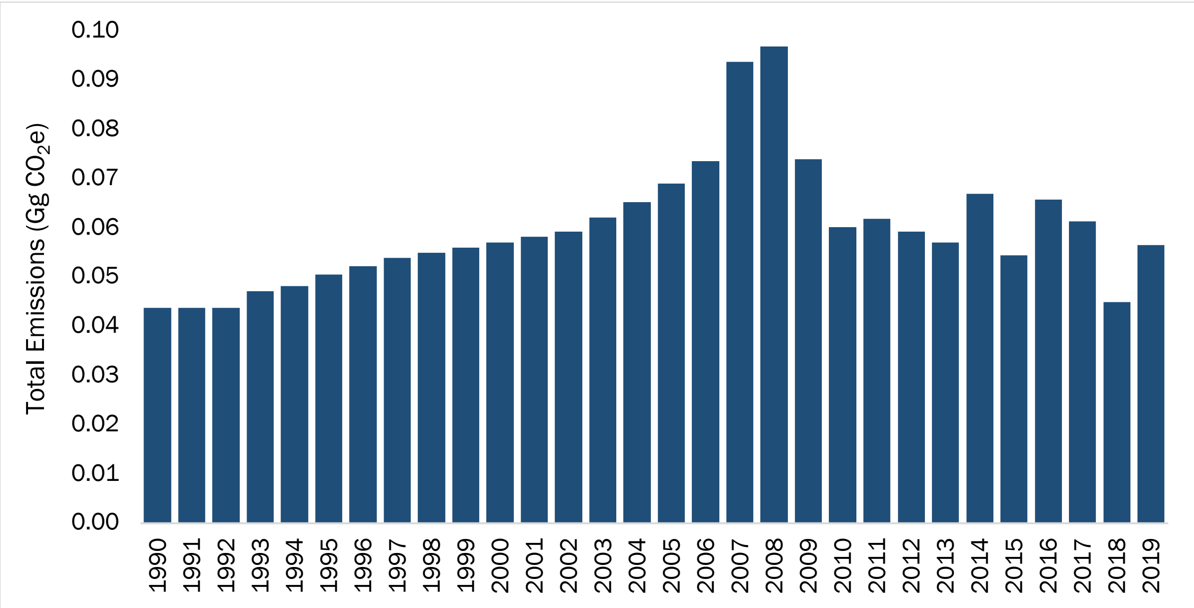


Figure 33: Soda Ash Use emissions

3.3.3 Other (Limestone and Dolomite use) (2A4d)

Limestone ($CaCO_3$) and dolomite ($CaCO_3MgCO_3$) are basic raw materials used by various industries, including construction, agriculture, chemical, metallurgy, glass production, and environmental pollution control. Emissions may result from several other source categories. According to the 2006 guideline, emissions from Limestone use are reported under the source from which they are used. As for flux, limiting use in the cement and steel industry has been reported accordingly. Deposits of limestone occur in some parts of Ghana, and significant quantities are extracted for industrial cement applications. Limestone is heated sufficiently to calcine the material and generate CO_2 as a by-product for this application. Other applications include limestone used as a flux in metallurgical furnaces for the iron and steel industrial plants. In the cement and steel industries, carbon dioxide emissions from limestone use have slightly increased from 1990 with 0.015 $MtCO_2e$ to 1994. It remained fairly stable until 2005, when emissions increased until 2012 (Figure 34). The total limestone consumption was 722.32 kilotonnes in 2016 to 1,109.72 kilotonnes in 2019 (Table 67).

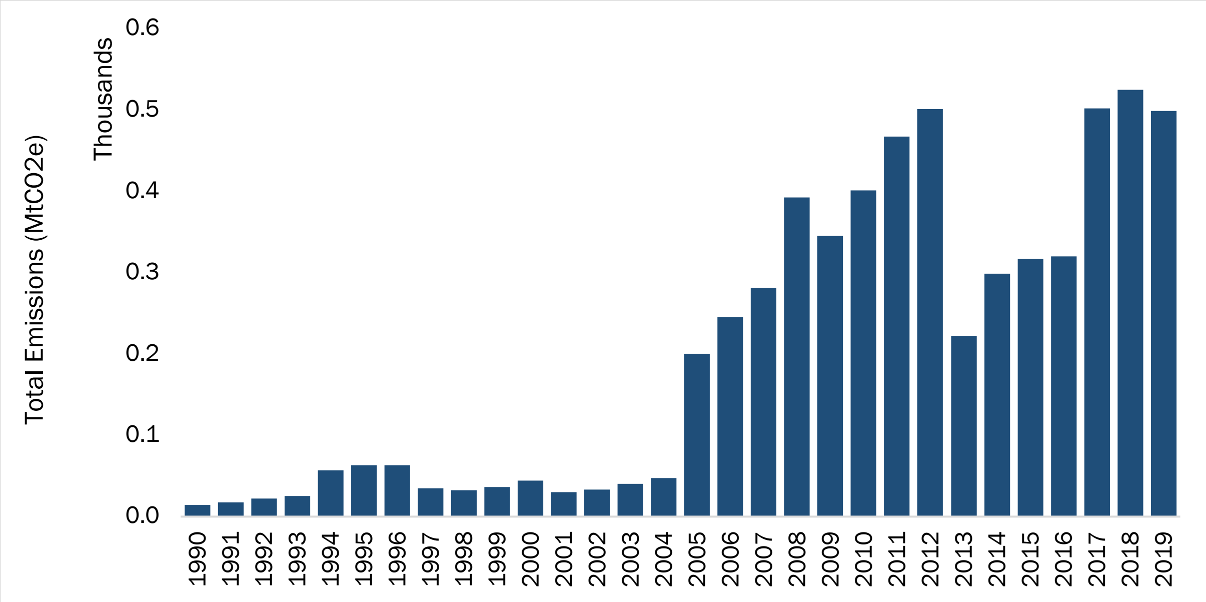


Figure 34:Limestone use emission trends for the period 1999-2019

From 2013, emissions dropped but increased again to 0.49 $MtCO_2e$ in 2019. Data have been obtained directly from the cement-making plants (Table 5). Some cement industry has recently used small amounts of dolomite. The emission estimation has included data on dolomite use from 2016 to 2019.

Table 67: Annual limestone and Dolomite consumption in Ghana in tonnes

Year	Quantity (T)	
	Limestone	Dolomite
1990	33,472.85	
2005	455,309.36	
2006	558,570.36	
2007	639,962.64	
2008	892,839.75	
2009	786,413.94	
2010	913,927.85	
2011	1,062,872.15	
2012	1,1416,41.54	
2013	505,544.64	
2014	679,427.42	
2015	720,940.93	
2016	722,320.17	4,969.94
2017	1,114,367.48	18,136
2018	1,146,323.49	43,597
2019	1,109,719.25	20,950

4.5.4 Chemical Industry (2B)

Emissions from the chemical category are basically from producing some chemicals with the resultant emissions of greenhouse gases. In Ghana, the production of chemicals by the chemical industry is non-existent and GHG emissions are not occurring and hence not estimated.

4.5.5 Metal Industry (2C)

The metal industry covers iron and steel emissions, metallurgical coke production; ferroalloy production; aluminium production; magnesium production; lead production, and zinc production. Under this category, aluminium production and iron and steel emissions have been reported. Under iron and steel, primary production of iron does not occur; therefore, emissions have only been reported for steel recycling. Total emissions from metal production decreased from 1990 to 2003, rising slightly from 2011 until 2016. The decreases in CO_2 emissions from the metal industry were associated with the consistent decline in the only aluminium production plant due to significant power cuts to the facility over time, resulting in no production activities in 2004, 2009 and 2010. Emissions from the facility started picking up in 2011 when production resumed following the restoration of limited electricity to the plant to be fully operational. Emissions decreased from 1.95 $MtCO_2e$ in 1990 to 0.6 MtCO2e in 2019 (Figure 35).

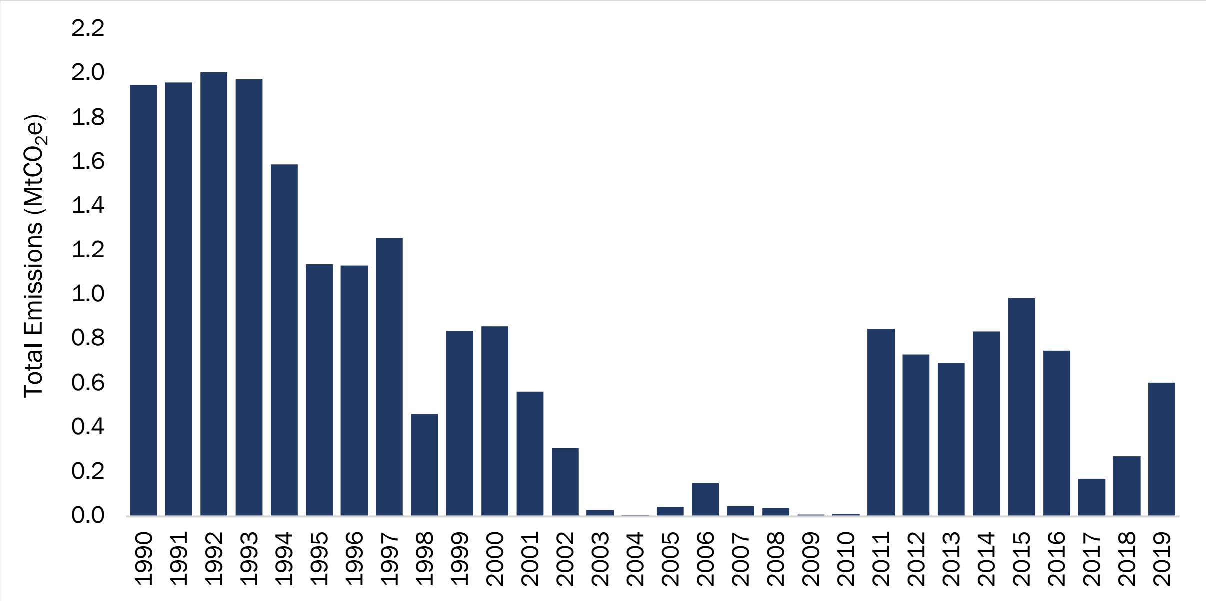


Figure 35: Total metal industry emission trends

Emissions from metal production were dominated by Aluminum production, followed by steel recycling plants. CO_2 and PFC are the greenhouse emissions from the Aluminum industry. In 1990, 1948.46 $GgCO_2e$ emissions were from Aluminum production, whiles iron and steel contributed 0.48 $GgCO_2e$, whilst in 2019, 590.64 $GgCO_2e$ and 12.97 $GgCO_2e$ were from Aluminum and steel production, respectively (Figure 36).

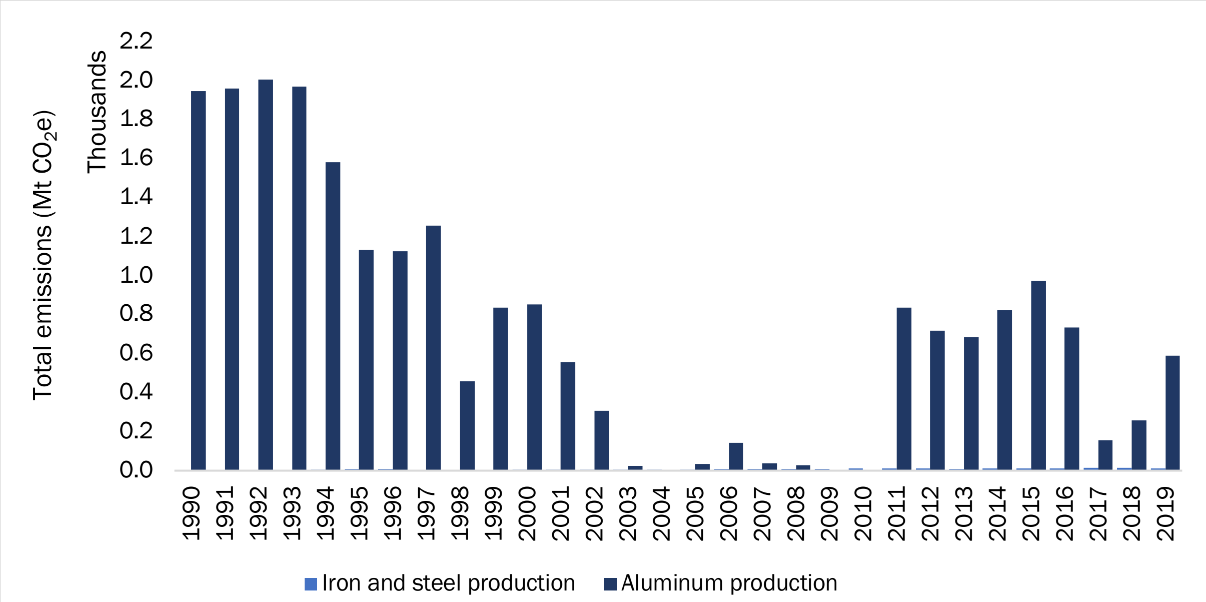


Figure 36: Metal industry emission trends by sub-category

In terms of gases from the Metal Industry, 85.76% of emissions from PFC in Aluminum production were emitted in 1990, whilst 14.2% came from the emission of carbon dioxide. In 2019, the share of PFC emissions increased to 86.4%, whilst the share of carbon dioxide emissions decreased to 13.6% (Figure 37).

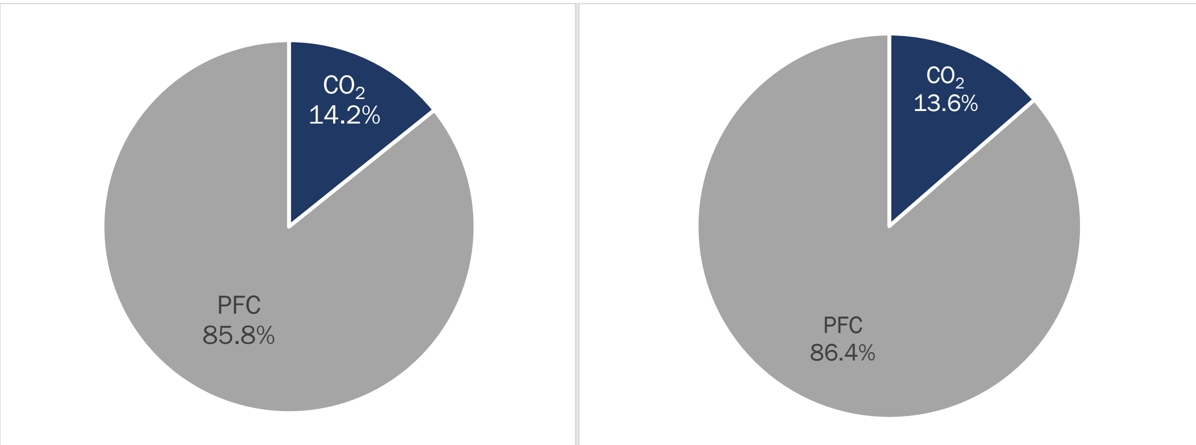


Figure 37: Share of emissions from the metal industry for1990 (left) and 2019(right)

4.5.5.1 Iron and Steel Production (2C1)

The production of iron and steel is an energy-intensive activity that also generates process-related emissions of CO_2 and CH_4. Process emissions occur at each step of steel production, from the production of raw materials to the refinement of iron to the making of crude steel. Primary production using a Basic Oxygen Furnace (BOF) with pig iron as the primary feedstock is usually the dominant method. But secondary production through scrap steel and Electric Arc Furnaces (EAFs) also occurs for steel recycling, which the increased availability of scrap steel has driven. Iron is produced by first reducing iron oxide (iron ore) with metallurgical coke in a blast furnace.

Iron can be introduced into the blast furnace in raw iron ore, briquettes, or sinter. Carbon dioxide emissions occur in BOFs through a reduction process resulting primarily from the consumption of carbon electrodes and supplemental materials used to augment the melting process. Pig iron or crude iron is produced from this process. The pig iron production process in a blast furnace produces CO_2 and fugitive CH_4 emissions. Steel is produced from pig iron and scraps steel levels in specialised BOF and EAF steel-making furnaces. Carbon inputs to BOF steel-making furnaces include pig iron and scrap steel and natural gas, fuel oil, and fluxes (e.g., limestone, dolomite).

Steel production in Ghana is mainly secondary steelmaking from scrap recycling using EAF. No primary activity with the production of pig iron occurs in the country. The ferrous metals are melted using heat produced from electricity through the graphite electrode of an EAF. To maintain the silicon and manganese levels, Ferro-silicon and ferromanganese are added. Metallurgical refining to remove impurities as slag is achieved with the aid of fluxes (oyster, limestone, activated carbon). The molten metal is converted into ingots or square billets reheated in the furnace and rolled into iron rods. Data used in the calculations were obtained from four scrap recycling companies.

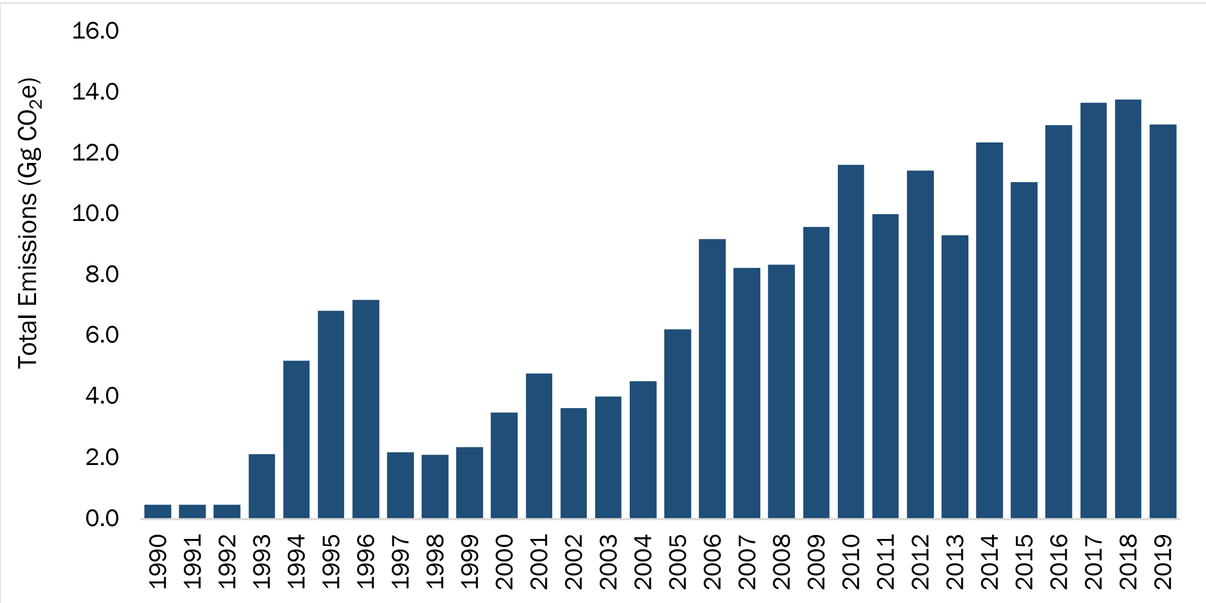


Figure 38: Total emissions from the Iron and steel industry

Figure 38 above shows a general increase in CO_2 emission from 1990 till 2010, after which there was a decreasing trend. The decrease could be due to the unavailability of scrap due to export to other countries. The low emission years could also be times that the export activity was high. One industry was completely shut down in 2013, accounting for the extremely low emission levels recorded.

4.5.5.2 Aluminium Production (2C3)

Aluminium is a lightweight, malleable, corrosion-resistant metal used in many manufactured products, including aircraft, automobiles, bicycles, and kitchen utensils. The production of primary Aluminum results in process-related emissions of CO_2 and two perfluorocarbons (PFCs): perfluoro methane (CF_4) and perfluoro ethane (C_2F_6).

Carbon dioxide 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). Most carbon is oxidised and released into the atmosphere as CO_2 during reduction. In Ghana, only the Centre-Worked Prebake (CWPB) alumina feed system is available at the only Aluminum production plant. There was no production in 2004, 2009 and 2010 due to the unavailability of electricity. Production of Aluminum in the country involves anode production where petroleum coke, pitch and butts are used to produce anodes for the reduction cells. The molten Aluminum produced is further processed and cast into various products, including sows, billets, ingots, etc.

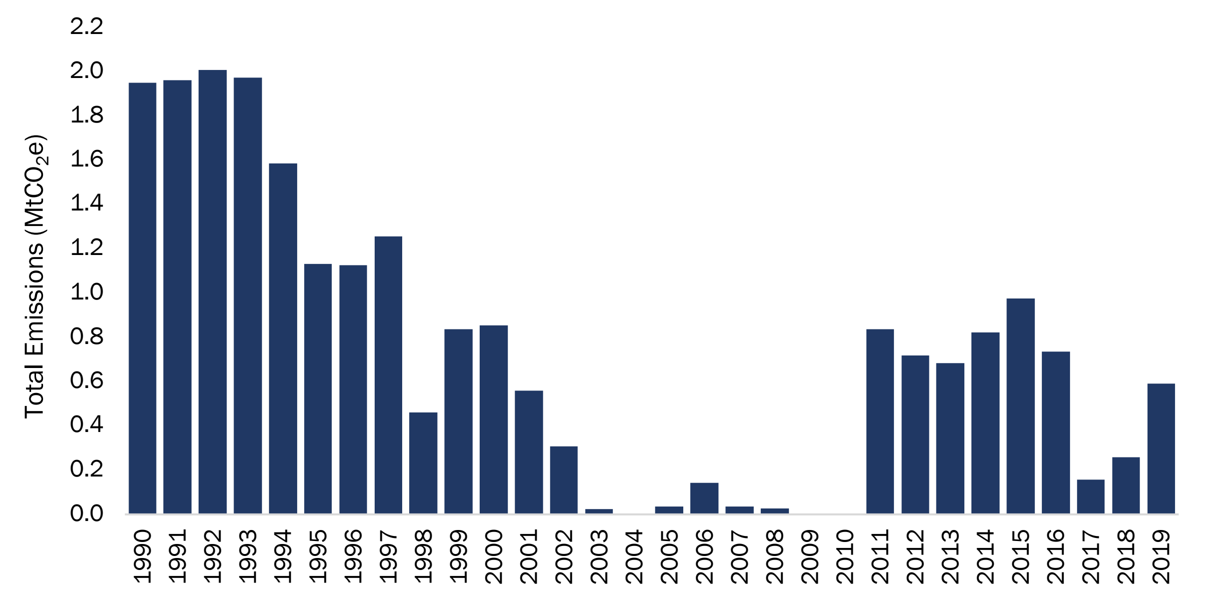


Figure 39: Total emissions from Aluminum Production

Generally, aluminium production emissions show a declining trend because production has not been stable due to an inadequate electricity supply (Figure 39). Given the electricity-intensive nature of the operations, the industry is unable to operate when the supply is not adequate. It accounted for the no production in 2004, 2009 and 2010 when the nation was confronted with an acute power supply. As of 2019, total emissions were 0.59 $MtCO_2e$, whilst in 1990 the total emissions from Aluminum production were 1.95 $MtCO_2e$(Figure 40).

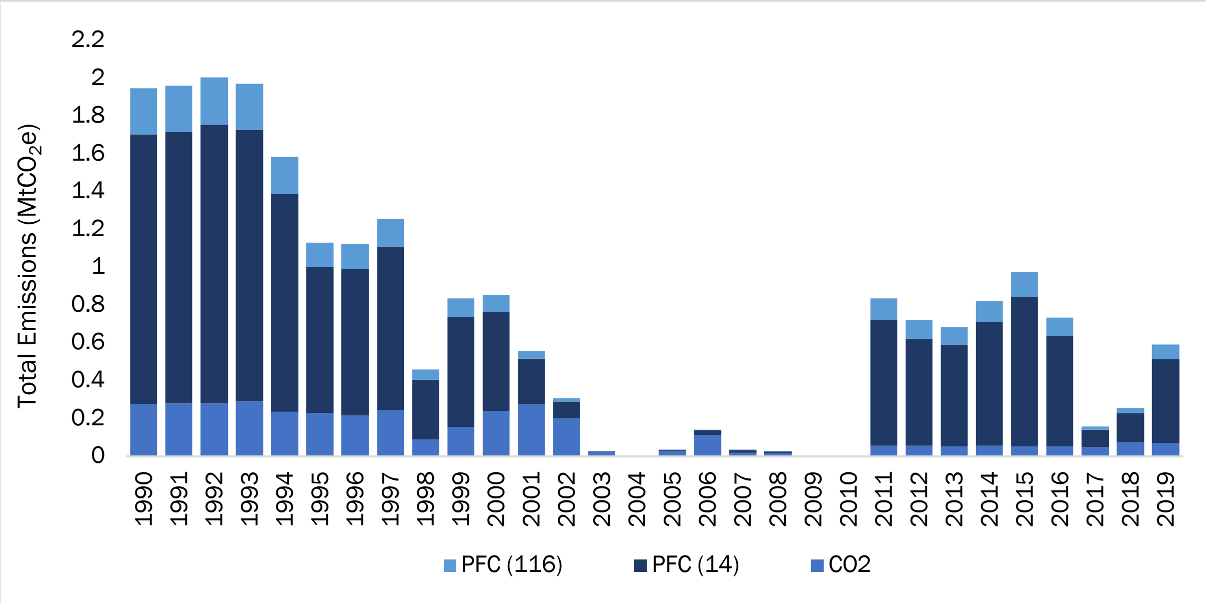


Figure 40: Emissions from Aluminum Production by gases

Most of the emissions released during Aluminum production occurred during the electrolysis reaction of the carbon anode. Figure 40 indicates that emissions from CF_4 contributed more to the total emissions followed by CO_2, whilst emission from C_2F_6 was the least contributor to the total emission from Aluminum production. As of 2019, 75.4% of emissions were from CF_4, while 12.9% and 11.7% of emissions were from C_2F_6 and CO_2. About 88.3% of emissions are from PFC (Figure 40).

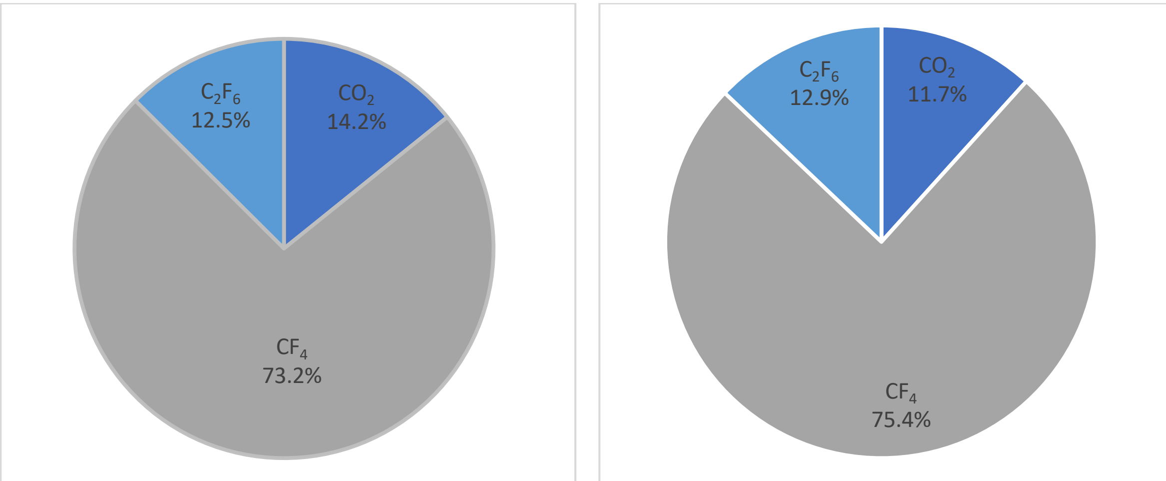


Figure 40: Emissions by gases from Aluminum production for 1990 (left) and 2019 (right)

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

4.5.6.1 Lubricant Use (2.D1)

Lubricants are mostly used in industrial and transport applications to reduce friction in machinery parts and protect internal combustion engines in motor vehicles and powered equipment. Lubrication helps to reduce friction, surface fatigue, heat generation, noise and vibrations etc. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities.

Lubricants are sub-divided into two: (a) motor oils and industrial oils and (b) greases, which differ in terms of physical characteristics (e.g., viscosity), commercial applications, and environmental fate. It is difficult to determine which fraction of the lubricant consumed in machinery and vehicles is combusted and thus directly results in CO_2 emissions. Therefore, for calculating CO_2 emissions, the total lubricants lost during their use are assumed to be fully combusted, and these emissions are directly reported as CO_2 emissions. There is only one known industry in Ghana operating since 1992 to produce lubricants, including engine oils, hydraulic oils, gear oils and industrial oil, under franchise for distribution by the OMCs. The main raw materials (base oils and additives) are imported. Production activities are mainly blending of the materials to meet the required standard.

Production data was available from the company; however, in calculating emissions estimates, it was assumed that all motor oil produced by the company in a particular year is consumed in that same year. The trend depicted in Figure 41 shows a general increase in CO_2 emissions. The fluctuating levels recorded from 2004 resulted from a reduction in the oil marketing companies (which could mean an increase in import quantities) and power outages. As of 2019, 0.0021 $MtCO_2e$ was emitted.

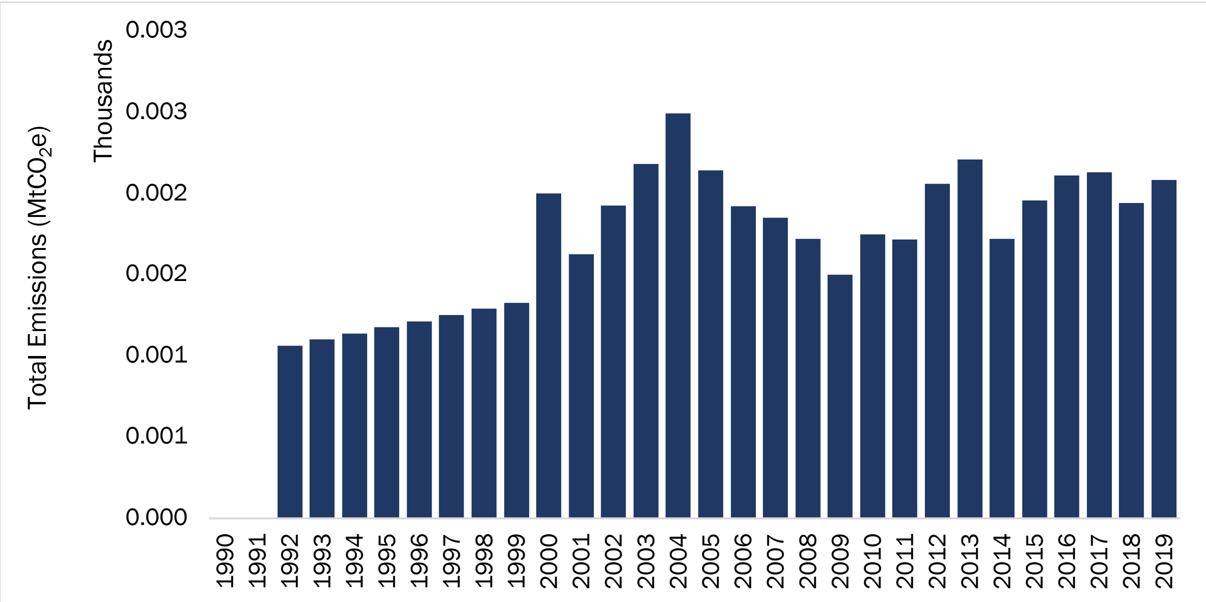


Figure 41: Total emissions from lubricant use from 1990 to 2019

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

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. Hydrofluorocarbons and perfluorocarbons serve as alternatives to ozone-depleting substances (ODS) being phased out under the Montreal Protocol. Until the inception of the Kigali Amendment to the Montreal Protocol, HFCs and PFCs were not controlled by the Montreal Protocol because they did not contribute to the depletion of the stratospheric ozone layer. However, HFCs and PFCs have high global warming potentials and are potent greenhouse gases; in the case of PFCs, they have long atmospheric residence times. Emissions have been estimated from imports of HFCs into the country for use in the refrigeration and mobile air-conditioning sectors.

HFC-32, HFC-125, HFC-134a and HFC-143a are the gases used for refrigeration and stationary air conditioning subcategory, whilst HFC-143a was used in mobile air-conditioning. Emissions have been estimated from 2005 to 2019. As of 2019, a total of 0.59 $MtCO_2e$ was emitted from the Product Uses as Substitutes for Ozone Depleting Substances category. Of the total 2019 emissions, 84.9% came from refrigeration and stationary air conditioning, whilst 15.1% was from mobile air-conditioning categories (Figure 41). The products used as substitutes for ozone-depleting substances grew from 0.04 $MtCO_2e$ in 2005 to 0.59 $MtCO_2e$ in 2019, representing 13.8% (Figure 17).

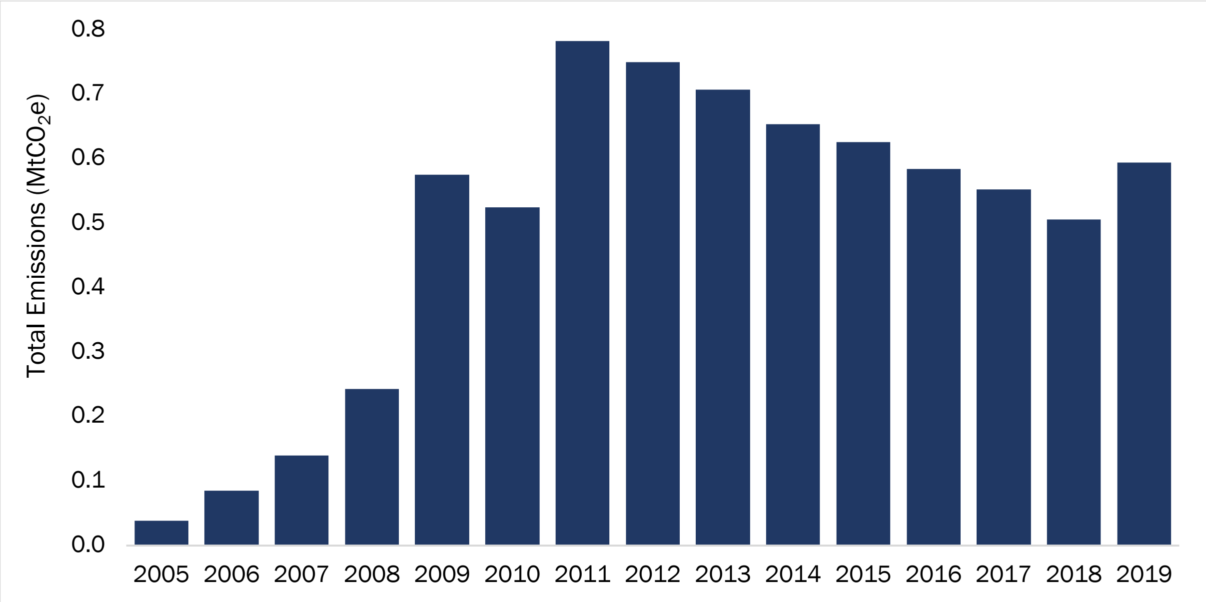


Figure 41:Total emissions from product use as a substitute for ODS

Products used as substitutes for ozone-depleting substances include HFC-32, HFC-125, HFC-134a and HFC- 143a gases emitted under the refrigeration and stationary air condition subcategory. The MAC sector, however, only uses HFC-134a gas. The refrigeration and air conditioning GHG emissions share was 0.5 $MtCO_2e$ for 2019, representing 84.9%. Of the total emissions, the MAC sector accounted for 15.1% in 2019 (Figure 42).

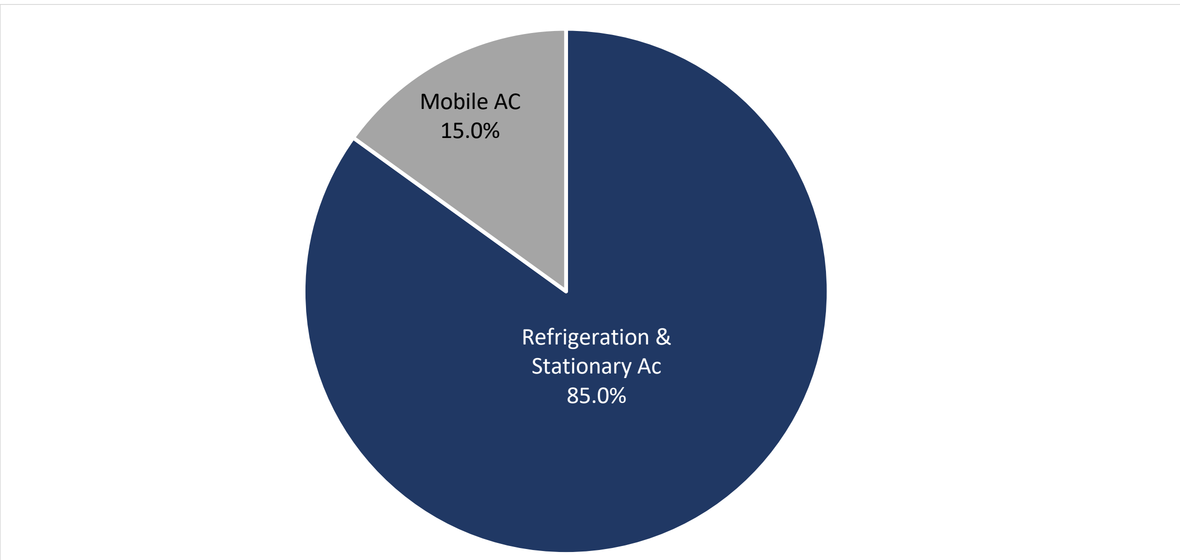


Figure 42: Share of emissions by subcategory under ozone-depleting substances for 2019

4.5.7.1 Refrigeration and Air Conditioning (2F1)

The refrigeration and air-conditioning subcategory includes various equipment types that have used CFCs or HCFCs. End-uses within this subcategory include motor vehicle air-conditioning, retail food refrigeration, refrigerated transport (e.g., ship holds, truck trailers, railway freight cars), household refrigeration, residential and small commercial air-conditioning and heat pumps, chillers (large comfort cooling), cold storage facilities, and industrial process refrigeration (e.g. systems used in food processing, chemical, petrochemical, pharmaceutical, oil and gas, and metallurgical industries).

These HFCs are emitted to the atmosphere during equipment manufacture and operation (as a result of component failure, leaks, and purges) and servicing and disposal. Following the sustained rural electrification programme in Ghana, which has brought power to a large proportion of rural communities and resulted in increasing urbanisation and improved standard of living, the distribution of domestic refrigerators and freezers in the country is very high. These factors contributed to the fast growth of the domestic refrigeration sector containing HFC equipment. Ghana is also implementing a national green cooling plan under which the Government is overseeing the phase-out of hydrochlorofluorocarbons in the refrigeration and air-conditioning industry.

Comfort air conditioning in offices and other indoor workplaces and residential homes has become a standard feature of a modern lifestyle in the country. With increasing estate development, stationary air conditioning has become a fast-growing sub-sector. The sector is dominated by unitary air conditioners, of which the single split has the largest market share. It is presumably because of their ease of installation and relatively low cost. The multi-split system, variable refrigerant volume (VRV) (aka variable refrigerant flow, VRF), has become popular for complex office applications, especially due to its higher energy efficiency. In Ghana, refrigeration and air conditioning appliances use HFCs (HFC-32, HFC-125, HFC-134a and HFC-143a). Emissions have been estimated for these gases from 2005 to 2019 (Figure 43).

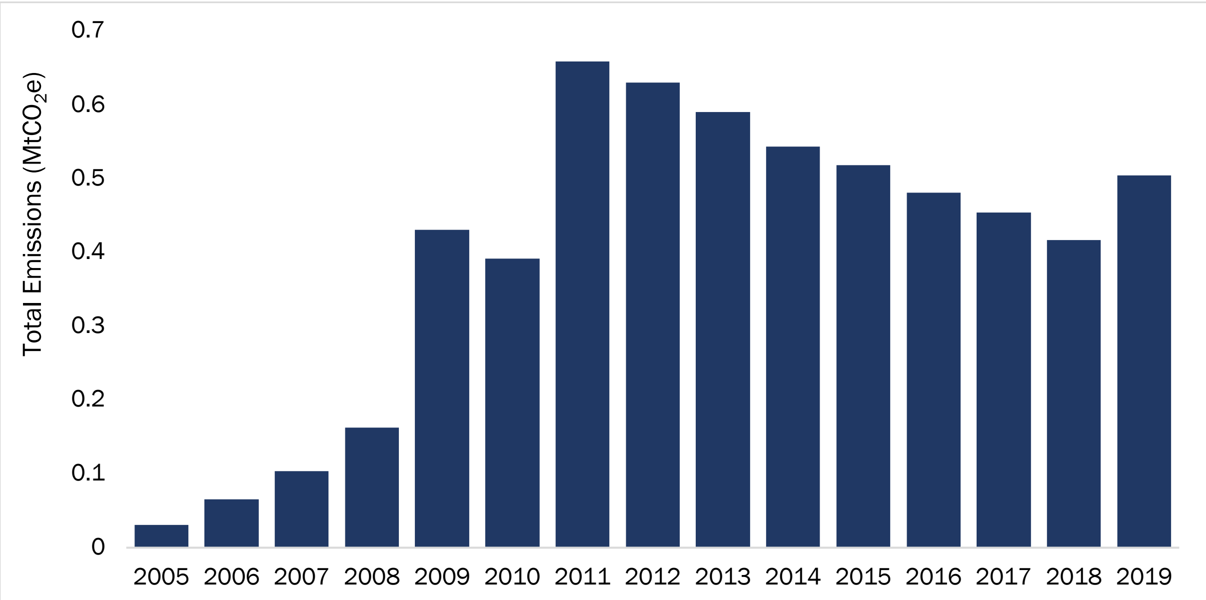


Figure 43: emissions in refrigeration and air-condition subcategory for 1990-2019

Generally, emissions gradually increased for this subcategory from 2005 to 2011 and decreased thereafter for HFC-125, HFC-134a and HFC-143a until 2016. The increase has been due to increases in import of the HFC containing equipment and refrigerants for charging or recharging, increase in power availability and phase-down of HCFC containing equipment under the Montreal Protocol phase down activities. The decreases have been due to the conversion of HFC based ACs to hydrocarbon-based air conditioners in 2012, and the phase has necessitated down schedules of HCFCs under the Montreal protocol. It also related to the high imports of HFCs based refrigerants equipment and gas stocks that were not completely utilised from 2012, and these served as stocks in subsequent years whilst imports and consumption reduced. In 2016, under the refrigeration and AC subcategory, 0.033 $MtCO_2e$ of emissions was from HFC-32, 0.229 $MtCO_2e$ emissions from HFC-125, 0.13 $MtCO_2e$ emissions from HFC-134a and HFC-143a emitted 0.113 $MtCO_2e$ (Figure 45).

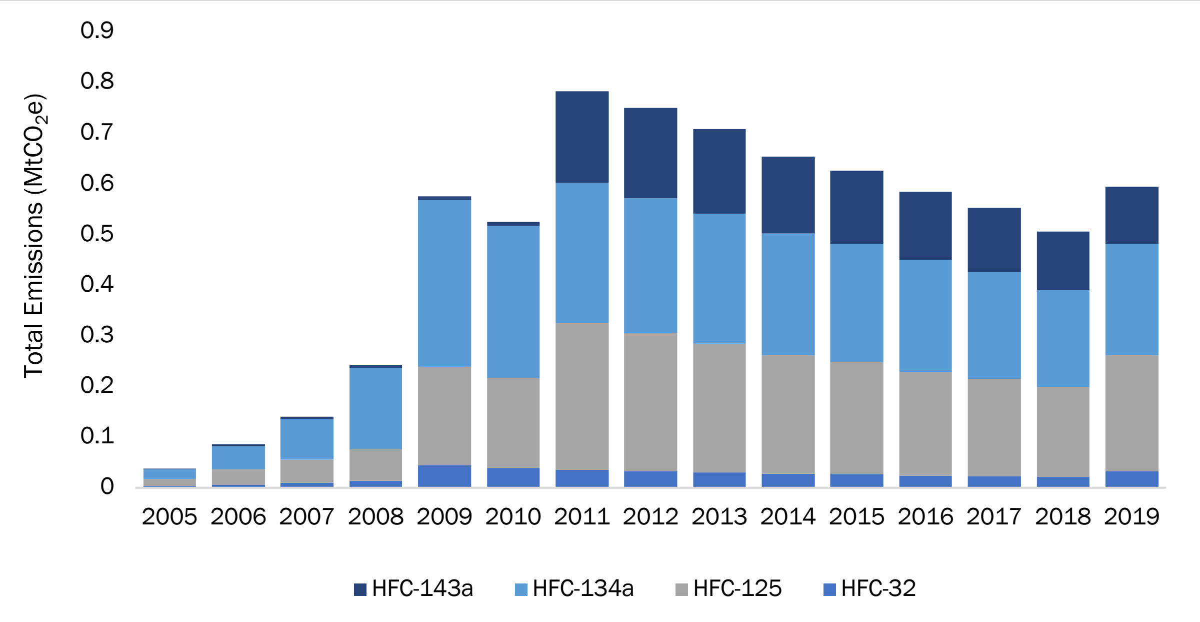


Figure 44:Trend by gases of emissions under refrigeration and stationery AC

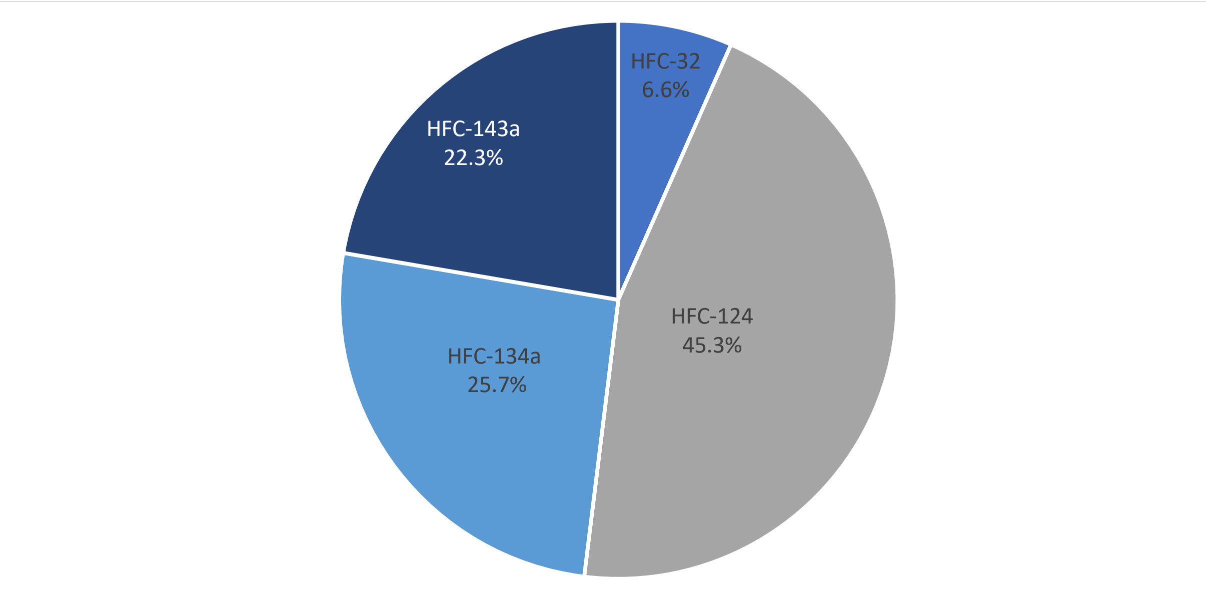


Figure 45: Share of emissions by subcategory under refrigeration and stationery AC for 2019

3.7.2 Mobile Air Conditioning (2F2)

The Mobile Air-Conditioning (MAC) subcategory includes a wide variety of equipment types that have historically used CFCs, HCFCs or HFCs. End-uses within this category include motor vehicle air-conditioning refrigerated transport (e.g., ship holds, truck trailers, railway freight cars). In Ghana, most of the emissions are from motor vehicles. Transport refrigeration is not actively used and is very limited in operation. The MAC sector is rapidly expanding, driven by improving standard of living and rapidly increasing vehicle population. The dominant refrigerant in the mobile air-conditioning sector is R134a. Servicing of MAC units was carried out by private workshops operated by refrigeration service technicians, where R134a refrigerants are used for top-ups. Data were available for emission estimations for 2005-2019 (Figure 46). As of 2019, a total of 0.09 $MtCO_2e$ of HFC-134 was emitted from the mobile AC subcategory.

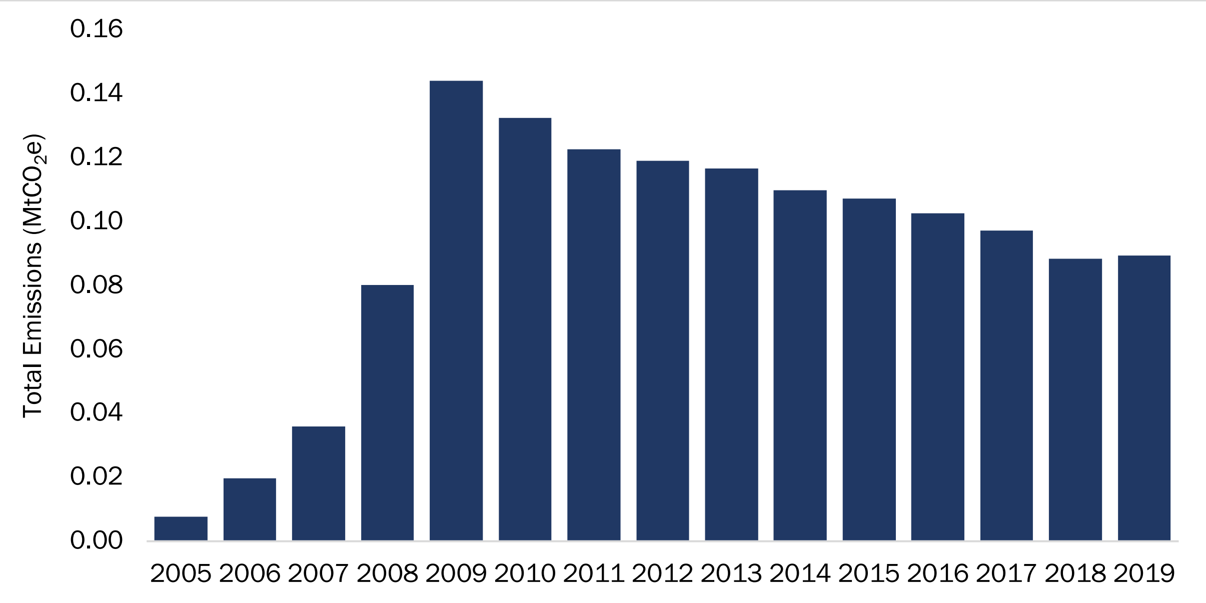


Figure 46: Total emissions from Mobile AC (134a) from 1990 to 2019

4.6 Key categories and recalculations in the IPPU sector

4.6.1 Key categories in the IPPU sector

The IPPU sector recorded two key categories for the level and trend analysis. HFC emission from Refrigeration and Air Conditioning was part of the level and trend KCA. PFC emissions from Aluminum production made it to the trend assessment key category list. The methodology and results of the key category analysis in the IPPU sector are presented in Table 68.

Table 68: Result of the key category analysis of the IPPU sector

IPCC Category code	IPCC Category	Greenhouse gas	Key Source Assessment (2019 Level Assessment – LA)	Key Source Assessment Trend Assessment (TA) (2016-2019)
2.F.1	Refrigeration and Air Conditioning	HFC	LA	TA
2.C.3	Aluminium production	PFC	-	TA

4.6. 2 Description of recalculation in the IPPU sector

Recalculation was done for CO_2 PFC emissions for both Lubricant use from 1992 to 2012 and Aluminum production from 1990 to 2016. Generally, activity data for both sub-categories were updated due to new datasets' availability and corrected errors from the emission estimation and the company. New datasets were received from one industry on steel production from 2010 to 2012.

4.7 QA/QC Protocols Observed in IPPU Sector

The QA/QC procedures followed in the IPPU sector are detailed in Table 69.

Table 69: QA/QC procedures implemented in the IPPU sector

Data Type	QA/QC procedure	Remarks/Comment/Examples
Activity data check	Check for transcription, typographical errors and error transposition.	Division of tasks among the inventory team ensures that one or two team members always focus on double-checking and avoid data errors associated with those described in the left column.
	Consistency checks of categories and sub-categories with totals	Ensuring that disaggregated figures at the category and sub-categories levels add 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
	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 used were kept and 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: easy understanding and further probing of how the final results in the IPCC software would be like, easy cross-referencing and avoidance of mistakes, easy transmission into the IPCC software and aid in better interpretation of the implication of the use of the data.
Calculation by the approved 2006 IPCC software	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 mistakes and blunders in data entry into the software.
	Checked completeness of data coverage	Ensuring all the relevant gases for the specific activity were covered.
	Check of recalculation differences	To identify and pinpoint changes, revisions and reallocation to improve the accuracy and transparency of the estimates
Results (emissions)	Identify and fix outliers in the results	checking for dips and spikes in trends and levels
	Assumptions, corrections, data and sources.	Ensure consistency and transparency, facilitate repeatability and easy retrieval
Documentation	Improvement list (internal and external findings)	Help prioritize areas that require action.

