Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change

White Sand Beach Resort, Gomoa Fetteh, Ghana. Credit: https://images.app.goo.gl/jVcoWTKfAEML2q4k6

May 2020

Environmental Protection Agency (EPA)

With kind support from

National Climate Change Report, 2020

The document is available for download on EPA website address www.epa.gov.gh

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Foreword

I present Ghana's Fourth National Communication (NC4) to the United Nations Framework Convention on Climate Change (UNFCCC). The NC4 outlines the latest information on Ghana's progress at addressing climate change through specific policies.

The potential disruptive effects of climate change on Ghana is not markedly different from the rest of Africa. Climate change threatens to erode the development gains Ghana has made in the past and hampers our ability to accomplish the sustainable development aspirations we have envisaged for ourselves. Despite the pressing economic challenges that confront us, Ghana has not relented on taking bold steps to deal with climate change, and I call on the international community to show greater commitment to fighting climate change.

We hold the view that acting on climate change must not be done in isolation. It must be a well-coordinated and embrace a holistic governmental strategy that integrates climate actions into national sustainable development programmes. That is why Ghana's climate policy is aligned with the latest medium-term national development plan.

In the last decade, Ghana's climate change efforts have focussed on putting in place, suitable policy conditions to enable Ghana to increase its efforts on tangible climate actions. In this regard, Ghana published its national climate change policy in 2012, low carbon development strategy in 2015, ratified the Paris Agreement in 2016 and has already started implementing the measures in the nationally determined contributions. The focus is now on scaling-up the implementation of our climate actions.

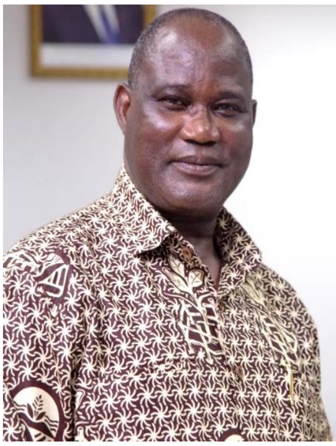
We are already implementing climate change programmes aimed at promoting renewable energy, lowering deforestation, supporting the adoption of clean cooking, pursuing low carbon electricity generation, building resilience in the savannah dryland and investing in sea defence infrastructure. Investing in these climate actions, have direct developmental benefits as well as strong climate objectives. We have also introduced significant policy interventions that have development and climate protection imperatives. Our flagship programmes on planting for food and jobs, one-village-one-dam, and the one-district-one-factory, are all geared towards boosting green industrialisation and rural development as well as building resilience to the impacts of climate change.

These policy initiatives are already contributing positive results to the attainment of the Sustainable Development Goals (SDGs), as well as resilience and low carbon development objectives. Admittedly, we need to do more than if we are to achieve the goals outlined in the nationally determined contributions.

In conclusion, I wish to emphasise that as we strive to do our bit to halt climate change at the national level, there is the need for more concrete efforts at the international level. Consequently, I call for reforms at the international level to streamline access to climate finance to complement national funding for initiatives aimed at addressing climate change.

Professor Kwabena Frimpong-Boateng
(Minister for Environment, Science, Technology and Innovation)

Preface



This report is Ghana's NC4 to the UNFCCC. The Environmental Protection Agency (EPA) collaborated closely with several national institutions and individuals in the preparation of the NC4 while the Ministry of Environment, Science, Technology and Innovation (MESTI) provided oversight. The components considered in the report include the following: national circumstances, national greenhouse gas inventory, greenhouse gas mitigation assessment, climate change vulnerability and impacts assessment, climate change education, training and awareness, constraints, gaps, and related financial, technical and capacity needs, and other information.

It presents comprehensive, up-to-date information on current findings from country-level studies and literature, surveys, interviews and assessments, all of which were undertaken as part of the preparation of the NC4. The report presents new evidence and observations in twelve chapters to fulfil the reporting requirements specified in the UNFCCC reporting guideline for the preparation of national communication from Parties not included in Annex 1.

The compilation started with a stocktaking to assess previous national communications and recommend ways to improve on the NC4. The review comments were incorporated in the NC4 project document for approval by the Global Environment Facility (GEF) through the UN Environment. A national inception workshop was organised to kick-start the preparation of the NC4. During the workshop, the EPA introduced the NC4 to national stakeholders to solicit their inputs on the implementation of the project. Six sector teams were formed and assigned specific components of the NC4.

Each sector team conducted assessments for each component and produced first drafts. The EPA undertook two rounds of expert and stakeholder reviews on the chapter drafts. The expert review evaluated the overall consistency of the draft report with the UNFCCC guidelines and technical errors. After the reviews, the chapter authors incorporated all comments, suggestions and responses into the first draft to produce the second chapter draft. EPA then compiled a draft national communication report from the second drafts and submitted it to UNEP and international partners for their reviews. Thereafter, the EPA organised a national stakeholder validation workshop to validate the report. MESTI approved the final NC4 report before submission to the UNFCCC.

The report is the result of four years of information gathering and an assessment process designed to present both big-picture messages and essential details on Ghana's greenhouse emission trends, projections and opportunities for mitigation, how the country is affected by climate change, and efforts being made or envisaged to address climate change in the context of sustainable development. The benefits of this report are to:

- Help Ghana meet its reporting obligations under Articles 4 and 12 of the UNFCCC.
- Provide information to support decision-making at all levels and inform national-level policy.
- Strengthen capacity at the national level.
- Serve as a reliable reference for researchers, NGOs, businesses, industry players and project developers.

John A. Pwamang
(Ag. Executive Director, Environmental Protection Agency)

Acknowledgement

The preparation of the NC4 has been four years of a great learning experience and fantastic teamwork. In many ways. The team made up of a variety of professions, knowledge and practice communities, exuded high professional and ethical standards at every stage of the work. When the team did not reach consensus on data and methodological choices, they strove not to compromise on minimum standards.

The EPA wishes to recognise the immense contributions from all those who offered their service for the preparation of this report. We are appreciative of GEF for providing funding support for the NC4. We are also pleased with the enthusiastic partnership we had with Ms Suzanne Lekoyiet and her supportive team at UN Environment. We greatly benefitted from her great insight, advice and guidance in the preparation of the project document, compilation and submission of the report. We gratefully acknowledge the contributions Ms Suzanne Lekoyiet made in ensuring that there were positive results at every step of the compilation process. We also thank Mr William Kojo Agyemang-Bonsu for his rich inputs into this report. We also appreciate the technical support from NDC-SP, ICAT and RRR+ initiatives.

We are thankful to the management of the EPA for providing strategic technical guidance and direction during the compilation process. Sincere thanks go to MESTI for their insightful advice and support throughout the approval and submission of the NC4. We are particularly grateful for the effort put into securing final signature to this report before its submission. And to all the international partners that provided technical support during the preparation and review of the report, we say a 'big thank you'; we truly value our partnership with you. Furthermore, we wish to thank various working group members, consultants and other state institutions that were engaged in the entire national communication process, culminating in the preparation of this report. We also recognise and appreciate the high level of dedication and commitment exhibited by various public and civil servants who in diverse ways, contributed to producing this report.

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Content

List of Tables

Vulnerability, Impacts and Adaptation Assessment

Other Information

Financial, Technical and Capacity Gaps

List of Figures

National Circumstances

National Greenhouse Gas Inventory

Greenhouse Gas Mitigation Assessment

Vulnerability, Impacts and Adaptation Assessment

Other Information

Financial, Technical and Capacity Gaps

Abbreviations

AAI	-	African Adaptation Initiative
ACE	-	Action for Climate Empowerment
ACPC	-	African Climate Policy Centre
AFB	-	Adaptation Fund Board
AfDB	-	African Development Bank
AFOLU	-	Agriculture, Forestry and Other Land Use
AGN	-	Africa Group of Negotiators
AIC	-	Annual Incremental Carbon
AMA	-	Accra Metropolitan Assembly
AMCEN	-	African Ministerial Conference on Environment
ANN	-	Artificial Neural Network
AREI	-	Africa Renewable Energy Initiative
ATS	-	Automatic Timer Switches
AWS	-	Automatic Weather Stations
BAU	-	Business-As-Usual
BiomassWeb	-	Biomass-Based Value Web
BUR	-	Biennial Update Report
CBEA	-	Community Based Extension Agent
CCAC	-	Climate and Clean Air Coalition
CCAFS	-	Climate change, Agriculture and Food Security
CCV	-	Climate Change Vulnerability
CDM	-	Clean Development Mechanism
CD-REDD	-	Capacity development for REDD Project
CDT	-	Climate Data Tool
CERSGIS	-	Centre for Remote Sensing and Geographic Information Centre System
CfRN	-	Coalition for Rainforest Nations.
CGE	-	Consultative Group of Experts
CH_4	-	Methane
CIF	-	Climate Investment Fund
CO_2	-	Carbon dioxide
CO_2e	-	Carbon dioxide-equivalent
CORDEX	-	COordinated Regional climate Downscaling EXperiment
COMAP	-	Comprehensive Mitigation Assessment Process
COP	-	Conference of Parties
CPEIR	-	Climate Public Expenditure and Institutional Review
CPESDP	-	Coordinated Programme of Economic and Social Development Policy
CRM	-	Cylinder Recirculation Model
CSIR	-	Council for Scientific and Industrial Research
CSIRO	-	Commonwealth Scientific and Industrial Research Organization of Australia
CSIR-IIR	-	CSIR Institute for Industrial Research
CSR	-	Corporate Social Responsibility
CTCN	-	Climate Technology Centre and Network
CVCA	-	Climate Vulnerability Capacity Analysis
DECCMA	-	DEltas, Vulnerability and Climate Change: Migration and Adaptation
DTRRS	-	Decentralised Treatment, Re-use and Recovery Systems
ECA	-	Economic Commission for Africa
ECREE	-	ECOWAS Centre for Renewable Energy and Energy Efficiency
EF	-	Emission Factors

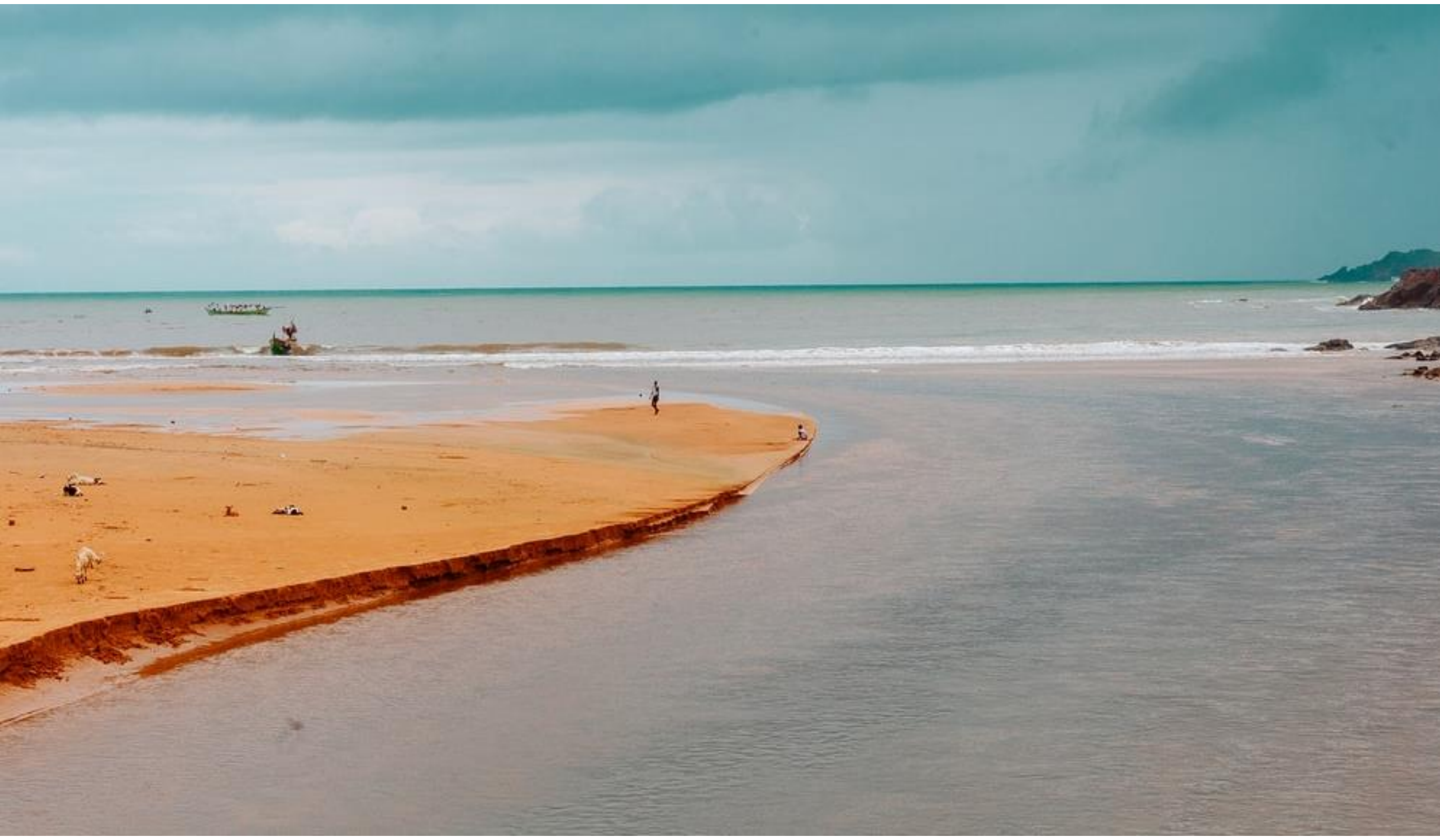
EFDB	-	IPCC Emission Factor Database
EGTT	-	Expert Group on Technology Transfer
ENACTS	-	Enhancing National Climate Services
EORIC	-	Earth Observation Research and Innovation Centre
EPA	-	Environmental Protection Agency
ERP	-	Emission Reduction Programme
ESP	-	Environmental Sustainability Project
ETPA	-	Information on Education, Training and Public Awareness
FAOSTAT	-	FAO Statistics
FASDEP II	-	Food and Agriculture Development Policy
FC	-	Forestry Commission
FCPF	-	Forest Carbon Partnership Facility
FIP	-	Forest Investment Plan
FIT	-	Feed-in Tariff
FOLU	-	Forestry and Other Land Uses
FORIG	-	CSIR-Forest Research Institute of Ghana
GACMO	-	Greenhouse Gas Cost Abatement Model
GAP	-	Ghana Astronomical Project
GARID	-	Greater Accra Resilient and Integrated Development
GCARP	-	Ghana Climate Ambitious Reporting Programme
GCCES	-	Ghana Climate Change Education in Schools
GCF	-	Green Climate Fund
GCIC	-	Ghana Climate Innovation Centre
GCRF	-	Global Challenges Research Fund
GCFRP	-	Ghana Cocoa Forest REDD+ Programme
GDP	-	Gross Domestic Product
GEF	-	Global Environment Facility
GEONETCast	-	Global Network of Satellite-based data dissemination systems
GhEA	-	Ghana Energy Access Database
GHG	-	Greenhouse Gas
GIDA	-	Ghana Irrigation Development Authority
GLSS	-	Ghana Living Standards Survey
GMet	-	Ghana Meteorological Agency
GMI	-	Global Methane Initiative
GNCPC	-	Ghana National Cleaner Production Centre
GSGDA	-	Shared Growth and Development Agenda
GSS	-	Ghana Statistical Service
GWP	-	Global Warming Potential
HFZs	-	High Forest Zones
HFC	-	Hydrofluorocarbon
HPMP	-	Hydrofluorocarbon Phase-out Management Plan
HSD	-	Hydrological Service Department
ICAT	-	Initiative for Climate Action Transparency
IFC	-	International Finance Corporation
INM	-	Integrated Nutrient Management
IPCC	-	Inter-governmental Panel on Climate Change
IPM	-	Integrated Planning Model
IPPU	-	Industrial Processes and Product Use
ISA	-	International Solar Alliance

ISSER	-	Institute for Statistical, Social and Economic Research
ITMOs	-	Internationally Transferred Mitigation Outcomes
KCA	-	Key Category Analysis
KETS	-	Korean Emission Trading Scheme
KMA	-	Kumasi Metropolitan Assembly
KNUST	-	Kwame Nkrumah University of Science and Technology
KNUST-TCC	-	KNUST Technology Consultancy Centre
KSNR	-	Kogyae Strict Nature Reserve
LCO	-	Light Crude Oil
LEAP	-	Long-range Energy Alternative Planning
LECBP	-	Low Emission Capacity Building Project
LoCAL	-	Local Climate Adaptive Learning Living
LPG	-	Liquefied Petroleum Gas
LTO	-	Landing and Take-Off
MDAs	-	Ministries, Departments and Agencies
MDGs	-	Millennium Development Goals
MEA	-	Multilateral Environmental Agreement
MESTI	-	Ministry of Environment, Science, Technology and Innovation
METASIP	-	Medium Term Agriculture Sector Investment Plan
MLGRD	-	Ministry of Local Government and Rural Development
MLNR	-	Ministry of Lands and Natural Resources
MMDAs	-	Metropolitan, Municipal, and District Assemblies
MoFA	-	Ministry of Food and Agriculture
MoI	-	Means of Implementation
Mt	-	Million tonnes
MTDPF	-	Medium-term Development Policy Framework
N_2O	-	Nitrous oxide
NADMO	-	National Disaster Management Organisation
NAMAs	-	Nationally Appropriate Mitigation Action
NCAP	-	National Climate Assessment Programme
NCCAS	-	National Climate Change Adaptation Strategy
NCCC	-	National Climate Change Committee
NCEP	-	National Clean Energy Access Programme
NC4	-	Fourth National Communication
NDC	-	Nationally Determined Contribution
NDC-SP	-	NDC Support Programme
NDPC	-	National Development Planning Commission
NF3	-	Nitrogen Trifluoride
NFP	-	National Focal Point
NFPDP	-	National Forest Plantation Development Programme
NIBP	-	National Institutional Biogas Programme
NIR	-	National Inventory Report
NTP	-	National Transport Policy
PAC	-	Project Advisory Committee
PAM	-	Policies and Measures
PATPA	-	Partnership on Transparency in Paris Agreement
PCS	-	Post-construction support for community-managed water systems
PFCs	-	Perfluorocarbons
PIER	-	Private Investment for Enhanced Resilience

PSC	-	Project Steering Committee
QA/QC	-	Quality Assurance/Quality Control
RAC	-	Refrigeration and Air Conditioning
RCCs	-	Regional Coordinating Councils
RCMs	-	Regional Circulation Models
RCP	-	Representative Concentration Pathways
RCS	-	Rainwater collection from ground surfaces
REDD+	-	Reducing Emission for Deforestation and Forest Degradation Plus
REMP	-	Renewable Energy Master Plan
REPO	-	Renewable Energy Purchase Obligation
RIPS	-	Regional Institute for Population Studies
RMSC	-	Resource Management and Support Centre of Ghana Forestry Commission
RSO	-	Research and Systematic Observations
RTIMP	-	Root and Tuber Improvement and Marketing
SADA	-	Savannah Accelerated Development Authority
SDF	-	Skills Development Fund
SDGs	-	Sustainable Development Goals
SE4ALL	-	Sustainable Energy for All Action Plan
SFDRR	-	Sendai Framework for Disaster Risk Reduction
SF6	-	Sulphur Hexafluoride
SIS	-	Safeguard Information System
SLCP	-	Short-Lived Climate Pollutant
SLWM	-	Sustainable Land and Water Management
SRES	-	Special Report on Emission Scenarios
STMA	-	Sekondi-Takoradi Metropolitan Assembly
SUNREF	-	Sustainable Use of Natural Resources and Energy Finance
SWM	-	Solid Waste Management
TAHMO	-	Trans-African Hydro-Meteorological Observation
TCCCA	-	Transparency, Consistency, Comparability, Completeness, Accuracy
TAMA	-	Tamale Metropolitan Assembly
TNA	-	Technology Needs Assessment
TNC	-	Third National Communication
TT1PS	-	Tema Thermal 1 Power Station
TTMC	-	Ghana Technology Transfer and Marketing Center
UNCBD	-	United Nations Convention on Biological Diversity
UNDP	-	United Nations Development Programme
UNECA	-	United Nations Economic Commission for Africa
UNEP	-	United Nations Environment Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
UNU-INRA	-	United Nations University, Institute for Natural Resources in Africa
V&A	-	Vulnerability and Adaptation
VALCO	-	Volta Aluminium Company Limited
VSLA	-	Village Savings and Lending Associations
WABiCC	-	West Africa Biodiversity and Climate Change
WAM	-	Scenario with Additional Measures
WAPCo	-	West African Gas Pipeline Company limited
WAPP	-	West Africa Agricultural Product Programme
WASCAL	-	West African Science Service Center on Climate Change and Adapted Land Use
WFP	-	World Food Programme

WM	-	Scenario with Measures
WOM	-	Scenario without Measures
WMO	-	World Meteorological Organisation
WRC	-	Water Resources Commission

Executive Summary (ES)



Akwidaa, Ghana Source: https://unsplash.com/photos/XOdKX5WtPTc

Executive summary

ES 1 Mandate for the preparation of national communication to UNFCCC

ES 1 is the summary of chapter one of the NC4, which gives the general background to the preparation of national communications. Ghana joined the UNFCCC in September 1995. After becoming a Party to the UNFCCC, Ghana has actively implemented various domestic policies to address climate change while continuing to advance national economic development. Since 2001, the country has published three national communications in compliance with its obligations under Articles 4 and 12 of the UNFCCC. The preparation of the Fourth National Communication (NC4) is consistent with those provisions. The overall objective of the NC4 is to update and communicate information on Ghana's climate change policies to domesticate the UNFCCC.

ES 2 National circumstances and institutional arrangements relevant for climate change

ES 2 presents the overviews of updates on Ghana's national circumstances and climate change governance. Ghana is a unitary democratic republic governed by the 1992 Constitution. Democratic power is shared among the Executive, Legislature and the Judiciary. The President heads the Executive arm and oversees high-level appointments. The Legislative functions are vested in the National Parliament. The Judiciary is independent of the other branches of Government. The National Development Planning Commission (NDPC) facilitates development planning together with line ministries and 260 district assemblies. The Ministry of Environment, Science, Technology and Innovation (MESTI) and the Environmental Protection Agency (EPA) coordinate the climate change issues within the Government. The EPA facilitates the regular preparation and dissemination of international climate reports, including national communications.

Ghana, with a total land area of 239,460km^{2,} is in West Africa on the Guinea Coast. It lies close to the equator on latitude 11.50N and 4.50S and longitude 3.50W and 1.30E. Ghana's climate is tropical and strongly influenced by the West Africa monsoon. The climate is generally warm with variable temperatures masked by seasons and elevation. The northern part of the country typically records one rainy season, which begins in May and lasts until September. Southern Ghana records two rainy seasons from April to July and from September to November.

Ghana's 2020 population is estimated at 30.9 million and represents a 26% increase over 2010 levels of 24.6 million at an annual growth rate of 2.3% compared to the 1.5% target for 2020. With an average yearly growth rate of 2.3% per annum, Ghana's population is likely to reach 37 million by 2030. Under a tenth (8.2%) of the population live in extreme poverty with a threshold of GH¢792.05 per adult equivalent per year. Extreme poverty is outstandingly high in the rural Savannah at 36.1% and accounts for more than a quarter of those living in extreme poverty in rural Ghana. Poverty and livelihoods, gender and geographic locations determine the level of climate change vulnerabilities in the country.

The utilisation of gold, cocoa, timber and crude oil generate export revenues, taxes, and jobs. In 2018 alone, Ghana earned US$ 14.9 billion in revenues from the merchandise exports[1] with gold (36.4%) and crude oil (30.6%) contributing the most. Besides, the country is agrarian and endowed with forest and fish resources. The rebased economic figures show that the economy has increased by over 100% from US$ 32.2 billion in 2010 to US$ 65.6 billion in 2018. Climate change issues are highlighted in the Coordinated Programme of Economic and Social Development Policies and the Medium-Term Development Policy Framework.

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[1] https://www.bog.gov.gh/wp-content/uploads/2020/02/Statistical-Bulletin-November-2019.pdf

In 2016, Ghana put forward thirty-one priority adaptation and mitigation actions in the Nationally Determined Contributions (NDC) to the UNFCCC in response to the Lima call for action. The latest National Development Policy Framework for the period 2017-2024 affirms Ghana's commitment to the NDC under the Paris Agreement. The NDC is also aligned with priority areas in the National Climate Change Policy (NCCP). Some regional initiatives Ghana is involved in are as follows:

- West African South-South Network on MRV and Transparency
- West African Alliance on Carbon Markets and Climate Finance
- West Africa Biodiversity and Climate change (WABiCC)
- Climate change, Agriculture and Food Security, West Africa (CCAFS)
- West African Science Centre on Climate Change and Adapted Land Use (WASCAL)
- UNFCCC CDM Regional Collaboration Centre in LOME
- Regional Centre for Renewable Energy and Energy Efficiency (ECREE)
- West Africa Gas Pipeline
- Sustainable Greenhouse Gas Inventory in West Africa

ES 3 National greenhouse gas inventory

ES3 summarises the national greenhouse gas inventory processes and results. It reports on the inventory results per sector and according to gases for the period 1990-2016.

ES 3.1 Greenhouse gas emission trends

Ghana's total greenhouse emissions were estimated at 42.2 million tonnes of carbon dioxide equivalent (Mt CO_2e) in 2016, representing more than 7.1% of the 2012 levels (Table ES.1). When the Forestry and Other Land Uses (FOLU) emissions are excluded from the national total, emission stood at 29.3 MtCO_2e. Generally, the total national emissions have increased by 66.3% between 1990 and 2016.

Table ES 1: Trends in greenhouse gas emission share by sectors

IPCC Sectors/Categories	Total Emissions (MtCO_2e)					Change (%)			
	1990	2000	2010	2012	2016	1990-2016	2000-2016	2010-2016	2012-2016
National Emissions with FOLU	25.34	27.26	35.23	39.35	42.15	66.3	54.6	19.6	7.1
National Emissions without FOLU	11.32	14.53	22.5	26.39	29.28	158.7	101.5	30.1	10.9
Energy	3.73	5.96	10.11	13.07	15.02	302.7	152.0	48.6	14.9
Industrial Processes and Product Use	0.49	0.36	1.09	1.52	1.04	112.2	188.9	-4.6	-31.3
Agriculture, Forestry, and Other Land Use	20.10	19.47	21.49	22.05	22.92	14.0	17.7	6.7	4.0
Waste	1.02	1.48	2.53	2.71	3.17	210.8	114.2	25.3	17.0

The need to address poverty demands expansion of the economy, which is accompanied by an increase in greenhouse gas emissions. Consequently, Ghana's expects that the national emissions will grow as we develop, but will plateau and then decrease over time as it implements the NDC. The carbon-intensive economic expansion has led to a notable increase in emissions from road transport, thermal electricity generation and, biomass utilisation for cooking, deforestation and disposal of domestic liquid waste.

ES 3.2 GHG emissions and development indicators

Population, economy, energy, and greenhouse gas indicators relate well. The relationship depicts the extent to which economic growth, population rise, and energy utilisation drive GHG trends. The NC4 results suggest that Ghana's total emissions grew alongside the rising population, GDP, and energy consumption but at varying rates (Table ES 2). Population, GDP, and energy consumption are rising at a faster rate than the emissions. The results reveal a positive sign of possible moderate effects of some mitigation policy interventions on slowing down emission growth in the country.

Table ES 2: Macro economy, energy and emission indicators

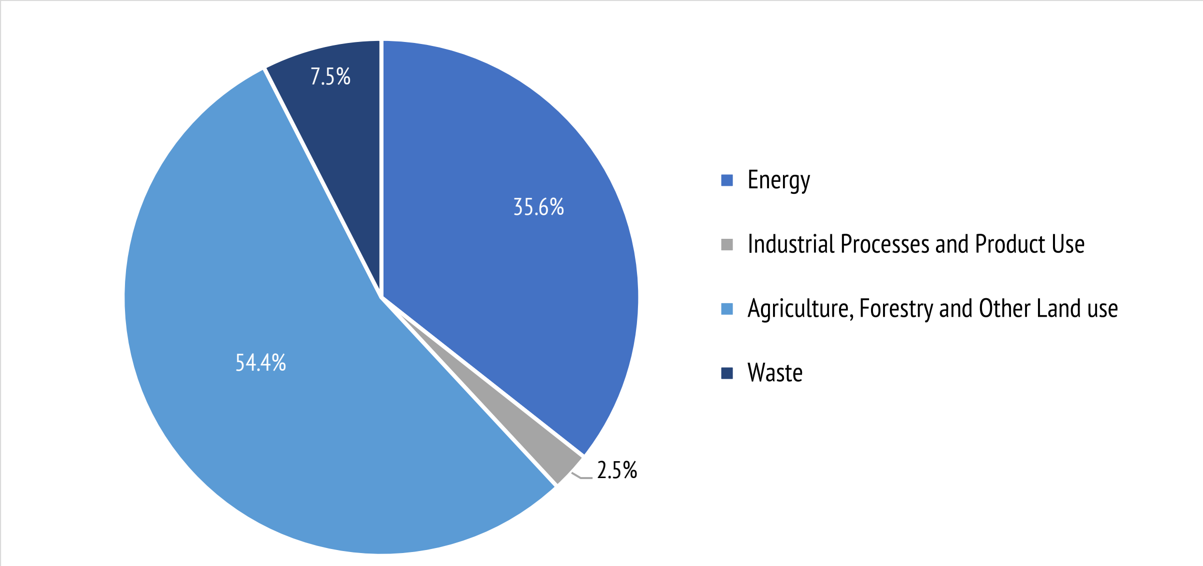
Indicators	1990	2000	2010	2012	2016	Change (%)	
						1990-2016	2012-2016
Population (million)	14.43	18.91	24.23	25.87	28.21	95.5	9
GDP (Constant 2010 US$ billion) *	12.05	18.36	32.17	40.10	48.20	300	20.2
Total primary energy supply (Mtoe)**	5.29	6.88	9.84	8.36	9.67	82.8	15.7
Total final energy consumed (Mtoe)**	4.31	5.54	5.63	6.61	7.09	64.5	7.3
Total GHG emission ($MtCO_2e$)	25.34	27.54	35.24	39.35	42.15	66.3	7.1
Total CO_2 emission ($MtCO_2$)	16.84	17.86	22.71	25.71	27.29	62.1	6.1
Total electricity generated (GWh)**	5,721	7,223	10,167	12,024	13,022	127.6	8.3
of which is Hydroelectric (GWh)**	5,721	6,609	6,996	8,071	5,561	-2.8	-31.1
of which is Oil Products (GWh)**	-	614	3,171	3,953	7,435	-	88.1
of which is Renewable (GWh)**	-	-	-	-	26	-	-
Total Electricity Consumed*** (GWh)	4,462	6,067	8,317	9,258	11,418	155.9	23.3
Total energy consumed per capita (toe)	0.30	0.29	0.23	0.26	0.25	-16.7	-3.8
GHG emissions per capita (t CO_2 e)	1.73	1.45	1.44	1.53	1.49	-13.9	-2.6
CO_2 emission per capita (t CO_2)	1.15	0.94	0.93	1.00	0.97	-15.7	-3.0
GHG emissions per GDP unit (kg CO_2e / constant 2010 US$)	2.10	1.50	1.09	0.98	0.87	-58.6	-11.2
GHG emissions per GDP unit (kg CO_2 / constant 2010 US$)	1.39	0.97	0.71	0.64	0.57	-59.0	-10.9

* Source: World Bank, National Account (2018),

** Source: National Energy Statistics. This also considers electricity export to the neighbouring countries and total hours of electricity load.

ES 3.3 Greenhouse Gas Inventory by Sources/Removals

The Agriculture Forestry and Other Land Uses (AFOLU) sector emissions of 22.9 $MtCO_2e$ make it the largest source of GHG emissions in Ghana, accounting for 54.4% of the national emissions of 42.2 $MtCO_2e$. With 15 $MtCO_2e$, the Energy is the next leading source contributing 35.6% of the national emissions, followed by the Waste with 3.2 $MtCO_2e$ (7.5%) and the Industrial Process and Product Use (IPPU) by 1.04 $MtCO_2e$ (2.5%). Total emissions increased by 7.1% between 2012 and 2016. The emissions from all the sectors increased, except IPPU, with the waste sector recording the highest growth. While emissions from Waste and Energy grew by 17% and 15% respectively, AFOLU rose slightly by 4% over the period. In contrast, IPPU emissions recorded a significant drop of 31.3% in the same period (ES Figure 1).



ES Figure 1: Total 2016 emissions by source/removal category

Below are highlights of the emission trends and the underlying drivers:

For the AFOLU sector:

- The land category is the leading emissions source with 12.9 $MtCO_2e$ and accounted for 30% of the total national emissions. It also contributed 46% of the overall AFOLU emissions in 2016 and has declined by 0.7% since 2012 due to carbon stock enhancement interventions in degraded areas.
- Cropland, grassland, and forestland were responsible for most of the emissions in the land category.
- The emissions from "aggregated sources and non-CO_2 emission on land" was the second-highest in the AFOLU sector. Its emissions levels of 6.6 $MtCO_2e$ in 2016 contributed 16% of the national emissions, representing 3% increment compared to the 2012 levels.
- The "direct N_2O emissions from managed soils" has a 63% share of the total emissions under the 3C category.
- Livestock emissions were 3.03 $MtCO_2e$, made up of 8% of the total net emissions. The emissions increased by 18% between 2012 and 2016.

Similarly, in the Energy sector:

- The emissions from stationary combustion were 7.83 $MtCO_2e$ with the energy industry being the most significant source in 2016.
- The 2016 levels accounted for 52% of all the energy sector emissions. Between 2012 and 2016, emissions emanating from stationary combustion increased moderately by 19.8%.
- Mobile combustion emissions were estimated at 7.2 $MtCO_2e$ in 2016. It was singularly responsible for 48% of the total energy emissions and 17% of the overall national emissions.
- The 2016 transportation emissions increased by 7% relative to the levels reported in 2012.
- Within the transportation category, road transport was the most significant emission source due to growing vehicle ownership and the associated traffic congestion in the cities.

Furthermore, in the Waste sector,

- The 2016 total emissions of 3.2 $MtCO_2e$ represented 17% more than the 2012 levels and contributed 8% of the total 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% to all waste sector emissions, followed by solid waste disposal, which was 36%.

For the IPPU sector

- The total emissions were 1.04 $MtCO_2e$ for 2016, representing 3% of the total emissions.
- The 2016 emissions value was 31% less than the 2012 figures.
- HFC from product use as a substitute for ODS was the dominant emissions source, followed by emissions from the mineral industry.

ES 3.4. Emission Sources and Removals by Sinks According to Gases

Carbon dioxide (CO_2) was the dominant greenhouse gas in Ghana and constituted 66% of the total emissions. Without FOLU emissions, CO_2 was the leading GHG with 14.4 $MtCO_2$ levels. The AFOLU and the energy sectors are sources of 99% of the total CO_2 emissions. Among the sectors, the AFOLU was the leading source until 2015, when Energy became the most significant source. In 2016, Energy generated the most CO_2 emissions of 13.9 $MtCO_2$, followed by AFOLU producing 12.9 $MtCO_2$. Across time series from 1990 to 2016, net CO_2 levels went up by 62%. Notably, in the last four years of the time series (2012-2016), CO_2 emissions marginally inched up by 6%. Activities in forestland remaining forestland, forest conversion to cropland and grassland, thermal electricity generation and road transport were responsible for the rising CO_2 emissions.

The other leading GHG was nitrous oxide totalling 7.7 $MtCO_2e$ in 2016, which was 18.3% of the total emissions. Similarly, the AFOLU sector, specifically, "direct N_2O emission from managed soil" under the "aggregate sources and non-CO_2 emission on land" category, was the principal source of N_2O releases into the atmosphere. Likewise, N_2O emissions exhibited an upward trend over the 26 years rising from 4.1 $MtCO_2e$ in 1990 to 6.9 $MtCO_2e$ in 2012 and further to 7.7 $MtCO_2e$ in 2016. The implementation of the Government's fertiliser subsidy programme partly accounted for the rising emissions. Apart from AFOLU, insignificant amounts of N_2O came from Waste (0.6 $MtCO_2e$) and Energy (0.4 $MtCO_2e$) sectors (Table ES 3).

Table ES 3: Contributions from different gases to the national emissions in 2016

Sectors & Sub-sectors	Mt	Emissions $MtCO_2e$					Share of Total	
	CO_2	CH_4	N_2O	PFC	HFC	Total	% with FOLU	% w/o FOLU
1. Energy	13.97	0.66	0.38	-	-	15.01	35.6	51.3
2. Industrial Process & Product Use	0.39	-	-	0.03	0.61	1.03	2.4	3.5
4. Waste	0.009	2.56	0.60	-	-	3.16	7.5	10.8
3. AFOLU	12.91	3.29	6.72	-	-	16.2	54.4	34.5
Total net emissions (including FOLU)	27.29	6.51	7.71	0.03	0.61	42.15	100	
Total emissions (excluding FOLU)	14.41	6.51	7.71	0.03	0.61	29.27		100

For CH_4 emissions, a significant proportion came from the AFOLU and waste sectors. Almost half (50.6%) of the AFOLU's methane came mostly from livestock rearing. The rest of the methane emissions came from the waste sector (39.3% of the total methane emissions) through the disposal of solid waste and wastewater treatment and discharge facilities. A relatively smaller percentage of 10.1% of the methane, was produced by the energy sector using biomass for cooking and heating in residential and commercial areas. The upturn in methane levels corresponds to the rise in the nitrogen addition to managed soil, unmanaged waste disposal practices and the wastewater treatment technologies. For the 1990-2016 window, methane emissions from the waste sector recorded the highest (287.9%) growth at the fastest annual growth rate of 5.6% compared to AFOLU that increased by 27.2% at a 1% rate per annum. Unlike the sectors, methane emissions from energy showed a quantum decline of 31.1% at 1.5% drop every year.

Perfluorocarbons (PFC) and Hydrofluorocarbons (HFC) are key industrial gases that are emitted exclusively from IPPU. PFC emissions are associated with Aluminium production at VALCO in the metal industry category. The 2016 levels stood at 0.03 $MtCO_2e$, representing a reduction of 83.4% from 1990. But with recent efforts to renew the VALCO plant, though still operating at limited capacity, PFC emissions shot up by 101% from 2012 to 2016. The HFC emissions level of 0.61 $MtCO_2e$ in 2016 signalled response to policy interventions. As a result of the major policy push to phase out CFCs in the 2000s with HFC substitute in the RAC sector, there was a substantial increment in HFC consumption by 981.9% from 2005 to 2016 peaking in 2012 at 0.96 $MtCO_2e$ before declining in the subsequent year till 2016. Between 2012 and 2016, HFC emissions showed a significant drop of 36% following the efforts to promote the adoption of low-GWP HFCs. Due to the lack of activity data, Ghana did not estimate SF_6 emissions. NF_3 emissions do not occur in Ghana.

ES 3.5 Precursor gases and SLCPs emissions

Precursor gases are not greenhouse gases at the point of release, but when they get into the atmosphere, they can contribute to global warming, local and regional air pollution with its attendant public health challenges. Methane, HFCs, black carbon and tropospheric ozone are classified as Short-Lived Climate Pollutants (SLCP) because they have a relatively short life span in the atmosphere. Methane, HFCs and Black Carbon (BC) emit directly, while tropospheric ozone forms photochemically in the atmosphere from primary emissions of methane, nitrogen oxides, volatile organic compounds, and carbon monoxide.

For these SLCPs, CH_4 was the foremost and accounted for 310 Gg in 2016. Black carbon was 234.28 Gg, and HFC emissions were 0.29 Gg in the same year. The primary source of CH_4 was livestock rearing, solid waste disposal and biomass use in cooking. Black carbon emissions were mainly from transport, residential cooking, and manufacturing industry. HFC emissions were primarily from stationary and mobile air conditioners. In addition to the SLCPs, the NC4 also reports on the estimates of precursor gases such as Nitrogen Oxides (NOx), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCs) and Particulate Matter ($PM_{2.5}$). The most predominant precursor gas was carbon monoxide recording 1,767.7 Gg in 2016. In the same year, NOx, NMVOC and $PM_{2.5}$ levels were 122.4 Gg, 271.8 Gg, and 605.2 Gg respectively. These emissions were significant to quantify alongside emissions of GHGs and SLCPs for the development of integrated strategies to reduce air pollution and greenhouse gases.

ES 4 Greenhouse gas mitigation assessments

ES4 presents the methods and results for mitigation assessment. Ghana has adopted a voluntary national emission target of minus 45% against the BAU emissions of 74 $MtCO_2e$. The mitigation target translates to 33.3 $MtCO_2e$ emission reductions between 2017 and 2030 and divided into an unconditional of minus 15% (11 $MtCO_2e$) and a conditional of minus 30% (22.2 $MtCO_2e$) (Figure ES1). Ghana identified twenty mitigation measures in the energy, transport, forestry, industry and waste sector to achieve the minus 45% emission reduction commitment.