4.8 IPPU sector planned improvements

Significant improvements in the IPPU sector are needed in short to the medium term. The improvements are in areas such as:

- Collecting additional data to improve completeness.
- Improvements in methodology for estimation.
- Further processing of aggregated data.
- Collect additional data on emission factors. Details of the planned improvements are provided below:

Data improvements

- Conduct an industrial survey in-country to identify all possible sources according to the IPCC Guidelines for formal and informal sources and ensure data is collected and maintained for future inventories.
- Identify, track and monitor any potential new sources that would be important for inclusion in inventories according to the IPCC Guidelines, e.g., SF_6 use in electrical equipment's
- Collect data for the Ceramics industry on carbonate used and estimate emissions for the sub-category
- Update data on ODS substitute gas, especially in the refrigeration and air-conditioning and mobile air-condition subcategories.
- Improve data completeness for lubricants use to cover imported quantities by oil marketing companies and individuals. Efforts will be made to identify the importers to collect data to improve future calculations.

Methodological improvements

- Improvement in estimates on non-energy use and feedstock to ensure internal consistency.
- Collect data reported for dolomite use by the cement industry to improve the emission estimates for the Other Carbonate use source category. In implementing improvements and integrating data from the plant, the latest guidance from the IPCC on the use of facility-level data in national inventories will be relied upon.
- Improvements in methodology to ensure the use of the tier 2 method for all years to improve emission
- Calculations for lubricant use, steel production, limestone use, refrigeration and AC, and mobile AC sub-sectors.
- Future improvements to involve evaluating and analysing data reported under all source categories would be useful to improve the emission estimates using a Tier 2 option. Particular attention will be made to ensure time-series consistency for all inventory years as required for inventory.

Agriculture, Forestry and Other Land Use Inventory




Chapter 5

5.0 AFOLU Sector

5.1 Summary of AFOLU Sector Net Emissions in 2019

The AFOLU sector involves emission sources associated with landscapes and livestock rearing. It involves agricultural and forestry activities. The AFOLU sector contributes the most to the GHG emissions in the country, with net emissions of 26.64 $MtCO_2e$. The net emissions from the sector in 2019 are 44.6% of the total emissions representing an increase of 12% from the levels reported for 2016. The LULUCF category of the AFOLU sector continues to be the main contributor of emissions to the AFOLU emissions, as was the case in the 2016 emissions. It represents 57.1% of the AFOLU emissions, whereas the aggregated sources and non-CO_2 emissions on land represent 29.4% and livestock takes up the remaining 13.5% of the AFOLU emissions (Figure 47). The livestock emissions saw a marginal reduction while the land category increased compared to the 2016 AFOLU emissions.

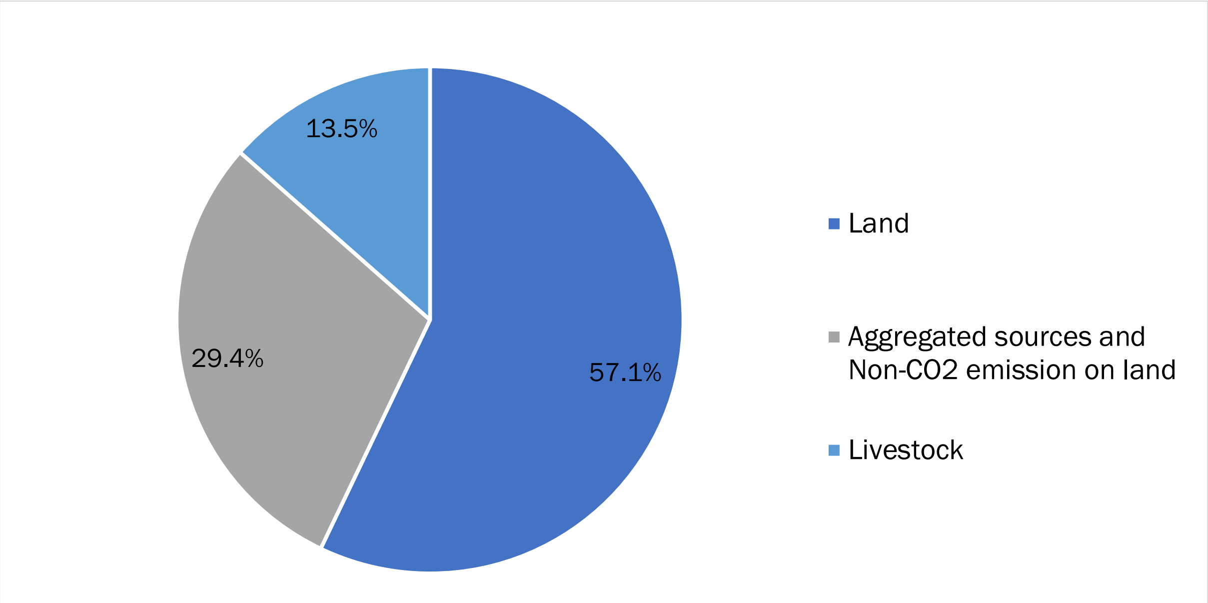


Figure 47: Share of the net GHG emissions in the AFOLU sector in 2019

Within the AFOLU inventory, a mix of tier 1 and higher tier methods was used to calculate the GHG emissions. For the LULUCF category, Ghana used country-specific and tier 3 factors and methodologies, whereas livestock and the aggregated sources and non-CO_2 emissions on land categories relied on tier 1 and IPCC defaults factors(Table 70).

Table 70: Snapshot of methods and factors used in the AFOLU sector inventory

Category code	Sources/Removals	GHG reported	Status	Method	EF
3.A.1.a.i	Dairy cows	CH_4, N_2O	NO	NA	NA
3.A.1.a.ii	Other cattle	CH_4, N_2O	E	T1	D
3.A.1.b	Buffalo	CH_4, N_2O	NO	NA	NA
3.A.1.c	Sheep	CH_4, N_2O	E	T1	D
3.A.1.d	Goats	CH_4, N_2O	E	T1	D
3.A.1.e	Camels	CH_4, N_2O	NO	NA	NA
3.A.1.f	Horses	CH_4, N_2O	E	T1	D
3.A.1.g	Mules and asses	CH_4, N_2O	E	T1	D
3.A.1.h	Swine	CH_4, N_2O	E	T1	D
3.B.1	Forest land	CO_2	E	T3	CS
3.B.2	Cropland	CO_2	E	T3	CS
3.B.3	Grassland	CO_2	E	TE	CS
3.B.4	Wetlands	CO_2	E	T3	CS
3.B.5	Settlements	CO_2	E	T3	CS
3.B.6	Other Land	CO_2	E	T3	CS
3.C.1	Emissions from biomass burning	CH_4, N_2O	E	T1	D
3.C.2	Liming	CO_2	NE	T1	D
3.C.3	Urea application	CO_2	E	T1	D
3.C.4	Direct N_2O emissions from managed soils	N_2O	E	T1	D
3.C.5	Indirect N_2O emissions from managed soils	N_2O	E	T1	D
3.C.6	Indirect N_2O emissions from manure management	N_2O	E	T1	D
3.C.7	Rice cultivation	CH_4	E	T1	D
3.D.1	Harvested Wood Products	CO_2	NE		

Notation keys: E – estimated, NE – Not Estimated, NA – Not Applicable, D – Defaults, T1 – Tier 1, CS – Country Specific, T3 – Tier 3

5.2 Overview of the Agriculture, Forestry and Other Use Sector

The relevance of agriculture, forestry, and other land use to the Ghanaian economy cannot be underestimated. The AFOLU sector supports significant rural livelihoods in Ghana. The exportation of commodities such as cocoa, cashew, pineapple, oil palm, non-timber forest products, timber, etc., depends on the sector. All the products within the AFOLU sector contribute to about 18.2% of the national gross domestic product for the country in 2020.

Greenhouse gases within the AFOLU sector in the country are driven by land-based activities through the extraction of forest and forest products, increasing livestock and agricultural productivity. Aside from exploiting these land-based resources, the means and processes of extraction of the resources influence the emissions or removals associated with the activity. The type of feed given to livestock, management strategies for manure, expansionist agriculture into new forest areas, felling of timber, and the conversion rate are typical examples of the practices that lead to emissions or removals in the AFOLU sector.

The national policies, action plans and measures, management plans for resources and activities, and technologies to enhance production efficiency exacerbate or otherwise reduce the quantum of greenhouse gas produced within the AFOLU sector. Some of the practices associated with emissions or removals in AFOLU include:

- livestock rearing and dung management
- land-use change via forest conversion,
- farming land preparation, including slash and burn
- conservation or sustainable forest management
- afforestation and reforestation
- woodfuel extraction
- wildfire disturbance
- application of nitrogen-based fertilisers
- generation and disposal of crop residue and
- rice cultivation in different ecosystems
- harvested wood products

In preparing the AFOLU inventory, the 2006 IPCC Guidelines were followed for estimating emissions/removals and, to some extent, the 2003 Good Practice Guidance. Country-specific data for both activity data and emission factors have been used as much as possible to calculate the land-based activities within the country. Default values within the IPCC guidelines were used where country-specific data were unavailable. The inventory of emission/removals is restricted to land-based activities within the national boundaries of Ghana. The inventory considers the accounting of other land-based estimations of emissions/removals at sub-national and programme levels and other domestic and international reports on land-based inventories to ensure consistency in reporting.

5.2.1 Categorisation of AFOLU activities under IPCC 2006 Guidelines

Following the 2006 IPCC Guidelines guidance, the AFOLU sector was divided into three clusters of emissions/removals. The different categories were based on whether the activity was land-based or non-land-based. Each category was further disaggregated into activities leading to emissions/removals.

The four emission/removal categories were: livestock, land, aggregated source and non-CO_2 emission sources from land and others. The categories are assigned unique codes that enhance the aggregation of the estimates of the various activities that fall under that cluster. It followed the IPCC guidelines for assigning unique codes to the sectors, categories, sub-categories and activities. With AFOLU being the third sector in the inventory sequence within the IPCC Guidelines, it is assigned in the number 3. The four different categories under the AFOLU are Livestock (3A), Land (3B) and Aggregated, Non-CO_2 Emissions Sources (3C) and Other (3D). The sub-categories and their activities derive their unique codes from three main categories under the sector. For instance, the Aggregated sources and non-CO2 emission sources from Land are assigned 3C under the IPCC Guidelines. The sub-category Biomass Burning (3C.1) means biomass burning is the first activity under the Aggregated sources and non-CO_2 emission. In essence, the total emissions/removals for 3C are achieved by aggregating the various sub-categories of activities from the bottom-up.

5.2.1.1 Livestock (3A)

Two greenhouse gases, Nitrous oxide (N_2O) and Methane (CH_4), are associated with livestock rearing. The type of animal husbandry system and the management practices adopted to influence the quantum and type of the emissions and the management practices adopted. The Livestock (3A) category of AFOLU is further disaggregated into Enteric fermentation (3. A1) and Manure management (3.A2) sub-categories.

The factors that influence emissions associated with enteric fermentation include, but are not limited to, animal feed (quantity and quality) and digestive processes (e.g. animal weight, excretion rate). Emissions from manure management estimates depend on the various livestock management systems (mainly pasture/range/paddock, dry lot, liquid/slurry etc.) and utilisation rate. The main data inputs for estimating N_2O and CH_4 emissions are animal type, population (head), average weight, age and excretion rate and the type of management of the animal dung. The data on the livestock population is mainly from the Agriculture Facts and Figures published by the Statistics Research and Information Directorate of the Ministry of Food and Agriculture.

5.1.2 Land (3B)

The emission/removals of carbon dioxide from deforestation, forest degradation, afforestation/reforestation, and sustainable forest management/conservations are dealt with under the land category (3B). The Land category is further disaggregated into six land representations, namely; Forestland (3.B1), Cropland (3.B2), Grassland (3.B3), Wetland (3.B4), Settlement (3.B5) and other lands (3.B6). A myriad of drivers determines the magnitude and direction of emissions/removals associated with the six land representations. These drivers are unique for each of the sub-category or land representations. The management practices adopted, for instance, in the cropland sub-category will determine the emission rates of the class. The manner in which manure is managed or the type of feed given to cattle will influence the linked emissions from cropland. In the same vein, the amount of wood harvesting for both timber and woodfuel coupled with the level of enhancement activities such as natural regeneration, forest plantations, enrichment planting etc., will also determine the net CO_2 emissions from the forestland.

Aside from the emissions/removals generated by the various factors within each land representation, the transitions between land representations, such as cropland becoming forestland, also led to CO_2 emissions/removals. CO_2 emissions/removals were estimated for each land representation for two main activities – (a) lands remaining the same over a given period and (b) lands converted to another land category over a given timeframe.

Net emissions/removals in the land category result from the direction and magnitude of transitions in the land classes and the internal factors within each class. Therefore, the direction of the transition can be a net removal or net emissions. The conversion of grassland with low carbon stocks to forest land with more carbon stocks leads to removals. However, there are associated emissions when forestland is converted to settlements because the settlement has fewer carbon stocks than the forestland. At any point in time, net emissions from forestland will depend on the balance of carbon stock removal and sources. The main data requirements for the category are:

- Areas of managed and unmanaged lands.
- Areas of the six land representations for each ecological zone.
- Transitions in land representations over a defined timeframe or temporal scale (land representation matrix).
- Average carbon stocks for five biomass pools in each land representation per ecological zone.
- Quantity of round wood and wood fuel extraction per year.
- Size of areas and intensity of wildfire per annum.
- Soil classification and their soil carbon stocks.

The calculation of emissions/removals for the land category used a country-specific dataset. These datasets comprise inventory conducted by the Forestry Commission in 2012 and the Forest Reference Level prepared in 2017. The Forest Preservation Project made activity data (land use maps) available for 1990, 2000 and 2010 and various emission factors. During the Forest Reference Level establishment, land use maps were also developed for 2013 and 2015. In addition, the Forestry Commission prepared a 2019 land use map to complete the time series. Notwithstanding the similarities in data sources for both the FRL and the land category, there remain some differences regarding the completeness level of the activity and the emission factors. These differences have been tabulated below in Table 71

Table 71: Relationship between LULUCF GHG inventory and REDD+ FREL

Item	Land inventory	REDD+ FREL
Activity covered	Forestland, Cropland, Grassland, Wetland, Settlement and Other lands	Forestland
Land transition pathways	Loss, Gain and Persisted for all the 6 IPCC land representation classes	Forest loss
Carbon stock enhancement	Natural forest regeneration and tree plantation. Annual biomass increment	Carbon stock enhancement through tree plantation

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

Emissions related activities not reported under 3A or 3B are covered under the Aggregated sources and non-CO_2 emission sources from Land (3C). The GHG emissions activities under 3C are subdivided into:

- Biomass burning (3C.1)
- Liming (3C.2)
- Urea application (3C.3)
- Direct N_2O emissions from managed soil (3C.4)
- Indirect N_2O emissions from managed soil (3C.5)
- Indirect N_2O emissions from manure management (3C.6) and
- Rice cultivations (3C.7).

The methane emissions associated with rice cultivation in the circumstances of the ecosystem in which the cultivation happens are considered under 3C.7. The emissions from rice cultivation differ with each ecosystem (upland rice, irrigated rice and valley-bottom rice). Because of the sporadic rice flooding regime, the valley-bottom and irrigated rice cultivation produce most of the CH_4 from rice cultivation.

Also, fires used in land preparation for the cropping season under Cropland lead to the generation of CH_4, N_2O, CO and black carbon emissions. Biomass burning on forestland produces emissions from fires accounted for under 3C. The following are the areas with applicable data for reporting for 3C in Ghana:

- Area cultivated and yield of major staple crops (plantain, cassava, maize, sorghum)
- Areas affected by fire in cropland, grassland, forestland
- Quantities of nitrogen fertiliser and urea consumption and mode of application
- Areas of rice cultivations and quantities produced per year.

The Agriculture Facts and Figures published by the Ministry of Food and Agriculture of Ghana and data from FAOSTAT are the main sources of data used to compute emissions under the category.

5.1.4 Others (3D)

Under emission/removals from Harvested Wood Products (3D.1) are reported. Ghana is unable to calculate the new GHG emissions from 3D.1 at this stage to calculate the net GHG emissions from 3D.1 due to the non-availability of national statistics. Ghana plans to use the existing IPCC tier 1 to compute the net GHG emissions from 3D.1 in the next inventory.

5.3 Methods and data sources for the AFOLU sector

Under this section of the NIR, Ghana reports on information on the overview of the data, data sources and the description of the methods applied in the inventory.

5.3.1 Data and Data sources

Data for computing GHG emissions for the AFOLU sector was gathered from several institutions in Ghana. For continuity and easy access to institutional data, memoranda of understanding has been signed between the EPA and various national agencies. Also, for data that are not available in the country, international institutions are consulted for the data. For data from national institutions and international sources, the in-country data was preferred and used to estimate, especially in situations where these two data sets were at variance for the same activity.

Different agencies collect data at varying times and for different purposes. The data collated by the inventory team comes in different formats and with different publication dates. Some of these datasets are also obtained from institutional online repositories, while for others, a special request had to be sent to the responsible agency that generates the data to remind them of the new inventory process and the need for their data as input for the estimation of the GHGs. The institutions and agencies are assured of data privacy and confidentiality, especially the private sector, so they enhance trust in providing their data. Table 72 provides an overview of the data, data source and data providers.

Table 72: Sources/Removals in the AFOLU sector, data types and data sources

Categories		Sub-categories	Data Type	Data Source	Data Providers	Remarks
3.A Livestock	3.A1	Enteric Fermentation	Animal population (cattle, goats, sheep, swine, donkey, poultry, horse	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate,	Expert judgment was used in splitting proportions of dairy and non-dairy cattle heads and Percentage allocation of the manure management practices.
	3.A2	Manure Management		FAOSTAT	FAO	
			Fractions of manure management practices	Expert Judgment	AFOLU Team	
3.B. Land	3.B1	Forestland	Land representation maps (1990, 2000, 2010, 2015 and 2019), Land representation change maps (1990-2000, 2000-2010 and 2010-2015, 2015-2019 and 1990-2019. Land representation matrix and change matrix Accuracy estimates	Forest Preservation Programme, 2012 and RMSC National Forest Reference Level, 2017	Forestry Commission of Ghana	Datasets (maps and tables, reports) are readily available at the Forestry Commission Office The land representation change maps were derived from the land representation maps for 1990, 2000, 2010, 2015 and 2019. The land representation map and change matrix are in excel format and obtained from individual land maps. Accuracy assessment was derived from the individual and change matrix.

			Biomass estimates for Above-ground biomass, Below-ground biomass, Deadwood, Litter and Soil for forestland Average biomass estimates for teak plantations Annual Biomass Growth for Natural Forest	Forest Preservation Programme, 2012 Adu-Bredu et al., 2012 2006 and 2003 IPCC	CSIR-FORIG IPCC	Biomass estimates are for natural forests (closed and open forests) and non-teak plantations. Biomass estimates for teak plantation were applied to the plantation with dominant teak plantation in both on-reserve and off-reserve areas. The above-ground net biomass growth in natural forests was changed from 4.7 tonnes d.m/ha/yr. to 1.6 tonnes d.m/ha/yr. for the first time in the current inventory. The new figure was obtained from IPCC, 2003. Annex 3A_1_Data_Tables. Table 3A.1.5. Africa >20 years. Average of Moist with the short dry season and Moist Long Dry Season (2000 > R> 1000).
			Ecological zone map	Shapefile of ecological zones	Forestry Commission and Survey Department.	The GIS layer of the ecological zone map was used to delineate and calculate the areas of 9 forest ecological zones.
			The volume of industrial round-wood production per year (1990-2016)	Resource Management Support Centre FAOSTAT	Forestry Commission UN Food and Agriculture Organisation	The majority of the data on industrial timber production was obtained from the Forestry Commission. Where there were missing data in the time series, timber production data from the FAOSTAT was used.

			Wood-fuel supply data for 1990 to 2016	Energy Statistics	Energy Commission	Dataset on woodfuel supply for the time-series was obtained from the individual Energy Statistics published from 1990 to 2016.
			Areas affected by fires that led to deforestation and forest degradation	National Forest Reference Level, 2017	Forestry Commission	The methodology to estimate areas affected by fires and intensities was based on MODIS fire products.
	3.B2	Cropland	Land representations, change maps, area and change matrix and Accuracy Estimates Delineations of cropland areas and changes over a given period.	Forest Preservation Program, 2012 National Forest Reference Level, 2017 FAOSTATS Agric Facts and Figures	Forestry Commission, Ghana FAO Ministry of Food and Agriculture	Datasets (maps and tables, reports) are readily available at the Forestry Commission Office Data on cultivated areas for 1990-2016 were obtained from FAOSTAT and Agric and Fact Figures to complement the land representation maps. Cropland areas were divided into annual and perennial crops according to different management.
			Biomass estimates for Above-ground biomass, Below-ground biomass, Deadwood, Litter and Soils for the Cropland			Biomass estimates for specific tree crops such as cocoa, citrus, rubber, oil palm, cashew and mango were average and applied. The figures were from Kongsager et al. 2013; Noumi et al. 2017 and Tom-dery et al., 2015.
			Forest ecological zone maps	Ditto as described under Forestland	Ditto as described under Forestland	Ditto as described under Forestland
	3.B3	Grassland	Land representations, change maps, area and change matrix and Accuracy estimates	Forest Preservation Programme, 2012	Forestry Commission, Ghana	Datasets (maps and tables, reports) are readily available at the Forestry Commission Office
			Biomass estimates for Above-ground biomass, Below-ground			

			biomass, Deadwood, Litter and Soils for the Grassland			
			Forest ecological zone maps	Ditto as described under Forestland	Ditto as described under Forestland	Ditto as described under Forestland
	3.B4	Wetland	Land representations, change maps, area and change matrix and Accuracy estimates	Forest Preservation Program, 2012	Forestry Commission, Ghana	Datasets (maps and tables, reports) are readily available at the Forestry Commission Office
			Forest ecological zone maps	Ditto as described under Forestland	Ditto as described under Forestland	Ditto as described under Forestland
	3.B5	Settlement	Land representations, change maps, area and change matrix and Accuracy estimates	Forest Preservation Program, 2012	Forestry Commission, Ghana	Datasets (maps and tables, reports) are readily available at the Forestry Commission Office
			Biomass estimates for Above-ground biomass, Below-ground biomass, Deadwood, Litter and Soils for the Settlement			
			Forest ecological zone maps	Ditto as described under Forestland	Ditto as described under Forestland	Ditto as described under Forestland
	3.B6	Other lands	Land use maps, Land use change map, Land use change matrix	Forest Preservation Program, 2012	Forestry Commission, Ghana	
			Forest ecological zone maps	Ditto as described under Forestland	Ditto as described under Forestland	Ditto as described under Forestland
3. C Aggregated and non-CO_2 emissions on land	3.C1	Biomass burning	Areas affected by fire in cropland, forestland and grassland	Forest Preservation Program, 2012, National Forest Reference Level, 2017	Forestry Commission	The methodology to estimate areas affected by fires and intensities was based on MODIS fire products.
			Mass fuel available for burning			The mass of fuel available was derived from the biomass estimates for each affected land representation (Forestland, cropland and grassland).

	3.C3	Urea application	Annual Urea consumption figures	Agric Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate	Data on Urea from FAOSTAT were used to fill missing data for the time series.
	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,	Data on Nitrogen-based fertiliser application from FAOSTAT were used to fill missing data for the time series
	3.C5	Indirect N_2O emissions from manage soils	Annual crop production in tonnes per annum			Data on crop production from FAOSTAT were used to fill missing data for the time series
	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,	The splitting proportions for dairy and non-dairy cattle heads were based on expert judgment.
	3.C7	Rice cultivation	Annual rice production areas	Agriculture Facts and Figures	Ministry of Food and Agriculture – Statistics Research and Information Directorate	Data on rice production from FAOSTAT were used to fill missing data for the time series. Expert judgement was used to split the proportions of rice cultivation areas under different production systems (upland rice, valley-bottom rice and rice under irrigation.

5.3.2 Description of methods used in the AFOLU sector

The inventory estimation for the AFOLU followed the guidance of the 2006 IPCC guidelines as was done for the previous report for the 2016 reporting year. The assumptions and methodological choices and also description of methods used for the estimation are provided under this section for activity data and emission factors. The specific and unique methods as per each category and sub-category of AFOLU were used as described in the 2006 IPCC guidelines. The 2006 IPCC Guidelines integrated agriculture and forestry operations into a single sector.

Following the adoption of the 2006 Guidelines, new datasets were included and revisions to the methodology for estimating emissions and removals. The 2006 IPCC Guidelines offer step-by-step guidance on the following: (a) identification of data types and the selection of methods, (b) application of selected methods and their underlying assumptions. The Guidelines also suggest estimating GHG emissions/removals and other gases using activity data and emission factors. The degree or frequency of usage or the scope of an activity that can result in the emission of gases (GHG, SLCPs, or local pollutants) or the removal of carbon dioxide from the atmosphere is referred to as activity data. In the case of the estimation of greenhouse gases for the AFOLU sector, examples of activity data included the following:

- land representation areas for different forest ecological zones and areas change over time;
- volumed of industrial wood extracted in a given period,
- annual livestock population and
- amount of fertiliser consumption per year.

After obtaining the activity data, the emission or removal factors, i.e., the factors that quantify the amount of a specific gas, such as carbon dioxide or methane, released or removed as a result of the use of or change of a specific technology or practice, or the fluctuation in the rate of usage or the number of activities in a given circumstance is needed to complete the calculations of emissions/removals. The biomass estimates for different pools (aboveground, soil, litter etc.) in different land representations under a specific forest ecological zone, the rate of nitrous oxide from combustion activity of fire or the rate of methane emission per head of livestock are examples of some emission factors under the land category. Therefore, the quantum of emissions/removals of gases depends on the products of the quantum or extent of activity data, emission/removal factors, and the global warming potential expressed in Equation 1.

$$Etj = \sum_{i,j}^{i+1n,j+1y} ADij * EFi * GWPi \qquad \text{Eq - 1}$$

Where:
I = Type of greenhouse gas
J = inventory
I+1n = n^{th} greenhouse gas
J+1y = y^{th} inventory year
AD = Activity Data,
EF = Emission Factor and
GWP = Global Warming Potential of the gas in question.
Etj = Total emission in an inventory year

Generally, using accessible country-specific data and internationally reliable data sources, a combination of tier one and higher tier approaches was used in the emission/removal computation. The employment of higher-tier methodologies was made possible by the increasing availability of country-specific activity data and emission factors.

For example, the time-series landcover maps and burnt area estimations were created in-country by national experts using multi-temporal satellite imagery. Because the dataset tended to approximate reality on the ground rather than depending on global or regional default values, higher-tier methods/algorithms and the related dataset improve the rigour and level of confidence in the estimations. The establishment of biomass factors also used field-based data collection by national experts to collect data for distinct land representations such as forestland, grassland, cropland, etc., within Ghana's various forest ecological zones.

Under the various sections to a specific category, a step-by-step description of the approaches is offered for transparency purposes. In this inventory, where country-specific activity data and emission factors were available, it was the preference. Ghana has strived to ensure data consistency as feasible during the inventory compilation process, especially when similar datasets are utilised to report to numerous international organisations or different mechanisms. Ghana, for example, provides land representation statistics to the UNFCCC (through BUR and FREL) and the FAO (via FRA and FAOSTAT) for various reporting purposes. In that situation, every effort is made to ensure that the data presented is derived from the Forestry Commission's single land cover maps.

The inventory in the AFOLU sector was based on data from 1990 to 2019. However, when incomplete/missing data was encountered, we relied on credible sub-regional and worldwide sources to fill in the gaps. In cases where there were time-series gaps, IPCC-recommended statistical methods (e.g., trends extrapolation, interpolation) were adopted to fill the data gaps. Expert judgment was used, and the underlying assumptions were documented in rare cases where data was unavailable both in-country and from international sources. Although applying expert opinion in the inventory was not frequent, the emissions/removals that resulted are likely to be highly uncertain. Expert judgment has been used to allocate the percentage share of manure management systems and the proportion of dairy and non-dairy cattle.

5.3.3 Overview of completeness of the AFOLU sector

This section highlights information on the completeness of the AFOLU sector inventory. The completeness information is presented using notation keys as a footnote in Table 73. Completeness comprises coverage of gases, categories as well as time series. Table 73 also indicates for all sub-categories whether emissions/removals were estimated. The AFOLU sector estimates are deemed complete because emissions/removals of all subcategories - 3A (Livestock), 3B (Land) and 3C (Aggregated and Non-CO_2 emission source on land) have been appropriately estimated. The overview of the completeness status of the estimations under various subcategories of the AFOLU sector is indicated in Table 73.

Table 73: Overview of sub-categories in the AFOLU sector and status of estimations

IPCC Category	Time series Completeness								Notation key per gas						
	1990-2016 (recalculations)				2017-2019 (new estimates)										
	Notation keys				Notation keys										
	E	NE	NO	IE	E	NE	NO	IE	CO_2	CH_4	N_2O	CO	PM	BC	NMVOC
3.A.1.ai Dairy Cows							*[22]		NA	NA	NA	NA	NA	NA	NA
3.A.1.aii Other Cattle					*				NA	*	NA	NA	NA	NA	NA
3.A.1b Buffalo							*		NA	NA	NA	NA	NA	NA	NA
3.A.1c Sheep					*				NA	*	NA	NA	NA	NA	NA
3.A.1d Goat					*				NA	*	NA	NA	NA	NA	NA
3.A.1e Camel							*		NA	NA	NA	NA	NA	NA	NA
1.A.1.f horses					*				NA	*	NA	NA	NA	NA	NA
1.A.1.g donkey					*				NA	*	NA	NA	NA	NA	NA
1.A.1.h swine					*				NA	*	NA	NA	NA	NA	NA
3.A.2.ai Dairy Cows							*		NA	NA	NA	NA	NA	NA	NA
3.A.2.aii Other Cattle					*				NA	*	NA	NA	NA	NA	NA
3.A.2b Buffalo							*		NA	NA	NA	NA	NA	NA	NA
3.A.2c Sheep					*				NA	*	NA	NA	NA	NA	NA
3.A.2d Goat					*				NA	*	NA	NA	NA	NA	NA
3.A.2e Camel							*		NA	NA	NA	NA	NA	NA	NA
3.A.2f horses					*				NA	*	NA	NA	NA	NA	NA
3.A.2.g donkey					*				NA	*	NA	NA	NA	NA	NA
3.A.2.h swine					*				NA	*	NA	NA	NA	NA	NA
3.A.2i Poultry					*				NA	*	NO	NA	NA	NA	NA
3.B.1a Forest land remains forest land	*				*				*	NA	NA	NA	NA	NA	NA
3.B.1b All other lands converted to forestland	*				*				*	NA	NA	NA	NA	NA	NA
3.B.2a Cropland remaining cropland	*				*				*	NA	NA	NA	NA	NA	NA

[22] Assumed that there are no typical dairy cows because milk produced in the country is from beef cattle.

3.b.2b All other lands converted to Cropland	*				*				*	NA	NA	NA	NA	NA	NA
3.B.3a Grassland remaining grassland	*				*				*	NA	NA	NA	NA	NA	NA
3.b.3b All other lands converted to grassland	*				*				*	NA	NA	NA	NA	NA	NA
3.B.4a Wetland remaining wetlands		*					*		*	NA	NA	NA	NA	NA	NA
3.b.4b Other land converted to wetlands	*				*				*	NA	NA	NA	NA	NA	NA
3.C.1a biomass burning in Forestland	*				*				*	*	*	*	*	*	*
3.C.1b biomass burning in cropland	*				*				*	*	*	*	*	*	*
3.C.1c biomass burning in grassland	*				*				*	*	*	*	*	*	*
3.C.1d biomass burning in other lands			*				*		NA	NA	NA	NA	NA	NA	NA
3.C.2 Liming		*[23]					*		NA	NA	NA	NA	NA	NA	NA
3.C.3 Urea application					*				*	*	NA	NA	NA	NA	NA
3.C.4 Direct N_2O Emissions from Managed Soils					*				NA	NA	*	NA	NA	NA	NA
3.C.5 Indirect N_2O Emissions from Managed Soils					*				NA	NA	*	NA	NA	NA	NA
3.C.6 Indirect N_2O Emissions from Manure Management and Managed Soils					*				NA	NA	*	NA	NA	NA	NA
3.C. Rice cultivations					*				NA	*	NO	NA	NA	NA	NA
3D1. Harvested Wood Products					*	*			NA	NA	NA	NA	NA	NA	NA

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

[23] Liming application is very limited. It is usually used in research or rarely in correcting poor soil. Emissions are considered to be negligible

5.4 Category-specific activity and emission factors

The AFOLU sector inventory uses data from a variety of sources. This section summarises the datasets that were used in the calculations, as well as their sources.

5.4.1 Description of data generation platform

Estimating CH_4 and N_2O emissions from enteric fermentation and manure management took the heads of various livestock and their weight per year. These livestock figures were compiled using information from Agriculture Facts & Figures from Ghana's Ministry of Food and Agriculture and FAOSTAT. The two datasets agreed to a larger extent. However, where there were variations in the livestock data, MOFA's country-specific data was used. The IPCC default emission factors were used under this category.

5.4.1.1 Livestock (3A)

5.4.1.1.1 Description of Livestock activity data

Animal population (3.A1 and 3.A2)

The total animal population in Ghana was estimated at 95,431,839 in 2019, representing an increase of 11.4% of the animal population of 2016, 85,687,752. All the different animal types recorded increases except horses, which dropped by 0.1% compared to the number in 2016. Poultry, totalling 79,391,000, makes up the larger animal population share. It constituted 83.2% of the total animal population. The remaining 16.8% (16,040,839) was livestock such as cattle, sheep, goats, horses, donkeys and pigs. Goats were the majority with a population 7,764,000 and followed by sheep (5,333,000), Cattle (2,032,000), Pigs (894,000), Donkeys (14,914) and Horses (2,925).

The total animal population is significantly influenced by the country's poultry population, as shown in Figure 48. Though the animal population is on the increase each year, the annual growth rate over the period 1990-2019 was higher (6.2%) when poultry is included compared to 1990-2019(3.4%). That notwithstanding, the per cent change in the animal population for the period 2012-2016 is higher than that of the 2016-2019 period. The animal population with poultry changed by 23.3% and 11.4% between 2012-2016 and 2016-2019, respectively. However, without poultry, the per cent changes by 21.3% and 13.8% from 2012 to 2016 and 2016-2019, respectively.

The livestock population has also grown through time, with cattle numbers increasing by 1.93 per cent per year from 1,144,787 in 1990 to 2,032,000 in 2019. The 2019 cattle population was up 11.9% from the 1,815,000 animals in 2016. This growth in the cattle population is due to many factors, including culture and policy measures. The increase in the cattle population could be due to different public and private activities to enhance animal husbandry techniques. Calves of improved breeds were provided to farmers as part of the "Heifer International Project," for example.

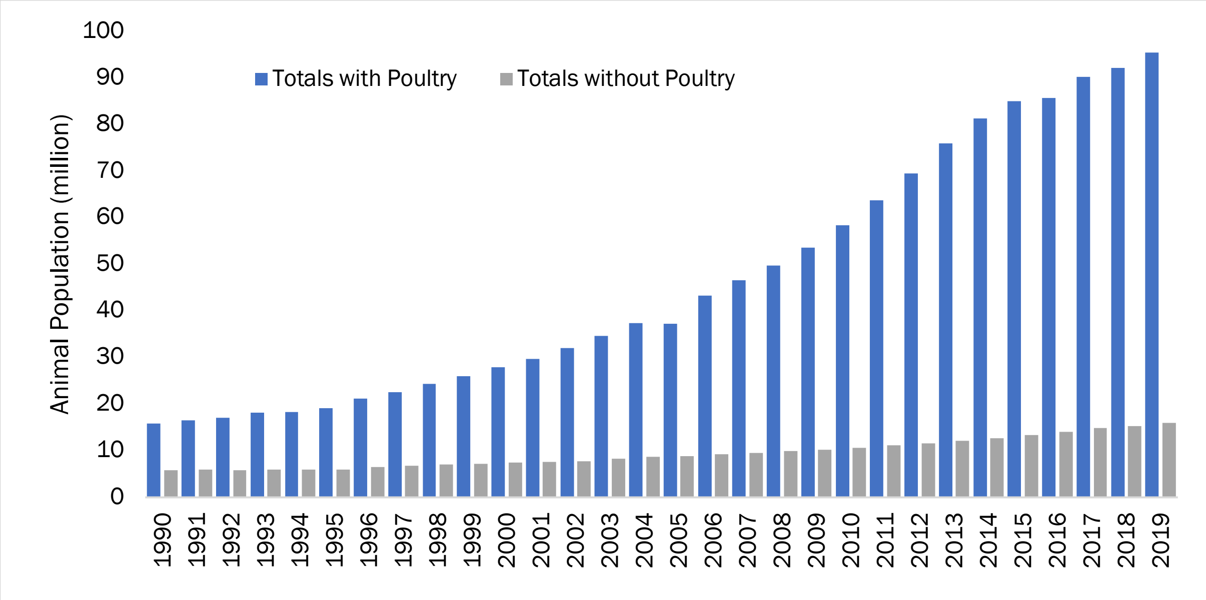


Figure 48: Trends of the animal population with and without poultry

It is also worth noting that many of Ghana's cattle are found in the northern part of the country, where they have cultural significance and are protected as social capital. The sheep population reached 5,333,000 in 2019 at a rate of 2.9% each year, representing a 12.4% increase in the sheep population between 2016 and 2019. Similarly, the goat population also saw a gradual increase at a rate of 4.6% per annum, with an increase from 2,018,027 in 1990 to 7,764,000 in 2019. The goat population in 2019 constituted a 15.2% change from the population recorded in 2016 (Table 74).

Table 74: Categorisation of the animal population for 1990-2019 in Ghana ('000)

Type/Year	Cattle	Sheep	Goats	Pigs	Horses	Donkeys	Poultry	Totals with Poultry	Totals without Poultry
1990	1,144.8	2,223.6	2,018.0	473.9	1.4	10.4	9,989.9	15,862.0	5,872.1
1991	1,194.6	2,162.3	2,194.4	453.9	1.3	12.0	10,572.5	16,591.0	6,018.6
1992	1,159.4	2,125.5	2,157.3	413.2	1.6	13.0	11,231.6	17,101.7	5,870.2
1993	1,168.6	2,225.0	2,124.5	408.1	1.6	11.8	12,169.5	18,109.3	5,939.7
1994	1,216.7	2,216.0	2,204.2	351.9	1.9	11.5	12,289.4	18,291.5	6,002.1
1995	1,344.1	2,010.1	2,155.9	365.3	2.2	12.0	13,247.3	19,137.0	5,889.7
1996	1,247.9	2,418.7	2,532.7	354.7	2.8	13.2	14,589.3	21,159.3	6,570.0
1997	1,261.6	2,496.1	2,580.5	365.3	2.8	13.5	15,888.0	22,607.7	6,719.7
1998	1,273.0	2,576.0	2,792.0	339.0	2.9	14.0	17,302.0	24,298.9	6,996.9
1999	1,288.0	2,658.0	2,931.0	332.0	3.0	14.3	18,810.0	26,036.3	7,226.3
2000	1,302.0	2,743.0	3,077.0	324.0	2.8	14.0	20,472.0	27,934.8	7,462.8
2001	1,315.0	2,771.0	3,199.0	312.0	2.7	13.5	22,032.0	29,645.2	7,613.2
2002	1,330.0	2,922.0	3,230.0	310.0	2.7	13.1	24,251.0	32,058.8	7,807.8
2003	1,344.0	3,015.0	3,560.0	303.0	3.0	13.5	26,395.0	34,633.5	8,238.5
2004	1,359.0	3,112.0	3,925.0	297.0	3.0	13.7	28,727.0	37,436.7	8,709.7
2005	1,373.0	3,211.0	3,923.0	290.0	3.0	13.7	28,386.0	37,199.7	8,813.7
2006	1,392.0	3,314.0	3,997.0	477.0	3.0	14.0	34,030.0	43,227.0	9,197.0
2007	1,407.0	3,420.0	4,196.0	491.0	3.1	14.1	37,038.0	46,569.2	9,531.2

2008	1,422.0	3,529.0	4,405.0	506.0	2.6	14.2	39,816.0	49,694.7	9,878.7
2009	1,438.0	3,642.0	4,625.0	521.0	2.6	14.2	43,320.0	53,562.8	10,242.8
2010	1,454.0	3,759.0	4,855.0	536.0	2.7	14.3	47,752.0	58,372.9	10,620.9
2011	1,498.0	3,887.0	5,137.0	568.0	2.7	14.3	52,575.0	63,682.0	11,107.0
2012	1,543.0	4,019.0	5,435.0	602.0	2.7	14.4	57,885.0	69,501.1	11,616.1
2013	1,590.0	4,156.0	5,751.0	638.0	2.9	14.4	63,732.0	75,884.3	12,152.3
2014	1,657.0	4,335.0	6,044.0	682.0	3.0	14.4	68,511.0	81,246.4	12,735.4
2015	1,734.0	4,522.0	6,352.0	730.0	3.1	14.5	71,594.0	84,949.5	13,355.5
2016	1,815.0	4,744.0	6,740.0	777.0	2.9	14.8	71,594.0	85,687.7	14,093.7
2017	1,901.0	4,978.0	7,151.0	816.0	2.9	14.8	75,363.0	90,226.7	14,863.7
2018	1,943.0	5,102.0	7,366.0	845.0	2.9	14.8	76,870.0	92,143.8	15,273.8
2019	2,032.0	5,333.0	7,764.0	894.0	2.9	14.9	79,391.0	95,431.8	16,040.8

From 1990 until 2006, the pig population decreased significantly but increased to 894,000 in 2019, with an average growth rate of 2.14%. However, between the previous reporting year and 2019, the pig population increased by 29.1%. Because it is profitable and requires little capital expenditure, the piggery business has seen rapid growth. Livestock production in Ghana is mostly done on a small-medium scale for subsistence, cultural, and commercial reasons. Horse and donkey populations are generally low compared to other livestock, despite an increase from 1990 to 2019. Horses and donkeys had 2.6% and 1.2% annual growth rates. In Ghana, horses are mostly employed for sports, cultural activities, and special official ceremonial occasions. In Ghana, the majority of horses are housed and fed in stables. On the other hand, donkeys are mostly utilised for transportation or farm labour and are allowed to roam freely.

There are two main categories of poultry management, with the majority being kept under a deep litter system and the rest falling under the free-range and semi-intensive systems. They are mainly managed on a free-range basis; therefore, the feed and manure of the animals are not properly managed, unlike cattle that are typically herded. However, many of them are housed and fed proper rations and agricultural cum household waste for pigs. Usually, the manure is managed and applied as manure in agricultural fields for those under the deep-litter system. The poultry population has since 1990 increased at a rate of 7.2% annually to peak at 79,391,000. This rate could have been higher, but for the influence of increased importation, relatively cheaper cost of imported chicken and the outbreak of Avian Influenza.

5.4.1.2 Land category (3B)

5.4.1.2.1 Description of data generation platform (National Forest Management System)

The Forestry Commission of Ghana, with the support of other stakeholders, is putting together a functional unit of the National Forest Monitoring System (NFMS) which serves as the main source of data for the Land category of the inventory. A framework document for the NFMS, the blueprint to guide its full establishment and deployment developed by the FC in 2018, is in force as a consultant has been procured to carry out the first development phase. Under the first phase, the FC leads the process of conducting capacity and technological needs assessment and formulating a concrete Capacity and Technology Plan (CTP) for the NFMS.

The priorities in the NFMS CTP will guide the mobilisation and sourcing of capacities and technology. Though the NFMS has not been completely integrated as a functional unit, almost all the components exist in isolation. The processes leading to the development of the national FREL brought together the publicly available data relevant to the land category inventory from different institutions and literature sources. New projects such as the Forest 2020 project and readily available FREL datasets at the Forestry Commission aided in acquiring the activity data and emission factors for the emission calculations for the Land category. The other operational activity under the ongoing efforts is to develop a web portal for the satellite land monitoring component of the NFMS. The details of the existing data of the NFMS relevant to the inventory process are found in Table 75.

Table 75:Existing data for the NFMS relevant for the inventory

Existing NFMS system	Institutional owners	Data Supply / Data system	Remarks/Status	Link to a specific component of NFMS
National Forestry Inventory System	Forestry Commission (Production Unit of the RMSC)	• Permanent sampling plots (PSPs) • Biomass and biomass growth dataset	• Spatial coverage of PSPs is limited to forest reserves. • Regular monitoring of biomass has ceased and is no longer useful due to the poor state of the PSPs • Data storage and format need to be clarified. • PSPs dataset does not cover all the carbon pools. • There are plans to revive and expand PSPs.	GHG Inventory Component. Indicator: Emission Factors
	Forest Services Division, FC	Forestry plantation areas, average heights, DBH, survival survey, stocking.	• Focused on on-reserve areas with planted forests across the country. • The annual publication of the National Forest Plantation Development Programme.	
Land use/cover mapping	Forestry Commission (GIS/Remote Sensing Unit of the RMSC)	• GIS layers of all forest/wildlife reserve boundaries. • Land cover maps (1990, 2000, 2010, 2012, 2015, 2019).	• GIS layers are used to produce timber yield maps and for regular updates. • GIS layers are also used to inform the development of forest management plans • Land cover maps were produced in a one-off exercise during FPP and the preparation of the FRL. • Tree crops (cocoa, rubbers, citrus, etc.) are not spatially isolated in the current land cover	GHG Inventory Component Indicator: Activity Data

			map. It has been bunched into the forest category. • Land-cover maps are not produced at regular intervals. Funding for most of them is from Projects.	
	CERSGIS	• National land-cover map (2000). • Land cover maps are prepared specifically for selected areas in the country. • Forest degradation maps for selected forest reserves (2018)	• Most land-use maps are produced on demand. • Limited in scale and focused on specific areas of interest. • Forest degradation maps show the extent of degradation but do not show the type of activity responsible for the degradation.	GHG Inventory Component Indicator: Activity Data
Other GIS Layers	Forestry Commission (GIS/Remote Sensing Unit of the RMSC)	• Fires affected areas	Fire affected areas are non-spatial format. The affected area is contained in the Annual Report on Monitoring and Evaluation of Wildfire Incidents.	GHG Inventory Component Indicator: Activity Data
	Lands Commission (Survey Department)	• National boundary Map (District boundary, River, Road Maps) • Settlement Map • Forest reserve • Ecological Layers • Land-cover classification scheme	• All the maps are produced once but are seldom updated. • District boundary maps are updated when new administrative areas are delineated. • There is no standard land-cover classification code.	GHG Inventory, Social and Environmental Safeguards Component Indicator: Activity Data, Biodiversity, Water Quality
	Soil Research Institute, CSIR	• National soil map	• The existing national soil map is at the "association classification" scale. • There are plans to update the national soil maps	Social and Environmental Safeguards Component. Indicator: Soil Quality
	Ghana Cocoa Board	• Maps of cocoa-growing areas (including age classes and CSSVD infected areas). • Shapefile of individual cocoa farms.	• Maps of cocoa-growing areas are available but not updated. • Compilation of Shapefile of individual farms is still ongoing.	GHG Inventory Component Indicator: Activity Data; productivity and yield estimates
Data Manage	The University of Energy and	• Ground station for Level TERRA, AQUA, NPP, FY3,	• Real-time active wildfires over Ghana and parts	GHG Inventory Component

ment & Registry	Natural Resource	METOP. NOAA POES, FY1, FY3, DMSP. • Ground station for COSMIC-2 Programme. • Weather Forecasting for West Africa GEONET Cast. • Receiving Station – real-time vegetative and atmospheric indexes ZY-3 Cloud Platform – High-resolution satellite land mapping services. • Carbon Flux Tower –Bia- Tano Forest Reserve (to be operational in January 2019)	of West Africa • Real-time vegetative indices across Africa • Land mapping services • Carbon fluxes over Bia Tano Forest Reserve	Indicator: Activity Data
	Forestry Commission, ICT (SIS Data)	• Depository of all REDD+ safeguard data • Interface for communicating feedback	Safeguard Information System (www.reddsis.fcghana.org) is fully operational Principles Criteria and indicators have been defined and found on the SIS website above.	Social and Environmental Safeguards Component Indicators: Resource use rights; Participation and Cultural Heritage, species diversity and richness, equitable benefit sharing, participation and involvement in decision making
	Forestry Commission, ICT and Climate Change Unit (Registry)	• Database of Emission transactions and cash flows. • Data on emission reduction at the jurisdictional scale.	Information /database system developed and shall be upgraded to a REDD+ registry (https://www.ghanaredddatahub.org	Registry Component Indicator: ERs, Non-ERs and Transactions
	Forestry Commission, Timber Validation Department	The wood tracking system is a repository of data on (Tree information Form, Log Information, yield allocation, TUCs,) etc.	The wood tracking system is operational and will be used to issue a FLEGT license to check the chain of custody of wood products.	NFMS Component: Registry Indicator: Non-ERs

	EPA	• Provide data on national GHG inventory, NDCs progress and achievement, Climate Support and emission traction registry	Fully deployed on the url: http://climatedatahubgh.com/gh/ Plan to upgrade to include tracking of actions in the Nationally Determined Contribution. http://gcr.epa.gov.gh/index.php	Registry Component Indicator: ERs and Non-ERs
	Olam farmer information system	• Enable a better understanding of the farmer community to invest appropriately and measure improvements. • Promote traceability and transparency	Fully deployed on the web address: “http://olamgroup.com/sustainability/ofis/	NFMS Component: Registry Indicator: ERs and Non-ERs
	CERGIS/ Parliament	E-mapping and monitoring system for development activities	http://ghemms.cersgis.org/map/	NFMS Component: Registry Indicator: Non-ERs
Manuals	FC, Climate Change	Using twelve Standard Operating Procedures for LULUCF Carbon Accounting	SOPs are adopted but not in operations	NFMS Component: GHG Inventory Indicator: Activity Data
		Ghana Forest Reference Level Guidance Document and Recommendation	Ghana Forest Reference Level Guidance Document and Recommendation in use.	NFMS Component: GHG Inventory Indicator: Activity Data
	FC, FSD	Manual of Procedures (MOP)	MOP for Forest Resource Management	NFMS Component: Social and Environmental Safeguards. Indicator: Biodiversity

The NFMS has been designed to have three main components: GHG Inventory (for the REDD+ accounting and the AFOLU inventory), environment and social safeguards, and the registry sub-system (Figure 49). A central data storage system and a web portal would house all the data collected from the components. The centralised storage would be updated as and when new data becomes available. The web portal would provide information on REDD+ and related activities to the public online, while key stakeholders would have access to more detailed information and data per their access rights. Depending on the specific needs, reports and regular publications shall also be generated from the centralised database system. The publications could be synced with the reporting periods of the FC and that of the BURs, BTR and NATCOMs.

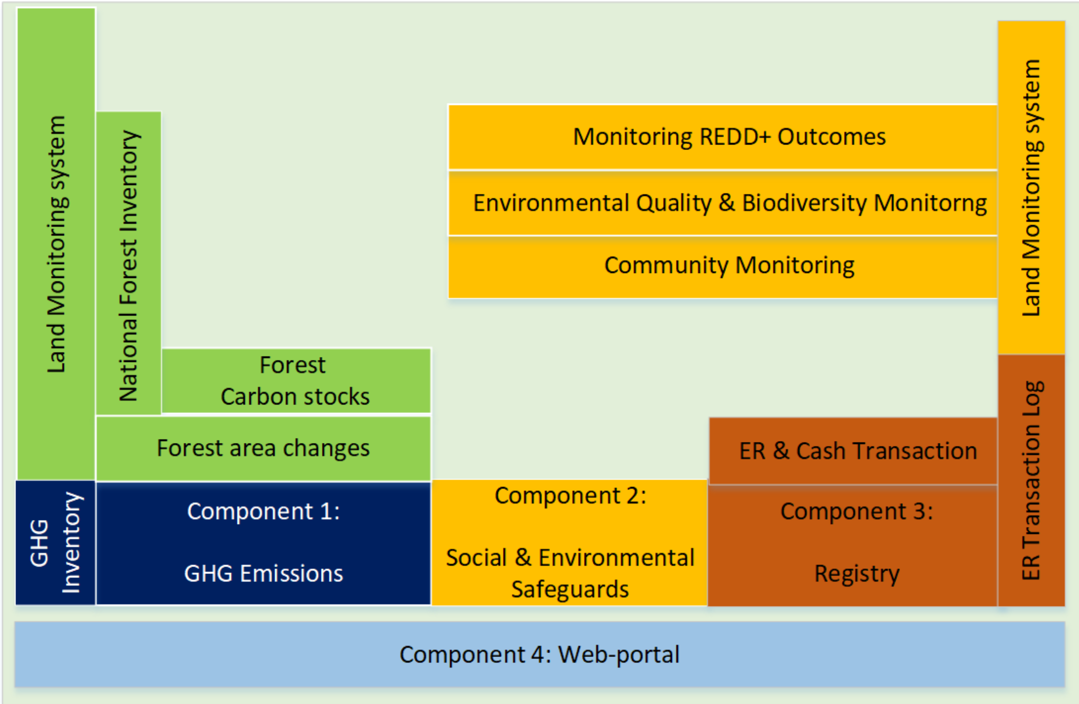


Figure 49: Proposed framework of the National Forest Management System

5.4.1.2.2 Description of Activity Data in the Land category

5.4.1.2.2.1 Land representations

Land-based human activities contributed to landscape modification and the release of greenhouse gases. According to the IPCC Guidelines, accounting for the emissions associated with land-use changes requires categorising the predominant activities. Within the Land category, the main data types are:

- six identified IPCC land categories or subcategories per ecological zone,
- areas of each identified land category or subcategory and
- transfer in the land categories or subcategories over the inventory period.

The activity dataset for the land category is derived from the processing of satellite imageries for the years 1990, 2000, 2010, 2015 and 2019. Previous projects carried out by the Forestry Commission led to the creation these land-use maps. Notable among the projects is the Forest Preservation Programme between 2010 and 2012 and the establishment of the Forest Reference level in 2016. The land representations matrix obtained from land-use maps for the periods 1990-2000, 2000-2010, 2010-2015, and 2015-2019 is found in Table 76.

The annual area changes have been estimated by dividing the total change area per time by the number of intervening years. The pre-land use refers to the state of the land category in the initial year under consideration, while the post-land use refers to the state of the land category in the final year under consideration. The changes in the land categories over the period followed five main transition pathways, namely: persisted forests, persisted non-forest, forest loss, forest gain and non-forest change.

Table 76: Land representations matrix for the periods 1990-2000, 2000-2010, 2010-2015 and 2015-2019 and the associated annual area changes

Pre-land-use type	Post-land-use type	Post-land-use areas (ha)				Annual area change (ha)			
		1990-2000	2000-2010	2010-2015	2015-2019	1990-2000	2000-2010	2010-2015	2015-2019
Closed forest	Closed forest	1,668,403.16	1,321,248.13	1,011,206.91	846,840.01	166,840.32	132,124.81	202,241.38	211710.00
Closed forest	Open forest	546,295.33	413,006.71	187,188.51	235,819.53	54,629.53	41,300.67	37,437.70	58954.88
Closed forest	Water	1,192.11	479.86	928.49	867.43	119.21	47.99	185.70	216.86
Closed forest	Grassland	79,262.44	65,578.33	26,241.52	50,010.33	7,926.24	6,557.83	5,248.30	12502.58
Closed forest	Settlement	249.92	0.09	592.41	3,856.91	24.99	0.01	118.48	964.23
Closed forest	Cropland	15,933.96	32,220.88	23,237.45	76,043.95	1,593.40	3,222.09	4,647.49	19010.99
Closed forest	Wetland	1,272.45	63.49	67.72	-	127.24	6.35	13.54	0.00
Closed forest	Other land	1,115.91	3,762.82	384.46	3,817.53	111.59	376.28	76.89	954.38
Open forest	Closed forest	848,200.15	17,821.60	-	306,821.16	84,820.01	1,782.16	-	76705.29
Open forest	Open forest	2,464,061.70	3,964,467.53	3,878,652.02	2,810,425.87	246,406.17	396,446.75	775,730.40	702606.47
Open forest	Water	1,591.46	2,531.00	46,604.51	37,810.32	159.15	253.10	9,320.90	9452.58
Open forest	Grassland	1,964,531.88	1,638,578.59	2,327,105.96	3,009,820.79	196,453.19	163,857.86	465,421.19	752455.20
Open forest	Settlement	1,759.96	3.61	39,229.95	136,783.98	176.00	0.36	7,845.99	34195.99
Open forest	Cropland	367,784.26	803,811.79	1,748,665.22	2,385,635.11	36,778.43	80,381.18	349,733.04	596408.78
Open forest	Oil palm	30,048.18	213,584.18	70,363.45		3,005	21,358	14,073	0.00
Open forest	Cocoa	808,046.75	103,337.20	120,429.35		80,805	10,334	24,086	0.00
Open forest	Rubber	781.25	13,118.26	2,362.57		78	1,312	473	0.00
Open forest	Citrus	32,051.40	26,814.05	1,735.97		3,205	2,681	347	0.00
Open forest	Mango	81.13	6,683.92	821.76		8	668	164	0.00
Open forest	Cashew	16,091.80	61,810.50	16,024.38		1,609	6,181	3,205	0.00
Open forest	Wetland	1,302.50	1,865.40	3,258.28	1.89	130.25	186.54	651.66	0.47
Open forest	Other land	7,901.89	17,821.60	31,090.08	12,625.67	790.19	1,782.16	6,218.02	3156.42
Cropland	Closed forest	106,448.90	204,574.56	94,109.47	32,553.55	10,644.89	20,457.46	18,821.89	8138.39
Cropland	Open forest	445,942.39	1,062,734.81	1,251,754.87	908,839.87	44,594.24	106,273.48	250,350.97	227209.97
Cropland	Water	1,630.78	1,279.20	80,991.81	43,556.62	163.08	127.92	16,198.36	10889.16
Cropland	Grassland	1,687,751.79	2,236,330.05	1,516,766.65	1,885,908.95	168,775.18	223,633.00	303,353.33	471477.24
Cropland	Settlement	4,132.13	0.46	84,745.46	171,501.56	413.21	0.05	16,949.09	42875.39
Cropland	Cropland	1,644,392.78	1,842,690.59	1,706,013.91	1,588,646.49	164,439.28	184,269.06	341,202.78	397161.62
Cropland	Wetland	3,491.86	2,614.76	9,133.85	1,275.78	349.19	261.48	1,826.77	318.95
Cropland	Other land	6,230.09	19,051.01	32,505.53	14,548.40	623.01	1,905.10	6,501.11	3637.10

Grassland	Closed forest	106,733.28	81,326.31	60,646.68	66,378.38	10,673.33	8,132.63	12,129.34	16594.60
Grassland	Open forest	820,826.78	872,153.05	1,879,009.09	1,612,371.01	82,082.68	87,215.31	375,801.82	403092.75
Grassland	Water	3,867.82	2,521.84	93,637.32	58,483.46	386.78	252.18	18,727.46	14620.86
Grassland	Grassland	7,876,226.73	6,075,469.98	4,253,833.53	4,726,963.48	787,622.67	607,547.00	850,766.71	1181740.87
Grassland	Settlement	4,575.47	1.48	47,519.86	148,604.74	457.55	0.15	9,503.97	37151.19
Grassland	Cropland	1,097,843.75	1,243,554.24	1,695,709.47	1,243,364.19	109,784.37	124,355.42	339,141.89	310841.05
Grassland	Wetland	7,430.66	21,126.50	5,864.10	53.16	743.07	2,112.65	1,172.82	13.29
Grassland	Other land	28,290.77	108,650.37	33,093.60	1,241.37	2,829.08	10,865.04	6,618.72	310.34
Settlement	Closed forest	2,522.50	2,511.48	13,603.32	3,135.53	252.25	251.15	2,720.66	783.88
Settlement	Open forest	13,762.32	18,767.91	174,793.89	98,176.50	1,376.23	1,876.79	34,958.78	24544.13
Settlement	Water	65.31	287.73	52,306.35	34,685.78	6.53	28.77	10,461.27	8671.44
Settlement	Grassland	64,387.62	74,916.89	204,507.47	243,935.85	6,438.76	7,491.69	40,901.49	60983.96
Settlement	Settlement	90,607.60	209,611.58	176,490.83	256,096.84	9,060.76	20,961.16	35,298.17	64024.21
Settlement	Cropland	29,398.23	45,426.37	156,791.31	129,750.80	2,939.82	4,542.64	31,358.26	32437.70
Settlement	Wetland	229.05	1,942.31	3,297.22	3,925.30	22.90	194.23	659.44	981.32
Settlement	Other land	2,658.97	1,352.87	10,483.53	1,527.90	265.90	135.29	2,096.71	381.97
Wetland	Closed forest	5,507.86	209.90	529.88	243.91	550.79	20.99	105.98	60.98
Wetland	Open forest	4,962.23	1,054.49	1,522.94	4,040.36	496.22	105.45	304.59	1010.09
Wetland	Water	333.41	592.12	5,140.05	3,739.86	33.34	59.21	1,028.01	934.97
Wetland	Grassland	16,626.41	13,226.97	20,986.67	13,986.24	1,662.64	1,322.70	4,197.33	3496.56
Wetland	Settlement	355.18	-	1,077.34	5,189.28	35.52	-	215.47	1297.32
Wetland	Cropland	2,245.50	3,743.57	4,888.34	3,603.99	224.55	374.36	977.67	901.00
Wetland	Wetland	13,403.00	5,734.92	1,861.15	737.50	1,340.30	573.49	372.23	184.38
Wetland	Other land	264.31	307.54	209.07	3,673.64	26.43	30.75	41.81	918.41
Otherland	Closed forest	6,924.07	4,819.44	70.31	15.50	692.41	481.94	14.06	3.87
Otherland	Open forest	18,447.46	12,825.12	46.90	109.75	1,844.75	1,282.51	9.38	27.44
Otherland	Water	1,034.05	514.47	-	160.12	103.40	51.45	-	40.03
Otherland	Grassland	119,483.41	71,048.85	34.41	379.70	11,948.34	7,104.88	6.88	94.92
Otherland	Settlement	141.60	-	151.34	3,409.63	14.16	-	30.27	852.41
Otherland	Cropland	8,484.23	19,177.71	170.03	129.48	848.42	1,917.77	34.01	32.37
Otherland	Wetland	1,008.14	261.63	-	-	100.81	26.16	-	0.00
Otherland	Other land	1,072.82	4,183.36	3,855.78	-	107.28	418.34	771.16	0.00
Water	Closed forest	4,165.06	3,401.70	2,162.35	136.15	416.51	340.17	432.47	34.04

Water	Open forest	4,033.98	7,697.13	10,990.37	5,018.98	403.40	769.71	2,198.07	1254.75
Water	Water	715,403.74	761,933.53	595,756.55	590,652.79	71,540.37	76,193.35	119,151.31	147663.20
Water	Grassland	13,631.78	63,373.65	21,046.43	8,265.53	1,363.18	6,337.37	4,209.29	2066.38
Water	Settlement	90.05	-	1,137.93	6,566.07	9.01	-	227.59	1641.52
Water	Cropland	3,261.55	25,026.75	6,823.31	3,882.23	326.16	2,502.67	1,364.66	970.56
Water	Wetland	4,755.13	11,371.93	1,220.35	5,783.43	475.51	1,137.19	244.07	1445.86
Water	Other land	957.85	5,989.34	518.41	1,569.88	95.78	598.93	103.68	392.47
Total		**23,854,000**	**23,854,000**	**23,854,000**	**23,854,000**	**2,385,400**	**2,385,400**	**4,770,800**	**5,963,500**

Land transitions among the six IPCC land categories over the four-time periods are presented in Table 77. This category includes: persisted forest and persisted non-forest. Persisted lands represent areas that remained unchanged over a given period. Aside from the persisted areas, the remaining lands were involved in transitions. For example, 12,490.996.33 ha representing 52% of the landscape, changed between 2015-2019, out of which 2,731,019.50 was forest gain and 5,717,273.91 was forest loss.

Table 77: Summary of areas under the different transition pathways for the four-time periods

Transition pathways	1990-2000	2000-2010	2010-2015	2015-2019
	Land change/persisted area (ha)			
Persisted forest	5,526,960.34	5,716,543.97	5,077,047.44	4,199,906.57
Forest Loss	3,330,999.26	2,992,065.56	4,459,143.53	5,717,273.91
Forest gain	1,540,276.82	2,272,075.89	3,489,240.07	2,731,019.50
Non-forest change	3,114,656.90	3,973,690.61	4,090,757.21	4,042,702.92
Persisted non- forest	10,341,106.68	8,899,623.96	6,737,811.74	7,163,097.10
Total	23,854,000.00	23,854,000.00	23,854,000.00	23,854,000.00

FL – Forest land, OL – Non-Forest land

5.4.1.2.2.2 Industrial round wood supply and fuelwood production

Biomass harvesting is the primary source of industrial round wood and fuelwood. Biomass extraction has a considerable impact on forest land carbon stores, and it is the most important dataset for measuring the variance in carbon stocks in remaining forest land. The Resource Management and Support Centre of the Forestry Commission and the Energy Commission were the primary data sources on industrial round wood and fuelwood harvesting. The industrial round wood data were segregated into “planned logging” and “unplanned logging”. Planned logging refers to the permitted systematic and supervised extraction of timber. Unplanned logging is the unsupervised removal of timber unaccounted for in official records. However, this is relevant because the resulting impact on the forest stocks is severe. The total harvested forest biomass for the year 2019 was 3,114,317.55 m^3/yr and consisted of 2,467,685 m^3/yr of industrial round wood and 646,632.33 m^3/yr of fuelwood extracted (Table 78)

Table 78: Quantities of wood harvesting for 1990-2019

Years	Harvesting (m3/yr.)						
	Logging			Fuelwood (FW)			Total harvested
	Planned logging	Unplanned logging	Total production	Total	Fraction as whole	Fraction as part	
1990	1,328,677	1,131,836	2,460,512	607,173.73	364,304.24	242,869.49	3,067,686.06
1991	1,337,488	1,139,341	2,476,829	630,298.29	378,178.98	252,119.32	3,107,127.23
1992	1,346,357	1,146,897	2,493,254	654,449.86	392,669.92	261,779.94	3,147,703.61
1993	1,355,285	1,154,502	2,509,787	679,677.49	407,806.49	271,871.00	3,189,464.97
1994	1,364,273	1,162,158	2,526,431	706,034.83	423,620.90	282,413.93	3,232,465.68
1995	1,373,320	1,169,865	2,543,185	733,580.12	440,148.07	293,432.05	3,276,764.71
1996	1,382,427	1,177,623	2,560,049	762,373.16	457,423.89	304,949.26	3,322,422.59
1997	1,391,594	1,185,432	2,577,026	792,478.31	475,486.99	316,991.32	3,369,504.42

1998	1,400,822	1,193,293	2,594,115	779,282.01	467,569.21	311,712.81	3,373,397.38
1999	1,469,853	1,252,097	2,721,950	796,428.46	477,857.08	318,571.38	3,518,378.28
2000	982,955	837,332	1,820,287	204,635.34	122,781.20	81,854.13	2,024,922.74
2001	1,245,526	1,061,004	2,306,530	222,263.10	133,357.86	88,905.24	2,528,792.91
2002	1,364,392	1,162,260	2,526,651	230,693.77	138,416.26	92,277.51	2,757,344.88
2003	1,177,482	1,003,040	2,180,523	239,124.44	143,474.66	95,649.77	2,419,647.03
2004	902,232	768,568	1,670,800	242,956.56	145,773.94	97,182.62	1,913,756.74
2005	934,886	796,384	1,731,270	248,321.53	148,992.92	99,328.61	1,979,591.72
2006	858,861	731,623	1,590,484	470,232.07	282,139.24	188,092.83	2,060,715.96
2007	878,498	748,350	1,626,848	465,250.31	279,150.19	186,100.13	2,092,098.46
2008	898,161	765,100	1,663,261	465,848.13	279,508.88	186,339.25	2,129,109.61
2009	760,953	648,219	1,409,172	474,662.01	284,797.20	189,864.80	1,883,833.86
2010	901,154	767,650	1,668,804	487,016.77	292,210.06	194,806.71	2,155,821.03
2011	816,421	695,469	1,511,890	511,971.55	307,182.93	204,788.62	2,023,861.55
2012	864,413	736,352	1,600,765	517,919.00	310,751.40	207,167.60	2,118,684.00
2013	1,012,557	862,549	1,875,106	540,206.63	324,123.98	216,082.65	2,415,312.74
2014	957,272	815,454	1,772,726	551,672.34	331,003.40	220,668.94	2,324,398.26
2015	778,226	662,933	1,441,159	549,986.20	329,991.72	219,994.48	1,991,145.46
2016	801,053	682,378	1,483,431	552,193.51	331,316.10	220,877.40	2,035,624.71
2017	1,036,546	882,984	1,919,530	598,316.93	358,990.16	239,326.77	2,517,846.54
2018	279,297	237,920	517,217	642,585.61	385,551.37	257,034.24	1,159,802.98
2019	1,332,550	1,135,135	2,467,685	646,632.33	387,979.40	258,652.93	3,114,317.55

Between 2016 and 2019 saw, a 66% change (increase) in the harvesting of round wood compared to a 7% reduction in harvesting between 2012 and 2016. In 2018, round wood extraction reduced significantly and was less than the fuelwood extraction. However, round wood harvesting increased again in 2019.

5.4.1.2.2.3 Disturbances (areas affected by fire)

In the land category, biomass consumption by fires on forest land, cropland, and grassland is a significant source of emissions. Data from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite assessed the regions impacted by fire in different ecological zones. The area burned the frequency of fire episodes, and the type and amount of available fuel load influence emissions from burned areas. The meteorological conditions at the time of combustion play a role in determining the emissions produced. From 1990 to 2019, Table 79 shows the land use types affected by annual fires in Ghana.

Table 79: Areas of forest land, cropland, and grassland burnt per annum (ha)

Year	Forest land	Cropland	Grassland	Total burn per annum.
1990	184867.74	264753.68	1042938.92	1,492,560.34
1991	221341.69	259525.56	1000515.32	1,481,382.58
1992	257815.64	254297.44	958091.73	1470204.81
1993	294289.59	249069.32	915668.13	1459027.04
1994	330763.54	243841.19	873244.54	1447849.27
1995	367237.50	238613.07	830820.94	1436671.51
1996	403711.45	233384.95	788397.34	1425493.74
1997	440185.40	228156.82	745973.75	1414315.97

1998	476659.35	222928.70	703550.15	1403138.20
1999	513133.30	217700.58	661126.55	1391960.43
2000	549607.25	212472.45	618702.96	1380782.67
2001	560163.71	205807.05	586492.76	1352463.51
2002	570720.16	199141.64	554282.55	1324144.36
2003	581276.62	192476.24	522072.35	1295825.21
2004	591833.07	185810.83	489862.15	1267506.05
2005	602389.53	179145.42	457651.94	1239186.90
2006	612945.98	172480.02	425441.74	1210867.74
2007	623502.44	165814.61	393231.54	1182548.59
2008	634058.89	159149.21	361021.34	1154229.43
2009	644615.35	152483.80	328811.13	1125910.28
2010	655171.80	145818.40	296600.93	1097591.13
2011	572122.57	140565.35	294869.31	1007557.23
2012	489073.34	135312.30	293137.69	917523.33
2013	406024.11	130059.26	291406.07	827489.44
2014	322974.88	124806.21	289674.45	737455.54
2015	239925.66	119553.17	287942.82	647421.65
2016	206098.95	97729.43	217394.42	521222.80
2017	172272.24	75905.69	146846.02	395023.95
2018	138445.53	54081.95	76297.62	268825.10
2019	104618.82	32258.21	5749.22	142626.26

The total area affected by fire declined by 72.6%, from 521,222.80 ha in 2016 to 142,626.26 ha in 2019. The reduction in the area burnt was common in forestland, cropland and grassland, but the rate differed across the inventory years.

5.4.1.2.3 Description of Emissions Factors in the Land category

Emission factors for the land category are obtained from the Forestry Commission, Forestry Research Institute of Ghana and international sources, especially from the IPCC 2006 guidelines. Under the Forest Preservation Programme by the Forestry Commission, biomass stock data was generated in different land-use types and different pools. The data included carbon stocks for the five main biomass pools (above-ground biomass, dead wood, litter, herbs and soil) in Ghana's ten different ecological zones. 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 unavailable from the FPP study. Country specific teak plantation and natural forest emission factors were obtained from a study by Adu-Bredu et al. 2008 and IPCC 2003 guidelines, respectively.

Table 80: List of emission factors used in the inventory

Type of land representations	Area fraction (%)	AGB	AGB	Herb	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	124.0	263.83	NA	NA	28.00	2.80
Moist evergreen	6.32	139.0	295.74	0.50	1.06	79.50	2.60
Moist semi-deciduous (SE type)	5.95	124.0	263.83	0.20	0.43	56.00	2.40
Moist semi-deciduous (NW type)	5.37	40.0	85.11	0.70	1.49	10.90	2.20
Dry semi-deciduous (inner zone)	3.17	23.0	48.94	2.10	4.47	6.00	1.30
Dry semi-deciduous (fire zone)	4.68	15.0	31.91	0.90	1.91	NA	NA
Savannah	53.24	18.0	38.30	0.60	1.28	NA	NA
Upland evergreen	0.22	73.0	155.32	0.90	1.91	25.00	1.40
Coastal savannah	0.91	11.0	23.40	0.90	1.91	2.00	2.20
Open Forest							
Wet evergreen	0.55	30.0	63.83	NA	NA	NA	NA
Moist evergreen	1.35	40.0	85.11	0.50	1.06	10.90	2.60
Moist semi-deciduous (SE type)	1.27	35.0	74.47	1.20	2.55	56.00	2.20
Moist semi-deciduous (NW type)	1.15	17.0	36.17	1.10	2.34	13.00	2.10
Dry semi-deciduous (inner zone)	0.68	14.0	29.79	2.30	4.89	8.00	1.90
Dry semi-deciduous (fire zone)	1.00	12.0	25.53	NA	NA	3.00	1.60
Savannah	11.37	13.0	27.66	NA	NA	38.00	1.70
Upland evergreen	0.05	26.0	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	NA	NA	NA	0.60
Average forest land		**35.8**	**76.19**	**0.57**	**1.21**	**15.34**	**0.87**
Wet evergreen	3.10	21.0	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	NA	NA	NA	NA
Average cropland	**-**	**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		5.95	12.65	1.05	2.23	14.25	1.85
Average Annual aboveground biomass growth for Teak plantation		8.31 t.d.m/ha/yr.[24]					
Average annual aboveground biomass growth for natural forest		1.6 t.d.m/ha/yr.[25]					
The ratio of below-ground to aboveground for natural forest		0.37 t BG d.m/t ABG d.m[26]					
Carbon fraction		0.47[27]					
Basic wood density		0.51 t/m^3[28]					
BCEF		1.67 tonnes per biomass removal (m^3 of removals per year)[29]					
Mass of fuel forestland		132.25 t.d.m[30]					
Mass of fuel cropland		56.44 t.d.m					
Mass of fuel grassland		17.33 t.d.m					
The fraction of biomass lost in disturbances		0.002 t.d.m[31]					

24 Adu-Bredu et. al 2008
25 IPCC, 2003. Annex 3A_1_Data_Tables. Table 3A.1.5
26 IPCC 2006 (Mokany et al. 2006 R of BGB to AGB for tropical moist deciduous forest >125 t dry matter per ha
27 IPCC 2006 Guidelines Volume 4 Table 4.3
28 Based on field research conducted by Dr. Stephen Adu-Bredu of the Forestry Research Institute. The study covered nearly 100 different tree species in nine forest reserves in the nine ecological zones across the country
29 IPCC 2006 Guidelines Volume 4 Table 4.5
30 Derived by the AFOLU inventory team based on the total carbon stocks for each land use category.
31 Weight average of areas of land use categories affected by fires in all the ecological zones

5.4.1.3 Aggregated sources and non-CO_2 emission sources on Land (3C)

5.4.1.3.1 Nitrogen-based fertiliser and Urea application

Applying nitrogen-based artificial fertilisers in cultivated fields produces direct and indirect N_2O emissions. The emission estimates are based on statistics on the quantities of nitrogen-based fertilisers and urea used in the country over a specific time. All fertilisers are assumed to be used in the year they were imported in estimating the emissions for that year. Due to surpluses or deficits from the previous year's stock, actual consumption per imported year may be less or more than what was imported. Furthermore, the method of fertilizer application would have an impact on emissions (broadcasting, ring or dip). The emissions are calculated using data on total nitrogen-based fertiliser and urea used in agricultural fields in a particular year.

The Nitrogen-based fertilisers include NPK, Sulphate of Ammonia and Nitrate fertilisers (calcium and potassium nitrates). The N_2O emissions from fertilisers applied to soils are derived from the N-based fertiliser's calculated nitrogen fraction. The quantities of individual fertiliser types applied vary from year to year. Generally, nitrogen-based fertilisers and urea quantities increased from 1990 to 2019. Between 2016 and 2019, the total fertiliser quantities increased by 49%, from 292,511 t/year in 2016 to 435,659t/year in 2019 (Table 81). Quantities of sulphate of Ammonia, calcium nitrate and urea increased from 2016 to 2019, and that of NPK dropped by 2% for the same period.

Table 81: Nitrogen-based fertiliser, urea and the nitrogen fraction for the period 1990-2019

Year	Nitrogen-based Fertilisers(t/yr.)				Urea (t/yr.) (E)	Total F=(D+E)	N Fraction of N-based fertilisers G= N_{frac} *F
	NPK (A)	Sulphate of Ammonia (B)	Calcium Nitrate (C)	Total N-based D= (A+B+C)			
1990	21,250	2,500	-	23,750	20,100	43,850	12,745
1991	19,375	7000	-	26,375	10,050	36,425	9,431.9
1992	17,500	11,500	-	29,000	-	29,000	17,240.2
1993	10,000	7,600	-	17,600	-	17,600	5,874.9
1994	13,040	8,500	-	21,540	-	21,540	5,341.6
1995	9.3	9,000	-	9,009	4,250	13,259	5,152.5
1996	8,700	5,320	-	14,020	950	14,970	2,823.1
1997	37,080	10,700	-	47,780	1,850	49,630	8,588
1998	21,858	13,265	-	35,123	500	35,623	6,223
1999	3,602	4,800	-	8,402	-	8,402	1,524.3
2000	14,902	23,165	-	38,067	141	38,208	7,047.6
2001	49,287	22,628	-	71,915	2,500	74,415	13,156.8
2002	800	20,047	-	20,847	-	20,847	4,229.6
2003	18,890	25,715	7.35	44,612	500	45,112	8,331.2
2004	18,223	7,688	95,312	121,223	250	121,473	19,195.4
2005	38,978	15,000	157	54,135	4,540	58,675	10,989
2006	84,907	19,090	52,601	156,598	9,072	165,670	28,885.1
2007	87,388	17,458	52,823	157,669	4,962	162,631	27,107.6
2008	18,873	4,172	64,085	87,130	13,773	100,903	19,817.2
2009	197,631	4,616	110	202,357	25,028	227,385	41,870.6

2010	30,560	12,077	236,547	279,184	11,521	290,705	48,909
2011	139,128	46,222	75,292	260,642	12,363	273,005	47,578.3
2012	230,723	83,840	267	314,830	31,950	346,780	66,214.5
2013	227,571	68,979	407	296,957	51,044	348,001	71,309.2
2014	89,332	7,551	49,319	146,202	3,864	150,066	24,331
2015	121,510	59,676	49,492	230,678	23,594	254,272	48,748.7
2016	258,290	14,417	3,450	276,158	16,353	292,511	49,592.8
2017	153,767	36,833	2,203	192,803	78,590	271,393	59,163.7
2018	224,176	10,084	90,019	324,279	42,005	366,284	79,849.9
2019	252,000	19,000	90,000	361,000	74,659	435,659	94,973.7
Change (%) (2016-2019)	-2	32	2509	31	357	49	92

Source: Ministry of Food and Agriculture, Facts and Figures (2020). The calculation of the nitrogen fraction of n-based fertilisers is based on the total N-based fertilisers.

5.4.1.3.2 Nitrogen content of crop residues (crop production)

Crop residues are one of the most significant sources of direct N_2O emissions from managed soils. The crop residues produced each year are determined by the crop type, harvested quantities, and harvesting method. As a result, crop residue nitrogen content is determined by the amount of residue available per crop type. The nitrogen content of crop residue is a percentage of the total crop residue generated in a year (above- and belowground residue yield ratios, renewal time, and nitrogen contents). The quantities of crop production per year are presented in Table 82.

Table 82: Quantities of crop production between 1990 and 2019 in kt/year

Year	Maize	Millet	Sorghum	Cassava	Cocoyam	Yam	Plantain	Total
1990	553.0	75.0	136.0	2717.0	815.0	877.0	799.0	5972.0
1991	931.5	112.4	241.4	5701.5	1296.8	2631.9	1178.3	12093.8
1992	730.6	133.3	258.8	5662.0	1202.2	2331.4	1082.0	11400.3
1993	960.9	198.1	328.3	5972.6	1235.5	2720.3	1321.5	12737.2
1994	939.9	167.8	323.9	6025.0	1147.7	1700.1	1474.7	11779.1
1995	1034.2	290.0	360.1	6611.4	1383.2	2125.7	1637.5	13442.1
1996	1007.6	193.3	353.4	7111.2	1551.8	2274.8	1823.4	14315.5
1997	996.0	143.5	332.6	6999.5	1529.8	2407.9	1818.4	14227.7
1998	1015.0	162.3	355.4	7171.5	1576.7	2702.9	1912.6	14896.4
1999	1014.5	159.8	302.0	7845.4	1707.4	3249.0	2046.2	16324.3
2000	1012.7	169.4	279.8	8106.8	1625.1	3362.9	1932.5	16489.2
2001	938.0	134.4	279.7	8965.8	1687.5	3546.7	2073.8	17625.9
2002	1400.0	159.1	316.1	9731.0	1860.0	3900.0	2278.8	19645.0
2003	1289.0	176.0	337.7	10239.3	1804.7	3812.8	2328.6	19988.1
2004	1157.6	143.8	287.4	9738.2	1715.9	3892.3	2380.8	19316.0
2005	1171.4	154.6	299.0	9567.2	1685.8	3922.8	2791.6	19592.4
2006	1188.8	165.0	315.0	9638.0	1660.0	4288.0	2900.0	20154.8
2007	1219.6	113.0	154.8	10217.9	1690.1	4376.0	3233.7	21005.1
2008	1470.1	193.8	331.0	11351.1	1688.3	4894.9	3337.7	23266.9
2009	1619.6	245.5	350.6	12230.6	1504.0	5777.9	3562.5	25290.7
2010	1871.7	219.0	324.0	13504.1	1354.8	5960.5	3537.7	26771.8

2011	1683.0	183.0	287.0	14240.0	1299.0	5855.0	3619.0	27166.0
2012	1950.0	180.0	280.0	14547.0	1270.0	6639.0	3556.0	28422.0
2013	1764.0	155.0	257.0	15990.0	1261.0	7075.0	3675.0	30177.0
2014	1769.0	155.0	259.0	16524.0	1299.0	7119.0	3828.0	30953.0
2015	1692.0	157.0	263.0	17213.0	1301.0	7296.0	3952.0	31874.0
2016	1722.0	159.0	230.0	17798.0	1344.0	7440.0	4000.0	32693.0
2017	2011.0	163.0	278.0	19008.0	1387.0	8253.0	4279.0	35379.0
2018	2306.0	182.0	316.0	20846.0	1461.0	7789.0	4688.0	37588.0
2019	2852.0	230.0	347.0	22750.0	1551.0	8754.0	5479.0	41963.0
Change (2016 2019)	66%	45%	51%	28%	15%	18%	37%	28%

Source: MOFA, 2018

Crop production in Ghana has significantly increased from 1990 to 2019. The production growth gradually increased year after year, translating into a 603% increase in total crop production between 1990 and 2019. Between 2016 and 2019, cereals (maize, millet and sorghum) increased significantly by 66%, 45% and 51%, respectively. The trend of increase is also seen for the roots and tubers, although the change is not as high as that of the cereals. Plantain recorded the highest change for the roots and tubers with a 37% increase. It is reasonable to assume that the rise in overall crop yield was accompanied by an increase in apparent above and below ground residue. However, after accounting for the effects of the quantity of residues burned, collected, or grazed, the available residues can be determined as a possible source of soil nitrogen.

5.4.1.3.3 Rice Cultivation

Under different growing ecosystems, methane emissions associated with rice production vary based on the soil environment's level of flooding and the agricultural practices used in the production process. The aerobic conditions created by intermittent inundation of the rice fields under the bottom-lands (low-land) rice production ecosystem has a higher potential of producing more methane. However, methane emissions in rice production in upland rice systems or under irrigation are highly influenced by the slope and the dwell time of the available water to the rice. As a result, the fraction of total rice cultivated areas under rainfed, irrigated, and upland and the prevailing management approaches determine the potential for methane emissions from rice production. Data on annual rice cultivation areas and percentage areas under various systems were gathered from the MOFA's Agric Fact and expert judgment. Generally, there was an increase in rice cultivation areas from 88,300 ha in 1990 to 321,215 ha in 2019 (Table 83). For years, rice cultivated under low land areas formed the majority, followed by rice grown under irrigation and upland rice.

Table 83: Rice Cultivation areas (Ha) from 1990 to 2019

Year	Irrigated	Rainfed	Upland	Total
1990	14,128	68,874	5,298	88,300
1991	15,184	74,022	5,694	94,900
1992	12,752	62,166	4,782	79,700
1993	12,352	60,216	4,632	77,200
1994	12,944	63,102	4,854	80,900

1995	15,984	77,922	5,994	99,900
1996	16,848	82,134	6,318	105,300
1997	18,832	91,806	7,062	117,700
1998	20,864	101,712	7,824	130,400
1999	16,848	82,134	6,318	105,300
2000	14,976	73,008	5,616	93,600
2001	14,080	68,640	5,280	88,000
2002	19,648	95,784	7,368	122,800
2003	18,864	91,962	7,074	117,900
2004	19,104	93,132	7,164	119,400
2005	19,200	93,600	7,200	120,000
2006	20,000	97,500	7,500	125,000
2007	17,424	84,942	6,534	108,900
2008	21,248	103,584	7,968	132,800
2009	25,984	126,672	9,744	162,400
2010	28,960	141,180	10,860	181,000
2011	31,597	154,034	11,849	197,480
2012	30,325	147,833	11,372	189,529
2013	34,545	168,406	12,954	215,905
2014	35,840	174,720	13,440	224,000
2015	37,323	181,951	13,996	233,270
2016	39,017	190,209	14,631	243,858
2017	41,111	200,417	15,417	256,945
2018	43,596	212,531	16,349	272,476
2019	51,394	250,548	19,273	321,215

The IPCC 2006 Guidelines factors used in the calculation of the rice emissions are as below:

- Cultivation period = 120 days
- Baseline emission factor for continuously flooded fields without organic amendments = 1.3 (kg CH_4/ (ha day))
- Scaling factor to account for the differences in water regime during cultivation period = (Irrigated = 0.6, Rain-fed = 2.8)
- Scaling factor to account for the differences in water regime in the pre-season before the cultivation period = (Irrigated = 0.68, Rain-fed = 1)
- Scaling factor for both types and amount of organic amendment applied = (Irrigated = 1, Rainfed = 1, Upland =1)
- Scaling factor for soil type, rice cultivar etc, if available = (Irrigated = 1, Rain-fed = 1)
- Adjusted daily emission factor for each harvested area (kg CH_4/ (ha Day)) = (Irrigated = 0.53, Rain-fed= 0.36) from 2006 IPCC Guidelines.

5.5 Identification of AFOLU sector key categories

The KCA identified significant sources of emissions from the AFOLU sector using both the level and trend approach. Ten key categories were identified for the level and trend approach. Of the 10 KCA, five were in the land category, one in livestock, and four fell within the aggregate source and non-CO_2 emissions category. In terms of the gases, key categories were dominated by CO_2 emissions, followed by N_2O and CH_4 in that order of frequency. The methodology and results of the key category analysis in the AFOLU sector are in Table 84.

Table 84: Results and methods for estimating AFOLU sector key category analysis

IPCC Category	Gas	Level Assessment (2019)	Trend Assessment (2016-2019)
3.B.2.b - Land converted to cropland	CO_2	x	x
3.B.3.b - Land Converted to Grassland	CO_2	x	x
3.C.4 - Direct N_2O Emissions from managed soils	N_2O	x	x
3.B.1.a - Forest land Remaining Forest land (net sink)	CO_2	x	x
3.A.1 - Enteric Fermentation	CH_4	x	x
3.C.5 - Indirect N_2O Emissions from managed soils	N_2O	x	
3.B.1.b - Land Converted to Forest land (net sink)	CO_2	x	x
3.C.1 - Emissions from biomass burning	CH_4		x
3.C.1 - Emissions from biomass burning	N_2O	x	x
3.B.5.b - Land Converted to Settlements	CO_2	x	x

Under the land category, the 2019 level assessment produced the following key categories for CO_2: 'land converted to cropland', 'land converted to grassland", 'forest land remaining forest land', and 'land converted to the forest' land conversions to cropland and grassland were the major contributors under the land category, which are the key drivers of deforestation in Ghana. On the other hand, the consistent implementation of the government strategy on forest and national park management has contributed to preserving the forest lands. The continuous implementation of the National Forest Plantation development has aided the reforestation of degraded forests to improve total carbon sinks. In addition, traditional practices, including sacred groove protection, have been instrumental in maintaining forest patches outside reserved areas. These initiatives helped to boost the forest sink capacity.

5.6 Time series consistency in the AFOLU sector

5.6.1 AFOLU section recalculations

The AFOLU section recalculations covered the period 1990-2016 due to new activity and emission factors and the adoption of new methods. The changes in both activity data and emission factors were a result of:

- adoption of a new methodology for generating activity data and emission factors
- revisions of published data from the agricultural facts and figures
- use of new logging data
- revision of the land representation areas and the changes in them.

Additional information on the reasons and impacts of the recalculations has been provided under each sub-category. Table 85 shows the assessment results of recalculations and their impacts on the emissions.

Table 85: Impacts of recalculations on the previous GHG estimates

Year	Net CO_2			CH_4			N_2O		
	PE (Mt)	LE (Mt)	Change	PE ($MtCO_2e$)	LE ($MtCO_2e$)	Change	PE ($MtCO_2e$)	LE ($MtCO_2e$)	Change
1990	14.02	14.31	2.1%	2.59	2.02	-21.8%	3.49	2.64	-24.3%
1991	14.07	14.64	4.1%	2.62	2.09	-20.2%	3.8	3.03	-20.2%
1992	14.13	14.70	4.0%	2.54	2.04	-19.8%	3.72	3.08	-17.3%
1993	14.18	14.75	4.0%	2.53	2.05	-18.8%	3.77	3.07	-18.7%
1994	14.24	14.80	3.9%	2.55	2.11	-17.4%	3.87	3.12	-19.3%
1995	14.3	14.86	3.9%	2.6	2.20	-15.3%	4.01	3.29	-18.0%
1996	14.36	14.92	3.9%	2.6	2.24	-13.9%	4.12	3.41	-17.2%
1997	14.43	14.99	3.9%	2.61	2.28	-12.5%	4.16	3.49	-16.2%
1998	14.43	14.98	3.8%	2.63	2.35	-10.7%	4.22	3.57	-15.4%
1999	14.59	15.14	3.8%	2.62	2.37	-9.7%	4.31	3.68	-14.6%
2000	12.74	13.31	4.5%	2.61	2.40	-8.1%	4.4	3.80	-13.6%
2001	13.31	13.86	4.1%	2.61	2.42	-7.1%	4.56	3.98	-12.8%
2002	13.53	14.08	4.1%	2.64	2.50	-5.3%	4.65	4.08	-12.2%
2003	13.17	13.72	4.2%	2.66	2.56	-3.6%	4.78	4.24	-11.3%
2004	12.63	13.18	4.4%	2.7	2.64	-2.3%	4.02	3.54	-12.0%
2005	12.71	13.26	4.3%	2.69	2.66	-1.0%	4.8	4.33	-9.9%
2006	12.89	13.45	4.3%	2.7	2.72	0.8%	4.98	4.52	-9.2%
2007	12.93	13.48	4.2%	2.7	2.76	2.2%	5.08	4.64	-8.6%
2008	12.97	13.52	4.2%	2.74	2.84	3.7%	5.22	4.81	-7.9%
2009	12.72	13.27	4.4%	2.79	2.93	5.2%	5.5	5.10	-7.2%
2010	13.02	13.55	4.1%	2.8	3.02	7.8%	5.68	5.18	-8.8%
2011	12.89	13.42	4.1%	2.95	3.20	8.4%	5.84	5.27	-9.8%
2012	13.01	13.55	4.1%	2.96	3.26	10.1%	6.08	5.65	-7.1%
2013	13.34	13.88	4.1%	3.02	3.37	11.4%	6.33	5.91	-6.7%
2014	13.2	13.76	4.2%	3.09	3.50	13.3%	6.18	5.86	-5.1%
2015	12.86	13.43	4.4%	3.18	3.65	14.7%	6.51	6.31	-3.1%
2016	12.91	13.40	3.8%	3.29	3.77	14.4%	6.72	6.52	-3.0%

The recalculations led to a reduction of an average of 0.4% of the total AFOLU GHG emissions compared to the figures reported for the same period in the NIR4. The impact of recalculation on the previous estimates differed from year-to-year, ranging from -5.6% in 1990 to 3.7% in 2018. Further breakdown of the impacts of recalculation on the individual GHG revealed a different trend. For CO_2 emissions, the recalculation has led to a net average increase of 4%. It ranges from the least of 2.1% in 1990 to the maximum of 4.5% in 2000. The recalculation produced lower CH_4 and N_2O emissions than the figures previously reported in NIR4. The average methane levels marginally decreased by 3.5%, with the highest change of -21.8% recorded in 1990 and 0.8% in 2006. Between 2016 and 2019, recalculation led to more methane emissions from 13.3% to 14.7%. A similar decrease for N_2O emissions also occurred due to the recalculation, with the highest change of -24.3% recorded in 1990.

5.6.1.1 Reasons for recalculations in the AFOLU sector

The revisions and adoption of new methods have led to changes in emissions/removals (Table 86). The recalculations resulted in the revisions of the previous activity data and emission factors between 1990 and 2016 due to the inclusion of a new dataset, application of new methodologies and correction of errors. Table 86 summarises the reasons for the recalculations.

Table 86: Description of reasons for recalculations

GHG	Data in category	Reasons
CH_4 and N_2O	Changes in the grasslands area affected by fires.	The annual average of -82% decrease in the grassland areas affected by fire between 1990-2016. The satellite-based technique and MODIS were used to derive grassland areas affected by fire for the same period instead of the expert judgement used for the previous estimates.
	Changes in the cropland affected by fires.	The annual average of -69% decrease in the grassland areas affected by fire between 1990-2016 The use of satellite-based techniques and MODIS to derive croplands affected fire for the same period instead of the expert judgement used for the previous estimates
	Changes in the forestland affected by fires.	The annual average of -80% decrease in the grassland areas affected by fire between 1990-2016. The use of satellite-based technique and MODIS to derive croplands affected fire for the same period instead of the expert judgement used for the previous estimates
Carbon Dioxide	Land representations	Changes and updates in the method for deriving activity data using remote sensing and a field-based approach. Revisions resulted in changes to the land-use change matrix for 1990-2000 and 2000-2010. Inclusion of new plantation areas and further categorisation into the teak and non-teak species. Revision of industrial round wood and fuelwood harvest data in forest lands.

5.6.2 Filling of data gaps in the AFOLU sector

The applicable IPCC splicing methodology for filling gaps was used in the AFOLU inventory, where gaps existed in the time series. The IPCC splicing methodology used to fill a specific gap depended on the type of gaps and the proven relationship with other proxy datasets. Generally, extrapolation and interpolation techniques were used to fill the data gaps to ensure time-series consistency. Table 87 presents the categories with data gaps and the methods applied.

Table 87: Data gaps and the method used to fill them

Category	Data Gap	Method applied	Justification for the methodology used	Description of approach for filling gaps
Land (3B.1-3B. 6)	Absence of data on annual areas and changes in land representations for the years 1991-1999, 2001-2009, 2016-2018	Interpolation and extrapolation	Inter-decadal data for 1990, 2000, 2010 and 2019 and half decade data were available. Annual data on area changes in different land uses are required for the intervening years in each decade and half-decade.	We assumed an equal interval for each decade and a half-decade for each year. The annual land area figures were derived by dividing the matrix per decade by the number of years.
			The interpolation technique made it possible to calculate the	The first two decades were divided by ten years, while the last half-decade was

			annual land-use matrix. Extrapolation was then used to generate data for 2016, 2017 and 2018.	divided by five years. The 2016-2018 matrix was interpolated using the 2015 and 2019 land-use matrix.
Emissions from biomass burning (3 C1)	Missing interannual data on areas affected by fires.	Interpolation and extrapolation	Inter-decadal data on areas affected by fire existed for 1990, 2000, 2010 and 2015.	Emissions from biomass burning (3 C1)

5.7 Quality Control/Quality Assurance Protocol for the AFOLU Sector

The QA/QC procedures followed in the AFOLU sector are detailed in Table 88.

Table 88: QA/QC procedures implemented in the AFOLU sector

Data Type	QA/QC procedure	Remarks
Activity data check	Check for transcription, typographical errors and error transposition.	Division of tasks among the inventory team ensures that one or two team members always focus on double-checking and avoid data errors associated with those described in the left column.
	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 FRL and Ghana Statistical services.
	Consistency checks of categories and subcategories with totals	Ensuring that disaggregated figures at the category and subcategories levels add 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 used were kept and 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	One thousand two hundred 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 as a measure of potential errors of commission or omission.
Emission factors	Ensure representativeness of field biomass sampling in the various land cover representations.	Ensure the sampling design adequately covered representative land classes in each ecological zone. Samples were taken at optimal intensity covering five biomasses consistent with the IPCC Guidelines.

	Reduce potential errors resulting from sampling biomass and integrity of the 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 mistakes and blunders in the data entered 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 the accuracy and transparency of the estimates
	Identify and fix outliers in the results	Check for dips and spikes in trends and levels
Documentation	Assumptions, corrections, data and sources.	Ensure consistency and transparency, facilitate repeatability and easy retrieval
	Improvement list (internal and external findings)	Help prioritise areas that require action.

5.8 AFOLU sector emission trend analysis

The total GHG emissions for the AFOLU sector were 26.3 $MtCO_2e$ in 2019. This amount accounts for 44.2% of the national total GHG emissions. The sector had, since 1990, contributed a greater share of the total national emissions. On average, the sector contribution since 1990 is 63.7% of the national total. The 2019 AFOLU emissions of 26.3 $MtCO_2e$ is 38.6%, and 11% rise in emissions from 1990 and 2016 AFOLU emissions.

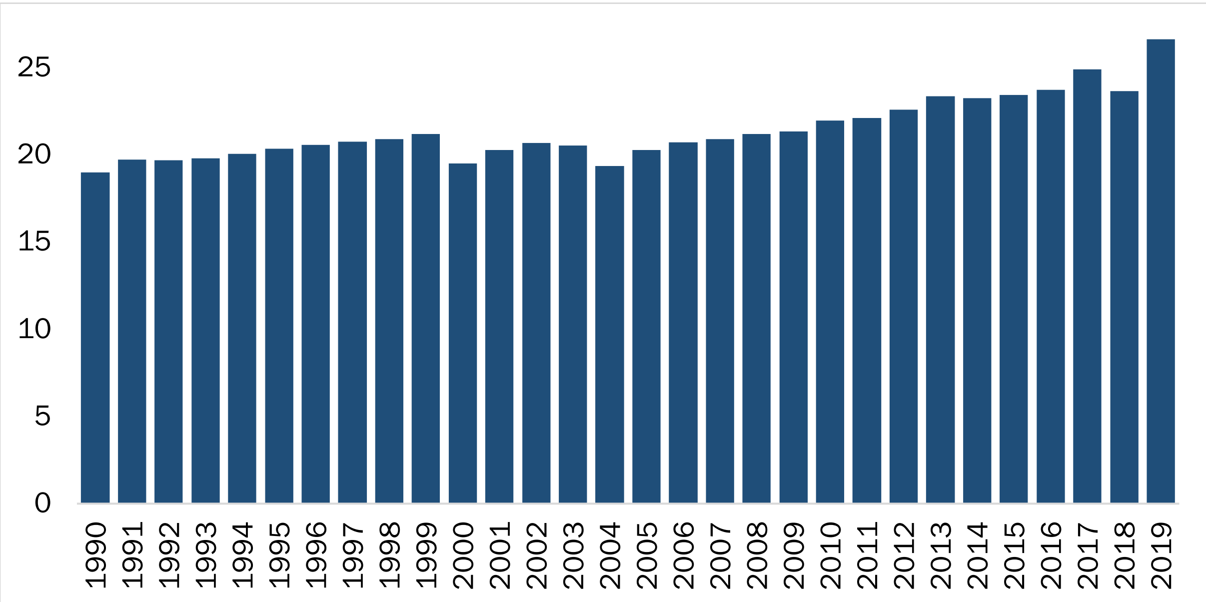


Figure 50: Trends of net total greenhouse gas emissions in the AFOLU sector

The varying emission trends correspond to changes in net CO_2 emissions from the land category, particularly from "forest remaining forest land" as well as "other lands converted to forestland" (Figure 51). Two crests were visible in the emission patterns, separated by a dip. The first crest occurred from 1995 to 1999, while the second occurred from 2013 to 2017. The dip that lapsed from 2000 to 2004 separates the two crests. There was a significant dip in 2018 before the emissions rose in 2019.

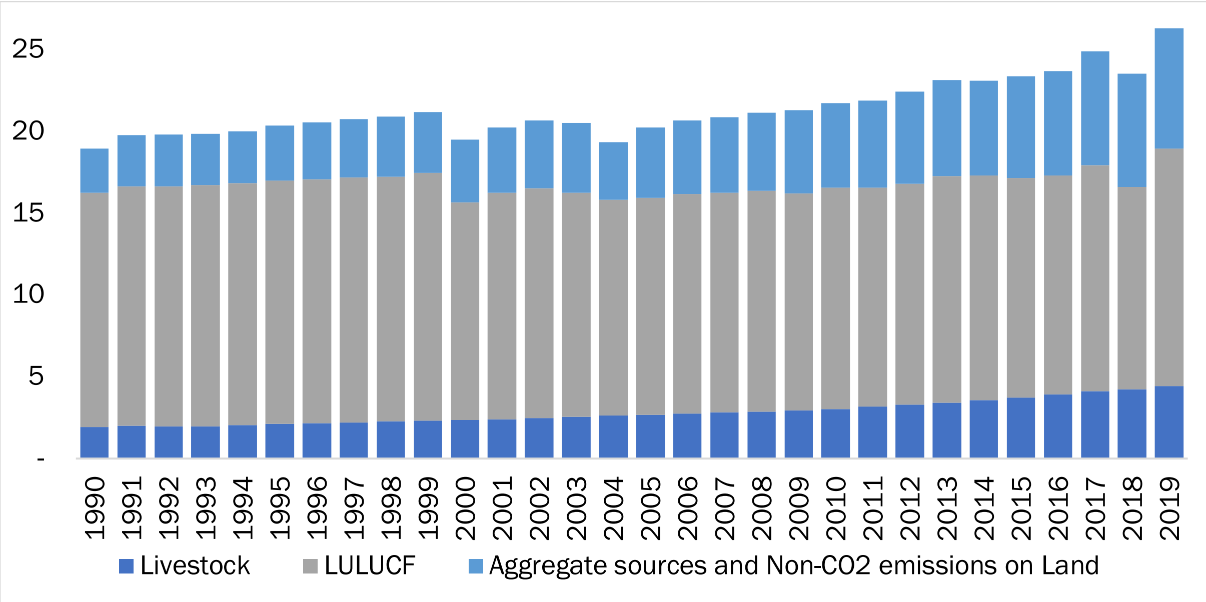


Figure 51: Total emissions trend according to sub-categories in AFOLU

The total AFOLU sector emissions for 2016 consisted of contributions from Land (3B.), Aggregated sources and non-CO_2 emissions on land (3C.) and Agriculture (3A). Net emission from the Land or LULUCF is the largest emission source. It makes up 55.2% of the 2019 net total AFOLU emissions of 26.3 $MtCO_2e$. Emissions from 3C followed with a contribution of 27.9% to the AFOLU emissions. The rest of the AFOLU emission of 16.9% comes from Livestock. The emissions from 3A went up by 13% between 2016 and 2019, whereas that of 3B and 3C changed by 8.6% and 16.5%, respectively. Similarly, 3A and 3C emissions grew more than 3B over the 1990-2019 period. While 3A and 3C emissions recorded substantial increases by 128.7% and 168.4% at 2.9% and 3.5% growth rates per annum accordingly, the increase in 3C was relatively nominal at 1.5% at a 0.1% growth rate. The results indicated that the emissions within the LULUCF category remained steady over the years.

Carbon dioxide continues to be the predominant gas in terms of its contributions to the AFOLU emissions. It makes up 55.4% of the 2019 emissions for the AFOLU, followed by Nitrous Oxide with 29.2% and methane with 15.4% contribution. The trend of per cent contributions by these gases is similar to that of the 2012 and 2016 reporting years. Carbon dioxide increased 8.8% between 2016 and 2019, whereas CH_4 and N_2O saw a rise of 7.6% and 17.7% over the same period. Between 1990 and 2019, Methane recorded an annual increase of 2.4%, with nitrous oxide recording 3.7%. However, carbon dioxide recorded a slight annual rate of 0.1% for the same period.

Table 89: AFOLU sector emissions segregated into gas types

Years	CO_2 [Mt]	CH_4 [MtCO_2e]	N_2O [MtCO_2e]	Total [MtCO_2e]
1990	14.31	2.02	2.64	18.98
1991	14.64	2.09	3.03	19.76
1992	14.70	2.04	3.08	19.81
1993	14.75	2.05	3.07	19.87
1994	14.80	2.11	3.12	20.03
1995	14.86	2.20	3.29	20.35
1996	14.92	2.24	3.41	20.57
1997	14.99	2.28	3.49	20.76
1998	14.98	2.35	3.57	20.90
1999	15.14	2.37	3.68	21.19
2000	13.31	2.40	3.80	19.51
2001	13.86	2.42	3.98	20.26
2002	14.08	2.50	4.08	20.66
2003	13.72	2.56	4.24	20.53
2004	13.18	2.64	3.54	19.36
2005	13.26	2.66	4.33	20.25
2006	13.45	2.72	4.52	20.69
2007	13.48	2.76	4.64	20.88
2008	13.52	2.84	4.81	21.17
2009	13.27	2.93	5.10	21.31
2010	13.55	3.02	5.18	21.75
2011	13.42	3.20	5.27	21.88
2012	13.55	3.26	5.65	22.46
2013	13.88	3.37	5.91	23.16
2014	13.76	3.50	5.86	23.12
2015	13.43	3.65	6.31	23.38
2016	13.40	3.77	6.52	23.68
2017	13.87	3.90	7.13	24.89
2018	12.42	3.97	7.14	23.53
2019	14.57	4.05	7.68	26.30

Practically all net CO_2 emissions (99.9%) came from the 3B category, primarily cropland, with only a small percentage (0.07%) coming from 3C in 2019. Urea application is responsible for the relatively small quantity of CO_2 in 3C. Agriculture accounted for most methane emissions, with the livestock subcategory accounting for 82.3%. Biomass burning and rice cultivation accounted for 17.7% of CH_4 emissions. Nitrous Oxide emissions in the sector come from the 3C, specifically from biomass burning and soil emissions. Nitrous oxide emissions from 3C in 2019 were mainly contributed by "direct N_2O emissions from managed soils" (73.8%) and "indirect N_2O emission from managed soils" (18.9%) and with the remaining being emitted from biomass burning and manure management.