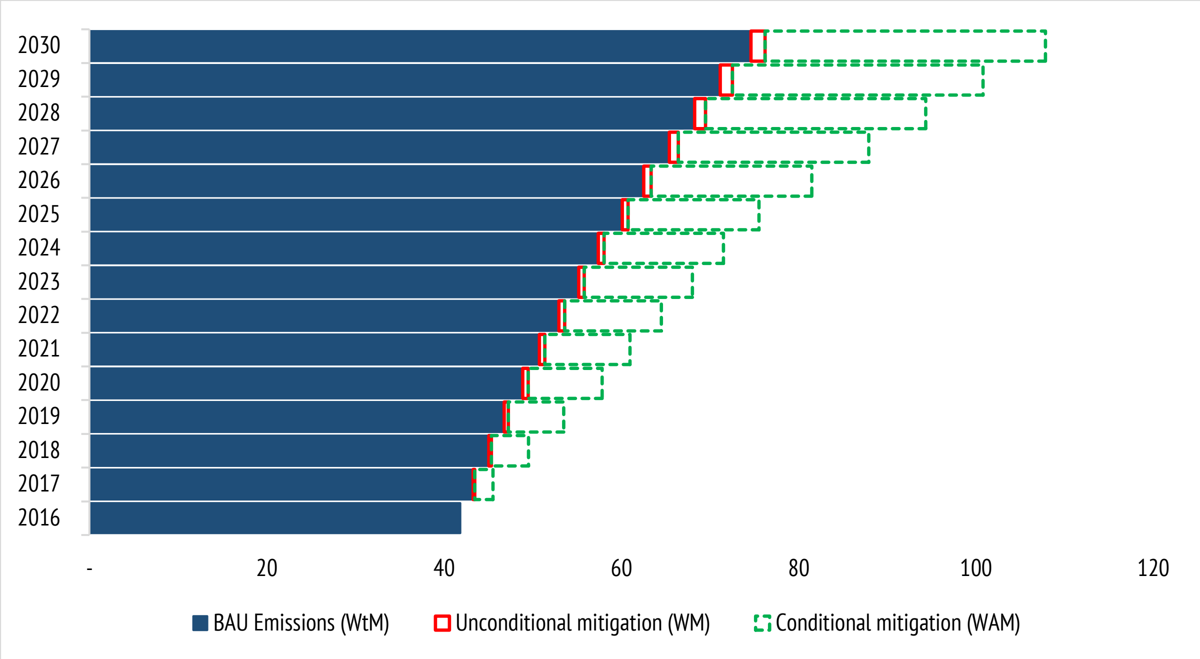


Figure ES 1: Mitigation scenario relative to BAU emissions

The first blue bar represents the baseline emissions for 2016, covering all the IPCC sectors and direct greenhouse gases obtained from the national GHG inventory results. Multi-year blue bars from 2017 depict the Business-As-Usual (BAU) the emissions pathway up to 2030 under the current policies. The potential effects of the twenty mitigation options would amount to 45% below the 2030 BAU emissions expressed in two tiers bars (red bold line bars and dash bars). The red bold line bars from 2017 to 2030 represent the lower ambition mitigation pathway that corresponds to the 15% NDC unconditional commitment and expected from the implementation of fuel switch and forest plantation mitigation options. The green-dash bars (2017 to 2030) show the ambitious mitigation trajectory, which is consistent with the additional 30% emission reductions under the conditional mitigation commitment (Table ES 4).

Table ES 4: Breakdown of mitigation scenario by sectors, mitigation options and their corresponding emission reduction potentials

Category		No. of mitigation options	Mitigation reduction potential	
			2017-2030	Annually
Mitigation scenario	With Measures (WM) and With Additional Measures (WAM) scenario	20	33 $MtCO_2e$	2.4 $MtCO_2e$
	WM scenario	2	11 $MtCO_2e$	0.8 $MtCO_2e$
	WAM scenario	18	22 $MtCO_2e$	1.6 $MtCO_2e$
Breakdown of mitigation options by sectors	Energy	13	14 $MtCO_2e$	1 $MtCO_2e$
	Forestry	2	9 $MtCO_2e$	0.6 $MtCO_2e$
	IPPU	1	1 $MtCO_2e$	0.1 $MtCO_2e$
	Transport	1	5 $MtCO_2e$	0.4 $MtCO_2e$

Table ES 5 presents the identified twenty priority mitigation options and their potential effects.

Table ES 5: List of prioritised mitigation options

		Development Impact Visualation														
		Climate			Economic				Social							
No	Mitigation policy/technology options	Abatement potential 2030(ktCO$_2$/year)	Abatement cost 2030($/tCO$_2$)	Climate resilience	Institutional ownership	Technical effectiveness	Capacity availability	Ease of implementation	Employment	Resource access	Health	Education	Gender	Environmental Impacct	Total Score
1	**Switch from fuel oil to natural gas** (Replace crude oil with natural gas in thermal plants)	64.1	-128.7												
2	**Forest plantation** (Annual 25,000ha forest plantation up to 2030)	1466.7	-26.9												
3	**LPG for cooking** (Access by 2030, projected to 50%)	1158.9	-20.7												
4	**Efficient lighting with LED** (Ligting with 7 million LED bulbs)	552.42	350.6												
5	**Efficient woodstoves** (Distribute 2 million efficient stoves by 2030)	14597	292.5												
6	**Single cycle to combined cycle** (Add 330 MW of steam capacity by 2030)	398.46	-43.0												
7	**Power factor increase in buildings** (Installation of power bank in 1000 commercial and industrial buildings)	83.777	-1.8												
8	**Reduced flaring in oil fields** (Recover 120 MMSCF/day of natural gas from oil fields)	2713.6	163.0												
9	**Mini hydro power** (Install 300 MW mini hyro-dams connected to national grid)	516	321.2												
10	**Solar PV, Large grid** (250MW utility scale by 2030)	177.94	405.4												
11	**Solar home PV** (200,000 50W PV by 2030)	64.058	413.3												
12	**Solar LED Lamps** (2 million LED lamps by 2030)	187.82	151.5												
13	**Mini-grid** (Install 55 mini-grids - 300 MW by 2030)	8.03	321.2												
14	**On-shore wind turbines** (Install 150 MW by 2030)	146.25	336.2												
15	**Avoided deforestaton (REDD+)** (Avoid deforestation in 270,000ha)	1414.3	9.0												
16	**Bus Rapid Transit** (200km BRT line in Urban areas)	395.1	-125.3												
17	**Landfill gas flaring** (200 t/day plant nationwide)	1704.5	-1.3												
18	**Institutional biogas** (200 t/day plant nationwide)	7.1	-0.3												
19	**Composting of municipal waste** Domestic requirement for 20% by 2015 and 30% by 2040	1754.9	0.0												
20	**HFC phase-down** (All flourinated gases)	613	0.0												

key
- Highly positive
- Positive
- Neutral/Minor impact
- Negative
- Uncertain/ policy specific

Table ES 6 provides an overview of some of the critical interventions that must be implemented to achieve the minus 45% mitigation objectives. It also captures information on barriers, investment cost, abatement potentials, sustainable development benefits, implementing institution and alignment with national policy.

Table ES 6: List of mitigation actions, the status of implementation and enabling policies

Mitigation Options	Line Ministries	Supporting Agencies	Investment costs for implementation to 2030 (US$)	Estimated split between the public-private sector and consumer investments*	Abatement potential and sustainable development impacts	Priority Barriers	Alignment with National Policy/Programme removing barriers
Clean cooking (Improved cookstoves and LPG Cookstoves)	Ministries of Energy, Land and Natural Resources, Local Government and Rural Development	Energy Commission National Petroleum Authority Forestry Commission District Assemblies	US$ 0.65billion Improved cookstoves (US $0.16billion) LPG stoves (US$ 0.49billion)	Improved cookstoves: about 70% consumer costs and 30% public support costs, LPG stoves: about 80% consumer cost and 20% public support.	- Abatement potential of 15.8 $MtCO_2e$ by 2030 - Health benefits from reduced indoor air pollution. - Lower fuelwood demand and deforestation. - Potential cost savings to households.	- Inadequate production and distribution capacity; - Limited expertise to design and produce more efficient technologies; - The sector is not attractive to financial institutions.	- Policy target: 50% LPG penetration by 2020. - Reduce wood fuel demand from 72% to 50% by 2020. - Programmes – SEforALL Action plan.
Utility-scale solar	Ministry of Energy	Energy Commission, Private sector	US$ 169 million[2]	80% of the total cost expected to come from the private sector	- 11 $MtCO_2$ - 1,169 job prospects	- The challenging investment climate, - Uncertainty of available resources, - Limited technological capacity. - Insufficient experience in renewable energy development - Information and awareness barriers	Renewable Energy Act. Renewable Energy Master Plan. SREP Investment Plan.
Solar lanterns	Ministry of Energy	Energy Commission, Private sector	US$ 300 million	Private sector involved in importation, distribution, sales and	- 947 $ktCO_2e$/year	- Inadequate resource availability.	National Energy Policy.

[2] Referenced from Table 13 in the Renewable Energy Master Plan

				installation of LED lamps	- Health benefits from reduced indoor air pollution.	- The incentive for manufacturers or importer of efficient LED lamps. - The disposal of inefficient bulbs is a potential source of mercury emissions.	Light for all initiative. (Distribution of 12 million LEDs)
Switch from liquid fuel to natural gas in thermal power plants	Ministry of Energy	Volta River Authority, Ghana Gas Company	US$ over 1 billion	About 80% investment in gas infrastructures by GNGC. GNCP is the gas aggregator. 20% of the cost of gas production and distribution by the private sector.	- Potential to generation 145 ktCO_2e/year	- Irregular flow of natural gas from the West Africa Gas Pipeline.	National Gas Master Plan
Forest plantation development	Ministry of Lands and Natural Resources	Forestry Commission Private sector	US$ 4.1 billion investment cost, projected income of US$ 9.4 billion	The shared cost between public and private sector plantation development companies.	- Potential to generate 2,456.67 kt/year. - 2.8 million jobs for over 25 years.	- Lack of sustainable financing framework for plantation development. - Lengthy land acquisition processes. - Weak legal and institutional framework for plantation. - Lack of a unified legal framework for regulating plantation development, benefits sharing, financing.	National Forest and Wildlife Policy. Forest Plantation Strategy. Forest Plantation Development Fund. REDD+ Strategy.
Ghana Forest Cocoa REDD+ Programme	Ministry of Lands and Natural Resources	Forestry Commission, Ghana Cocoa Board Private sector	US$ 50 million results-based payment model.	The results-based payment scheme would help to leverage an over US$ 200 million additional investment	- Potential to generate 1414.29 kt/year.	- There are challenges in mobilising funds for implementation. - There are inadequate capacities to use state-of-the-art GIS technology to	National Forest and Wildlife Policy. REDD+ Strategy. Forest Plantation Strategy.

				into the cocoa landscape.		map and monitor existing plantations spatially. - Threats from illegal mining.	Forest Plantation Development Fund.
Bus Rapid Transit (BRT) – High Occupancy Buses	Ministry of Transport, Infrastructure, and local Government	Ministry of Transport	US$ 0.35 billion	About 70-80% public investment cost for infrastructure and 20%-30% private costs for vehicles.	- Abatement potential to 2030 of 1.63 $MtCO_2e$. - Reduced traffic congestion - Improved local air quality - Improved road safety - Job creation	- Difficult to regulate informal transport service providers. - Inadequate funding. - Lack of consistent political commitment. - BRT integration into road development.	National Transport Policy. Policy target: 80% of all trips in urban areas must be on public. Mass Transit Systems.
Institutional biogas	Ministries of Energy, Education and Health	Energy Commission	US$ 0.11 billion	About 55% public investment through a rebate scheme 45% private costs for cost institutional biogas.	- Abatement potential to 2030 of 0.024 $MtCO_2e$. - Reduction in indoor pollution - Improved sanitation - Reduction in out-pocket-expenditure on cooking fuels - Job creation and increased incomes.	- Lack of access to improve to finance. - There are local professional artisans. - High upfront cost. - Non-existing public capital incentives. - Ensure standardisation of design and production of biomass plants.	SEA4ALL Action Plan. Renewable Energy Act. Renewable Energy Master Plan.
HFC Reductions in the RAC Sector - scale-up market share of climate-friendly and energy-efficient conditioners to 70% by 2030	Ministry of Environment, Science, Technology and Innovation	Environmental Protection Agency, Energy Commission	US$ 15.5 million	Private sector involvement in the importation of efficient conditioners	- Potential to reduce the emission of 900 kt/year.	- Industry refusal to get backing of national agencies. - Inadequate funding	HFC phase-out management plan
Avoided methane from the disposal of solid waste	Ministry of Sanitation and Water Resources	Private companies	Not estimated	Private sector-led	- Potential to reduce 1,754.9 kt/year	- Mixed waste stream introduces extra costs to processing.	Double the current waste to compost capacity of 200tonnes/day to

through compositing						- Underdeveloped compost market. - Limited compost production capacity	400tonnes/day by 2030
Landfill gas management	Local Government, Waste and the Environment sectors.	Ministry of Local Government and Rural Development	US$ 0.51 billion	About 30% public investment to equity, 70% private capital cost	- Abatement potential to 2030 of 0.4MtCO_2e/yr. - Reduce the incidence of fire at landfills. - Additional Energy generated - Improve sanitation	- High upfront transaction cost. - No landfill gas collection obligation - Challenges in the operational management of landfills	National Environmental Sanitation Policy Renewable Energy Act

ES 5. Vulnerability, Impacts and Adaptation Assessments

ES 5 provides the summary information on vulnerability, impact and assessments.

ES 5.1 Key Policy Messages

Under this section, as much information as possible on adaptation efforts across the country from 2015 and synthesises it into key messages. The key messages are:

More than 30 years of climate records show that the climatic conditions in Ghana have severely deteriorated and are more likely to worsen in the future.

The uncertainties in the future climate will be far more significant than in the past.

- Rainfall variability will be high in the forest regions than the rest of the country.
- Ghana will continue to be warm and even get worse by 2080.
- Temperatures are likely to increase by at least 3°C by 2080 nationwide.
- The savanna regions are likely to record temperature above 30°C.
- The high likelihood of wet spells may lead to more floods across the country.
- The projected increases in dry spells may exacerbate drought conditions, especially in the savanna.

Climate-induced events are on the rise, and their impacts could become alarming if concrete steps are not taken to deal with the human aspects that contribute to them.

In the past 50 years, 22 major hydrometeorological events in Ghana have affected 16 million people with over 400 deaths.

- There have been over 19 significant flood events in the past five decades.
- Three drought events have occurred in the past five decades.
- Five of climate-induced disasters have cost Ghana more than US$120 million.

Vulnerability due to dependence on agriculture adversely impacts livelihoods, with increasing severity from the coast to the Northern savanna.

Using agriculture-livelihood sensitivities, the communities in the Northern dry savanna will experience the worst impacts of climate change.

- Upper West is the most vulnerable region to climate change.
- Wa East is the most vulnerable district in the whole country.
- 10% (roughly 28,000km) of Ghana's land area falls in the high flood hazard zones mostly along the White Volta and downstream of the Akosombo dam.
- Majority of the land in Northern Ghana falls in the high drought hazard category.

Climate change is likely to bring unbearable disruptions to the electricity system, cash crop production, urban migration, livelihoods of smallholder farmers and the coastline.

The changing climate is a threat to energy and food security and rural livelihoods.

- The already harsh ecological conditions coupled with adverse climate change impacts in Northern Ghana could accelerate migration toward the southern cities. Most migrants tend to live in slums and urban-stressed areas that are prone to recurrent floods.
- The projected future severe drought conditions may affect cash crop production.
- Prolonged drought conditions, will increase the population of variegated grasshoppers which destroy cassava.
- There is an increasing reduction in marine fish catch as well as freshwater landings due to rising sea temperatures and to high fishing intensity; leading to generally low incomes in fishing communities.
- An increase in extreme temperatures could lead to increased demand by competing water users which could reduce water availability for power generation.
- Climate change-induced sea-level rise is very likely to exacerbate the erosion taking place along vulnerable sections of the 560 km coastline.

ES 5.2. Adaptation policies and investments are producing positive returns and must be scaled-up at all levels.

The principal government flagship policy initiatives support climate change adaptation measures under the 'modernising agriculture' agenda.

- '1 Village 1 Dam' policy has increased access to water all year round to vulnerable farmers. So far, five hundred and seventy small dams and dugouts are under different stages of construction in the Northern, Upper East, and Upper West Regions.
- 1 District 1 Warehouse has contributed to reverse post-harvest losses. The construction of 300 warehouses 1,000 metric tonnes capacity is underway[3].
- Planting for Food and Jobs involves the supply of improved seeds, fertiliser and extension services to farmers and has contributed to increased food production (maize 75%, rice 24%, soybean 39%, and sorghum 100%). Five hundred and fifty-seven thousand farmers supplied with high-quality seeds. Seven thousand, six hundred metric tonnes of seeds and cassava planting materials distributed to farmers.
- Rearing for Food and Jobs supports climate-smart livestock production. So far, 53,500 livestock (sheep, pigs, cockerels and guinea fowls) have been distributed as of June 2019.
- Planting for Export and Rural Development (PERD) is a decentralised tree crop programme to promote rural economic growth and farmer incomes. The plan is to develop nine commodity value chains, namely cashew, coffee, cotton, coconut, citrus, oil palm, mango, rubber and shea, through a decentralised system. PERD seeks to support one million farmers in 170 districts with certified free planting materials to cover over one million hectares of farmlands and engage 10,000 young graduates as crop specialised extension officers.

ES 5.3. Key national and sector policies that Prioritise Climate Change Adaptation Measures

- 2018-2021 Medium-Term Development Framework
- National Climate Change Policy (2015-2020)
- National Climate Change Adaptation Strategy (2010-2020)
- Nationally Determined Contributions (2020-2030)

[3] 2019 Mid-year National Budget Speech

- Strategic Medium-Term Plan for the Ministry of Works and Housing (2018-2021)
- Ghana Plan of Action for Disaster Risk Reduction and Climate Change Adaptation (2012)
- National Climate-smart Agriculture and Food Security Action Plan (2016-2020)
- Ghana Irrigation Development Policy (2011)
- National Adaptation Plan Framework (2018)

ES 5.4 Adaptation Intervention Areas:

Strengthening capacities of District Assemblies and EPA Regional Staff on mainstreaming climate change

- Trained 100 district assembly staff from 22 District Assemblies in Western Region in 2018 on mainstreaming climate change into district plans, programmes, and policies.
- Trained 60 EPA regional staff on the effective integration of climate change adaptation into Environmental Impact Assessment.
- Created awareness amongst about 800 regional stakeholders on Ghana's NDC nationwide.
- Trained 138 district assembly staff from 10 districts, on mainstreaming Ghana's NDC into District Development Plans.

Tackling the recurrent flood in urban areas

- Implementing a national flood management strategy.
- Investing US$ 200 million in Greater Accra Resilient Integrated Development Project to improve flood risk and solid waste management in the Odaw River.

Strengthening systematic observation, climate services, and early warning systems

- Modernisation and automation of weather observation networks. The Ghana Meteorological Agency (GMet) has added ten automatic weather stations to beef up the existing stations.
- The National Disaster Management Organisation (NADMO) has established emergency operation centres for early warning and communication for priority hazards in 10 sites to benefit nearly 6 million people.
- Water Resources Commission has invested over US$ 4 million in flood and drought hazard assessment in White Volta and Oti River basins.

Building resilience in vulnerable agricultural landscapes

- Investing more than US$ 100 million in the Northern drylands to build the resilience of smallholder farmers and the fragile ecosystem they depend on for their livelihoods.
- Invested € 3.8 million in climate risk transfer (drought index insurance).

Expanding coastal protection and irrigation development

- Invested nearly US$ 670 million in seven sea defence projects across Ghana's coastline.
- Planning to undertake sea defence projects in Amanful Kumar Coastal Protection works; Dixcove Coastal Protection Works; Komenda Coastal Protection Works; and Nkontompo Coastal Protection Works (Phase 2) - Western Region
- Rehabilitation of 3,000 ha through the Kpong Right Bank Irrigation Project and the extension of new irrigation infrastructure and services to a proposed additional 8,000 hectares under the New

Development Irrigation Scheme (NDIS) underway. This US$ 90 million initiative, is part of the Accra Plains Irrigation Project.

Developing capacity and research for adaptation

- Introduced specialised graduate and post-graduate training programmes on climate change adaptation at University of Ghana, University for Development Studies, Kwame Nkrumah University of Science and Technology (KNUST), the University of Cape Coast and the University of Energy and Natural Resources (UNER).
- CSIR College of Science & Technology offers a programme on climate change and integrated natural resources management.
- On-going research on climate impacts and cocoa production, climate change and migration, climate change, and water resource management.

ES 5.5 Barriers to Climate Change Adaptation

- Limited institutional and technical capacity
- Slow adaptation and mainstreaming into district development plans
- Poor spatial distribution and population coverage of climate change adaptation projects.
- Low private sector participation.
- Limited adaptation funding

ES 5.6 Best Practices and Lessons for Adaptation Communication

- Need to establish an electronic database for adaptation best practices in Ghana.
- Develop standard indicators for tracking adaptation actions.
- Track implementation of adaptation actions under Ghana's NDCs and document best practices.
- Develop institutional arrangements for tracking and reporting adaptation actions at all levels.
- Develop a functional national system for adaptation communication.

ES 6. Other Information

ES6 addresses issues on technology transfer, research and systematic observation, Action for Climate Empowerment (ACE), REDD+ safeguard and response measures. It also includes information financial, technical and capacity needs.

ES 6.1 Technology Development and Transfer

Ghana has conducted two Technology Needs Assessment (TNA) in 2003 and 2013. Both assessments produced priority mitigation and adaptation technology option for addressing climate change. The 2003 assessment highlighted mitigation technology options in the Energy and Waste sectors. The 2013 TNA focused on adaptation technologies in the Water and Agriculture sectors. Although the 2013 TNA is the most current, it is nearly seven years old and needs to be updated to reflect the current technology needs of the country (Table ES7).

Table ES 7: Climate technology options identified in 2003 technology needs assessment and the links with policy documents

Priority technology portfolios	2003 TNA	Supporting policy document	Comments
Biofuels	x		
Industrial energy efficiency improvement	x	x	Consistent with Ghana's NDCs
Energy efficiency lighting	x	x	Aligns with 12 prioritised NAMAs and Ghana's NDCs, strategic national energy plan
Solar PVs	x	x	Aligns with Ghana's SEforALL Action Plan; 12 prioritised NAMAs, Renewable Energy Master Plan, Strategic National Energy Plan and Ghana's NDC, Internationally Transferred Mitigation Outcomes (ITMOs)
Natural gas combined cycle and Natural gas distribution system	x	x	The technology aligns with Ghana's NDC, National Gas Master Plan.
Management technologies and efficiency improvement in transport sub-sector or BRT	x	x	The technology aligns with Ghana's NDC, National Transport Policy.
Wind Energy	x		The technology aligns with Ghana's NDC, Renewable Energy Master Plan, Strategic National Energy Plan, Scaling Up Of Renewable Energy Penetration Investment Plan (SREP-IP).
Solar water heater	x	x	Renewable energy master plan, strategic national energy plan, Ghana's SEforALL Action Plan, SREP-IP
Small and mini-hydro	x		The technology aligns with the Renewable Energy Master Plan, Strategic National Energy Plan, SEforALL Action Plan, SREP-IP and NDC.
Biomass for power generation (co-generation from sawmill residues)	x		The technology aligns with The Renewable Energy Master Plan, SEforALL Action Plan.
Landfill methane gas capture for power generation	x	x	The technology aligns with Ghana's NDC and the Renewable Energy Master Plan.
Anaerobic and CH_4 generation technologies for wastewater handling (Biogas technologies)	x	x	The technology aligns with Ghana's SEforALL Action Plan, 12 prioritised NAMAs, Renewable Energy Master Plan and Ghana's NDC.
Incineration	x	x	
LPG and improved stoves		x	Aligns with Ghana's SEforALL Action Plan, Strategic National Energy Plan, LPG Promotion Policy, Renewable Energy Master Plan, National Gas Master Plan, Clean Development Mechanism (CDM), NDC, and ITMOs.
Efficient fridges		x	Strategic National Energy Plan and the NDC.

Similarly, the top technology lists from the 2013 TNA were in line with relevant government policy documents. Notable among them are the National Climate Change Policy, National Climate Change Adaptation Strategy, National Disaster Management Plan, Nationally Determined Contribution and the Strategic Medium-Term Development Plan for the Ministry of Works and Housing. Table ES 8 shows adaptation technology options and their supporting policy documents.

Table ES 8: Climate technology options identified in 2013 technology needs assessment and the links with policy documents

Priority technology portfolios	Sector	2013 TNA	Links to policy	Comments
Rainwater collection from ground surfaces	Water	x	x	The technology aligns with the National Water Policy.
Post-construction support for community-managed water systems	Water	x	x	The technology aligns with the National Water Policy.
Improving the resilience of protected wells to flooding	Water	x	x	The technology aligns with the National Water Policy.
Demarcation and protection of buffer zones for water bodies	Water	x	x	The technology aligns with the Riparian Buffer Zone Policy.
Rainwater harvesting from roofs	Water	x	x	The technology aligns with the National Water Policy.
Community-based extension model	Agriculture	x	x	The technology aligns with Ghana's NDC, Planting For Food And Jobs, with the National Climate-Smart Agriculture Action Plan.
Water user associations	Agriculture	x		
Integrated soil nutrient management	Agriculture	x		The technology aligns with the Food and Agriculture Sector Development Policy II and the National Climate-Smart Agriculture Action Plan.
Ecological pest management	Agriculture	x	x	The technology aligns with the National Climate-Smart Agriculture Action Plan and Ghana's NDC.
Seed and grain storage	Agriculture	x	x	Aligns with Ghana's NDC, Planting For Food And Jobs (one district one warehouse programme).

ES 6.2 Research and Systematic Observation

ES 6.2.1 Research

The NCCP and the NDC recognise research as a strong pillar for policy and practice. The main research interest gathered through a nationwide survey broadly include:

- technology adoption pathways
- pathways for indigenous knowledge transfer
- socio-economic impacts on local communities
- documenting past and on-going ecological and social dynamics
- policy-research diagnostics
- climate finance
- institutional coordination

The major challenge Ghana faces with climate change research is inadequate funding from the Government; climate change research in the country is often project-driven and donor-funded. Because funding from the government is not adequate, most academic and research institutions involved in climate change research rely on external funding sources. The donor funding for climate research has been useful, but an increase in government funding in research areas, that directly respond to national priorities would be necessary. Notwithstanding, the ongoing research contributes immensely to informing the climate change strategy development in the country.

As a result, the EPA has developed a climate change research database to collate and synthesise research findings to inform climate actions. Many on-going studies address different aspects of climate change on landscape dynamics, climate change and society, climate modelling and cross-cutting issues.

ES 6.2.2 Systematic Observation

The GMet[4] manages the national systematic observation infrastructure and provides climate services for public use, agriculture application, civil aviation, commercial airlines, military aviation and maritime. The synoptic and automatic network of meteorological and radar stations support the systematic observation infrastructure. GMet also collaborates with other international bodies such as the World Meteorological Organisation (WMO) on climate observations and data services. Besides, the University of Energy and Natural Resources, Sunyani has established the Earth Observation Research and Innovation Centre (EORIC) to research into earth and atmospheric observations. The centre undertakes research, training and provides services in carbon flux monitoring, aerial and satellite operations and fire monitoring. The Centre for Remote Sensing and Geographic Information Services (CERSGIS), Legon provides specialised services on geo-information for earth observation monitoring and mapping on land and coastal resources.

ES. 6.2.3 Participation in International Climate Change Activities

Ghana is active in climate change activities at the regional and global levels. The country's participation in international climate change activities demonstrates its commitments to the collective efforts to tackle climate change. The summary of activities that Ghana was involved in or contributed to are listed below:

Continental level

- Africa-wide climate change initiatives
- Climate for Development in Africa Programme (ClimDev-Africa)
- Africa NDC Hub
- African Adaptation Initiative (AAI)
- African Renewable Energy Initiative (AREI)
- Africa Ministerial Conference on the Environment (AMCEN)
- African Group of Negotiators (AGN)
- African Climate Policy Centre (ACPC)
- United Nations University – Institute for Natural Resource in Africa (UNI-INRA)

International level

- UNFCCC and Climate Change Negotiations
- Intergovernmental Panel on Climate Change (IPCC)
- Partnership on Transparency in Paris Agreement (PATPA)
- Climate and Clean Air Coalition (CCAC)
- NDC Partnership
- Coalition for Rainforest Nations (CfRN)
- Global Methane Initiative (GMI)
- UN-REDD

[4] http://www.meteo.gov.gh/website/

ES. 6.2.4 Action for Climate Empowerment (ACE)

ACE is an integral part of Ghana's climate strategy covering areas such as access to public information, public participation, public awareness and education. The updates on Ghana's ACE activities are as follows:

Efforts to promote access to public information

- Installing Automatic weather stations in Senior High schools
- Climate change sharing information platforms.
- Climate change data hub.

Efforts to promote public participation

- National school drawing contest on climate change

Efforts to promote public awareness

- National Climate Change Week
- REDD Eye Campaign
- Climate Change and Population Conference on Africa
- Africa Climate Change Week
- Renewable Energy Fair
- Accra SDG investment Fair
- Climate Chance Summit - Africa
- Climate Change Dialogue with Political Parties and Parliamentarians
- National Climate Change and Green Economy Learning Strategy

Efforts to promote education

- Ghana achieved the full integration of climate change into school curricula.
- Seven tertiary institutions in the country have introduced climate change courses at the undergraduate and graduate level.
- The University of Ghana and the KNUST, Kumasi have introduced graduate courses on "Climate Change and Sustainable Development" and "Climate Science and Meteorology respectively".
- WASCAL has introduced graduate and post-graduate programmes on climate change at KNUST.
- Several stakeholders educate the public on climate change through mass and print media such as radio and TV interviews, jingles, documentaries, community durbars, information vans and dissemination of educational materials. Social media is now an effective means of communication on climate change.

ES. 6.2.5 First Summary of Information on How Safeguards for REDD+ are being Addressed and Respected

In May 2019, as mandated by Decision 12/CP. 19 paragraphs 3-4, Ghana voluntarily provided its first summary of information (SOI) on how safeguards for REDD+ are being addressed and respected via the UNFCCC website. Ghana has established an online Safeguard Information System (SIS) to meet the National Environmental Regulations, Cancun, World Bank and GCF safeguard requirements. With the establishment of the SIS, Ghana wishes to update the SOI submitted to the UNFCCC consistent with Decision 12/CP. 19. The URL reference to SIS is http://reddsis.fcghana.org/.

ES 6.2.6. Ghana's Experience on Response Measures

Ghana opted to report response measures information in its BUR2 and has further provided an update in this national communication as follows:

- Established a national working group on response measures made of thirteen state and non-state institutions.
- Continued public awareness on response measures.
- Ghana adopted a new national employment policy in 2015.
- Organised successful National Dialogue on decent work and just transition in Accra in 2018. The recommendations from the dialogue are as follows:

    - Need to conduct scoping and rigorous impact evaluation of the NDC on jobs and the labour market.
    - Retooling of the education system, especially the vocational and technical training schools and centres and to mainstream the "Just Transition Concept" in their curriculum.
    - Upgrade existing skills to reflect the needs of the transition to a green economy.
    - Ensure that in the NDC implementation, the findings from the scoping study on decent work and a just transition to an environmentally sustainable economy and society for all in Ghana to ensure a just transition is achieved.
    - Undertake a climate change and employment diagnostics to give a better understanding of the labour market and its implications in implementing the NDC.
    - Enhance policy and institutional coherence and a strong need for economic modelling.

ES 6.3 Financial, Technical and Capacity needs

ES 6.3.1 Financial, technical and capacity needs

Ghana has identified the following as critical financial, technical and capacity needs

- Difficulty in tracking climate financial inflows
- Duplication of activities and funding
- Mislabelling of climate finance
- Lack of transparency on reporting on non-financial support for training and technical assistance
- Inadequate financial allocation in the national budget
- Data processing and management strategies
- QA/QC Protocols and Management of GHG inventory
- Uncertainty assessment and management of GHG inventory
- Strengthening the national system for GHG inventory
- GHG and mitigation action data management and institutional arrangement
- Training on marginal abatement curves
- Training new technical experts on GHG at the international level
- Improving the estimation of emission baselines
- Use of statistical and dynamic crop and hydrological models in climate impact assessment.
- Methodology for monitoring adaptation action

ES. 6.3.2 GEF, Annex II Parties, multilateral/bilateral financial contributions

Total climate-related financial inflows for the period 2011-2019 amounted to US$ 15.5 billion (the equivalent of GHC 29.7 billion). The financial investment in the natural gas industry development alone amounted to US$14.2 billion in three oil and gas fields and processing plants. When the loan investments in the natural gas industry development are excluded, total climate inflows for the period hover around US$ 1.3 billion (GHC 2.5 billion). Of the total amount of climate finance for the period, the grant component constituted the largest share of 72.1% followed by loans (19.1%), national budget (8.5%) and result-based payments (0.4%) (Figure ES 2).

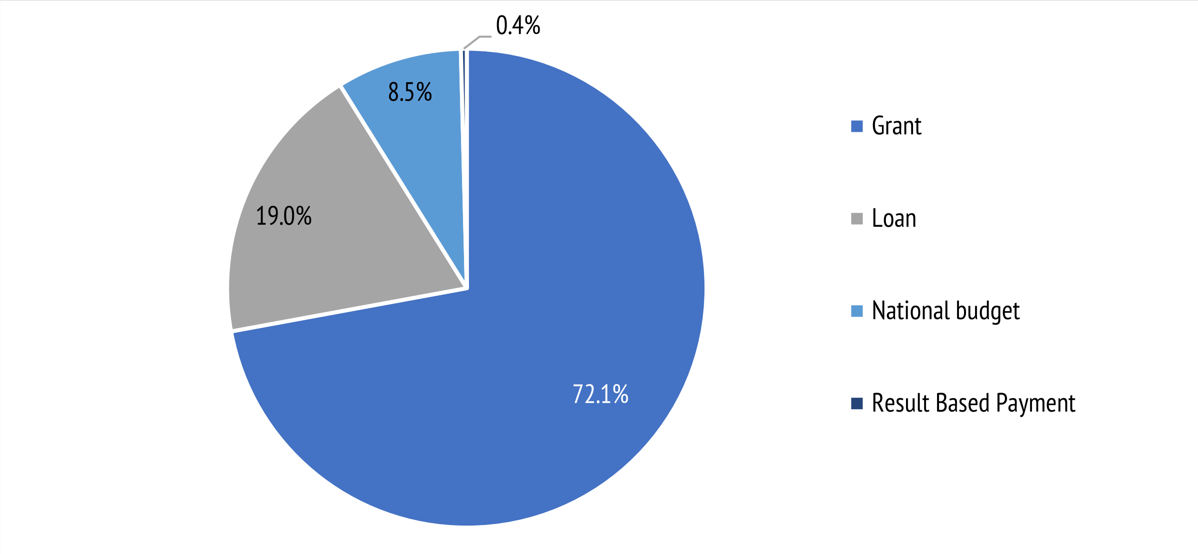


Figure ES 2: Share of climate financial inflows for the period 2012-2017

As shown in Table ES9, the financial flows through bilateral channels were the largest (45.1%), followed by multilateral (29%), global projects (11.6%), national funds (7.1%), and the GEF (4.4%). The remaining 2.8% are private foundations (1.3%), private sector (0.13%) and technical cooperation (0.02%).

Table ES 9: Breakdown of climate change finance flows for the period 2011-2019 in US$

Climate finance flow channels	Grant	Loan	National budget	Result-based payment	Total
Bilateral	**591,529,884**				**591,529,884**
Adaptation	7,979,847				7,979,847
Adaptation (MOI**)	1,113,558				1,113,558
Mitigation	516,648,586				516,648,586
Mitigation (MOI)	48,581,393				48,581,393
SD* (MOI)	17,206,500				17,206,500
Co-financing	**-**		**18,000,000**		**18,000,000**
Mitigation	-		18,000,000		18,000,000
GEF	**58,366,182**				**58,366,182**
Adaptation	13,418,182				13,418,182
Adaptation (MOI)	70,000				70,000
Enabling Activities	1,678,000				1,678,000
Mitigation	43,200,000				43,200,000
Global Project	**152,000,000**				**152,000,000**

Mitigation	152,000,000				152,000,000
Multilateral	**125,348,308**	**249,500,000**	**-**	**5,200,000**	**380,048,308**
Adaptation	22717296				22,717,296
Mitigation	68499128.24	249500000		5,200,000	323,199,128
Mitigation (MOI)	31020894				31,020,894
Finance (MOI)	938,679				938,679
Adaptation (MOI)	68,966				68,966
SD	50,000				50,000
SD (MOI)	2,053,345				2,053,345
National Funds	**-**		**93,280,000**		**93,280,000**
Mitigation	-		93,280,000		93,280,000
Private Foundations	**16,921,063**				**16,921,063**
Adaptation (MOI)	16,445,100				16,445,100
Mitigation (MOI)	475,963				475,963
Private Sector	**1,700,000**				**1,700,000**
SD (MOI)	1,700,000				1,700,000
Technical Cooperation	**249,000**				**249,000**
Grand Total	**946,114,437**	**249,500,000**	**111,280,000**	**5,200,000**	**1,312,094,437**

* SD: Sustainable development, **MOI: Means of Implementation

In terms of sectors, the Energy sector is the leading recipient of climate financial inflows. The total climate funds committed to energy sector projects over the eight years, amounted to US$ 758.8 million, making up 57.8% of total funds committed.

1. Introduction

1.1 Reporting Context on National Communication

National Communication (NC) is a tool that allows countries to report on their national and regional efforts toward the achievement of the ultimate objective of the United Nations Framework Convention on Climate Change, UNFCCC (hereinafter referred to as the "Convention"). The preparation of NC contributes to raising awareness and strengthening technical capacities on climate change among national stakeholders. It also allows Ghana to highlight critical gaps in national climate efforts. Since 2001, Ghana has published three NCs[5], and each NC preparation cycle took four years to complete (Figure 1). Ghana submitted the third NC to the Secretariat of the Convention in 2015 and continued to prepare the Fourth National Communication (NC4) in 2016. The four years of work has culminated in the compilation of this NC4 report.

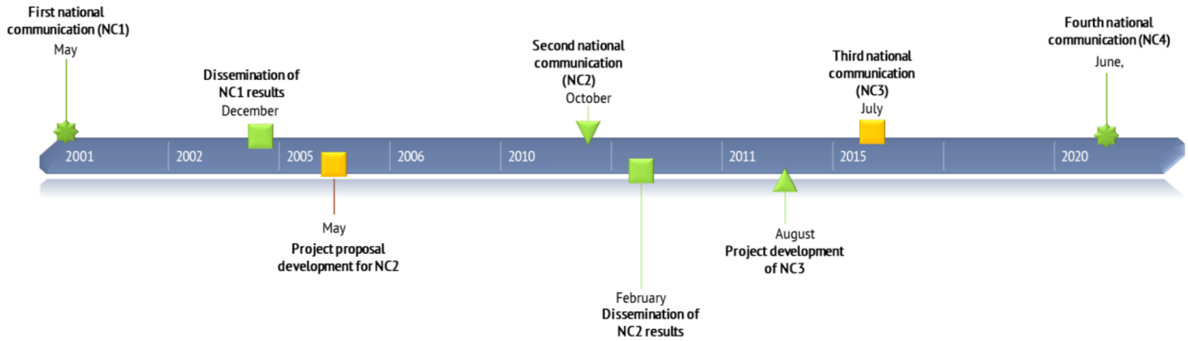


Figure 1: Milestone diagram showing the overview of publications of national communications

In each preparation cycle, Ghana ensured continuity with the previous national communications. This NC4 report, therefore, builds on the NC3[6] by incorporating updates and additional information to reflect significant policy changes and efforts made after the submission of the previous national communication, in 2015. Ghana has prepared the NC4 by pursuant to decision 17/CP.8 on the guidelines for the preparation of national communications from Parties not included in Annex I to the Convention[7]. The main objective of the NC4 is to communicate to the COP, the status of Ghana's effort to implement the Convention up to 2020 by highlighting the pertinent achievements and constraints. The update information in the NC4 covers the period between 2015 and 2020. The compilation of the NC5 would commence immediately after submission of NC4, to avoid a break in reporting.

1.2 Background to the Preparation of National Communication

Ghana became a Party to the UNFCCC in September 1995[8]; ratified the Kyoto Protocol in May 2003 and the Paris Agreement in September 2016[9]. Over the period, Ghana adopted strategies to domesticate the Convention to address climate change. As a Party to the Convention, Ghana has an obligation under Article 4, paragraph 1, and Article 12, paragraph 1 of the Convention, to regularly prepare, publish and report on national communications to the Conference of Parties (COP) to the Convention.

[5] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/national-communications-and-biennial-update-reports-non-annex-i-parties/national-communication-submissions-from-non-annex-i-parties

[6] https://unfccc.int/sites/default/files/resource/ghanc3.pdf

[7] https://unfccc.int/files/meetings/workshops/other_meetings/application/pdf/dec17-cp.pdf

[8] https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXVII-7&chapter=27&Temp=mtdsg3&clang=_en

[9] https://unfccc.int/node/61071

The process for compiling the NC is hands-on, collaborative, evidence-based and delivered coherently. As much as possible, relevant stakeholders got involved in the NC4 preparation. In all, fifty national experts from twenty-four state and non-state institutions contributed to the preparation of the NC4. The national experts worked in five groups with each responsible for a specific component of the report. There are eleven inter-related chapters in the NC4, all of which were informed by the latest climate change literature and the best available data in the country.

The compilation of NC4 started with a stocktaking exercise to assess the results and processes of the previous three national communications. The outputs of the stocktaking informed the design and implementation of the NC4. During the stocktaking exercise, a team of experts evaluated the national system for the compilation of NCs to identify the inherent strengths and weaknesses and come up with concrete approaches to tackle them immediately in the NC4 and future compilations. The recommendations from the exercise covered critical areas like improvements in institutional arrangements, revamping the structure for data management, capacity development and result dissemination.