5.9 Description of source/removal categories

5.9.1 Summary of source-specific emission trends

5.9.1.1 Livestock (3A)

Key category (2019): CH_4 emissions - Enteric fermentation

Domestic animals such as cattle, sheep, goats, swine, horses, and donkeys (mules and asses) produce emissions through enteric fermentation and manure management. Overall, livestock emissions totalled 4.44 $MtCO_2e$ in 2019, accounting for 16.9% of total AFOLU emissions. It also contributed to 37.7% of the entire Agricultural emissions. The total livestock emissions increased by 2.3 folds over the 1990 to 2019 period. Total livestock emissions climbed from 1.94 $MtCO_2e$ in 1990 to 3.93 $MtCO_2e$ in 2016 increasing by 0.51 $MtCO_2e$ in 2019 (Figure 52). Rising animal populations and accompanying management regimes are accountable for the observed higher trends in emissions. Since 1990, annual total emissions from enteric fermentation and manure management have risen. The annual emissions from enteric fermentation, on the other hand, were larger than those from manure management.

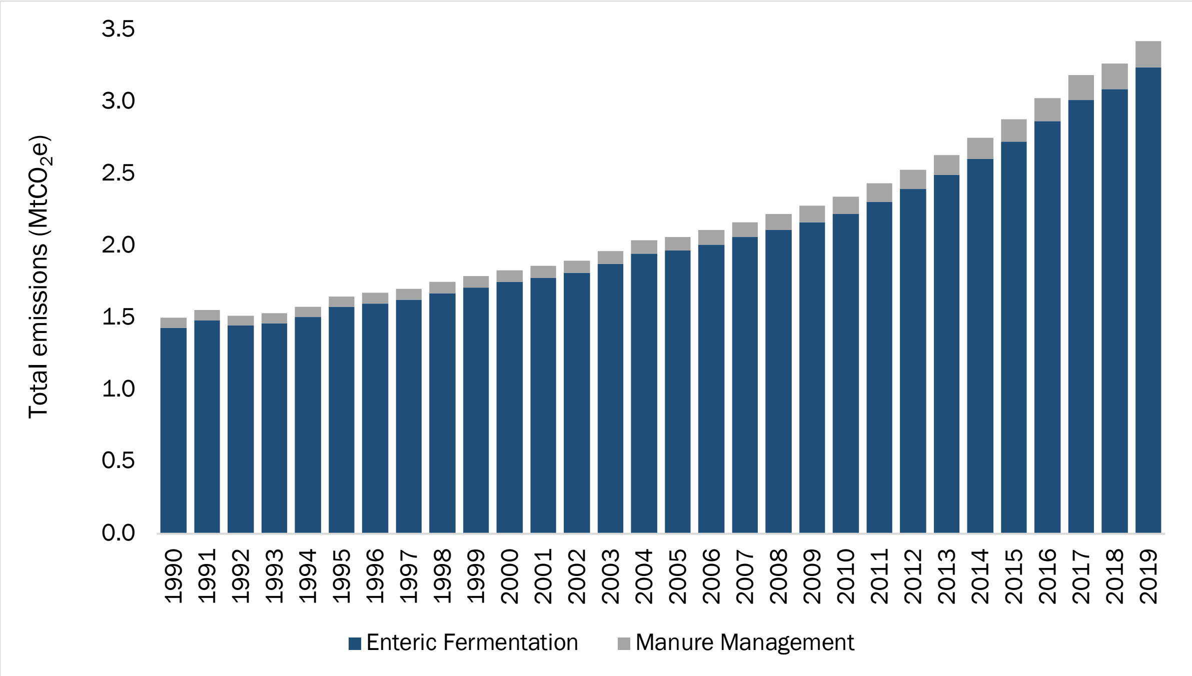


Figure 52: Greenhouse gas emission trends associated with livestock rearing

5.9.1.1.1 Enteric Fermentation (3.A1)

5.9.1.1.1.1 Source category description and results

Methane is produced by enteric fermentation in the alimentary canal of herbivores as part of their digestive processes. Methane is produced when microbes in the animal's digestive system ferment the feed taken by the animals. Methane production is influenced by the number of animals, their weight and age, and the quantity and quality of feed.

Methane production is also influenced by an animal's digestive tract type and effectiveness. Ruminant cattle produce significantly more methane than non-ruminant livestock. In 2019, enteric fermentation contributed 3.24 $MtCO_2e$ in total emissions. The figure represents 72.9% of the overall emissions from Livestock. Enteric fermentation in 2019 shows an increasing trend with a 126% increase from 1990, a 35% increase from 2012 and 13% from the last reporting period of 2016 (Figure 53).

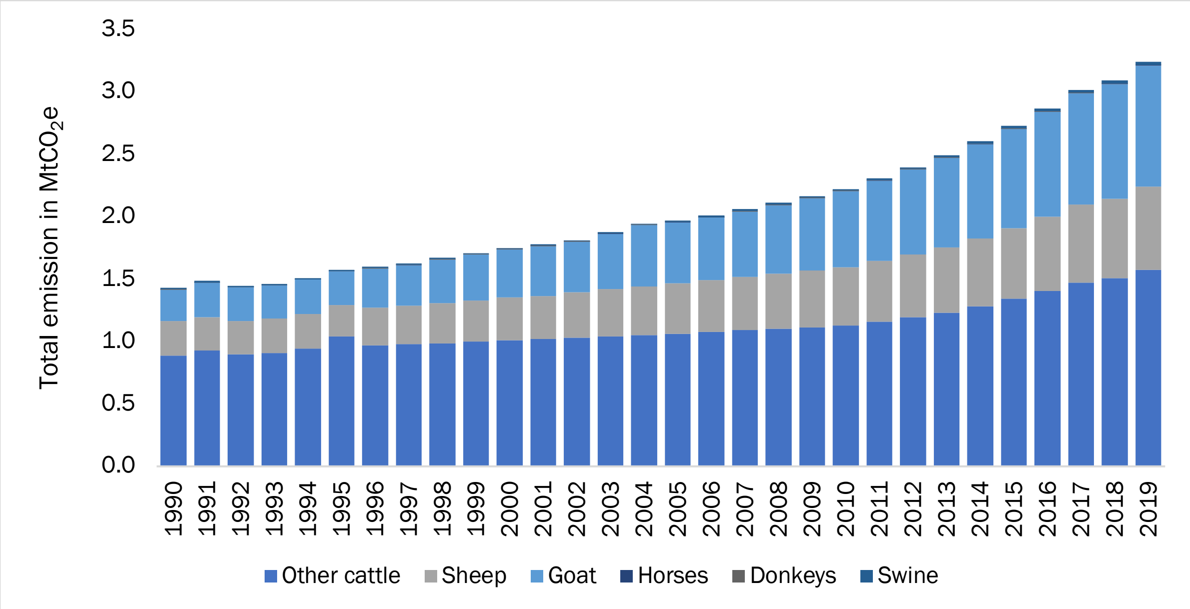


Figure 53: Total emission trends from enteric fermentation of livestock

Other cattle contributed a chunk of emissions from enteric fermentation in 2019, with 48.6% of emissions. This was followed by goats (29.9%), sheep (20.6%), swine (0.7%), donkey (0.1%) and horses (0.04%) in a declining order. Since 1990, cattle have been the main source of emissions through enteric fermentation, followed by goats, sheep, swine, donkeys and horses within the same period.

5.9.1.1.2 Methodological issues for enteric fermentation in livestock

The estimates from enteric fermentation were made using IPCC Tier 1 and default emission factors. Individual animal populations were multiplied with emission factors for the corresponding animals to estimate emissions (see IPCC default emission factors in tables 10.10 and 10.11 and Annex 10. A1 in Vol. 4 Chapter. 10). Table 90 summarises the methodology and emission factors used.

Table 90: Methodologies, reported emissions and emission factors applied

Sector code	Source	Emissions reported	Method	EF
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

The animal population data for cattle, sheep, goats, swine, and poultry came from MOFA's Statistics, Research, and Information Directorate (SRID), which publishes Agriculture Facts and Figures every year. Each year's animal population figures are presented in the data. The MOFA data was complemented with FAOSTAT statistics on horses and donkeys. The IPCC tier 1 and default emission factors were used because there were no country-specific data on the age and weight classes of the animals. Because many cattle in Ghana are not raised for milk production, the whole cow population is presumed to be other cattle. No information on the cattle population is that breastfeeding.

5.9.1.1.2 Manure management (3.A2)

Emissions in the manure management category are mainly methane and nitrous oxide from livestock management. Manure management systems included in this inventory were: paddock and pasture, slurry dry lot and poultry with or without litter. Ghana accounts for both CH_4 and N_2O emissions from manure management for cattle, sheep and goats and CH_4 emissions for horses, donkeys, swine and poultry. Manure management accounts for 27.1% of the livestock emissions and total agricultural sector emissions

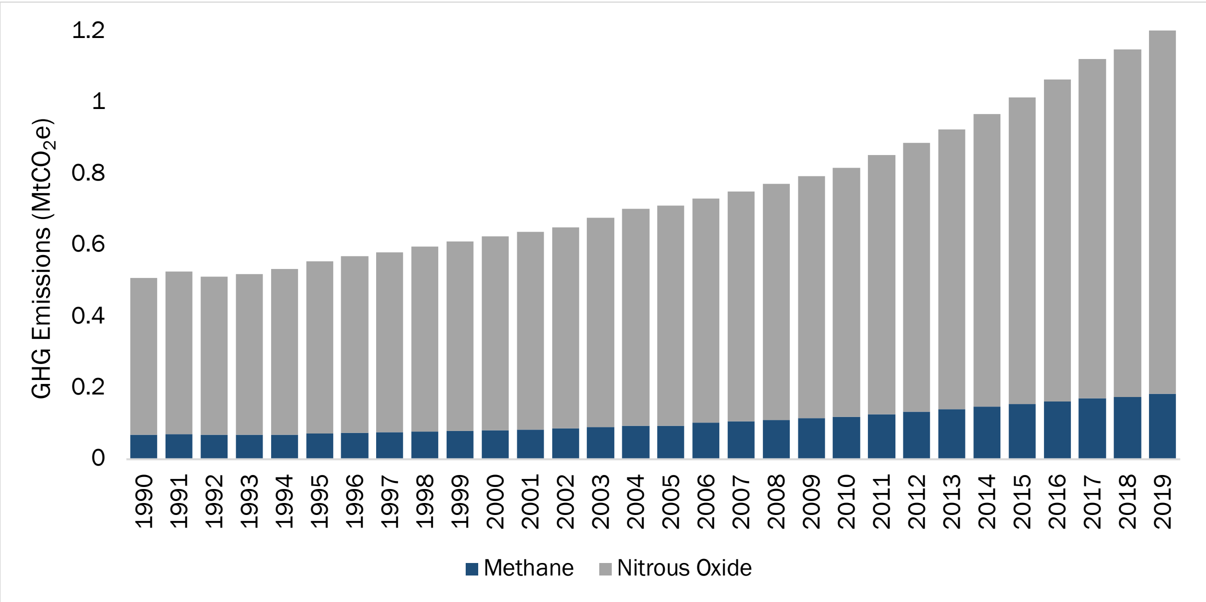


Figure 54: Trend of livestock GHG emissions between 1990 and 2019

Total emissions from manure management increased from 0.51 $MtCO_2e$ in 1990 to 1.06 $MtCO_2e$ in 2016 and further to 1.2 $MtCO_2e$ in 2019 (Figure 54). Nitrous oxide was the largest source of manure management emissions. It formed 86% of the average the total manure management GHG emissions. The remainder, 14% of the total livestock emissions, was methane. The total levels associated with manure management have increased by 136% at a 3% annual growth rate from 1990 to 2019. A similar rising trend was observed in the 2016-2019 window, growing by 13%. Both methane and nitrous gases recorded upward trends over the 29 years, with methane showing the highest growth at 3.5% per annum. While methane grew by 169% in the 1990-2016 period, nitrous oxide trends showed the same pattern at 131%. The emissions increase resulted from growing livestock populations reported from 1990 to 2019. The feeding regimes and animal waste management technologies have not seen any major changes.

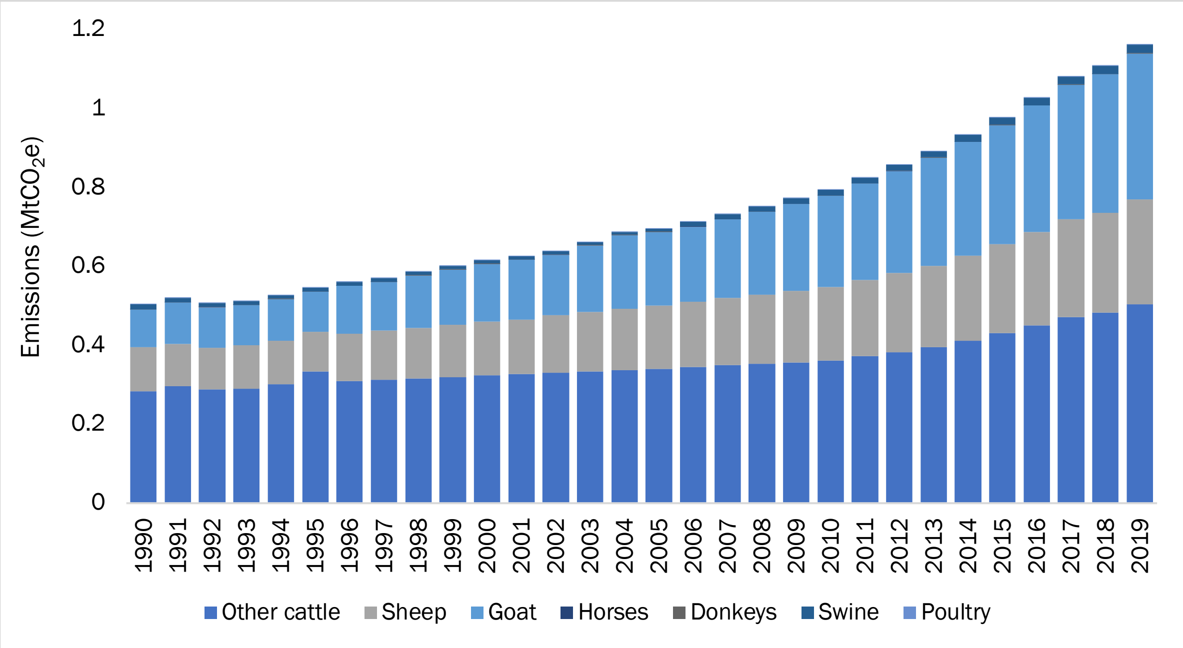


Figure 55: Greenhouse gas emissions trend for manure management for 1990-2019

Cattle, sheep and goats were the largest sources from 1990 to 2019 (Figure 55). The average contribution of emissions from cattle amounted to 49.9% of the all-manure management emission then, followed by a goat (25.9%), sheep (22.4%) and swine (1.7%). Other cattle, sheep, goats and swine produced 99% of the manure management emissions. The rest were shared among donkeys, horses and poultry.

5.9.1.1.3 Methodological issues for manure management in livestock

The IPCC default emission factors and the methodology were used to calculate emissions from manure management. The share of the individual animal waste management systems common in Ghana was estimated by expert judgment and categorised by animal type (Table 91). Data on animal population for the period 1990-2019 were obtained from the Agriculture Facts and Figures produced by the Ministry of Food and Agriculture.

Table 91: Share of Animal waste management system applied

Livestock	Manure Management systems (1990-1999)					Manure Management systems (2000-2019)				
	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%

5.9.1.2 Land Category (3B)

Key category (2019 level assessment): CO_2 emissions – Land converted to Cropland, Land Converted to Grassland, and Land converted to Forestry

Key category (2016-2019 trend assessment): CO_2 emissions – Land converted to Cropland, Forest land remaining forest land, Land converted to Grassland, Land converted to Forest land, and Land converted to Settlement

Carbon dioxide emissions can be produced and absorbed due to changes in land use and associated land cover due to anthropogenic activities. The formulation and implementation of the following policy efforts are the push or pull elements that influence land-use change:

- Unintended policy conflicts - Policies on food crop production, tree crop expansion, mineral resource extraction and conservation, forest restoration and diversification of energy from fossil to bioenergy sources.

- Adoption of landscape management practices - Surface mining, forest fire-prevention techniques, afforestation and reforestation and chemical inputs.

- Forest governance - Forest management programmes such as REDD+, Forest Investment Programme and community awareness and involvement, i.e., Community Resource Management Areas

The type of human activities, the direction of change, and the intensity (quantum of change) determine whether the land category is a net sink or source of CO_2 emissions at any particular time. The transitions within the various land categories among the IPCC classes: forestland, cropland, grassland, wetlands, settlements, and other lands are responsible for the land-use changes. The most common classifications are forestland, cropland, and grassland, which collectively account for 94 per cent of the country's land area in 2019. The settlement, water, wetlands, and other lands split the remaining 6%. Forestland made up 41.6% of the land area in 2019, followed by grassland (32.9%) and cropland (19.5%). Transitions between these classes, by extension, accounted for the majority of net CO_2 emissions.

5.9.1.2.1 Emission trends and methodological issues of the land category

5.9.1.2.1.1 Emission trends in the land category

The land emissions were 14.52 $MtCO_2$ in 2019 and constituted 25% of the total national emissions. The land emissions contributed 34.6% of the total CO_2 emissions in the country; it also amounted to 56% of the AFOLU emissions in 2019. The trend of emission from land has generally been steady from 14.3 $MtCO_2$ in 1990 and marginally increased to 14.52 $MtCO_2$ in 2019 though the intervening years had variations of increase or decrease (Figure 56). Between 1990 and 1999, emissions increased with relatively high levels, then dropped in 2000 with a sinusoidal pattern through 2018, before ramping up again in 2019. The observed emission patterns, on the surface, appear to be driven by net changes in land-use transitions, primarily between forestland, grassland, and cropland.

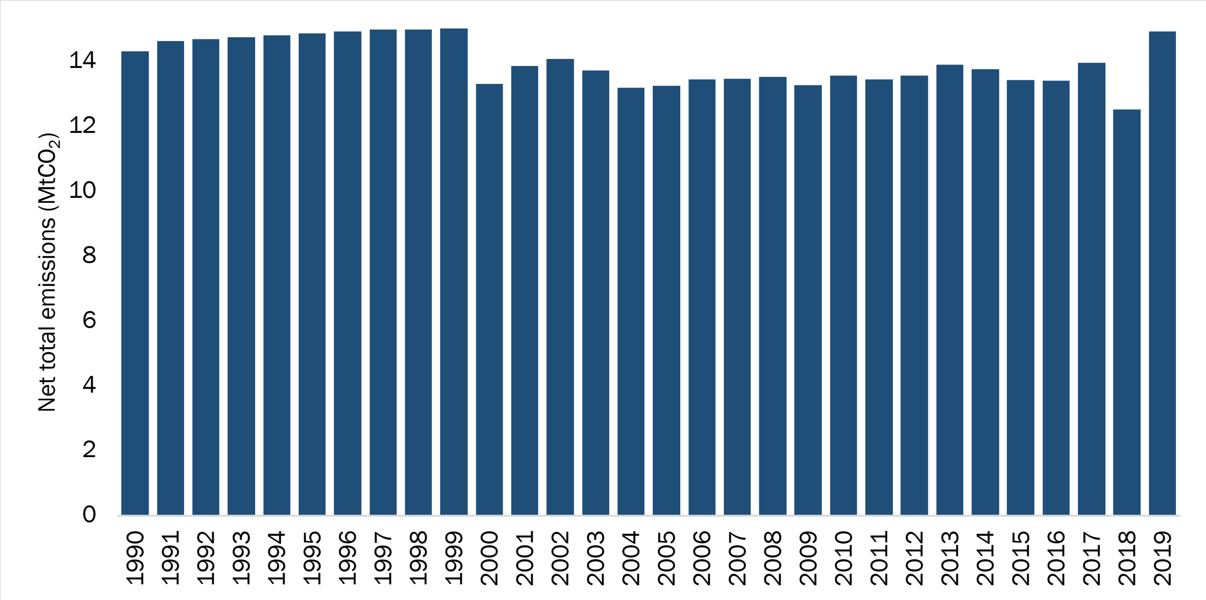


Figure 56: Net emissions trend in the land category from 1990 to 2019

Deforestation can be blamed for the overall rise in net CO_2 emissions from the land for the following reasons: (a) extension of cropland areas as part of food security initiatives, (b) forest to grassland conversion due to fires and cropland conversion. The forest remained a sink among the three land categories, whereas grassland and cropland were sources of emissions. On the other hand, increased net CO_2 removals in forestland were due to (a) an aggressive forest plantation development program focused on degraded forest lands and (b) the Forest and Wildlife Policy, which allowed private sector participation in sustainable forest management.

5.9.1.2.1.2 Methodological issues for the land category

Land-use mapping

The primary source of activity data for land category inventory is land-use maps. They are used to identify and calculate the areas of the six IPCC classes and additional sub-classes and the transition between them over time. The land-use map data came from research undertaken by the Forest Preservation Project (FPP) and Winrock International's production of the National Forest Reference Level (FREL) for REDD+. The Forestry Commission executed the FPP with support from the Japanese government.

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, and its local counterpart RUDAN Engineering Limited. The FPP studies produced land-use maps for 1990, 2000 and 2012, whereas, during the preparation of the FREL, Winrock International facilitated the refinement of the 2000 and 2010 maps and produced new 2012 and 2015 maps. Recently, the Forest 2020 project also by the Forestry Commission has produced the 2019 map. The land-use maps for 1990, 2000, 2010, 2012 and 2015, and 2019 were produced from wall-to-wall remote sensing and ground-truthing techniques. For decades of consistency, 1990, 2000, 2010 and 2015 and 2019 were used in the inventory. The reasons were that persistent and distinguishable land-use change might take a half-decade or full decade to crystallise in the Ghanaian landscape.

The five and ten-year intervals also coincided with the epoch where good quality remote sensing imageries with less cloud effect were available for the entire country. The definitions adopted for various land categories used in the study are provided in *Table 92*.

Table 92: Land-use definition applied in the land mapping

Category	Definition
Forestland	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: The minimum Mapping Unit (MMU) is 1.0 ha The minimum crown cover is 15 % Potential to reach a minimum height at maturity (in situ) as 5 m
Cropland	Includes currently cropped or in fallow, including rice fields and some agroforestry systems where the vegetation structure falls below the thresholds used for the forestland category. Includes land where over 50% of any defined area is used for agriculture.
Grassland	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 land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the forest land, cropland, and 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 the other five categories.
Water	Natural rivers and lakes as unmanaged sub-divisions of wetland.

Archives of Landsat and ALOS data were obtained from the USGS database and the propriety owners of DMC. The data covered Landsat TM for 1990, Landsat ETM+ for 2000, ALOS AVNIR – 2, DMC for 2010 and Landsat 8 for 2015. For 2010, the DMC satellite data was used to fill up gaps in the ALOS AVNIR data, mainly resulting from cloud cover. The images were pre-processed to evaluate and correct haze effects using geometrical and radiometric methods in the ENVI Software environment. After pre-processing the individual bands, the stacked satellite photos were ready for further processing.

A supervised classification method was performed on the individual composite image for each year to delineate and estimate the areas of the six land-use variants using 1,100 field data. The ground data was collected through an extensive field campaign nationwide. The field data represents the different types of land-use classes on the ground. The individual land-use maps were validated using a mix of on-screen digitising on Google Earth, ground-truth and the key-informant approach. For the 2000 land-use, 500 data points were generated from Google Earth, while for the 2010 map, 2,213 field points were utilised. For the 2015 map, 1000 data points were applied to validate the land-use map.

The previous 1990 land-use map was validated using the existing land use map for 1990 developed by RSMC, data from the permanent sampling plots, areas with relatively similar signatures and interviews with key informants. 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.
- Legal management scheme.

After the analysis, it was observed that cropland areas might have been underestimated because tree crop areas were poorly separated from other vegetation. For most of them, the typical tree crop was misclassified as open-forest. The reported areas of oil palm, cocoa, rubber, citrus, mango and cashew in the FAOSTAT for 1990, 2000, 2010, 2015 and 2019 were adjusted to open- forest by subtracting their areas from the mapped open-forest areas and adding them to cropland. Afterwards, both closed-forest and the rest of the open-forest areas were summed up to form forestland for the four selected years. Using the four land-use maps, we conducted change detection to produce land-use change maps and the associated matrices. The analysis of the land-use areas was originally done for ten years and five years intervals, i.e., 1990–2000; 2000–2010, 2010-2015 and 2015-2019, in line with the IPCC guidelines, 20-year intervals and single year land-use matrix.

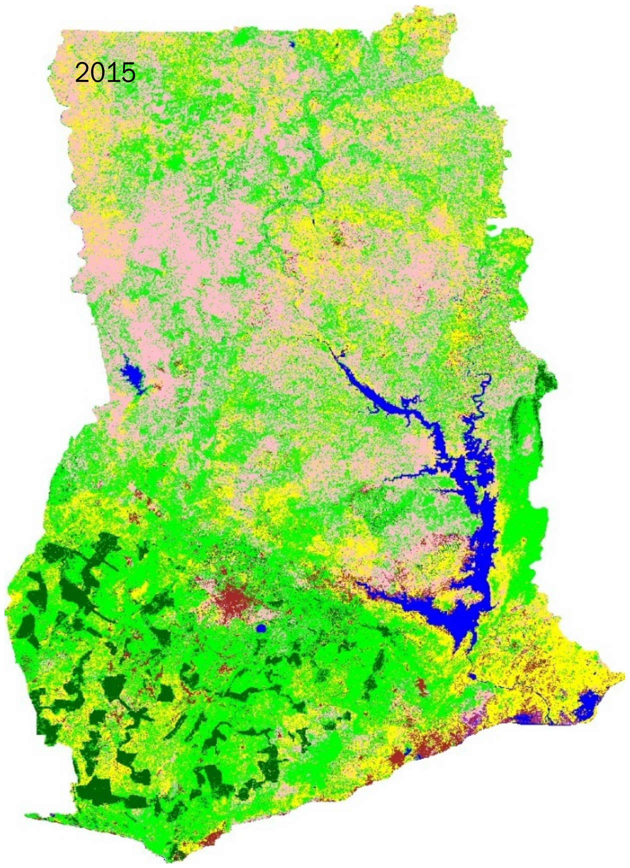
To calculate the areas of the land-use areas for the intervening years, for example, 1990–1991 or 2011-2012, or 2016-2019 the overall land-use transition areas for each land-use class for a given period were divided by the number of years in each epoch. For example, if for the entire 2010-2015 period, the area of cropland was 10,000ha, to get the areas for the intervening areas, the 10,000ha was divided equally to 2,000ha per annum by dividing by five years. The land-use areas for 2016 were a repetition of the 2015 areas. The 20 years land-use figures were interpolated, which followed the general steps: (a) generated individual 20-year epochs land-use matrix for the period (e.g., 2015-1995, 2010-1990, 2000-1980 and 1990- 1970) are assumed that land-use changes in the previous epoch were generally slower than the present; calculated annual land-use change matrix for the individual years in each 20-year epoch. The analysis recognised the following assumptions, considering the principle of conservativeness:

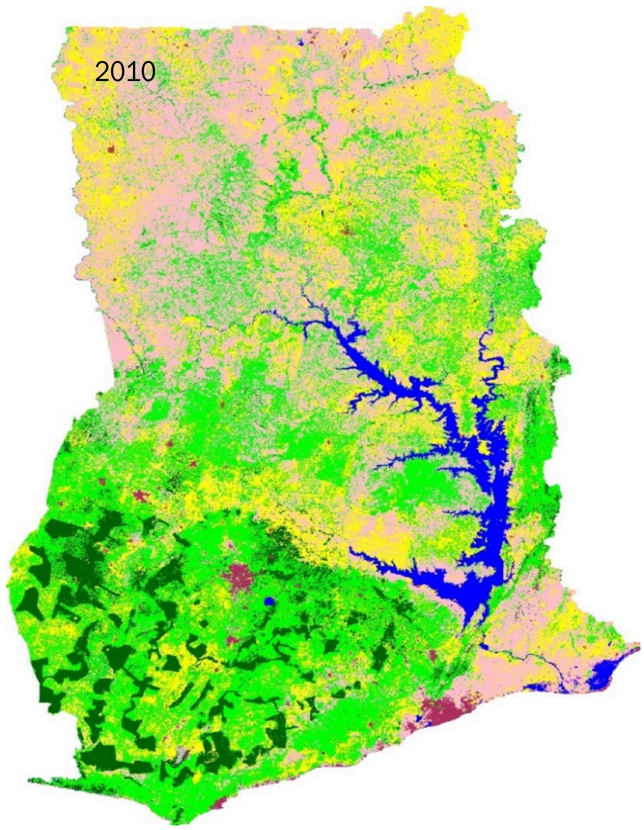
- Annual area changes were assumed to be insignificantly different from the previous years. Thus, it was assumed that area change would be spatially difficult to notice within a year.

- 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 was applied to the base year to retrieve the data for the intervening years.

- The rate of change in the various land-use classes was slower in the 1980s than in the 1990s and 2000s. The same applies to the 1990s and 2000s because: (a) 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 1990s. Thus land-based economic activities in the 1990s were more intense than in the 1980s, and (b) population growth rate was higher beyond the 1980s. Population growth and urbanisation and its associated high consumptive lifestyle influenced landscape dynamics.

- The effects of wildfires that happened in 1983 were a major one-off event, and a result of wildfires that led to deforestation may be exceptionally high in the early 1980s.
- The impacts of cocoa/tree crops expansion into forest areas catalysed the modification of the landscape in the 1980s at the time of the establishment of the crop. The subsequent expansion of cocoa or tree crops may be localised and largely target fallow and croplands.





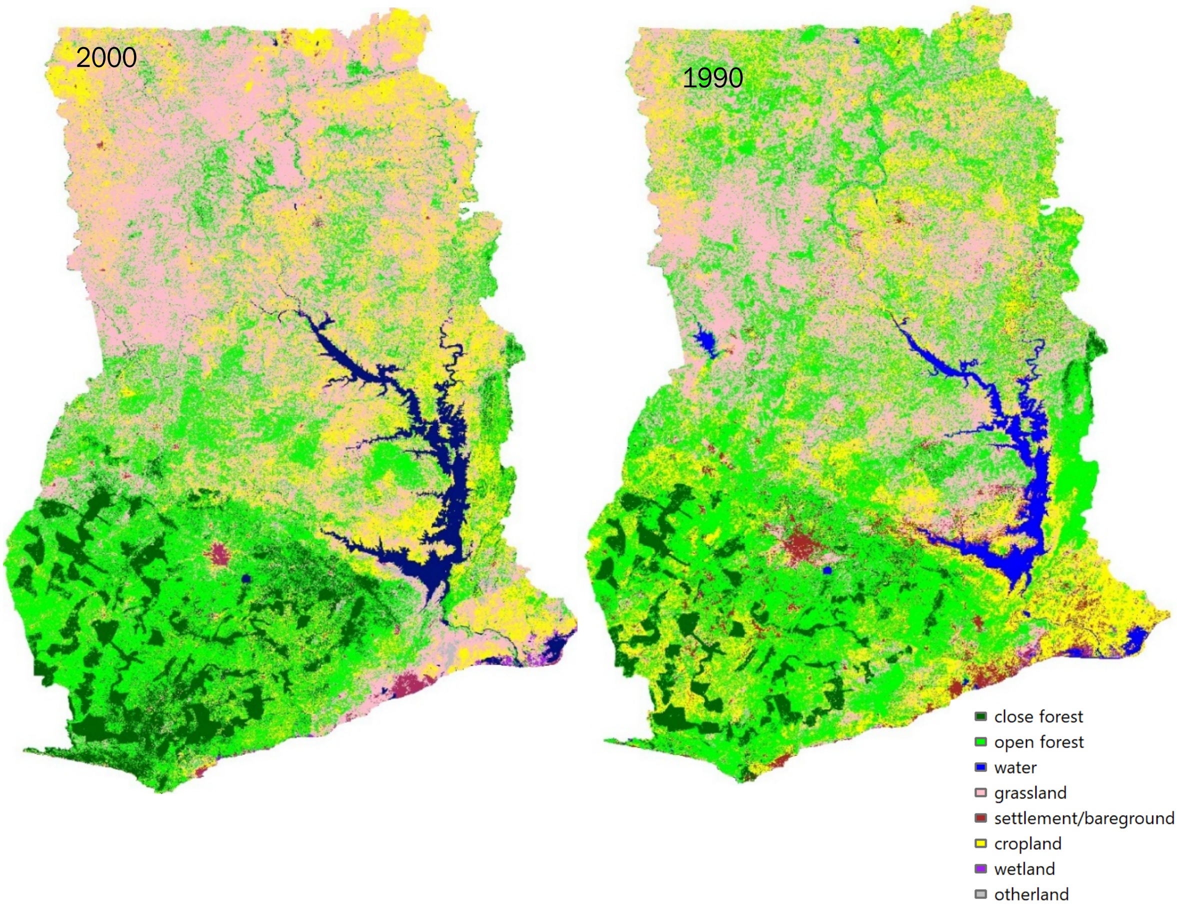


Figure 57: Land-use maps for Ghana for 2015, 2010, 2000 and 1990

Accuracy assessment of the land-use maps

Two strings of assessments were done. One on the individual 2000, 2010, and 2015 maps and the others on the change maps for 2000-2010 and 2012-2015. The purpose of adopting the two approaches was to complement each other. Even though the primary focus was to conduct the accuracy assessment of the individual maps evaluating the assessment was an added advantage. The accuracy assessment results are provided in Tables 93, 94 and 95.

Table 93: Accuracy assessment for 2000 land-use map

Class name	Reference total	Classified total	Correct number	Producer's Accuracy [%]	Users Accuracy [%]	Kappa
Closed forest	40	43	33	81.25	75.58	0.7346
Open forest	163	152	136	81.87	88.85	0.8334
Water body	11	15	11	100.00	70.00	0.6936
Grassland	100	104	82	82.00	78.85	0.7356
Settlement/ Bare ground	45	49	37	82.22	76.29	0.7394
Cropland	125	129	103	82.00	79.77	0.7302
Wetland	11	5	5	52.63	100	1
Other lands	5	3	4	77.78	100	1
Total	500	500	407			
Overall classification accuracy				81.70%		
Overall kappa statistics				0.7664		

For the 2000 map - 500 data points generated from Google Earth were used to assess the accuracy of this map. The assessment yielded an overall accuracy of 81.7%.

Table 94: Accuracy assessment for 2010 land-use map

Class name	Forestland	Cropland	Grassland	Settlement	Wetland	Other lands	Classified total	User's 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
Settlement	17	13	12	283	1	5	331	85.50
Wetland	0	0	1	0	152	0	153	99.35
Other land	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	99.35	99.35	60.00	-	83.87

For the 2010 map - 2,213 field points were used for the accuracy assessment of the 2010 map. The overall accuracy for this map is 83.9%.

Table 95: Accuracy assessment for 2015 land-use map

Class name	Reference total	Classified total	Correct number	Producer's Accuracy	User's Accuracy	Kappa
Closed forest	80	87	76	0.95	0.8735	0.7346
Open forest	331	263	255	0.7703	0.9696	0.8334
Water body	21	25	21	1	0.84	0.6936
Grassland	200	186	154	0.77	0.8279	0.7356
Settlement/Bare ground	90	142	84	0.933	0.5915	0.7394
Cropland	250	275	189	0.756	0.6872	0.7302
Wetland	19	15	15	0.7894	1	1
Other lands	9	7	7	0.7778	1	1
Total	1000	1000	801			
Overall classification accuracy				80.1%		
Overall kappa statistics				0.7664		

The accuracy assessment of selected change map areas and a special focus on the high forest zone. For the 2015 map, an accuracy assessment with 1,000 field data points produced an overall accuracy is 80.1%. The following steps were followed:

- Step 1: Comprehensive review of the existing accuracy/uncertainty worksheet and the accuracy assessment report - This step involved carefully reviewing map sources, extents, map years, and metadata. The associated spreadsheets generated from the maps were reviewed for accuracy. The team further went through the methodological flows in a step-by-step manner to link them to the results. These included checking the validation sample size, source of the data, and the sampling approach. The values in the accuracy/uncertainty worksheets were cross-referenced with the map areas in the attribute tables of the maps. The equations in the accuracy/uncertainty worksheets were also checked for consistency compared with the equations provided in Olofson et al. 2014. All data gaps and inconsistencies were discussed and noted.

- Step 2: Review, discuss and agree on the steps to implement Olofson et al., 2014 – After reviewing the Olofson, 2014 paper, the team discussed the general import of the paper and its implication for the accuracy assessment; the sequence of steps and the data required to inform the workflow of the accuracy/uncertainty analysis.

- Step 3: The implementation of the accuracy assessment following Olofsson's approach was done at this stage and was included in the creation of new change maps from the four individual maps, generation of the validation points and visual interpretation in Google Earth, after which the validated points were used for the accuracy assessment and uncertainty analysis. The three steps are further elaborated below:

Map processing (generation of change maps)

The team downloaded all the maps used by Winrock from FC's website, publicly available on http://www.fcghana.org/nrs/index.php/category/9-spatial-data. Each map was clipped to fit the extent of the high forest zone, which represents the boundary of the Ghana Cocoa Forest REDD+ area. Maps were reclassified to forest non-forest. In ArcGIS, we used the combined function to detect changes in the maps to represent each period (2000 and 2010, 2010 and 2012, 2012 and 2015) and further identified the areas of change (forest to other lands, (DF), forest remaining forest, (FL), other lands to the forest (RG), other land remaining other lands, (OL).

Framing the Response Design

Using the change maps in each period (period 1 – 2000/2010 and period 2- 2010/2012 stratified random points were generated using create accuracy assessment points tools (spatial analyst tool). We generated 4,000 points based on stratified random sampling on each of the three change maps using the accuracy assessment points functionality in the Spatial Analyst package in ARCGIS, 4000 points. This sampling approach considered the relative area proportions of the four change classes (FL, DF, RG and OL) to ensure the sample's representativeness.

Figure 58: Spatial distribution of the 4000-validation point displayed in Google Earth Pro

Every 4,000 points were converted to KMZ and exported to Google Earth Pro (*Figure 58*) in tabular format with three columns labelled as FID, classified, and ground-truth. Then, visual validation of each point followed. Two-time reference images were used to validate the change sample points for the three periods (e.g., 2000/2010 - P1 and 2010/2012 -P2). The FID column contains the unique identifier of each of the 4000 validation points in each period. The “classified column” represented change classes (0 for OL-OL, 1 for OL to FL, 2, FL-OL and three and FL-FL is assigned) during the change detection process. The “Ground truth column” is for the visually validated code for the change (Figure 59).

FID	Classified	GrndTruth
0	3	
1	2	
2	0	
3	2	
4	1	
5	1	
6	3	
7	0	
8	3	
9	2	
10	3	

Figure 59: Extract of the table accompanying the validation samples used in Google Earth

The visual interpretation of the validation images followed the following steps:

- Individual interpreters familiar with the landscape and experienced visual interpretation and mapping were assigned several samples to validate. The validation was based on the visual interpretation elements of colour, texture, tone, pattern, and shape that define the conspicuous nature of the interesting feature.
- There were discrepancies or challenges in the visual interpretation of the features in the validation maps. The whole team discussed and agreed on the type of change assigned to the sampling points. This approach ensures quality checks on the visual interpretation and the labelling of the assigned points.
- In all cases, the individual interpreters ensured that the determination of the change class assigned to each point was based on the interpretation of the minimum of two maps (previous and current years)[33]. The team excluded the reference points if the previous validation image was of poor quality or did not exist.
- The first 2,000 points were accurately validated and labelled using available High-Resolution Imagery on Google Earth of the corresponding years. Points that fell in clouds or haze and areas without high-resolution imagery were excluded from the additional analysis (Figure 60).

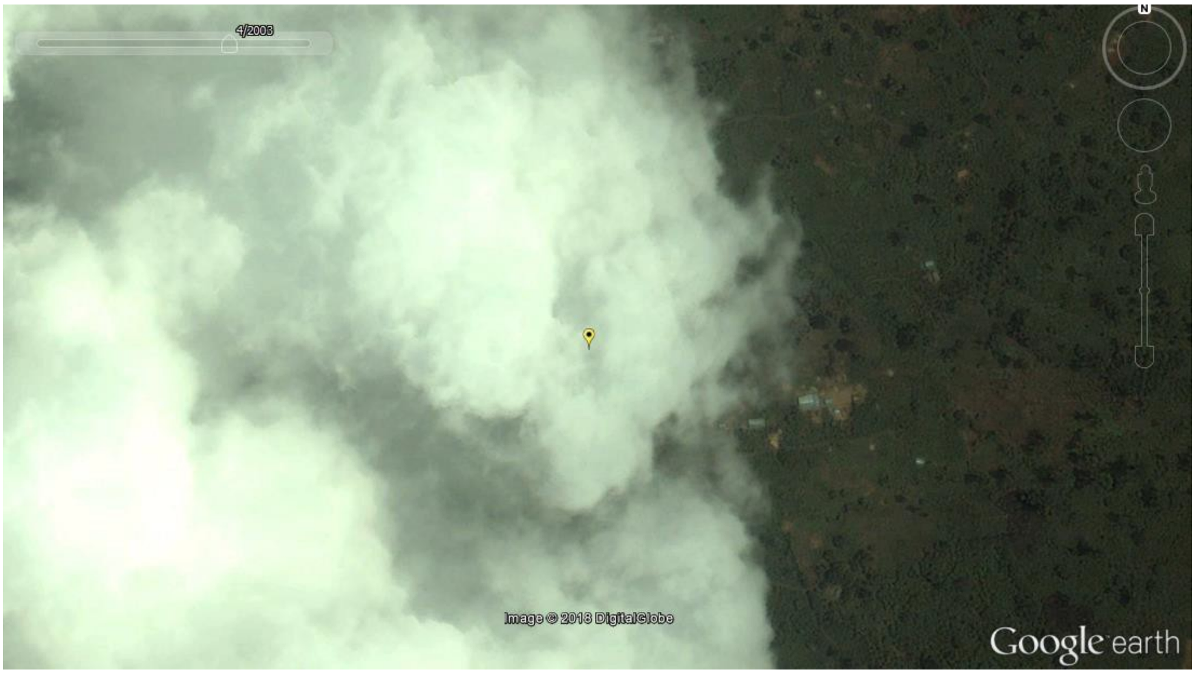


Figure 60: Validation point located in a cloud cover

Accuracy/Uncertainty analysis stage

The individual validated points from the six interpreters were collated and populated into a single table. In the table, every referenced point under the column "classified" has a corresponding validated point under the "GrndTruth" column (Figure 61).

FID	Classified	GrndTruth
1682	0	0
1693	0	0
1695	2	2
1699	3	0
1701	3	0
1704	0	0
325	0	0
327	1	0
333	2	3
342	2	2
345	3	0
346	1	1
349	0	0
351	0	0
352	0	0
358	0	0
363	3	0
369	3	3
370	3	3

Figure 61: Validation points showing the classified and corresponding ground truth points

Then the table containing all the 2,000 validated samples was sorted into four classes and permuted based on OL, RG, DF and FL. The resulting total counts were used to generate a classified and ground truth matrix for Olofsson's approach.

Accuracy assessment and uncertainty of change areas

The accuracy was 74% and 74% for periods 1 and 2, respectively. For period 1, OL and FL recorded the highest user accuracy, followed by DF and RG having the least accuracy. Similar accuracy levels were obtained for periods 2 (Tables 96 and 97). For example, in period 2, the user's accuracy for DF increased to 56%, while that one for RG declined to 18%.

Table 96: Period 1 (2000-2010) accuracy assessment information

Unbiased change area matrix								
Land-use classes	Lower limit	Upper limit	Error – adjusted area estimate ('000 ha)	Map areas ('000 ha)	SE of adjusted area estimates	User's Accuracy	Producer's Accuracy	Overall accuracy
OL	284.6	540.4	1,159	354	65.3	0.86	0.31	0.74
RG	940.9	1,123.6	341	286	46.6	0.28	0.84	
DF	504.9	655.1	390	272	38.3	0.47	0.70	
FL	3,756.8	4,024.1	4,026	3,476	68.2	0.89	0.86	

Table 97: Period 2 (2010-2012) accuracy assessment information

Unbiased change area matrix								
Land-use classes	Lower limit	Upper limit	Error-adjusted area estimates (000, ha)	Map areas (000, ha)	SE of adjusted area estimates	User's Accuracy	Producer's Accuracy	Overall accuracy
OL	1,000.1	1,197.4	1,838	924	50.35	0.84	0.50	0.74
RG	446.2	514.3	108	87	17.37	0.18	0.81	
DF	286.3	406.7	439	194	30.73	0.56	0.44	
FL	3,885.8	4,093.8	3,530	3,161	53.07	0.79	0.90	

Biomass estimation

Biomass estimation was done using ground inventory. After a scoping exercise, a pilot area within Ghana's nine forest ecological zones was selected. A nested plot design in a rectangular shape, grouped in clusters, was laid to delineate sampling areas for data collection. A cluster comprising three rectangular plots was systematically placed 500m apart. The main plot of 20m by 20m was laid to measure trees with a 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 a diameter below 10cm in addition to deadwood 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 to estimate below and above-ground biomass.

5.9.1.2.1.3 Recalculations in the land category

The availability of new activity data from the FREL work justified the recalculation in the land category. All the land-use areas and the accompanying change matrix were affected by the inclusion of the new dataset. The recalculation led to the changes in the activity data for the various land categories. The variations between previous CO_2 emission estimates and the latest figures are in Table 98.

Table 98: Recalculations results for the LULUCF category

Year	Net CO_2		
	PE	LE	Change
1990	14.01	14.59	4.1%
1991	14.07	14.64	4.0%
1992	14.12	14.70	4.1%
1993	14.18	14.75	4.0%
1994	14.24	14.80	3.9%
1995	14.30	14.86	3.9%
1996	14.36	14.92	3.9%
1997	14.42	14.99	3.9%
1998	14.42	14.98	3.9%
1999	14.59	15.14	3.8%
2000	12.73	13.31	4.5%
2001	13.30	13.86	4.2%
2002	13.52	14.08	4.1%
2003	13.16	13.72	4.3%
2004	12.62	13.18	4.5%
2005	12.70	13.26	4.4%
2006	12.87	13.45	4.5%
2007	12.91	13.48	4.4%
2008	12.95	13.52	4.4%
2009	12.69	13.27	4.6%
2010	12.98	13.57	4.5%
2011	12.86	13.44	4.5%
2012	12.96	13.57	4.7%
2013	13.34	13.90	4.2%
2014	13.20	13.77	4.3%
2015	12.86	13.43	4.4%
2016	12.91	13.40	3.8%

Reasons for recalculations

- Revision of industrial round wood and fuelwood harvest data in forest lands
- Changes in areas affected by the fire as disturbances.
- Inclusion of teak specific emission factors.

5.9.1.2.1.4 Source-specific emissions for the land category

Emissions from Forestland

Forests are divided into two types: open and closed forests. The gazetted government reserves and national parks are closed forests, whereas open forests are forestlands outside the gazetted forests, known as off-reserve forests. Furthermore, certain gazetted forest reserves that have been degraded and restored have been categorized as open forests. Throughout the period 1990-2019, forestland remained a net carbon sink. Figure 62 shows that the country's forest sink capacity has remained constant over time, despite sinusoidal changes in the intervening years. Carbon removal has increased from -3.02 $MtCO_2$ in 1990 to -3.08 $MtCO_2$ in 2019.

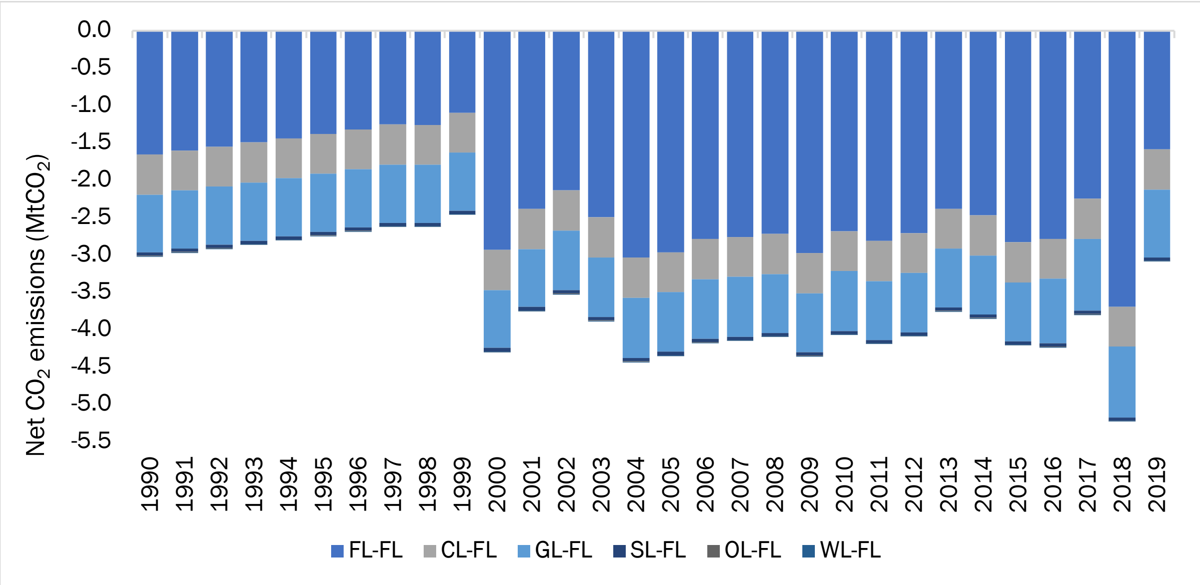


Figure 62: Trends of Net CO_2 emissions for forestland between 1990 and 2019

Carbon dioxide removals from forestland remaining forestland (FL-FL) accounted for 51.62 per cent of total CO_2 removals inside the forest in 2019, with the remaining 48.38% coming from other lands (all other conversions to forestland combined). The remaining forestland generated 65.79% of total CO_2 reductions within the forest in 2016. The conversion of grassland to forestland removes the most CO_2. It has regularly contributed to the removal of 60.8% of CO_2 in the forest. Cropland-to-forestland conversion is the second-largest source of removals, accounting for 36% of all removals. The rest of the 3.2% CO_2 removals were shared among settlement-forest, other land-forest and wetland-forest conversions. The following factors could explain the general increasing removals of forestland: (a) the impacts of the ban on the export of round logs as part of the government's policy to facilitate the enhancement of downstream timber processing and (b) the 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.

Emissions from Cropland

Cropland is a term used to describe crop fields where annual staple foods and perennial crops are grown. In cropland, land preparation methods include (a) slash and burn, (b) mechanisation, (c) weedicide treatment, and (d) a combination of the above. Under 3C, GHG emissions connected with agriculture management techniques such as fertiliser application, crop residue handling, and burning are recorded. Carbon emissions in agriculture are caused by the conversion of forestland to cultivation. Land-use changes involving crops are the source of emissions reported under this category.

Cropland was the land category's second-largest source of net CO_2 emissions. Cropland contributed 19.23 $MtCO_2$ making up 74.3% of the total land emissions in 2019. One of the key categories in the overall emission inventory is deforestation due to agriculture expansion. The largest contributor to this statistic was forest-cropland conversion through deforestation (Figure 63). It happened all around the country, in varying degrees of severity. Although the drivers of forest-to-cropland conversion are diverse, factors such as crop variety, agronomic and management practices, and land tenure can all impact emission levels.

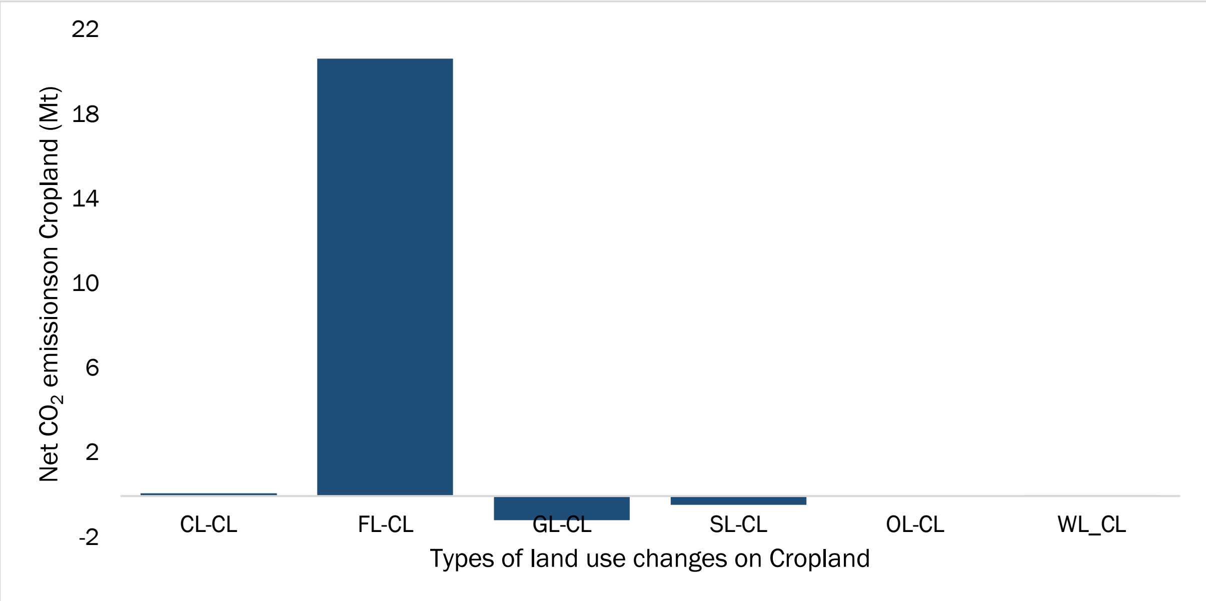


Figure 63: Net CO_2 emissions for cropland in 2019

Emissions from Grassland

Grasslands can be found in large sections throughout Ghana's savannah and transition zones. Grassland can also be found in coastal savannahs. Grassland was formerly dominated by herbaceous plants, making it excellent for animal grazing and susceptible to seasonal fluctuations. Grass also appeared as shrubs during fallow periods or transition plants following a big forest or agricultural operation. In the grassland sub-category, there was very little woody vegetation. In the grassland, burning is also a widespread practice. In some sections of the country, particularly the drylands, the grass is burned to make young grass for animal grazing. Grassland emissions make up about 2.8% of all emissions in the land category. In 2019, grassland CO2 removals totalled 2.6Mt, with the majority of this coming from forest-to-grassland conversion due to deforestation (Figure 64).

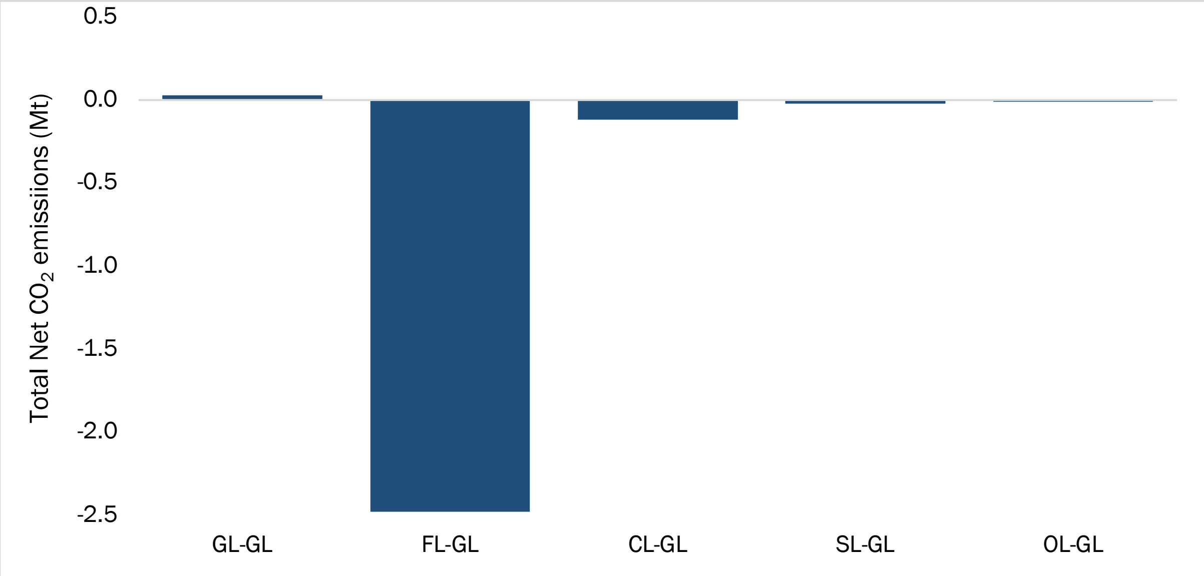


Figure 64: Net CO_2 emissions for grassland in 2019

5.9.1.3 Aggregated sources and non-CO_2 emission sources on land (3C)

The 3C category includes GHG emissions from activities other than livestock and land. Methane and nitrous oxide emissions from biomass burning, CO_2 from urea application, direct and indirect N_2O from managed soils, indirect N_2O from manure management, and CH_4 emissions from rice production are among them. In 2019, total GHG emissions of 7.5 $MtCO_2e$ were observed. Nitrous oxide contributed 84.7% of the 2019 total emissions followed. In the 1990-2019 period, GHG emissions in the 3C category increased by 3.4% each year. In the 1990-2019 period, GHG emissions in the 3C category increased by 3.4% each year. Compared to 1990 and 2016, the 2019 figure is 172.6% and 16.5% higher.

In 2019, it was also responsible for 29.4% of all AFOLU emissions. Though all the gases are experiencing an increase in yearly amounts, the contributions of nitrous oxide reduced while carbon dioxide increased significantly. The contribution of CO_2 has increased from 0.6% in 2016 to 5.4% in 2019. Direct N_2O emissions from managed soils were the most common N_2O emissions in 2019. It accounted for 62.5% of overall 3C emissions of 7.47 $MtCO_2e$, followed by indirect N_2O emissions from managed soils, which accounted for 16.1% of total 2019 emissions. The noticeable decline in emissions in 2004, particularly in "Direct N_2O" emissions from Managed soils, is due to a significant drop in crop production. The rest came from biomass burning (10.3%), urea application (5.4%), rice farming (4.8%), and finally, indirect emissions from manure management (0.9%) (Figure 65).

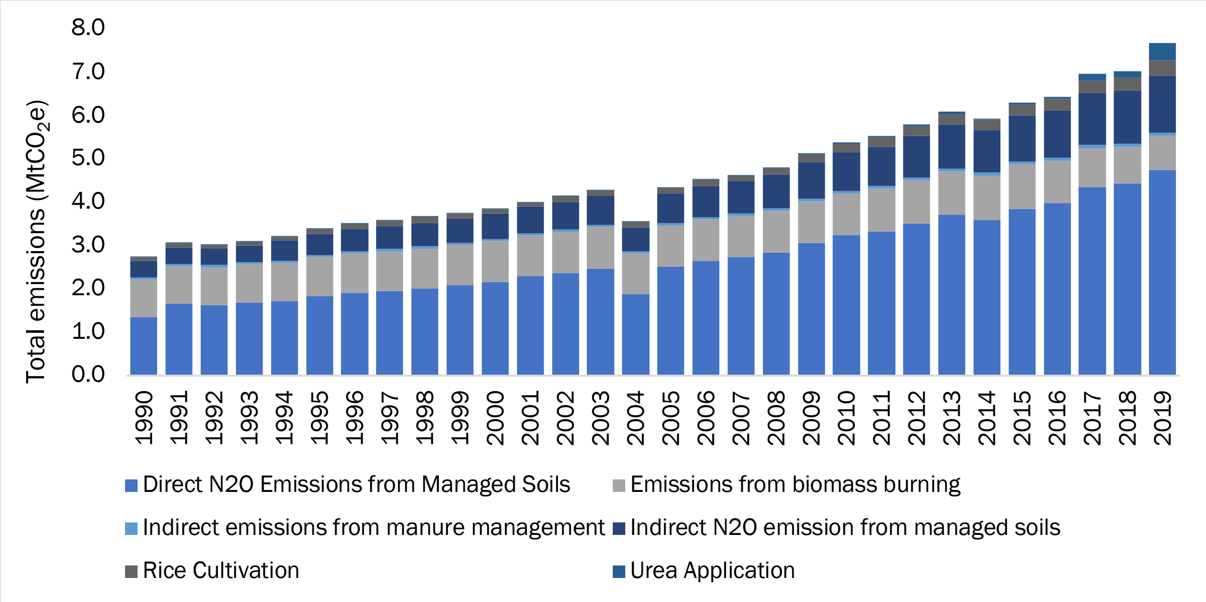


Figure 65: Total 3C emissions according to the subcategories

5.9.1.3.1 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 2.43 $MtCO_2e$ in 1990 to 1.22 $MtCO_2e$ in 2012 and further to 0.97 $MtCO_2e$ in 2016 (Figure 66). The decline in the emissions was attributed to the country's sustained public awareness of fire management. In 2016, biomass burning from grassland and cropland accounted for 44.3% and 44% of the total emissions, whereas biomass burning from the forest was 11.7% each. Generally, there was a steady decline in the emission levels of the three activities.

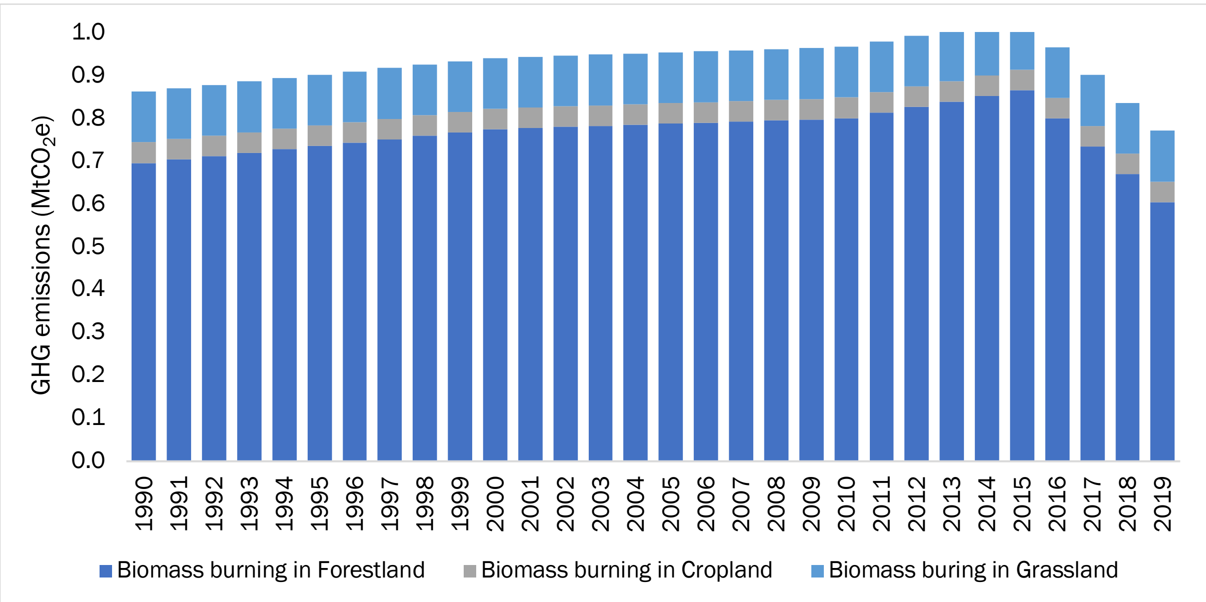


Figure 66: Emissions for biomass burning in different land-use types from 1990 to 2019

5.9.1.3.1.1 Methodological issues for biomass burning

Estimating emissions in the IPCC 2006 Guidelines and the revised 1996 IPCC Guidelines differ in how the accounting of emissions from burning are disaggregated. The 1996 Guidelines considered burning as part of forestland to grassland conversion. The 2006 Guidelines classify biomass burning separately under 3C. The methodology for estimating emissions from fire got better with the adoption of the remote sensing approach. The MODIS fire product made it possible to delineate the fire spots and burnt areas for each land-use type and ecological zones. Expert judgment was used to determine the various areas affected by wildfire based on available biomass load. The actual areas affected by fire were derived from the sum of the individual areas 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 due to burning.

Country-specific data on the mass of fuel from the FPP field survey were used to estimate total emissions from biomass burning for 1990, 2000 and 2010. To derive the inter-annual biomass burning estimates within each decade, trend interpolation for 1991 to 1999 and 2001 to 2014 was done. In 2015, areas affected by fire were obtained using a trend extrapolation approach based on the data generated for the immediate past five years. The measurement approach for fire uses spatial data to capture areas burned annually and IPCC factors to derive emission factors. The biomass values input incorporates live biomass (above and belowground) and down dead wood and litter as stocks impacted by degradation caused by forest fires. These stocks are derived from the FPP. The MODIS burned area product was used to identify areas that experienced emissions due to forest fires between 2001-2015 (Figure 76). Only forest areas that remained forested and where forest fires occurred but caused no change in land use were counted as forest degradation. Any areas that burned and were identified as deforestation were removed from degradation forest fire accounting. Subsequently, the areas affected by the fire that led to forest degradation and deforestation were added for further analysis.

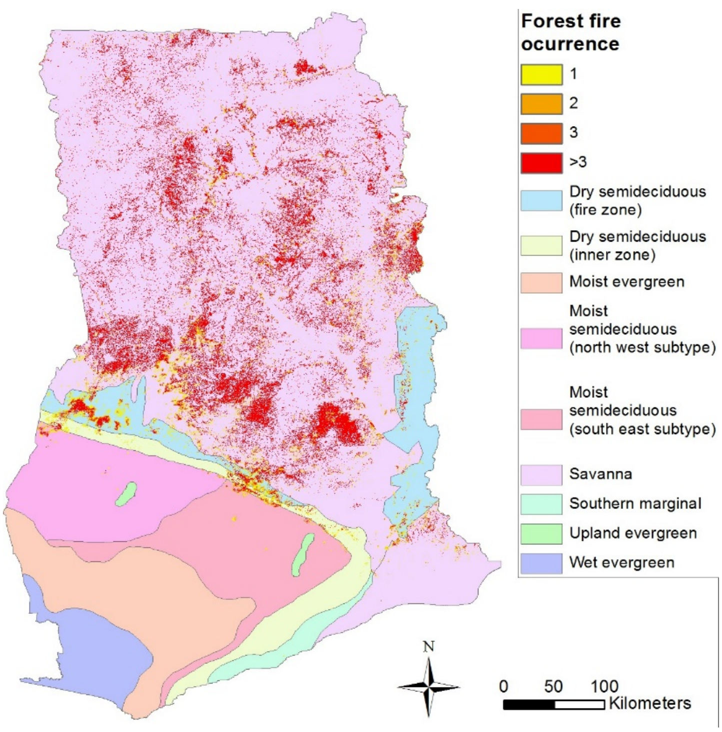


Figure 67: Forest fire occurrence in Ghana

5.9.1.3.2 Recalculations of 3C.1 emissions

A remote sensing-based methodology has been used to estimate the fire spots and the fire-affected areas. Therefore, it is good to conduct recalculations on the previous emission levels (1990-2016). The results of the recalculation are presented in Table 99.

Table 99: Recalculations in biomass burning under 3C1

Year	PE	LE	Change (%)
1990	2.62	0.86	-67%
1991	2.57	0.87	-66%
1992	2.52	0.88	-65%
1993	2.46	0.89	-64%
1994	2.41	0.89	-63%
1995	2.36	0.90	-62%
1996	2.30	0.91	-60%
1997	2.25	0.92	-59%
1998	2.20	0.93	-58%
1999	2.14	0.93	-56%
2000	2.07	0.94	-55%
2001	2.03	0.94	-53%
2002	1.96	0.95	-52%
2003	1.90	0.95	-50%
2004	1.84	0.95	-48%
2005	1.78	0.95	-46%
2006	1.71	0.96	-44%
2007	1.65	0.96	-42%
2008	1.59	0.96	-39%
2009	1.52	0.96	-37%
2010	1.38	0.97	-30%
2011	1.39	0.98	-29%
2012	1.31	0.99	-24%
2013	1.24	1.01	-19%
2014	1.17	1.02	-13%
2015	1.09	1.03	-6%
2016	1.05	0.97	-8%

Reasons for the recalculations

- Adoption of a remote sensing technique to estimate areas affected by fires.
- Revisions in the fire burnt areas for the three land-use types.
- Separation of forest degradation and deforestation fires.
- Use of new GWP based on IPCC's AR4.

5.9.1.3.3 Description of emissions trends from Urea Application (3.C3)

This sub-category covers CO_2 emissions from urea-based fertiliser application to agricultural soils in Ghana. The emission estimates focus on the fraction of cropland artificial fertiliser to boost crop yields. In 2016, the CO_2 emissions from urea application to agricultural soil amounted to 0.04 $MtCO_2$, 0.6% of the total 3C emissions. The current value increased 289% over the 1990 figure of 0.01 $MtCO_2$ (Figure 68). The variations in the emission trends reflect the factors that drove demand patterns for agricultural inputs in Ghana, especially the government fertiliser subsidy programme.

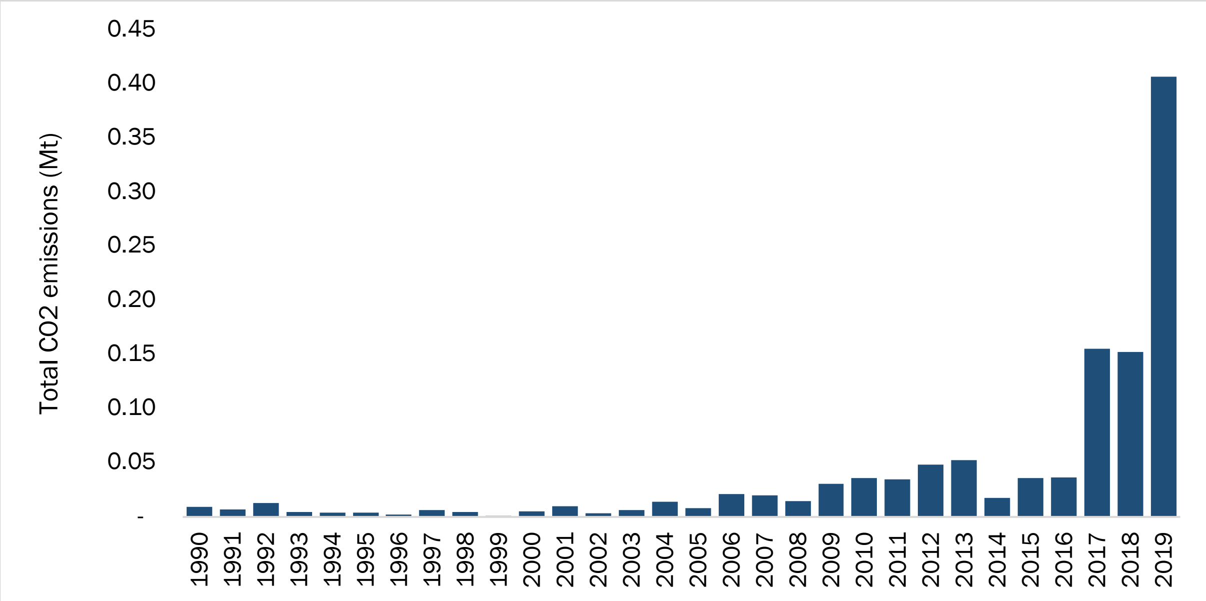


Figure 68: Carbon dioxide emissions from urea application to soils between 1990 to 2019

The fertiliser subsidy programme regulates the amount of urea imports in the country each year. It depends on how much money the government votes to subsidise fertiliser imports. It is most likely that the inter-annual variation in the CO_2 emissions associated with urea application is influenced by the quantities of urea imports and its use in the agricultural fields.

5.9.1.3.3.1 Methodological issues for urea application

The IPCC Tier 1 method and default emission factors were used to calculate 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 were mainly annual urea imports into the country. Total annual imports of urea fertiliser were assumed as annual consumption because there was no data on annual stock balances or stock changes for fertilisers.

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

Nitrogen inputs from crop residues, synthetic nitrogen fertilizer application, and land-use practices associated with land-use change contribute to direct and indirect N_2O emissions from managed soil. Under 3C, both sources create the most emissions. The combined contribution of 3C.4 and 3C.5 accounted for 78.6% of total 3C emissions in 2019, representing a reduction of their per cent contribution of 80.5% in 2016. Their actual emissions amounted to 5.87 $MtCO_2e$.

Direct N_2O emissions from managed soil alone constituted 62.5% of the 2019 3C emissions. The direct N_2O emissions from managed soils in 2019 have seen an increase of 245% of the levels in 1990. In 1990, the emissions were 1.36 $MtCO_2e$ and reached 3.98 $MtCO_2e$ in 2016. The current direct N_2O emissions from managed soils now stand at 4.67 $MtCO_2e$. On the other hand, indirect N_2O emissions from managed soil made up 16.1% of the total 3C emissions in 2019. Similarly, the emission saw an upward trend from 0.38 $MtCO_2e$ in 1990 to 1.10 $MtCO_2e$ in 2016, then to 1.20 $MtCO_2e$ in 2019 (Figure 69), representing an increase of 215%. The observed increasing trends of direct and indirect N_2O emissions from managed soils could also be linked to the Government of Ghana's fertiliser subsidy programme and the prevailing crop residue practice. The current government's flagship programme dubbed "planting for food and jobs" could contribute to the trend as more fertilizers are needed under this programme to support farmers. The common farm practice is that for most staple crops, the leftover after harvesting is usually allowed to decompose or ploughed into the soil for farmers into farm mechanisation and the plough for land preparation. Only a limited fraction is burnt in situ or grazed.

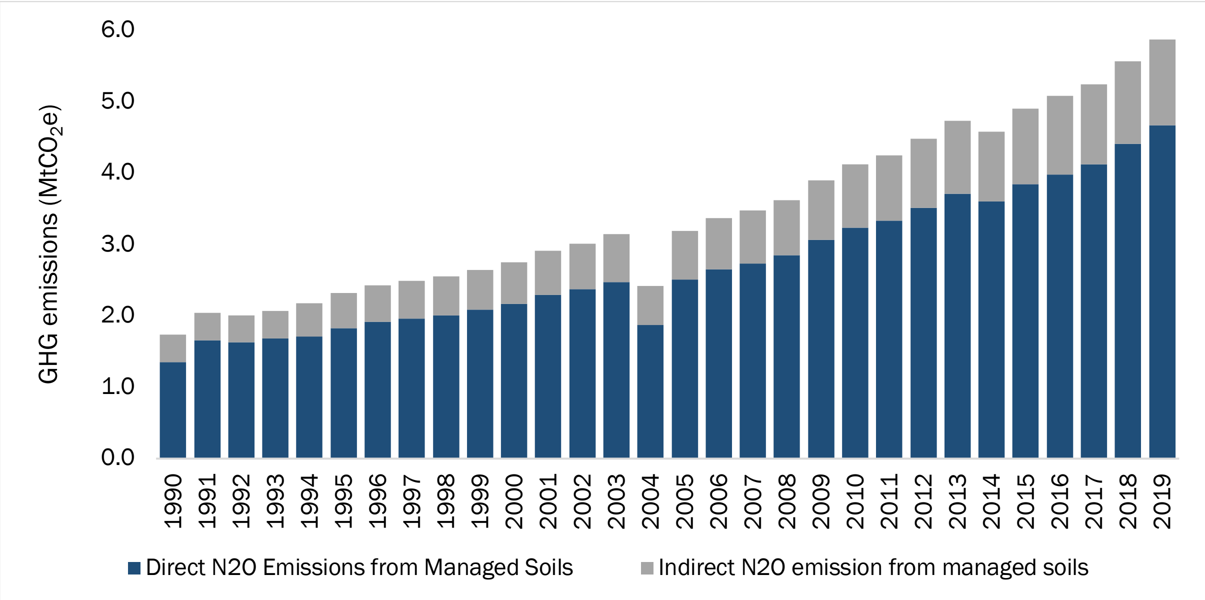


Figure 69: Trends in direct and indirect N_2O Emissions from Managed Soils

5.9.1.3.4.1 Methodological issues in 3.C4 and 3.C5

The IPCC tier 1 and default emission factors were used to calculate direct and indirect N_2O emissions. The Agriculture Facts and Figures database was used to acquire country-specific activity data on yearly crop production of key staple crops such as maize, yam, cassava, cocoyam, sorghum, and millet. The above-ground biomass residue was estimated using the appropriate default residue slope, residue intercept, and dry matter fraction for the respective staple crops. Using the proper root-to-shoot ratio of the various crops, the annual nitrogen fraction of the crop residue was calculated. The individual crop residues were aggregated to form the total nitrogen fraction from the crop residue. Data on nitrogen-based fertilisers were obtained from the Agriculture Facts and Figures 1990-2019 and were subsequently summed up based on the fraction of nitrogen content for different fertilisers published in the FAOSTAT. The percentage of nitrogen content in fertilisers was derived by multiplying the total volume consumed yearly by its corresponding nitrogen fraction.

To calculate the annual total nitrogen input from synthetic fertilisers, the nitrogen content of the various fertiliser types was added together. Annual soil organic matter loss and the carbon-nitrogen ratio of the soil were used to compute total annual N mineralisation in soils. Carbon stock change in mineral soils of individual land-use conversions was acquired from the land-use matrices and then summed to provide the annual total loss of soil organic matter per land category for the annual soil organic matter. The total annual nitrogen mineralisation in managed soils was calculated by multiplying the annual loss of soil organic matter by the carbon-nitrogen ratio. For the computation of direct and indirect N_2O emissions from managed soils, the total annual N – synthetic fertilisers, N – crop residues, and N – mineralisation was used.

5.9.1.3.5 Description of emission trends from indirect N_2O Emissions from manure management (3.C6)

Nitrous oxide emissions are largely determined by animal manure's quantity, characteristics, and management. The 2019 N_2O emissions of 0.07 $MtCO_2e$ account for only 0.9% of the total 3C emissions. The emissions grew by 100% over the 1990 figure of 0.03 $MtCO_2e$ and 16% of the 2016 value of 0.06 $MtCO_2e$. The increases in the N_2O emissions were because of reported raising livestock populations from 1990 to 2019 (Figure 70).

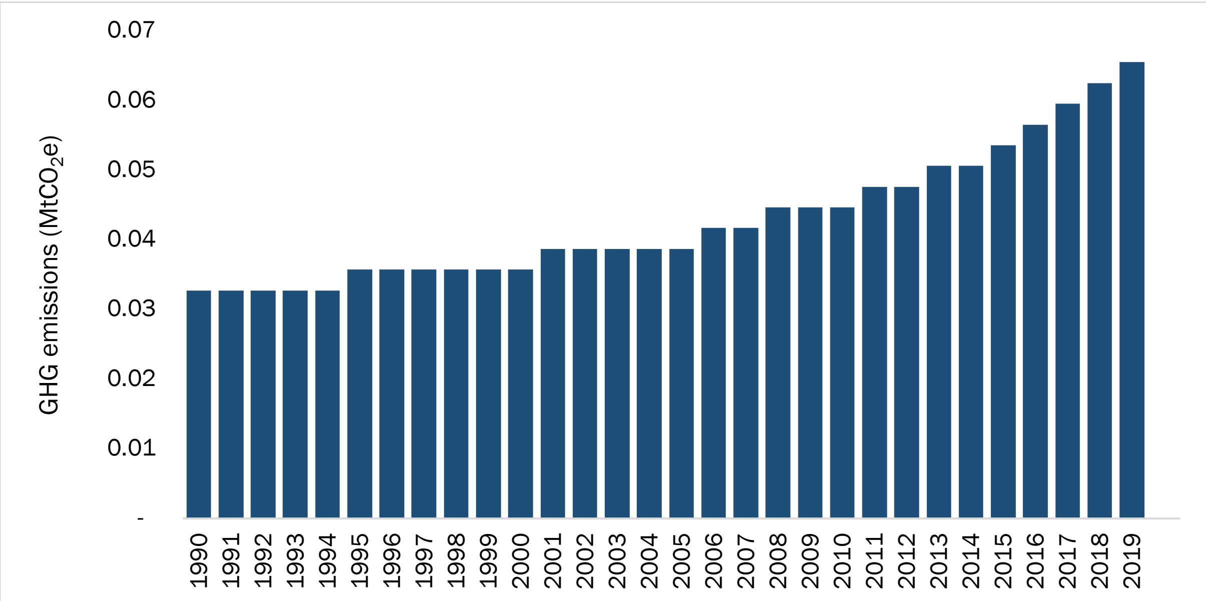


Figure 70: Emission trends of indirect N_2O Emissions from Manure Management

5.9.1.3.5.1 Indirect N_2O emissions from manure management methodological issues

Ghana used the IPCC default emission factors to compute manure management emissions. The category of proportions of animal waste management systems was estimated using expert judgment according to animal type.

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

Farm management practices mostly determine methane emissions from rice cultivation. Whether bottomland or irrigated, rice farms provide ideal biological conditions for methane production. The length of time water is flooded a major contributor to emission levels. Between 1990 and 2019, methane emissions related to rice cultivation increased by 264% (Figure 71).

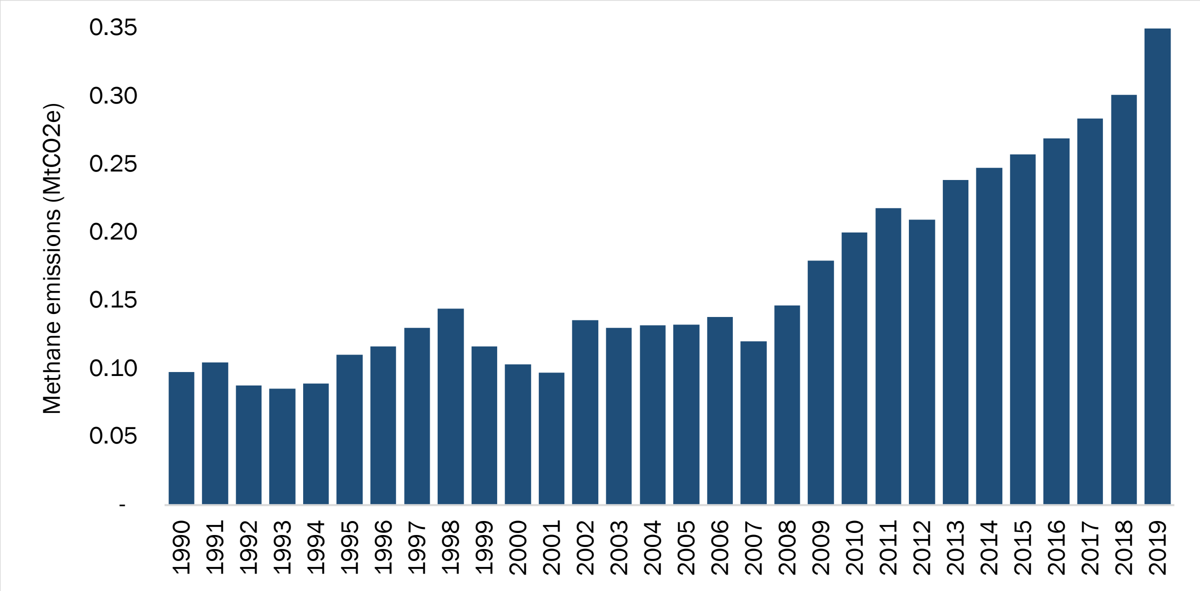


Figure 71: Methane emissions trend from rice cultivation

5.9.3.6.1 Methodological issues in rice cultivation

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

5.10 Planned Improvement List for AFOLU

The country takes stock of key activities that can be improved upon for every inventory's next reporting cycle. These initiatives involve generating data in areas where it is inadequate and reducing as far as possible the reliance on expert knowledge and associated uncertainties. These activities are also noted during the in-country voluntary review process. The list of these activities is captured in

Table *100* below:

Table 100: List of improvements list for the AFOLU sector

Improvement tasks	Responsibility & Collaborators	Priority	Next Step	Target	Assumptions/ Status
Estimate net emissions from Harvested Wood Product (HWP)	FC and EPA	High	Assess data availability and determine the methodological choice for the estimating HWP net emissions	Before 2024	Use existing tier 1 IPCC methodology to estimate HWP
Develop land-use schemes with definitions (including the possibility of delineating tree crops from annual crop areas)	FC, EPA, CERSGIS, Geomatics-KNUST, FAO, NATU-KNUST, Cocoa Board RMSC, FC	High	Explore the possibility of linking with the ongoing land use mapping projects.	Before 2024	Funding secured on time. Funding is not secured at the time of publishing the NIR5
Produce land-use maps and LUC matrices	FC, AFOLU Team, CERSGIS, RMSC	High	AFOLU technical team from the collaborating institutions would proceed with these activities following the initial action.		
Overlay land cover maps with maps of ecozones, climate, and soil and recalculate land-use change maps		High			
Integrate maps on perennial crops (mainly cocoa and rubber) in land-use maps and recalculate		High			
Include wetlands in the change analysis for the dominant land use and account for the associated emissions.		High			
Cross-check area estimates from LUC matrices with data available at the plantation unit.		High			
Include the annual fire hotspots and overlay them on the land-use maps to assign disturbances to land-use subcategories	FC, Ghana National Fire Service, NADMO, District Assemblies	High	Link with AGRHYMET	Next Inventory	FC to initial contact with AGRHYMET supported by EPA
Update existing biomass figures	FC and FORIG	High	EPA to follow up with FC and FORIG	Next Inventory	Contact FORIG

Remove outliers from biomass plot estimation (deadwood estimates)	FC and FORIG	High			Contact FC for updates
Quality check deadwood calculations in inventory data	FC and FORIG	High			Contact FC
Explore the possibility of including trees in annual croplands	FC and MOFA	Medium	Include in the discussions of the AFOLU team.	Next Inventory	Part of the activity 1
Explore the possibility of reducing the uncertainty associated with time-series data (infilling of data gaps) Biomass changes in different land representations, including different pools.	AFOLU Team	Medium	EPA to coordinate the revision of existing estimates.	Next Inventory	Funding is secured on time
Account for the burning of crop residues beyond the burning of fields	MOFA	Low	MOFA lead the team to identify, collect and include data in the inventory	Next Inventory	Availability of funds
Clarify the fertiliser used in rice					

Waste sector inventory

Chapter 6

6.0 Waste Sector

6.1 Overview of the waste sector

The GHG from the waste sector is from the treatment and disposal of liquid waste (domestic and industrial) and municipal solid waste such as landfilling, composting, incineration, and opening burning. The emissions from the waste sector are predominantly CH_4 from solid waste disposal and CH_4 and N_2O from both biological treatments of solid waste and wastewater treatment and discharge. Incineration and open burning of waste containing fossil carbon, e.g., plastics, are the most important sources of CO_2 emissions in the Waste Sector and produce some CH_4.

Carbon Dioxide is also produced in SWDS, wastewater treatment and burning of non-fossil waste, but this CO_2 is of biogenic origin and is therefore not included as a reporting item in this sector. Carbon dioxide emissions from the breakdown of organic material were not reported because the carbon dioxide emitted is assumed to be reabsorbed by vegetation and other organic matter growth in the following year. Nitrous oxide is produced in most treatments addressed. The importance of the N_2O emissions varies much depending on the type of treatment and conditions during the treatment. The key factors that affect emission generation in the waste sector are (a) population, (b) technology and (c) extent of emission (methane) recovery and (d) management practices.

6.2 Classification of waste activities under IPCC 2006 guidelines

According to the 2006 IPCC guideline, the following source categories are included 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 is divided into sub-categories that account for different waste attributes, management characteristics, and approaches.

6.2.1 Solid waste disposal (4A)

Solid waste generation is closely linked to population growth, urbanisation and affluence. Methane and non-fossil CO_2 are the main greenhouse gases that are associated with the disposal of solid waste disposal through biological decomposition. Based on the level of management of the solid waste disposal site, emission from solid waste disposal is further divided into sub-categories such as managed waste disposal sites (4.A1), unmanaged waste disposal sites (4.A2) and the uncategorised waste disposal sites (4.A3). Based on Ghana's current solid waste management practices, the estimation of methane from solid waste disposal was not disaggregated into managed, unmanaged and uncategorised. The main data input is population, waste generation per capita, solid waste streams, annual total waste generation, and fractions of waste disposed of through formal and informal.

Methane resulting from the decomposition of solid waste deposited in different sites (landfills and others) was accounted for. The data were obtained from Ghana Statistical Service, Published Statistics in national reports, literature and personal communication with national waste experts at various Waste Management Departments of the MMDAs.

6.2.2 Biological treatment of solid waste (4B)

Methane and Nitrous oxide are the key emission sources from the biological treatment of solid waste through composting. The data was collected from Waste management companies, mainly from Zoomlion Ghana Limited, which is currently the operator of the major Compost plants in Ghana. The main data input is the quantities of waste composted, the type of waste and the treatment system used. Additional data was sourced from Ghana Statistical Service and other literature for household composting and the decommissioned Teshie-Nungua treatment plant.

6.2.3 Incineration and open burning of solid waste (4C)

Solid waste disposal through incineration and open burning produces CO_2, CH_4 and N_2O emissions. The emission from this sub-category is divided into incineration (4C.1) and open burning (4.C2). Under incineration, municipal solid waste, hazardous waste and clinical waste emissions were the main sources considered using the aggregate approach. Emissions from open burning were from municipal solid waste. Data on the 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, Environmental Management Plans from the Petroleum department of the EPA.

6.2.4 Wastewater treatment and discharge (4D)

Methane and Nitrous Oxide are the main gases from wastewater treatment and discharge divided into two subcategories: domestic (4D.1) and industrial (4D.2) wastewater treatment and discharge. Emissions from domestic wastewater treatment and discharge are due to the disposal and treatment of sewage. Emissions from industrial wastewater treatment and discharge were mainly from seven industrial sectors, namely: Beer and malt, Dairy Products, Fish Processing, Meat and Poultry, Organic Chemicals, soap and detergents and fruit and juices. 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-level environmental reports by the EPA.

6.3 Waste sector data sources and methodology

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

6.3.1 Data sources

The data used in this inventory were obtained from different relevant national and international sources. Table 101 provides an overview of the data used in the inventory.

Table 101: Overview of data and the sources in the waste sector

Categories		Subcategories	Data Type	Data Source	Principal Data Providers
4A. Solid Waste Disposal	4A	Solid Waste Disposal	Population Figures (1950- 2019). Waste Generation Rate per Capita (1950- 2019). Amounts or % of Waste to Solid Waste. Disposal Sites. Composition/Streams of the Waste to SWDS, i.e., Food, Garden, Paper, Wood, Textiles, Nappies, Plastics, Others inert. Methods of Disposals and their various percentages, SWDS Type/Practice,i.e. Managed (≥ 5m) (Shallow and Deep), unmanaged (≤ 5m), uncategorised. Management Practices at the various SWDS. Amount of Methane Recovered from SWDS	Population Census Reports and Ghana Living, Standards Survey Reports. Published Waste National Reports, Publication from the Academia. World Bank Country Database/Reports, National Environmental Sanitation Strategy & Action Plan (NESSAP). State of the Environment Reports. Various Reports by the Private Waste Management Companies and NGOs (Zoomlion, Waste care, Jekora Ventures, etc.) Third National Communication Data from the various SWDS sites or Waste Landfill sites	Ghana Statistical Service (GSS). Academia; Civil Engineering Department, KNUST, UCC, UDS, Legon World Bank Country Database Sanitation Directorate of MLGRD. Private Waste Management Companies and NGOs (Zoomlion, Waste Care, Jekora Ventures, etc.). Environmental Protection Agency (EPA-Ghana), Sanitation Directorate of MLGRD, Ministry of Sanitation and Water Resources (MSWR)
4B. Biological Treatment of Solid Waste	4B.	Biological Treatment of Solid Waste	Fraction of waste composted. The number of compost plants and operational capacities.	Population Census Reports and Ghana Living, Standards Survey Reports, Published national reports Private Waste Management	Ghana Statistical Service (GSS). Academia; Private Waste Management Companies (Zoomlion) and NGOs Expert judgment by Waste Team
4C. Incineration and open burning	4C	4C.1 Waste Incineration	Amount and types of waste incinerated. Incinerator type including capacities and combustion efficiencies	Ghana Health Service Facts and Figures. National Environmental Sanitation Strategy Action Plan document.	Ghana Health Service. Ministry of Local Government and Rural Development. Expert Judgment by Waste Team.

				Environmental Management Plans from EPA.	Private operators (Zeal and Zoil Companies).
		4C.2 Open Burning of Solid Waste	Population figures Fraction of population burning waste. Duration of burning in the 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. Ghana Living Standards Survey 6 and 7.
4D Wastewater treatment and discharge	4D	4D.1 Domestic wastewater treatment and discharge	National population. Wastewater is generated per year. Wastewater is treated per year. Wastewater Treatment Systems and their various percentages. Protein consumption, GDP/capita (income classes).	Multiple cluster indicator survey reports World Bank Country Database. Agriculture Facts and Figures Population Census Reports Ghana Living Standards Survey reports National Environmental Sanitation Strategy & Action Plan (NESSAP)	Sanitation Directorate of MLGRD. World Bank. Ghana Health Service. Ministry of Food and Agriculture Ghana Statistical Services. Expert Judgment by Waste Team
		4D.2 Industrial wastewater treatment and discharge	The number of industries whose data on wastewater are included in the inventory. Total Industry Product Quantity of wastewater generated. Type of Wastewater. Treatment/discharge System.	Industry-level Environmental Management Report submitted to EPA	Manufacturing Industry Department of EPA. Expert Judgment by Waste Team.

6.4 Description of Waste Sector Methodology

6.4.1 Description of methods and assumptions for the estimation of emissions

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 guided data collection, methodological choices, and assumptions consistently and transparently. The guidelines further guide 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 Tier 1 and Tier 2 methodologies in estimating the emission 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. For example, the availability of national data on solid waste quantities, composition, properties, and disposal practices from 1990 to 2019 was used to estimate the emissions. The purpose of striving to use country-specific data and the higher tier was meant to help improve the robustness and quality of the estimates as much as possible. In addition, the use of the country-specific helped make the results more representative of the national situation.

Available country-specific activity data for all the categories were used. Where country-specific data did not exist, reliable international data sources were used. Most of these national data were obtained from primary or publicly available secondary sources covering the 1990-2019 time series. However, data from credible sub-regional and international sources were used where there were gaps. In the absence of data to fill the gaps, appropriate statistical methods (e.g., trends extrapolation, interpolation, etc.) were applied according to the IPCC good practice guidance, 2000. In situations where there was a complete absence of data for activities in the country, expert judgment was used, and the assumptions were documented. Detailed descriptions of the respective methodologies are given in the specific sections of the various sub-categories

6.5 Category-Specific Activity Data Inputs

The 2006 IPCC accounting rules require various activity data into the various categories to estimate the GHG emissions from a particular activity. A description of the key dataset has been provided below:

6.5.1 Solid waste disposal (4A)

Emissions from municipal solid waste disposal were composed mainly of domestic, institutional and commercial sources. The emissions were estimated considering population, per capita waste generation rate, and quantity collected and deposited in different waste disposal sites. The management style, the depth of placement, and the water table's depth were considered at the various disposal sites. The relevant waste generation and disposal data were collected from different national sources.

6.5.1.1 Total solid waste generation and deposited

The total amount of MSW generated has increased steadily from 2.09 Mt in 1990, 2.76 Mt in 2000, 4.91 Mt in 2016, to 5.24 Mt in 2019. In 2019, the MSW generated was 6%, 19%, 47% and 60% higher than the 2016, 2012, 2000 and 1990 levels respectively.

The observed increases in the annual solid waste generation were due to growing population and lifestyle changes, particularly in the urban areas. The changes have led to an increase in the average generation rate per capita. Of the 5.24 Mt generated, 4.19 Mt (80%) was deposited at the solid waste disposal sites in 2019, which represented an increase from 3.92 (80%) in 2016, 3.4 Mt (80%) in 2012, 1.7 Mt (60%) in 2000 and 0.75 Mt (36%) in 1990. A total of 4.19 Mt (in 2019) was sent to SWDs with the following compositions: (a) food (47%), (b) Paper (9%), (c) Textiles (8%) and (d) Plastics and other inert (36%). Table 102 shows the various waste composition in 2019, 2000, and 1990. In 2019, about 80% of the waste disposal sites were classified as managed-semi aerobic (i.e., according to This was the same as in 2016 but an improvement from 2012 when it was 43% managed-semi aerobic and about 56% unmanaged sites.

Table 102: Solid waste generations and Compositions deposited

Year	Total MSW Generated [Mt]	% Of MSW to SWDS	Amount of MSW to SWMS [Mt]	Composition of the Amount of Waste to SWDS [Mt]			
				Food	Paper	Textile	Plastic & Other Inert
1990	2.094	36	0.754	0.550	0.053	0.015	0.136
1991	2.149	38	0.816	0.596	0.057	0.016	0.147
1992	2.204	40	0.882	0.644	0.062	0.018	0.159
1993	2.262	42	0.950	0.693	0.066	0.019	0.171
1994	2.321	44	1.021	0.745	0.071	0.020	0.184
1995	2.381	46	1.095	0.800	0.077	0.022	0.197
1996	2.443	49	1.192	0.870	0.083	0.024	0.215
1997	2.506	52	1.293	0.944	0.091	0.026	0.233
1998	2.571	54	1.399	1.021	0.098	0.028	0.252
1999	2.638	57	1.509	1.102	0.106	0.030	0.272
2000	2.761	60	1.657	0.994	0.133	0.066	0.464
2001	2.836	61	1.725	1.035	0.138	0.069	0.483
2002	2.912	62	1.796	1.077	0.144	0.072	0.503
2003	2.991	62	1.869	1.122	0.150	0.075	0.523
2004	3.072	63	1.945	1.167	0.156	0.078	0.545
2005	3.549	64	2.277	1.366	0.182	0.091	0.638
2006	3.645	65	2.369	1.421	0.190	0.095	0.663
2007	3.743	69	2.573	1.544	0.206	0.103	0.721
2008	3.844	73	2.787	1.672	0.223	0.111	0.780
2009	3.948	76	3.010	1.806	0.241	0.120	0.843
2010	4.050	80	3.240	1.944	0.259	0.130	0.907
2011	4.151	80	3.321	1.561	0.299	0.266	1.196
2012	4.255	80	3.404	1.600	0.306	0.272	1.226
2013	4.362	80	3.489	1.640	0.314	0.279	1.256
2014	4.471	80	3.577	1.681	0.322	0.286	1.288
2015	4.786	80	3.829	1.800	0.345	0.306	1.378
2016	4.906	80	3.925	1.845	0.353	0.314	1.413
2017	5.016	80	4.013	1.886	0.361	0.321	1.445
2018	5.127	80	4.102	1.928	0.369	0.328	1.477
2019	5.240	80	4.192	1.970	0.377	0.335	1.509

6.5.2 Biological treatment of solid waste (4B)

The total amount of solid waste composted, apart from the general household composting by an individual, has been random depending on when a private or commercial composting plant is functioning. The total amount of solid waste composted in 2019 was 154.34 Gg, about 2.95% of the total national solid waste generated (in 2019, i.e., 5,239.79 Gg). The total amount of solid waste composted in 2016 was 167.09Gg, less than 4% of the total national solid waste generated. From Table 103, the amount of solid waste composted was high from 1990 until 1994, when it reduced and remained studied until 2012. The amount of solid waste composted arose again from 2012 to 2016. In 2017 the amount of solid waste composted decreased again (mainly due to the reduction in household composting) but rose again in 2019 by introducing a new compost plant (i.e., Integrated Recycling & Company Plant Limited).

Table 103: Amount of solid waste composted

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Amount Composted (Mt)	0.168	0.167	0.166	0.165	0.139	0.163	0.143	0.133	0.122	0.118
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Amount Composted (Mt)	0.116	0.117	0.119	0.119	0.120	0.132	0.132	0.128	0.128	0.128
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Amount Composted (Mt)	0.111	0.114	0.117	0.143	0.150	0.161	0.167	0.131	0.135	0.154

6.5.3 Incineration and open burning (4C)

The disposal of municipal and hazardous waste through incineration and open burning generates carbon dioxide, methane and nitrous oxide emissions. The emission levels that will be generated will depend on the amount and type of waste, the types of incineration technology used and open burning.

In all, a total of 0.68 Mt of waste (MSW, waste oil, industrial hazardous and clinical Wastes) was disposed-off through incineration and open burning in 2019. Of the total (0.68 Mt), 0.14 Mt were incinerated, whereas the remaining 0.54 Mt were openly burnt (

Table 104). Out of the 0.14 Mt waste incinerated, 0.13 Mt were a municipal solid waste, 0.00008 Mt was industrial waste, 0.00039 Mt was a hazardous waste, 0.00007 Mt was waste oil, and the other 0.01 Mt were clinical waste 2019. As of 2019, the total amount of 0.14 Mt of municipal solid waste incinerated was 35% higher than the 2016 levels of 0.09 Mt. The observed increase in the total amount of incinerated waste could result from large-scale hazardous incineration plants (Zeal Environmental Technologies Limited and Zoil Services Limited) set up from 2010.

Table 104: Solid Waste disposal by incineration and open burning

Quantities of Waste Incineration [Mt]							Open Burning [Mt]	Total [Mt]
Year	MSW	Industrial	Hazardous	Waste Oil	Clinical Waste	Total	MSW	
1990	0.053				0.0028	0.056	0.225	0.281
1991	0.053				0.0028	0.056	0.223	0.279
1992	0.053				0.0028	0.055	0.222	0.277
1993	0.052				0.0027	0.055	0.220	0.275
1994	0.052				0.0027	0.054	0.218	0.272
1995	0.051				0.0027	0.054	0.216	0.269
1996	0.050				0.0026	0.052	0.210	0.262
1997	0.048				0.0025	0.051	0.203	0.254
1998	0.047				0.0025	0.049	0.197	0.246
1999	0.045				0.0024	0.047	0.189	0.237
2000	0.044				0.0023	0.046	0.185	0.231
2001	0.044				0.0023	0.047	0.186	0.233
2002	0.044				0.0023	0.047	0.187	0.234
2003	0.045				0.0024	0.047	0.188	0.235
2004	0.045				0.0024	0.047	0.189	0.236
2005	0.051				0.0027	0.053	0.213	0.266
2006	0.051				0.0027	0.053	0.214	0.267
2007	0.056				0.0029	0.059	0.235	0.293
2008	0.063				0.0033	0.066	0.264	0.330
2009	0.071				0.0037	0.074	0.297	0.372
2010	0.068	0.00002	0.00008	0.00009	0.004	0.072	0.288	0.360
2011	0.070	0.00004	0.00008	0.00008	0.004	0.074	0.295	0.369
2012	0.072	0.00006	0.00008	0.00006	0.004	0.076	0.302	0.378
2013	0.074	0.00022	0.00131	0.00007	0.004	0.079	0.310	0.389
2014	0.075	0.00008	0.00039	0.00007	0.004	0.080	0.318	0.398
2015	0.081	0.00008	0.00039	0.00007	0.004	0.086	0.340	0.426
2016	0.083	0.00008	0.00039	0.00007	0.004	0.088	0.348	0.436
2017	0.123	0.00008	0.00039	0.00007	0.006	0.130	0.517	0.646
2018	0.125	0.00008	0.00039	0.00007	0.007	0.133	0.528	0.661
2019	0.128	0.00008	0.00039	0.00007	0.007	0.135	0.540	0.675
Change (2016-2019)	35%	0%	0%	0%	35%	35%	35%	35%

6.5.4 Wastewater Treatment and Discharge (4D)

Domestic and industrial water treatment and discharge are methane and nitrous oxide sources. The main input data for estimating the emissions were domestic wastewater, total population, biological oxygen demand (BOD), type of treatment systems, and protein intake per person per year. IPCC BOD default value of 13.51 kg BOD/person/year was used across the time series. Table 105 illustrates the rising trend of the national population and BOD per person and a decline in the protein intake per person.

Table 105: Trend of population and protein intake/capita

Year	Population (million)	Protein intake (kg/person/year)
1990	14.34	31.60
1991	14.72	31.38
1992	15.10	31.16
1993	15.49	30.94
1994	15.89	30.72
1995	16.31	30.50
1996	16.73	31.14
1997	17.17	31.78
1998	17.61	32.42
1999	18.07	33.06
2000	18.91	33.70
2001	19.42	33.10
2002	19.95	32.50
2003	20.49	31.90
2004	21.04	31.30
2005	21.61	30.70
2006	22.19	30.10
2007	22.79	29.50
2008	23.40	28.90
2009	24.04	28.30
2010	24.66	27.70
2011	25.28	27.10
2012	25.91	26.50
2013	26.55	29.30
2014	27.22	29.15
2015	27.90	29.01
2016	28.60	28.87
2017	29.24	28.75
2018	29.89	28.61
2019	30.54	28.47

The country's main domestic treatment and discharge facilities were centralised, aerobic, septic systems, latrines, sea, river and lake discharge, and stagnant sewer. In 2019, among the five treatment and discharge systems, the latrine facility was the commonest among the populace, followed by sea, river and lake discharge, septic systems, and centralised aerobic and stagnant sewer facilities (Table 106). For latrine facilities, the fraction of the rural population generally declined from 36.52% in 1990, 34.1% in 2000, 30.54% in 2012, 29.34% in 2016 to 28.67% in 2019 followed by sea, river and lake discharge thus 20.79% in 1990, 16.44 % in 2016 to 13.93% in 2019.

Dependence by the high urban communities largely was between 7.5% for the septic system, 6.4% for stagnant sewer and 5.8% for centralised aerobic treatment plant with the other systems being the least for 1990 while there was a significant increase for latrine (15.7%) and septic system (9.1%) for 2016. The use of septic systems recorded increases among low urban incomes (7%), stagnant sewer (5.9%%) and centralised aerobic systems (4.5%) for 1990. There was an increase in the use of latrine (11.5%), septic systems (8.24%) and sea, river and lake discharge (3.5%) in 2016. For the 2019 year, the dependency in urban areas was still on Latrines with a split of 17.5% for urban high and 14% for urban low. In the country's rural areas, a significant fraction of the population depends on latrines and sea, river and lake discharge (Table 106).