Based on the findings from the stocktaking, Ghana developed the NC4 project proposal as part of the UN Environment's umbrella NC project for approval by the Global Environment Facility (GEF) council. The UN Environment was GEF's implementing agency for Ghana's NC4, which started in January 2016. The GEF is the primary funding source for the preparation of the NC4[10] even though it is not adequate to cover the full cost. Additional support came from the Low Emission Capacity Building (LECB), NDC Support Programme (NDC-SP) and the Initiative for Climate Action Transparency (ICAT) projects. Besides, Ghana provided in-kind support to match financial and technical assistance received to enable the preparation of this report.

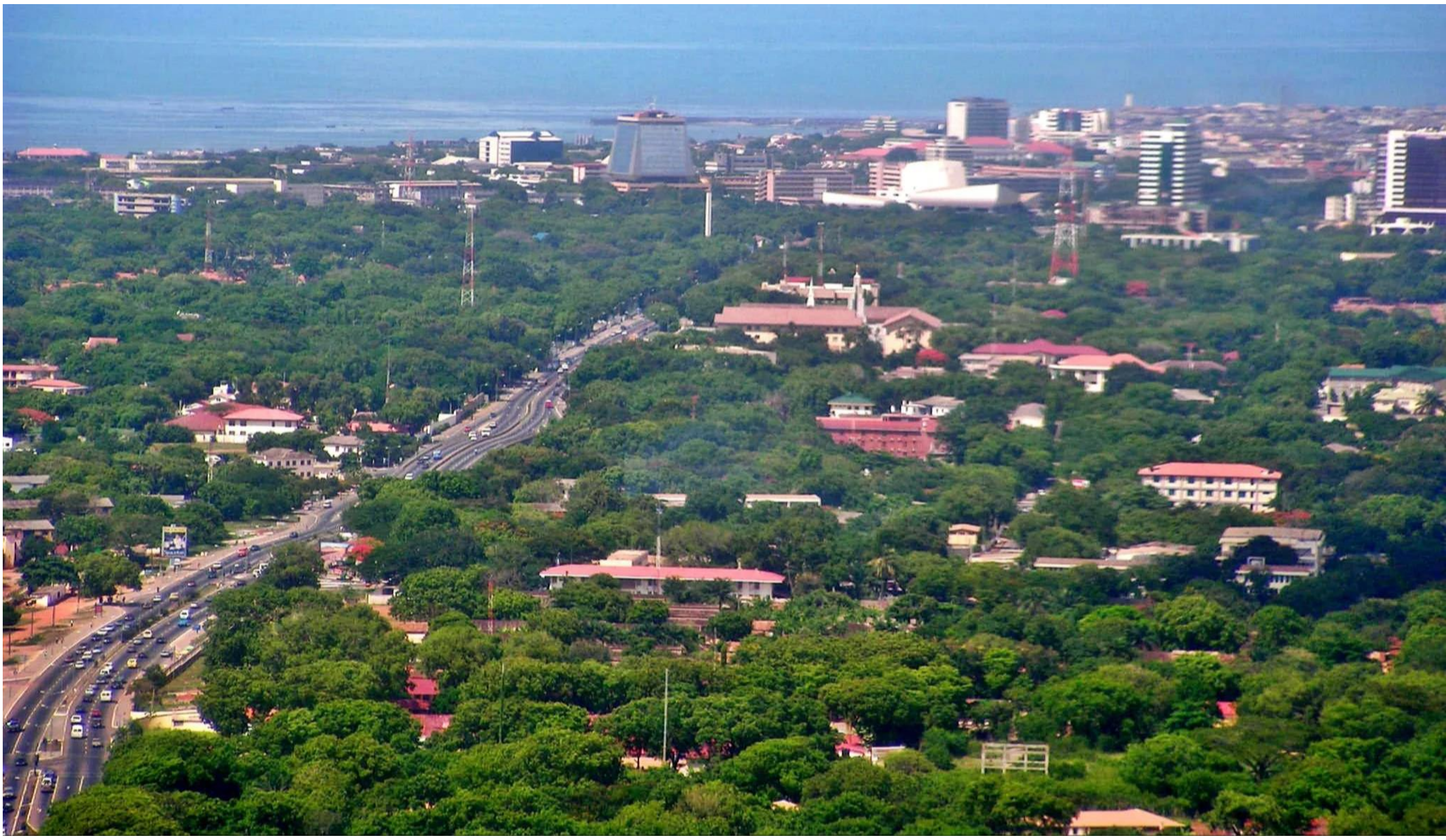
1.3 Climate Change in Ghana

As in many developing nations, climate change is a significant threat for Ghana, as the country is susceptible to both the Atlantic Ocean and Sahelian climate effects. The effects of climate change are intensifying across the country and would worsen in the future, with undesirable consequences on development. Hence, Ghana has integrated its climate change strategies into economic development plans and sectoral policies. The national development plan seeks to improve the lives of Ghana's citizens and tap into the opportunities that climate change presents.

As part of the pursuit of Ghana's agenda of prosperity for all, the strategy is to adopt development choices that promise to deliver growth-focused, people-centred and climate-resilient outcomes. The government's latest Coordinated Programme of Economic and Social Policies (CPESDP) for 2017-2024, demonstrates the relevance and commitment to respond to the challenges and opportunities offered by climate change. In line with this, the CPESDP fully embraces Ghana's obligations under the NDC to the Paris Climate Agreement and linkages to the Sustainable Development Goals (SDGs) and the Africa Union's Agenda 2063. Taking bold steps to promote climate-compatible development can lead to unlocking the investment opportunities to the benefit of Ghana's sustainable development agenda. Indeed, climate adaptation is an uncontested priority of Ghana. At the same time, mitigation serves as the primary vehicle for technology transfer and foreign direct investment. In this respect, mitigation actions are usually implemented at the lowest cost possible to promote long-term economic development.

[10] https://www.thegef.org/project/enabling-preparation-ghanas-fourth-national-communication-nc4-and-second-biennial-update

Updates of national circumstances



Accra, Ghana Source: http://www.bruna.cat/imgdownload/full/141/1410851/ghana-wallpaper.jpg

2. National Circumstances

2.1 Key Achievements since the Submission of Third National Communication to UNFCCC

Ghana continues to implement policies that have positive effects on development and climate protection. Highlights of the significant accomplishments are listed below:

- Adopted 2018-2021 Medium-Term Development Framework plan that highlights climate change as a priority.
- Put forward Thirty-One adaptation and mitigation measures in the NDC under the Paris Agreement to the UNFCCC in 2016.
- Adopted the Renewable Energy Master Plan in 2019.
- Promulgated the Petroleum Exploration and Development Act, 2016, (Act 919,) to restrict the flaring of gas in petroleum exploration and development.
- Established the SDG delivery and Green funds in 2019 with the target to raise US$100 million and US$200 million, respectively.
- The Forestry Commission signed an agreement to deliver six million tonnes of greenhouse gas emissions reduction under the Ghana Cocoa Forest REDD+ Programme with the World Bank in 2019.
- Investing US$ 200 million in the Greater Accra Resilient Integrated Development Project to improve flood risk and solid waste management in the Odaw River led by the Ministry of Water Resources and Sanitation with funding from the World Bank.
- Investing more than US$ 100 million in the Northern drylands to build the resilience of smallholder farmers and the fragile ecosystem they depend on for livelihood since 2016.
- Investing nearly US$ 670 million in 7 sea defence projects across Ghana's coastline over the last decade.
- Development of the National Adaptation Plan Framework in 2018, which seeks to clarify Ghana's approach to its NAP process.
- The EPA, National Council for Curriculum and Assessment (NaCCA) and Ghana Education Service, has incorporated climate change issues into school curricula. Currently, Climate change is taught as part of the following subjects in lower and upper primary: English Language, Science, Our World and Our People, Creative Arts and Religious and Moral Education.

2.2 Government Profile

Ghana has managed a remarkable democratic transition since 1992. As a nation-state, Ghana's 1992 constitution distributes democratic power among the executive, legislative and the judicial arms of government (Figure 2). The President is the head of the executive arm, and the legislative functions are vested in parliament. There is also the judiciary that is independent of the other arms of government. The national house of chiefs, advises on matters of chieftaincy, customary laws and land administration.

Ghana operates a local government system that seeks to decentralise development (administrative, political, planning and fiscal), to the sub-national level. The decentralised local government comprises structures at the national, regional and district levels. The country is subdivided into sixteen administrative regions and 260 Metropolitan/Municipal/District Assemblies (MMDAs) each headed by a Chief Executive. The National Development Planning Commission (NDPC) has a legal mandate to coordinate the entire national development planning system in Ghana.

It occupies the apex of the decentralised planning system involving Ministries, Departments and Agencies (MDAs), Regional Coordinating Councils (RCCs) and the MMDAs. Accordingly, the NDPC works with all MDAs, including the MESTI, to integrate climate change issues into the national development plans. Also, the Ministry of Local Government and Rural Development (MLGRD) coordinates the operations of the MMDAs and the RCCs under the Local Governance Act (Act 936)[11].

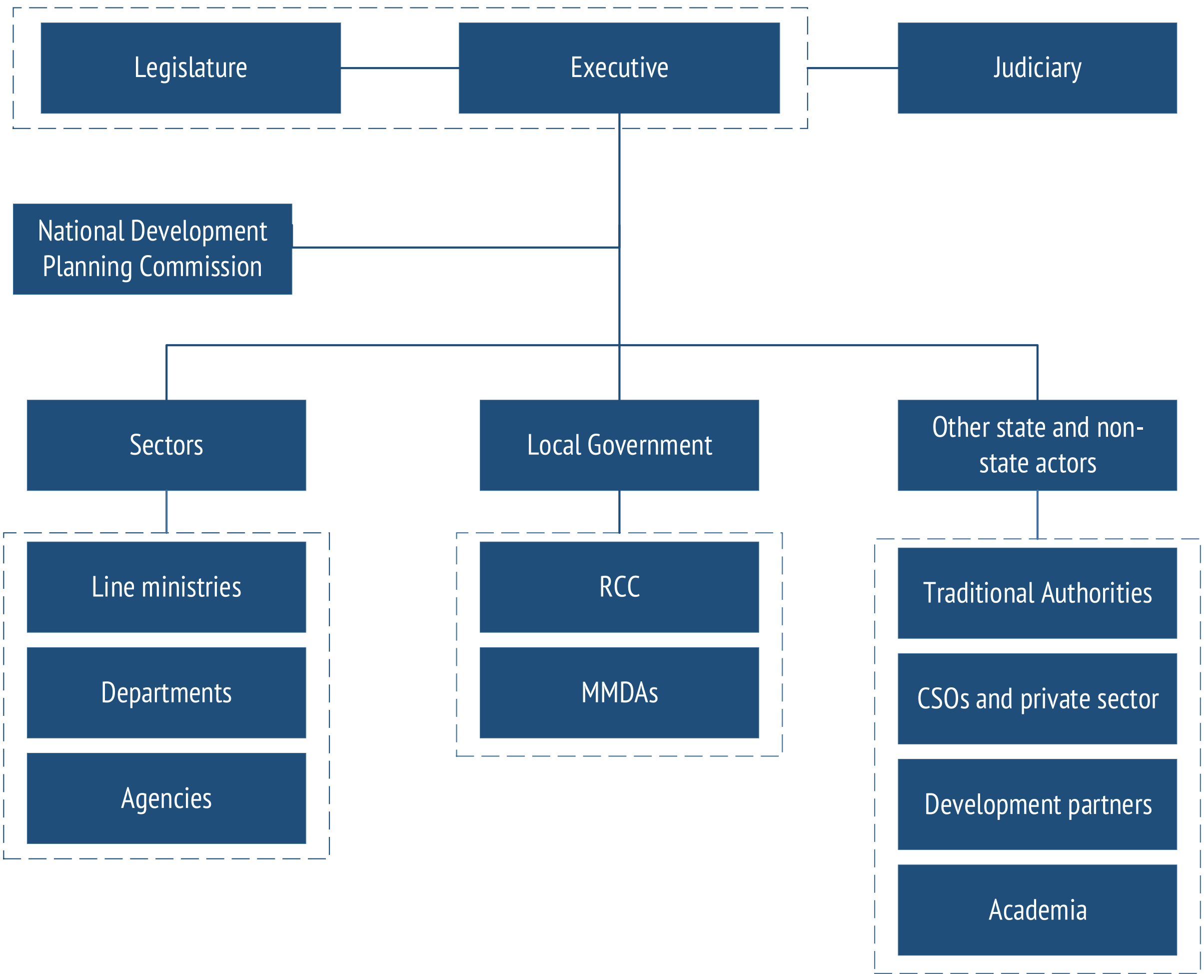


Figure 2: Overview of the Government profile in Ghana

2.2.1 Climate Change Governance in Ghana

Within the Government, the MESTI leads the formulation of climate change policies and supervises the implementation of the Convention and its Protocol activities within the country (Figure 3). The EPA is responsible for the technical coordination of the implementation of climate programmes and as a result, facilitates the preparation of international climate change reports in close collaboration with sector ministries. Ten years after becoming a Party to the Convention, in 2005, Ghana ratified the Kyoto Protocol and acceded to the Doha amendment in 2014 to extend its obligations under the Kyoto Protocol to 2020. In this regard, the EPA serves as the Convention National Focal Point (NFP) while MESTI is the National Designated Authority (NDA) for the Clean Development Mechanism (CDM). The EPA is also the focal point for international bodies such as the Inter-governmental Panel on Climate Change (IPCC), Climate Technology Centre and Network CTCN) and the Action for Climate Empowerment (ACE).

[11] https://ghalii.org/gh/gh/legislation/LOCAL%20GOVERNANCE%20ACT%2C%202016_3.pdf

MESTI hosts the National Climate Change Committee (NCCC), which is a multi-sectoral task force on climate change. The NDPC and Ministry of Finance play critical roles in the mainstreaming of climate change issues into the national development plans and the mobilisation of climate finance. With regards to the mobilisation of finance from international sources, the Ministry of Finance acts as the National Designated Authority (NDA) for the Green Climate Fund[12]. Besides, several MDAs have either established focal units or teams to work on climate change issues in their respective ministries. For instance, the Crop Services Directorate under the Ministry of Food and Agriculture is leading the implementation of the National Climate-Smart Agriculture Action Plan for the sector. Similarly, the Climate Change Unit at the Forestry Commission is the National REDD+ secretariat. At the Energy Commission, the Renewable Energy, Energy Efficiency, and Climate Change Division oversees the energy and climate change issues in the sector (Figure 3).

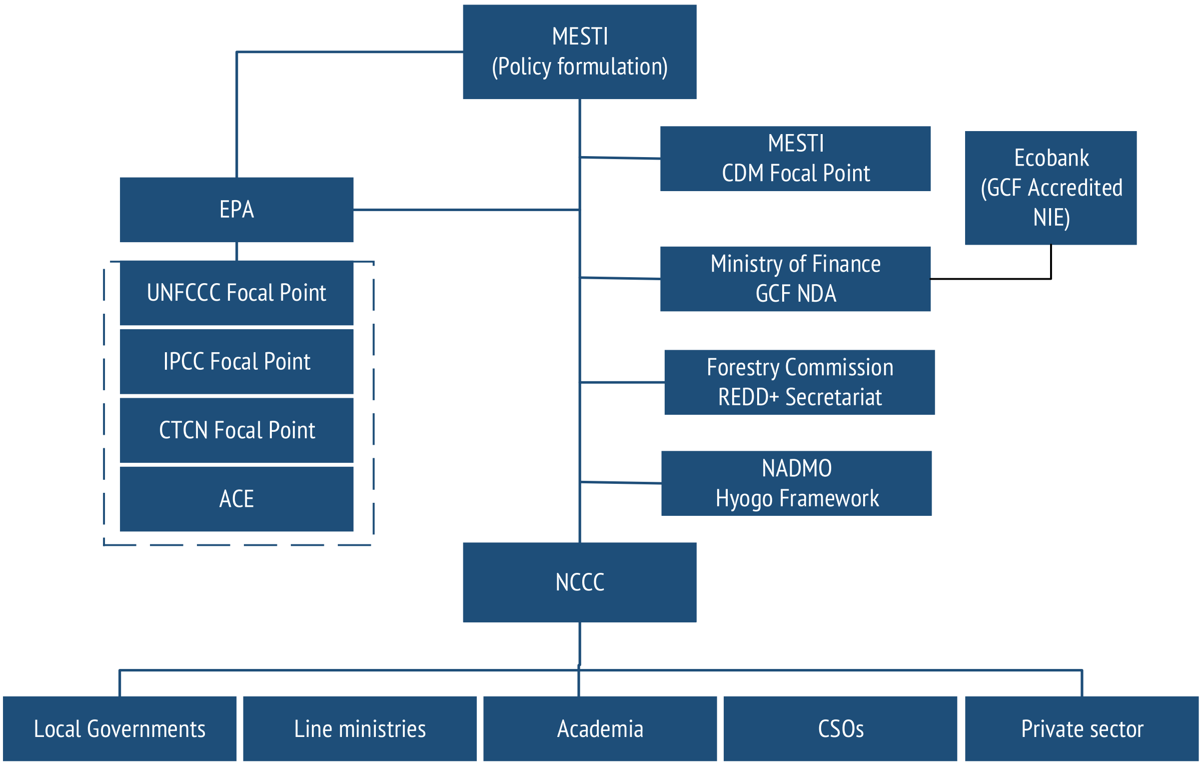


Figure 3: Overview of the institutional involvement in the implementation of the UNFCCC in Ghana

Recently, the Ministry of Local Government and Rural Development established a new climate change team to coordinate the activities within the Ministry. Many academic institutions are actively involved in teaching and research into climate change. Table 1 summarises institutions engaged in climate change activities in the country.

Table 1: Institutions and summary of climate change activities relating to their mandates

Ministry and Institution	Operational areas
Ministry of Planning	Defines broad government development policy, including climate change.
	Lead inter-ministerial efforts and policy alignment to SDGs.
National Development Planning Commission	Ensure the integration of climate change issues into national planning.
	Incorporated climate change indicators into the national results framework.
	Coordinate the preparation of sectoral and the national annual progress reports, which also cover climate change issues.

[12] https://www.greenclimate.fund/countries/ghana

	National planning and budgeting processes.
Ministry of Finance	Facilitate the domestication of the SDGs in the country.
	Prepares SDG compliant budget, including climate change.
	Tracks domestic and international climate change inflows.
	Serves as the national designated entity for the Green Climate Fund.
Ecobank Ghana Limited	Green Climate Fund Accredited National Implementing Entity.
MESTI	Leads in formulating climate and environmental policies and programmes.
	The focal point for the Clean Development Mechanism.
	Hosts the National Climate Change Committee to oversee the implementation of the National Climate Change Policy.
	Coordinates the regular preparation and implementation of the Nationally Determined Contribution.
EPA	UNFCCC Focal Point.
	GEF Focal Point.
	Coordinates adaptation planning and mitigation assessment
	Evaluates and promote relevant climate technologies.
	Coordinates the regular preparation of national and international climate reports.
	Administers Environmental Impact Assessment of projects.
	Manages the technical aspects of the preparation and implementation of the Nationally Determined Contribution.
Ministry of Food and Agriculture	Leads in the policymaking and implementation of climate-smart agriculture.
	Create and promote sustainable crop production.
Ministry of Lands and natural resources	Championing forest and wildlife policy.
	Implementing the forest investment programme with funding from the climate investment funds
Forestry Commission	Serves as the national REDD+ secretariat.
	Implementing the forest plantation strategy.
	Implementing the national REDD+ strategy.
	Implementing the cocoa landscape REDD+ project.t
Ministry of Energy	Responsible for sustainable energy policies.
	Implementing the scaling up of renewable energy investment plan.
	Adopted the national gas master plan.
	Adopted the renewable energy master plan.
Energy Commission	Leads in the implementation of sustainable energy for all action plan.
	Implementing energy efficiency regulation for home appliances and buildings.
	Promoting renewable energy through technical regulation.
	Proficiency training for artisans in electric wiring and solar installations.
Ministry of Transport and Ministry of Railways	Promoting sustainable transport modes.
	Developing policy and regulation for electric vehicles.
	Railway infrastructure development.
NADMO	Promote disaster risk reduction through early warning systems.
Ghana Meteorological Agency	Manages the network for systematic observation and climate services.
Ministry of Local Government and Rural Development	Facilitates the involvement of local government in national climate change activities.
	Effective spatial planning to support climate resilience.
Academic institutions (Universities, CSIR)	Contributes to knowledge generation via research, human capacity building through training and supporting evidence-based decision-making in climate change.
	Contributes to the works of international climate change bodies like the IPCC, WMO, WASCAL, Climate and Development Knowledge Network (CDKN) and the UN Environment.

2.3. Institutional Arrangement for the Preparation of National Communications and Biennial Update Reports

The culture of climate reporting is gaining roots in Ghana. Barely a decade after introducing the Ghana Climate Ambitious Reporting Programme (GCARP) as the national system for reporting, the country has chalked significant achievements (Figure 4). With the GCARP system, Ghana has successfully published three national communications, two biennial update reports and the accompanying International Consultation Analysis (ICA). This feat has been possible due to the GCARP arrangement that backs the timely data collection, process and analysis and reporting. The GCARP consists of the institutions, data management, tools and method and capacity development building blocks that helped to produce national communication. The same GCARP will continue to support Ghana's participation in the Enhanced Transparency Framework (ETF) under the Paris Agreement.

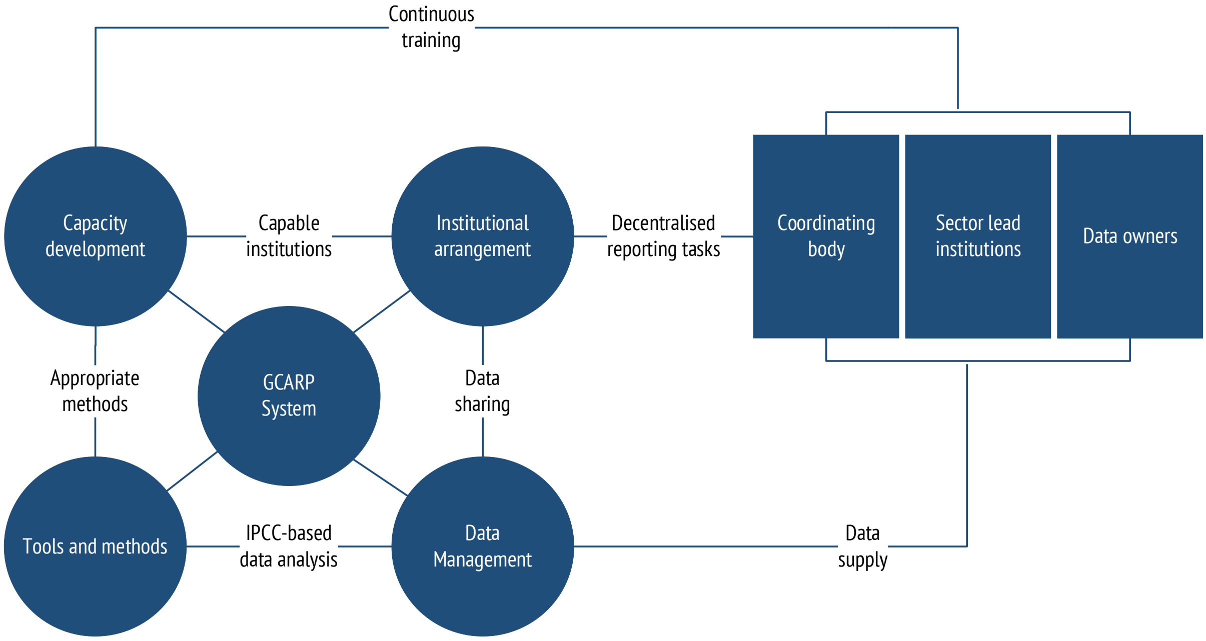


Figure 4: Elements of the GCARP system

Since the submission of the NC3 in 2015, Ghana has continued with the reforms of the functionality of the GCARP system in the following areas:

Institutionalisation of climate reporting – The transfer of climate reporting tasks to the line ministries, while EPA plays the coordination role, has been relatively successful. The process of permanently getting climate reporting into the governmental structures is a priority of the reforms in the national arrangement. The institutionalisation process started almost a decade ago, but it is yet to reach the desired level. The aim was to ensure that climate reporting becomes a credible source of information for policy formulation. It would be achieved by systematically integrating climate reporting tasks into the work routines of line ministries and secure budgetary allocation.

In the last decade, EPA has taken several steps to facilitate the institutionalisation by first decentralising the climate reporting tasks to relevant organisations under the ministries. The purpose was to let the line ministries play a more significant role in reporting, developing capacities, creating awareness, inspiring ownership of the national communication results and ultimately infusing stability or permanence in the institutional arrangements for reporting.

Even though over the years, the transfer of climate reporting tasks to the line ministries has brought improvements in climate reporting, Ghana will continue to address the practical challenges in the institutionalisation process. Ghana's Capacity Building Initiative for Transparency (CBIT) project is expected to contribute to strengthening the institutionalisation efforts.

Continuous capacity development – Continuous capacity development is one of the strategies to institutionalise the GCARP. Ghana is implementing a three-prong, interwoven capacity development strategy. The strategy is based on the thinking that as the climate reporting task is fully decentralised to line ministries, their capacities and interest must be widespread, sustained and incentivised over time. So, national experts who are already part of the GCARP undergo refresher training on advanced topics in international climate reporting to update their knowledge on current trends. Usually, these experts attend international and domestic training programmes on national communications, greenhouse inventories and biennial update reports.

Another approach to capacity development is via learning-by-doing. New entrants into the GCARP team get the opportunity to work closely with experts and learn on the job. Through this, the new experts get to know of the climate reporting stages. Another viable option is to collaborate with universities to train more people on various climate reporting topics. This approach is a viable option because it may be cheaper and more sustainable in the long term. The capacity development process would continue in the coming years with an emphasis on the following areas:

- Continuous training of experts from line ministries as an incentive to sustain their interest and add value to career progression.
- Collaborate with line ministries to include the time their experts spend on climate reporting the staff appraisal.
- Encourage line ministries to add more personnel to support sector works.

2.3.1. Institutional Arrangements for the Continuous Preparation of National Communications

The EPA coordinates the development of the national communications with technical inputs from line ministries. Fifty national experts from twenty-four state and non-state institutions contributed to the compilation of NC4. The national experts worked in five technical teams with each team responsible for specific components of the report while the EPA hosted the NC4 project management unit.

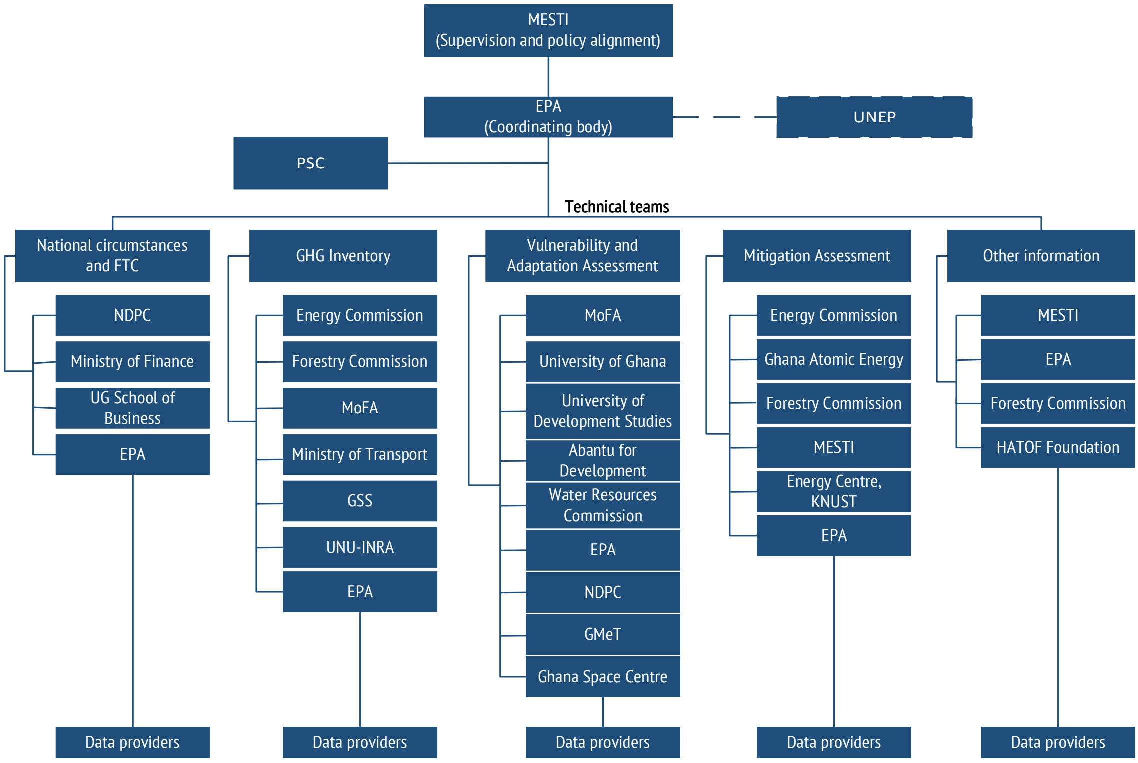


Figure 5: Institutional arrangement of national communication in Ghana

The institutional arrangement is in three tiers (Figure 5). MESTI and EPA occupy the upper-tier where MESTI ensures policy alignment of the national communication and oversight, and the EPA provide support for the Project Steering Committee (PSC). The PSC is composed of thirteen senior representatives drawn from the government, tertiary institutions, and civil society. The PSC met every six months to evaluate the progress of work and where necessary, make policy decisions. It served as the information clearinghouse for all the stakeholders involved in the preparation of the national communication.

The five Technical Teams (TT) were the nerve-centre of the institutional arrangement for the preparation of the national communication and occupied the middle-tier. Each of them focused on compiling specific chapters of national communication. So, the TT was responsible for the day-to-day planning and execution of the activities outlined to complete the section assigned to them. The members of the sector TT were from relevant private, public institutions, and the academic community based on competence, experience and relevance to climate reporting. Among the TT members, a competent institution was selected to lead the technical work for the group, which is governed by a Memorandum of Understanding (MOU) signed between the EPA and the lead institution. The MOU helped to streamline the preparation process and ensure the timely delivery of the tasks and future continuity.

2.3.2 Areas for Future Improvements in the Institutional Arrangements

From the time Ghana adopted the GCARP, the institutionalisation process has focused on decentralising the reporting task to the line ministries. Since the introduction, decentralisation reforms have brought improvements in the institutional arrangement for the preparation of national communications in the areas of coordination and participation. Despite these improvements, Ghana will continue to work on the following:

- Even though the EPA has a standing MOU that governs the relationship among the institutions involved in the national communication, the entirety of the MOU is not fully operationalised. It is Ghana's priority to review the existing MOU to reflect practical realities that are achievable within the scope of the national communications. One area that would receive attention in the coming years is working to achieve full operationalisation of the MOU between the EPA and the partnering state institutions. Under the streamlined MOU, the line ministries would be able to follow the timelines and deliverables according to plan.

- Another critical aspect of the institutionalisation process that Ghana intends to put greater focus on is the idea of getting the line ministries to fully incorporate the national communication preparation activities into their work programme.

- Even though the line ministries are responsible for the national communication activities in their sectors, the time the experts spend is not part of the staff performance appraisal. The current situation sometimes makes the officer prioritise other tasks from their institution over the national communication. Ghana would continue to work with the line ministries to tackle this issue as it serves as a significant incentive for the staff who work on national communication.

2.4 Climate Change Relevant National and Sectoral Policies

In Ghana, climatic change issues are captured in the Coordinated Programme of Economic and Social Development Policies (CPESDP) and the Medium-term Development Policy Framework (MTDPF). In 2016, Ghana put forward thirty-one priority adaptation and mitigation actions in the Nationally Determined Contributions (NDC)[13] to the Secretariat of the Convention in response to the Lima call for action. The latest CPESDP (2017-2024) affirms Ghana's commitment to the NDC[14] under the Paris Agreement. Having incorporated climate change issues into the current CPESDP and the MTDPF (2018-2021), all MDAs and MMDAs reflect the same in their sector and district medium-term plans. Besides, the National Climate Change Policy (NCCP, 2015–2020)[15] and Climate Change Adaptation Strategy (NCCAS, 2012) outlines the critical measures for the realisation of the medium-term climate protection outcomes (Figure 6).

[13] Government of Ghana. 2015. Ghana's intended nationally determined contribution (INDC) and accompanying explanatory note. UNFCCC. Available at: http://www4.unfccc.int/ndcregistry/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf
[14] https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party=GHA
[15] Ministry of Environment, Science and Technology (MESTI), Republic of Ghana. 2014. Ghana National Climate Change Policy. Available at: https://s3.amazonaws.com/ndpc-static/CACHES/NEWS/2015/07/22//Ghana+Climate+Change+Policy.pdf

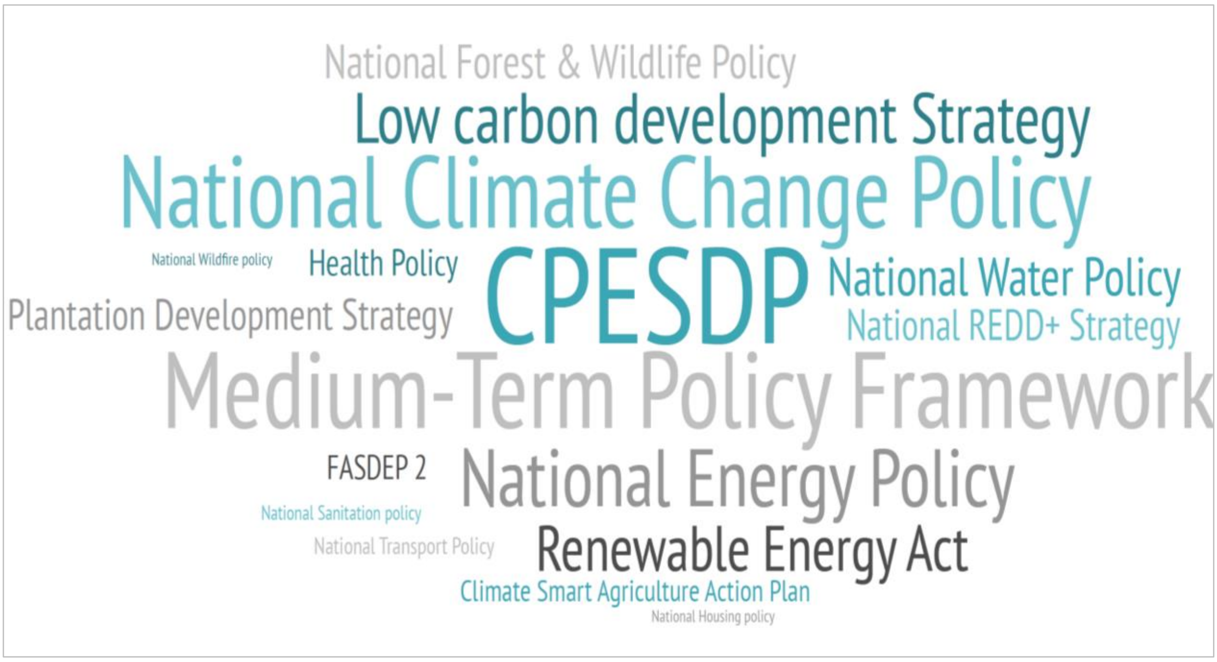


Figure 6: An overview of national and sector policies that support climate change and the NDC

Besides committing to climate change efforts in the national development plan and the cross-cutting strategies, some sectoral policies explicitly seek to address climate change (Figure 6). Table 2 presents the relevant national and sectoral policies, strategies and legislation that support climate change.

Table 2: Policies, legislation and measures that support climate change

Organisation or sector	Parent policy	Legislation/ measures/instruments	Comments
NDPC	Decentralised planning system	National Development Planning System Act, 1994 (Act 480)	Relevant for mainstreaming climate change into sector and district medium-term development plans.
Ministry of Finance	National policy on public-private partnership		Streamline national efforts to mobilise public and private financing to support infrastructure and service delivery.
	National budget guidelines	Local Government Act (Act 936) Financial Administration (Act 654)	Guide MMDAs to budget for climate change programmes in their annual budgets.
	Environmental fiscal reform	15% environmental tax on plastics with an exemption on pharmaceutical and agricultural sectors	Mobilise funds at the national level to support proper waste disposal.
Environment	National Climate Change Policy	There is no measure anticipated by way of instruments and legislation	Framework for addressing climate change. Complement efforts by NDPC to facilitate mainstreaming of climate change.
	National Environment Policy		Framework for addressing environmental challenges. Complement efforts of NDPC to facilitate mainstreaming the environment.
	Environmental Assessment	Environmental Assessment Regulations, 1999 (L1 1652)	Addressing climate change issues at the project level through permitting and licensing.
			Incorporated climate change issues into the administration of Environmental Assessment.

			Strategic Environmental Assessment	Strategic level mainstreaming of the environment into development policies, plans and programmes.
Ministry of Local Government and Rural Development	Local Government Policy		Functional Organisational Assessment Tool	M & E system that evaluates the performance of MMDAs to compliance with Government Policies, rules, regulations and procedures in carrying out their mandated functions. Climate change indicators are part of the assessments.
Ministry of Energy	National Energy Policy	Renewable Energy Act	Renewable Energy Act Feed-in-Tariff Scheme Renewable Energy Fund Renewable Energy Master Plan[16]	Provide a framework for renewable energy promotion. The National Energy Policy under review.
		National gas master plan		Promote downstream natural gas market development and clean cooking.
		Sustainable energy for all action plan[17]		Promote clean cooking
		National LPG promotion policy		
		National Energy Fund		Funding for energy research and seed capital for the development of renewable systems.
		Energy Efficiency Standards and Labelling Regulations, 2005 (LI1815), Energy Efficiency Standards And Labelling (Household Refrigerating Appliances) Regulations, 2009 (LI 1958), Energy Efficiency Standards and Labelling (Household Refrigerating Appliances) Regulations, 2009(LI 1958)		Obligation to display a label, which indicates the energy efficiency rating of the product before the first retail sale. It is an offence under LI. 1815 to import, display for sale or sell Air Conditioners and Compact Fluorescent Lamps in Ghana unless they meet the minimum performance standards and are correctly labelled.
		Energy Efficiency Regulations, 2008 Regulations, 2008 (LI 1932)		Prohibition of manufacture, sale or importation of incandescent filament lamp, used refrigerator, used refrigerator-freezer, used freezer and used air-conditioner
		Automatic Utility and Petroleum Price Formulae		Phasing-out of subsidies on utility and petroleum products
Transport	National Transport Policy		10-year over-aged vehicle importation tax	Disincentive for importing over-aged vehicles.
			Annual roadworthy certification for all vehicles	Yearly physical inspection of vehicles before roadworthy certificates are issued.
			Motor emission standards	Proposed standards for mobile and stationary engine emissions and fuel economy. Ghana Standards Authority (GSA) published the first-ever motor vehicle emission standards. The GSA and EPA are working closely with MESTI to develop legislation to back the implementation of the standards.

[16] http://www.energycom.gov.gh/files/Renewable-Energy-Masterplan-February-2019.pdf

[17] http://energycom.gov.gh/files/SE4ALL-GHANA%20ACTION%20PLAN.pdf

Forestry	National Forest and Wildlife Policy	Stumpage Fees	Surcharge on timber as part of the timber harvesting regulation regime.
		Annual Allowable Cuts	Cut off the threshold of volumes of timber harvested every year
		Ban on chain-saw operations	
		Timber certification	Implementation of timber certification through the voluntary partnership agreement with the EU
		National REDD+ Strategy	Promoting avoided deforestation and restoration of degraded forest.
		National Forest Plantation Strategy	Restoration of degraded areas and enhanced food production and create jobs.
Waste Management	National Environmental Sanitation Strategy and Action Plan	MMDAs bye-laws.	National Institutional Biogas Programme (NIBP)
Manufacturing industry		Environmental Assessment Regulations 1999 (L1 1652)	Promotion of cleaner production Incorporation of climate change issues into the administration of Environmental Impact Assessment
		Environmental Protection Agency Act, 1994 (Act 490)	
Ministry of Communication		Ghana Meteorological Agency Act 2004(Act 682)	Weather forecasting, early warning, provision of metrological services
Ministry of Works and Housing	Sector strategic medium-term plan for the Ministry of Works and Housing (2018-2021)[18]		Flood control, coastal production and slum management
NADMO	Ghana plan of action for disaster risk reduction and climate change adaptation (2012)[19]		Promoting community-based early warning system
Ministry of Food and Agriculture	National climate-smart agriculture and food security action plan (2016-2020)[20]		Disseminate climate-smart agriculture technologies at the community level.