Table 106: Type of wastewater treatment and discharge facilities

Year	Rural					Urban High					Urban Low				
	Sea, river and lake discharge	Stagnant sewer	Latrine	Septic system	Centralised, aerobic treatment plant	Sea, river and lake discharge	Stagnant sewer	Latrine	Septic system	Centralised, aerobic treatment plant	Sea, river and lake discharge	Stagnant sewer	Latrine	Septic system	Centralised, aerobic treatment plant
1990	20.79	0.71	36.52	2.41	1.56	0.11	6.40	0.53	7.53	5.75	0.06	5.89	0.16	7.04	4.54
1991	20.71	0.69	36.40	2.35	1.48	0.19	6.31	1.02	7.40	5.49	0.23	5.84	0.62	6.79	4.48
1992	20.63	0.67	36.21	2.22	1.38	0.38	6.22	1.98	7.11	5.31	0.51	5.53	1.01	6.54	4.29
1993	20.52	0.65	36.11	2.10	1.30	0.57	5.87	2.34	6.91	5.20	0.62	5.25	2.05	6.29	4.22
1994	20.45	0.63	35.95	1.98	1.25	0.82	5.37	2.73	6.73	5.15	0.73	4.79	3.19	6.04	4.18
1995	20.26	0.61	35.65	1.86	1.21	0.94	5.19	3.69	6.45	4.72	0.84	4.59	4.07	5.79	4.13
1996	20.09	0.59	35.47	1.77	1.18	1.07	4.71	4.93	6.22	4.50	0.97	4.28	4.48	5.65	4.09
1997	19.90	0.52	35.15	1.63	1.09	1.10	4.20	6.52	5.90	4.06	1.03	3.82	6.03	5.36	3.69
1998	19.73	0.48	34.73	1.49	0.98	1.19	3.87	8.10	5.59	3.61	1.12	3.36	7.40	5.08	3.28
1999	19.57	0.45	34.31	1.34	0.86	1.33	3.30	9.88	5.38	3.27	1.22	2.97	8.27	4.87	2.98
2000	19.40	0.41	34.08	1.27	0.75	1.47	3.01	11.19	5.06	2.83	1.35	2.54	9.49	4.58	2.58
2001	19.24	0.34	33.93	1.13	0.69	1.61	2.47	12.77	4.75	2.38	1.48	2.41	10.35	4.30	2.17
2002	19.07	0.28	33.83	0.99	0.63	1.74	1.93	13.98	4.43	2.28	1.60	2.05	11.41	4.01	1.77
2003	18.90	0.22	33.53	0.92	0.57	1.88	1.40	15.26	4.32	1.83	1.73	1.49	12.36	3.93	1.67
2004	18.87	0.16	33.20	0.77	0.44	2.02	0.86	16.47	4.01	1.39	1.85	0.94	14.11	3.65	1.26
2005	18.76	0.11	32.88	0.63	0.32	2.18	0.42	17.55	3.69	0.94	1.98	0.38	15.94	3.36	0.86
2006	18.48	0.13	32.50	0.63	0.29	2.28	0.36	17.36	4.18	0.94	2.07	0.33	15.79	3.80	0.86
2007	18.13	0.15	32.13	0.63	0.25	2.38	0.30	17.24	4.67	0.95	2.16	0.28	15.63	4.25	0.86
2008	17.77	0.16	31.81	0.64	0.22	2.48	0.25	17.05	5.16	0.95	2.26	0.22	15.47	4.69	0.87
2009	17.42	0.18	31.46	0.64	0.18	2.58	0.19	16.86	5.65	0.96	2.35	0.17	15.35	5.14	0.87
2010	17.35	0.20	31.00	0.64	0.15	2.68	0.13	16.61	6.14	0.96	2.44	0.12	15.13	5.58	0.87
2011	17.40	0.22	30.84	0.65	0.13	2.92	0.12	16.56	6.63	0.97	2.62	0.11	13.91	6.02	0.88
2012	17.21	0.24	30.54	0.65	0.12	3.05	0.11	16.38	7.12	0.97	2.73	0.11	13.44	6.47	0.88
2013	17.01	0.25	30.24	0.65	0.10	3.17	0.10	16.20	7.61	0.98	2.84	0.10	12.95	6.91	0.88

2014	16.82	0.27	29.94	0.66	0.08	3.29	0.09	16.02	8.10	0.98	2.95	0.09	12.45	7.36	0.89
2015	16.63	0.29	29.64	0.66	0.07	3.42	0.08	15.84	8.59	0.99	3.07	0.09	11.96	7.80	0.89
2016	16.44	0.31	29.34	0.66	0.05	3.54	0.07	15.65	9.08	0.99	3.18	0.08	11.48	8.24	0.89
2017	14.85	0.18	29.18	1.03	0.18	2.75	0.10	17.16	8.75	0.73	2.45	0.20	13.88	7.97	0.59
2018	12.74	0.09	29.13	1.71	0.26	1.73	0.12	19.15	8.01	0.35	1.57	0.11	17.40	7.31	0.32
2019	13.93	0.17	28.67	1.22	0.19	2.66	0.15	17.49	9.38	0.63	2.36	0.04	14.01	7.97	0.49

Datasets on total industry products, COD and BOD levels, wastewater generated, and the fraction treated for seven main industrial sectors were obtained from the Environmental Management Plans (EMPs) and Environmental performance assessment disclosure reports submitted to the EPA. The Manufacturing Industry Department, EPA, collected the reports. In 2019, industry products from the Organic chemical industry constituted 46.5% of the industries, followed by beer and malt (17.2%), fish processing (13.4%), dairy products (11.8%), Fruit and Juice (7.4%), meat and poultry (3.1%), and Soap and Detergents (0.6%) (Table 107). The increase percentage change between 2016 and 2019 was positive across all industry products reported. The highest percentage change was 88% for fish processing, and the least was 9% attributed to soap and detergent.

Table 107: Total Industry Product in tonnes per year

Year	Beer and Malt	Dairy Products	Fish Processing	Meat and Poultry	Organic Chemicals	Soap & Detergent	Fruit & Juice
1990						5,760	
1991						5,721	
1992						3,940	
1993						4,007	
1994						4,041	
1995						3,020	
1996						3,241	
1997						5,000	15,089
1998					15	4,248	15,733
1999					18	4,240	16,865
2000				3,146	22	4,671	15,560
2001		10,882		5,692	21	6,070	19,602
2002		14,128		5,557	173	7,000	22,225
2003		16,465		7,736	174	6,811	22,421
2004		24,002		9,137	3,778	6,746	22,994
2005	9,396	23,973		10,587	3,093	6,080	23,696
2006	46,900	22,045	36,174	12,104	2,425	6,840	25,022
2007	153,279	27,001	31,979	13,644	541,480	4,831	23,948
2008	148,479	28,275	46,677	11,215	539,530	3,020	72,547
2009	158,880	39,701	37,494	11,752	525,181	5,080	52,503
2010	160,506	41,514	42,367	14,772	468,741	7,843	63,088
2011	179,728	35,552	43,542	27,692	501,895	7,915	75,517
2012	186,679	44,613	46,317	20,285	531,457	8,068	86,469
2013	172,384	59,807	33,116	30,724	537,788	8,221	90,752
2014	171,986	75,650	19,915	41,164	710,560	8,374	93,783
2015	219,198	127,019	22,942	42,789	670,072	8,527	97,047
2016	213,136	153,421	25,809	44,415	664,753	8,680	00,312
2017	236,112	153,671	200,210	46,410	662,960	8,910	05,600
2018	244,727	170,248	212,290	48,404	696,586	9,217	14,161
2019	270,804	186,824	212,290	50,398	733,424	9,370	117,423
Change 2016- 2019	21%	18%	88%	12%	9%	7%	15%

6.6 Description of notation key and completeness information

Information on completeness and notation keys in the Waste sector is provided below. Completeness includes coverage of gases, categories and as well as time series. Additional information is given on the status of emission estimates of all sub-categories. Emissions of all sub-categories of category 4A (Solid Waste Disposal), 4B (Biological Treatment of Solid Waste), 4C (Incineration and Opening Burning of Solid Waste) and 4D (Wastewater treatment and discharge). Table 108 contains information on the completeness status of the estimations under various sub-categories.

Table 108: Overview of sub-categories of waste and status of estimations

IPCC Category	Time Series Completeness								Status of Gas		
	2013-2016 (Previous Estimates)				2017-2019 (Latest Estimates)						
	E	NE	NO	IE	E	NE	NO	IE	CO_2	CH_4	N_2O
Solid Waste Disposal	x				x				NO	x	NO
Biological Treatment of Solid Waste	x				x				NO	x	x
Incineration	x				x				x	x	x
Open Burning	x				x				x	x	x
Domestic wastewater treatment and discharge	x				x				NO	x	x
Industrial wastewater treatment and discharge	x				x				NO	x	NO

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

6.7 Identification of key categories in the Waste sector

The methodology and results of the key category analysis in the waste sector are presented in Table 109. Methane emissions from solid waste disposal, biological treatment of solid waste and wastewater treatment and discharge were the key categories in terms of trends (1990-2019), whilst solid waste disposal and wastewater treatment and discharge are key categories in terms of levels (2019) for the waste sector.

Table 109: Results of the key category analyses of the waste sector

IPCC Category Code	IPCC Category	GHG Type	2019 Level Assessment	Trend Assessment (2016-2019)
4.A.1	Solid Waste Disposal	CH_4	2019	TA
4. B	Biological Treatment of Solid Waste	CH_4	2019	TA
4.D	Wastewater Treatment and Discharge	CH_4, N_2O	2019	TA
4.A.2	Unmanaged Waste Disposal Sites	CH_4	-	TA

The levels of methane emissions from solid waste disposal and wastewater treatment and discharge were a result of the following: rising population, especially in the major cities, an increase in efficiency of waste collection, disposal and treatment, and no methane recovery in the landfills, poor state of existing treatment systems and discharge pathways.

6.8 Time-series consistency in the Waste sector

6.8.1 Waste sector recalculations

Recalculations have been done for the waste sector mainly due to changes in some activity data due to the identification and use of new datasets on the total industry product from the Industrial wastewater and discharge. Detailededed information on the description of the reasons and impacts of the recalculations has been provided. The result of the assessment of recalculation and its impacts are shown in Table 110.

Table 110: Assessment of the impacts of recalculation on the previous estimates

Years	Total Methane Emissions		
	Previous Estimates	Latest Estimates	% Change
2005	1205.30	1202.87	-0.202
2006	1280.66	1281.83	0.091
2007	1811.07	1812.06	0.055
2008	1904.30	1896.96	-0.387
2009	1973.12	1973.48	0.018
2010	2015.97	2016.03	0.003
2011	2138.53	2138.78	0.012
2012	2190.70	2190.48	-0.010
2013	2242.28	2241.04	-0.055
2014	2493.47	2432.23	-2.518
2015	2485.34	2480.27	-0.204
2016	2559.71	2564.07	0.170

Reasons for recalculations

Recalculations led to the revision of the previous activity data only. The re-calculation was due to the improvement in the total industry product data set (tonnes/year), which was missing during the previous Industrial Wastewater treatment and discharge inventory. The new data sets were mainly improved data from the Beer & Malt and Soap & Detergent Industry sectors from 2005 to 2016. The effect was minimal since the improved data was due to little variations in industry products (from 2005 to 2016) and for only Beer & Malt and Soap & Detergent Industry sectors. The percentage change also affected only the methane emissions and explained the changes in the emissions illustrated in Table 110.

6.8.2 Filling of data gaps

The data gaps 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 data type and the nature of the gaps. Table 111 presents the data gaps and how they were filled.

Table 111: Data gaps and the method used

Category	Data Gap	Method applied	Justification for the methodology used	Description of approach for filling 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 the 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 of interval years. The annual average difference was applied to the preceding known figure to generate the missing annual data
Wastewater 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 shares were obtained from the Ghana Statistical Service for 1990 and 2010	Based on the available 1990 and 2010 urban and rural population share, the 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 the population in different income classes using different waste treatment facilities. Missing data from 1990 to 2004, 2007-2010 and 2012	Interpolation	Data on populations using different treatment systems were obtained from the Multiple Cluster Indicator Survey data for 2011, 2005, 2006	The fraction of the population using different treatment systems was derived every five years in the time series. For every five years, interpolation was made using the average interpolation factor. The factor is derived from the difference between the two known years and divided by the difference in the intervening years.
	Missing data from total industry product	Interpolation and extrapolation	Data from an industry report	Based on the available data, the interpolation factor was derived by finding the difference between the share for the years and dividing by the year.

6.9 Quality Control/Quality Assurance

The QA/QC procedures followed in the waste sector are detailed in Table 112.

Table 112: 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 tasks among the inventory team to ensure that one or two team members always focus on double checking and that data errors associated with those described in the left column are avoided.
	Comparison with published data/literature	Data on per capita solid waste generation and the fraction of waste composited 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 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 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 used were kept to help 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: • easy understanding and further probing of how the final results in the IPCC software would like, • easy cross-referencing and avoidance of mistakes, • easy transmission into the IPCC software and • 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 to record all data sources and assumptions.
	Check for transcription, typographical errors and error transposition.	Check mistakes and blunders in data entry into the software
	Checked completeness of data coverage	Ensuring all the relevant gases for the specific activity were covered.
Results)	Check of recalculation differences	To identify and pinpoint changes, revisions and reallocation to improve the 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 prioritise areas that require action.

6.10 Waste sector emission trends

In 2019, the total waste sector emissions stood at 3.6 $MtCO_2e$ representing an increase of 12% from the 2016 levels of 3.17 $MtCO_2e$. The sector emissions have seen a consistent rise from 1.02 $MtCO_2e$ in 1990 to 3.17 $MtCO_2e$ in 2016 and further to 3.60 $MtCO_2e$ in 2019 (Figure 72). The growing waste emissions correspond to the rising emissions from wastewater treatment and discharge and solid waste disposal. Within the waste sector, wastewater treatment and discharge (4D) contributed the largest emissions of 56.7% to the total emissions in 2019. The 4D emissions are followed by solid waste disposal (36.1%), incineration and open burning of waste (4.2%) and biological treatment of solid waste (2.3%).

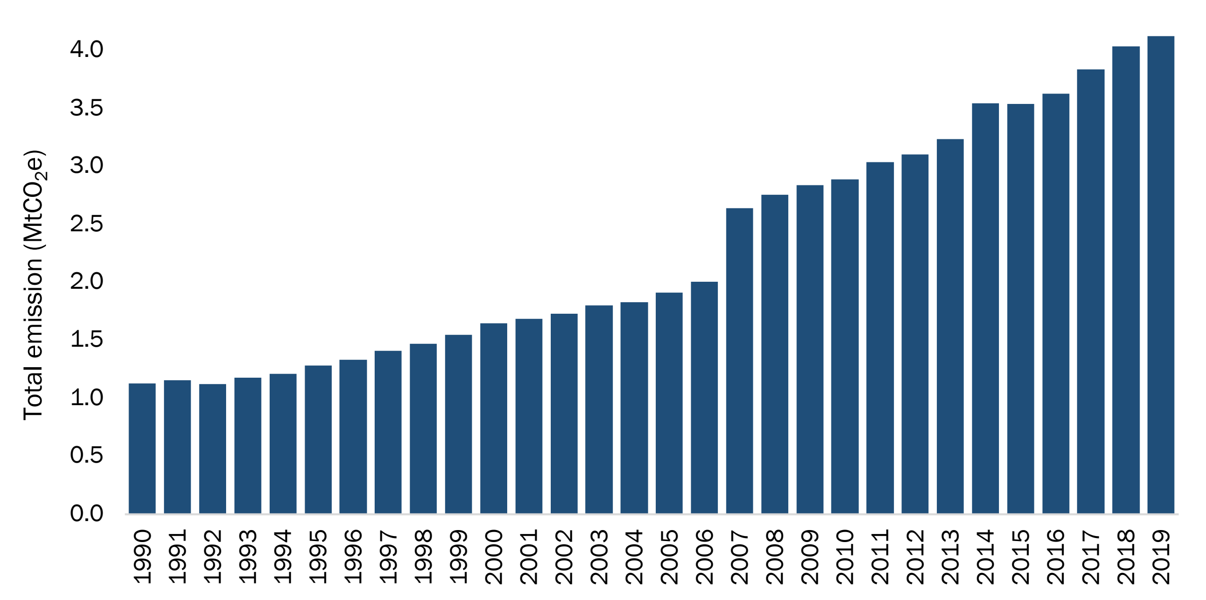


Figure 72: Total emission trends in the waste sector

In 2019, the total emissions of 3.60 $MtCO_2e$ represented 257.9% and 42.5% above the 1990 and 2016 levels, respectively. The rising trend is associated with: (a) rising domestic and industrial wastewater generation because of increasing population and expansion of industrial production; (b) inadequate wastewater treatment facilities; and (c) a significant amount of untreated wastewater, particularly from households.

Emissions from solid waste disposal recorded similar trends rising steadily from 0.26 $MtCO_2e$ in 1990, 1.16 $MtCO_2e$ in 2016 and 1.32 $MtCO_2e$ in 2019. The observed emissions trends can be attributed to the growing population, changing lifestyles due to improving socio-economic conditions in the country, particularly in the large cities, increased the fraction of solid deposited on solid waste disposal sites and non-existing landfill management programmes. The waste sector emissions came from biological treatment of solid waste (compositing), incineration, and open burning. The emissions from biological treatment of solid waste, incineration and opening burning all recorded increases (Figure 73).

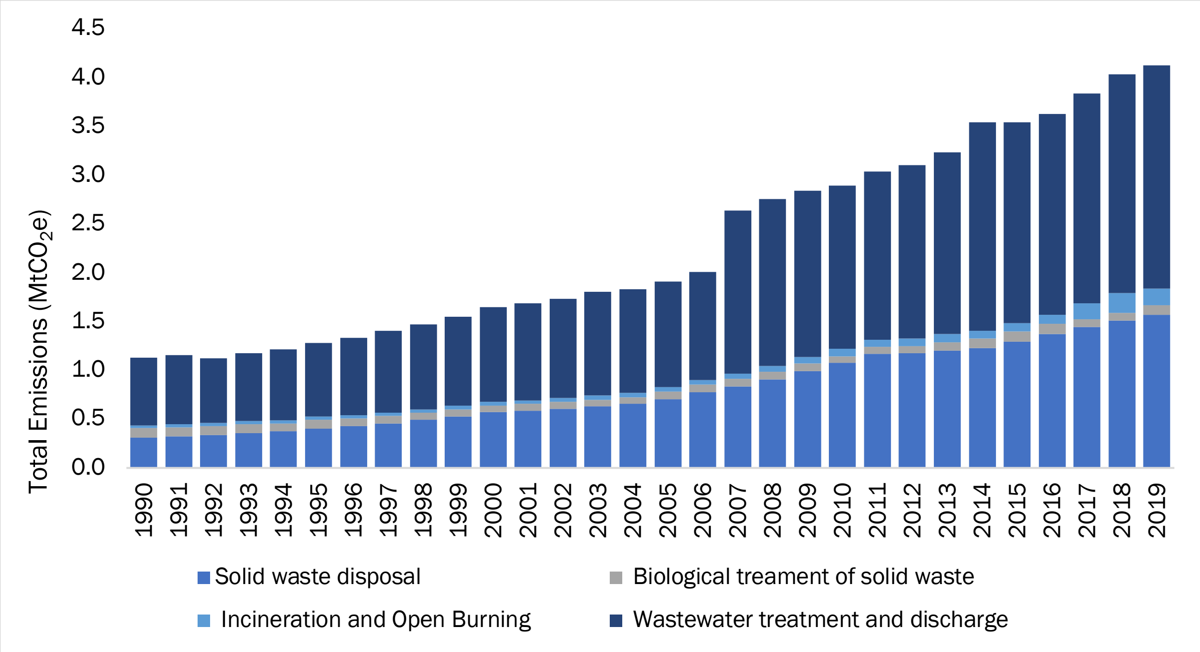


Figure 73: Total emissions trend according to sub-categories in the Waste sector

Methane is the most important gas in the waste sector. It constituted 80.9% of the total emissions from the waste sector in 2019 (Table 6.13). Within the waste sector, wastewater treatment and discharge (4D) are the dominant sources of methane (49.2%), closely followed by solid waste disposal (45.4%). 3.9% was emitted from incineration and opening (4C) and 1.56% from biological solid waste treatment (4B) in 2019. Nitrous oxide emissions are the next important greenhouse gas making up 18.7% of the total emissions from the waste sector. Wastewater treatment and discharge (4D) account for the most nitrous oxide emissions making up 90.5% of the total nitrous oxide emission in the waste sector in 2019 (Table 113). The rest of the waste sector emission was carbon dioxide, accounting for 0.4% of the total waste sector emissions.

Table 113: Waste sector emissions according to gases

Year	CO_2	CH_4 ($GgCO_2e$)					N_2O ($GgCO_2e$)			
	4C	4A	4B	4C	4D	Total	4B	4C	4D	Total
1990	2.97	263.65	46.93	18.24	331.13	659.95	41.57	4.37	309.12	355.05
1991	3.03	270.40	46.68	18.71	342.05	677.85	41.35	4.46	314.95	360.75
1992	3.07	282.04	46.40	19.19	295.66	643.29	41.09	4.54	320.87	366.50
1993	3.12	297.28	46.07	19.68	323.34	686.36	40.80	4.63	326.89	372.32
1994	3.17	315.30	40.44	20.18	339.55	715.47	35.82	4.72	333.00	373.54
1995	3.22	355.58	45.58	20.70	362.60	784.47	40.37	4.77	339.21	384.36
1996	3.25	357.85	41.01	21.23	375.83	795.91	36.32	4.89	335.34	376.55
1997	3.29	383.88	38.59	21.77	398.09	842.32	34.18	4.97	379.56	418.71
1998	3.32	413.07	35.88	22.32	418.38	889.66	31.78	5.06	389.43	426.27
1999	3.36	444.88	34.55	22.89	438.67	940.99	30.60	5.14	407.44	443.18
2000	3.46	479.11	34.14	23.94	464.63	1001.82	30.24	5.33	434.66	470.23
2001	3.54	491.99	34.34	24.58	480.77	1031.68	30.41	5.46	438.45	474.32
2002	3.62	508.80	34.86	25.24	496.08	1064.99	30.88	5.59	442.13	478.59
2003	3.70	528.79	34.94	25.92	511.16	1100.81	30.95	5.72	445.68	482.36
2004	3.78	550.86	35.00	26.61	529.28	1141.75	31.00	5.86	449.11	485.97

2005	4.35	589.12	38.68	30.74	544.33	1202.87	34.26	6.75	452.39	493.40
2006	4.44	650.17	38.80	31.57	561.30	1281.83	34.36	6.91	455.53	496.80
2007	4.98	703.00	37.60	35.50	1035.97	1812.06	33.30	7.75	458.50	499.56
2008	5.50	761.73	37.59	39.11	1058.54	1896.96	33.29	8.56	461.30	503.16
2009	6.13	832.76	37.69	43.42	1059.60	1973.48	33.38	9.52	463.92	506.83
2010	7.20	906.97	32.61	47.85	1028.60	2016.03	28.88	10.35	465.84	505.07
2011	7.34	983.70	33.43	48.82	1072.83	2138.78	29.61	10.57	467.14	507.31
2012	7.18	990.57	34.26	50.04	1115.61	2190.48	30.34	10.83	468.22	509.40
2013	9.11	1008.74	44.23	51.29	1136.78	2241.04	39.17	11.14	530.64	580.95
2014	7.97	1034.40	46.01	52.57	1299.25	2432.23	40.75	11.39	541.12	593.25
2015	8.48	1088.89	49.50	56.28	1268.79	2463.45	43.84	12.19	541.12	597.15
2016	8.68	1155.21	51.37	57.70	1265.73	2530.01	45.57	12.49	541.12	599.18
2017	15.00	1215.69	38.60	107.36	1335.67	2697.32	34.19	22.76	581.30	638.25
2018	15.31	1269.57	39.67	109.74	1405.10	2824.09	35.14	23.26	594.21	652.61
2019	15.63	1321.27	45.38	112.14	1430.98	2909.77	40.19	23.77	607.22	671.18

6.11 Summary description of source-specific categories emission trends

6.11.1 Solid waste disposal (4A)

Key category: CH_4 emissions (LA – 2019, TA: 2016-2019)
Ghana estimates CH_4 emissions from solid waste disposal using figures on the amounts and compositions of the waste disposed into SWDS and the waste management practices at the disposal sites. The nature of the management practice at the final solid waste disposal site determines anaerobic conditions which produce methane. Solid waste is disposed-off and treated by unmanaged sites (dump sites) and few managed sites (landfills). Over the years, it has been observed that the amount of waste deposited keeps increasing due to the increase in waste generated, which is influenced by population increase.

The fraction of solid waste collected for deposition at solid waste disposal site have also recorded increases. As of 2019, there were five operational engineered sanitary landfills and 172 official dumpsites in the Country. Most of the disposal sites in the country are unmanaged, with very few well-managed sites, and well-engineered landfills are normally overloaded and not properly managed. Most disposal sites are unmanaged dump sites, and only four well-engineered landfills are not properly managed. The total of 5.24 Mt of MSW generated in 2019 represented 60%, 47%, 19% and 6% higher than the 1990 (base year), 2000, 2012 and 2016 MS, respectively.

Similarly, the fraction of MSW collected and deposited for the period 1990-2019 increased from 36% in 1990, 60% in 2000 and 80% from 2012 to 2019. From Table 74, the amount deposited at the SWDS increased from 0.75 Mt in 1990, 1.66 Mt in 2000, 3.4 Mt in 2012, 3.93 Mt in 2016 and finally to 4.19 Mt in 2019. The 2019 waste deposited was a 6.4% increase over the 2016 year. The increasing trend in waste collection and disposal in Ghana is due to the policy shift in Public-Private Partnership (PPPs) arrangements (private sector to about 80% of waste). Notwithstanding the increase in waste collection, no policy has been introduced to ensure methane collection from the final disposal sites.

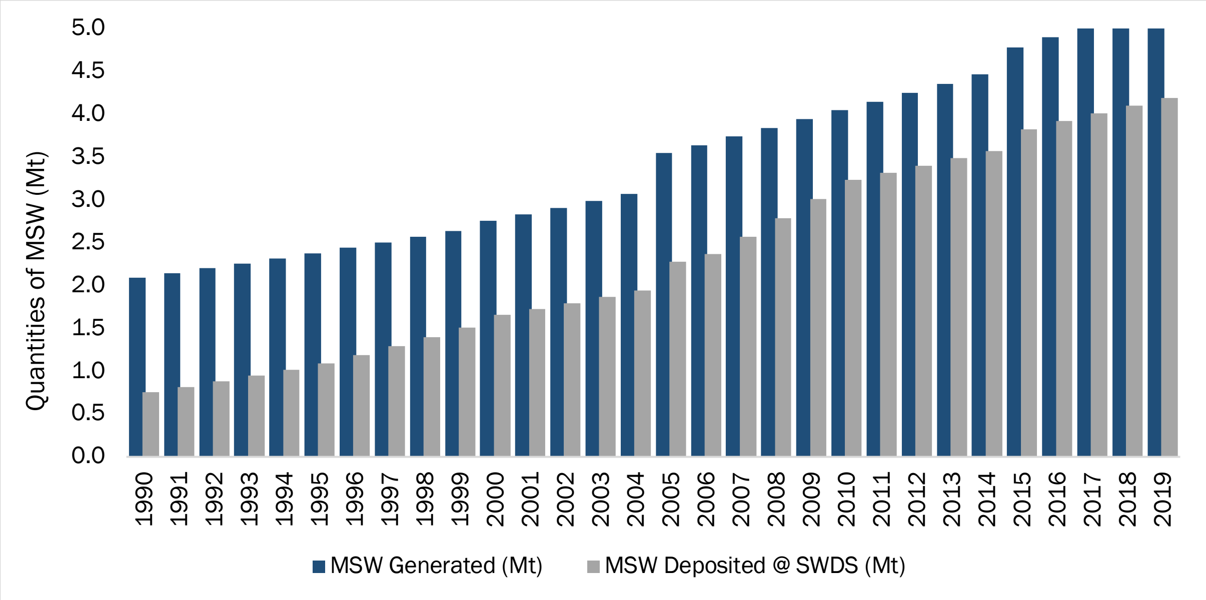


Figure 74: Trends of total MWS generation and fraction of deposited

Between 1990 and 2019, the country had three distinctive waste streams, and these can be grouped under 1990- 1999, 2000-2010 and 2011-2019. Food waste dominated the waste stream in the country, constituting about 73% in 1990-1999, reduced to 60% from 2000 to 2010 and finally to 47% in 2011-2019. The paper fraction also increased from 7%, 8% to 9% in 1990-1999, 2000 to 2010 and 2011-2019, respectively. The trends for the different streams of MSW deposited in SWDS are shown in Figure 74. The increasing MSW generation and fractions deposited at SWDS translated to similar patterns of CH_4 emissions for the solid waste disposal category (4A). Figure 75 shows the CH_4 emissions trend.

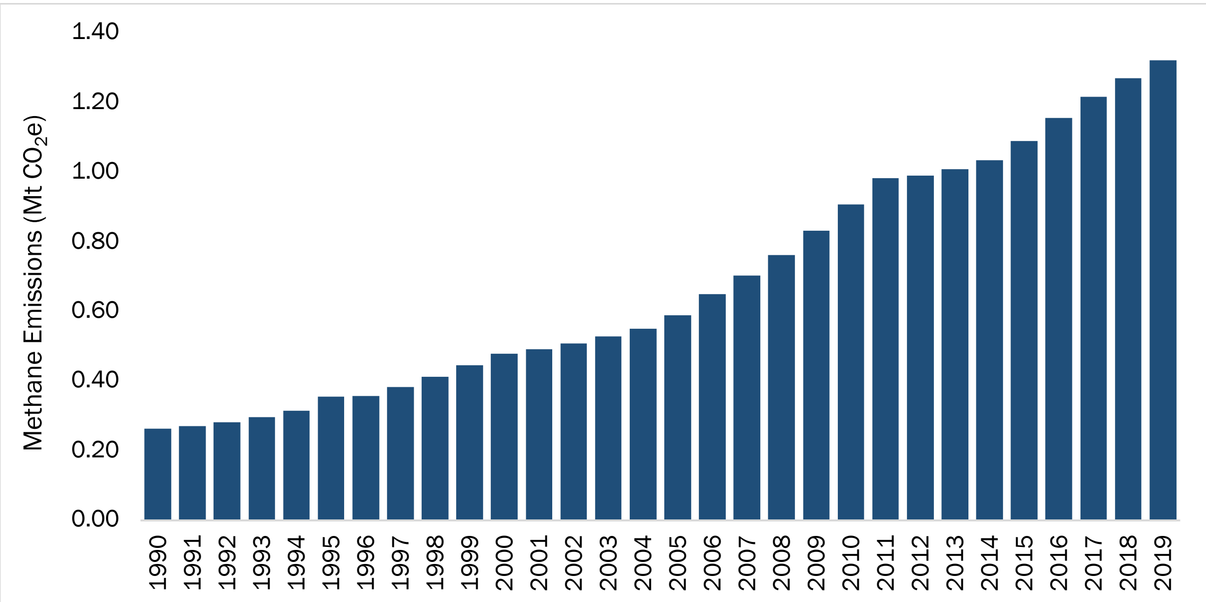


Figure 75: Total emission trends from solid waste disposal

It was observed that CH_4 emissions increased with the amount of waste collected and disposed of increases from 1990 to 2019. The increasing trend in the amount of waste disposed of at SWDS reiterates the afore mention policy shift over the years in solid waste service provision from central government to the sole provision by local governments and now the involvement of the private sector in the country. In the early 1990s, there was a policy shift towards private sector-led development, which led to contracting out and franchising the solid waste collection services to the private sector in Accra and Tema.

In 1995 Private Sector Involvement (PSI) in solid waste services in four of the selected cities (Tema, Takoradi, Kumasi, Tamale) was supported as a component of the Urban Environmental Sanitation Project (UESP-World Bank funded), and the private sector was to collect 40% of waste, and in 1999 Policy shift in public, private partnerships arrangements where the private sector was to collect 80% of waste. The shift helped increase the amount of waste collected and deposited for treatment on landfill sites. Although the policy that allowed private sector participation yielded some efficiency in waste collection and disposal, not much has been done to improve the management of waste disposal sites. In addition, the existing policy does not offer clarity on landfill gas management.

6.11.1.1 Methodological issues in the solid waste disposal category

The key parameters used in calculating the emission were (a) the amount of MSW generated, (b) the 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 MSW generated was obtained from the annual national population trend and per capita solid waste generation products. The national population data were obtained from the national population census for 1984, 2000 and 2010.

The intervening years' population was derived using the inter-census population growth rate published by the Ghana Statistical Service. Various studies and consultations with the waste management departments of some major MMDAs helped obtain solid waste generation rates for specific years. For other years, the waste generation rates were interpolated or were based on expert judgments (Table 114). After estimating the amount of waste generated, the waste deposited was calculated with the various percentage estimates from each year. The fraction of MSW collected and deposited were obtained from national experts from Accra and Tema Metropolitan Assemblies, Zoomlion Ghana Limited and the data published in the Ghana Living Standard Survey (2008, 2014, 2019).

Table 114: Overview of the amount of waste collected and deposited

Year	Population (Mil)	Waste per Capita (kg/Cap/year)	Total MSW Generated (Gg)	% to SWDS	MSW Deposited to SWDS (Gg)
1990	14.34	146.0	2,094.13	36.0	753.89
1991	14.72	146.0	2,148.58	38.0	816.46
1992	15.10	146.0	2,204.44	40.0	881.78
1993	15.49	146.0	2,261.76	42.0	949.94
1994	15.89	146.0	2,320.56	44.0	1021.05
1995	16.31	146.0	2,380.90	46.0	1095.21
1996	16.73	146.0	2,442.80	48.8	1192.09
1997	17.17	146.0	2,506.31	51.6	1293.26

1998	17.61	146.0	2,571.48	54.4	1398.88
1999	18.07	146.0	2,638.34	57.2	1509.13
2000	18.91	146.0	2,761.16	60.0	1656.70
2001	19.42	146.0	2,835.71	60.8	1724.97
2002	19.95	146.0	2,912.28	61.7	1795.71
2003	20.49	146.0	2,990.91	62.5	1869.29
2004	21.04	146.0	3,071.67	63.3	1945.29
2005	21.61	164.3	3,548.93	64.2	2277.20
2006	22.19	164.3	3,644.75	65.0	2369.09
2007	22.79	164.3	3,743.15	68.8	2573.42
2008	23.40	164.3	3,844.22	72.5	2787.06
2009	24.04	164.3	3,948.01	76.3	3010.36
2010	24.66	164.3	4,050.21	80.0	3240.17
2011	25.28	164.3	4,151.47	80.0	3321.17
2012	25.91	164.3	4,255.25	80.0	3404.20
2013	26.55	164.3	4,361.63	80.0	3489.31
2014	27.22	164.3	4,470.68	80.0	3576.54
2015	27.90	171.6	4,786.11	80.0	3828.89
2016	28.60	171.6	4,905.76	80.0	3924.61
2017	29.24	171.6	5,016.14	80.0	4012.91
2018	29.89	171.6	5,127.50	80.0	4102.00
2019	30.54	171.6	5,239.79	80.0	4191.83

Methane recovery does not occur at any of the landfills in Ghana. Methane recovery was therefore assumed to be zero throughout the time series. The composition of waste available for Ghana was normally for the total municipal waste. The country's general composition of municipal waste is shown in Table 115. The composition of waste in Ghana was predominantly made of biodegradable materials and a high percentage of inert materials. The inert material was mostly made of wood ash, sand and charcoal. The food waste ranges from 73-47%, paper from 7-9%, textile 2-8%, plastics 3-17% and others 15-20% for the various waste streams. Most of the garden and wood waste was combined with the food waste, and also nappies were included in 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 115: Composition of municipal solid waste

Years	Food	Garden	Paper	Wood	Textile	Nappies	Plastics	Others	Total
	(73%,60%,47%)	IE	(7%,8%,9%)	IE	(2%, 4%, 8%)	IE	(3%,8%, 17%)	(15%,20%,19%)	MSW Deposited to SWDS (Gg)
1990	550.34	IE	52.77	IE	15.08	IE	22.62	113.08	753.89
1991	596.02	IE	57.15	IE	16.33	IE	24.49	122.47	816.46
1992	643.69	IE	61.72	IE	17.64	IE	26.45	132.27	881.78
1993	693.45	IE	66.49	IE	18.99	IE	28.49	142.49	949.94
1994	745.37	IE	71.47	IE	20.42	IE	30.63	153.16	1021.05
1995	799.51	IE	76.66	IE	21.90	IE	32.86	164.28	1095.21

1996	870.22	IE	83.45	IE	23.84	IE	35.76	178.81	1192.09
1997	944.08	IE	90.53	IE	25.86	IE	38.79	193.99	1293.26
1998	1021.19	IE	97.92	IE	27.98	IE	41.97	209.83	1398.88
1999	1101.66	IE	105.64	IE	30.18	IE	45.27	226.37	1509.13
2000	994.019	IE	132.54	IE	66.27	IE	132.54	331.34	1656.69
2001	1034.97	IE	137.99	IE	68.99	IE	137.99	344.99	1724.97
2002	1077.43	IE	143.66	IE	71.83	IE	143.66	359.14	1795.71
2003	1121.57	IE	149.54	IE	74.77	IE	149.54	373.86	1869.29
2004	1167.17	IE	155.62	IE	77.81	IE	155.62	389.06	1945.29
2005	1366.32	IE	182.18	IE	91.09	IE	182.18	455.44	2277.20
2006	1421.45	IE	189.53	IE	94.76	IE	189.53	473.82	2369.09
2007	1544.05	IE	205.87	IE	102.94	IE	205.87	514.68	2573.42
2008	1672.24	IE	222.96	IE	111.48	IE	222.96	557.41	2787.06
2009	1806.22	IE	240.83	IE	120.41	IE	240.83	602.07	3010.36
2010	1944.10	IE	259.21	IE	129.61	IE	259.21	648.03	3240.17
2011	1560.95	IE	298.91	IE	265.69	IE	564.60	631.02	3321.17
2012	1599.98	IE	306.38	IE	272.34	IE	578.71	646.79	3404.20
2013	1639.98	IE	314.04	IE	279.15	IE	593.18	662.97	3489.31
2014	1680.97	IE	321.88	IE	286.12	IE	608.01	679.54	3576.54
2015	1799.58	IE	344.60	IE	306.31	IE	650.91	727.49	3828.89
2016	1844.57	IE	353.22	IE	313.97	IE	667.18	745.675	3924.61
2017	1886.07	IE	361.16	IE	321.03	IE	682.19	762.453	4012.91
2018	1927.94	IE	369.18	IE	328.16	IE	697.34	779.380	4101.99
2019	1970.16	IE	377.27	IE	335.35	IE	712.61	796.448	4191.83

The “tier 2” methodology based on national data on waste quantities, composition, properties, and disposal practices was used to estimate the methane emissions from the various disposal sites. The First-Order Decay (FOD) methodology for calculating 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. Due to the FOD methodology for calculating the methane generation, waste deposited at the SWDS was estimated from 1950 to 1990. Only the methane remaining after subtraction of methane recovered is available for oxidation. In Ghana’s case, there was no Methane recovery.

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. It is estimated based on information on disposal of different waste categories (municipal solid waste, industrial and other waste) and the different waste types/materials (food, paper, wood, textiles, etc.) included in these categories, or as mean DOC in bulk waste disposed of. 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 generated throughout the years was estimated based on 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.

6.11.1.2 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. The IPCC default values were used based on the lack of data from the waste management sectors. Fraction of Degradable Organic carbon that decomposes (DOCf) estimates the fraction of carbon that is ultimately degraded and released from SWDS and reflects that some degradable organic carbon does not degrade or degrade slowly under anaerobic conditions the SWDS.

The recommended IPCC default value for Western Africa by weight fraction on the 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^{o} C) for the IPPC default range was 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 include; (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).

6.11.2 Biological treatment of solid waste (4B)

Key category: CH_4 emissions (LA, 2019)

Composting is the major biological treatment of solid waste in Ghana. Methane and Nitrous oxide gases are the dominant emissions in compositing. In the past, composting was mostly practised in backyard 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 of 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 (ACARP) by Zoomlion Ghana Limited in 2012, the Integrated Recycling and Compost Plant Limited located at Korle-Bu (IRECOP) in 2019, and the partnership venture between CHF International and Jekora Ventures has increased composting in Ghana. The amount of compost is likely to increase from 2020 with the commissioning of several composts in 2020 by Zoomlion Ghana.

From Figure 76, the trends for solid waste composting were high from 1900 to 1994 when the Teshie-Nungua composting plant was operational and started dropping when the plant broke down. Solid waste to compost rose again in 2012-2013 when the ACARP was commissioned and started operations. In 2017 the amount of household composting reduced from the previous years. In 2019, a new compost plant was introduced, Integrated Recycling and Compost Plant Limited, located at Korle-Bu (IRECOP) 2019. In 2019, the total amount of solid waste composted amounted to 0.154 Mt, representing a decrease of 8% in 2016 but 24% in 2012.

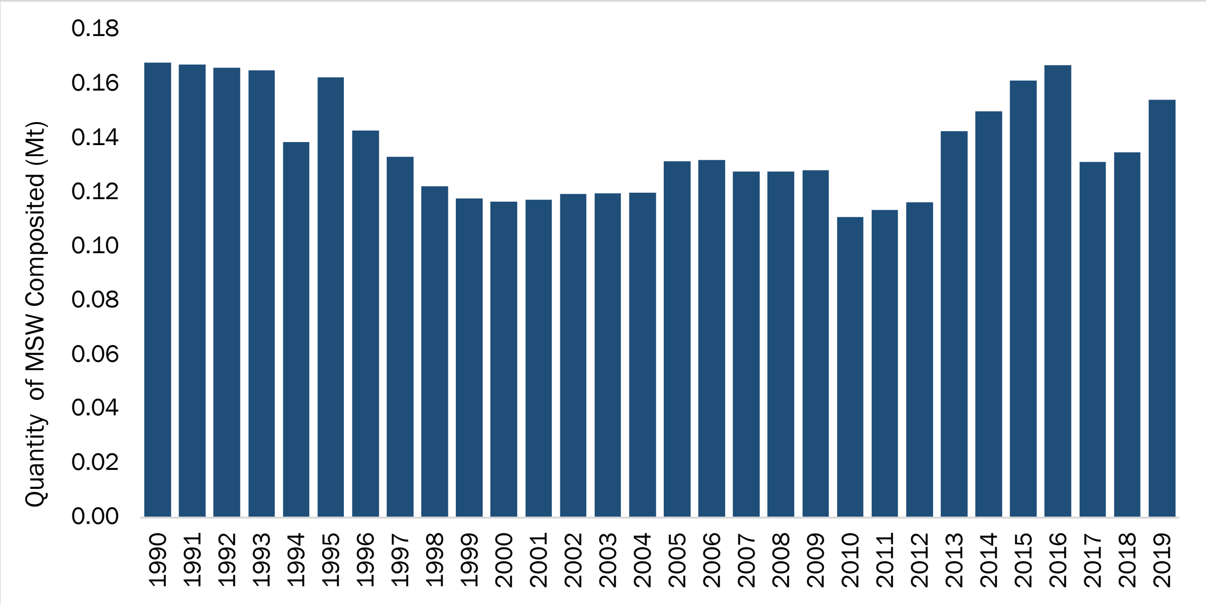


Figure 76: Trend of fractions of MSW composited

Generally, total GHG emissions associated with waste composting amount to 0.09 $MtCO_2e$ in 2019. The 2019 emission levels are 0.01 $MtCO_2e$ lower than the 2016 levels. The observed decreases may be related to the reduction in household composting and was back to normal in 2019 due to the introduction of IRECOP.

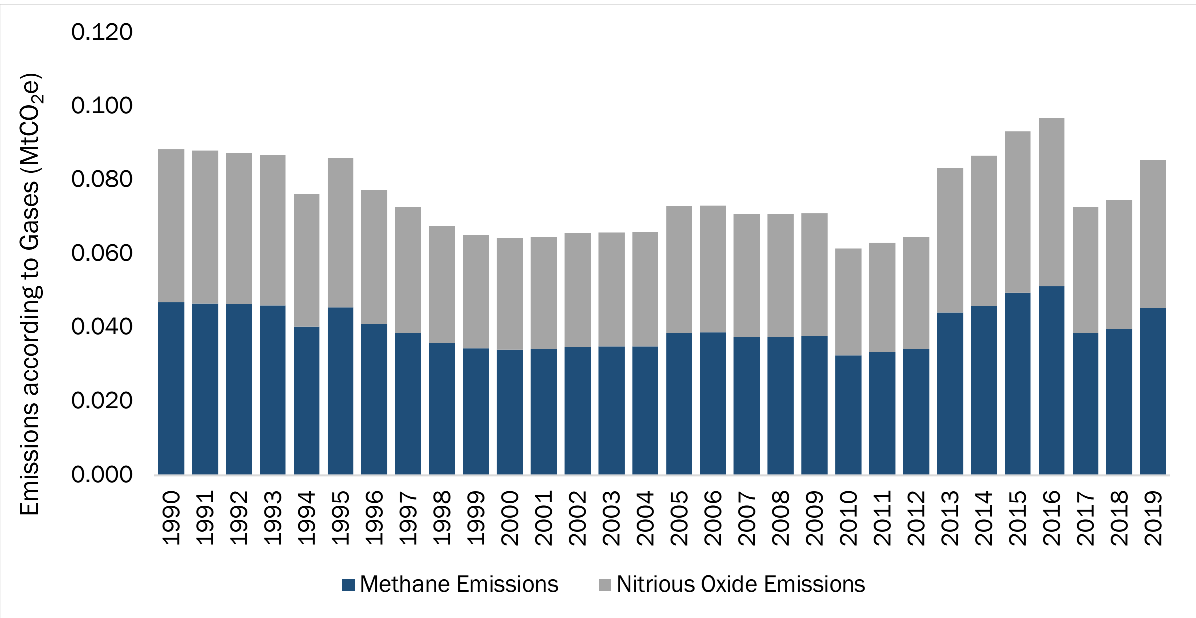


Figure 77: Trends of total GHG emissions associated with composting

611.2.1 Methodological choices in biological treatment of solid waste

The main data input is the amount of waste composted in Ghana and the technology. The input data were derived from the fraction of solid waste treated. Although the amount of solid waste treated through composting was derived as a fraction of solid waste treated, the data was compared with the actual existing composting capacity in the country provided by Zoomlion Ghana Limited, which operates almost all the commercial plants. Extra data were sourced from Ghana Statistical Service and other literature for household composting and the decommissioned Teshie-Nungua treatment plant.

6.11.3 Incineration and open burning (4C)

In Ghana, the fraction of MSW, industrial waste, hazardous waste, waste oil and clinical waste accounts for the proportions of wastes 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 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 municipal waste generated in these institutions.

Few manufacturing companies incinerate their waste generated onsite to meet regulatory standards but hardly keep records of the volumes incinerated. It is also important to state that these incinerator plants are of small capacities and hence supplied in small quantities. Furthermore, a large portion of the incinerators has been installed across the country in almost all District, Regional, and Teaching Hospitals. They 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. Also, it is important to add that from 2010, large scale incineration plants were set up to treat industrial waste, hazardous waste and waste oil. These incineration facilities, Zeal Environmental Technologies Limited and Zoil Services Limited, were established in 2010 and 2012, respectively.

Open burning of waste is how communities treat and reduce their waste. Open burning covers the open burning of residential, municipal solid wastes and yard waste. In the early 1980s, almost every household had an area demarcated for open burning. This practice was predominant in low-income areas and rural areas. Open burning of waste resulted in public health and environmental issues; hence, stricter measures and strategies were developed to stop or abate this practice forcing Metropolitan, Municipal and District authorities to develop bye-laws to criminalize open burning of waste (NESSAP, 2010).

With the advent of these strategies and actions, some households moved towards operating 'backyard' dumps or composts. Even though the open burning of waste has been criminalized in the assembly laws, open burning is still ongoing for various reasons, such as high solid waste collection fees (polluter pays principle). Open burning practices have worsened considerably and will continue to worsen due to a lack of enforcement of regulations that criminalise open burning, lack of education of the general public and a conscious effort to reduce the volumes of waste at various dumpsites. The total amount of solid waste openly burnt is rising, showing a lack of enforcement to reduce open burning and incineration (Table 116). Generally, there was a rise in the trends for both incineration and open burning of waste from 1990 to 2019.

Table 116: Solid Waste disposal by incineration and open burning

Quantities of Waste Incineration [Gg]							Open Burning[Mt]	Total [Gg]
Year	MSW	Industrial	Hazardous	Waste Oil	Clinical Waste	Total	MSW	
1990	53.36				2.81	56.17	224.68	280.85
1991	53.04				2.79	55.83	223.32	279.14
1992	52.66				2.77	55.43	221.73	277.16
1993	52.23				2.75	54.98	219.91	274.89
1994	51.74				2.72	54.46	217.85	272.31
1995	51.19				2.69	53.88	215.53	269.41
1996	49.80				2.62	52.42	209.67	262.09

1997	48.30				2.54	50.84	203.36	254.19
1998	46.69				2.46	49.14	196.57	245.72
1999	44.96				2.37	47.32	189.30	236.62
2000	43.97				2.31	46.29	185.15	231.44
2001	44.22				2.33	46.55	186.21	232.76
2002	44.46				2.34	46.80	187.18	233.98
2003	44.66				2.35	47.01	188.03	235.03
2004	44.85				2.36	47.21	188.83	236.03
2005	50.63				2.66	53.30	213.19	266.49
2006	50.79				2.67	53.46	213.85	267.31
2007	55.72				2.93	58.66	234.63	293.29
2008	62.75				3.30	66.06	264.23	330.29
2009	70.60				3.72	74.32	297.27	371.59
2010	68.33	0.02	0.08	0.09	3.60	72.12	287.72	359.84
2011	70.04	0.04	0.08	0.08	3.69	73.92	294.91	368.83
2012	71.79	0.06	0.08	0.06	3.78	75.77	302.28	378.05
2013	73.59	0.22	1.31	0.07	3.87	79.06	309.84	388.90
2014	75.43	0.08	0.39	0.07	3.97	79.94	317.58	397.53
2015	80.75	0.08	0.39	0.07	4.25	85.55	339.99	425.54
2016	82.77	0.08	0.39	0.07	4.36	87.67	348.49	436.16
2017	122.67	0.08	0.39	0.07	6.46	129.68	516.51	646.19
2018	125.40	0.08	0.39	0.07	6.60	132.54	527.98	660.52
2019	128.14	0.08	0.39	0.07	6.74	135.43	539.54	674.98
Change (2016-2019)	35	0%	0%	0%	35%	35%	35%	35%

In 2019, out of the 135.43 Gg of waste incinerated, 128.14 Gg were Municipal Solid Waste (MSW), 0.08 Gg was industrial waste, 0.39 Gg was hazardous, 0.07 Gg was waste oil, and the other 6.74Gg was clinical waste. In 2019, the total amount of 128.14 Gg MSW incinerated was 35% higher than the 2016 levels. The Industrial, Hazardous and Waste oil incinerated quantities remained constant from 2016 to 2019. Most waste incinerated was due to large-scale hazardous incineration plants (Zeal Environmental Technologies Limited and Zoil Services Limited) between 2010 and 2012.

On the other hand, the 6.74Gg clinical waste incinerated increased by 35.3% in 2016. The disposal of municipal and clinical waste through incineration and open burning generates Carbon dioxide, methane and nitrous oxide emissions. The observed reduction in the total amount of incinerated MSW (of the total treated) throughout the years could result from the declining incineration capacity at the local government level. The emissions will be generated depending on the amount and type of waste, the capacity and the combustion efficiency of the incinerators and open burning. 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, industrial solid waste is collected as part of the MSW, which may sometimes be incinerated. Few industries treat their waste separately through on-site incineration, but records are not kept on incinerated amounts. Data on municipal solid waste and clinical waste incineration were obtained from the National Environmental Sanitation Strategy Action Plan document and the Ghana Health Service Facts and Figures. In all, 674.98Gg of waste was disposed of through incineration and open burning in 2019. Of the total, 135.43 Gg were incinerated, forming 20%, whereas the remaining 539.54 Gg (80%) were openly burnt.

The total amount of waste disposed of through incineration and open burning resulted in a total emission of 0.15 $MtCO_2e$ in 2019, representing 4.2% of the total waste sector emissions. Of the total emission, 96.3% came from open burning, and 3.7% were from incineration. The 2019 emissions of 0.15 $MtCO_2e$ represent 48% higher than the emissions in 2016 (Figure 78). Its contributions to the total emissions in 2019 increased to 4.2% from the previous estimates (2016), which was 2.5% of its total emissions. The increase is due to the increase in the fraction of the population using burning to waste disposal. The upward emissions trend is linked to the high rate/cost for other disposal modes, especially low-come.

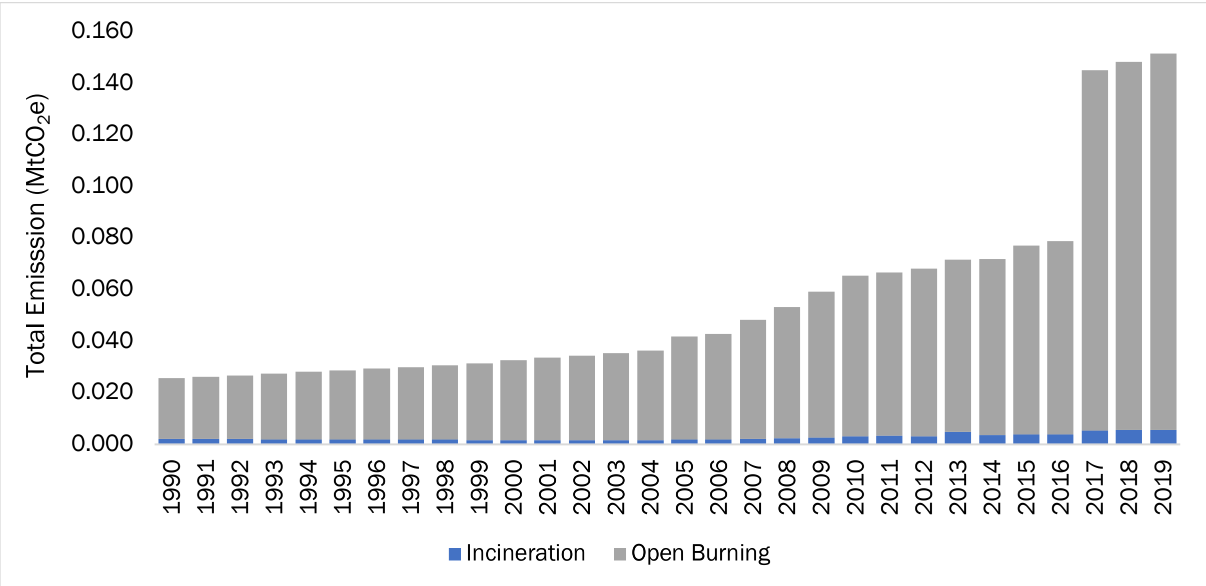


Figure 78: Emissions trend for waste incineration and open burning

6.11.3.1 Methodological issues for incineration and open burning

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

$$MSW = P \times P_{frac} \times MSWP \times Bfrac \times 365 \times 10^{-6}$$

Where;

MSW = Total amount of municipal solid waste open-burned, Gg/yr.

P = population (capita)

P_{frac} = fraction of population burning waste, (fraction)

MSWP = per capita waste generation, kg waste/capita/day

B_{frac} = fraction of the waste amount that is burned relative to the total amount of waste treated,

10^{-6} = conversion factor from kilogram to gigagram

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. Based on our national circumstances, a plant-by-plant basis and 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 MSW and clinical waste. Hazardous and industrial waste has been estimated from 2010 to 2019 with data from Zeal Ghana limited.

The Tier 1 Approach requires using activity data and default emission factors from IPCC, 2006 for MSW and clinical waste. The CH_4 and N_2O emissions calculation was based on the amount of incinerated or open-burned waste and the related emission factor. The amount of waste used is consistent with the activity data used for CO_2 calculation and default CH_4 emission factors (IPPC, 2006). To determine the amount of incinerated and openly burnt waste, 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 the population burning waste and the fraction of MSW treated (Table 117)

Table 117: Trend of the amount of waste openly burnt

Year	Total MSW Generation (Gg)	Fractions of population Burning	Amount of MSW Openly Burnt (Gg)	fractions of total MSW treated
1990	2094.13	0.0632	224.68	0.741
1991	2148.58	0.0632	223.32	0.741
1992	2204.44	0.0632	221.73	0.741
1993	2261.76	0.0632	219.91	0.741
1994	2320.56	0.0632	217.85	0.741
1995	2380.90	0.0632	215.53	0.741
1996	2442.80	0.0632	209.67	0.741
1997	2506.31	0.0632	203.36	0.741
1998	2571.48	0.0632	196.57	0.741
1999	2638.34	0.0632	189.30	0.741
2000	2761.16	0.0632	185.15	0.741
2001	2835.71	0.0632	186.21	0.741
2002	2912.28	0.0632	187.18	0.741
2003	2990.91	0.0632	188.03	0.741
2004	3071.67	0.0632	188.83	0.741
2005	3548.93	0.0632	213.19	0.741
2006	3644.75	0.0632	213.85	0.741
2007	3743.15	0.0688	234.63	0.7805
2008	3844.22	0.0744	264.23	0.82
2009	3948.01	0.08	297.27	0.8595
2010	4050.21	0.0856	287.72	0.899

2011	4151.47	0.0856	294.91	0.899
2012	4255.25	0.0856	302.28	0.899
2013	4361.63	0.0856	309.84	0.899
2014	4470.68	0.0856	317.58	0.899
2015	4786.11	0.0856	339.99	0.899
2016	4905.76	0.0856	348.49	0.899
2017	5016.14	0.156	516.51	0.925
2018	5127.50	0.156	527.98	0.925
2019	5239.79	0.156	539.54	0.925

Heat is not recovered from any incineration plant reported under the waste sector because, in Ghana, there is no form of energy recovered in the incineration of waste.

6.11.4 Wastewater Treatment and Discharge (4D)

Key category: CH_4, N_2O (LA: 2019, TA: 2016-2019)

Wastewater originates from domestic, commercial and industrial sources. In Ghana, these may either be treated on-site (uncollected), channelled to a centralised point (collected) or disposed of in a nearby 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 practised also differs for people living in rural and urban areas and those in urban high-income and low-income areas.

Domestic wastewater includes human sewage mixed with other household water. The type of treatment and discharge pathway or system was categorised 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., centralised, aerobic treatment plant, septic system and latrine), (MICs 1996, 2005, 2011, 2018). It is important to note that treatment systems are not final disposal points or sites. They are usually considered intermediary treatment facilities since they end up in the sea or rivers but not in their raw state.

After this effluent is processed in Ghana, it is directly discharged into water bodies generating N_2O during nitrification and denitrification of the nitrogen present. Industrial Wastewater Treatment and discharge sources are estimated to be the major contributor to Wastewater treatment and discharge emissions, while domestic and commercial wastewater treatment and discharge contributed the least. It is rather the reverse in Ghana since wastewater coming from most industries ends up in commercial wastewater streams. Industrial wastewater may be treated on-site or released directly into the domestic sewer system. Usually, most industries treat processed water to meet regulatory standards before discharge. The historical trend indicates that public toilet facilities were free for users before 1982. The service providers and their supervisors were poorly motivated, which led to the poor management and deterioration of sanitary conditions within the major cities.

The situation improved due to 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 Decentralisation Programme, 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 to pay not less than 20% of gross revenue to the Assembly (Ayee and Crook, 2003). In the 1990s and after that came into being the 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 manifests 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 the increase in population and access to improved treatment systems such as flush to piped sewer systems and flush to septic tanks, as shown in Table 118 (MICS, 1996, 2006, 2011 and 2018.

For industrial wastewater, it has been observed 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 and EMPs submitted to the Department revealed additional data from existing and new industries. Hence, industrial outputs in terms of product output have increased over the years. The data obtained from the survey and EMPs were from 1990 basically for soap and detergents, while data for the other sectors were from 1997 to 2019. There are, however, gaps for some industry categories for some years.

Table 118: Distribution of population and the dominant treatment system

Classification of wastewater treatment system to IPCC classification		1996		2006		2011		2018	
IPCC Classification	MIC Survey, 1996, 2006, 2011, 2018	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Sea, river and lake discharge	No Facilities or bush or field, Missing, others, Flush to somewhere else, No Facilities	20.09	2.05	18.76	4.16	17.35	5.12	12.74	3.31
Stagnant sewer	Bucket, Pan/Bucket	0.59	9.00	0.11	0.80	0.20	0.25	0.09	0.22
Centralized, aerobic treatment plant	Flush to piped sewer system, Flash toilet (water closet)	1.18	8.59	0.32	1.80	0.15	1.83	0.26	0.67
Septic system	Flush to septic tank, Flush don't know where, Septic tank	1.77	11.86	0.63	7.05	0.64	11.71	1.71	15.36
Latrine	Flush to pit (latrine), Ventilated Improved Pit latrine (VIP), Pit latrine with Slab, Pit Latrine without slab/open pit, VIP, KVIP	35.46	9.41	32.88	33.50	31.00	31.80	29.13	36.55

It has been observed that industrial wastewater output keeps increasing due to new data sets from industries in the country. The Environmental Performance Rating and Disclosure programme, the introduction of a new data-intensive EMP format by the Manufacturing Industries Department of the EPA, and frequent submission of the Annual Environmental Report and quarterly monitoring report revealed that industrial outputs in The data obtained from the survey were from 2000 to 2019, but there are still gaps for some industry categories for some years. Table 119 present the percentage change in industrial product output as per IPCC, 2006 categorisation.

Table 119: Total Industrial product output as per IPCC, 2006 categorisation.

Year	Total Industry Product (t/yr.)						
	Beer and Malt	Dairy Products	Fish Processing	Meat and Poultry	Organic Chemicals	Soap & Detergent	Fruit & Juice
1990						5,760.0	
1991						5,721.0	
1992						3,940.0	
1993						4,007.0	
1994						4,041.0	
1995						3,020.0	
1996						3,241.0	
1997						5,000.0	15,089.0
1998					15.0	4,248.0	15,733.0
1999					17.5	4,240.0	16,865.0
2000				3,146.2	21.8	4,671.0	15,560.0
2001		10,882.0		5,691.6	20.7	6,070.0	19,602.0
2002		14,128.0		5,556.5	172.9	7,000.0	22,225.0
2003		16,465.0		7,736.5	173.7	6,811.0	22,421.0
2004		24,002.0		9,137.4	3,778.4	6,746.0	22,993.8
2005	9,396.5	23,973.0		10,587.4	3,092.9	6,080.0	23,695.6
2006	146,899.8	22,045.0	36,174.0	12,104.4	2,425.5	6,840.0	25,021.8
2007	153,279.4	27,001.0	31,979.0	13,643.9	541,479.7	4,831.0	23,948.4
2008	148,479.0	28,275.0	46,677.0	11,214.9	539,529.7	3,020.0	72,547.1
2009	158,879.6	39,701.0	37,494.1	11,751.6	525,181.2	5,080.0	52,503.3
2010	160,506.2	41,514.0	42,366.9	14,771.8	468,741.3	7,843.0	63,087.7
2011	179,727.6	35,552.0	43,541.9	27,691.7	501,895.3	7,915.0	75,517.1
2012	186,678.8	44,613.0	46,317.0	20,285.1	531,456.6	8,068.0	86,469.4
2013	172,383.9	59,806.5	33,116.0	30,724.3	537,788.2	8,221.0	90,752.4
2014	171,985.7	75,650.0	19,915.0	41,163.5	710,560.0	8,374.0	93,782.5
2015	219,198.1	127,019.4	22,942.3	42,789.5	670,071.6	8,527.0	97,047.2
2016	213,136.1	153,421.2	25,809.1	44,415.4	664,752.6	8,680.0	100,311.9
2017	236,111.5	153,671.2	200,210.0	46,409.7	662,960.4	8,910.0	105,599.6
2018	244,726.7	170,247.5	212,289.7	48,404.0	696,586.4	9,217.0	114,161.3
2019	270,803.9	186,823.8	212,289.7	50,398.2	733,424.5	9,370.0	117,423.0
Change 2016-2019	21.3%	17.9%	87.8%	11.9%	9.4%	7.4%	14.6%

6.11.4.1 Emissions trends wastewater treatment and discharge

The trends in wastewater treatment and discharge emissions show a steady increase from 1990 to 2019. It has increased from 0.64 $MtCO_2e$ in1990 amounted to 2.04 $MtCO_2e$ in 2019. Within the sub-category, 67.2% of the emissions were from Domestic wastewater treatment and discharge (4.D.1), while 32.8% were from Industrial wastewater treatment and discharge (4.D.2) for 2019. The massive contribution of industrial wastewater treatment and discharge to the total wastewater treatment and discharge started in 2007 due unavailability of data, as shown in Figure 79.

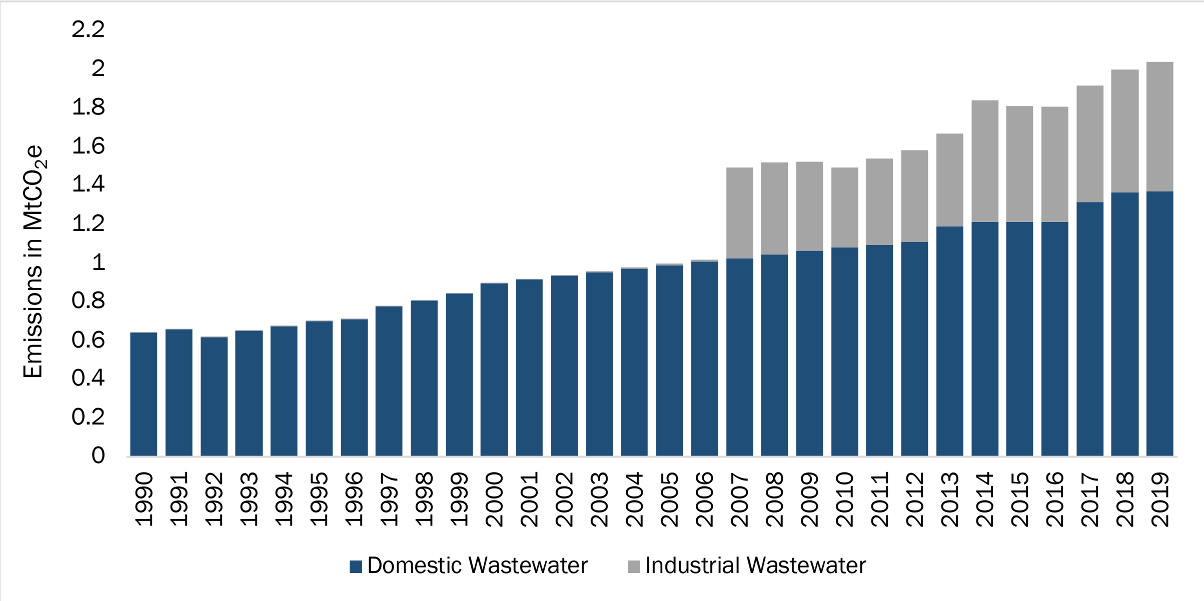


Figure 79: Trends of emission from Waste Water treatment and discharge

Emissions of CH_4 and N_2O from wastewater have increased steadily during 1990-2019 inventory estimates. The emission trend for this period is shown above. The increase in domestic wastewater treatment and discharge emissions is mainly due to Ghana's treatment systems and discharge pathways.

6.11.4.2 Methodological issues in wastewater treatment and discharge category

The methodology used to estimate emissions from wastewater treatment and discharge management activities require country-specific knowledge of wastewater generation, population country-specific BOD, per capita protein intake and management practice/ discharge pathway. In Ghana, waste management activities are generally inadequately organised, resulting in the lack and inconsistency of data. Therefore, the effort was made to evaluate and compile data from different sources and adjust or classify them to the recommended Intergovernmental Panel on Climate Change (IPCC, 2006) methodology used for GHGs emissions. Estimating the wastewater treatment and discharge emissions commenced from 1990 to 2019. 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 information on activity data and emission factors to estimate emissions. According to the analysis of emission estimates, CH_4 from wastewater handling are a key category in level and trend from 1990 to 2019.

6.11.4.3 Methane emissions from domestic/commercial wastewater treatment

Generally, in estimating CH_4 emissions from wastewater treatment and discharge, for this sub-category, the total population (30,543,804 for 2019) of the country (GSS, 2010). The household size (4) 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 considered. These income classes are equivalent to metro-urban, peri-urban and rural in Ghana. For the urban population, data on improved facilities (treated system) and unimproved facilities (untreated) and the rural population for 2010 was obtained from 1996, 2005, 2010 and 2018 survey data from the MICS. The fraction of the urban population was divided into metro-urban (52.40%) and peri-urban (47.6%) using the population share of 1996, 200 and 2010, 2018, respectively (see table 6.19). The IPCC methodology for estimation of methane emissions from Domestic/ commercial Wastewater treatment and discharge is given by standard IPCC Equations below:

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

Where:

Methane emissions= CH_4 emissions in inventory year, kg CH_4/year
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 utilisation 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 CH_4/kg BOD
R = amount of CH_4 recovered in inventory year, kgCH_4/year

The emission factor used for the 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 CH_4 producing capacity, kg CH_4/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/year
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

Table 120: Treatment systems and population use distribution

Year	Rural					Urban High					Urban Low				
	Sea, river and lake discharge	Stagnant sewer	Latrine	Septic system	Centralised, aerobic treatment plant	Sea, river and lake discharge	Stagnant sewer	Latrine	Septic system	Centralised, aerobic treatment plant	Sea, river and lake discharge	Stagnant sewer	Latrine	Septic system	Centralised, aerobic treatment plant
1990	0.208	0.007	0.365	0.024	0.016	0.001	0.064	0.005	0.075	0.058	0.001	0.059	0.002	0.070	0.045
1991	0.207	0.007	0.364	0.023	0.015	0.002	0.063	0.010	0.074	0.055	0.002	0.058	0.006	0.068	0.045
1992	0.206	0.007	0.362	0.022	0.014	0.004	0.062	0.020	0.071	0.053	0.005	0.055	0.010	0.065	0.043
1993	0.205	0.007	0.361	0.021	0.013	0.006	0.059	0.023	0.069	0.052	0.006	0.053	0.021	0.063	0.042
1994	0.205	0.006	0.360	0.020	0.013	0.008	0.054	0.027	0.067	0.052	0.007	0.048	0.032	0.060	0.042
1995	0.203	0.006	0.357	0.019	0.012	0.009	0.052	0.037	0.065	0.047	0.008	0.046	0.041	0.058	0.041
1996	0.201	0.006	0.355	0.018	0.012	0.011	0.047	0.049	0.062	0.045	0.010	0.043	0.045	0.057	0.041
1997	0.199	0.005	0.352	0.016	0.011	0.011	0.042	0.065	0.059	0.041	0.010	0.038	0.060	0.054	0.037
1998	0.197	0.005	0.347	0.015	0.010	0.012	0.039	0.081	0.056	0.036	0.011	0.034	0.074	0.051	0.033
1999	0.196	0.005	0.343	0.013	0.009	0.013	0.033	0.099	0.054	0.033	0.012	0.030	0.083	0.049	0.030
2000	0.194	0.004	0.341	0.013	0.008	0.015	0.030	0.112	0.051	0.028	0.013	0.025	0.095	0.046	0.026
2001	0.192	0.003	0.339	0.011	0.007	0.016	0.025	0.128	0.047	0.024	0.015	0.024	0.104	0.043	0.022
2002	0.191	0.003	0.338	0.010	0.006	0.017	0.019	0.140	0.044	0.023	0.016	0.021	0.114	0.040	0.018
2003	0.189	0.002	0.335	0.009	0.006	0.019	0.014	0.153	0.043	0.018	0.017	0.015	0.124	0.039	0.017
2004	0.189	0.002	0.332	0.008	0.004	0.020	0.009	0.165	0.040	0.014	0.019	0.009	0.141	0.036	0.013
2005	0.188	0.001	0.329	0.006	0.003	0.022	0.004	0.176	0.037	0.009	0.020	0.004	0.159	0.034	0.009
2006	0.185	0.001	0.325	0.006	0.003	0.023	0.004	0.174	0.042	0.009	0.021	0.003	0.158	0.038	0.009
2007	0.181	0.001	0.321	0.006	0.003	0.024	0.003	0.172	0.047	0.010	0.022	0.003	0.156	0.042	0.009
2008	0.178	0.002	0.318	0.006	0.002	0.025	0.002	0.171	0.052	0.010	0.023	0.002	0.155	0.047	0.009
2009	0.174	0.002	0.315	0.006	0.002	0.026	0.002	0.169	0.057	0.010	0.023	0.002	0.154	0.051	0.009
2010	0.174	0.002	0.310	0.006	0.002	0.027	0.001	0.166	0.061	0.010	0.024	0.001	0.151	0.056	0.009
2011	0.174	0.002	0.308	0.007	0.001	0.029	0.001	0.166	0.066	0.010	0.026	0.001	0.139	0.060	0.009

2012	0.172	0.002	0.305	0.007	0.001	0.030	0.001	0.164	0.071	0.010	0.027	0.001	0.134	0.065	0.009
2013	0.170	0.003	0.302	0.007	0.001	0.032	0.001	0.162	0.076	0.010	0.028	0.001	0.130	0.069	0.009
2014	0.168	0.003	0.299	0.007	0.001	0.033	0.001	0.160	0.081	0.010	0.030	0.001	0.125	0.074	0.009
2015	0.166	0.003	0.296	0.007	0.001	0.034	0.001	0.158	0.086	0.010	0.031	0.001	0.120	0.078	0.009
2016	0.164	0.003	0.293	0.007	0.001	0.035	0.001	0.157	0.091	0.010	0.032	0.001	0.115	0.082	0.009
2017	0.149	0.002	0.292	0.010	0.002	0.028	0.001	0.172	0.088	0.007	0.025	0.002	0.139	0.080	0.006
2018	0.127	0.001	0.291	0.017	0.003	0.017	0.001	0.192	0.080	0.004	0.016	0.001	0.174	0.073	0.003
2019	0.139	0.002	0.287	0.012	0.002	0.027	0.001	0.175	0.094	0.006	0.024	0.004	0.140	0.080	0.005

Industrial Wastewater Treatment and Discharge

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

Indirect nitrous oxide emissions from human sewage estimation

The estimation of nitrous oxide emissions from human sewage was mainly based on the country's per capita protein consumption from FAO statistics and population. 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 121 below shows the range of years and their respective per capita protein consumption values.

Table 121: Annual protein intake for 1990-2019

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Population (million)	14.34	14.72	15.10	15.49	15.89	16.31	16.73	17.17	17.61	18.07
Protein intake (kg/person/year)	31.60	31.38	31.16	30.94	30.72	30.50	31.14	31.78	32.42	33.06
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Population (million)	18.91	19.42	19.95	20.49	21.04	21.61	22.19	22.79	23.40	24.04
Protein intake (kg/person/year)	33.70	33.10	32.50	31.90	31.30	30.70	30.10	29.50	28.90	28.30
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Population (million)	24.66	25.28	25.91	26.55	27.22	27.90	28.60	29.24	29.89	30.54
Protein intake (kg/person/year)	27.70	27.10	26.50	29.30	29.15	29.01	28.87	28.75	28.61	28.47

Sludge Handling System

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

6.12 Planned improvements measures for the Waste Sector

Table 122 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 122: Future improvements measures 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 in 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 uncategorised	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 the 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 initiate a review of the industrial survey	next inventory	Funding is secured on time

Chapter 6

7.0 Conclusions

7.1 Remarks on the National GHG Inventory Arrangements

The NIR5 marks the fifth time Ghana has produced a stand-alone national inventory report to the UNFCCC. The inventory preparation helped the country produce the latest inventory results. The processes have lent to further consolidate the national inventory system. Since the publication of the NIR4 document, Ghana has continued its efforts to improve key aspects of the national system. It is worthy to note the consistent progress in GHG data management. Through the CBIT project, the EPA conducted a comprehensive review of the GHG data system in the energy, transport, agriculture and waste sectors. Findings from the assessments fed into the road map for implementing the planned improvements for Ghana's GHG inventory.

In the same vein, the EPA has revived the climate data hub by redesigning it in response to the emerging international reporting requirements under ETF and its MPGs. There is still a dedicated GHG inventory portal in the renewed data hub that hosts all GHG inventory data and provides analytical options for users to visualise and query to suit their needs. The inventory data portal also serves as an online archive of all GHG inventory data to ease retrieval when necessary. Apart from the climate data hub, the other data platforms that generate data for the GHG inventory are also undergoing some reforms. For instance, the Forestry Commission is establishing an online database for land-based information relevant toREDD+ and GHG inventory. Additionally, with technical support from CfRN, the Forestry Commission has prepared the Ghana FREL Foundational Platform. It is an excel-based package that automates the 2006 IPCC Guidelines steps for calculating net GHG emissions from the land category.

High integrity data and adequate financing are the lifelines of a robust inventory system. Although some improvements have been made to the activity data, emission factors and methodology, many efforts remain in the coming years. More attention would be given to improving the methodology and the emission factors for key categories. It would be a priority to develop country-specific emission factors and higher tier methodology for emission estimation for the electricity, transport, waste disposal, and livestock category on the data side. Ghana is still seeking funding to support the efforts to improve the inventory methodology. The EPA considers the option of forging partnerships in the ECOWAS sub-region with similar socio-economic and ecological conditions as viable means of raising funding.

The rationale for improving the data quality and methodological thoroughness is grounded on the MPGs requirements. In the MPGs, countries are recommended to use a higher tier to estimate emissions/removals from key categories. Even if a country chooses not to use a higher tier for the estimation due to the capacity gap under the flexibility option, it is expected to justify doing so and the effort to address them.

Thus, countries must start to increase investment in data and methodological systems. With these investments, it would be possible for Ghana to further increase the rigour and credibility of the GHG inventory dataset. In inventory governance, more institutions and experts have joined the team and received additional training both in the country and abroad on the inventory. There are serious efforts toward deepening the institutionalisation of the inventory.

Despite taking commendable steps to involve more institutions, there is more to be done, particularly devolving the inventory tasks to the relevant key line ministries. Some line ministries have already started incorporating inventory tasks into their annual work plans and dedicated staff time to the inventory in the official performance appraisal. Energy Commission, Forestry Commission and the Crop Services Directorate of the Ministry of Food and Agriculture have dedicated teams working on their respective inventories. Furthermore, the Energy Commission has taken an extra step to incorporate the energy sector inventory into the annual work plan with an associated budget for preparing the energy statistics. The EPA Act 490, 1994, which mandates the Agency to coordinate the GHG inventory preparation, is reviewed. The review of the EPA Act will enable the Agency to strengthen its legal capacity to perform the inventory function as the lead institution and facilitate data access from the industry. The review of Act 490 is still ongoing and is expected to be complete in 2022. When the legal review is completed, it will contribute to making the national GHG inventory system streamlined.

Ghana continues to work on increasing the use of the inventory results and making sure that the whole inventory process is visible at a high level. The team plans to engage the inventory users on how best to package the inventory results for their future use, prepare infographics for dissemination and where resources permit, and organise policy meetings with the key stakeholders. In 2021, Ghana used the 2019 inventory results to construct the baseline emissions as part of Ghana's updated NDC mitigation analysis to the UNFCCC. Presently, Ghana does not provide direct funding to support the inventory but covers operational costs through in-kind contributions. The current funding arrangement is not enough to cover the full cost of running an efficient national inventory system that can produce inventories on time and high quality. In the coming years, Ghana would consider applying for a medium-size project fund window from GEF or develop a specific project proposal to seek funding from other donors to complement the GEF funding. Another option Ghana is seriously considering is the possibility of raising funding from the national budget.

7.2 Concluding Remarks

The document is the fifth time Ghana has voluntarily prepared a standalone National Inventory Report (NIR). The NIRs have been compiled during the preparation of the first, second, third and fourth national communications to the UNFCCC. The NIR5 covers 29 years of full time-series, from 1990 to 2019, for the four main IPCC sectors: Energy, Industrial Process and Product Use (IPPU), Agriculture, Forestry and Other Land Uses (AFOLU) and Waste. The inventory has been prepared using the 2006 IPCC Guidelines covering Greenhouse Gases (GHGs) (Carbon dioxide, Methane, Nitrous oxide, Hydrofluorocarbons, Perfluorocarbons), some Precursor gases (PGs) (Non-methane Volatile Organic Compound, Particulate Matter, Nitrogen Oxides) and Short-Lived Climate Pollutants (SLCPs) (Black carbon).

Chapter 7

Annexes

Annexe 1: Institutional Assessment of Climate Reporting in Ghana

MRV Roles	Institutions involved	Specific role(s)	Rating				Explanation of Ratings	Comments
			1	2	3	4		
Overall coordination of the GCARP[32]	Environmental Protection Agency (Climate Change Unit - CCU)[33]	Coordination of the GCARP involves oversight of the planning, preparation, and management of national climate reporting (GHG inventory, mitigation actions, adaptation and support, NDC progress) and policy uptake of the reports' findings. CCU also manages the Memorandum of Understanding (MOUs) between the EPA and the institutions involved in the GCARP. The CCU is also responsible for facilitating continuous improvements of the structures (institutional roles, data management, IT system, tools and capacity development). It is also responsible for resource mobilisation and the overall				x	The CCU has dedicated staff and the requisite capacity to regularly plan and coordinate climate reporting nationwide. CCU staff are also involved in the reformation of the GCARP. They perform the coordination and facilitation roles based on the mandate derived from the EPA Act, Act 490 1999 and the LI 1652, 1999. The CCU has fully incorporated the climate reporting functions into its annual work plan and budget. The EPA provides in-kind support (office space, utility) to the CCU staff involved in the GCARP. The EPA Management backs the CCU's work on climate reporting in institutional visibility, policy relevance, the mobilisation of state	The CCU has a staff strength of five with adequate capacity. Besides, there are departmental focal points (Environmental Quality Unit, Environmental Assessment and Audit Unit, Human Settlement Unit, Natural Resource Unit, Petroleum Unit and Manufacturing Industry Unit) for climate change that provide additional staff support to the GCARP. The EPA receives funds from donor agencies. EPA must consider increasing its annual budget allocation to the CCU and the various units to strengthen the efforts to entrench the GCARP. The CCU must also continue its advocacy work on policy relevance and visibility of the functionality of

[32] Defines institutional roles and responsibilities as well as the strategic planning and implementation of GCARP activities. These include the development of collaboration arrangement such as MOUs with stakeholder institutions, work plans, data templates and administrative processes for mainstreaming the GCARP into the government structures. Ensures timely delivery of the climate reports and for submission. Prepares GCARP activities and budget. Leads Quality Control and Quality Assurance and Ensures alignment with national policies and relative activities.

[33] epa.gov.gh/epa/projects/climate-change

		mainstreaming of the GCARP into governmental structures. CCU also facilitates the tracking of NDC progress and achievements and reporting.					and non-state actors and sourcing of additional funds.	the GCARP and resource mobilisation.
Oversight of GCARP	Ministry of Environment Science Technology and Innovation (MESTI)	Facilitates uptake of climate report findings into policy planning and implementation across the government. Ensures climate reporting is consistent with and informs national and sector policies.			x		MESTI's Environment Directorate[34] has oversight over sustainable development and climate change issues in the country. MESTI is part of the Central Management Agencies of government machinery and derives its mandate to perform the oversight role for climate reporting from the Executive Instrument (EI) 1 Civil Service (Ministries) Instrument. MESTI is the host of the inter-ministerial national climate change implementation committee (NCCIC). The NCCIC members also facilitate climate change issues, including participation in preparing climate reports in their respective organisations. Within MESTI, the Environment Directorate is responsible for climate reporting and has adequate staff with the requisite capacity. MESTI has incorporated the activities in the climate reporting in its work plan and budget.	MESTI contributions to the GCARP activities are mostly committed resources as in-kind (Government time, office space, utilities and training costs). Most of the funds applied to GCARP activities come from donor projects. MESTI must begin to indicate climate reporting, especially the aspects of NDC and climate finance tracking and the improvement of the policy uptake and reports in their work plan and budget. Especially when it comes to their involvement in the NDC tracking, the PPMED of the MESTI will play a key in coordinating the training of other MMDs and MMDAs. MESTI must consider organising regular fora to discuss the use of climate reports to inform climate policy planning and implementation.
NDC Tracking	National Development Planning Commission (NDPC)[35]	Manages the Annual Progress Report (APR) that underpins the M&E system for the national development policy framework. NDPC coordinates the regular			x		NDPC's Monitoring and Evaluation Division is responsible for preparing and disseminating the APR. The M&E ion derives its mandate from Article 87(2) (e) of the 1992	NDPC has embedded the NDC into the 2018-2021 national development policy framework.

[34] https://mesti.gov.gh/environment/

[35] https://www.ndpc.gov.gh/

		preparation and publication of the sectoral, district and national APRs. The APR system will be used as the MRV system for Ghana's NDC.					Constitution, which requires the Commission to "monitor, evaluate and coordinate development policies, programmes and projects" in the country. The NDPC, The M&E Division, has adequate capable staff who work on the APR, but they do not have the requisite skills in the NDC and climate reporting in general. M&E Division already r	The EPA CCU, MESTI and NDPC's M&E Division and Development Planning Division have developed indicators for tracking NDC progress and achievements. They also developed a tool for the data collection on the NDC implementation. The team also organised training on the NDC, the indicators and the data collection template for the officers of the Policy Planning and Monitoring and Evaluation Division (PPMED) of relevant NDC sectors (Gender, Finance, Transport, Energy, Agriculture, Water, Forestry etc.). NDPC staff need more training on the NDC and climate reporting in general. Ministries, Department and Agency (MDAs) and the Metropolitan and Municipal District Assemblies (MMDAs) need additional training on the NDC and the tracking system.
Tracking climate support	Ministry of Finance (MoF)	Tracks climate finance inflows			x		Ministry of Finance's Real Sector Division[36] is responsible for climate change issues and acts as the National Designated Authority (NDA) for the Green Climate Fund (GCF). The NDA is responsible for tracking international and national climate change financial inflows and reports it in the BUR or National Communications to the UNFCCC.	The NDA has developed a climate finance tracking tool[37] for the MDAs and MMDAs. The end-users of the tool need training on the tool. NDA must provide regular support services to the MMDA and MDAs on demand. Budget allocation to support climate finance tracking is crucial to complement donor funds.

[36] https://www.mofep.gov.gh/divisions/rsd/climate-change
[37] https://www.mofep.gov.gh/sites/default/files/docs/Climate-Change-Tracking-Tool.pdf

							The NDA unit has five capable, dedicated staff, of which two work directly on climate finance tracking. They collaborate with the Budget and the Resources Division to track government climate change allocations and the EPA CCU on tracking international inflows. MoF is one of the central management agencies and delivers its core functions, including climate finance tracking under the mandate from sections 11 & 13 of the Civil Service Law 1993(PNDCL 327) and amended by an Executive instrument 28(E.I 28) Civil Service (Ministries) (Amendment instrument,2017). Even though the NDA has incorporated climate tracking into its mandate, there is no clear budget line for continuous tracking. The tracking of climate finance is usually donor-funded.	The NDA must consider dedicating some of its budgets to finance the annual or biennial tracking of domestic and international climate inflows. Currently, in the BUR, Ghana reports on committed climate funds but not the actual disbursement. The NDA should improve climate tracking to include actual fund disbursement to the beneficiaries. The NDA also needs additional training on the NDC, climate finance, and emerging UNFCCC reporting requirements.
GHG inventory and mitigation actions	Environmental Protection Agency (EPA) (Environmental Information and Data Management Department - EIDM)	Manages the online climate data hub			x		The EIDM is responsible for the data hub. They manage the content and ensure regular updates. Facilitates data upload on the hub. Two persons from the EIDM are directly in charge of the system. The management of the hub is part of the overall IT infrastructure of EPA. The EPA is yet to provide a dedicated budget to support the hub's management.	Funding for the development and maintenance of the hub came from a project funded by UNEP, UNDP and the World Bank. After the projects, no budget has been dedicated to the continued maintenance of the hub.
	Ghana Statistical Service (GSS)	Supplier of household, agricultural and environmental statistics data for GHG inventory and mitigation assessment.				x	Produces Ghana Living Standard Surveys (GLSS) every five years; multi-cluster survey (MICS) every three years. Integrated Business Establishment Survey (IBES). Within	Even though the GSS has capable staff working on the surveys and data supplies, their involvement in climate reporting is limited. GSS also manages the administrative

							GSS, different Departments with capable staff are responsible for the surveys. GSS functions are backed by the Statistical Service Act, 2019 (Act 1003). Within GSS, the Agriculture and Environmental Statistics Directorate is responsible for supplying relevant agriculture and environment data for the GHG inventory and the mitigation assessment. The regular publication of the GLSS, MICS and the IBES is integrated into GSS's annual plans and a budget	data archives for all Government institutions. They collect the data from various MDAs that mandate publishing technical data. Strengthen the collaboration with GSS to ensure the regular free flow of data for climate reporting. Train more GSS staff on climate reporting, including the NDC and the data needs.
	Energy Commission (EC)[38]	Manages Energy Statistics and balances. Leads in the regular preparation of the Energy sector GHG inventory and the BUR and National Communications mitigation actions.				x	Produces the National Energy Statistics (which also contains the Energy Balance) updated yearly[39]. The Statistics contain data on energy production (primary and secondary data), imports, exports and consumption in-country. The Strategic Planning and Policy Directorate (SPPD) is a dedicated directorate set up to manage energy data and information relevant to climate reporting with adequate staff (3 of them) capacities. Besides the staff from SPPD, there are three staff from the Energy Efficiency Renewable Energy and Climate Change Directorate that also work on the energy sector reporting.	As the sector lead, the EC the energy sector inventory and reports on progress and achievement of mitigation actions. EC produces the GHG estimates from stationary and mobile combustion concerning GHG inventory. The EC also undertakes a detailed review of data needs per the sector, identifies the sources and accesses them with the support of the inventory coordinator/compiler using appropriate channels and documents all the data and processes used. The EC relies on data supplied to it by the oil refinery, electricity-producing companies, National Petroleum Authority (NPA), Petroleum Commission (PC) and the Ghana National Gas Company (GNGC).

[38] http://www.energycom.gov.gh/

[39] http://www.energycom.gov.gh/planning/energy-statistics

							The Commission's function is backed by the Energy Commission Act, 1997 (ACT 541). Climate reporting is budgeted for and mainstreamed into their work plan.	The EC collects data from the Ghana Statistical Service (GSS) and uses survey data to compile the inventory. The Energy Commission has six staff with adequate capacity to work on the energy sector climate reporting. The work of staff has been consolidated into an energy sector climate action reporting team. Their task includes producing GHG inventory and progress and achieving mitigations in the energy sector. Other relevant MDAs are represented on the energy sector climate reporting team. They are representatives from EPA CCU, EPA Petroleum Unit, EPA Environmental Quality Unit, Ministry of Transport and the Volta River Authority. Some plans include the Tema Oil Refinery (TOR) in the energy sector team to improve petroleum refineries' inventory estimates. This year, the Commission has incorporated the climate reporting activities into its annual plan and approved by the management and board. The incorporation has paved the way for the Commission to allocate some of its annual budgets to support the climate reporting activities.

								Some of the areas in the energy statistics that need to be improved include the following: sectoral fuel allocation (fuel supply and consumption data), publication of metadata, and the need to have a systematic approach for collecting data on the implementation of energy sector mitigation actions. The reporting on open and closing stocks of different fuels must also be improved.
	Environmental Quality Department Unit (EQU), EPA	Contributes to the energy sector GHG inventory, focusing on mobile combustion (especially the road transport category)			x		EQU and the Ministry of Transport (MOT) contribute to the GHG estimates on mobile combustion. They contribute to processing activity data, analysing transport GHG emission estimates, and compiling the transport section of the energy sector inventory report. The EQU performs these functions based on the legal mandate in the EPA Act (Act 490), 1994 and the Environmental Assessment Regulations 1999 (LI1652) to ensure compliance to environmental quality standards from the point and nonpoint pollution sources, including transport. The core activity is supported by donor funding. The EQU has dedicated staff with limited knowledge. EQU has not fully mainstreamed the GCARP activities into their work plan and budget.	The EQU has developed a motor vehicle emission standard awaiting the finalisation of the accompanying legal instrument to back its implementation. EQU was also involved in the 2005 vehicular emission inventory exercise that led to the development of country-specific emission factors. The emission factors are outdated and must be revised to reflect Ghana's current vehicular and traffic situation. EQU staff involved in the inventory need more training on the 2006 IPCC guidelines and the software, and the energy-sector data collection template. Additional EQU staff must be added to support the lead person.

	Petroleum Unit (PU), EPA	Contributes to the energy sector GHG inventory, focusing on fugitive emissions (especially the oil and gas category) as well as the report on progress and achievement of the mitigation actions in the oil and gas industry			x		PU Contributes to the energy sector group. They focus on producing the fugitive emission estimates of the energy sector inventory. PU also supplies oil and production figures to the inventory and is expected to contribute to assessing the oil and gas mitigation actions. EPA Act (Act 490), 1994 and the Environmental Assessment Regulations 1999 (LI1652) mandate the PU to regulate the environmental aspect of the oil and gas industry. The PU has staff with adequate knowledge (international GHG review experts). Climate reporting is part of the PU work plan but not budgeted for climate reporting. Their work is supported by donor funding.	PU Continuously gathers relevant activity data from permitted upstream oil and gas industry operators for the inventory. The operators supply the data as part of the annual environmental reporting to the EPA. There is no dedicated template for regularly collecting data on oil and gas mitigation measures. Currently, data collection on mitigation measures is ad-hoc. PU should consider involving additional staff in the climate reporting and develop their capacity in relevant topics on GHG inventory and tracking mitigation measures. PU must consider adopting the mitigation action data template for data collection.
	Ministry of Transport (MOT)[40]	Contributes to the energy sector GHG inventory, focusing on mobile combustion and mitigation actions in the transport sector.			x		The MOT has the mandate for Ghana's transport sector's infrastructural development and service delivery. MOT is a member of the energy sector team and focuses on the transport sector. Contributes to estimating GHG emissions for mobile combustion, including road transport, domestic aviation, railways and inland water-borne navigation. They facilitate access to activity data from Civil Aviation and the Railways Corporation within the transport sector. They also work closely with the DVLA to supply on-road vehicles and traffic data. The MOT has the capacity and limited staff to undertake climate reporting.	Currently, MOT is leading in the transport sector policy reforms and expects to make access to vehicle and traffic data relatively easy. Most of the data on transport mitigation actions are not held at once central location. Typically, such a dataset is generated at the project level, so it is difficult to access them when the project ends. MOT staff need additional training and staff on the transport sector GHG inventory and the assessment of mitigation actions. It is crucial to continue the advocacy work on making the GCARP and its findings visible to the decision-makers in the transport sector actors. The

[40] http://www.mot.gov.gh/3/3/monitoring-and-evaluation

							The activities and budgets are not mainstreamed in their work plan.	advocacy must include strategies mainstreaming the GCARP activities into the work plan and budget of the Transport Ministry.
	Forestry Commission (FC)[41]	Manages the land category GHG inventory, REDD+ FRL and forestry mitigation actions				x	FC's mandate from the Forestry Commission Act, 1999 (Act 571) allows them to manage data on land-use change. The FC is developing a comprehensive national forest management system (NFMS) for REDD+ and GHG inventory for the land category. The FC has adequate staff and capacity who participate in the REDD+ and GHG inventory reporting. The REDD+ secretariat is the lead for the forestry sector climate reporting. Within FC, the staff from the REDD+ secretariat, Forest Plantation Department, GIS Unit of the Resource Management Support Centre and Forest Production are involved in the GCARP. The RMSC GIS unit has a functional GIS lab that produces land use maps of the GHG inventory for the land category. Climate reporting activities for REDD+ and GHG inventory are covered in the work plan and the budget of the REDD+ secretariat. Funding for the forest climate reporting is donor-driven. FC covers not much of the budget.	FC is leading the way in establishing NFMS for REDD+ and GHG inventory reports for the forest sector. NFMS seeks to build on existing reporting structures in the sectors. The plantation department regularly publishes a progress report on tree plantations for government and private sector programmes. Apart from the forestry commission, the forest research institute and the Faculty of Renewable Natural Resources of the Kwame Nkrumah University of Science and Technology are part of the land GHG inventory team. The forest plantation report is the main data source for reporting forest mitigation action. In future, the REDD+ monitoring report would also be useful for climate reporting for the sector. The FC must begin to forest mitigation action data template. EPA must work with FC to train the staff involved in the GCARP on using the data template.

41 https://www.fcghana.org/

	Forestry Research Institute of Ghana (FORIG), CSIR	Contributes to land category GHG inventory and supplies natural and planted forest carbon stock data			x		Member of the REDD+ MRV and the national GHG inventory team. Forestry Research Institute of Ghana is one of the 13 institutes of the Council for Scientific and Industrial Research (CSIR). They operate on the broad mandate of the CSIR. The head of the Forest and Climate Change Divisionrepresents FORIG on the team. FORIG no clear-cut budget line and work plan for climate reporting. FORIG has adequate, well-trained staff involved in forest inventory and mensuration. They also rely on some donor funds to conduct research relevant to climate reporting.	FORIG chaired the REDD+ MRV committee and actively developed Standard Operating Procedures for REDD+ MRV. The scientific work developed country-specific emission factors for four land categories across six ecological zones. The FORIG staff need training on the NDC tracking and other relevant topics on the GHG inventory. Another area is where FORIG can improve by incorporating its GCARP functions into the work plan and budget.
	Faculty of Renewable Natural Resources (FRNR) of the Kwame Nkrumah University of Science and Technology (KNUST)	Contributes to land category GHG inventory and supplies natural and planted forest carbon stock data and land use mapping			x		The FRNR of KNUST is a member of the REDD+ MRV and the national GHG inventory team. The FRNR is represented by the Department of Silviculture and Forest Management. They have two trained staff who work on forestry inventories and land use mapping. The Department is also a GIS laboratory that provides technical services for developing land use maps. Map making is part of the core functions of the Department. The Department performs this function with some of its financial resources with donor projects.	The Department is involved in the Forest 2020 Project led by RMSC with funding from the UK Government. The project seeks to improve the mapping of cocoa in the high forest landscape of Ghana. FRNR GIS lab also provides quality control services to land map producers. They are involved in continuous training for students and practitioners on land use mapping.
	Ministry of Food and Agriculture (MOFA)	Manages agriculture and food statistics and prepares GHG inventory for the agriculture sector			x		Produces the annual data on food ad livestock which is available online. The Ministry of Food and Agriculture (MOFA) Statistics Research and Information Directorate (SRID) publishes the Agric Facts and	MOFA's SRID and CSD have not fully mainstreamed climate reporting. Climate reporting is not captured in their annual work plan for MOFA and thus, has no dedicated budget line. In 2017, one expert from

							Figures. The SRID was created in 1999 in response to Civil Service Law (PNDC Law 135 of 1985) that requires a Statistics and Information Directorate within the MOFA. The SRID has dedicated staff with the capacity to regularly produce an agricultural statistic that is relevant for climate reporting. Additionally, the staff from the Crop Services Directorate (CSD) of MoFA that leads the agriculture sector climate reporting also has dedicated and capable staff for the GHG inventory.	MOFA qualified to be a reviewer of the Annex 1 Party's annual inventory submission. In 2019, one additional person was nominated to participate in the training to be a reviewer. In 2019, MOFA and GSS commenced a nationwide agricultural census to update the 1980s. The census is expected to generate relevant data for the agriculture inventory report. Metadata for the facts and figures (FNF) Frequency of publication of the FNF. Train more expert No dedicated data collection template for agriculture mitigation actions.
	Animal Research Institute (ARI), CSIR	Contribute to the GHG inventory on Agriculture on livestock enteric fermentation and manure management			x		ARI is one of the 13 CSIR institutions. ARI joined the agriculture GHG inventory team in 2016. ARI involvement is to improve the GHG inventory for livestock, especially in sex, weight and age disaggregation of animals. ARI has staff on the GHG inventory team but has not incorporated the GHG inventory into the work plan and the budget.	There is a need to engage with ARI to discuss the strategies for incorporating GHG livestock inventory data into their research work.
	Driver and Vehicle Licensing Authority (DVLA)	Supply vehicle statistics and traffic data relevant to climate reporting.			x		DVLA produces annual vehicle statistics (vehicle imports, registration and roadworthy certification) through the annual registration of import vehicles and roadworthy certification for road and off-road vehicles. The DVLA has franchised 27 private garages nationwide to undertake the official registration and roadworthy certification on their behalf. The	The DVLA has figures on vehicle registration and roadworthy certification per region between 1995 and 2016. The vehicle data (the data includes vehicle make, model, year of manufacture, chassis, gross weight and fuel type) between 1995 and 2016. The data collection template used by the private garages for both

							DVLA is mandated by the Driver and Vehicle Licensing Authority Act (Act 569), 1999, to provide a regulated framework for drivers and vehicles. The Act allows private participation in the country's vehicle licensing and inspection regime. Even though both DVLA and private garages have the requisite staff and capacity to undertake their mandate of collecting vehicle registration and inspection data, they play a limited role in climate reporting. In this regard, staff do not have adequate capacity to effectively participate in the GCARP. The climate reporting activities are not incorporated into their work plan. Therefore, there is no budget.	vehicle registrations and inspections needs to be updated to capture distances covered by vehicles and odometer readings during the biannual and annual inspections for commercial and private vehicles. A survey should be conducted to establish a fuel economy baseline for different vehicles and update the existing 2005 data on fuel allocation to the various vehicle classes.
	Manufacturing Industry Unit (MIU)	Environmental data in the industry				x	The MIU is responsible for managing industrial data and provides regular updates. The Unit has been mandated to regulate industry in-country. There are dedicated staff with adequate capacity. The Unit has a dedicated budget, and activities are mainstreamed into annual work plans	The EPA provides overall budgets for the activities of the Unit.
	National Zone Unit (NOU)	Manages data on F-gases				x	NOU supplies data on F-gases importation and uses in the Refrigeration and Air-Conditioning (RAC) sector. The data is useful for the IPPU sector GHG inventory and mitigation actions on promoting low-GWP gases in the RAC sector. The Unit has been mandated to regulate industry in-country. There are dedicated staff with adequate capacity.	The EPA provides the budgets for the activities for the Unit.

							The Unit has a dedicated budget, and activities are mainstreamed into annual work plans. Most of the activities in the Unit are funded through donor projects.	
GHG inventory and mitigation actions	Human Settlement Unit (HSU), EPA	Leads in the regular preparation of the Waste sector GHG inventory and the BUR and National Communications mitigation actions.			x		The Unit has been mandated through the legal mandate in the EPA Act (Act 490), 1994 and the Environmental Assessment Regulations 1999 (LI1652) that allows them to regulate waste management facilities. There are dedicated staff with adequate capacity. The Unit has no dedicated budget, and activities have not been mainstreamed into annual work plans.	Donors provide the budget for the inventory preparation through the CCU of the EPA. The EPA provides overall budgets for the activities of the Unit. The Unit continuously gathers relevant activity data from permitted waste management companies and facilities for the inventory. The operators supply the data as part of the annual environmental reporting to the EPA. There is no dedicated template for regularly collecting data on mitigation measures in the waste. Presently, data collection on mitigation measures is ad-hoc.
	Ministry of Sanitation and Water Resources (MSWR) Ministry of Local Government and Rural Development (MLGRD)	Contributes to the energy sector GHG inventory, focusing on mobile combustion (especially the road transport category)		x			The MSWR was established in 2017 to provide policy direction in waste and sanitation in Ghana. The MLGRD initially provided this function. The MSWR contributes in the areas of processing activity data. The MSWR and MLRGD contribute to the GHG estimates on sanitation and solid waste. The MSWR has no budget to undertake this task.	The MSWR (MLRD) to engage with the MSWR to contribute to preparing the waste sector GHG inventory. There is a need to train the MSWR in this area. As part of the discussions, the MSWR must be encouraged to mainstream the uncertainty function into their core duties.
GHG inventory	Department of Statistics and Actuarial Science, University of	Uncertainty assessment		x			The Department joined the GHG inventory in 2012 and had not been active. Uncertainty management in the GHG inventory has reached a desirable level.	Re-Engage with the Department to take the role of leading the uncertainty management in climate reporting.

	Ghana Statistics[42]						University has a broad mandate for academic training and research. The Department draws on the mandate of the University of Ghana to implement the uncertainty assessment. The Department had one trained statistician in the team when they joined in 2012. The Department has not incorporated the climate reporting functions into its work plan and the budget.	As part of the discussions, the Department must be encouraged to mainstream the uncertainty function into their core duties.

Ratings

1: No responsible institution

2: Responsible institution with limited staff and capacity and no authority or mandate

3: Responsible for an organisational unit, staff with some capacity, has authority and mandate

4. Responsible with an organisational unit, staff with some capacity, has authority and mandate, integrates function into planning and budgeting

[42] https://www.ug.edu.gh/statistics/

Annexe 2: Summary of the comprehensive review of the methodology preparing climate statistics in the Energy, Transport, Agriculture and Waste sectors

General Overview

The success of Ghana's MRV system depends on the efficient flow of reliable and high-quality data from national and international sources. At the national level, the MRV system uses data published by public institutions such as Energy statistics by the Energy Commission, Agriculture Facts and Figures by the Ministry of Food and Agriculture, Vehicle Population and Inspection Statistics by Driver Vehicle and Licensing Authority, Forestry Inventory by the Forestry Commission, Waste management by the District Assemblies, Living Standard Statistics by the Ghana Statistical Service, Annual Environmental Report for Industry by Environmental Protection Agency, National and Sectoral Annual Progress Report by the National Development Planning Commission and Multiple Indicator Cluster Survey by UNICEF.

The public data often do not contain the necessary details or the statistical information to allow for comprehensive climate reporting. Most of the data are published without metadata which is usually essential to determine the level of transparency of the datasets before using them. Most of the data are published without metadata which is usually essential to determine the level of transparency of the datasets before use. The review covered the Energy, Waste, Transport and Agriculture sectors involving the review of existing data management systems in the sectors, recommendations of concrete steps on the institutionalisation of climate change reporting data supply into the compilation and publication of sector data and the development of practical road map on a national programme to improve data system relevant for climate change reporting.

Summary of Recommendations

Waste sector

- **Data collection** - Create a central waste data management centre managed by the Sanitation Directorate of the Ministry of Water and Sanitation. The Ministry must support the regular data collection efforts by the various stakeholders. Ensure that waste data reporting is actively included within various regulatory reporting requirements. Need to create a system to invest in new waste management services and facilities to institutionalise routine data collection. Further research is required to develop suitable protocols in emerging areas. It is also important to develop fit-for-purpose data collection and management information systems, to promote performance monitoring and sound strategic planning. Support academia to produce research addressing key gaps or issues, such as providing country-specific emission factors.

- **Waste statistics -** Currently, there is no central point for collecting and publishing waste statistics. Waste management data has dotted across various institutions, and there is a need to streamline this function to one point. The Sanitation Directorate of the MSWR has policy oversight on the sector and needs to integrate all the waste data management sources into one. The Directorate has established a system currently used to collect data from the district, regional and nation levels. There is a need to engage them to see the entry points for collecting sanitation and municipal waste data.

Data on new investments into the sector can also be secured from the PPMED of the MSWR, as the Directorate is responsible for collecting this data annually. The staff of the MSWR must be adequately trained to generate climate-smart data in a format that can easily be assessed for climate change and NDC reporting.

- The GSS has the mandate and currently publishes the Census Reports, MICs and GLSS, which provide reliable and useful waste data. There is no need to establish new sources to collect similar data. Efforts should be made to further strengthen this platform to collect new or additional data to fill the current gaps. It is also important to embed the current data collection systems or arrangements within the sector into the single source as envisaged through stakeholder collaboration. The GSS can be sensitised and trained in collecting data relevant to waste sector climate reporting. The online data hub hosted by the EPA can be used to host the relevant waste sector data. All the current data sources, such as the EPA MIU Industry Database and the MICs, can be linked to the system as the one-stop waste statistics outlet.