2.5 Government Flagship Policies in the Medium-Term Development Framework that Support Climate Change

The current MTDPF highlights the government flagship programmes that seek to initiate concrete development actions that deliver tangible climate benefits. Generally, the flagship programmes focus on promoting growth poles for green industrialisation and rural developments and support climate change. They are:

- One-district one factory,
- Integrated Aluminium Industry
- Planting for food and jobs,
- One village one dam
- Aquaculture for food and jobs
- One district one warehouse

Table 3 shows the linkages between nationally determined contributions, national climate change policy, medium-term development frameworks, government flagships projects and SDGs

[18] https://www.mwh.gov.gh/wp-content/uploads/2018/05/SECTOR-MEDIUM-TERM-DEVELOPMENT-PLAN-2018-2021.pdf

[19] http://nadmo.gov.gh/images/NADMO_documents/2015_documents/GHANA%20PLAN%20OF%20ACTION%20ON%20DRRCCA%202011-2015.pdf

[20] Essebey G.O, Nutsukpo D, Karbo N, and Zougmore R. 2015. National Climate-Smart Agriculture and Food Security Action Plan of Ghana (2016-2020). Working Paper 139. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: www.ccafs.cgiar.org

Table 3: Linkages between nationally determined contributions, national climate change policy, medium-term development frameworks, government flagships projects and SDGs

SDGs	Medium-term national development priorities (GSGDA 2 - 2014 to 2017)	Medium-term National development priorities (Agenda for Jobs - 2018 to 2021)	National climate change policy priorities	Paris Agreement (Ghana's Nationally Determined Contributions)			
				NDCs mitigation action	NDCs Adaptation Actions	Progress and achievements– mitigation actions	Progress and achievements – adaptation actions
Goal 1: No Poverty	Ensuring and sustaining macroeconomic stability Enhancing the competitiveness of Ghana's private sector,	Strong and resilient Economy. Industrial Transformation (flagship programme: One-district one factory, Integrated Aluminium Industry)	Energy, Industrial, and Infrastructural Development	1. Promote clean rural households lighting 2. Expand the adoption of market-based cleaner cooking solutions.	17. Value addition-based utilisation of forest resources 18. Resilience for gender and the vulnerable		Investing more than US$ 100 million in the Northern dryland to build the resilience of smallholder farmers and the fragile ecosystem they depend on as their livelihood. Multiple projects. Relate to SDG 2 and 3, NDC 3 and 6
Goal 2: Zero Hunger	Accelerated agriculture modernisation and sustainable natural resource management	Livelihood Empowerment Against Poverty (LEAP) Programme Agricultural development and rural transformation (flagship programme - planting for food and jobs, one village one dam, one district one warehouse) Fisheries and aquaculture development (flagship programme – aquaculture for food and jobs	Agriculture and food security. (Focus area 1: develop climate-resilient agriculture and food systems)	3. Promote Forest Plantation Development 4. REDD+ in cocoa landscapes 5. Enrichment Planting and enforcement of timber felling standards. 6. Wildfire Management	19. Agriculture resilience building in climate-vulnerable landscapes	Employed 20,000 youth to 10 million trees to enhance carbon stocks. Forestry Commission. Links to SDG 15 and 13. Planted 192, 253ha of degraded forest under National Forest Plantation Development Programme with more than US$ 50 million investment. Forestry Commission. Relate to SDG 15 and 13. Galamstop to support community-based mining. Ministry of Local Government and Rural Development	Supplied 577,000 farmers with subsidised fertilisers and high-quality seeds for the 2018 cropping season. Two thousand seven hundred extension agents being recruited to support the dissemination of climate-smart technologies under Planting for Food and Jobs (PFJ) – MoFA. Links to SDG1 and 2 50,000t warehouse capacity added in 2018 One district one Warehouse (1D1W) – Ministry of Special Development Initiative Five hundred seventy small dams and dugout constructed or rehabilitated in Northern (310), Upper East (150) and Upper West

							(110) Regions in 2018. - Ministry of Special Development Initiative.
Goal 3: Good health and well being	Infrastructure and human settlements development	Ensure affordable, equitable, easily accessible and Universal Health Coverage (UHC). Strengthening early warning and emergency preparedness system. Promoting healthy diets and lifestyles. Implement the Water-for-All programme to ensure every Ghanaian has access to potable water.	Disaster preparedness and response. (Focus area 2: build climate-resilient infrastructure)	6. Effective solid waste collection and landfill gas management. 7. 200 institutional biogases 8.Double composting capacity	20. City-wide resilient infrastructure planning 21. Managing climate-induced health risks 22. Integrated water resources management 23 Early warning disaster reduction and climate services	Installed 600 tonnes/day capacity compost facility and produced average 8,545.4 tonnes of compost. Ministry of Water and Sanitation 1000 biogas project by the Ministry of Special Initiatives	Implementing the US$ 200 million Greater Accra resilient and integrated development project to deal with recurrent floods in the Odaw river. Ministry of Works and Housing. Relate to SDG1 and NDC 23. Developed multi-hazard Early Warning System and EWS Master Plan to benefit roughly 6 million people (NADMO). Developed floods and drought, hazards, vulnerability and risk maps at current (2010) and future scenarios (2050) at the national level and the ten pilot districts (NADMO). Implementing insurance risk transfer programme for drought and floods (NADMO, Ministry of Finance). Invested about US$ 4 million in flood risk in White Volta and Oti Basin – Water Resources Commission
		Enhance inclusive and equitable access to and participation in quality education at all levels.	Equitable social development (Focus area 7: minimise impacts of climate change on access to water and sanitation)				

							Expanding coastal protection Invested nearly US$ 670 million in 7 sea defence projects across the coastline. Ministry of Works and Housing. Relate to SDG 13.
Goal 4: Quality Education	Human Development, Productivity, and Employment	Strong and resilient Economy. Enhance inclusive and equitable access to and participation in quality education at all levels. Strengthen Technical and Vocational Education and Training (TVET)	Equitable social development. (Focus area 6: addressing impacts of climate change on human health).		NDC 21		Climate change issues incorporated into school curricular. (Ministry of Education, Ghana Education Service, National Council for Curriculum and Assessment EPA). Link to SDG 13.
Goal 7: Affordable and Clean Energy	Oil and gas development Infrastructure and human settlements development	Industrial Transformation (flagship programme: One-district one factory, Integrated Aluminium Industry)	Energy, Industrial, and Infrastructural Development	9. Scale-up renewable energy penetration by 10% by 2030. 10. Promote clean rural households lighting 11. Expand the adoption of market-based cleaner cooking solutions. 12. Double energy efficiency		More than quadrupled solar PV installed capacity to 39 MW. Ministry of Energy. Link to SDGs 12 and 13 Disseminated 1.2 million improved cookstoves to households and additional 1,000 institutional stoves. Ministry of Energy. Link to SDG 12 and 13 Replaced 18,000 inefficient 250W streetlights with 150W LED. And 32,893 automatic timer switches installed.	

				improvement to 20% in power plants		Forty-six capacitor banks installed in public buildings. Energy Commission. Relate to SDG 12 and 13. Invested nearly US US$13.2 billion (Tweneboa-Enyenra-Ntomme (TEN) and ENI/Vitol, (Sankofa) fields (ENI/Vitol - US$7.28 billion, TEN - US$5.9billion) in natural gas production and infrastructure development. Ministry of Energy. Relate to SDG 12 and 13. The Ministry of Energy is leading in the distribution of 12 million LED Lamp[21] to selected government institutions, including the security services. Relate to SDG 12 and 13.	
Goal 8: Decent Work and Economic Growth	Human Development, Productivity, and Employment	Private Sector Development (Public-private sector dialogue, Support entrepreneurship and SME development) Industrial Transformation (flagship programme: One-district one factory,	Equitable social development (focus area 8: addressing gender issues in climate change) Equitable social development (focus area 9: Address climate	13. Scale-up Sustainable mass transportation – bus-based transport. 14 Scale-up Sustainable mass transportation – railway development	NDC 22	Implementing the Ghana Railway Master Plan. Ministry of Railway Development Conversion of 2 x110MW Simple Cycle Takoradi 2 Thermal Power Plant (T2) to 330MW Combined Cycle Plant by Takoradi International Company (TICO). Ministry of Energy. Link to SDG 12, 7 and 13.	

[21] https://www.graphic.com.gh/news/general-news/government-to-distribute-12-million-led-bulbs.html

		Integrated Aluminium Industry) Expand the railway network to northern Ghana to open-up economic opportunities and link up with neighbouring countries	change and migration) (focus area 3: increase the resilience of vulnerable communities to climate-related risks)	15. Reduce consumption of high-GWP gases in electronic appliance			
	Ensuring and sustaining macroeconomic stability Enhancing the competitiveness of Ghana's private sector. Accelerated agriculture modernisation and sustainable natural resource management.	Private Sector Development (Public-private sector dialogue, Support entrepreneurship and SME development)	Energy, Industrial, and Infrastructural Development. Focus area 5: Improve management and resilience of terrestrial and aquatic ecosystems	NDCs 9, 10, 11, 12, 13, 14	NDC 22		
Goal 12: Responsible consumption and production	Accelerated agriculture modernisation and sustainable natural resource management	Agricultural development and rural transformation (flagship programme - planting for food and jobs, one village one dam) Industrial Transformation (flagship programme: One-district one factory, Integrated Aluminium Industry).	Energy, Industrial and Infrastructural Development	NDCs 12	NDC 20		

		Establish a Presidential Advisory Council on Science, Technology and Innovation to ensure high-level attention on STI.					
Goal 13: Climate Action	Ensuring and sustaining macroeconomic stability Accelerated agriculture modernisation and sustainable natural resource management	Agricultural development and rural transformation (flagship programme - planting for food and jobs, one village one dam) Industrial Transformation (flagship programme: One-district one factory, Integrated Aluminium Industry) Expand the railway network to northern Ghana to open economic opportunities and link up with neighbouring countries.	Energy, Industrial and Infrastructural Development Natural Resource Management (focus area 4: increase carbon sinks)	NDCs 1 to 17	NDC 17	Develop national indicators to track SDG goal 13 and the 31 climate actions in the NDCs. NDPC, MESTI and EPA Implementing the Ghana Railway Master Plan. Ministry of Railway Development	
Goal 15 Life on Land	Accelerated agriculture modernisation and sustainable natural resource management	Agricultural development and rural transformation (flagship programme - planting for food and jobs, one village one dam, one district one warehouse)	Natural Resource Management (focus area 4: increase carbon sinks)	NDC 3,4,5 and 7		Employed 20,000 youth to plant 10 million trees to enhance carbon stocks. Forestry Commission. Linked to SDG 15 and 13 Investing US$ 50 million in Integrated Mining Integrated Project to tackle illegal mining as a driver of deforestation. Ministry of Lands and Natural Resources. Linked to SDG 13, 2 and 3.	

						Ghana has negotiated for the first-ever US$ 236 million result-based payment scheme for REDD+ in the cocoa landscape with the World Bank. Forestry Commission. Relate to SDGs 2, 15 and 13 Invested US$ about 51 million through Forest investment programme to pilot REDD+ in the cocoa landscape. Ministry of Lands and Natural Resources. Relate to SDG 13, 2 and 3. Planted 192, 253ha of degraded forest under National Forest Plantation Development Programme with more than US$ 50 million investment. Forestry Commission. Relate to SDG 15 and 13.	

2.6 Geographic Profile

Ghana, with a total land area of 238,535 square kilometres [22], is situated in West Africa on the Guinea Coast and lies close to the equator on latitude 11.50N and 4.50S and longitude 3.50W and 1.30E. The country is subdivided into twelve distinct vegetation zones (Figure 7). The total land area consists of 69% of agricultural land and 41% of forest areas (FAO, 2020)[23]. Agricultural lands have increased from 55% of the total land area in 1990 to 69% in 2017 (World Bank, 2020). In the same vein, the share of arable land of the country's land area increased from 12% to 21%. Irrigated agricultural land constitutes only 0.2% of the total agricultural land. Agricultural machinery use is 4.5 tractors per 100 km^2 of arable land. Forest lands, between 1990 and 2017, increased from 38% of the total land area to 41% (World Bank, 2020).

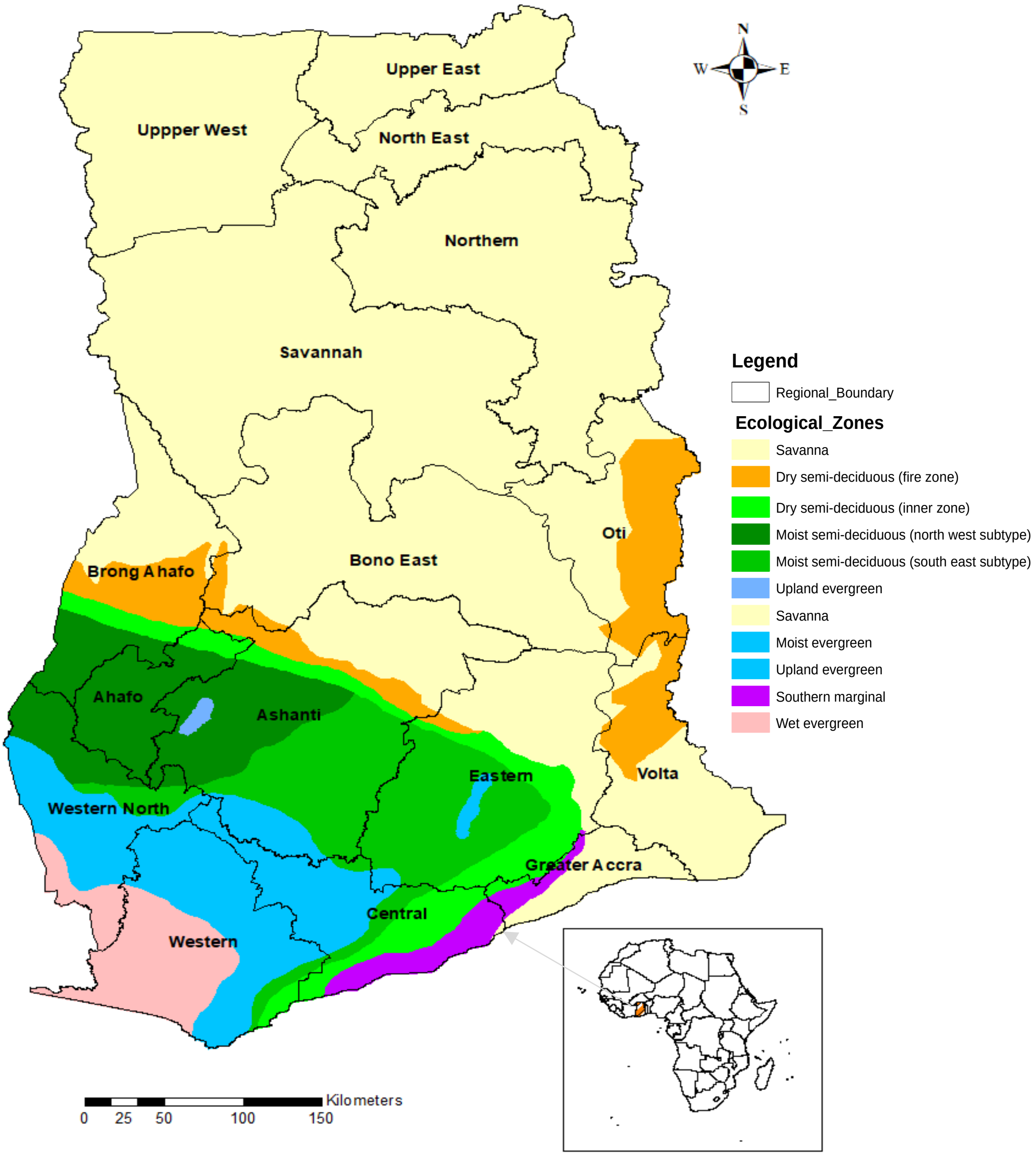


Figure 7: Map of Ghana showing the twelve vegetation zones

[22] https://data.worldbank.org/country/ghana
[23] http://www.fao.org/countryprofiles/index/en/?iso3=GHA

2.7 Climate Profile

Ghana's climate is tropical and strongly influenced by the West Africa monsoon winds. The climate is generally warm with variable temperatures masked by seasons and elevation. The northern part of the country typically records one rainy season, which begins in May and lasts until September. Southern Ghana records two rainy seasons; major season from April to July and minor from September to November. Several climate models have confirmed that air temperature has increased by 1.0^{0}C between 1960 and 2003, at an average rate of 0.21^{0}C per decade. The rate of increase has generally been more rapid in the northern parts than in the southern parts. Between 1960 and 2003, the:

- average number of 'hot' days per year has increased by 48 (an additional 13.2% of days).
- number of hot nights per year increased by 73 (an extra 20% of nights).
- frequency of cold days per year has decreased by 12 (3.3% of days).
- number of cold nights per year has reduced by 18.5 (5.1% of days).

Rainfall is highly variable on inter-annual and inter-decadal timescales suggesting that long-term trends would be both difficult to identify and manage their associated consequences.

2.6.1 Past and Future Climate

The scientific evidence unanimously points to changing climatic conditions in Ghana over the last three decades. More than 30 years of climate records show that the prevailing climatic conditions in Ghana have severely deteriorated and are more likely to worsen in the future. The following are key messages on the future of the changing climate based on Figure 8:

- There are uncertainties in the rainfall patterns that vary across the different ecological zones in Ghana.
- Rainfall variability will continue to be higher in the forest regions than the rest of the country.
- Ghana would continue to be warm and even get worse by 2080.
- Temperatures are more likely to increase by at least 3^{o}C by 2080 nationwide.
- The savanna regions are likely to record average temperatures above 30^{o}C.
- More than ever before, the high likelihood of wet spells may lead to more floods.
- The projected increases in dry spells may exacerbate drought conditions.

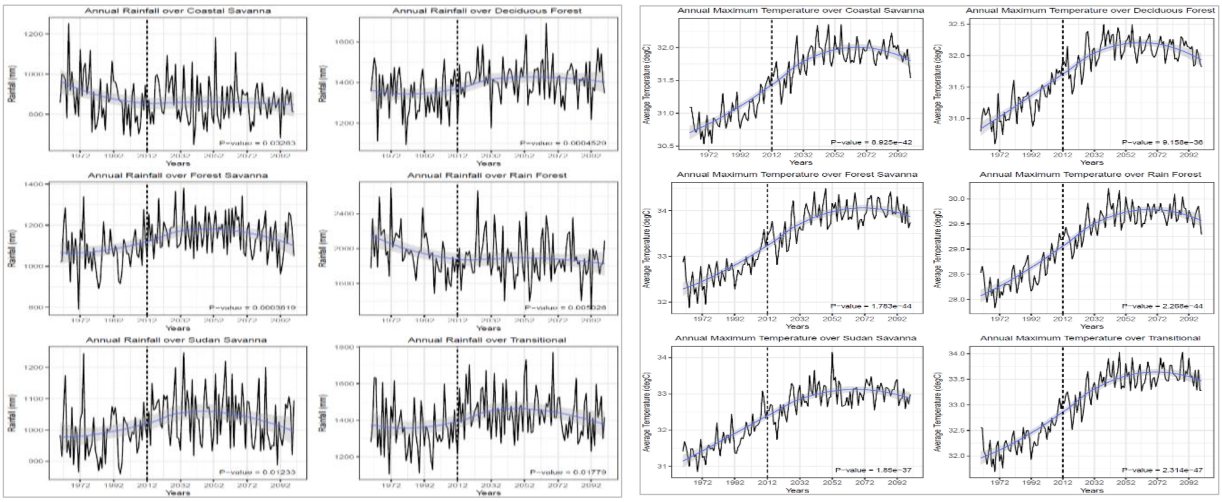


Figure 8: Climate projections per ecological zones in Ghana

2.8 Demography Profile

Ghana's 2020 population is estimated at 30,955,202 and represents a 26% increase over the 2010 levels of 24,658,823 at an annual growth rate of 2.3%[24] compared to the 1.5% target for 2020 (NDPC, 2017). With an average yearly growth rate of 2.3% per annum, Ghana's population is likely to reach 37 million by 2030 (GSS, 2020). The population is dominated by females (51% of the population) and the youth adults and those under 15 years make 35% of the population (Figure 9).

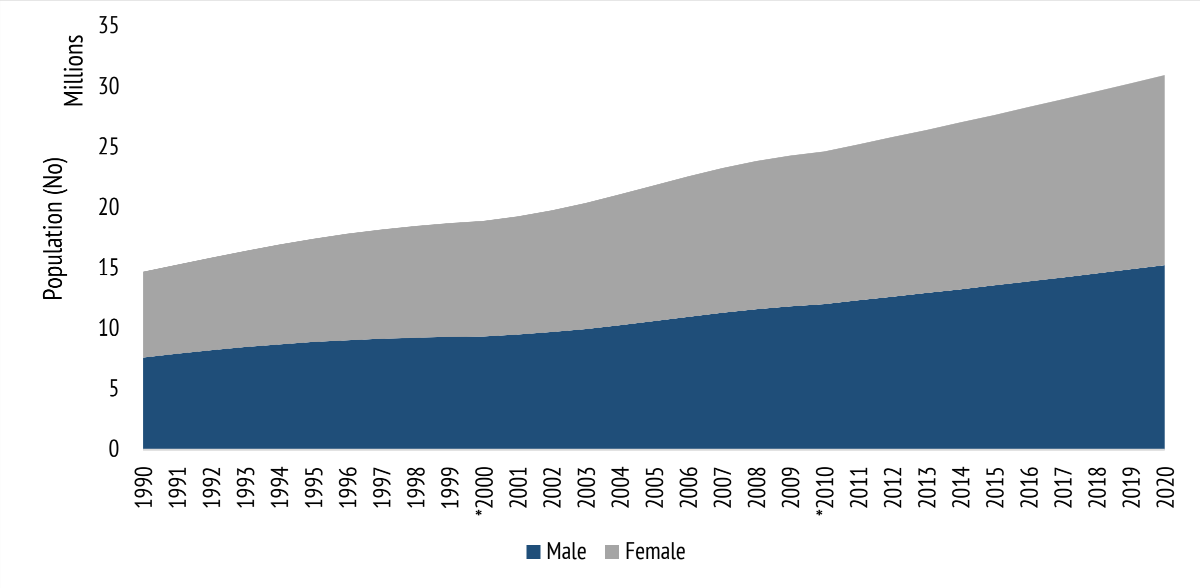


Figure 9: Trends of population growth by sex * Population consensus years

The breakdown of the total population translates into 7.5 million households of 4.1 average size (GSS, 2017). Even though more persons live in the urban area (56.1%) compared to the rural area (43.9%), urbanisation rate has marginally declined from 4.9% to 3.4% in the last three decades (World Bank, 2020). The high annual growth of the urban population of 3.4% means that many people are migrating to urban areas. Greater Accra region has the highest share of in-migrants (51.3%) seeking economic opportunities (GSS, 2018). Not only does the rising urban migration contribute to additional pressures on urban infrastructure and services, but it can also worsen the vulnerabilities of people living in distressed neighbourhoods, particularly women (Owusu and Nursey-Bray, 2019)[25]. About a quarter (23.4%) of Ghanaians are poor, representing a 0.8% decline of the 2012 figures (GSS, 2018).

Generally, the incidence of poverty is predominant in rural communities. The rural savannah areas record the highest poverty of 67.7%, followed by rural coastal areas (29.9%). Conversely, the populace in the Greater Accra is least poor with 2% incidence of poverty. According to GSS (2018), with the extreme poverty threshold of GH¢792.05 per adult equivalent per year, under a tenth (8.2%) of the population live in extreme poverty. Between the periods 2006-2017, extreme poverty has reduced from 16.5% to 8.2%. Extreme poverty is generally prime in rural areas, with 2.2 million persons affected (GSS, 2017).

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[24] https://www.statsghana.gov.gh/nationalaccount_macros.php?Stats=MTA1NTY1NjgxLjUwNg==/webstats/s679n2sn87

[25] Mensah Owusu & Melissa Nursey-Bray (2019) Socio-economic and institutional drivers of vulnerability to climate change in urban slums: the case of Accra, Ghana, Climate and Development, 11:8, 687-698, DOI: 10.1080/17565529.2018.1532870

Extreme poverty is outstandingly high in the rural Savanna at 36.1% and accounts for more than a quarter of those living in extreme poverty in rural Ghana. Poverty and livelihoods, gender and geographic boundaries influence the level of vulnerabilities to climate change impacts in the country.

2.9 Macro-Economic Context

The Ghanaian economy depends on natural resources. The utilisation of gold, cocoa, timber and crude oil generate export revenues, taxes, and jobs. In 2018 alone, Ghana earned US$ 14.9 billion in revenues from the mechanise exports[26] with gold (36.4%) and crude oil (30.6%) contributing the most. Besides, the country is agrarian and endowed with forest and fish resources. Agriculture, forestry and fishing engage 38.3% of the employable population. Latest calculation estimates the cost of environmental degradation at 10.7% of the 2017 GDP, implying that the country would need to mobilise about US$6.4 billion yearly to invest in ecological restoration. The country has mostly experienced stable and consistent economic growth since 1960.

The rebased economy figures show that the economy has grown by over 100% from US$ 32.2 billion in 2010 to 65.6 billion in 2018 (World Bank, 2020). The service and agriculture sectors drive consistent growth in the economy. The expanding trend of the economy along a carbon lock-in pathway leads to rising energy and GHG emissions (Table 4). The predominant roles of service and agriculture sectors in the economy implied their relatively high greenhouse emission intensities of value-added GDP of 0.7 and 2.4 kg CO_2e per constant 2010 GDP US$ respectively. The rising population, high urbanisation rates and the policies to reduce poverty continue to drive the increasing trend of GHG emissions in the country (EPA, 2019).

Table 4: Macroeconomic indicators relevant to greenhouse gas emissions and removals in Ghana

Indicators	1990	2000	2010	2012	2016	2018	Change (%)	
							1990-2018	2012-2018
Population (million)	14.43	18.91	24.23	25.87	28.21	29.61	105	14
GDP (Current US$ billion) *	5.89	4.98	32.17	41.94	55	65.56	1013	56
Total primary energy supply (Mtoe)**	5.29	6.88	9.84	8.36	9.67	10.5	98	26
Total final energy consumed (Mtoe)**	4.31	5.54	5.63	6.61	7.09	7.5	74	13
Total GHG emission ($MtCO_2e$)	25.34	27.54	35.24	39.35	42.15	45.41***	79	15
Total electricity generated (GWh)**	5,721	7,223	10,167	12,024	13,022	16,246	184	35
of which is hydroelectric (GWh)**	5,721	6,609	6,996	8,071	5,561	6,017		-25
of which is thermal (GWh)**	-	614	3,171	3,953	7,435	10,195		158
of which is renewable (GWh)**	-	-	-	-	27	33		100
Total Electricity Consumed** (GWh)	4,462	6,067	8,317	9,258	11,418	13,185	195	42
Total energy consumed per capita (toe)	0.3	0.29	0.23	0.26	0.25	0.25	-17	-4
GHG emissions per capita (t CO_2 e)	1.73	1.45	1.44	1.53	1.49	1.52***	-12	-1
GHG emissions per GDP unit (kg CO_2e /2010 GDP US$)	2.1	1.53	1.09	0.98	0.87	0.74***	- 65	-24
Grid emission factor (wind/solar projects) (tCO_2/MWh)			0.35	0.35	0.39	0.46		31
Grid emission factor (all other projects) (tCO_2/MWh)			0.51	0.48	0.43	0.53		10

* World Bank, Ghana Country Data, 2019, ** Ghana Energy Statistics 2019, *** Projected figure

[26] https://www.bog.gov.gh/wp-content/uploads/2020/02/Statistical-Bulletin-November-2019.pdf

2.9.1 Fiscal Instruments that Support Climate Change in Ghana

Ghana needs to mobilise US$ 22.6 billion investments from domestic, international and private sources to implement NDCs for the ten years (2020 and 2030). The financing consists of existing public sector investment. Ghana's NDCs provide fantastic investment opportunities to green the Ghanaian economy. The projected US$22.6 billion NDC investments can bring a substantial positive return on the economy, green jobs and achieve SDGs. Not only can the NDC investments help to build resilient and decarbonise the economy, but also rake in foreign exchange to stabilise the cedi depreciation, reduce the balance of trade, create decent green jobs and above all facilitate the transfer of green technology.

Besides technological and regulatory measures, fiscal instruments are also effective if they are well implemented. In this regard, Ghana has adopted the strategy to pursue a variety of economic policy instruments that would support the implementation of climate actions. Ghana is aware that there is no single pot from which the country can easily tap the funds. The funds are in a variety of investment portfolios like public funds, capital markets, bond markets, pension funds, institutional investors, philanthropists, earmark funds and Corporate Social Responsibility (CSR). Over-reliance on grant financing is no longer a viable option because many development partners are shifting their overseas development assistance policy to favour more trade and investment than role grant. Besides, with such a broad scope of Ghana's NDC, it would not be feasible to rely on grant financing. Financing Ghana's NDC requires a careful blend of multiple financial instruments that look beyond grant and government's limited funds. Some of the critical fiscal strategies Ghana is working on and which are at different stages of progress are explained in the following sections:

2.9.1.1 Climate trust funds

Globally, climate trust funds are a vital policy instrument that many countries and multilateral organisations adopt to raise climate finance. Ghana has commenced the initial processes towards the establishment of the Ghana Green Fund (GGF). In this regard, the Ministry of Finance with the support from GIZ developed draft legislation for the fund awaiting government review and approval in 2015. The proposed fund aims to facilitate, co-finance and channel investments required to implement adopted environment and climate change policy and law, including investments in climate change adaptation and mitigation, waste management, industrial pollution and resource use, sustainable forestry, biodiversity and nature protection, sustainable transport, as well as other sectors covered by environmental and climate change policy.

Ghana has also introduced a public-private joint initiative to establish SDG Delivery and Green fund. The Government established SDG delivery and Green funds in 2019 to raise funds to support the implementation of the country's SDG programme. The private sector has the target of establishing US$100 million SDGs Delivery Fund and a US$200 million Green Fund to complement government's efforts at tackling climate change and funding the implementation of the SDGs in the country[27]. The private sector will raise from the corporate social responsibility (CSR) budget over five years to capitalise the fund. Ghana has mobilised mitigation finance from international funds such as Climate Investment Funds (CIF), Global Environment Facility (GEF) and the Green Climate Funds. Under the CIF[28], the Government and its partners are investing US$ 75 million to enhance the forest landscape vitality. An additional US$ 40 million is being invested in boosting the scaling up of renewable energy penetration.

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[27]https://www.presidency.gov.gh/index.php/briefing-room/news-style-2/1369-ghana-committed-to-reducing-her-carbon-footprints-president-akufo-addo

[28] https://www.climateinvestmentfunds.org/country/ghana

Similarly, the GEF has invested US$ 89 million in 32 national projects over the last two decades[29]. Under the current GEF 7 funding cycle, Ghana is seeking to raise US$ 13 to support the implementation of the landscape restoration and ecosystem management for sustainable food systems in the Pra Basin. Ghana is yet to receive direct mitigation finance from the GCF. The GCF has approved funding for two adaptation projects worth US$ 46 million[30].

2.9.1.2 Carbon pricing policy

Ghana is yet to adopt a carbon pricing policy though the country's NDC recognises carbon markets as a climate implementation strategy. In 2020, the UNFCCC Regional Office in Lome initiated work with Ghana to evaluate the options for carbon pricing policy in the country. In the pursuit of the strategy to adopt carbon market measures, the government of Switzerland and Ghana are implementing National Clean Energy Access Programme (NCEP) as a pilot under Article 6.2 on the Internationally Transferred Mitigation Outcomes (ITMOs). The NCEP[31] seeks to operationalise Article 6.2 in Ghana and transfer mitigation outcomes as ITMOs to Switzerland.

2.9.1.3 Green bonds

Ghana has initiated a programme to explore the potential of green bonds for SDGs and NDC financing in 2019[32]. As part of the programme, the Ministry of Finance began a process of tapping into green and SDG related bonds. The UNDP and the Ministry of Finance are training critical national stakeholders to improve their knowledge of green and SDG related bonds to facilitate Ghana's active participation in the green bond markets. With green bonds, Ghana can mobilise resources from domestic and international capital markets for climate change adaptation, renewable energy, low carbon transport, sustainable waste management, integrated water resource management, clean transportation and other environmentally friendly projects. The Green Bond Bootcamp drew about 30 government officials. Climate Bonds Initiative, an international, investor-focused not-for-profit organisation is working on mobilising the US$100 trillion bond market for climate change solutions delivered training.

2.9.1.4 Climate innovation centres[33]

A private sector consortium led by Ashesi University implements the Ghana Climate Innovation Centre (GCIC). GCIC supports Ghanaian entrepreneurs and new ventures involved in developing profitable and locally appropriate solutions to climate change mitigation and adaptation. The US$ 17.2 million programmes would provide targeted support, mentoring, training and funding facilitation to up to 100 companies in Ghana over five years (World Bank, 2014). Initial funding for GCIC is from the Danish Government through the World Bank. The total investment required is US$ 17.2 million, of which US$ 10 million is the expected contribution from DANIDA. It is projected that after five years, revenues of up to 100 GCIC-assisted companies would generate the equivalent of approximately US$ 28.6 million in economic impact. The investment will assist up to 304,000 people to increase their resilience to climate change by providing increased access to cleaner sources of energy and better and more efficient sources of water and agricultural resources.

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[29] https://www.thegef.org/country/ghana

[30] https://www.greenclimate.fund/countries/ghana

[31] https://www.international.klik.ch/en/Activities-and-impact/Mitigation-activities.287.html

[32] https://www.gh.undp.org/content/ghana/en/home/presscenter/articles/2020/exploring-the-potential-of-green-bond-issuance-for-sdgs-financin.html

[33] https://www.ghanacic.org/

In the long-term (over ten years), assuming continued financial support, GCIC-supported ventures are projected to generate close to 10,720 cumulative jobs and mitigate over 661,598 tons of CO_2e. So far, GCIC has achieved the following results:

- Cumulatively supported 83 businesses with 27 being women-owned or women-led.
- Businesses received over US$1.4 million as a grant of which GCIC disbursed US$ 772,435 as proof of concept grants.
- Generated a cumulative revenue of US$1.63 million by all GCIC businesses.
- Raised US$1.79 million as early-stage and growth-stage financing.
- Created 127 jobs, 57 of which are women employees.
- GCIC investment would have avoided 1,129 Mt CO_2 of greenhouse gas emissions.
- Over 200,000 households have access to products.

2.10 Natural Resources

Ghana's natural resource base accounts for a vast portion of the country's economy. The total natural rent (oil rent, natural rent, mineral and forest rent) amounts to 13.1% of GDP (World Bank, 2020). A little over one-third (34.4%) of economic outputs from crops (15%), livestock (3%), forestry and logging (2%), fishing (1%), mining and logging (14%), water and sewerage (1%) and hydroelectricity (1%) depend on natural resources (BOG, 2019).

2.10.1 Freshwater

Freshwater covers approximately 5% (11,800km^2) of the total land area of Ghana consisting of the Volta, Southwestern and Coastal river systems (EPA, 2016) (Table 5). Their total annual run-off is estimated at 54 billion m^3, of which 37.8 billion m^3 originates in Ghana whereas the remaining 16.2 billion m^3 come from outside the country. Table 5 shows the surface freshwater systems in Ghana.

Table 5: Surface freshwater systems in Ghana

River systems	Catchments	Coverage	River basins
Volta	70% of freshwater coverage	Least run-off of 146,000m^3/km^2/year	Black Volta
			White Volta
			Oti
			Daka
			Pru
			Sene
			Afram
South Western	22% of freshwater coverage	Highest run-off of 245,000m^3/km^2/year	Bia
			Tano
			Offin Ankobra
			Pra
Coastal	8% of freshwater coverage	Highest run-off of 202,000m^3/km^2/year	Ayensu
			Densu
			Ochi-Amissah
			Ochi-Nakwa
			Tordzie/Aka

Source: Adapted from Bawakyillenuo and Asante, 2012

The geology of a basin determines the amount of groundwater. Ghana's groundwater yield varies from 45m^3/h to 18m^3/h in the Voltaian formation and the limestone aquifers located in the south-eastern and western parts of Ghana. The total annual recharge is between 157.7mm and 195.0 mm. Ghana is estimated to have 30.3 billion m^3 of renewable internal freshwater resources (World Bank, 2020). An annual freshwater withdrawal of 0.982 billion m^3 is available for economic activities. Figure 10 shows the share of the economic uses of freshwater in Ghana (World Bank, 2020).

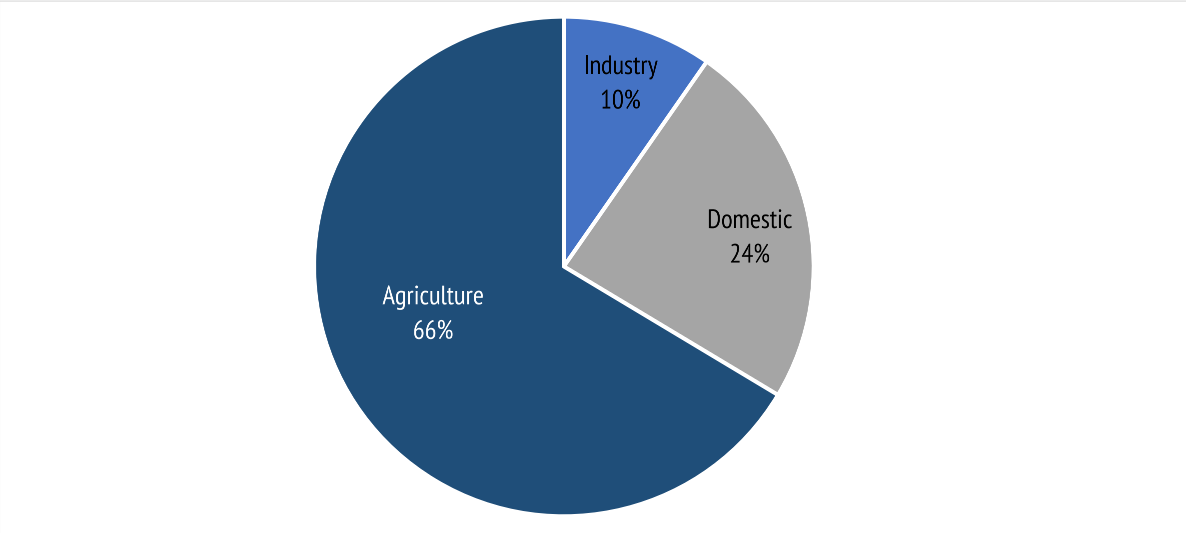

Figure 10: Share of economic use of freshwater in Ghana

Some of the critical challenges threatening freshwater resources are:

- Ineffective basin management systems
- Effects of land-use change through logging, fuelwood collection and wildfires
- Land degradation and desertification
- Poor agricultural practices, including the use of agrochemicals in farming and harmful chemicals in fishing.
- Surface mining including illegal mining
- Infrastructure development including the siting of industries at unauthorised locations
- Negative impacts of climate variability and change.

2.10.2 Agriculture

The agricultural sector consists of crops, livestock, forestry and logging, and fishing. The sector contributed 18.3% of the national GDP in 2018 (World Bank, 2020). Agriculture is a crucial sector for jobs and livelihoods in rural areas (World Bank, 2018). In 2011, the annual agriculture GDP growth rate increased from 0.8% to 4.2%. Crop production is predominantly peasant, rain-fed and depends on simple technology. The use of irrigation to counter poor rainfall is particularly low across the country. For instance, the World Bank (2020) reports that the agricultural irrigated land was 0.22% of the total agricultural land in 2014. This figure translates into 40,000 hectares of the areas under irrigation in the country with potential irrigable lands of 500,000 hectares.[34]

[34] Between 1 and 2 percent of the irrigation potential of the country has been developed (Bawakyillenuo and Kpieta, 2013 citing National Investment Brief, 2008).

The Ministry of Food and Agriculture is currently implementing the national agriculture investment plan (2018-2021)[35] to operationalise the government's agriculture transformation agenda articulated in the national medium-term development policy framework. The plan recognises that climate change adversely affects actors in agricultural value chains, especially those in the savannah zone because most farmers are smallholders and rely mostly on unreliable rain-fed agriculture. In terms of greenhouse gases, the sector accounts for 24% of the total national emissions in 2016. Of this, 16% came from crop management practices and the remaining 8% attributed to livestock. Implementation of the National Climate Smart Agriculture and Food Security Action Plan seeks to respond to climate challenges in the sector.

2.10.3 Forestry

Forestry contributes to the GDP of the agriculture sector. There are two main types of natural forest in Ghana: the closed forest located in the south-western and middle belt and savannah forest found in the north. Apart from environmental and ecological functions of the forest, it also accounted for 6% of GDP[36], employs about 120,000 people[37] and exports wood products worth about US$220 million annually (Bank of Ghana, 2018). According to the Forestry Development Master Plan,[38] Ghana's forest cover stood at 9,294,349 ha in 2015 and increases by 0.3% annually. The plan attributes the gains in forest cover to the national afforestation programme, natural regeneration, and significant reduction in the incidence of forest fires. Nevertheless, land-use change trends and the drivers are localised and differ from ecological zones. While in the high forest zone, the dominant land-use change drivers relate to mining, settlement and agriculture expansion, in the savannah and transition landscapes it is more of fire, grazing and wood-fuel extraction which is estimated to be 1.2 million tonnes in 2018.

Ghana's total terrestrial carbon stocks amount to 2.04Gt of which, 1.6Gt is from above and below ground stock, and about 0.34Gt are in the soils to 1m depth. Ecologically, the high-forest zone has carbon stocks of up to 93.47MgC/ha and a maximum of 34.05MgC/ha in savannah forest. Carbon stocks in cultivated areas are generally lower compared to the forest but vary by ecological zones. For cropland within the high forest zones, the carbon stocks typically fall within the range of 28.27-72.7MgC/ha, whereas those in the savannah areas have carbon stocks that cover 18.46-32.04MgC/ha (Forestry Commission, 2015). In 2013, Ghana had 2,400 ha [39] of mangrove forest along the coast. Most mangroves occur in the east coast, especially along the Volta delta as compared to the few in the western coastline in Amansuri River estuary and Kakum River estuary[40]. Pressures from agriculture, urbanisation and oil pollution are a threat to mangrove forests[41]. Mangrove above-ground biomass ranges from 378-2077MgC/ha for undisturbed, with degraded mangrove areas, carbon stocks range from 146.88-529.59MgC/ha. The estimated percentage of the total land area of Ghana prone to desertification is 64.97% representing about 165,000km^2 with the Upper East and eastern part of the Northern Region facing the greatest desertification threat on an area of about 78,718 km^2 (Dorm-Adzobu, 2010).

[35] http://mofa.gov.gh/site/publications/policies-plans/316-national-agriculture-investment-plan-ifj

[36] https://www.gipcghana.com/invest-in-ghana/sectors/75-forestry/313-investing-in-ghana-s-forestry-sector.html

[37] https://www.gipcghana.com/invest-in-ghana/sectors/75-forestry/313-investing-in-ghana-s-forestry-sector.html

[38] https://www.fcghana.org/userfiles/files/MLNR/FDMP%20Final%20(2).pdf

[39] https://eros.usgs.gov/westafrica/mangrove

[40] http://gh.chm-cbd.net/biodiversity/faunal-diversity-ghana/ecosystem-diversity/mangrove-and-tidal-forests

[41] http://www.fao.org/forestry/mangrove/vegetation/en/gha/

2.10.4 Mineral Resources

Ghana has commercial minerals (metals and industrial ore) and hydrocarbon deposits (mineral fuels). Mineral exploitation is vital for the socio-economic development of the country. The mineral sector contributed 14% to the country's GDP in 2018, compared with 8.5% in 2016 (Bank of Ghana, 2019). Gold and crude oil exports constitute 40% of the total merchandise trade inflows in the same period. The entire extractive industry contributes 18% to government revenue (mineral royalty, property rate, corporate tax and dividend) and 2% to employment[42]. The regulatory framework for the mineral sector is in the Minerals and Mining Act 703 of 2006[43], the Environmental Protection Agency Act of 1994[44] and Petroleum (Exploration and Production) Act of 2016[45].

Ghana also joined the Extractive Industries Transparency Initiative (EITI) in 2007 to improve accountability of the use of mineral revenues. There are also unexploited economic deposits of iron ore, limestone, kaolin, feldspar, silica sand, and others[46]. There is a wide range of environmental impacts associated with the exploitation of mineral resources which the EPA regulates in collaboration with other stakeholders. The environmental impacts that border on climate change are deforestation, carbon-intensive fossil-fuel use, waste management and electricity generation. Mineral extraction is also affected by changing climatic conditions. Extreme flooding and poor visibility conditions can impede smooth mining operations.

2.10.5 Biodiversity

Ghana has over 300 vital areas for biodiversity conservation (Hackman, 2014). The biological resources for the country include 3,600 species of flora[47], 504 species of fishes, 728 species of birds, 225 species of mammals, and 221 species of amphibians and reptiles (Allotey, 2007). There are 16 legally constituted wildlife reserves, covering about 5.3% of the country's total land surface area. Human-induced fragmentations and degradation of the biologically diverse landscapes are some of the significant threats to the conservation of the biological resources and ecosystem services. Ghana's high forest zones fall within the West African Biodiversity Hotspot identified by Conservation International. The country has developed a national strategy on biodiversity conservation under the framework of the Convention on Biological Diversity.

2.11 Energy Resources

Ghana produces energy from fossil-fuel, biomass, hydro and solar resources. Fossil-fuel (oil and natural gas) accounted for the largest share of the final energy supply of 58% in 2018 (Energy Commission, 2019). For fossil fuels, the oil share was consistently high, showing a declining trend from 46% in 2012 to 42% in 2018. Conversely, the natural gas proportion more than doubled from 5% to 14% over the same period. Biomass is the second dominant primary energy supply source in Ghana and comprises wood fuels, agro-waste and municipal waste. Its share of the total energy supply has declined by 4% from 41% in 2012 to 37% in 2018. In the same period, the component of renewable (hydro and solar) of the total primary energy supply saw a consistent downturn from 8% in 2012 to 5% (Figure 11).

42 https://eiti.org/es/implementing_country/4

43 https://resourcegovernance.org/sites/default/files/Minerals%20and%20Mining%20Act%20703%20Ghana.pdf

44 https://www.lexadin.nl/wlg/legis/nofr/oeur/arch/gha/490.pdf

45 http://www.petrocom.gov.gh/L&C_folder/Pet_register/laws/PETROLEUM%20(EXPLORATION%20AND%20PRODUCTION)%20ACT,%202016%20(ACT%20919).pdf

46 www.ghana-mining.orgwww.ghana-mining.org

47 https://www.cbd.int/countries/profile/?country=gh

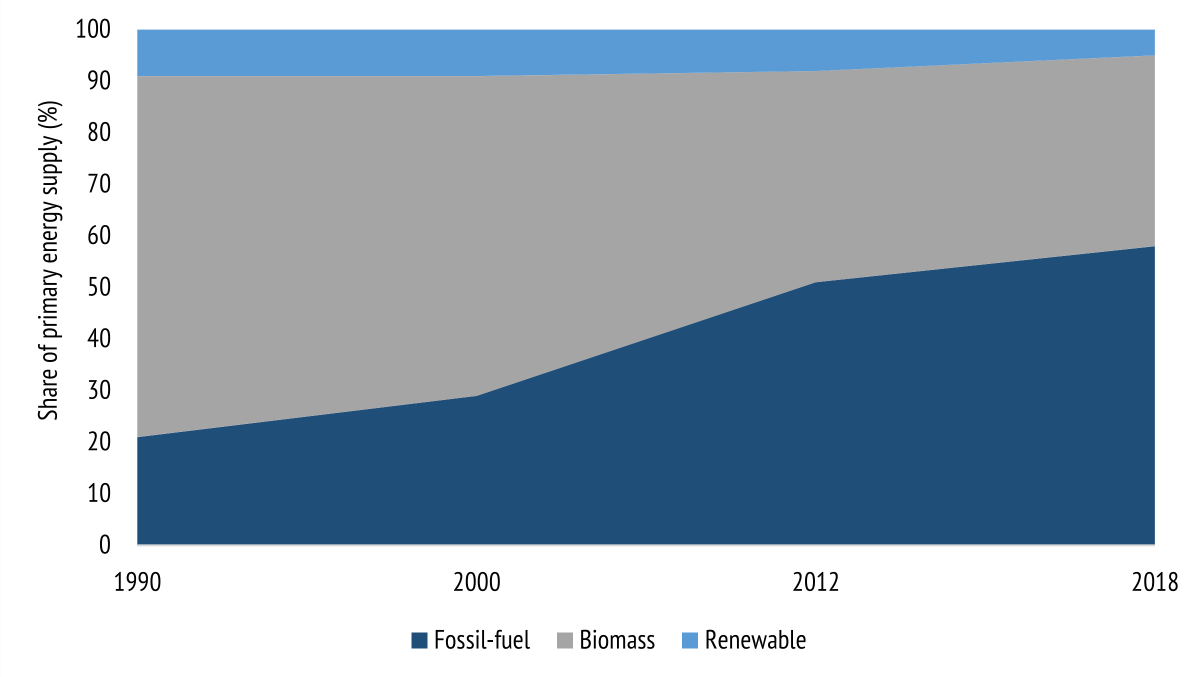

Figure 11: Share of total primary energy supply

2.11.1 Fossil Fuels

Ghana is still a net importer of oil products after starting commercial oil production in 2010. The value of petroleum products (crude oil, premium, gas oil, LPG, aviation fuel and natural gas) import, is US$ 2.6 billion in 2018 (Bank of Ghana, 2019). The total crude oil export volume of 62.1 million barrels in 2019 is almost equal to production (Energy Commission, 2019) and represents 136% higher than the 2012 figures. Besides, crude oil imports for electricity generation and oil refining has substantially declined by 514% from 1,210 kilotonnes to 197 kilotonnes over the 2012-2018 period (Figure 12).

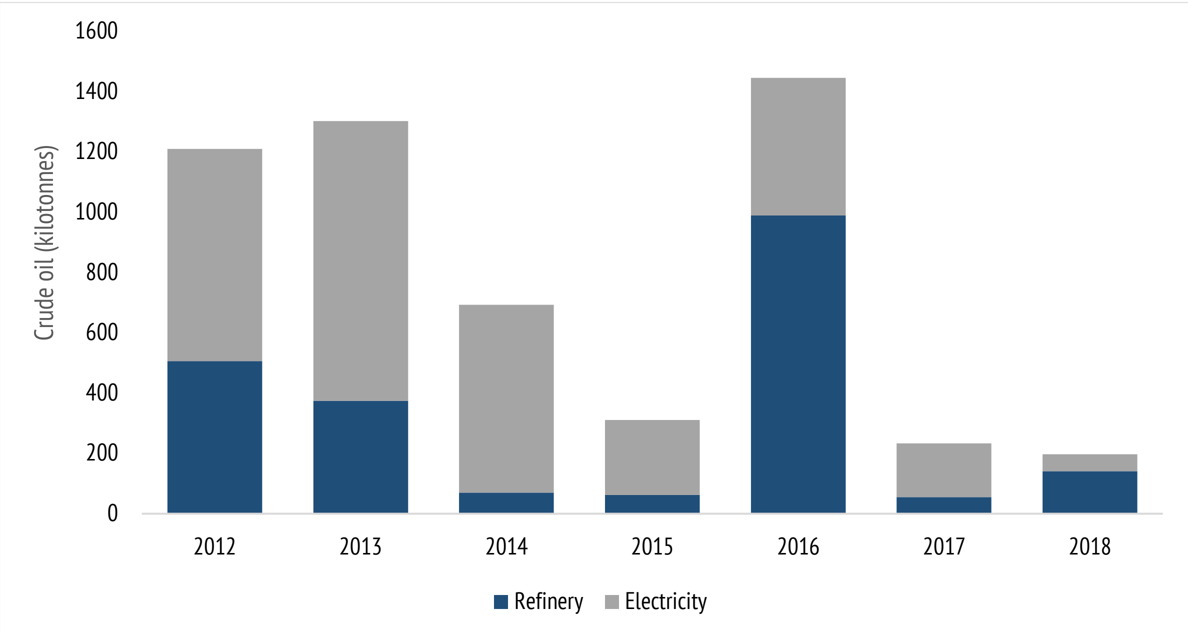

Figure 12: Crude oil imports showing a declining trend from 2012 to 2018 Source: Energy Commission, 2019

The pattern of natural gas supply (import and production) to the domestic market is on the upturn. It had significantly gone up by 275% from 15.4 TBtu in 2012 to 57.9 TBtu in 2018 as the dominant fuel for electricity generation in the country. While the trend of imports component showed inter-annual variations, the production side saw an impressive jump from 2 TBtu in 2014 to 32.6 TBtu in 2016 as domestic demand grew compared to crude oil. The policy on the deregulation of the downstream petroleum market drives the supply of secondary petroleum products. Whereas the policy encourages private sector participation in the downstream market at the imports, distribution and retail segment of the value chain, the state-owned companies still maintain strategic bulk storage and refinery roles. Generally, the supply of petroleum products (production and imports) has increased by 21% from 3.2 to 3.9 megatonnes over the period 2012-2018. The large share (average of 91%) of petroleum products supply comes from imports with the remaining 9% produced from the refinery.

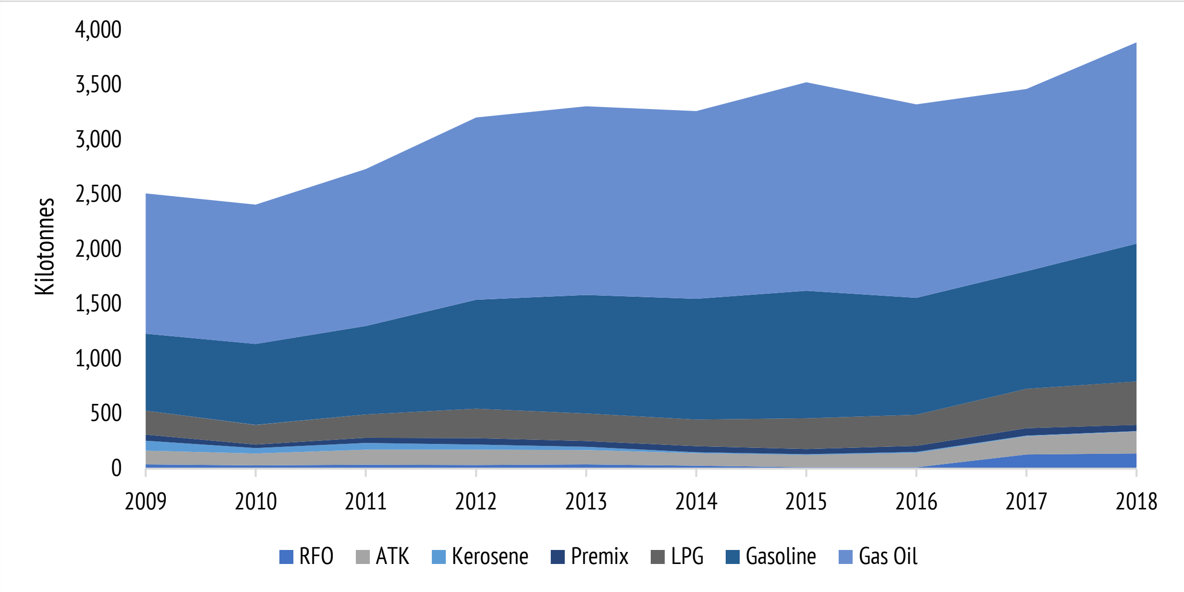

Figure 13: Trend of petroleum products supplied to the economy between 2009 and 2018 Source: Energy Commission, 2019

Commercial oil production started in 2011 and was followed by natural gas in 2014. Since 2011, Ghana has cumulatively produced 317.5 million barrels of crude oil from the Saltpond, Jubilee TEN and lately Sankofa fields (Energy Commission, 2019). In 2018, the country produced 62.1 million barrels, all of which are exported offshore (Figure 13). Spring Fields Limited confirmed the prospects of an additional commercial oil find to the tune of 1.5 billion barrels in 2019. In terms of natural gas, a cumulative total of 118.22 TBtu has been produced between 2014 and 2018 at an average of 23.6 TBtu per annum.

2.11.2 Biomass

In Ghana, the dominant sources of biomass are fuelwood, crops residue, animal waste and municipal waste. Wood fuels (firewood and charcoal) form the bulk of biomass fuel obtained from dead trees, forest clearings, logging residues and sawmill residues. Inefficient earth mound is the rudimentary technology for most charcoal production systems in the country. In 2018, out of the total biomass supply of 1.2 million tonnes, charcoal consumption was 1.1 million tonnes and 0.5 million tonnes of firewood (Energy Commission, 2019). It is estimated that with an annual rainfall of 1,300 – 2,200mm, about 243PJ/year or 65,000GWh/year of wood fuel could be obtained from the existing tropical forests (Ministry of Energy, 2012).

2.11.3 Renewable Energy

Ghana has the potential to receive abundant sunlight because of its unique geographical location close to the centre of the world. A study conducted in Ghana by the Ministry of Energy shows that the country gets average levels of solar radiation in the range of 4-6 kWh/m^2/day with a sunshine duration between 1800 to 3000 hours per annum (Energy Commission, 2014). The study further indicates that the south-eastern coastal part of the country has good wind regimes for wind power generation. The average wind speed along the coastline is estimated to be between 6 and 7 meters per second at 50 meters high. The gross wind electric potential is about 5,600 MW representing 1,128km^2 (Ministry of Energy, 2012)

2.12 Transport

Transportation features firmly in the latest socio-economic development programme for the country (NDPC, 2018). According to GOG (2018), the entire national transportation infrastructure includes one international airport; five domestic airports; road network of 78,401km in 2018, of which 41% is in excellent condition[48]; a limited rail network in southern Ghana; and an underdeveloped inland water transport system. The transportation and storage service sub-sectors contribution to the GDP increased from 5% in 2013 to 7.5% in 2018 and projected to inch up to 8.2% in 2020 (Ministry of Finance, 2019). The national transport policy provides a broad vision for achieving an effective, sustainable and efficient transportation hub in the long-term.

2.12.1 Road Transport

Road transport is the most dominant carrier of freight and passenger in Ghana's land transport system. It carries over 95% of all passengers and freight traffic and reaches most communities. Ghana's road network increased from 38,000km in 2000 to nearly 78,401km in 2018, out of which 23% is paved[49]. Traffic congestion is on the rise in major urban areas leading to longer travel distances, increasing travel times and cost. Diesel, petrol and LPG are the petroleum fuels used in road transport activities. Transport is the biggest consumer of petroleum products. In 2018, the road transport sector consumed 3.8 million tonnes of petroleum products representing 72% over 2012 levels of 2.2 million tonnes. Road transport accounts for an average of 85% of the total fuel consumption.

2.12.2 Rail Transport

The rail network is confined mostly to the southern part of the country, forming a triangle connecting Accra, Kumasi and Takoradi. There is also a central track connecting Kotoku to Huni Valley. The rails have mostly deteriorated, with only 13% of the 947 km network operational, including 54 km from Nsuta to Kojokrom and about 10 km from Accra to Tema (NDPC, 2020). Moreover, service is generally poor and unreliable. Despite the limited rail operations in the country, trains consumed 0.3 million tonnes of diesel mainly for freight transport. In this regard, Ghana adopted a new programme to develop a vibrant and modern rail transport to catalyse economic development. The current railway development plan outlines the ambitious railway industry revitalisation agenda. The plan envisages that the over 4,000km of rail line will be constructed in 15 years (Ministry of Finance, 2019).

[48] https://www.mofep.gov.gh/sites/default/files/pbb-estimates/2019/2019-PBB-MRH.pdf

[49] https://www.ghanaweb.com/GhanaHomePage/NewsArchive/It-s-a-shame-only-23-of-our-entire-road-network-is-paved-Roads-Minister-717991

2.12.3 Inland Water Navigation

The Volta lake transport system is the leading inland water transport system in Ghana connecting the south to the north. The Volta River spans about 450km from the south to the north with ports at Akosombo in the south and Buipe and Yapei in the North (Ministry of Transport, 2010). Some of the items transported by the Volta lake transport are petroleum products, cement and agricultural commodities. It also provides passenger services, mostly for the rural population along the lake. The lake transport operates cargo vessels, ferries and motorboats for passenger and freight transport.

2.12.3 Domestic Aviation

The domestic aviation market is slowing down as reflected in the decline of total passenger movements from 719,234 in 2014 to 418,610 in 2018[50]. The decrease in passenger movement correspondingly influenced the general downturn in domestic aircraft movement from 16,978 to 10,140 in the same period. Consequently, the aviation kerosene fuel consumption in domestic aviation rose from 141.3 kilotonnes in 2012 to 200.3 kilotonnes in 2018. Bunkering services for aviation kerosene fuel to support international commercial airlines are also on the increase.

2.13 Industry

The industrial sector contributed 33.9% to the national GDP at an annual growth rate of 15.7% in 2018. Mining and quarrying account for most of the sector GDP with 42.1%, followed by manufacturing (30.7%), and construction (22.7%). The remaining 5.5% of the GDP is from the utilities (electricity and water and sewerage). Section 2.9.4 elaborates on the utilisation of mineral resources through mining. For manufacturing, the dominant industries include cement; iron and steel, aluminium, pulp and paper and food and beverages. The only aluminium smelter in Ghana is the Volta Aluminium Company Limited (VALCO), which currently operates a single pot. The government's industrial transformation policy focuses on Agri-processes and integrated aluminium industry. Implementation of the one-district one-factory and integrated aluminium industry programmes is to deliver broad policy objectives. Industry consumes 814.2 kilotonnes of all final energy of which electricity is 401.7 kilotonnes and 403.5 kilotonnes of petroleum products. Therefore, the technological and policy changes that promote carbon-intensive practices will lead to GHG emissions.

2.14 Waste Sector

Liquid and solid waste management can contribute to global climate change. The waste problem is more severe in urban areas than the rural areas, owing to high population, prevailing economic activities and consumption patterns. New sprawling suburbs with no access to roads, social infrastructure and waste collection services, compound the situation. In 2016, Ghana produced 4.9 million tonnes of municipal solid waste which is 13% higher than the 2012 level. The breakdown of the waste stream are as follows: (a) food waste including garden and wood waste (73%), (b) paper waste (8%), (c) textile (4%), plastic (8%) and others including inert/metals (7%). Over the last two decades, the involvement of the private sector in waste management has contributed to improving collection and disposal. The participation of the private sector in waste management also led to the halving the fraction of waste dumped elsewhere from 28.2% in 2000 and increased the capacity to incinerate and compost.

[50] http://www.gcaa.com.gh/web/wp-content/uploads/2018/erd/Statistics-Domestic-Passengers-Thruput-2018.pdf

Disposal of solid waste to the land with relatively deeper depth and sanitary landfill sites is increasingly common in urban waste management. There are also potentials for waste to energy and compost. Incineration with energy recovery and recycle " are not just disposal methods but also provides "added-value". Decentralised Treatment, Re-Use and Recovery Systems (DTRRS) for sewage management in bio-digesters; and aerobic composting of sewage developed in Ghana are currently being piloted in peri-urban communities. DTRRS technologies are already being promoted in Ghana. Several of the DTRRS technologies have been installed in institutions, hospitals, schools and in hotels to address the sanitation and water problems associated with the uncontrolled discharge of septic and faecal sludge, contributing to land-based sources of polluting the beaches, rivers and watercourses – a leading cause of public-health related diseases such as cholera and typhoid outbreaks.

2.15 Climate Change and the Implementation of Multilateral Agreements and Other Initiatives

Ghana is a Party to nineteen multilateral agreements on the environment. Several national implementation structures have been put in place to support Ghana to meet its commitments under these various agreements.

2.15.1 Rio Conventions, the Kyoto Protocol and Paris Agreement

Ghana has ratified the three Rio Conventions and taken active steps to meet its obligations under them. The Rio Conventions are (a) United Nations Framework Convention on Climate Change (UNFCCC), (b) United Nations Convention on Biological Diversity (UNCBD) and (c) United Nations Convention to Combat Desertification (UNCCD). The Ministry of Environment Science, Technology and Innovation is responsible for coordinating the implementation of the Rio conventions. The focal points of the UNFCCC, UNCBD and UNCCD are in EPA and MESTI. In line with the implementation of the Rio conventions, Ghana prepared the following documents: National Climate Change Policy (UNFCCC), National Action Plan to Combat Desertification (UNCCD) and National Biodiversity Strategy and Action Plan (UNCBD). As a party to the Kyoto protocol, Ghana has put in place many structures to support its implementation at the national level. These are Designated National Authority for CDM, establishing a National Carbon Trading Committee and a Technical Committee to screen CDM projects. Since the submission of the last national communication, Ghana has joined the following international multilateral agreements

- Paris Climate Agreement
- Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer
- Minamata Convention on Mercury

2.15.2 Other multilateral agreements

Table 6 presents a non-exhaustive list of multilateral agreements to which Ghana is either a signatory or a party.

Table 6: List of international conventions on the Environment in which Ghana participated

United Nation Conventions	Date of Ratification
International Plant Protection Convention, Rome, 1951	22 February 1991
International Convention for Prevention of Pollution of the Sea by Oil London, 154 (as amended in 1962 and 1969). London, 155 (as amended in 1962 and 1969)	17 August 1962
Convention on Fishing and Conservation of the Living Resources of the Seas, Geneva, 1958	29 April 1958 (signed)
Convention on the Continental Shelf, Geneva, 1958	29 April 1958
Convention concerning the Protection of Workers Against lionizing Radiations, Geneva, 1960	7 November 1961

Convention on African Migratory Locust, Kano, 1962	28 November 1963
Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, 1963	27 November 1963
International Convention for the Conservation of Atlantic Tunas, Rio de Janeiro, 1966	17 April 1968
Treaty on Principles Governing Activities of States in the Exploration and Use of Outer Space including the Moon and the Other Celestial Bodies, London, Moscow, Washington, 1967	3 March 1967
African Convention on the Conservation of Nature and Natural Resources, 1969 (Ghana is yet to ratify the revised version of this Convention, which is, however, to come into force).	17 May 1969
Copenhagen Amendment to the Montreal Amendment on Substances that Deplete the Ozone Layer, Copenhagen, 1992	30 September 2000
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, Brussels, 1969	20 April 1978
Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar, 1971	22 February 1988
Treaty on the Prohibition of the Emplacement of Nuclear Weapons and other Weapons of Mass Destruction on the Sea Bed and the Ocean Floor and in the Subsoil thereof, London, Moscow, Washington, 1971	6 June 1975
International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, Brussels 1971 and the 1976 Protocol.	20 April 1978
Convention on the Prohibition of the Development Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, London, Moscow Washington, 1972.	6 June 1972
Convention Concerning the Protection of the World Cultural and Natural Heritage, Paris, 1972	4 July 1975
International Convention for the Prevention of Pollution from Ships and Protocol (MARPOL 73/78)	3 September 1991
Convention on International Trade in Endangered Species of Wild Fauna and Flora, Washington, 1973	14 November 1975
Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, Geneva, 1976.	22 June 1978
Convention Concerning the Protection of Workers against Occupational Hazards in the Working Environment Due to Air pollution, Noise and Vibration, Geneva, 1977	27 May 1986
Protocol Concerning Cooperation in Combating Pollution in Cases of Emergency, Abidjan, 1981	20 July 1989
International Tropical Timber Agreement, Geneva 1983	9 March 1985
United Nations Convention on the Law of the Sea, Montego Bay, 1982.	7 June 1983
Vienna Convention for the Protection of the Ozone Layer, Vienna, 1985.	24 July 1989 (Ac)
Montreal Protocol on Substances that Deplete the Ozone Layer, Montreal, 1987	24 July 1989
Convention on the Conservation of Migratory Species of Wild Animals, Bonn, 1979	19 January 1988
Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal, Basel, 1989	12 March 2003
London Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer, London, 1990	24 July 1992
Convention for Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, Abidjan,1981	20 July 1989
United Nations Framework Convention on Climate Change, New York, 1992	6 September 1994
Convention on Biological Diversity, Rio de Janeiro,1992	29 August 1994
United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and Desertification, Particularly in Africa, Paris, 1994	27 December 1996
Treaty Establishing the African Community, 1991	25 October 1991
Convention on Nuclear Safety	6 July 1995 (signed)
Beijing Amendment to the Montreal Protocol	8 August 2005
Montreal Amendment to the Montreal Protocol	8 August 2005
Amendment to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, Geneva, 1995	9 June 2005
Rotterdam Convention on Prior Informed Consent Procedure for Hazardous Chemicals and Pesticides in International Trade, Rotterdam, 1998	12 March 2003
Cartagena Protocol on Biosafety	12 March,2003
Protocol on Liability and Compensation	30 May 2003
Stockholm Convention on Persistent Organic Pollutants	30 May 2003

In the implementation of the multilateral agreements, Ghana faces challenges such as inadequate coordination and integration among the conventions, insufficient participation and ownership of programmes and plans, as well as under-resourced institutions to implement them. That is why Ghana is seeking to localise the implementation of the multilateral environmental agreements through the national medium-term development framework.

2.16 Description of Regional Development Priorities, Objectives and Circumstances, on the basis of which Ghana is Addressing Climate Change and its Adverse Impacts

Ghana regularly participates in most of the ECOWAS climate change programmes. The recent regional collaboration among some selected member states led to the adoption of a regional framework on air pollution. This initiative followed the joint effort by the ECOWAS countries to adopt a single policy to reduce sulphur in diesel fuel. Besides, Ghana actively contributes to the following sub-regional climate change initiatives:

- **West African South-South Network on MRV and Transparency**[51] - Ghana is a founding member of the network. In 2016, West African nations came together with the support of UNFCCC, UNDP, ECOWAS, GIZ and Belgium, to form the network to facilitate experience and knowledge sharing on MRV and transparency. The platform also supports countries to improve capacities on climate reporting and the preparation of nationally determined contributions. So far, fourteen West African states have joined the group hosted at the UNFCCC-West Africa Development Bank Regional Collaboration Centre in Lome (RCC Lome). In Ghana, the EPA is the focal point for the network. In 2017, Sierra Leone and Liberia received P2P learning from Ghana and Senegal on MRV and Standard Baseline (SBL). In 2018, a team from São Tomé and Príncipe visited Ghana to learn and share experiences on the operationalisation of the Ghanaian national MRV system.

- **West African Alliance on Carbon Markets and Climate Finance**[52] **-** The alliance aims to strengthen the participation of West African nations in carbon markets and the mobilisation of climate finance. The partnership offers technical assistance to the member countries in the following areas: article 6 negotiation and climate diplomacy, in-country readiness for Article 6, support to access results-based climate finance, technology transfer, transparency and access to carbon-market demand sources. The secretariat of the alliance is in Enda Energie, Senegal. Ghana is already developing an Article 6 pilot project with the Government of Switzerland and looks forward to sharing experiences with the alliance members.

- **West Africa Biodiversity and Climate change (WABiCC)**[53] **–** USAID is funding the five-year WABiCC programme. The goal of WABiCC is to "improve conservation and climate-resilient, low-emissions growth across West Africa". "WABiCC increases the capacity of institutions at all levels to address combating wildlife trafficking, increasing coastal resilience to climate change and reducing deforestation, forest degradation, and biodiversity loss".

[51] https://unfccc.int/topics/capacity-building/events-meetings/pccb-at-cop-24/pccb-capacity-building-hub-programme/the-west-african-south-south-network-on-mrv-and-transparency

[52] https://www.westafricaclimatealliance.org/

[53] https://www.wabicc.org/en/

- **Climate change, Agriculture and Food Security, West Africa (CCAFS)** [54] **-** CCAFS is a collaboration among all 15 CGIAR Research Centres and collaborates with the other CGIAR research programmes. CCAFS research focuses on the interactions between climate change and agriculture. In West Africa, CCAFS researches in Ghana, Senegal, Niger, Mali and Burkina Faso. Some of CCAFS's critical researches in Ghana include the establishment of climate-smart village in Lawra-Jirapa district[55], development of science-policy dialogue platform and the formation of climate-smart agriculture alliance. Through the instrumentality of CCAFS, Ghana developed a National Climate-Smart Agriculture and Food Security Action Plan (2016-2020).[56]

- **West African Science Centre on Climate Change and Adapted Land Use (WASCAL)[57] –** WASCAL is a sub-region-wide capacity building and research initiative funded by the German Federal Ministry of Education and Research. WASCAL's research focuses on land use and cover/land degradation/climate change nexus, risks and vulnerability to climate extremes, sustainable rural-urban and cross border migration in West Africa and sustainable agriculture/climate-smart landscapes nexus**.** The headquarters of WASCAL is in Ghana and covers 11 West African countries involving 12 Universities. More than 300 West African citizens have benefitted from WASCAL's masters and doctoral programmes.

Furthermore, Ghana partakes in some of the major climate change-related activities that the ECOWAS institutions are implementing in the region. Below is an overview of the institutional initiatives:

- **UNFCCC CDM Regional Collaboration Centre in LOME** – The regional office supported Ghana to develop a standard baseline in the transport and waste sectors. The centre in collaboration with the West Africa Power Pool, also helped the West African countries, including Ghana, to establish grid emission factors for the countries that share electricity with common transmission infrastructure in the sub-region. It also played a crucial role during the 2019 Africa climate change week in Ghana. The centre is the host of the West African South-South Network on MRV and Transparency

- **Regional Centre for Renewable Energy and Energy Efficiency (ECREE)[58]** – ECREE is the ECOWAS Observatory for renewable energy and energy efficiency and operates in the "policy and capacity development, knowledge management and investment/business promotion" space. Ghana hosted the third ECOWAS Sustainable Energy Forum (ESEF), October 2019. In 2018, ECREE opened the third call for ECOWAS Renewable Energy Facility (EREF)[59]. Since its inception in 2017, EREF has brought together top government officials, industry players, businesses, and other stakeholders to deliberate on the advancement of the sub-regions' sustainable energy plan. "The third call of the facility aims to provide non-reimbursable grant co-funding for the capital expenditure in clean energy mini-grids in rural and peri-urban areas, with specific attention to those initiatives supporting and promoting productive uses of electricity (PUE)".

[54] https://ccafs.cgiar.org/regions/west-africa
[55] https://ccafs.cgiar.org/developing-climate-smart-village-models-west-africa#.XgMojEf7RPZ
[56] https://cgspace.cgiar.org/handle/10568/69000
[57] https://wascal.org/
[58] http://www.ecreee.org/
[59] http://www.ecreee.org/news/ecowas-sustainable-energy-forum-2019-concludes-accra

The Kumasi Institute for Technology and Environment (KITE) benefitted from EREF to enable it to provide grant co-funding for small to medium-sized renewable energy and energy efficiency projects and businesses in rural and peri-urban areas. The project run from 2011 to 2014.

- **West Africa Gas Pipeline**[60] - The West African Gas Pipeline Company limited (WAPCo) is a limited liability company that owns and operates the West African Gas Pipeline (WAGP). The company's primary mandate is to transport natural gas from Nigeria to customers in Benin, Togo and Ghana in a safe, responsible and reliable manner, at prices competitive with other fuel alternatives. The gas delivered in Ghana helps to generate electricity from a clean energy source. In 2019, WAPCo completed reverse flow transportation of gas from the Western Region of Ghana to the East (Figure 14).

Figure 14: Reverse flow facility at the eastern end of Ghana Source: WAPCo website

- **Sustainable Greenhouse Gas Inventory in West Africa**[61]– Ghana participates in the GHG inventory programme in West Africa with funding from the Australian Government through the UNFCCC secretariat. Seven West African countries (Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Ghana, Senegal and Togo) received capacity building support from FAO. In the project, Ghana received technical assistance for reviewing the AFOLU section of its national GHG inventory report. Ghana also received hands-on training on Collect Earth software for landscape mapping.

[60] https://www.wagpco.com/

[61] http://sdg.iisd.org/commentary/guest-articles/technical-assistance-for-sustainable-national-greenhouse-gas-inventory-management-systems-in-west-africa/

National greenhouse gas inventory

3. Updates of National Greenhouse Gas Inventory

3.1 Overview of National Greenhouse Inventory

This section provides the results of the national greenhouse gas inventory for 1990-2016 reported in the Fourth National Greenhouse Gas Inventory Report (NIR4). It contains comprehensive information on the description of findings, methodology, and processes for preparing the inventory. The NIR4 and associated tables are submitted to the UNFCCC in fulfilment of 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). It is also in compliance with reporting requirements in the preparation of its Second Biennial Update Report (BUR2) and consistent with Decision 1/CP.16 para 60(c). Although this is the fourth time Ghana has prepared a separate NIR, it is the second NIR submitted to the UNFCCC under the "BUR" reporting mechanism.

The Greenhouse Gas (GHG) emission estimates have been compiled based on the methodologies contained in the Intergovernmental Panel on Climate Change (IPCC Guidelines for National Greenhouse Gas Inventories IPCC 2006). The use of the 2006 IPCC guidelines was to enhance the quality of the GHG emission estimates on, Transparency, Completeness, Consistency, Comparability and Accuracy (TCCCA) over the 1990-2016 period. The inventory estimates cover direct anthropogenic GHG emissions by sources and removals by sinks and include CO_2, CH_4, N_2O, HFCs and PFCs. The emissions/removals from the following four economic sectors have been estimated; in accordance with the 2006 IPCC guidelines

- Energy
- Industrial processes and product use (IPPU)
- Agriculture, Forestry, and Other Land Use (AFOLU)
- Waste

The GHG inventory estimates are expressed in mass units, and carbon dioxide equivalents (CO_2e) terms using the 100-year Global Warming Potentials (GWPs) contained in the 1995 IPCC Second Assessment Report (IPCC 1996).

3.2 National System for Sustainable Inventory Preparation

Ghana launched the Climate Ambitious Reporting Program (CARP)[62] as its domestic MRV system in 2013. The operational aim of CARP was to put in place a workable climate data management to support regular national and international reporting of information on GHG inventory, climate actions, and support (Figure 14). Although the CARP design suits the national circumstances, the implementation of the various components on the ground is at different levels. Operationally, the GHG part of the CARP is the most advanced because of the anchor on functional institutions, data handling, methods, tools and protocols, and skills development. Elaborate information on the national system is in the fourth national inventory report[63].

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

[63] https://unfccc.int/sites/default/files/resource/gh_nir4-1.pdf

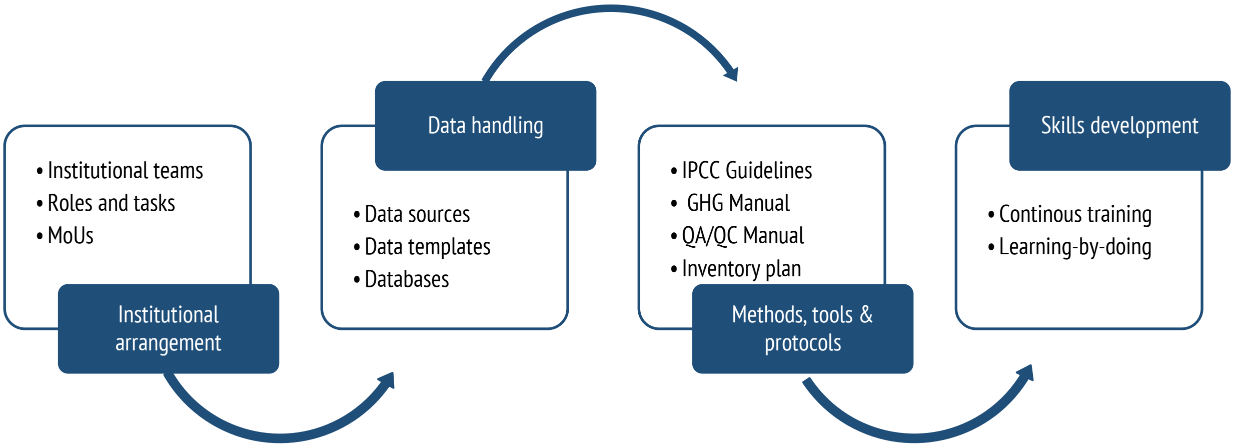

Figure 15: Overview of the relationships of the elements underpinning the national system for GHG inventory

3.2.1 Institutional Arrangement for GHG Inventory Preparation

In Ghana, the EPA is the national entity for the GHG inventory (Figure 16). The MESTI gives official approval and endorsement of NIR for onward transmission to UNFCCC. The EPA works with several public and private institutions and organisations to plan, implement, and compile the inventory. There are thirty national experts from twenty different public and private organisations. Each organisation has an assigned role at every stage of the inventory cycle with reporting lines. In each inventory, the EPA and the sector lead organisation agree on the tasks and capture them in the memorandum of understanding. The EPA's role as the coordinating entity is based on the legal mandate given to it by the EPA Act, 490 (1994). Within the EPA, the Climate Change Unit is the national inventory entity and is directly responsible for the management of the entire inventory process. The Unit ensures the prompt delivery of high-quality inventory estimates and reports that satisfy international standards.

The inventory compiler also serves as the generalist and ensures that cross-cutting issues in the inventory are addressed sufficiently. Some of the issues the generalist deals with include, recalculations, ensuring responsiveness of the national system, key category analysis, managing improvements list, addressing technical review comments and leads on QA/QC and uncertainty management. Four teams work on one IPCC inventory sector. A competent organisation is selected to lead each team with the members assigned to a specific task in the sector inventory. The members are from the public, private organisations and academia. Some institutions supply data to the inventory compilers. The detailed description of the institutional arrangement is in the NIR4.

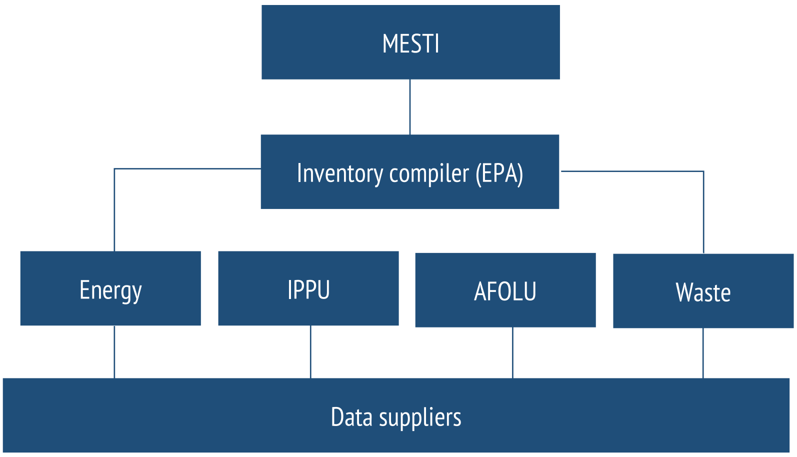

Figure 16: Institutional arrangement for the regular preparation of national GHG inventory

3.2.2 Data Handling

The EPA and the sector lead institutions are responsible for the identification and sourcing of all activity data and emission factors. Data sourcing starts with a data mapping table. Then, based on the table, the sectors prepare a plan to collect relevant data for national and international sources. After initial contacts with the data providers, the sector lead institutions directly request the data from the source with administrative support from the EPA. Where the sector lead institutions asked the EPA to help to access data, the climate change unit makes an official data request to the relevant institutions stating the data format, the period, and the primary use of the data in the inventory. The data request letters, especially those to industrial plants, usually refer to the relevant provisions of the EPA, Act 490[64], which permits EPA to access industry 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 a series of screening and documentation procedures to ensure proper indexing and backup. The team conducts initial technical and quality evaluation before transmission to the working groups. Documentation on the data and the acquisition processes are stored in the online database for archiving and retrieval. Ghana has established a climate change data-hub as an online database to hold all the inventory data and related information. The data hub is the storage unit of the inventory data and helps to streamline documentation and archiving protocols of the activity data and emission factors, reports, and relevant publications. The database hosts the following:

- inputs of datasets from each sector
- datasheets for each inventory sector
- emission estimates from the IPCC software for all the inventory sectors from 1990-2016
- IPCC 2006 software database file
- completed sector QA/QC templates
- reports and documentation

The online database is hosted on a cloud server managed by a webmaster at EPA. Access to the database is by open and restricted access. All users (public, institutional users, and the inventory team) can access to the front end of the database through this URL address http://climatedatahubgh.com/gh/. Users with open access can only search for publicly available data and upload files through trail filters. There are two levels of restricted access. Those who can access the backend to only view the inventory data and users who have the permission to (a) upload, (b) query, and (c) retrieve data from the database. The webmaster and the inventory compiler can view confidential data.