- **Waste sector annual progress report** - The APR prepared by the PPMED of MSWR and submitted to the NDPC contains useful information relevant to climate reporting, especially mitigation assessment. The immediate task is to engage with the PPMED of MSWR and NDPC, EPA, and MLGRD to discuss the concrete strategies for including NDC reporting in the sector APR. There is the need to implant climate reporting in the setup for the APR publication by the PPMED. This can be achieved through the training of the staff of the PPMED. However, due to the local assemblies' involvement in waste management, it is important to engage the MLGRD and possibly its PPMED to facilitate data collection and sharing, which may serve as an additional data source. The mainstreaming must develop specific indicators, specific data templates for the waste sector NDC, staff training, and the selection of a contact person to follow up on the data collection and report.

- **Project Reports -** The Ministry of Sanitation and Water Resources implements several projects within the sector, and these projects have specific reporting requirements. The project reports can be accessed through the Project website, management units, or the donor website. These projects, which may not be set up to address climate change issues, may have climate co-benefits that are important for mitigation assessment or adaptation. The Project Coordinating Unit (PCU) within the MSWR should be engaged to report or share the outcomes of these project interventions captured as part of the reporting requirements to facilitate climate reporting. The strategy for engaging the PPMED must also be used to engage the PCU of MSWR in collecting project data relevant to climate reporting. During the PCU engagement, it would be helpful to regularly discuss practical approaches for collecting data from the project managers to implement the approaches, timelines, and resources needed for rolling out.

- **Research from Academia -** Academia produces research that may form an integral part of climate reporting, especially in developing a country's specific emission factors. Ghana uses the IPCC emission factor database to estimate greenhouse gas emissions. Currently, there are no direct or formalised collaborative projects with academic institutions that contribute to climate reporting. Individual researchers in academia regularly assist with information and contributions to the national GHG inventory report and the national communication to the UNFCCC. These collaborators regularly assist with inputs in their capacities, not on an official basis. However, volumes of research and other reports provide valuable information and could be accessed for additional information on Ghana's climate reporting. Additionally, several internationally funded research projects in many academic institutions geared towards generating information on climate change could be assessed to provide valuable inputs for climate reporting, such as the Ghana Water, Sanitation and Hygiene (WASH) Project.

Annexe 2: Summary of review of the methodology preparing climate statistics in the Energy, Transport, Agriculture and Waste sectors

Matrix of data handling issues, challenges and improvement strategies in the Agriculture Sector

Issues	Challenges	Recommendations	Priority Strategy	Timelines	Lead/supporting institutions	Indicative cost ($)
Management of agricultural statistics	The inability of SRID to publish AFaF online.	Continue collecting the pdf document SRID until MoFA's website becomes active.	The EPA must create an email link with a reminder to request the pdf version of the AFaF on the 31st of August every year. EPA should share the email link with ASCU of SRID and ELMWU of CSD for the regular exchange of the pdf version of the AFaF whenever it is ready in August every year.	Immediately	CCU, EPA ELMWU, CSD ASCU, SRID	No cost
	Non-functioning MoFA website	Consider uploading the agriculture statistics on the climate change data hub managed by the EPA. Anytime the MoFA website becomes active, let the IT team of EPA and SRID collaborate to develop a functional webpage with the facts and figures	Complete the reconstruction of the climate data hub and create a specific page for collecting, publishing, and archiving agriculture statistics.	December 2021	CCU, EPA ELMWU, CSD ASCU, SRID	$10,000
	Lack of data repository in MoFA	Engage MoFA to establish a central database with SRID or any Directorate of MoFA deems fit to host all relevant agricultural statistics relevant for climate reporting.	EPA, SRID and ELMWU must collaborate to develop a proposal for funding to establish a central database for agriculture statistics	January 2022	ASCU, SRID ELMWU, CSD CCU, EPA	$20,000
Non-functional systems for continuous data collection, processing, analysis, archiving and reporting	Lack of disaggregated livestock data	Undertake a comprehensive livestock survey.	Engage the management of MoFA on the relevance of disaggregated livestock data for climate reporting and advocate for increased funding for the Animal Production Directorate (APD) and VSD. Establish partnerships for the Animal Research Institute, APD and Animal Science Departments of the Universities	December 2020	ELMWU, CSD ASCU, SRID APD ARI - CSIR CCU, EPA Animal Science Department, University of Ghana, Legon	$100,000

		Undertake academic research on livestock, feeding and manure management systems. Increase the financial budget for Veterinary Service Directorate (VSD) to strengthen data collection associated with the nationwide animal vaccination.	to promote research on livestock areas for climate reporting. Explore the development of large-ticket international proposals with international organisations such as New Zealand Agricultural Greenhouse Gas Research Centre43 or other West Africa Countries, livestock, feeding and manure management systems.			
	Lack of disaggregated crops statistics	Cultivated cropland areas are published in the AFaF, but the data is not used in any of the climate reports	Use the figures on cropland areas published in the AFaF instead of the Forestry Commission's data. They separate the annuals and perennials cropland areas and use a robust data collection system.	December 2021	CCU, EPA ELMWU, CSD ASCU, SRID	No cost
		Rice cultivation data does not include disaggregation of production and cultivated areas in the different ecosystems (upland, lowland and irrigated systems) and the changes over a given period.	Partner with CSD, Crop Science Department of the Public Universities, SARI-CSRI, FAO and International Research Organisation of Rice to conduct a one-time empirical study on Rice cultivation. Develop a study proposal to seek funding to finance the study on cultivation, production, ecosystems, areas and changes in them over a given period.	December, 2023	ELMWU, CSD ASCU, SRID	$200,000
		Data on crop-residue ratio does not exist. The ratios for different crops differ because agronomic practice is local and diverse.	Undertake a study on crop residue either with the existing data structure for the AFaF or with some academics.	December 2023	ASCU, SRID Crop Science Department in selected Universities	$75,000

[43] https://www.devex.com/organizations/new-zealand-agricultural-greenhouse-gas-research-centre-nzagrc-99691

	Non-existing disaggregated data on fertilisers	Fertiliser figures in the AFaF are based on imports but not actual consumption. There is no further breakdown on re-export, storage, and application mode percentages.	ASCU and SRID must introduce additional data collection instruments to include actual consumption and mode application of fertiliser. ASCU and SRID must explore ways to collect data on re-export figures on fertilisers regularly.	December 2023	ASCU, SRID ELMWU, CSD	$100,000
		No data on animal manure and compost application on croplands.	ASCU, SRID must begin to collect data on organic manure (animal, compost)	December 2023	ASCU, SRID ELMWU, CSD	$30,000
Institutionalisation of data exchange with SRID	A non-existing legal regime that compels industry players and stakeholders to provide data to SRID	Make the regular supply of livestock, crop and fertiliser statistics to SRID mandatory either through administrative fiat or as part of the proposed climate change law.	Director of CSD, Director SRID and through Chief Director of MoFA could write an official letter to request the Ministry's data supplier. For the data owners outside the Ministry of Food and Agriculture, the Chief Director could reach out to them to encourage them to continue exchanging data with SRID.	December 2021	ASCU, SRID ELMWU, CSD	$3,000
	Lack of climate change elements in data collection instruments	Incorporate climate change reporting elements on GHG inventory, NDC and support in existing data collection instruments used by SRID and PPMED for the compilation of AFaF and APR	Write to SRID and PPMED to request discussions on the possibility of incorporating climate change elements into the data collection for the AFaF and the APR.	December 2022	ELMWU, CSD ASCU, SRID	No cost
	Inadequate climate change reports from projects	Encourage project managers in the MoFA or outside MoFA to share climate change project reports with PPMED and SRID. Prepare a simplified table for the project managers to report on specific climate change elements, particularly information on support received and those related to the NDCs in the sector.	Directors of SRID and PPMED must issue a circular to request all project owners complete and submit the climate data table at the end of every year, preferably when AFaF and APR are being prepared. Organise a meeting with climate change-related project managers to review the data tables and provide further clarification.	December 2021	ELMWU, CSD SRID PPMED CCU, EPA	$ 2,000

Matrix of data handling issues, challenges and improvement strategies in the Energy Sector

Issues	Challenges	Recommendations	Priority Strategy	Timelines	Lead/Collaborating Institutions	Indicative cost (USD)
Need to enhance the quality of data which informs the preparation of Energy Statistics and APR	No funds to conduct periodic surveys as required to ensure statistically viable projections.	Secure funding to conduct requisite surveys to enhance recommended primary data collection	Conduct a nationwide survey on fuel allocation to the various sectors.	Immediately	Energy Commission NPA, EPA, MoF, GSS	100,000.00
	No central MIS system in the PPMED of the Ministry of Energy to facilitate effective data management	Procure a recommended software for data management in the PPMED of the Ministry of Energy	Conduct a data management audit at the Ministry of energy and prescribe an appropriate software (MIS) for the PPMED	August 2021	MoEn MoF	20,000
	There are no budgets for the EC and MoEn to conduct routine Data Quality Assessments (DQAs) for data received from sector institutions and other technical directorates at the MoEn.	Identify a sustainable funding source to enhance routine DQAs and data verification at the EC and MoEn.	Work with the MoF to provide a budgetary allocation for DQAs to enhance data quality in the sector.	Immediately	EC, MoEn MoF, EPA	No Funds required
Dysfunctional system for effective data collection, collation, processing, storage, and dissemination at Energy Sector Agencies/Ministry	Dispersed guidelines and manuals, and operative directives yet to be integrated into a single organisational, institutional manual/handbook	Consolidate existing guidelines and protocols into a single comprehensive manual or handbook	Technical support to institutions to develop data management manuals	October 2021	EC, MoEn, VRA, BPA, GRIDCo, GNGC, NPA, PC, and GNPC.	15,000
	Rationalise the existing methodologies for data collection, processing, storage, and dissemination	Employ enhanced and made-to-fit strategies to improve data management	Technical support to rationalise the processes	October 2021	EC, MoEn, VRA, BPA, GRIDCo, GNGC, NPA, PC, and GNPC.	15,000
Insufficient Integration of climate reporting requirements into mainstream energy sector data management system	Inadequate human resource capacity to enable comprehensive integration of climate reporting by the Energy Commission, Ministry of Energy, and other key sector institutions.	Progressively develop the capacities of relevant staff in the various sector institutions to keep up with climate change reporting requirements and sustainable development.	Train relevant staff in the Energy Commission, Ministry of Energy, and other key institutions on climate reporting requirements and mainstreaming	September 2021	EPA EC, MoEn, VRA, BPA, GRIDCo, GNGC, NPA, PC, and GNPC.	10,000.00
	There are no budgets for the EC and MoEn to conduct routine Data Quality Assessments	Identify a sustainable source of funding to enhance routine DQAs and	Work with the MoF to provide a budgetary allocation for DQAs to	September 2021	EC, MoEn MoF, EPA	No Funds required

	(DQAs) for data received from sector institutions and other technical directorates at the MoEn.	data verification by the EC and MoEn.	enhance data quality in the sector.			
Lack of a central Coordinating Unit for energy/climate data in the energy sector	No functional Unit in the Ministry of Energy to coordinate Climate change reporting	Establish and operate a functional unit in the Ministry of Energy to coordinate climate change reporting	Establish a functional climate unit in the Ministry of Energy	August 2021	**EPA, MoEn** MoF	*No Funds required
	No functional climate unit in the various energy sector Agencies to facilitate climate change reporting	Establish a functional climate unit in all the relevant energy sector Agencies	Employ and or assign designated staff with climate change reporting responsibilities in the various sector institutions	August 2021	**EPA/MoEn/EC** VRA, BPA, GRIDCo, ECG, NEDCo, PURC, SIGA, PC, GNGC, GNPC, NPA, TOR	No funds required salary for staff with newly employed
High variation in the fuel consumption allocation	Lack of background data to inform fuel consumption per end-user sectors	Undertake field survey to collect data to inform fuel consumption allocation per end-use sectors such as transport, household, industry/manufacturing, commerce and agriculture	Develop a proposal to seek funding to finance the field survey on sectoral fuel consumption and fuel intensities	December 2022	**EPA, MoEn** MoF	300,000
		Develop a data exchange channel for the regular sharing of fuel consumption data per end-user sectors	Prepare data exchange agreement. Develop sectoral fuel consumption data protocols and share them with NPA. Work with NPA on the continuous data collection on sectoral fuel consumption every year.	June 2022	**NPA, EC, GSS, EPA**	100,000
Development of emission factors for key emission sources	The lack of country-specific factors leads to using the tier 1 method to estimate emissions for key categories in the energy sector	Conduct a study to develop country-specific emission factors for key categories	Develop a proposal for funding a study on the development of country-specific emission factors for key categories	December 2023	**EPA, EC**	250,000

Matrix of data handling issues, challenges and improvement strategies in Road Transport

Issues	Challenges	Recommendations	Priority Strategy	Timelines	Lead/supporting institutions	Indicative cost ($)
Unrecorded motor Vehicle layoff	Motor vehicle owner does not inform DVLA of their laid-off vehicles	Embark on public education and sensitisation	Selected radio stations within the catchment of the operational office should engage and educate the public on the need to in DVLA about the vehicle layoff	2021	DVLA/MTTD of Ghana Police Service	$50,000
	Non-renewal of vehicle registration number	Implement regulation 12 of the Road Traffic Regulation 2012, L.I.2180	All offices are granted permission to conduct renewal of vehicle registration	March 2022	DVLA	NO cost
Non-functional systems for continuous data collection, processing, analysis, archiving and reporting	Lack of readily available data on motor vehicle emission test results.	Procure a comprehensive software system for data collection and storage Employ and train dedicated staff on data collection and entry at all operational offices. Implement the gazetted EPA emission limits.	All regional and district heads should be sensitised to the need to produce quality vehicle data Additional staff with data handling experience should be employed Regulations on the emission limitations should be formulated	December 2021 March 2021 December 2021	DVLA DVLA DVLA/ EPA	$50,000 $200,000
	Lack of real-time data on vehicles with DV/DP plates	Procure a software Package for data collection and maintenance on DV and DP plates.	Data on DV/DP plates should be captured on the new Vehicle Registration System	January 2022	DVLA	50,000
Vehicle circulation data	Lack of information on vehicle circulation data (annual kilometre driven)	Design a template for the systematic recording of odometer readings of vehicles Employ and train dedicated staff on data collection and entry at all operational offices	All DVLA operational offices are trained to capture and prepare data on odometer readings of vehicles Design and system an online system to collect real-time information from all operational offices	January 2022	DVLA	100,000

Matrix of data handling issues, challenges and improvement strategies in Aviation

Issues	Challenges	Recommendations	Priority Strategy	Timelines	Lead/supporting institutions	Indicative cost ($)
Institutional Data Management system, reporting and capacity	Lack of ICAO certified verifier(s) in Ghana to audit airline emissions reports	Encourage coordination and partnership with key institutions on climate change reportage	Seek technical assistance from States/ICAO to conduct an audit on airline emission reports.	Immediately	GCAA/ICAO, MESTI, EPA, Airline operators, OMCs	Not yet available
	Lack of/inadequate qualified research personnel. Limited aviation climate change experts at the Ministry and Agencies	Make a conscious effort to create a pool of researchers and build capacity sustainably. The need to make a conscious effort to build capacity and coordination with relevant institutions	Engage and collaborate with MESTI and EPA, and KNUST to train and create a pool of aviation climate experts	Immediately	MoT/OHCS, CSTC other educational institutions	$100,000
	Lack of data storage facility	Create a web-based data hub and link it to key data centres such as NITA and EPA climate change data hub	Develop a web-based data hub to be managed by RSIM. Upgrade Ministry's website to link to EPA data hub and NITA data centre	By the end of the year 2021	MoT/NITA, MESTI, EPA	$20,000
Institutionalisation of data access	Non-submission of periodic data on fuel consumption by airlines from OMCs.	The need to put systems in place to ensure periodic reportage of all relevant data by identified stakeholder(s).	Establish an institutional or administrative mechanism for access to data and reporting lines whilst ensuring confidentiality.	Immediately	MoT/GCAA, OMCs, Airline operators	No cost
	Inadequate climate change reports from projects	Create a Project Implementation Unit (PIU) and ensure reportage on climate change of projects	Set up a PIU at the Ministry with the additional function of climate change issues	By the end of the year 2021	MoT/MoF, MESTI	$10,000
	Conflicting air traffic data from GCAA and GACL	The appropriate mechanism to be put in place to ensure coherence in air traffic data reporting GACL is tasked to be the sole entity for reporting air traffic data information whilst GCAA focus on other air traffic data.	GCAA to create an administrative mechanism to receive air traffic data from the primary source (airlines) Establish an institutional arrangement to allow GACL solely report on air traffic statistics (international and domestic passenger numbers, international and domestic aircraft movements	Immediately	MoT/GCAA/GACL, Airline operators	No cost

			and freight) and allow GCAA to solely report on en-route, number of ACL/AOC and fuel sales in litres.			
Budgeting	Lack of funding to undertake research activities	Encourage sector agencies who generate IGF to set aside a fund for research activities As part of budget reporting, the Ministry of Finance should demand from MDAs their research reports in line with their budget allocation and releases for RSIM	Create a research fund account at the Ministry to enable identified key IGF generating agencies to make quarterly contributions Ministry of Finance to release a circular to MDAs to attach a research report to their annual budget report, which will form the basis for budget allocation RSIM (sub-programme) for the ensuing budget year	Immediately	MoT/GCAA,GACL,MoF MoF/MoT,MDAs	No cost

Matrix of data handling issues, challenges and improvement strategies in Railway Statistics

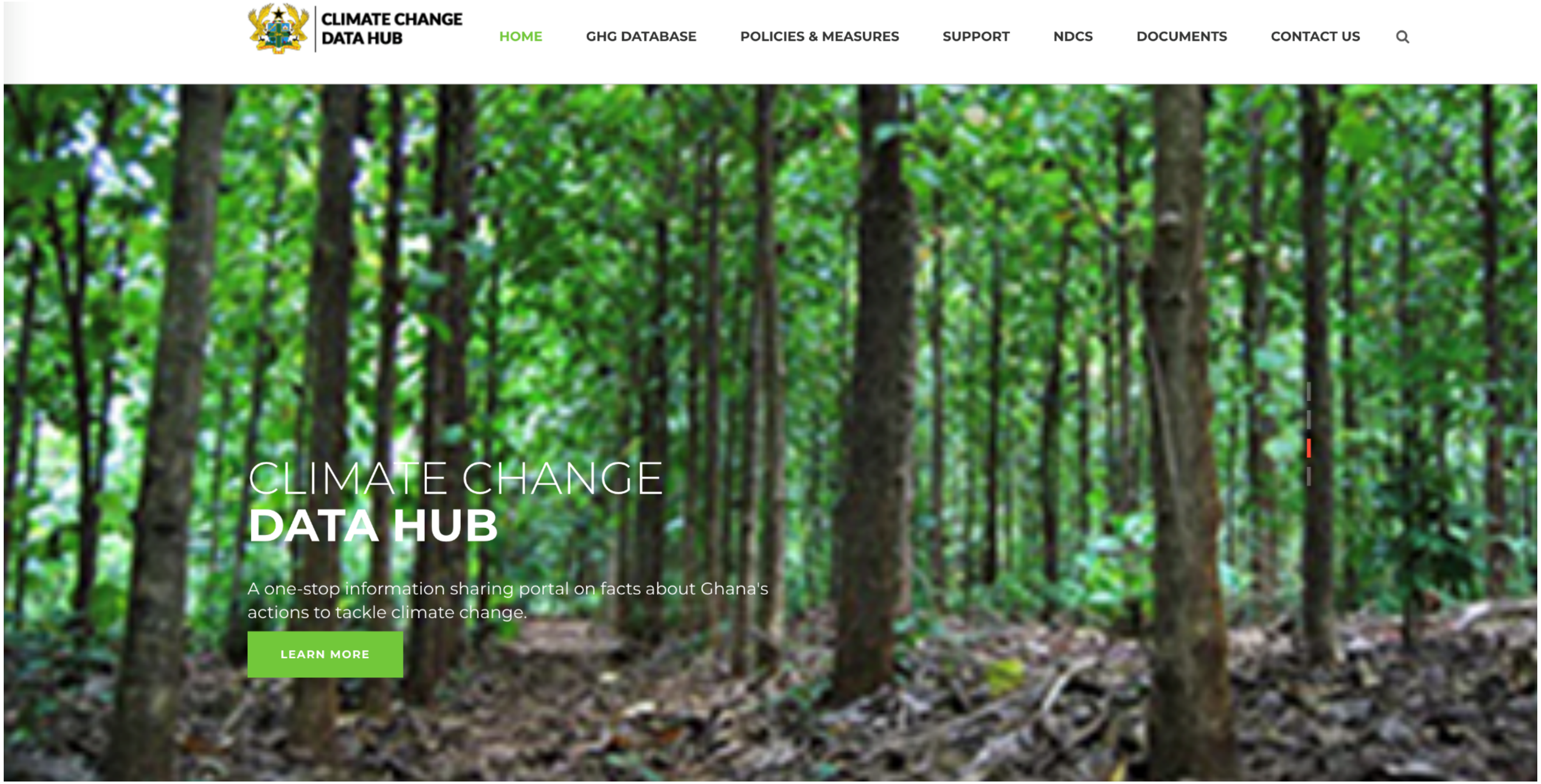
Issues	Challenges	Recommendations	Priority Strategy	Timelines	Lead/supporting institutions	Indicative cost ($)
Institutional Data Management system, reporting and capacity	Manual Documentation Management	A digital platform for documentation management	Develop an online tool for the documentation management	Immediately	GRCL/MORD, GRDA	20,000
	High staff attrition	Make a conscious effort to recruit and maintain staff		Immediately	MORD/ GRCL	
	Lack of data storage facility	Ensure the use of ICT at all operational offices	Fully equip operational offices with ICT	By end of year 2021	GRCL/ MORD NITA,	$20,000
	Discrepancies in traffic data	Introduce a data verification system to avoid discrepancies	Create a web-based data hub to enable operational offices to transmit data electronically	By the end of the year 2021	GRCL/ MORD NITA,	N/A
	Consolidated fuel usage data	Ensure that fuel and lubricant consumption by the Diesel Multiple is separated from general operational	Introduce a system to track and report on fuel and lubricant and by the Diesel Multiple Units	Immediate	GRCL/ GRDA	$5,000

Matrix of data handling issues, challenges and improvement strategies in Maritime Statistics

Issues	Challenges	Recommendations	Priority Strategy	Timelines	Lead/supporting institutions	Indicative cost ($)
Institutionalisation of data access	Non-submission of periodic data on fuel consumption vessels from OMCs	The need to put systems in place to ensure periodic reportage of all relevant data by identified stakeholder(s)	Establish an administrative mechanism for access to data and reporting lines whilst ensuring confidentiality	Immediately	GMA/GCAA, OMCs, Airline operators	No cost
	Conflicting air traffic from GSA and GPHA	An appropriate mechanism to be put in place to ensure coherence in traffic data reporting GPHA must be tasked to act as the sole entity for reporting traffic data information whilst GSA focuses on shipper services.		Immediately	GMA/GCAA/GACL, Airline operators	No cost

Annexe 3: Screenshot of the redesigned Ghana's climate datahub

Web address: https://climatedatahub.com.gh/



Annexe 4: Sample of MOU between EPA and the GHG inventory Institutions

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

Purpose of MOU

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

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. A new institutional arrangement has been put in place as part of the efforts to establish a national system under the NC3. The institutions have been identified, their roles and responsibilities defined, and reporting channels have been delineated. The various organisations (GHG inventory entities) were selected based on their competence and relevance to the GHG inventory sectors.

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 practical and suitable as the practical working guidance document between the Environmental Protection Agency and all the inventory entities.

This WP-MoU, therefore, seeks to establish a set of common understanding of GHG inventory tasks, which the inventory entities would undertake during the latest inventory cycle. The list of activities that the inventory entities would undertake would 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 would be progressively managed.

As much as possible, the activities undertaken by the inventory entities would depend on the overall satisfaction of all conditions precedent on the part of the Environmental Protection Agency and the said entity. Because the Agency intends to ensure that the efficiency of the National System is progressively improved and becomes more integrated, the WP-MoU would 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 make it more responsive to the lessons learnt in the previous inventory cycle.

Preamble

The Environmental Protection Agency is the Designated National GHG inventory Entity and, in collaboration with "National Entity A", recognises that:

There is an urgent need to have the national GHG inventories processes mainstreamed into the activities of the various inventory entities and make them relevant for national development and international reporting;

Strengthening the capacities of GHG inventories entities is fundamental to the ability of Ghana to meet the increasing demand for reporting on GHG emissions regularly;

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

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

Responsibilities of Entity A

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

Conduct a 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.

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 based on 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 up in your organisation.

Liaise with the inventory coordinator at EPA to undertake a comprehensive review of available methodological choices and make sound methodological choices based on their applicability to estimating GHG emissions.

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 Intergovernmental Panel on Climate Change (IPCC) Guidelines and fully documented.

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

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

Create and maintain hard and soft backup copies of all information, data, and estimates at the sector level and subsequent onward transmission to the Environmental Protection

Agency and Ghana Statistical Services as the inventory documentation and archiving depository.

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

Timelines
The activities listed above must be prioritised and implemented based on the sequence of activities and in a realistic and achievable manner within the inventory cycle's timeframe.

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

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

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

Annexe 5: Summary Tables

(List of Tables accompanying this report)

Annexe 5.1 Table A - Summary Table (2019)

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)		
Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF6
Total National Emissions and Removals	41,933.24	328.00	28.67	593.76	521.57	NE
1 - Energy	26,377.78	23.05	1.16	-	-	-
1.A - Fuel Combustion Activities	18,482.65	18.25	1.03	-	-	-
1.A.1 - Energy Industries	7,304.53	1.72	0.23			
1.A.2 - Manufacturing Industries and Construction	1,217.80	0.49	0.06			
1.A.3 - Transport	9,029.69	2.38	0.46			
1.A.4 - Other Sectors	930.63	13.66	0.28			
1.A.5 - Non-Specified	-	-	-			
1.B - Fugitive emissions from fuels	7,895.12	4.80	0.1237	-	-	-
1.B.1 - Solid Fuels	-	-	-			
1.B.2 - Oil and Natural Gas	7,895.12	4.80	0.1237			
1.B.3 - Other emissions from Energy Production	-	-	-			
1.C - Carbon dioxide Transport and Storage	-	-	-	-	-	-
1.C.1 - Transport of CO_2	-					
1.C.2 - Injection and Storage	-					
1.C.3 - Other	-					
2 - Industrial Processes and Product Use	615.80	-	-	593.76	521.57	-
2.A - Mineral Industry	531.67	-	-	-	-	-
2.A.1 - Cement production	32.79					
2.A.2 - Lime production	NE					
2.A.3 - Glass Production	-					
2.A.4 - Other Process Uses of Carbonates	498.88					
2.A.5 - Other (please specify)	-	-	-			
2.B - Chemical Industry	-	-	-	-	-	-
2.B.1 - Ammonia Production	-					
2.B.2 - Nitric Acid Production			-			

2.B.3 - Adipic Acid Production			-			
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			-			
2.B.5 - Carbide Production	NE	NE				
2.B.6 - Titanium Dioxide Production	-					
2.B.7 - Soda Ash Production	-					
2.B.8 - Petrochemical and Carbon Black Production	-	-				
2.B.9 - Fluorochemical Production				-	-	-
2.B.10 - Other (Please specify)	-	-	-	-	-	-
2.C - Metal Industry	82.05	-	-	-	521.57	-
2.C.1 - Iron and Steel Production	12.97	-				
2.C.2 - Ferroalloys Production	-	-				
2.C.3 - Aluminium production	69.08				521.57	
2.C.4 - Magnesium production	-					-
2.C.5 - Lead Production	-					
2.C.6 - Zinc Production	-					
2.C.7 - Other (please specify)	-	-	-	-	-	-
2.D - Non-Energy Products from Fuels and Solvent Use	2.08	-	-	-	-	-
2.D.1 - Lubricant Use	2.08					
2.D.2 - Paraffin Wax Use	-					
2.D.3 - Solvent Use						
2.D.4 - Other (please specify)	-	-	-			
2.E - Electronics Industry	-	-	-	-	-	-
2.E.1 - Integrated Circuit or Semiconductor				-	-	-
2.E.2 - TFT Flat Panel Display					-	-
2.E.3 - Photovoltaics					-	
2.E.4 - Heat Transfer Fluid					-	
2.E.5 - Other (please specify)	-	-	-	-	-	-
2.F - Product Uses as Substitutes for Ozone Depleting Substances	-	-	-	593.76	-	-
2.F.1 - Refrigeration and Air Conditioning				593.76		
2.F.2 - Foam Blowing Agents				-		
2.F.3 - Fire Protection				-	-	
2.F.4 - Aerosols				-		
2.F.5 - Solvents				-	-	
2.F.6 - Other Applications (please specify)				-	-	

2.G - Other Product Manufacture and Use	-	-	-	-	-	-
2.G.1 - Electrical Equipment					-	NE
2.G.2 - SF_6 and PFCs from Other Product Uses					-	NE
2.G.3 - N_2O from Product Uses			-			
2.G.4 - Other (Please specify)	-	-	-	-	-	-
2.H - Other	-	-	-	-	-	-
2.H.1 - Pulp and Paper Industry	-	-				
2.H.2 - Food and Beverages Industry	-	-				
2.H.3 - Other (please specify)	-	-	-			
3 - Agriculture, Forestry, and Other Land Use	14,924.02	166.38	25.35	-	-	-
3.A - Livestock	-	136.89	3.42	-	-	-
3.A.1 - Enteric Fermentation		129.57				
3.A.2 - Manure Management		7.31	3.42			
3.B - Land	14,517.40	-	-	-	-	-
3.B.1 - Forest land	(3,082.38)					
3.B.2 - Cropland	19,256.40					
3.B.3 - Grassland	(2,600.77)					
3.B.4 - Wetlands	16.25		-			
3.B.5 - Settlements	719.86					
3.B.6 - Other Land	208.03					
3.C - Aggregate sources and non-CO_2 emissions sources on land	406.62	29.50	21.93	-	-	-
3.C.1 - Emissions from biomass burning		15.28	1.31			
3.C.2 - Liming	NE					
3.C.3 - Urea application	406.62					
3.C.4 - Direct N_2O Emissions from managed soils			15.96			
3.C.5 - Indirect N_2O Emissions from managed soils			4.38			
3.C.6 - Indirect N_2O Emissions from manure management			0.28			
3.C.7 - Rice cultivations		14.22				
3.C.8 - Other (please specify)		-	-			
3.D - Other	-	-	-	-	-	-
3.D.1 - Harvested Wood Products	NE					
3.D.2 - Other (please specify)	-	-	-			
4 - Waste	15.63	138.56	2.17	-	-	-
4.A - Solid Waste Disposal	-	62.92	-	-	-	-
4.B - Biological Treatment of Solid Waste	-	2.16	0.13	-	-	-

4.C - Incineration and Open Burning of Waste	15.63	5.34	0.08	-	-	-
4.D - Wastewater Treatment and Discharge	-	68.14	1.96	-	-	-
4.E - Other (please specify)	-	-	-	-	-	-
5 - Other	-	-	-	-	-	-
5.A - Indirect N_2O emissions from the atmospheric deposition of nitrogen in NOx and NH3	-	-	-	-	-	-
5.B - Other (please specify)	-	-	-	-	-	-
Memo Items (5)						
International Bunkers	CO2	CH4	N20	-	-	-
1.A.3.a.i - International Aviation (International Bunkers)	625.84	0.0044	0.0095			
1.A.3.d.i - International water-borne navigation (International bunkers)	22.83	0.0022	0.0001			
1.A.5.c - Multilateral Operations	-	-	-	-	-	-

Annex 5.2 Table B - Table A Short Summary Table

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)		
Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF6
Total National Emissions and Removals	41,933.24	328.00	25.25	593.76	521.57	NE
1 - Energy	26,377.78	23.05	1.16	-	-	-
1.A - Fuel Combustion Activities	18,482.65	18.25	1.03	-	-	-
1.B - Fugitive emissions from fuels	7,895.12	4.80	0.12	-	-	-
1.C - Carbon dioxide Transport and Storage	-	-	-	-	-	-
2 - Industrial Processes and Product Use	615.80	-	-	593.76	521.57	-
2.A - Mineral Industry	531.67	-	-	-	-	-
2.B - Chemical Industry	-	-	-	-	-	-
2.C - Metal Industry	82.05	-	-	-	521.57	-
2.D - Non-Energy Products from Fuels and Solvent Use	2.08	-	-	-	-	-
2.E - Electronics Industry	-	-	-	-	-	-
2.F - Product Uses as Substitutes for Ozone Depleting Substances	-	-	-	593.76	-	-
2.G - Other Product Manufacture and Use	-	-	-	-	-	-
2.H - Other	-	-	-	-	-	-
3 - Agriculture, Forestry, and Other Land Use	14,924.02	166.38	21.93	-	-	-
3.A - Livestock	-	136.89	-	-	-	-
3.B - Land	14,517.40	-	-	-	-	-

3.C - Aggregate sources and non-CO2 emissions sources on land	406.62	29.50	21.93	-	-	-
3.D - Other	-	-	-	-	-	-
4 - Waste	15.63	138.56	2.17	-	-	-
4.A - Solid Waste Disposal	-	62.92	-	-	-	-
4.B - Biological Treatment of Solid Waste	-	2.16	0.13	-	-	-
4.C - Incineration and Open Burning of Waste	15.63	5.34	0.08	-	-	-
4.D - Wastewater Treatment and Discharge	-	68.14	1.96	-	-	-
4.E - Other (please specify)	-	-	-	-	-	-
5 - Other	-	-	-	-	-	-
5.A - Indirect N_2O emissions from the atmospheric deposition of nitrogen in NOx and NH_3	-	-	-	-	-	-
5.B - Other (please specify)	-	-	-	-	-	-
Memo Items (5)						
International Bunkers	648.67	0.0065	0.0096	-	-	-
1.A.3.a.i - International Aviation (International Bunkers)	625.84	0.0044	0.0095			
1.A.3.d.i - International water-borne navigation (International bunkers)	22.83	0.0022	0.0001			
1.A.5.c - Multilateral Operations	-	-	-	-	-	-

Annex 5.3: Table 1 - Energy Sectoral Table

	Emissions (Gg)						
Categories	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
1 - Energy	25,363.76	6,816.99	2.52	114.99	926.29	234.35	254.96
1.A - Fuel Combustion Activities	17,468.63	6,812.18	2.39	114.99	926.29	234.35	254.96
1.A.1 - Energy Industries	6,290.51	6,795.66	1.59	12.43	326.18	109.43	15.90
1.A.1.a - Main Activity Electricity and Heat Production	6,209.91	0.15	0.02	10.26	3.47	0.25	10.87
1.A.1.a.i - Electricity Generation	6,209.91	0.15	0.02	10.26	3.47	0.25	10.87
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				-	-	-	-
1.A.1.a.iii - Heat Plants				-	-	-	-
1.A.1.b - Petroleum Refining	75.91	0.00	0.00	0.12	0.01	-	0.32
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	4.69	6,795.51	1.57	2.05	322.70	109.18	4.71
1.A.1.c.i - Manufacture of Solid Fuels		5,776.80	1.55	0.60	322.11	109.14	4.69
1.A.1.c.ii - Other Energy Industries	4.69	1,018.71	0.02	1.45	0.59	0.04	0.02
1.A.2 - Manufacturing Industries and Construction	1,217.80	0.49	0.06	9.80	9.81	4.87	31.94
1.A.2.a - Iron and Steel	23.13	0.01	0.00	0.16	0.15	0.07	0.54
1.A.2.b - Non-Ferrous Metals				-	-	-	-
1.A.2.c - Chemicals	5.54	0.02	0.00	0.11	0.47	0.25	0.82
1.A.2.d - Pulp, Paper and Print	5.95	0.00	0.00	0.05	0.01	-	0.10
1.A.2.e - Food Processing, Beverages and Tobacco	151.65	0.35	0.04	1.94	5.41	2.83	10.67
1.A.2.f - Non-Metallic Minerals				-	-	-	-
1.A.2.g - Transport Equipment				-	-	-	-
1.A.2.h - Machinery				-	-	-	-
1.A.2.i - Mining (excluding fuels) and Quarrying	917.88	0.04	0.01	6.35	0.82	0.31	13.63
1.A.2.j - Wood and wood products	3.42	0.00	0.00	0.02	0.00	0.00	0.05
1.A.2.k - Construction	71.25	0.00	0.00	0.49	0.06	0.25	1.06
1.A.2.l - Textile and Leather	24.69	0.03	0.01	0.26	0.63	0.33	1.31
1.A.2.m - Non-specified Industry	14.29	0.03	0.00	0.40	2.26	0.83	3.76
1.A.3 - Transport	9,029.69	2.38	0.46	85.30	378.44	50.76	139.01
1.A.3.a - Civil Aviation	52.33	0.00	0.00	-	-	-	-
1.A.3.a.i - International Aviation (International Bunkers) (1)							

1.A.3.a.ii - Domestic Aviation	52.33	0.00	0.00	-	-	-	-
1.A.3.b - Road Transportation	8,971.45	2.38	0.46	85.15	378.42	50.61	138.69
1.A.3.b.i - Cars	3,708.88	1.23	0.17	-	-	-	-
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	206.99	0.10	0.01	-	-	-	-
1.A.3.b.i.2 - Passenger cars without 3-way catalysts	3,501.90	1.13	0.16	-	-	-	-
1.A.3.b.ii - Light-duty trucks	1,164.71	0.27	0.06	-	-	-	-
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts	48.27	0.02	0.00	-	-	-	-
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	1,116.44	0.24	0.06	-	-	-	-
1.A.3.b.iii - Heavy-duty trucks and buses	1,587.16	0.19	0.10	-	-	-	-
1.A.3.b.iv - Motorcycles	2,510.69	0.70	0.12	-	-	-	-
1.A.3.b.v - Evaporative emissions from vehicles				-	-	-	-
1.A.3.b.vi - Urea-based catalysts	-			-	-	-	-
1.A.3.c - Railways	2.79	0.00	0.00	0.07	0.01	0.07	0.15
1.A.3.d - Water-borne Navigation	3.13	0.00	0.00	0.08	0.01	0.08	0.17
1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.3.d.ii - Domestic Water-borne Navigation	3.13	0.00	0.00	-	-	-	-
1.A.3.e - Other Transportation				-	-	-	-
1.A.3.e.i - Pipeline Transport				-	-	-	-
1.A.3.e.ii - Off-road				-	-	-	-
1.A.4 - Other Sectors	930.63	13.66	0.28	7.47	211.86	69.30	68.11
1.A.4.a - Commercial/Institutional	53.69	0.83	0.01	0.35	24.92	3.73	3.00
1.A.4.b - Residential	575.86	12.79	0.26	5.85	186.55	64.59	55.97
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	301.08	0.04	0.00	1.27	0.39	0.98	9.14
1.A.4.c.i - Stationary	3.02	0.00	0.00	-	-	-	-
1.A.4.c.ii - Off-road Vehicles and Other Machinery	177.03	0.02	0.00	-	-	-	-
1.A.4.c.iii - Fishing (mobile combustion)	121.03	0.02	0.00	-	-	-	-
1.A.5 - Non-Specified				-	-	-	-
1.A.5.a - Stationary				-	-	-	-
1.A.5.b - Mobile				-	-	-	-
1.A.5.b.i - Mobile (aviation component)				-	-	-	-
1.A.5.b.ii - Mobile (water-borne component)				-	-	-	-
1.A.5.b.iii - Mobile (Other)				-	-	-	-

1.A.5.c - Multilateral Operations (1)(2)							
1.B - Fugitive emissions from fuels	7,895.12	4.80	0.12	-	-	-	-
1.B.1 - Solid Fuels	-	-		-	-	-	-
1.B.1.a - Coal mining and handling	-	-		-	-	-	-
1.B.1.a.i - Underground mines	-	-		-	-	-	-
1.B.1.a.i.1 - Mining	-	-		-	-	-	-
1.B.1.a.i.2 - Post-mining seam gas emissions	-	-		-	-	-	-
1.B.1.a.i.3 - Abandoned underground mines				-	-	-	-
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2	-	-		-	-	-	-
1.B.1.a.ii - Surface mines	-	-		-	-	-	-
1.B.1.a.ii.1 - Mining	-	-		-	-	-	-
1.B.1.a.ii.2 - Post-mining seam gas emissions	-	-		-	-	-	-
1.B.1.b - Uncontrolled combustion and burning coal dumps				-	-	-	-
1.B.1.c - Solid fuel transformation				-	-	-	-
1.B.2 - Oil and Natural Gas	7,895.12	4.80	0.12	-	-	-	-
1.B.2.a - Oil	7,895.12	4.80	0.12	-	-	-	-
1.B.2.a.i - Venting	-	-		-	-	-	-
1.B.2.a.ii - Flaring	7,895.12	4.80	0.12	-	-	-	-
1.B.2.a.iii - All Other	-	NE	-	-	-	-	-
1.B.2.a.iii.1 - Exploration				-	-	-	-
1.B.2.a.iii.2 - Production and Upgrading				-	-	-	-
1.B.2.a.iii.3 - Transport				-	-	-	-
1.B.2.a.iii.4 - Refining	-	NE		-	-	-	-
1.B.2.a.iii.5 - Distribution of oil products				-	-	-	-
1.B.2.a.iii.6 - Other				-	-	-	-
1.B.2.b - Natural Gas	0.00	0.00	-	-	-	-	-
1.B.2.b.i - Venting				-	-	-	-
1.B.2.b.ii - Flaring	-	-	-	-	-	-	-
1.B.2.b.iii - All Other	0.00	0.00	-	-	-	-	-
1.B.2.b.iii.1 - Exploration				-	-	-	-
1.B.2.b.iii.2 - Production				-	-	-	-
1.B.2.b.iii.3 - Processing	0.00	0.00		-	-	-	-

1.B.2.b.iii.4 - Transmission and Storage				-	-	-	-
1.B.2.b.iii.5 - Distribution	0.00	0.00		-	-	-	-
1.B.2.b.iii.6 - Other				-	-	-	-
1.B.3 - Other emissions from Energy Production				-	-	-	-
1.C - Carbon dioxide Transport and Storage	-			-	-	-	-
1.C.1 - Transport of CO2	-			-	-	-	-
1.C.1.a - Pipelines	-			-	-	-	-
1.C.1.b - Ships	-			-	-	-	-
1.C.1.c - Other (please specify)	-			-	-	-	-
1.C.2 - Injection and Storage	-			-	-	-	-
1.C.2.a - Injection	-			-	-	-	-
1.C.2.b - Storage	-			-	-	-	-
1.C.3 - Other	-			-	-	-	-

	Emissions (Gg)						
Categories	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
Memo Items (3)							
International Bunkers	648.6700	0.0065	0.0096	-	-	-	-
1.A.3.a.i - International Aviation (International Bunkers) (1)	625.8385	0.0044	0.0095	-	-	-	-
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	22.8315	0.0022	0.0001	-	-	-	-
1.A.5.c - Multilateral Operations (1)(2)				-	-	-	-
Information Items							
CO2 from Biomass Combustion for Energy Production	5,776.7952						

Annex 5.4: Table 2 - IPPU Sectoral Table

Categories	(Gg)			CO_2 Equivalents (Gg)				(Gg)
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)
2 - Industrial Processes and Product Use	615.86	-	-	593.76	521.57	NE	-	-
2.A - Mineral Industry	531.73	-	-	-	-	-	-	-
2.A.1 - Cement production	32.79							
2.A.2 - Lime production	-							
2.A.3 - Glass Production	-							
2.A.4 - Other Process Uses of Carbonates	498.94	-	-	-	-	-	-	-
2.A.4.a - Ceramics	-							
2.A.4.b - Other Uses of Soda Ash	0.06							
2.A.4.c - Non Metallurgical Magnesia Production	-							
2.A.4.d - Other (please specify) (3)	498.88							
2.A.5 - Other (please specify) (3)								
2.B - Chemical Industry	-	-	-	-	-	-	-	-
2.B.1 - Ammonia Production	-							
2.B.2 - Nitric Acid Production			-					
2.B.3 - Adipic Acid Production			-					
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			-					
2.B.5 - Carbide Production	-	-						
2.B.6 - Titanium Dioxide Production	-							
2.B.7 - Soda Ash Production	-							
2.B.8 - Petrochemical and Carbon Black Production	-	-	-	-	-	-	-	-
2.B.8.a - Methanol	-	-						
2.B.8.b - Ethylene	-	-						
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer	-	-						
2.B.8.d - Ethylene Oxide	-	-						
2.B.8.e - Acrylonitrile	-	-						
2.B.8.f - Carbon Black	-	-						
2.B.9 - Fluorochemical Production	-	-	-	-	-	-	-	-

2.B.9.a - By-product emissions (4)				-				
2.B.9.b - Fugitive Emissions (4)								
2.B.10 - Other (Please specify) (3)								
2.C - Metal Industry	82.05	-	-	-	521.57	-	-	-
2.C.1 - Iron and Steel Production	12.97	-						
2.C.2 - Ferroalloys Production	-	-						
2.C.3 - Aluminium production	69.08				521.57			
2.C.4 - Magnesium production (5)	-					-		
2.C.5 - Lead Production	-							
2.C.6 - Zinc Production	-							
2.C.7 - Other (please specify) (3)								
2.D - Non-Energy Products from Fuels and Solvent Use (6)	2.08	-	-	-	-	-	-	-
2.D.1 - Lubricant Use	2.08							
2.D.2 - Paraffin Wax Use	-							
2.D.3 - Solvent Use (7)								
2.D.4 - Other (please specify) (3), (8)								
2.E - Electronics Industry	-	-	-	-	-	-	-	-
2.E.1 - Integrated Circuit or Semiconductor (9)				-	-	NE		-
2.E.2 - TFT Flat Panel Display (9)					-	NE		-
2.E.3 - Photovoltaics (9)					-			
2.E.4 - Heat Transfer Fluid (10)					-			
2.E.5 - Other (please specify) (3)								
2.F - Product Uses as Substitutes for Ozone Depleting Substances	-	-	-	593.76	-	-	-	-
2.F.1 - Refrigeration and Air Conditioning	-	-	-	593.76	-	-	-	-
2.F.1.a - Refrigeration and Stationary Air Conditioning				504.41				
2.F.1.b - Mobile Air Conditioning				89.35				
2.F.2 - Foam Blowing Agents				-				-
2.F.3 - Fire Protection				-	-			
2.F.4 - Aerosols				-				-
2.F.5 - Solvents				-	-			-
2.F.6 - Other Applications (please specify) (3)				-	-			-
2.G - Other Product Manufacture and Use	-	-	-	-	-	-	-	-

2.G.1 - Electrical Equipment	-	-	-	-	-	-	-	-
2.G.1.a - Manufacture of Electrical Equipment					-	-		
2.G.1.b - Use of Electrical Equipment					-	-		
2.G.1.c - Disposal of Electrical Equipment					-	-		
2.G.2 - SF_6 and PFCs from Other Product Uses	-	-	-	-	-	-	-	-
2.G.2.a - Military Applications					-	-		
2.G.2.b - Accelerators					-	-		
2.G.2.c - Other (please specify) (3)					-	-		
2.G.3 - N2O from Product Uses	-	-	-	-	-	-	-	-
2.G.3.a - Medical Applications			-					
2.G.3.b - Propellant for pressure and aerosol products			-					
2.G.3.c - Other (Please specify) (3)			-					
2.G.4 - Other (Please specify) (3)								
2.H - Other	-	-	-	-	-	-	-	-
2.H.1 - Pulp and Paper Industry								
2.H.2 - Food and Beverages Industry								
2.H.3 - Other (please specify) (3)								

Annex 5.5: Table 3 - IPPU Sectoral Table

Categories	(Gg)		
	Net CO2 emissions / removals	Emissions	
		CH4	N2O
3 - Agriculture, Forestry, and Other Land Use	14,924.02	166.38	21.23
3.A - Livestock	-	136.89	-
3.A.1 - Enteric Fermentation	-	129.57	-
3.A.1.a - Cattle	-	62.99	-
3.A.1.a.i - Dairy Cows		-	
3.A.1.a.ii - Other Cattle		62.99	
3.A.1.b - Buffalo		-	
3.A.1.c - Sheep		26.67	
3.A.1.d - Goats		38.82	
3.A.1.e - Camels		-	
3.A.1.f - Horses		0.05	
3.A.1.g - Mules and Asses		0.15	
3.A.1.h - Swine		0.89	
3.A.1.j - Other (please specify)		-	
3.A.2 - Manure Management (1)	-	7.31	-
3.A.2.a - Cattle	-	2.03	-
3.A.2.a.i - Dairy cows		-	-
3.A.2.a.ii - Other cattle		2.03	-
3.A.2.c - Sheep		1.07	-
3.A.2.d - Goats		1.71	-
3.A.2.f - Horses		0.01	-
3.A.2.g - Mules and Asses		0.02	-
3.A.2.h - Swine		0.89	-
3.A.2.i - Poultry		1.59	-
3.B - Land	14,517.40	-	-
3.B.1 - Forest land	(3,082.38)	-	-
3.B.1.a - Forest land Remaining Forest land	(1,591.14)		
3.B.1.b - Land Converted to Forest land	(1,491.24)	-	-

3.B.1.b.i - Cropland converted to Forest Land	(536.30)		
3.B.1.b.ii - Grassland converted to Forest Land	(906.57)		
3.B.1.b.iii - Wetlands converted to Forest Land	(1.76)		
3.B.1.b.iv - Settlements converted to Forest Land	(43.74)		
3.B.1.b.v - Other Land converted to Forest Land	(2.86)		
3.B.2 - Cropland	19,256.40	-	-
3.B.2.a - Cropland Remaining Cropland	141.21		
3.B.2.b - Land Converted to Cropland	19,115.19	-	-
3.B.2.b.i - Forest Land converted to Cropland	20,674.82		
3.B.2.b.ii - Grassland converted to Cropland	(1,130.53)		
3.B.2.b.iii - Wetlands converted to Cropland	2.58		
3.B.2.b.iv - Settlements converted to Cropland	(421.67)		
3.B.2.b.v - Other Land converted to Cropland	(10.01)		
3.B.3 - Grassland	(2,600.77)	-	-
3.B.3.a - Grassland Remaining Grassland	-		
3.B.3.b - Land Converted to Grassland	(2,600.77)	-	-
3.B.3.b.i - Forest Land converted to Grassland	28.43		
3.B.3.b.ii - Cropland converted to Grassland	(2,477.40)		
3.B.3.b.iii - Wetlands converted to Grassland	(9.65)		
3.B.3.b.iv - Settlements converted to Grassland	(119.09)		
3.B.3.b.v - Other Land converted to Grassland	(23.06)		
3.B.4 - Wetlands	16.25	-	-
3.B.4.a - Wetlands Remaining Wetlands	-	-	-
3.B.4.a.i - Peatlands remaining peatlands	-		-
3.B.4.a.ii - Flooded land remaining flooded land			
3.B.4.b - Land Converted to Wetlands	16.25	-	-
3.B.4.b.i - Land converted for peat extraction			-
3.B.4.b.ii - Land converted to flooded land	16.25		
3.B.4.b.iii - Land converted to other wetlands			
3.B.5 - Settlements	719.86	-	-
3.B.5.a - Settlements Remaining Settlements	-		
3.B.5.b - Land Converted to Settlements	719.86	-	-

3.B.5.b.i - Forest Land converted to Settlements	482.28		
3.B.5.b.ii - Cropland converted to Settlements	189.68		
3.B.5.b.iii - Grassland converted to Settlements	47.90		
3.B.5.b.iv - Wetlands converted to Settlements	-		
3.B.5.b.v - Other Land converted to Settlements	-		
3.B.6 - Other Land	208.03	-	-
3.B.6.a - Other land Remaining Other land			
3.B.6.b - Land Converted to Other land	208.03	-	-
3.B.6.b.i - Forest Land converted to Other Land	148.02		
3.B.6.b.ii - Cropland converted to Other Land	39.45		
3.B.6.b.iii - Grassland converted to Other Land	20.56		
3.B.6.b.iv - Wetlands converted to Other Land	-		
3.B.6.b.v - Settlements converted to Other Land	-		
3.C - Aggregate sources and non-CO2 emissions sources on land (2)	406.62	29.50	21.23
3.C.1 - Emissions from biomass burning	-	15.28	1.31
3.C.1.a - Biomass burning in forest lands		11.60	1.06
3.C.1.b - Biomass burning in croplands		1.42	0.04
3.C.1.c - Biomass burning in grasslands		2.27	0.21
3.C.1.d - Biomass burning in all other land		-	-
3.C.2 - Liming	-		
3.C.3 - Urea application	406.62		
3.C.4 - Direct N2O Emissions from managed soils (3)			15.67
3.C.5 - Indirect N2O Emissions from managed soils			4.03
3.C.6 - Indirect N2O Emissions from manure management			0.22
3.C.7 - Rice cultivation		14.22	
3.C.8 - Other (please specify)			
3.D - Other	-	-	-
3.D.1 - Harvested Wood Products	-		
3.D.2 - Other (please specify)			

Annex 5.6: Table 4 - Waste Sectoral Table

Categories	Emissions [Gg]		
	CO_2	CH_4	N_2O
4 - Waste	15.31447007	134.3742156	2.1051905
4.A - Solid Waste Disposal	0	60.4559038	0
4.A.1 - Managed Waste Disposal Sites			
4.A.2 - Unmanaged Waste Disposal Sites			
4.A.3 - Uncategorised Waste Disposal Sites			
4.B - Biological Treatment of Solid Waste		1.889272	0.11335632
4.C - Incineration and Open Burning of Waste	15.31447007	5.22577697	0.07503786
4.C.1 - Waste Incineration	2.903255124	0.0264946	0.0066473
4.C.2 - Open Burning of Waste	12.41121494	5.19928237	0.06839056
4.D - Wastewater Treatment and Discharge	0	66.80326288	1.91679632
4.D.1 - Domestic Wastewater Treatment and Discharge		36.68161158	1.91679632
4.D.2 - Industrial Wastewater Treatment and Discharge		30.12165129	
4.E - Other (please specify)			

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