The IPCC software has a backend database file which has data inputs and emission results for the sectors. The software allows unlimited access levels to every user to the applicable sections of the database but not the entire database. Therefore, one "superuser login ID" was created for the inventory compiler to allow for access to the data for all the sectors. The team members have "login credentials" that only allow them to access their relevant sections. When the sector completes the database files, the lead institution submits them to the inventory compiler, who then creates a "single inventory database file" containing all data for all the sectors for the completed time-series. Then the compiler sends the inventory data, individual results sheets, and the database file to the online database administrator for archiving.

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

3.2.3 Summary of Inventory Steps and Data Flows

Generally, the inventory tasks are subdivided into six steps. It starts with the identification and sourcing of activity data and emission factors. The strategy is different for the variety of data sources, be it public, private, academia, or surveys. For much of the data obtained from the government sources, we focused on collecting data from public institutions that have the legal mandate to publish relevant statistics for the inventory. The administrative data from the public institutions are the preferred source because they are considered official government records. The EPA already collects data from industry as required under the Environmental Impact Assessment (EIA) regulations in the preparation of the Environmental Management Plans (EMPs). The Manufacturing Industry Department of EPA supply industry-specific data on energy, productions and waste from the Annual Environmental Reports (AER).

The inventory also uses data from published scientific literature or national reports. Following the data documentation plan, anytime data from national reports or peer-reviewed literature are used, the team references proper records of the source. The purpose is to ease up retrieval of the data and to correctly cite in the NIR. Since international data come from multiple sources, Ghana uses data published by reputable organisations like FAO, IEA, World Bank etc. After the team assembled all the data in a single location, they evaluate and process them in a usable format. Often the data processing involved the identification of outliers (inaccurate data, out-of-range data) time-series gaps, incompatible format, and indexing all selected data.

The next stage is the selection of an appropriate method for the inventory. Most of the methods used in the inventory are tier 1 except in transport and solid waste disposal categories where the team applied country-specific methods. In the next step, the team carried out recalculations of the previous year's emissions and calculated new estimates for the added years. After the recalculations and the latest estimates, the team performed the trends, Key Category Analysis (KCA), and Uncertainty Assessment (UA). All 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, both the datasheet and the report are uploaded to the climate change data hub for storage. Detailed elaboration of the inventory steps is in Figure 17.

3.2.4 Methodology and Data Sources

The inventory followed a series of iterative steps. The emissions and removals are not directly measured but estimated using the internationally-recognised and scientifically acceptable methodologies. Emissions calculations are linked to the Activity Data (AD) on economic activities in the country, and Emission Factors (EFs) published from scientific studies. Therefore, the estimation of the emissions/removals for a specific gas for a given inventory year uses the following: (a) a country-specific or regional or IPCC accepted methodology, AD from practices/technologies in a specific sector and EFs. The inventory method is consistent with the 206 IPCC Guidelines for National Greenhouse Gas Inventories and in line with international best practices. Broadly, the dominant use of tier 1 IPCC methodology and default emission factors was because, for most of the sectors, the existing dataset does not permit the use of higher-tier methodologies. Besides, the higher-tier or model-based method was not available in the country at the time of publishing this report. Furthermore, for many of the inventory categories, default emission factors were used due to the lack of country-specific emission factors. But where detailed datasets existed Land (3B), IPPU (2C), and solid waste disposal (4A), the higher inventory tier and country-factor factors were applied.

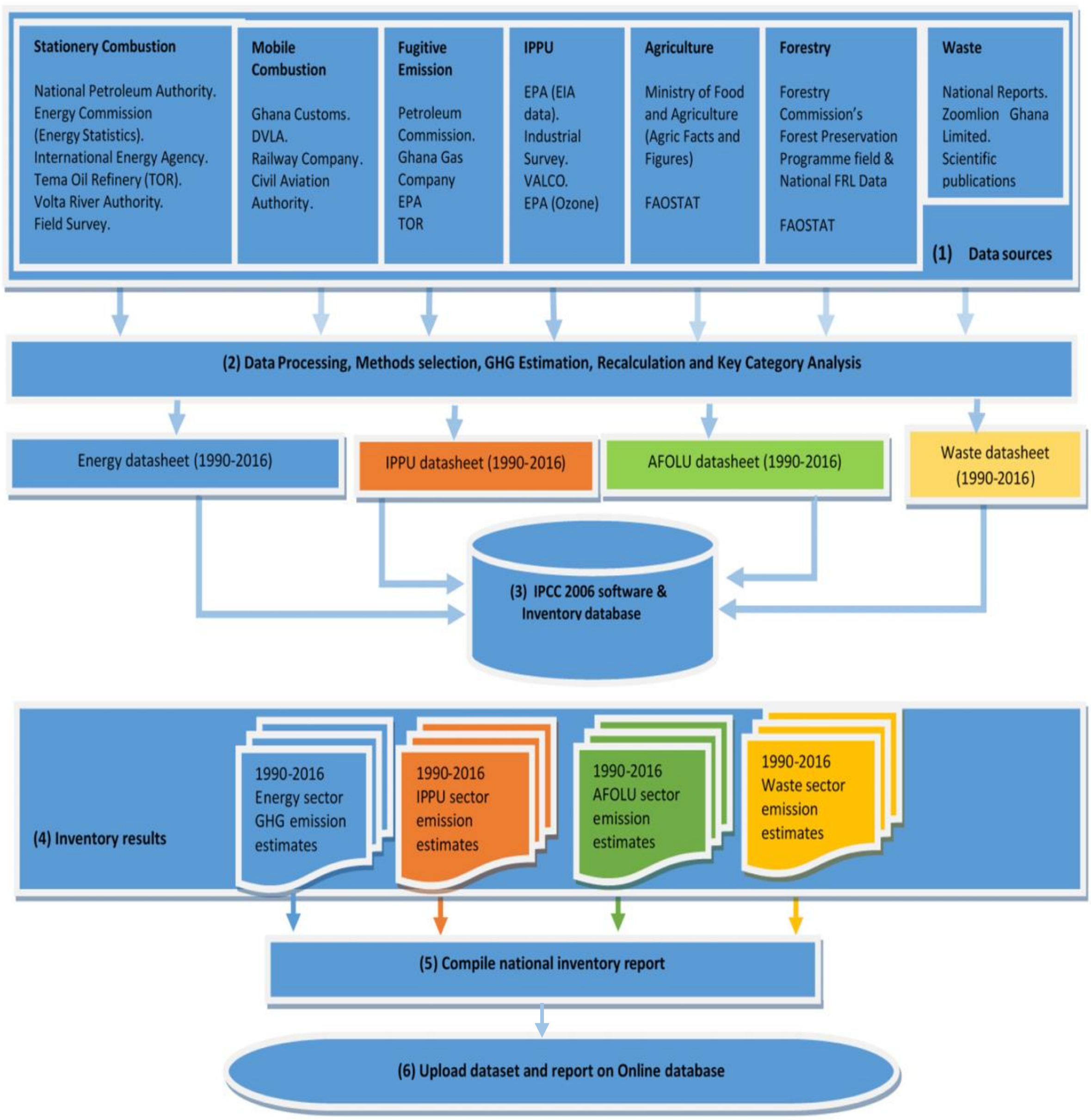

Figure 17: Summary of the inventory steps and data flows.

The team used the combination of tiers 1 and 2 approaches depending on the availability of adequate data to satisfy the level of detailed inventory calculation. The NIR4 contains a comprehensive elaboration of selected methods under each sector.

3.2.4.1 Selection of emission factors

The emission factors were from country-specific and regional/international sources. The Country-Specific (CS) factors were from stationary industrial plants (plant-specific such as VALCO) and land category (forestland, grassland, cropland). The default emissions factors were obtained mainly from the IPCC Emission Factor Database (EFDB)[65] and EMEP/EEA or EMEP/ CORINAIR[66] air pollutant emission inventory guidebook. Emission factors published in regional and international peer review studies were also used.

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

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

In the selection of the EFs, the following factors were considered: representativeness of the EFs for a set of facility-level plants, ecological zone or the production system, and applicability of the regional and international EFs to the unique country conditions. Generally, in the inventory, the default emissions factors from the IPCC EFDB and EMEP/EEA were commonly used because of the non-existing country-specific emission factors. The use of the default EFs per se does not render the calculated emissions/removals inaccurate but comes with 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 using the global elements. Table 7 shows the overview of methodological tiers and the type of emission factors used according to the category and gases.

Table 7: Emissions/removal categories, methodological tiers and emission factors for 1990-2016

Category		CO_2		CH_4		N_2O		PFCs		SF6		HFCs		Non-GHGs[67]	
		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
2.F	Product Uses as Substitutes for Ozone Depleting Substances											T1	D		
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
4.A	Solid waste disposal			T2[68]	D	T1	D							T1	D

[67] 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.

[68] 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.

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.

3.2.4.2 Activity data sources

Activity Data (AD) is a primary data point for the inventory. They have been collected from several national and international institutions, as well as from scientific literature. Majority of the AD was from existing data platforms managed by government institutions like the 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 varies and is published at different frequencies.

In the energy sector, the energy statistics are the primary data source and are published every year online on URL address http://www.energycom.gov.gh/planning/data-center/energy-statistics. It contains data on energy balance, supply, and consumption for different fuels and demand sectors. The Energy Commission relies on data supplied to it 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 data from the energy statistics was the primary source of the AD for most of the sub-categories under the energy sector 1A1, 1A2, 1A3, and 1B. Data on vehicle population, car traffic, and circulation patterns are obtained from the Ministry Transport and DVLA.

The IPPU sector AD came from a wide variety of sources. Most of them were from the facility level, obtained through official requests. Some of the AD also came from the Environmental Management Plans and Annual Environmental Reports companies submitted to 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 at different times. Usually, whenever they put out figures, it covers several years other than the publication year. They publish the dataset on the web address (http://mofa.gov.gh/site/wp-content/uploads/2011/04/mofa_facts_and_figures.pdf). The current online version of the Facts and Figures was published covering data from 1999 to 2009. The SRID made available the latest version of the facts and figures to the inventory team covering up to 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 is not complete yet, most of the requisite dataset has been pooled together at a central point at the Forest Commission during the preparation of the REDD+ National Forest Reference Level (FREL) to the UNFCCC.

The data on waste management was not well organised at a single location. Mostly, the AD for the waste sector was dispersed among several district assemblies. So, the waste inventory team had to consult a wide variety of data sources from government reports, scientific literature, data from environmental sanitation service companies, and the GSS to be able to assemble all the necessary data. In the absence of national data, alternative reliable data from international organisations such as FAO, IEA, World Bank was used. Table 8 provides an overview of the data used in the inventory.

Table 8: Sources of activity data, format and the principal data providers

Sector		Data Type	Data Sources	Principal Data Providers	Remarks
1. Energy					
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, processed, imports, and use as fuel for electricity generation. • Annual figures on production, imports, export, and petroleum products production. • Auto production of selected petroleum products in the refinery, 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.	Energy Commission publishes the National Energy Statistics online in April every year. Tema Oil Refinery updates the material balance every year. Energy Commission request for TOR's administrative data during the preparation of the Energy Statistics. Petroleum Commission publishes the Oil and gas production figures every month.
1.A2	Manufacturing Industry and Construction	Industrial sectors and their fuel consumption: • Fuel types and consumption. • Quantity of fuel used as feedstock. • 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 share of fuel allocation per industry sector is based on the fuel shares in the Energy' Commission's SNEP dataset. There plans to survey to improve the existing data.
1.A3	Transport	Fuel, vehicle and traffic information • 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	Vehicle registration database. Transport sector study reports. Petroleum product sales data. Railway fuel consumption data. Water transport fuel consumption. Premix fuel consumption data.	Energy Commission. Environmental Protection Agency. Driver Vehicle Licensing Authority. Oil Marketing Companies (Shell Ghana Limited, 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	Yearly vehicle population figures were from the annual release of administrative data on 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 involved vehicle inspections in collecting 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 share of fuel allocation per industry sector is based on the fuel shares in the Energy' Commission's SNEP dataset. There plans to survey to improve the existing data.
1.B	Fugitive emissions from fuels	Quantities of wet production, amounts of reinjected, volumes of gas flared, and gas consumed on site. Volumes 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.	Petroleum Commission publishes the Oil and gas production figures every month.
2. Industrial Process and Product Use					
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. The team officially request data from industry players and the Environmental Impact Statement (EIS)
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 refrigerant 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	Ministry of Food and Agriculture publishes the Agriculture Fact and Figure online annually. The metadata for the Agriculture Facts and Figures are not available.
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	The Forestry does not publish the land-use maps at any scheduled time. The maps are normally 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 generated from

					the Forest Preservation Programme in 2014. There are no 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 in every quarter at RMSC but not published online. The team classifies them as administrative data requested via an official letter.
		Wood fuel production.	Energy Statistics	Energy Commission	Energy Commission publishes total wood fuel supply in the Energy Statistics yearly.
		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 maps, land-use change matrix.	Forest Preservation Program, 2012, National Forest Reference Level, 2017.	Forestry Commission	The Forestry does not publish the land-use maps at any scheduled time. The maps are normally produced as part of projects.
		Biomass estimate for five 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 no scheduled updates.
		Climatic zones, soil classification, 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, 2017.	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, 2017.	Forestry Commission	Ditto
		Mass of fuel available for burning	Forest Preservation Program, 2012. National Forest Reference Level, 2017.	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	The Ministry of Food and Agriculture publishes the Agriculture Facts and Figures online.
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 disposals 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 and 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. Used multiple reports, literature, and scattered data at the various assemblies. Carry out a national survey on solid waste.

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 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. Carry out a national survey on incineration.
	4C.2 Open Burning of Solid Waste	Population, the proportion of population burning waste, duration of burning and the number of days per year, 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. Carry out a national survey on open burning.
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 and FAO. Expert Judgment by Waste team.	Data on domestic are scattered. The inventory team relied on different data sources. Carry out a national survey on domestic wastewater.
	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 output data collected from a national industrial survey. Environmental Management Plans. Expert Judgment by Waste team.	The quality of the data from the survey and the Environmental Management Plans for Industries need to be improved.

3.3 Summary of Emissions/Removals Trends

3.3.1 Analysis of Aggregate Emissions

Ghana's total national greenhouse gas emissions stood at 42.2 $MtCO_2e$ (million tonnes of carbon dioxide equivalent) in 2016. The 2016 levels are 66.4%, 53%, and 7.1% more than 1990, 2000, and 2012 emissions, respectively (Figure 18). Overall, the national GHG emissions increased at a 2.1% annual growth rate between 1990-2016. Without the FOLU emissions, total emissions showed a similar upturn to 29.3 $MtCO_2e$ in 2016.

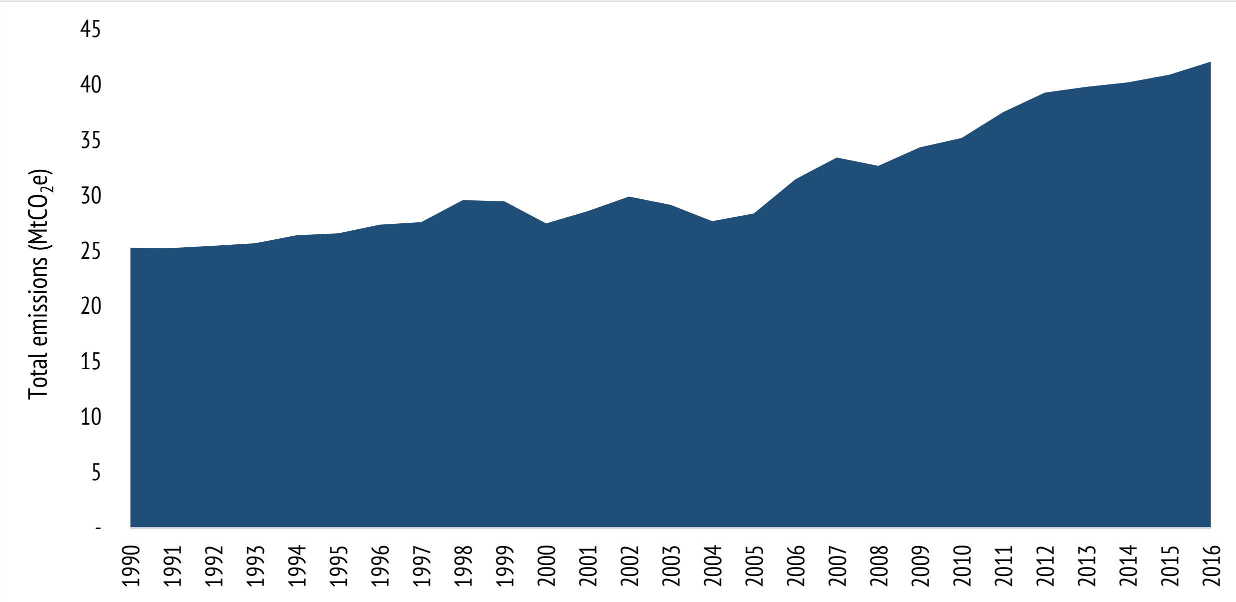

Figure 18: Trend of national aggregate net greenhouse gas emissions for the period 1990-2016

Ghana's GHG emissions expressed in per capita and Gross Domestic Product (GDP) in dollars showed a declining trend over the 26 years. The emissions per capita decreased from 1.7 tCO_2e per person in 1990 to 1.5 tCO_2e in 2016, representing a drop of 13.7%. Similarly, the emission intensity of GDP, the emission per unit GDP output (at constant 2010 US$), dropped from 2.1 kg/ per GDP (constant 2010 US$) to 0.87 kg per GDP (constant 2010 US$), which is a 59.3% reduction in the same period. The overall decreases in the emission per capita and GDP intensity suggest a positive effect of the growth-focus and economic diversification policies Ghana pursued in the last two decades.

3.3.2 Emission Trends by Sectors

The AFOLU is consistently the most significant contributor to national emissions between 1990 and 2016. In 2016, with total emissions of 42.2 $MtCO_2e$, the AFOLU sector accounted for 54.4%, of the total, followed by the energy sector (35.6% from stationary, mobile, and fugitive emissions), waste sector (7.5%) and IPPU (2.5%). Without the FOLU emissions, the energy sector emissions made up more than half (52.5%) of the total national emissions. This is followed by emissions from livestock and aggregated sources and non-CO_2 (3A and 3C; 33.4%) and then by the waste sector (10.5%) and IPPU (3.5%). Figure 19 shows the individual contributions of the emissions/removals by the categories. It further revealed that the land, livestock, stationary, and mobile combustion are the critical GHG emission sources.

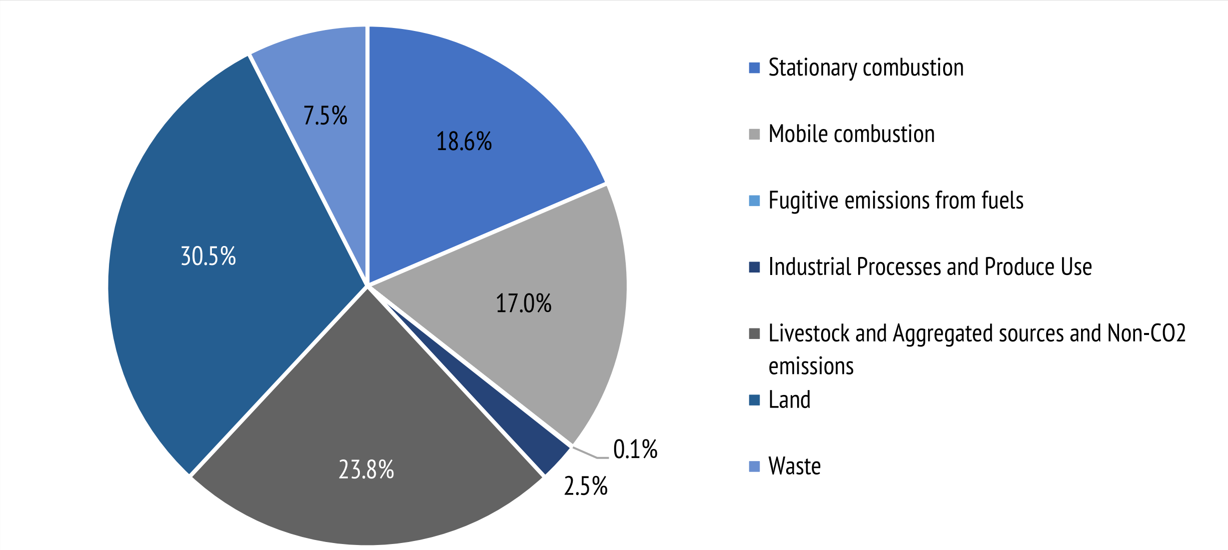

Figure 19: Breakdown of total net emissions by categories for 2016

All the inventory sectors recorded increases in the 1990-2016 time-series. For the emissions in 2012-2016, the waste sector recorded the highest rise of 17%, followed by the energy sector with 14.2% and then by AFOLU (4.0%). The IPPU emissions notably decreased from 1.52 $MtCO_2e$ to 1.04 $MtCO_2e$ representing a 31.3% reduction (Table 9).

Table 9: Sector contributions to total emissions and percentage change from 2012 to 2016

Sector/Category	Total emissions ($MtCO_2e$)				Percentage change
	1990	2000	2012	2016	(2012-2016)
National Emissions with FOLU	25.34	27.26	41.62	42.15	1.3%
National Emissions without FOLU	11.32	14.53	28.66	29.28	2.2%
1 - Energy	3.73	5.96	15.35	15.02	-2.1%
Stationery combustion	2.31	2.77	8.65	7.83	-9.5%
Transport Mobile combustion	1.41	3.17	6.68	7.17	7.3%
Oil and Natural Gas (Fugitive emission)	0.016	0.023	0.012	0.024	100%
2. Industrial Processes and Product Use	0.49	0.36	1.52	1.04	-31.6%
Mineral Industry	0.01	0.04	0.48	0.33	-31.3%
Metal Industry	0.48	0.31	0.08	0.09	12.5%
Non-Energy Products from Fuels and Solvent Use	-	0.00	0.00	0.00	1.9%
Product Uses as Substitutes for ODS	-	-	0.96	0.61	-36.5%
3. Agriculture, Forestry, and Other Land Use	20.10	19.47	22.05	22.92	3.9%
Livestock	1.72	1.82	2.91	3.48	19.6%
Land	14.01	12.73	12.96	12.87	-0.7%
Aggregate sources and Non-CO_2 emissions sources on land	4.36	4.91	6.18	6.57	6.3%
4. Waste	1.02	1.48	2.71	3.17	17.0%
Solid Waste Disposal	0.26	0.48	0.99	1.16	17.2%
Biological Treatment of Solid Waste	0.09	0.06	0.06	0.10	66.7%
Incineration and Open Burning of Waste	0.03	0.03	0.07	0.08	14.3%
Wastewater Treatment and Discharge	0.64	0.90	1.58	1.84	16.5%

The socio-economic factors that drive emission trends relate to policy changes. In the energy sector, even though the percentage of fugitive emissions from fuel was relatively small (average of 0.32%), it recorded the highest sectoral emissions rise of 100% (0.012 $MtCO_2e$ to 0.024 $MtCO_2e$) for the period 2012-2016.

Stationary and mobile combustions were the primary sources of emissions, so in terms of the trends, both recorded 22.7% and 7.2% increases respectively within the same timeframe. Fugitive emissions also increased over the period 2012-2016, primarily due to increased oil and gas production. It is during this period that Ghana started producing crude oil and natural gas in commercial quantities through investment in oil production and the establishment of a natural gas processing plant. The 20.6% rise in stationary combustion emissions was the resultant effect of the capacity expansion of electric power plants (2,280 MW in 2012 to 3,795 MW in 2016) as well as increased fuel use in the manufacturing industry and changes in household energy consumption patterns. The main drivers for the increase in transport emissions were the continued growth in the number of vehicles along with a rise in fuel (diesel and petrol) consumption.

IPPU emissions have decreased since 2012. The reductions are associated with HFCs and the Aluminium production by VALCO. The decline in HFC emissions corresponds to the influence of the phase-down of high-GWP HFCs in the country. Generally, the rise in the AFOLU sector emissions is associated with growth in land category emissions, mainly from land converted to cropland, grassland, and forestland (forest remaining forest and land converted to forest). The high emissions are linked with land conversions to cropland, and grassland showed the impacts of the drivers of deforestation on growing emissions. Furthermore, the emission increases under the direct N_2O emissions from managed soils sub-category influenced the rising emission trends. For the waste sector, emissions from unmanaged waste disposal sites and 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 poor state of domestic wastewater treatment facilities in the country.

3.3.3 Analysis of Greenhouse Gas Emissions by Gases

Carbon dioxide is the most prevalent GHG emissions in Ghana and accounted for 64.7% (27.3 $MtCO_2$) of the total emissions in 2016, trailed by nitrous oxide (18.3%) and methane (15.4%). The share of the fluorinated gases (different types of HFCs and PFCs) is 1.5% and 0.1%, respectively, in 2016 (Figure 20).

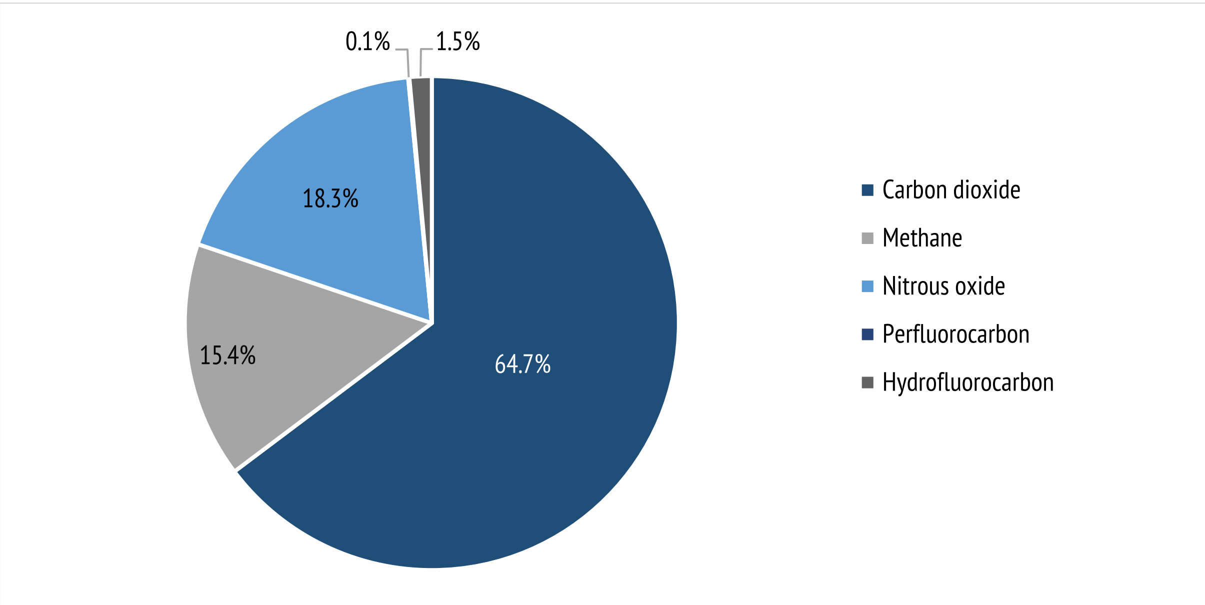

Figure 20: Share of the total national emissions in 2016 by gases

When the emissions from FOLU are excluded from the national totals, CO_2 still constituted almost half (49.2% - 14.41 Mt) of the total emissions in the same year. Nitrous oxide is the second important GHG in Ghana and constitutes 26.3% (7.71 $MtCO_2e$) of the total emissions. Methane levels made up 22.2% (6.51 $MtCO_2e$) of all the emissions (Table 16). The rest were HFCs emissions (2.1% - 0.61 $MtCO_2e$) and PFC (0.1% - 0.03 $MtCO_2e$). Overall, the total CO_2 emissions showed an upward trend and grew at a rate of 1.9% in the same period. Particularly for the period 2012-2016, CO_2 emissions recorded an average 6.1% increase. The rising trends in CO_2 emissions are associated with increasing CO_2 emissions from energy industries, transport, and land-use change (Figure 21). The spike in the emissions between 2007 and 2009, was due to the high consumption of crude oil for electricity generation during the electricity crisis.

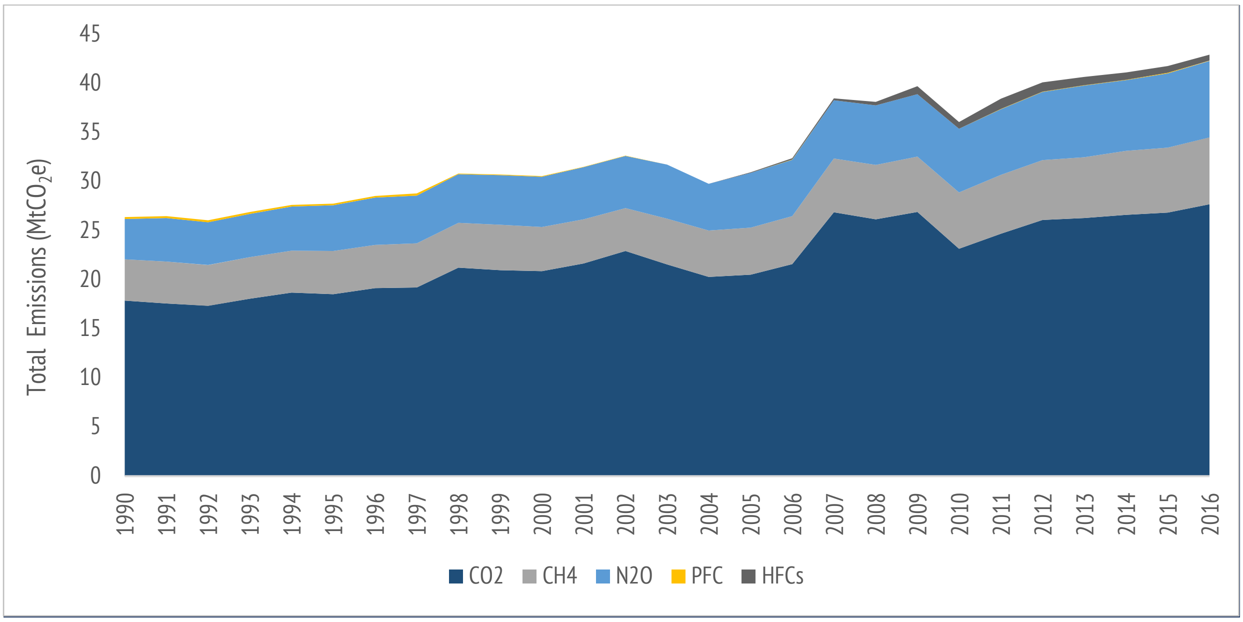

Figure 21: Trends of emissions by gases for the period 1990 to 2016

In the same vein, nitrous oxide emissions patterns exhibited a rising trend from 1990 to 2016 at a 2.6% growth rate per annum. Compared to 2012 levels, nitrous oxide emissions went up by 11.8% in 2016. A critical driver of N_2O emissions relates to multiple sources of nitrogen accumulation in soils from the application of synthetic fertilisers, crop residues, organic fertiliser, and land-use change and management. Methane was the third commonest GHG in Ghana and recorded a growth rate of 1.8% per annum over the 26 years. Between 2012 and 2016, CH_4 levels grew by 12.8% from 5.57 $MtCO_2e$ in 2012 to 6.51 $MtCO_2e$ in 2016. The majority 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 essential type of greenhouse emission in Ghana. It mainly comes from the industrial operations of VALCO. The level of PFC emission has steadily declined at an annual rate of 6.9% from 0.2 $MtCO_2e$ in 1990 to 0.03 $MtCO_2e$ in 2016. The operational capacity of the VALCO Aluminum Plant influenced the downward trend of PFC. The gases used in refrigerators and air-conditioners are the primary source of HFCs. The imports are for use in stationary and mobile air-conditioning and refrigerating appliances. In the national inventory, Ghana reported HFC emissions from 2005 to 2016. Between 2012 and 2016, the HFCs saw a considerable decrease of 35.9%. The HFCs between 2012 and 2016 has seen a considerable decrease of 35.9%. The notable inter-annual variations in the emissions were due to the fluctuations in the imports of HFC when Ghana started to implement measures to phase-out ODS.

3.3.3.1 Carbon dioxide emissions

Total CO_2 emissions grew from 16.83 Mt in 1990 to 27.29 Mt in 2016. The Energy and AFOLU sectors were the principal sources of CO_2 emissions mainly from fossil fuel combustion and land-use change. While CO_2 in the energy sector saw a four hundred-fold increment (from 2.52 Mt to 13.97 Mt), that of the AFOLU sector dropped by 7.9% from 14.02 Mt in 1990 to 12.91 Mt in 2016. The energy sector CO_2 emissions increased by 15% for the period 2012-2016, and AFOLU CO_2 slightly declined by nearly 1% in the same period (Figure 22).

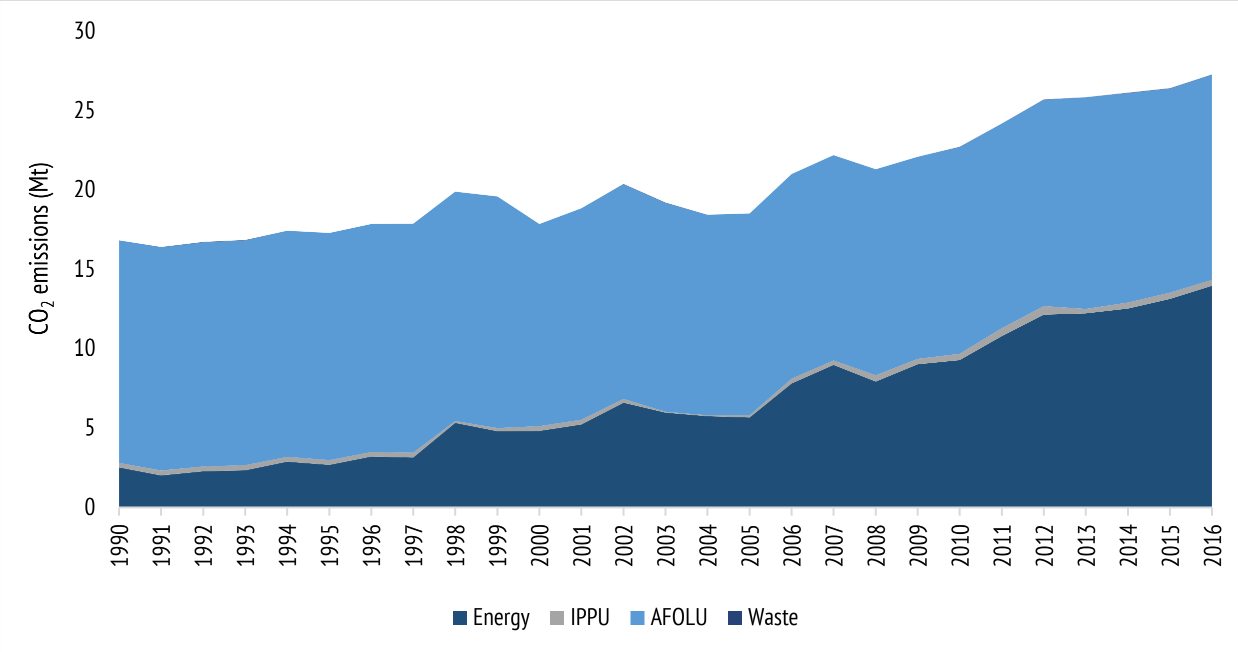

Figure 22: Trends of net carbon dioxide emissions per sector

3.3.3.1.1 Carbon dioxide emissions comparison using reference approach and sectoral approach

The Reference Approach (RA) is a top-down approach which uses Ghana's total energy supply data to calculate CO_2 emissions from combustion of mainly liquid and gaseous fuels. The RA does not distinguish between different source categories within the energy sector but only estimates total CO_2 emissions from the fuel combustion (1A) source category. On the other 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 how the individual fuels were used in each category. 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, excluded carbon calculation. Typically, the gap between the two approaches is relatively small (5% or less) when compared to the total carbon flows involved. Therefore, explanations should be provided when the difference is more than 5%.

3.3.3.1.2 Comparison of CO_2 emissions in the energy sector

The comparison and the reasons accounting for the differences between CO_2 emissions estimated using RA and SA have been provided below in Table 10. The differences in CO_2 emissions between RA and SA ranges from 0.4% to 4.6%. Generally, estimates for RA CO_2 emissions are higher than SA CO_2 emissions. The following reasons

explain the inconsistencies in RA and SA CO_2 emissions: (a) statistical differences among petroleum products and biomass (b) observed variations associated with secondary data used to derive the stock change.
Steps are underway to improve fuel allocation formulae in the energy balance and expected to correct some of the identified inconsistencies below.

Table 10: Differences in Carbon dioxide emissions by RA and SA

Year	Reference Approach ($MtCO_2$)			Sectoral Approach ($MtCO_2$)			Differences (%)			
	Liquid	Solid	Gaseous	Liquid	Solid	Gaseous	Liquid	Solid	Gaseous	Total
1990	2.61	-	-	2.52	-	-	3.62%	-	-	3.62%
1991	2.10	-	-	2.02	-	-	3.78%	-	-	3.78%
1992	2.38	-	-	2.28	-	-	4.37%	-	-	4.37%
1993	2.38	-	-	2.33	-	-	2.01%	-	-	2.01%
1994	2.88	-	-	2.86	-	-	0.87%	-	-	0.87%
1995	2.72	-	-	2.67	-	-	1.87%	-	-	1.87%
1996	3.40	-	-	3.30	-	-	2.89%	-	-	2.89%
1997	3.35	-	-	3.25	-	-	3.16%	-	-	3.16%
1998	5.51	-	-	5.32	-	-	3.63%	-	-	3.63%
1999	5.08	-	-	4.88	-	-	4.14%	-	-	4.14%
2000	5.10	-	-	4.99	-	-	2.19%	-	-	2.19%
2001	5.65	-	-	5.36	-	-	5.47%	-	-	5.47%
2002	7.01	0.02	-	6.69	0.02	-	4.74%	0.03%	-	4.78%
2003	6.09	0.03	-	6.07	0.03	-	0.40%	0.03%	-	0.44%
2004	6.02	0.03	-	5.81	0.03	-	3.53%	0.03%	-	3.56%
2005	5.72	0.03	-	5.69	0.03	-	0.47%	0.03%	-	0.51%
2006	8.20	0.01	-	7.87	0.01	-	4.22%	0.03%	-	4.25%
2007	9.10	0.04	-	8.92	0.04	-	2.03%	0.03%	-	2.06%
2008	8.10	0.03	-	7.93	0.03	-	2.14%	0.03%	-	2.18%
2009	8.89	0.01	-	8.85	0.01	-	0.49%	0.03%	-	0.52%
2010	8.55	0.02	0.82	8.45	0.02	0.80	1.21%	0.03%	3.56%	4.81%
2011	9.30	0.02	1.81	8.92	0.02	1.81	4.22%	0.03%	0.06%	4.32%
2012	11.36	0.01	0.94	11.16	0.01	0.93	1.77%	0.03%	0.72%	2.52%
2013	11.77	0.01	0.68	11.49	0.01	0.68	2.48%	0.03%	0.82%	3.34%
2014	11.20	0.002	1.49	11.00	0.002	1.47	1.82%	0.03%	1.88%	3.73%
2015	10.36	0.003	2.68	10.30	0.003	2.62	0.56%	0.03%	2.46%	3.06%
2016	12.16	0.02	1.62	12.06	0.02	1.60	0.81%	0.03%	1.04%	1.88%

Some specific explanations on the differences between CO_2 emissions for the major fuels are provided below:

- The national energy balance was based on mass-balanced and not carbon balanced. That approach introduced inherent inconsistencies 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, and consumption and ending stocks figures. Because most of the data on stock changes were not reported in the energy balance calculated and, there was a possibility of overestimations or underestimations.
- Kerosene – RA and SA excluded CO_2 emissions from non-energy use of kerosene in the industrial process.

3.3.3.2 Nitrous oxide emissions

Apart from the IPPU sector, nitrous oxide emissions occurred in AFOLU, waste, and the energy sectors. The N_2O emissions saw notable increment from 4.09 $MtCO_2e$ in 1990 to 7.1 $MtCO_2e$ in 2016 with the AFOLU sector being the dominant source. Within the AFOLU sector, direct and indirect N_2O emissions from managed soils (3.C4, 3.C5 and 3.C6) accounted for 86% of the N_2O emissions (Figure 23) in 2016. The remaining 14% came from livestock rearing. Besides the AFOLU sector, relatively smaller quantities of N_2O emissions were from the waste and energy sectors. In the waste sector, open burning was a significant source of N_2O while for the Energy sector, other sectors and road transport accounted for most of the emissions.

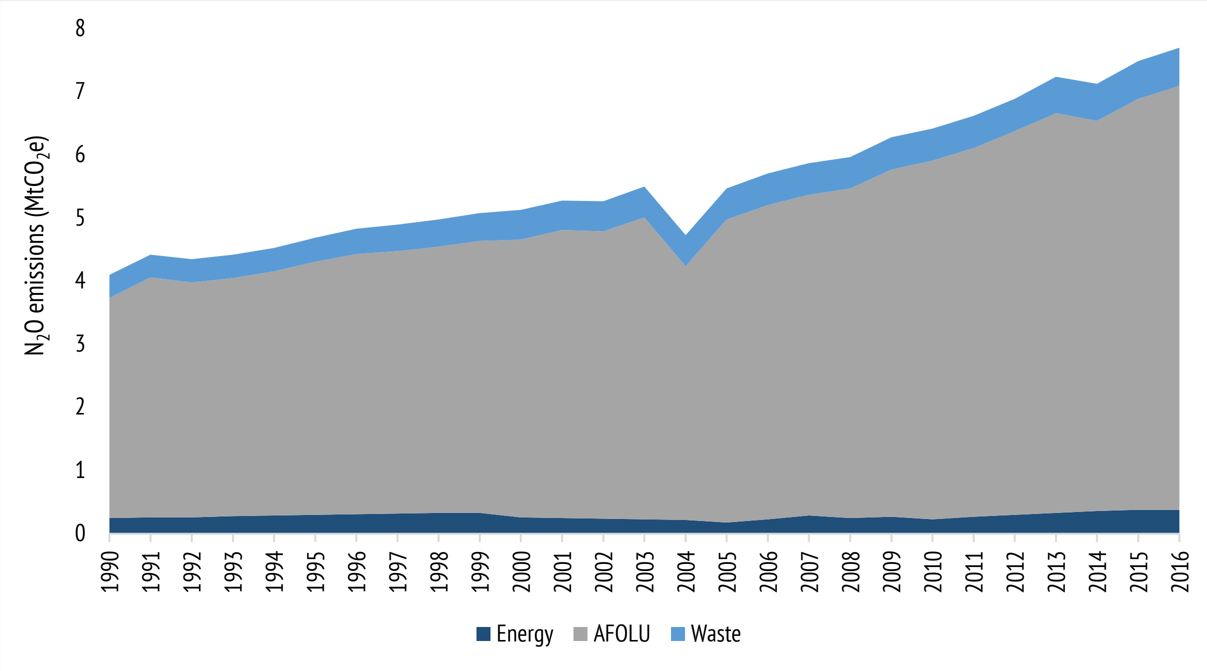

Figure 23: Trends of nitrous oxide emissions per sector

3.3.3.3 Methane emissions

From 1990 to 2016, methane emissions increased by 54.8%, with the majority coming from the AFOLU and Waste sectors (Figure 23). Methane emissions for the periods 2012-2016 also went up by 9.5%. The AFOLU and Waste sectors were the two dominant sources of methane, and they both correspondingly account for 50.6% and 39.3% of the total methane emissions. In the AFOLU sector, the emissions from enteric fermentation and manure management were the dominant sources of methane. For the waste sector, most of the methane emissions were from wastewater treatment and discharge and solid waste disposal.

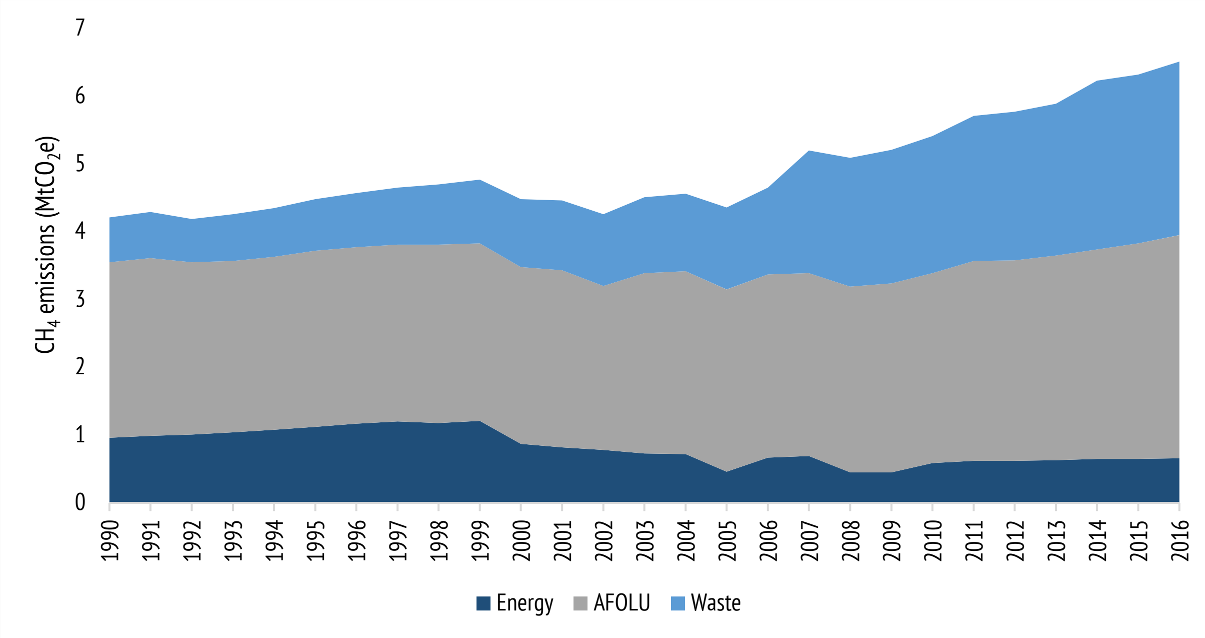

Figure 24: Trends of methane emissions per sector

3.3.3.4 Perfluorocarbon emissions

Perfluorocarbons are industrial emissions from technology used in the primary aluminium production by VALCO during anode effects. Apart from the fact that PFCs emissions generally depicted a declining trend (-83% between 1999-2016), there were years (2002, 2003, 2009, and 2010) that the emissions were completely missing because the aluminium plant (VALCO) was not operating at all (Figure 25). Since VALCO resumed limited operations (running a single pot), PFC emissions have increased a hundredfold between 2012 and 2016. The extent of VALCO's operations largely determined the emissions trends.

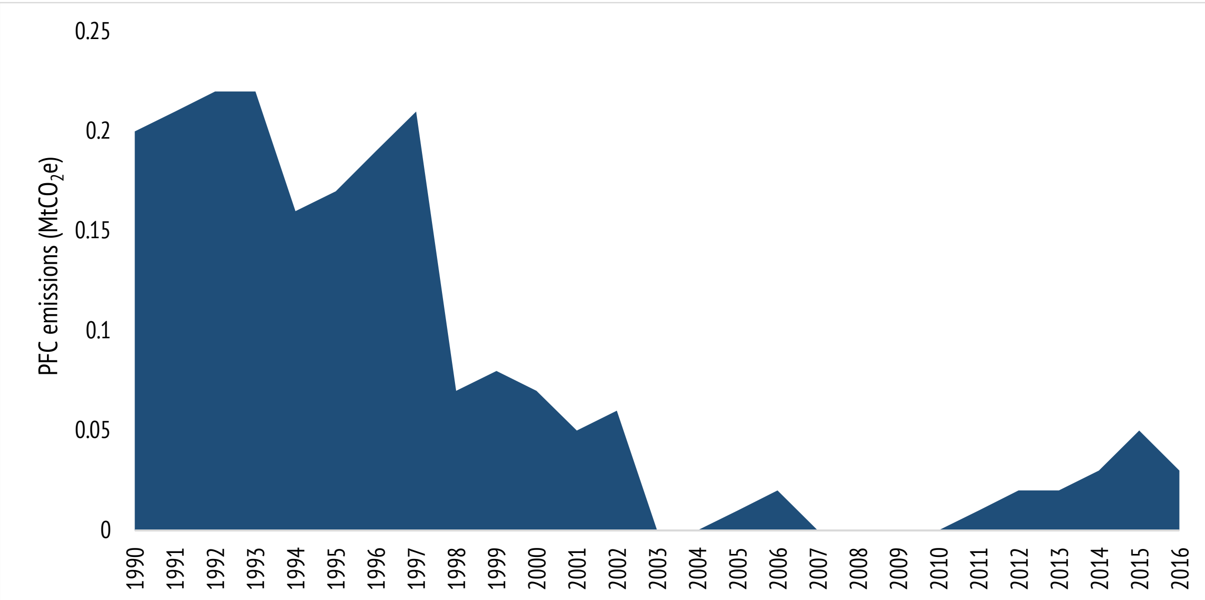

Figure 25: Trends of perfluorocarbon emissions per sector

3.3.3.5 Hydrofluorocarbons emissions

NC4 marks the first time Ghana is reporting on HFC emissions after EPA published a national survey report on HFC in 2017. With the available survey data, it was possible to estimate HFC emissions from stationary refrigeration and air-conditioning appliances. The HFC emissions increased from 0.1 $MtCO_2e$ (2005) until it peaked in 2011 (1.1 $MtCO_2e$) and started dipping afterwards to 0.6 $MtCO_2e$ in 2016 (Table 26).

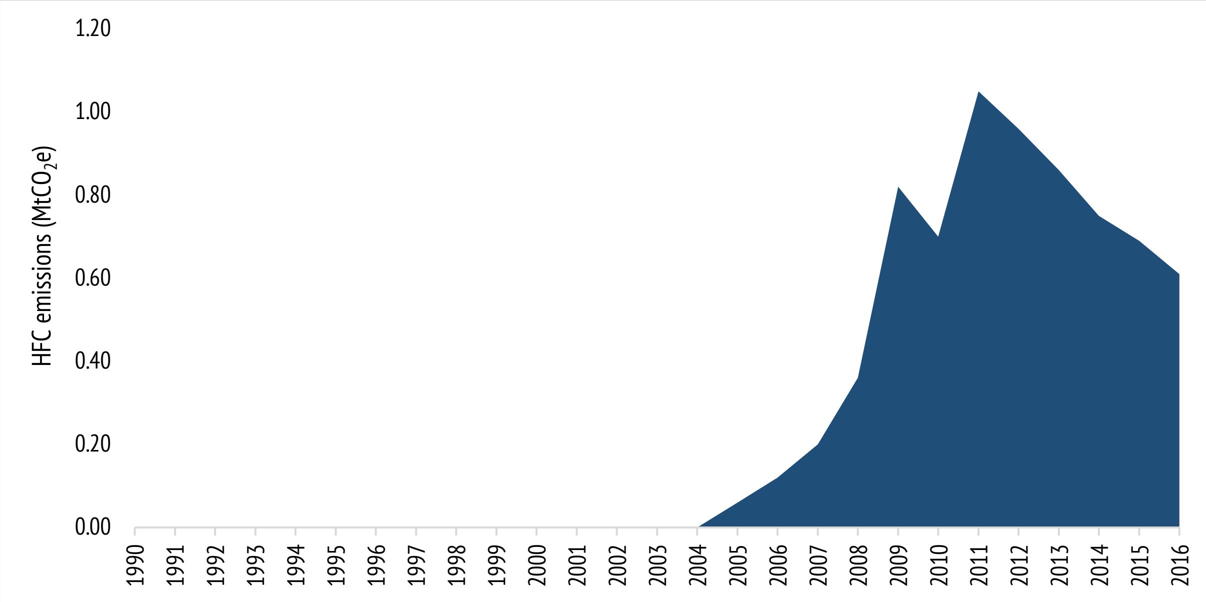

Figure 26: Trends of Hydrofluorocarbon emissions per sector

3.3.3.6 Precursors and indirect emissions

3.3.4 Short-Lived Climate Pollutants

Short-Lived Climate Pollutants (SLCPs) are potent GHGs and local air pollutants and are emitted through similar economic activities as the GHGs. Tackling SLCPs emission has a global climate and local air quality benefits. Therefore, Ghana has reported on an inventory of GHG and SLCPs covering CH_4, BC and HFC for the period 1990-2016. Figure 27 is a chart showing the trend in SLCP emissions for 1990-2016.

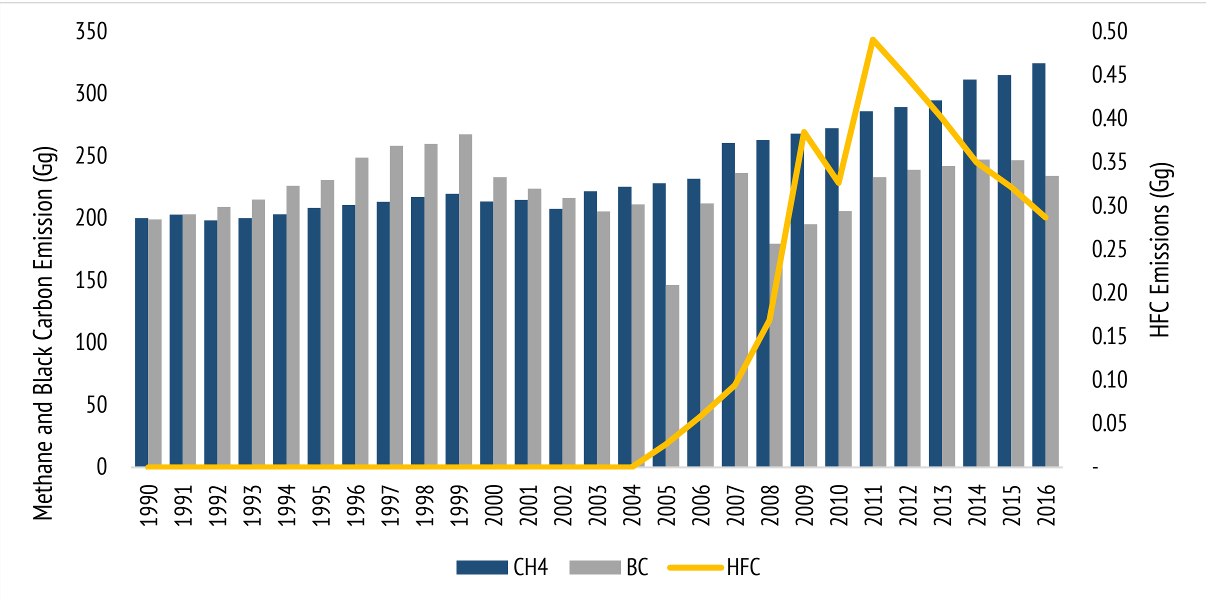

Figure 27: SLCPs emission trends for the period 1990-2016

In 2016, the methane emissions level was 324.66 Gg and, the majority (48%) of which came from livestock enteric fermentation and manure management. The waste sector was the second-largest source of methane constituting 38% of the total national emissions. Within the waste sector, municipal solid waste disposal and domestic wastewater were the primary sources of methane whereas, under the energy sector, residential cooking with solid biomass contributed most to methane emissions. Black carbon levels increased from 199.29 Gg in 1990 to 234.28 Gg in 2016, and almost all of BC emissions came from the Energy sector. Under the IPPU, Products Use as Substitutes for ODS was the only source of HFC emissions.

3.3.4.1 Precursor and local air pollutants

Consistent with the IPCC Guidelines, emissions of some precursor 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. It is noteworthy that these estimates do not replace the measured local air pollutants that are usually published by the Environmental Quality Department of EPA for different locations at the city level but are an essential complement to them. The measurements of air pollution at monitoring sites provide an estimate of the concentration of air pollutants at specific locations resulting from all sources. At the same time, the information in this report are estimates of the emissions of air pollutants from emission sources. Table 11 shows the trends of NOx, CO, BC, NMVOCs and $PM_{2.5}$ emissions for the period 1990-2016. Except for CO that saw a decline, the rest of the pollutants showed a rising pattern.

Nitrogen oxides are a group of poisonous, highly reactive gases. NOx gases form when fuel is burnt at high temperatures[69]. In 2016, most (80.4%) of the NOx emissions came from the energy sector through the burning of fossil fuels. The remaining 19.6% were from the burning activities in the AFOLU (18%) and waste (1.7%) sectors respectively. Between 1990 and 2016, NOx emission levels increased by 21.6%. Carbon monoxide (CO) is a common industrial hazard resulting from the incomplete burning of natural gas and any other material containing carbon such as gasoline, kerosene or wood.

Table 11: Trends of selected precursor and local air pollutants for the period 1990-2016

Year	Gg/Year				
	NOx	CO	BC	NMVOC	$PM_{2.5}$
1990	100.64	2,279.92	199.29	282.05	561.10
1991	97.54	2,281.99	203.43	291.18	576.20
1992	98.67	2,267.03	209.21	297.60	594.60
1993	97.24	2,291.83	215.24	310.25	608.57
1994	99.89	2,308.31	226.28	322.26	632.13
1995	97.50	2,310.02	230.89	332.81	652.13
1996	102.80	2,319.93	248.88	345.55	674.32
1997	101.57	2,334.33	258.41	359.58	701.82
1998	106.66	2,291.51	259.77	352.33	689.57
1999	106.76	2,278.42	267.66	357.98	698.62
2000	112.78	2,134.15	233.03	267.32	546.71
2001	111.64	2,070.30	223.94	253.37	526.07
2002	111.98	2,004.48	216.39	240.64	509.61
2003	104.36	1,903.41	205.64	223.73	499.30
2004	109.42	1.891.82	211.28	220.76	502.79
2005	96.87	1,730.13	146.64	172.58	367.50
2006	113.58	1,861.65	212.20	234.05	517.89

[69] https://www3.epa.gov/region1/airquality/nox.html

2007	121.23	1,973.53	236.60	248.32	517.74
2008	111.11	1,707.92	179.76	205.72	373.44
2009	119.37	1,734.54	195.38	219.73	401.44
2010	114.79	1,745.38	205.79	237.53	519.99
2011	127.09	1,816.14	233.10	250.94	561.45
2012	131.59	1,815.05	239.18	257.11	575.90
2013	128.51	1,827.43	242.05	265.92	582.34
2014	130.38	1,847.26	247.37	274.91	610.98
2015	127.83	1,804.80	246.90	274.63	625.47
2016	122.42	1,767.67	234.28	271.84	605.20

Most of the CO emissions were from the energy sector (69.2%) and followed by the AFOLU (29.9%) and waste (0.9%) sectors. The patterns of CO emissions indicated a steady decline of 22.5% between 1990 and 2016. Black carbon is a constituent of $PM_{2.5}$ and is produced from the incomplete burning of fossil fuels and biomass. The inventory estimates total black carbon emission in Ghana to be 234.3 Gg in 2016, mainly from road transport and residential cooking activities under the sector. The 2016 BC emission was 7.6% higher than the 1990 levels and increased at a 0.6% annual growth rate. $PM_{2.5}$ 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 located in strategic locations along roadsides, residential, commercial and industrial areas.

The $PM_{2.5}$ levels measured at these sites are the result of emissions of different pollutants, including primary $PM_{2.5}$ emissions, but also emissions of 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 is to complement 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 2016, a total of 605.2 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 from open burning in the Waste sectors.

3.4 Cross-Cutting Issues in Greenhouse Gas inventory

3.4.1 Key Category Analysis

Key category analysis was performed to identify the main activities that contributed most to the emissions/removals for a given year or across the entire time series. The 2006 IPCC Guidelines provides 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/removals, or both. In this inventory, the identification of key categories has been performed using the tier 1 level and trend assessments, as recommended in the 2006 IPCC Guidelines. This approach identifies sources/removals that amount to 95% of the total emissions or 95% of the trend of the inventory in absolute terms.

The methods used for the identification of the key categories were the level assessment for 2000 and 2016, and trend assessment for 2016, and 2000. The results of the key category analysis are presented as with and without the FOLU[70] category.

3.4.1.1 Key category analysis results

In 2016, 20 key categories were identified using the level assessment (L) with an aggregate emission of 40.1 $MtCO_2e$ (Table 12) amounting to 93% of the national totals. Out of the 20 identified key categories, 9 of them were sources of CO_2 emissions and contributed most to the key category emissions. The CO_2 levels were followed by CH_4 and N_2O with five each and then by HFC. Without FOLU, the key categories analysis identified 17 activities with emissions totalling 45.3 $MtCO_2e$. For the trend assessment (T) of KCA, 20 categories were identified (Table 13). For both L and T assessments, the categories with CO_2 emissions dominated followed by CH_4 and then N_2O. Some of the categories that emerged from L and T assessments are as follows: (a) Electricity generation (1. A1ai), (b) land converted to cropland (3B2.b), (c) land converted to grassland (3B3.b), (d) manufacturing industries and construction (1A2), (e) road transportation (1A3b), (f) wastewater treatment and discharge (4D). Most of the key categories identified in the level and trend assessment are in the Energy and AFOLU sectors. It is also important to note that CO_2 emissions are the dominant pollutant for the categories under L and T assessments (Table 14).

Table 12: Level assessment key categories in 2016

IPCC Category	Gas	Emissions/Removals ($MtCO_2e$)	Contribution to level	Cumulative
3.B.2.b - Land Converted to Cropland	CO_2	8.84.	16.59%	16.59%
3.B.3.b - Land Converted to Grassland	CO_2	8.80	16.53%	33.12%
1.A.3.b - Road Transportation	CO_2	5.92	11.11%	44.23%
1.A.1ai – Electricity generation	CO_2	5.04	9.46%	53.69%
3.C.4 - Direct N_2O Emissions from managed soils	N_2O	4.14	7.78%	61.46%
3.B.1.a - Forest land Remaining Forest land (net sink)	CO_2	-3.56	6.69%	68.15%
3.A.1 - Enteric Fermentation	CH_4	2.41	4.52%	72.67%
1.A.2 - Manufacturing Industries and Construction	CO_2	1.94	3.64%	76.31%
4.D - Wastewater Treatment and Discharge	CH_4	1.29	2.43%	78.74%
3.C.5 - Indirect N_2O Emissions from managed soils	N_2O	1.14	2.14%	80.89%
3.B.1.b - Land Converted to Forest land (net sink)	CO_2	-1.11	2.08%	82.96%
1.A.3.c - Railways	CO_2	0.94	1.77%	84.73%
3.A.2 - Manure Management	N_2O	0.94	1.76%	86.49%
4.A.1 - Managed Waste Disposal Sites	CH_4	0.92	1.73%	88.23%
1.A.4.b - Residential	CH_4	0.85	1.59%	89.82%
2.F.1 - Refrigeration and Air Conditioning	HFC	0.61	1.15%	90.97%
4.D - Wastewater Treatment and Discharge	N_2O	0.54	1.02%	91.98%
3.C.1 - Emissions from biomass burning	CH_4	0.53	0.99%	92.98%
3.B.2.a - Cropland Remaining Cropland	CO_2	-0.51	0.95%	93.93%
3.C.1 - Emissions from biomass burning	N_2O	0.44	0.83%	94.76%

[70] FOLU – Forestry and Other Land Use. Excludes emissions from Agriculture source categories (such as livestock), and includes emissions and removals from forest and other land use types

Table 13: Trends assessment key categories for the period 2000-2016

Category	Gas	Emissions/Removals ($MtCO_2e$)		Trend Assessment (Tx,t)	Contribution to trend (%)	Cumulative
		2000	2016			
1.A.1ai – Electricity generation	CO_2	0.55	5.04	0.11	19.0%	19.0%
1.A.2 - Manufacturing Industries and Construction	CO_2	3.74	1.94	0.07	12.0%	31.0%
3.B.2.b - Land Converted to Cropland	CO_2	8.84	8.84	0.05	9.9%	40.9%
3.B.3.b - Land Converted to Grassland	CO_2	8.80	8.80	0.05	9.8%	50.7%
1.A.3.b - Road Transportation	CO_2	3.04	5.92	0.05	9.2%	59.9%
3.C.4 - Direct N_2O Emissions from managed soils	N_2O	2.25	4.14	0.03	5.8%	65.7%
3.B.1.a - Forest land Remaining Forest land	CO_2	3.71	3.56	0.03	4.8%	70.5%
1.A.3.c - Railways	CO_2	0.04	0.94	0.02	3.9%	74.4%
3.C.1 - Emissions from biomass burning	N_2O	0.933	0.44	0.02	3.2%	77.6%
4.D - Wastewater Treatment and Discharge	CH_4	0.46	1.29	0.02	3.1%	80.7%
3.C.1 - Emissions from biomass burning	CH_4	0.99	0.53	0.02	3.1%	83.8%
3.A.1 - Enteric Fermentation	CH_4	1.47	2.41	0.01	2.5%	86.3%
3.C.5 - Indirect N_2O Emissions from managed soils	N_2O	0.61	1.14	0.01	1.7%	88.0%
4.A.2 - Unmanaged Waste Disposal Sites	CH_4	0.48	0.23	0.01	1.6%	89.6%
3.B.1.b - Land Converted to Forest land	CO_2	1.10	1.11	0.01	1.2%	90.8%
2.A.4 - Other Process Uses of Carbonates	CO_2	0.04	0.31	0.01	1.1%	91.9%
2.C.3 - Aluminium production	CO_2	0.24	0.055	0.01	1.1%	93.0%
3.A.2 - Manure Management	N_2O	0.57	0.94	0.01	1.0%	94.0%
1.A.4.b - Residential	CO_2	0.19	0.03	0.01	0.9%	94.9%
3.B.2.a - Cropland Remaining Cropland	CO_2	0.51	0.51	0.00	0.6%	95.5%

Table 14: Status of level and trend key category assessment

Category	Level assessment (L)	Trend assessment (T)
Electricity generation	L	T
Manufacturing Industries and Construction	L	T
Land converted to cropland	L	T
Land converted to grassland	L	T
Road transportation	L	T
Direct N_2O emissions from managed soils	L	T
Forest land remaining forest land (net sink)	L	T
Railways	L	T
Emissions from biomass burning (CH_4)	L	T
Wastewater treatment and discharge	L	T
Emissions from biomass burning (N_2O)	L	T
Enteric fermentation	L	T
Indirect N_2O Emissions from managed soils	L	T
Unmanaged waste disposal sites		T
Managed waste disposal sites	L	
Land converted to Forest land (net sink)	L	T
Other process uses of carbonates		T
Aluminium production		T
Manure management	L	T
Residential	L	T
Cropland remaining cropland	L	T
Refrigeration and air conditioning	L	

3.4.2 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, which means that as far as possible, the time series should be calculated using the same method and data sources in all years. Using different methods and data in a time series could introduce bias because the estimated emission trend reflects not only real changes in emissions or removals but also the pattern of methodological refinements."

3.4.2.1 Description of recalculations

In ensuring time-series consistency for the inventory period 1990-2016, recalculations were performed on the 1990-2012 estimates. The reasons for the recalculations were mainly due to methodological changes and refinement and the addition of new categories in the inventory. The general reasons for the recalculations have been provided in Table 15.

Table 15: Summary of the recalculations and the underlying reasons for each

Inventory sector	Category	Key reasons for the recalculations	Recalculation tasks
All sectors	All categories	Addition of new categories and methodological changes and refinement	Changes in methodology and the inclusion of extra data due to the use of the 2006 Guidelines
Energy	Manufacture of solid fuel (1A1c)	Addition of new categories	Inclusion of new activity data on the manufacture of charcoal.
	Other sectors (1A4)	Availability of new dataset	Revisions in solid biomass (firewood and charcoal) activity data for 2006-2012.
	Fuel combustion (1A)	Availability of new dataset	Changes in the activity data on fuel balance due to the revisions in the energy balance.
IPPU	Product Uses as substitutes for ODS (2F)	Addition of new categories	Inclusion of newly available HFC consumption figures from 2005 to 2012.
	Lubricant use (2D1)	Availability of new dataset	Changes in activity data on lubricant due to new dataset from companies.
AFOLU	Land (3B)	Methodological changes and refinement	Availability of new and more accurate land-use change matrix for the period 1990-2012
			Changes in timber harvesting figures due to the use of new bottom-up data collection methodology.
			Revision and changes of areas affected by fires due to the use of MODIS fire dataset.
		Addition of new categories	Inclusion of new plantation areas and further categorisation into the teak and non-teak species.
		Methodological changes and refinement correction of errors.	Revision of fuelwood harvesting figures due to the changes in the energy statistics.
		Choice of emission factors	Changes in aboveground net biomass growth in natural forests from 4.7 tonnes d.m/ha/yr. to 1.6 tonnes d.m/ha/yr.
Waste	Solid waste disposal (4A)	Changes in the solid waste dataset	Revision of solid waste generation, collection and disposal dataset.

The recalculations led to an average 72% increase in the previous emissions trends for 1990-2012. The most significant difference of 159% was recorded in 1991 and the least increase of 19% in 2012(Figure 28).

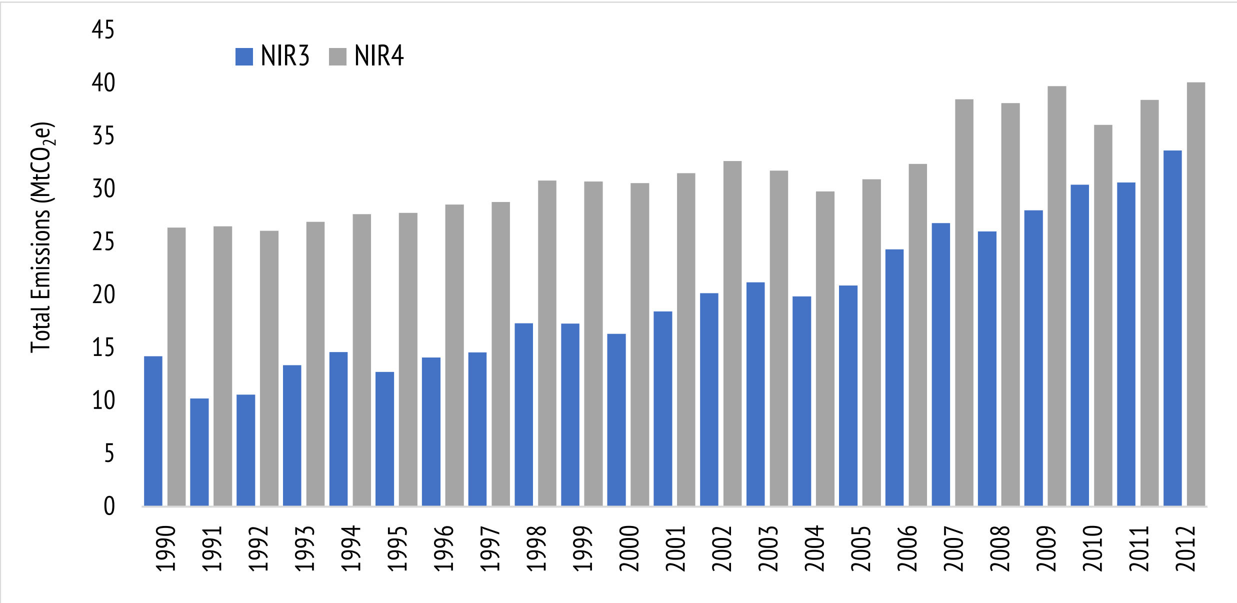

Figure 28: Comparison of total national emission trends in NIR3 and NIR4 as a result recalculation

3.4.2.2 Filling of time series gaps

In the inventory where we observed time series data gaps across the inventory years, interpolation and extrapolation techniques were used to resolve them. Table 16 contains the list of categories of interpolation and extrapolation techniques that have been used to fill time series gaps.

Table 16: Techniques used to fill time series data gaps

Sector	Category	Activity data	Type of Technique used
AFOLU	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
		20-year time points	Extrapolation
	Land – areas affected by fire	1991-1999 missing, 2001-2009, 2011-2014	Interpolation
	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

3.4.3 Quality Assurance/Quality Control procedures

The NIR4 comprehensively elaborates the QA/QC procedures under the sector chapters. Thus, this report provides a broad outlook of the QA/QC procedures across the inventory. It touches on the current state, institutional roles, general and specific processes, challenges and the improvement strategies. QA/QC is an integral part of the national system, and broadly consistent with the good practices in the 2006 IPCC Guidelines. Ghana uses the US EPA QA/QC template[71] to report on the QA/QC procedures for the inventory. Furthermore, the team followed the Forestry Commissions' twelve Standard Operating Procedures (SOPs) to guide QA/QC practices in the land category. The SOPs were useful in the planning and designing of the data collection techniques for activity data and emission factors (biomass inventory)[72]. Despite making progress in the improvement of QA/QC procedures; 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
- data restriction and confidential data
- non-standardised application of experts' judgement
- the use of tier 1 or default emission factors for the list of key categories

To address the challenges, Ghana has also adopted a country-specific QA/QC plan and GHG inventory manual[73]. The GHG plan clearly articulates the inventory steps, institutional responsibilities and timelines. The recommendations in the plan inform the training of existing experts. The QA/QC manual 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 are to ensure that the inventory system and estimates emerging from them are more transparent, credible and defensible.

3.4.3.1 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 17.

Table 17: List of QC procedures followed in the inventory

QC Tasks	Details of QC Tasks	Responsibility
Internal consistency	Ensured that the total GHG emissions equalled the sum of the individual emissions from the sectors and categories.	EPA
	Confirmed total GHG emissions equalled the sum of the emissions by gas.	EPA
	Ensured that parameters used in multiple categories (e.g., the population of livestock) are consistent across categories.	EPA
	Confirmed that the emissions data is reported in a manner consistent with the calculation tables in the Non-Annex 1 National Communications Reporting Guidelines.	EPA
	It was confirmed that the selection and application of the estimation methods were consistent with IPCC Guidelines.	EPA

[71] https://www.epa.gov/climatechange/Downloads/EPAactivities/Complete%20Template%20Workbook.doc

[72] http://fcghana.org/userfiles/files/REDD%2B/Ghana%20MRV%20Final%20Report%20(ID%2067024).pdf.

[73] http://www.gh.undp.org/content/dam/ghana/docs/Doc/SUS$ev/LECBP_National%20GHG%20Inventory%20%20Manual_revised_v2.pdf.

Documentation	Created back-ups of all documentation in hard and soft copies and uploaded files on to a 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
	Checked that the parameters and emission/removal units are recorded correctly, and that appropriate conversion factors are used.	EPA
	Checked for transcription errors in data input and reference.	EPA
	Checked for methodological, and data changes are resulting in recalculations.	EPA
	Checked that emissions/removals are calculated correctly.	EPA
	Compared current inventory estimates to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain any difference. Substantial changes in emissions or removals from previous years may indicate possible input or calculation errors	EPA
	Checked that emissions/removals data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries.	EPA
	Checked that data in tables are the same as the calculation in spreadsheets and the text.	EPA
	Checked if there were any unusual or unexplained trends noticed for activity data or other parameters across the time series.	EPA

3.4.2.2 QA Procedures

Quality Assurance measures are an essential part of the overall QA/QC procedures. The QA procedures allow experts who have not been directly involved in the inventory to scrutinise the inventory system and the emission estimate to provide comments. Ghana has undertaken extensive technical reviews of the inventory, and afterwards, documented the status of addressing the comments using the “issue-tracking template”.

3.4.2.2.1 Third-Party review of the inventory

After the team finishes putting together inventory figures, the inventory manager compiles from the dataset. Then, the NIR, the datasheet and all related documentation undergo an extensive third-party review both in Ghana and at the international level. During this round of inventory preparation, the first-ever voluntary in-country review was organised together with the Convention’s Secretariat. Besides, several international experts reviewed the draft NIR, and the team addressed the issues raised before submission to the Secretariat of the Convention. Furthermore, national stakeholders provided input into the draft inventory at a workshop.

3.4.2.2.2 Voluntary UNFCCC in-country review

Ghana was the first African country to undergo a voluntary in-country review of the National GHG Inventory Management System and National GHG Inventories of Ghana on 19-23 March 2018. The review was organised by the UNFCCC secretariat with support from the Global Support Programme, UNDP. Ghana responded positively to participate in a voluntary in-country review when it received an official invitation from the Convention in November 2017. Afterwards, the Ghana team, the Convention’s Secretariat and the GSP, started to work out the full details of the review modalities covering planning, selection of international review experts, data review exchanges, review week modalities and considerations of review outputs.

3.4.4 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. The physical measurements or modelling to generate activity data and emission factors carry a wide range of errors. Additionally, using expert judgments to fill time series gaps, select default activity data and emission factor, all add on to the uncertainty levels of the inventory. The 2006 IPCC Guidelines provide methods for assessing the overall uncertainties and report as well as the strategy to reduce their effects on the final emissions. The IPCC guidelines require that the inventory estimates must be published 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 AFOLU section of the NIR.

However, Ghana is unable to report on the uncertainty range for the other sectors because there is no credible basis to assign default range of uncertainty in the IPCC software due to the absence of requisite metadata, 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. Therefore, 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, Ghana plans to work closely with the Mathematics Department of KNUST and the Department of Statistics of the University of Ghana to come up with a practical approach to statistically quantify uncertainty levels associated with inventory and report on the progress in the next NIR.

3.4.5 General Assessment Completeness

According to the IPCC Guidelines, it is good practice to assess the completeness of inventory in terms of its geographic coverage, scope (sectors and gases included, missing or non-applicable) and the time series. Therefore, the sector assessment of completeness is part of this report. An overview of the inventory completeness is in Table 18.

Table 18: Overview of the general assessment of completeness

Completeness variable	Status	Comments
Geographic coverage	Nation-wide	The inventory covered the entire territorial boundary of the Republic of Ghana. Thus, none of the 16 administrative regions in Ghana has been left uncovered by the inventory.
Sectors (Identified sources and sinks)	4 IPCC sectors – economy-wide	All sources or removals of direct GHG gases that are associated with activities occurring in Ghana, outlined in the 2006 IPCC Guidelines, were covered in the inventory except the following activities which were considered insignificant or where there is no data: • 1B.2a.iii.5 – Distribution of oil products • 3D.i – Harvested wood products • 2G – SF6 electrical equipment; N_2O for medical applications. • 1B.2a.iii.5 – Distribution of oil products The emission inventory does not include activities that are not captured in the official records published by State institutions. For example, unreported fuel use, household animals that are not captured in the livestock census and unaccounted 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. SF_6 has not been considered in this inventory due to data unavailability. Also, SLCPs and local pollutants such as BC, CO, NMVOCs, Nox and $PM_{2.5}$ have been included in the inventory.

Time-series	26 years	Time series range – 1990 to 2016 Base year – 2010 Previous reporting year – 2012 Latest report year – 2016
Notation keys	-	Categories and gases where emissions are: • Not estimated (NE) • Not occurring (NO) • Included Elsewhere (IE) • Confidential © • Not Applicable

3.4.6 Planned Improvements

During the inventory, certain areas were identified for future improvements to ensure building greater confidence into the inventory estimation by reducing uncertainties to the extent possible. Tables 19, 20, 21 and 22 provide the list of identified planned improvement activities and the next steps that must be taken.

Table 19: Planned improvement activities in the Energy sector

Category	Identification of planned improvement areas	Prioritisation of improvement activities	Responsibility and next steps	Expected time to resolve
1.A1b – Electricity generation	Develop or request IPPs to report on their plant-specific emissions and emission factors or conduct a study.	KC	EPA & Energy Commission	When funding is available
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 on-going project on roadmap emission and fuel economy standards by 2020.
	Survey to improve the technology-based classification of the vehicle-based EU standards (besides, focus on separating the functional catalytic device).			
	Survey to establish fuels economy baseline for different classes of vehicles		DVLA, EPA and Energy Commission, private garages	
	Separate portions of the total fleet that 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 become available.
NE categories	Report emissions from NE categories	All categories	Energy Team	When funds become available.

Table 20: Planned improvement activities in the IPPU sector

Category	Identification of planned improvement areas
(a) Data improvements	
Conduct industrial survey in-country to identify all possible sources according to the IPCC Guidelines for both formal and informal sources and ensure data is collected and sources maintained for future inventories.	
Identify, track and monitor any potential new sources that would be important for inclusion in inventories according to the IPCC Guidelines, e.g. SF6 use in electrical equipment.	
Collect data for Ceramics industry on carbonate used and estimate emissions for the sub-category	
Update data on ODS substitute gas (HFCs) 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 would be made to identify the importers to collect data to improve upon future calculations	
(b) 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 integration of data from the plant, the latest guidance from the IPCC on the use of facility-level data in national inventories would be relied on in the estimation.	
Improvements on methodology to ensure the use of tier 2 method for all years to improve emission calculations particularly for lubricant use, steel production, limestone use and refrigeration and AC including mobile AC sub-sectors.	
Improvements on methodology to ensure the use of tier 2 method for all years to improve emission calculations particularly for lubricant use, steel production, limestone use and refrigeration and AC including mobile AC sub-sectors.	
Report emissions from NE categories	

Table 21: Planned improvement activities in the AFOLU sector

Improvement tasks	Responsibility & Collaborators	Priority	Next Step	Target	Assumptions
Develop all-embracing new land representations schemes with definitions (include the possibility of delineating tree crops from annual crop areas).	FC, EPA, UNU-INRA, Rudan, CERSGIS, Geomatics-KNUST, FAO, NATU-KNUST, Cocoa Board Survey department, RMSC, FC	High	Explore the possibility of linking with the FPP process as a follow-up. EPA to facilitate the discussions for the development of the land use mapping scheme.	Next Inventory	Funding is secured on time
Reprocess 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 map of ecozones, climate, soil and recalculate land-use change maps		High			

Integrate maps on perennial crops (mainly cocoa and rubber) in land-use maps and recalculate		High			
Reconsider the dealing with wetlands and eliminate some ways of change between categories.		High			
Reconsider factors that express the speed of land-use change in the 1970s and 1980s		High			
Cross-check area estimates from LUC matrices with data available at the plantation unit.		High			
Fire monitoring					
Include the annual fire hotspots and overlay on the land-use maps to assign disturbances to land-use subcategories	FC, Ghana National Fire Service, NADMO, District Assemblies	High	Link with AGRHYMET	Next Inventory	FC to initial contact with AGRHYMET supported by EPA
Work on biomass inventory	FC and FORIG	High			
Include the biomass density estimates for plantations	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 & MoFA	Medium	Include in the discussions of the AFOLU collaborating team	Next Inventory	part of the activity 1
Explore the possibility of reducing the uncertainty associated with time-series data.	AFOLU Team	Medium	EPA to coordinate the revision of existing estimates	Next Inventory	Funding is secured on time.
Biomass changes in different land representations, including different pools.					
Fuel production/supply					
Pools					
Account for the burning of crop residues beyond the burning of fields.	MoFA	Low	MoFA to lead AFOLU team in the identification, collection and inclusion of data into the inventory	Next Inventory	Funding for BUR3 would cover this activity.
Account for multiple cropping rice	MoFA, AFOLU Team	Low			
Include harvested wood products.	FC	Low			
Include crop residues from plantain.	MoFA and EPA	Low			
Clarify the fertiliser use in rice.	MoFA and EPA	Low			

Table 22: Planned improvement activities in the waste sector

Improvements	Responsibility & Collaborators	Priority	Next Step	Target	Assumption
Solid waste disposal					
Collect additional data on solid waste generation rate and waste classification at the landfill/disposal site	Built Environment Department, EPA, Civil Engineering Department, KNUST, MLGRD, AMA, KMA, STMA, TMA	high	Contact relevant institutions to include data need into surveys and research	next inventory	Funding is available
Support the establishment of proper waste data management system in selected assemblies	EPA Built Environment Department	high	Built Environment to prepare a project proposal to seek funding	medium to long term	Funding is available
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, statistical service, MID, private partners	high	EPA carry out a survey on incinerators for the Ghana Health Service and Ghana Education Service and private companies to include in their survey	next inventory	
Wastewater and treatment					
Update existing survey data on industrial and domestic waste	Manufacturing Industry Department, EPA, built environment	high	EPA to initiate a survey to review industrial and domestic WWTP for applicable sectors	next inventory	Funding is made available
Uncertainty management	Waste team	high	EPA to work closely with the University of Ghana's Statistic Department to start work on waste sector-specific uncertainty management	next inventory	Funding is made available
NE categories	Report emissions from NE categories	High	Waste Team	next inventory	When funds become available.

Climate mitigation assessment

Source: offgridenergyindependnece.com

4. Updates on Greenhouse Gas Mitigation Assessment

The mitigation assessment is a critical component of the section on the general description of steps taken or envisaged to implement the Convention in the National Communication. It includes information on the efforts underway to mitigate GHG emissions within the broader national development context. The information contained in the assessment is the updates of those previously reported in the second biennial update report to the Convention. There are four main areas of the mitigation assessment. The first part sets the tone by providing the context to the report consistent with the guideline for preparation of the national communications. The ensuing section is on the mitigation policies and the progress towards achieving mitigation policy commitments. It elaborates more on the main mitigation policy making-steps and the linkages with sectoral and national mitigation policies. It also touches on the progress made in the achievement of national and sector mitigation policies.

This section focuses on the arrangements for mitigation assessment. It reports information on institutional arrangements by defining clear roles and responsibilities assigned to the various institutions involved in the evaluation. The section also provides additional details on the methodology and tools in the assessment for each mitigation sector. The information includes the type of tools, the segment of the evaluation to which the tools are applied and the potential areas for improvements. It further discusses mitigation archiving strategy for Ghana by outlining archiving practices and the identification of improvements for future mitigation assessment. This crucial piece of information can be useful in the design of the strategies for mainstreaming the mitigation assessment into the governmental structures. Another vital aspect of the section is on the identification and prioritisation of the areas for possible future improvements. The screening was done with the view to pinpoint practical ways to address challenges and barriers encountered in the assessment.

Another aspect also presents the results in two parts according to the GACMO and LEAP tools. The GACMO tool results are on the economy-wide assessment. It covered all the mitigation sectors and built on the 2016 national GHG inventory results to project the emissions for the business-as-usual and mitigation trajectories. The LEAP model was used to conduct a refinement of the assessment on the energy sector. The improvement seeks to downscale the parameters for the mitigation assessment in the energy sector. Results on the baseline and mitigation scenarios from the GACMO and LEAP have been reported separately under each model. There is an area on the progress of implementation of prioritised mitigation measures since the submission of the second biennial update reports. The information includes new updates on the investment made in the mitigation measures; policy and regulatory reforms; steps that have been taken or envisaged to enable the implementation of the mitigation measures. It also highlights critical technical, financial, policy and regulatory barriers that militate against the implementation of the mitigation actions and the strategies to address them.

4.1 Mitigation Policy-Making Process

In Ghana, the central government defines the broad mitigation policy for the line ministries and local government to adopt and implement. The government captures its mitigation policies in the Coordinated Programme of Economic and Social Development Policies as required by Article 36(5) of the national Constitution. The current CPESDP (2017-2024) affirms Ghana's commitment to achieving the 45% emission reduction goal set out in the NDC under the Paris Agreement. The fulfilment of the CPESDP mandate paves the way for the NDPC to develop the four-year cycle MTDPF to operationalise the vision, policies, and programmes outlined in the CPESDP. The ministries and local governments are to make the broad policies defined in the MTDPF relevant to the sector or district by further developing a medium-term plan to reflect priorities of the government. The line ministries outline their specific-sector mitigation policies implemented by the Agencies under them.

The Ministries of Energy; Transport; Trade and Industries; Lands and Natural Resources and Sanitation and Water Resources are instrumental when it comes to developing and implementing mitigation policies in Ghana. In preparing the district-medium-term plans, even though the local governments are to tackle specific development issues in their jurisdiction, it must be consistent with the central government's priorities.

4.2 Ghana's Mitigation Policies and Measures

Since Ghana published its third national communication in 2015, it has continued to implement a wide range of socio-economic strategies that deliver long-term greenhouse Mitigation Outcomes (MO). The current national medium-term[74] and sectoral plans[75], as well as the NDC, outline the mitigation measures. The measures are in the following areas:

- Low carbon electricity supply
- Scaling-up renewable energy
- Clean cooking and lighting
- Electric mobility and rail transit
- Lowering deforestation and restoration of degraded areas
- Energy efficiency in households, commerce, and industry
- Innovative waste management
- HFC phase-down and
- Natural gas recovery and utilisation and no flaring

The expected cumulative effects of the policies and measures are estimated to lead to a 45% reduction of Business-As-Usual (BAU) GHG emissions of 74 million tonnes by 2030. In all, the national mitigation target translates into 33 million tonnes over fourteen years (2016-2030). After sufficiently defined sector priority measures, the focus is on the consistent implementation of coherent strategies for the achievement of the set mitigation outcomes. A brief discussion of the mitigation Policies and Measures (PAMs) can be found below.

4.2.1. Energy Sector Mitigation Policies and Measures

The National Energy Policy, adopted in 2010, is the primary document driving the mitigation efforts in the sector. It has set out concrete strategies to attain broad policy goals on universal access to electricity, renewable energy penetration, natural gas commercialisation, and infrastructure and LPG use into the broader development context of the country. Different documents like the National Gas Master Plan (2016)[76], Renewable Energy Master Plan (2019)[77], Sustainable Energy for All Country Action Plan (2012)[78], Mini-grid Electrification Policy (2015, revised in 2017) and Integrated Power System Master Plan[79], National LPG Promotion Policy (2017) and the Ghana Nuclear Power Programme (NPP) outlines the strategies to address the policy objectives and proposed interventions in the National Energy Policy.

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[74]https://s3-us-west-2.amazonaws.com/new-ndpc-static1/CACHES/PUBLICATIONS/2018/08/23/Medium-term+Policy+Framework-Final+June+2018.pdf

[75] Some of the major sectoral plans include the national energy policy, transport policy, forest and wildlife policy, national environmental sanitation strategy etc.

[76] https://www.thegasconsortium.com/documents/GMP-Final-Jun16.pdf

[77] http://www.energycom.gov.gh/files/Renewable-Energy-Masterplan-February-2019.pdf

[78] http://energycom.gov.gh/files/SE4ALL-GHANA%20ACTION%20PLAN.pdf

[79] http://www.energycom.gov.gh/files/Ghana%20Integrated%20Power%20System%20Master%20Plan%20_Volume%202.pdf

In 2017, the Ministry of Energy started a comprehensive review of the National Energy Policy, which is still ongoing. The review is to make the policy consistent with the government's sustainable energy programme and respond to the emerging energy issues in the country.

4.2.1.1. Diversification of the national energy mix

Over the last four decades, the national energy mix has transformed from the dominance of biomass (85%) and hydro (15%) in 1974 to a diverse share of oil products (44%), natural gas (14%), renewables (0.03%), hydro (5%) and biomass (37%) in 2018 (Figure 29). The 2030 national energy mix would have a comparatively less carbon-intensive outlook. The strategy is to develop alternative and domestic energy sources that are dominated by natural gas, biomass, nuclear and complemented by renewables and hydro. For instance, the reliance on traditional biomass for cooking would decline as set out in the energy sector policy target to increase LPG use penetration to 50% of households by 2030.

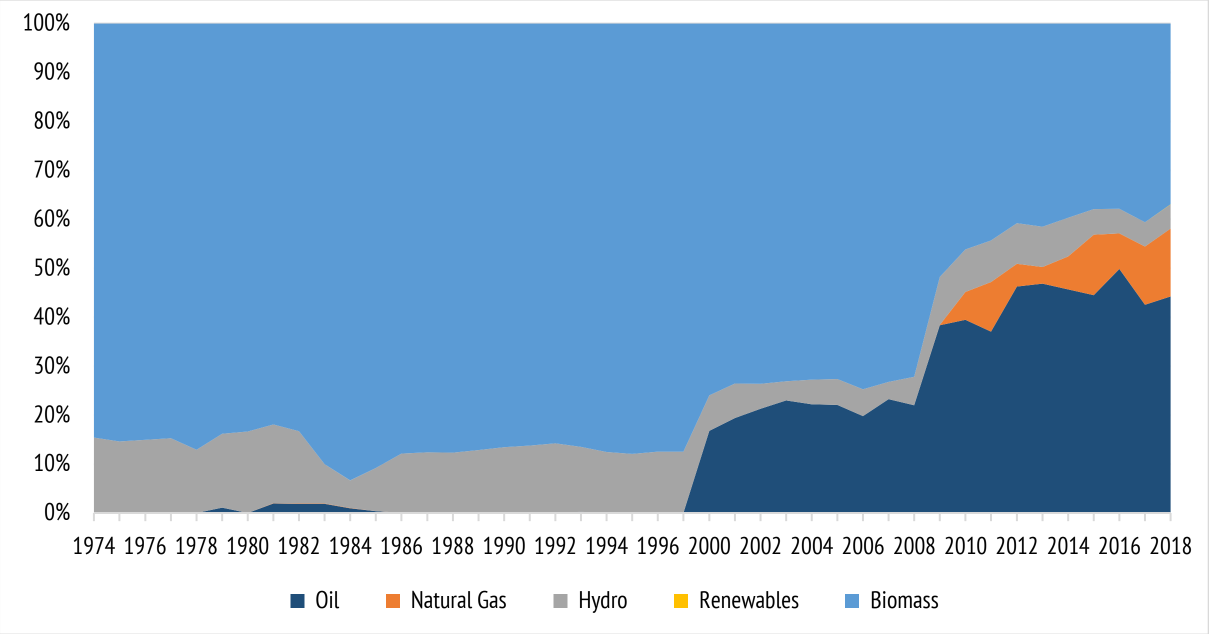

Figure 29: Total primary energy supply from 1974 to 2018

4.2.1.2. Low carbon electricity supply

The government has a target to achieve universal access to grid electricity by 2025 (recently updated from the initial 2020 target date) through the national electrification scheme and self-help electrification programmes. Access to power in Ghana presently stands at about 84.3 per cent with urban areas having about 100 per cent while the rural areas have 67.2%[80]. Electricity generation capacity has more than doubled since 2008 (increasing from 2,011 MW to 5,139 MW in 2018) and is likely to reach 9,700 megawatts by 2030. Besides, Ghana continues to implement policies to diversify the electricity generation mix, and improve efficiency in electricity production, transmission and distribution. All these measures are aimed at enhancing the sustenance of the electricity system and reducing carbon emissions. Generally, the electricity supply mix has shifted from being 100% hydro-based in the 1990s to a mix of hydro (49.8%), thermal (50.5%) and renewable (0.1%) in 2018. The thermal component consists of 24% light crude oil and natural gas dual-fired plant, 14% heavy fuel oil-fired plant, 12% natural gas-fired plant and 0.6% diesel-fired plant.

[80] http://www.energycom.gov.gh/files/ENERGY_STATISTICS--2019.pdf

The policy to diversify from light crude oil to natural gas in existing power plants has resulted in carbon emission reductions of 428.7 kt/ year since 2010. The strategy aims to increase electricity generation from natural gas and renewable energy sources over the next decade. The implementation of the National Gas Master Plan and the Renewable Energy Master Plan would drive the increased share of natural gas and renewable energy in the electricity supply. A thousand-megawatt capacity of nuclear power is also likely to kick in by 2029 to decarbonise further electricity supply in the country (Figure 30).

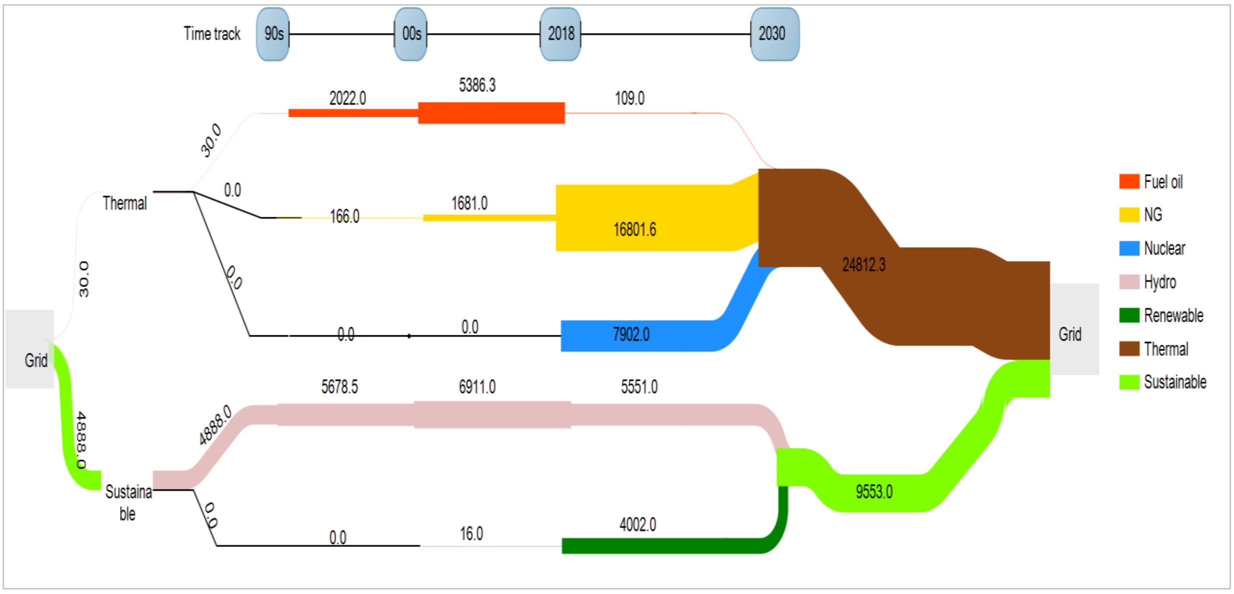

Figure 30: Overview of grid electricity share from the 1990s to 2030 expressed in GWh

Another policy Ghana is pursuing to lower greenhouse emission in electricity supply is the retrofitting of existing single cycle thermal plants to combined cycle by expanding the capacities to utilise steam instead of relying on fossil fuels. The policy aims to upgrade the installed capacity of each of three single-cycle thermal power plants by 330 MW through retrofits to convert the technology and thereby improve the thermal efficiency rates. As a result, there have been conversions of 2 x110MW simple cycle Takoradi 2 Thermal Power Plant (T2) to 330MW combined cycle plant; 110MW simple cycle Tema Thermal 1 Power Station (TT1PS) and 110 MW simple cycle CENIT Plant to 330MW combined cycle; 2x 110MW simple cycle Kpone Thermal Power Plant to 330MW combined cycle and 10MW capacity addition by Karpowership. This initiative has generated an average of 109.9 kt C/year greenhouse emission savings since 2014. Grid transmission losses have not improved significantly, contrary to expectation. It hovers around 4.1% of the total electricity transmitted annually.

4.2.1.3 Scaling-up the penetration of renewables

In Ghana, renewable energy currently contributes to 1% of the energy mix as of 2019 (Energy Commission, 2019). The policy goal is to achieve 10% renewable in the mix by 2030. In 2011, Ghana passed the Renewable Energy Act, 2011 (Act 832) to scale-up renewable energy to meet the 10% policy target. The achievements under the RE Act are as follows:

- Developed and gazetted a Feed-in-Tariff (FIT) scheme
- Established framework for the renewable energy fund
- Prepared net metering code and renewable energy sub-codes for transmission and distribution systems.
- Adopted licensing manual for RE service providers; and
- Drafted guidelines for the Renewable Energy Purchase Obligation

In furtherance to Act 832, the Ministry of Energy adopted the Renewable Energy Master Plan (REMP) in 2019. The target of the REMP is to increase the renewable energy share of the national energy generation mix from 42.5 MW in 2015 to 1363.63 MW in 2030 (Table 23). It is estimated to create about 220,000 jobs and 11 million tonnes of CO_2 savings. The estimated total investment required for the REMP is at US$ 5.6 billion, of which more than 80% would come from the private sector.

Table 23: Renewable energy targets in the REMP from 2015 to 2030

Renewable Energy Technologies	Reference 2015		2019-2020		2021-2025		2026-2030		Cumulative in 2030	
	No. of units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp	No. of Units	MWp
Solar Energy										
Solar Utility Scale	-	22.5	-	130	-	195	-	100	-	447.5
Distributed Solar PV		2		18		80		100		200
Standalone Solar PV	-	2	-	8	-	5	-	5	-	20
Solar Street/Community lighting	-	3	-	4	-	4	-	14	-	25
Solar Traffic signals (% of total traffic signals installed in the country)	14	3	11	-	15	-	20	-	60	-
Solar Lanterns	72,000	-	128000	-	300000	-	500000	-	1000000	-
Solar irrigation	150	2.8	6000	6	20000	20	20000	20	46150	48.8
Solar Crop Dryers	70	-	80	-	250	-	300	-	700	-
Solar Water Heaters	4,700	-	15300	-	50000	-	65000	-	135000	-
Wind Energy										
Wind Utility Scale	-	0	-	0	-	275	-	50	-	325
Standalone Wind Systems	-	0.01	-	0.1	-	0.9	-	1	-	2
Wind Irrigation/Water Pumping	10	-	25	-	30	-	35	-	100	-
Biomass / Waste-to-Energy										
Biomass Utility-Scale	-	0	-	0	-	72	-	0	-	72
Waste-to-Energy Utility Scale	-	0.1	-	0	-	30	-	20	-	50.1
Biogas (Agricultural/Industrial Organic Waste)	10	-	20	-	70	-	100	-	200	-
Biogas (Institutional)	100	-	80	-	140	-	180	-	500	-
Biogas (Domestic)	50	-	30	-	50	-	70	-	200	-
Woodlot Cultivation (ha)	190,000	-	60000	-	100000	-	78000	-	428000	-
Charcoal (Local Demand)	1,551,282	-	94017	-	93947	-	100877	-	1840123	-
Charcoal (Export)	190,450	-	59550	-	100000	-	78000	-	428000	-
Briquetting/Pelleting	19,700	-	20300	-	25000	-	35000	-	100000	-
Biofuel (tonnes)	0	-	100	-	4900	-	15000	-	20000	-
Hydro / Wave Power										
Small/Medium Hydro Plants	-	0	-	0.03	-	80	-	70	-	150.03
Wave Power	-	0	-	5	-	0	-	45	-	50
Hybrid Mini-Grids										
Mini/Micro-grids	13	-	73	-	114	-	100	-	300	12
End-User Technologies										
Improved Biomass Cookstove (Domestic)	800,000	-	500000	-	500000	-	1200000	-	3000000	-
Improved Biomass Cookstove (Institutional/Commercial)	1,800	-	1200	-	7000	-	8000	-	18000	-
Total Installed RE Electricity Capacity										**1353.63**

To drive investments into renewable energy, Ghana continues to implement the following concrete technical and fiscal strategies:

- Expand the National Interconnected Transmission System (NITS) to accelerate the interconnection of utility-scale renewable energy projects.
- Encourage bulk customers to integrate renewable electricity in their distribution and consumption mix under the Renewable Energy Purchase Obligation (REPO).
- Ensure that net-metered systems have access to the distribution grid, in line with the Net-Metering Code.
- Recommend tax incentives for the importation of materials and equipment required for local assembly, manufacturing or installation and maintenance of renewable energy systems.
- Deploy decentralised renewable energy technologies for electrification of the isolated island and lakeside communities under the Scaling-up Renewable Energy Programme (S-REP)[7].
- Institutionalised the Annual Renewable Energy Fair (Conference and Exhibition) as an avenue to disseminate information on government policies, interventions and emerging technologies on renewable energy and energy efficiency. It also provides the platform for consultation among academia, government representatives, decision-makers, private sector operators, project financiers, and consumers. The annual fair was introduced in 2015.
- In 2017, Ghana ratified the International Solar Alliance (ISA) framework agreement to become one of the founding members of ISA. As a member of ISA, Ghana can access up to US$10 billion renewable energy credit facility from India.

4.2.1.4 Improving access to clean cooking solutions

The promotion of clean cooking solutions is one of the significant emission mitigation strategies in the energy sector. The 2010 National Energy Policy proposes the promotion of the adoption of improved biomass cookstoves, LPG and alternative fuels like pellets for cooking. Accordingly, the Sustainable Energy for All Country Action Plan (SEforALL CAP, 2012), National LPG Promotion Policy (NLP, 2017) and National Gas Policy contain concrete actions towards achieving 50% of households adopting LPG as their primary fuel for cooking and adoption of 2 million improved biomass cookstoves by households by 2030 and the promotion of the establishment of sustainable woodlots for cooking. The improved biomass stove and LPG use policy actions are likely to generate a total of 15.8 million tonnes GHG emission reductions of which 93% (14.6 million tonnes) would come from the 2 million improved stoves replacement policy, whiles the remaining 7% (1.2 million tonnes) are attributable to the 50% LPG household adoption policy. The Ministry of Energy, National Petroleum Authority and the Energy Commission collaborate closely with the private sector and civil society organisations to implement the clean cooking policy. Some of the critical steps Ghana has taken towards the realisation of the policy are:

- Design and implementation of a Rural LPG Promotion Programme since 2013 to accelerate the penetration of LPG for cooking in unserved and underserved rural communities. The programme began with the free distribution of 6kg LPG cylinders, single burner stove and accessories. The programme has transitioned to the distribution of only stoves and accessories due to the national policy to transition to the Cylinder Recirculation Model (CRM) of distribution.
- The transition of the current user-ownership of LPG cylinders to the CRM of distribution to remove adoption barriers of the high cost of LPG cylinders in addition to stove and accessories cost.
- Established two test centres at the Kwame Nkrumah University of Science and Technology's Technology Consultancy Centre (KNUST-TCC), Kumasi and the Council for Scientific and Industrial Research's Institute

for Industrial Research (CSIR-IIR), Accra to test the technical performance (thermal efficiency, safety, durability and emissions levels) of stoves and fuels. The test centres were established with support from the United Nations Development Programme and the Clean Cooking Alliance.

- Development and adoption of ISO standards for clean cookstoves and clean cooking solutions and the development of regulations (and labelling scheme) for improved biomass cookstoves (on-going).
- Development of regulations for the wood-fuel sector (covering "traditional" firewood and charcoal production, transformation, distribution and sale).
- Dissemination of an electronic SEforALL Newsletter every quarter since 2014 to update the public on the progress of implementation of the country's SEforALL Action Plan.[81]
- Implementation of a Sustainable Woodlot for Schools Programme to support Senior High Schools to establish woodlots for cooking.

These policy initiatives have led to the deployment of over 9,000 improved institutional stoves (firewood and pellet stoves) for general cooking, agro-processing and fish smoking; and over 1.6 million domestic charcoal, pellet and ethanol cookstoves nationwide by the private sector since 2012. The Rural LPG Promotion Programme being implemented by the Ministry of Energy has reached 151,500 households with 151,500 cylinders and 132,800 stoves and accessories as at the end of 2019. Under the Energy Commission's Woodlots for Schools Programme, over 120 hectares of acacia woodlots have been established in schools nationwide from 2014 to 2019. The cumulative mitigation effects of clean cooking initiatives are estimated to be 642.5 kilotonnes per year. Furthermore, cookstove projects featured prominently in the international carbon markets. Currently, Ghana has registered five cookstove POAs as CPAs to generate emission reductions. Two more Programme of Activities (POAs) are in the validation stage. Under the Ghana-Korea Carbon Project spearheaded by the Ministry of Energy, 500,000 households would access improved biomass cookstoves by 2020. Funding for the initiative would come from private Korean companies participating in the Korean Emission Trading Scheme (KETS). The resulting carbon emission savings would be eligible as compliance offset under KETS.

4.2.1.5 Restriction on gas flaring, recovery and utilisation of natural gas

The discovery of 2,080 billion cubic feet (Bcf) of associated and non-associated natural gas reserves is a significant boost to Ghana's economy, particularly in the power generation, transportation, and industrial sectors (Figure 31). As a result, the Government adopted the National Gas Master Plan (GMP) in 2016 to facilitate gas commercialisation and gas infrastructure development for a vibrant downstream market. In this regard, the Ghana Gas Company (GNGC) was established in 2014 at Atuabo to produce lean gas, condensate, LPG and isopentanes for the downstream market especially for the power, transportation, and industrial sectors. GNGC currently supplies gas to Volta River Authority (VRA) and 470MW Karpowership after its relocation from Tema (East coast) to the Sekondi naval base (West coast)[82] for power generation.

[81] http://www.energycom.gov.gh/renewables/se4all/newsletters

[82] https://www.ghanagas.com.gh/article/Ghana%20Gas%20to%20commence%20supply%20of%20gas%20to%20Karpowership/PS-TRF-42819

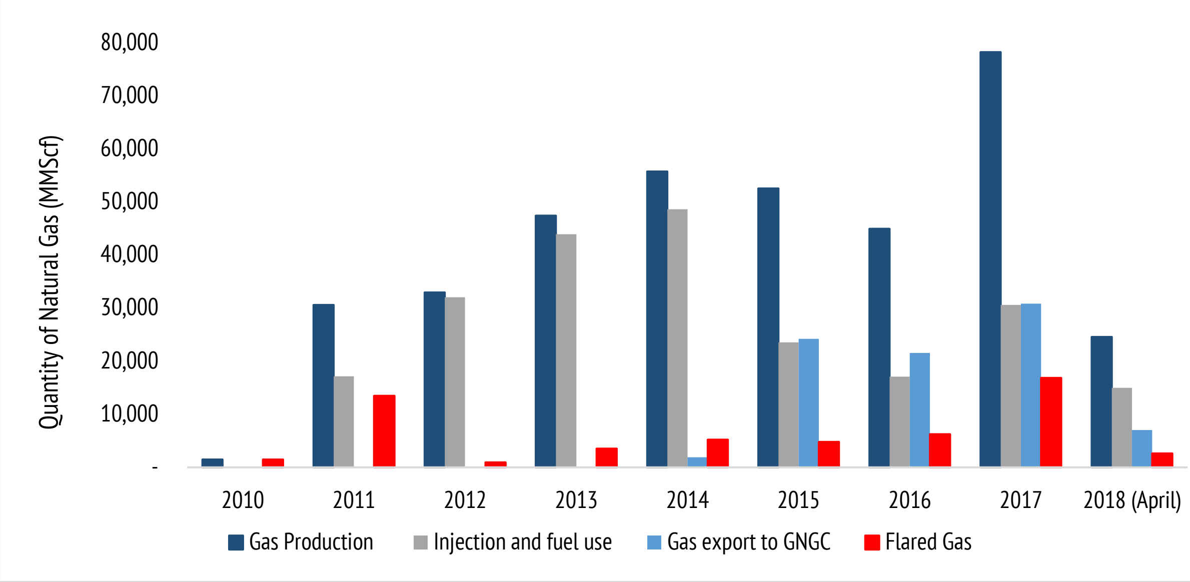

Figure 31: Natural gas production and utilisation in Ghana

Due to the implementation of gas commercialisation policy, since 2014, GNGC produces an average of 23,202.9 BCF of natural gas annually; mainly for power generation and allied industries. Ghana has also adopted zero-gas flaring as an industry practice. The fundamental petroleum policy for Ghana does not allow deliberate gas flaring in oil and gas development. Section 33 of the Petroleum (Exploration and Production) Act 919, 2016 further requires operators to seek authorisation before flaring or venting of petroleum[83]. As a result, the percentage of flared gas of the total natural gas production has consistently declined from an average of 38.6% before 2014 to 13% to date (Figure 32).

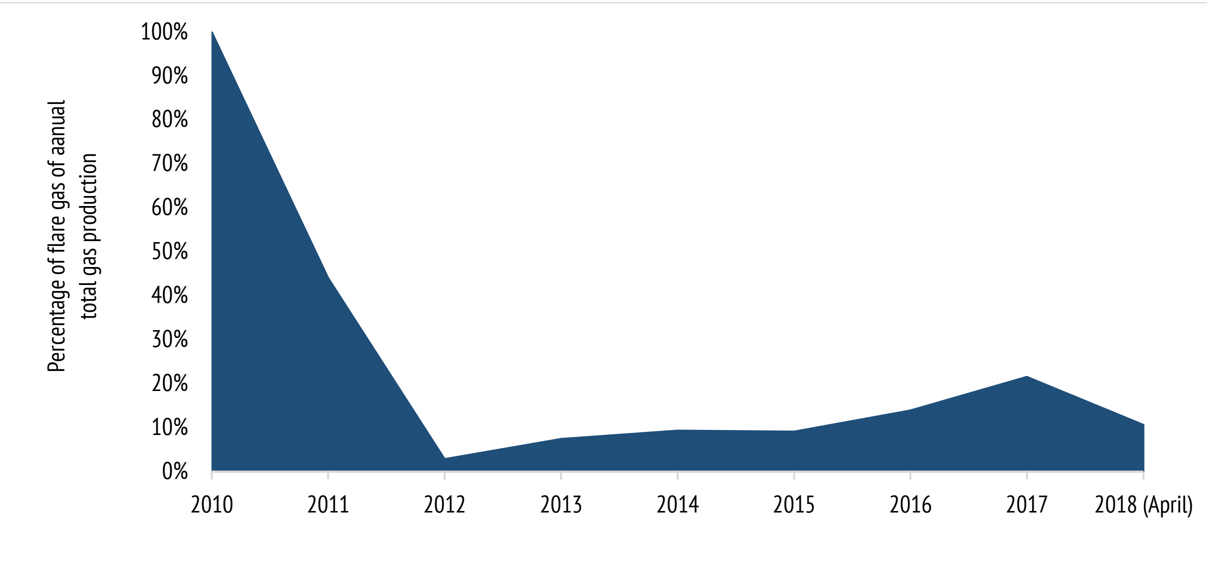

Figure 32: Trend of the percentage of flare gas of annual total gas production

Currently, environmental guidelines for offshore oil and gas development provides concrete guidance on safe disposal of gas in the event of an emergency and other plant upset conditions. The regulator imposes a penalty on the operator if gas is flared outside the allowable operational threshold. The implementation of this policy has led to cumulative avoided GHG emissions of 755kt per year since 2014.

[83] http://www.petrocom.gov.gh/L&C_folder/Pet_register/laws/PETROLEUM%20(EXPLORATION%20AND%20PRODUCTION)%20ACT,%202016%20(ACT%20919).pdf

4.2.1.6 Promoting energy efficiency and conservation

The 2010 National Energy Policy highlights energy efficiency and conservation in homes, offices and industries as a strategy to achieve emissions mitigation outcomes in the energy sector. Already, Ghana is implementing a broad range of measures in appliance energy efficiency standards and labelling, energy conservation promotion, and addressing financing barriers. Under standards and labelling, Ghana is implementing energy efficiency standards and labels Programme to ensure that only appliances that meet minimum energy efficiency standards and are labelled accordingly, enter the Ghanaian market. In this regard, Legislative Instruments (LIs) 1815, 1958 and 2353 are in force to specify the minimum energy efficiency standards and labelling requirements for air conditioners, refrigerators and lighting bulbs. Legislative Instrument (LI) 1932 is also in effect to ban the importation and sale of used air conditioners, refrigerators and incandescent bulbs.

In furtherance to the programme, the Energy Commission has developed a database application (App) for refrigerators, air conditioners and lighting bulbs which is running on the Google play store. The App helps consumers to identify energy-efficient refrigerators and the retail shops from which to procure them from designated shops. So far, there have been over 10,000 downloads of the certified refrigerating appliance APP. The development of new energy efficiency standards and regulations for twenty more appliances including ceiling fans and regulators, television sets, satellite decoders/TV signal boxes and lighting (domestic/commercial lighting/street lighting) is underway. The aim is to expand the standard and labelling initiative to cover 23 electronic appliances in homes, industry and commerce by 2023 and maintain Ghana's leadership in pushing for the operationalisation of the ECOWAS sub-region harmonisation of electronic appliance standard to reduce market dumping. It is with the same goal that Ghana has joined the global coalition to increase energy efficiency by 3% per annum[84].

Ghana implemented a refrigerator rebate and an exchange scheme from 2013 - 2015 at the cost of US$3.1 million, and has saved the country 400 Gigawatts hours (GWh) of electricity, 1.1 million tonnes of carbon dioxide and recovered 1,500 kilogrammes of Chlorofluorocarbon. Under the scheme, consumers who turned in their old refrigerating appliances received discounts when they purchased new and efficient ones. Over the three years, more than 10,000 old and inefficient refrigerators have been replaced with new and efficient ones under the rebate scheme. In 2007 the Government introduced a programme to replace almost 6 million government incandescent bulbs with the more energy-efficient compact fluorescent lamps (CFLs).

Afterwards, measures have been put in place to replace the CFLs with more energy-efficient LED ones. That is why the Ministry of Energy has introduced the “light for all initiative” under which 12 million LED lights are to be distributed nationwide under a cost-recovery programme led by local banks[85]. This initiative has the potential to reduce energy consumption by 50% from the current compact fluorescent bulbs’ usage and 0.96 Mt of carbon emission savings. So far, the Ministry of Energy has distributed over 3 million LED lights to public institutions and with a potential 0.24Mt carbon savings per annum. Under the Millennium Challenge Compact II (MCC II), Ghana is implementing the US$2.4-million Energy Efficiency and Demand Side Management (EEDSM) project. EEDSM would supply about 69,250 150W LED streetlights complete with fixtures to various Municipal, Metropolitan, and District Assemblies (MMDAs) across the country.

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[84] https://sdg.iisd.org/news/global-coalition-commits-to-3-annual-global-increase-in-energy-efficiency/

[85] https://www.ghanaweb.com/GhanaHomePage/business/Light-for-all-Gov-t-to-distribute-12m-LED-lamps-nationwide-623916

So far, MCC has replaced 18,000 inefficient street lights 250W (halogen, helium) with energy-efficient 150W LED street lights. Under the Regional Capitals Street Lighting Project, the replacement of the inefficient 250W High-Pressure Sodium (HPS) lamps with 150W LED types and rehabilitation of existing infrastructure in Accra and Kumasi is about 85% complete. Energy Efficiency standards have been developed and gazetted for more than 16 appliances. These appliances are washing machines, fan motors, distribution transformers, electric motors, computers, energy meters, microwave, blender, electric water heater, lighting (commercial lighting/streetlighting), TV Sets, Decoders, Ceiling fans, Batteries, Inverters, and Solar Panels. The Legislative Instrument to back the standards are being developed.

In the building sector, the Energy Commission is collaborating with the Ghana Green Building Council (GGBC) to secure funding for the development of energy efficiency standards and labels for commercial buildings. The move would eventually make public buildings green and save energy. The Ghana Building Code, GS1207 of 2018 already addresses issues on energy efficiency and sustainability in buildings. Some of the green-certified buildings in the country are as follows:

- One Airport Square, Accra - Green Star certified by GHGBC/GBCSA
- Mother and Baby Unit, Kumasi, Edge certified by IFC
- Takoradi Mall, Takoradi, Edge certified by IFC
- Atlantic Towers, Accra, Edge certified by IFC
- Greater Accra Regional Hospital, Ridge, Accra, LEED-certified by USGBC
- MPS Terminal, Tema, Edge certified by IFC

Besides, the Ministry of Energy introduced the Automatic Timer Switches (ATS) initiative for homes. The Ministry of Energy launched the deployment of the automatic timers to kick-start the free distribution at the graduation of certified electrical wiring personnel on 6th September 2017. The Ministry has distributed 32,893 ATS to consumers, including security agencies, government institutions, and households. The Ministry has also conducted tests on the energy-saving potential of the timers over 48 hours, indicating an energy savings of about thirty per cent. The 32,893 ATS distributed nationwide could lead to a total electricity savings of approximately 3,215 MWh (3 GWh) and 1.44 kilotonnes of avoided carbon emission per year.

4.2.1.7 Ghana nuclear power programme

Ghana has a schedule to start nuclear power production in 2029 if all technical, financial and regulatory processes are met. As a result, the Government has developed a national roadmap to integrate nuclear power into Ghana's energy mix, which was accepted by the International Atomic Energy Agency (IAEA). Primary data on plant sites have been completed, awaiting field data acquisition and feasibility studies. To give an additional boost to the roadmap, Ghana established the National Nuclear Power Ghana Limited[86] in 2019 as a Special Purpose Vehicle (SPV) jointly owned by the Volta River Authority (VRA), the Bui Power Authority (BPA) and the Ghana Atomic Energy Commission (GAEC). Currently, the preparation of a siting study report is underway to enable the Government take a final decision. The strategy is to bring 1000 MW capacity of nuclear power online by 2030. If the plan to commission a 1000 MW power plant is accomplished by 2030, it has the potential to reduce 1 million metric tonnes of GHG emissions in the first two years of operation.

[86] https://www.businessghana.com/site/news/business/182930/New-firm-established-to-actualise-Ghana-s-nuclear-dream

4.2.2. Environment Sector Mitigation Policies and Measures

The MESTI coordinates the implementation of the national climate change policy for the country. MESTI performs this policy function through the National Climate Change Implementation Committee with a technical backstop from the EPA. MESTI works closely with the EPA on the governmental processes to ratify Multilateral Environmental Agreements (MEAs). MESTI and EPA led the ratification of the Paris Agreement in 2015 and the Kigali Amendment in 2019. Furthermore, the ministry facilitated the promulgation of the Hazardous and Electronic Waste Act (Act 917) and the Hazardous, Electronic and Other Waste, Control and Management Regulations (LI 2250), 2016. The laws provide for the establishment of a national E-waste plant involving the private sector.

4.2.2.1 Hydrochlorofluorocarbon Phasedown

Ghana became the 79th country to ratify the Kigali Amendment in August 2019 and paved the way to implement a national programme to gradually phase out HFCs by introducing an alternative technology to HFCs with the support of the private sector. The amendment seeks to phase-down 19 identified Hydrochlorofluorocarbon refrigerants found in refrigerators, air-conditioning, cold storage systems and in mortuaries. The new HFC alternative technologies can deliver triple wins: no harm to the ozone layer, climate-friendly and improve energy efficiency. The EPA hosts the National Ozone Unit and leads in implementing the HFC Phase-out Management Plan (HPMP). Under the HPMP, the EPA started training technicians from well-established air-conditioning installation workshops in the conversion of existing R22 based air-conditioning units to run on Hydrocarbon R290. In 2019, the EPA hosted a week-long sub-regional training workshop of national ozone officers from Western, Eastern, Northern and Southern regions of the Africa Anglophone Network in Accra. The implementation of the HPMP could save 0.64 kilotonnes of GHG emissions every year.

4.2.3 Land and Natural Resources Sector Mitigation Policies and Measures

The 2012 National Forest and Wildlife policy is the foundation of the mitigation strategy for the forest sector. The policy is operationalised through the implementation of the Forestry Development Master Plan, Forest Plantation Development Strategy and the REDD+ strategy. The Forest Plantation Strategy aims to increase forest cover and restore degraded lands, whereas the REDD+ strategy seeks to address the key drivers of deforestation and forest degradation in the cocoa, shea, and sub-national mangrove landscapes. There are five major collaborative initiatives underway in the high forest ecological zone that anchor on the REDD+ strategy, namely: the Ghana Cocoa Forest REDD+ Programme (GCFRP), Ghana Forest Investment Programme (GFIP)[87], Dedicated Grant Mechanism (DGM)[88] and the Cocoa Forest Initiative (CFI)[89]. An additional six million tonnes of carbon emissions reductions have been projected over seven years, commencing when the Green Climate Fund (GCF) approves the Shea landscape initiative for implementation in Ghana.

The GCFRP is led by the Forestry Commission and seeks to build on the implementation of FIP. The aim is to increase forest cover and promote the co-existence of forest and cocoa, and achieve 10 million tonnes of carbon emissions reduction over six years (2019-2024) in selected deforestation hotspot intervention areas in the high forest zone[90].

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87 http://mlnr.gov.gh/index.php/programs-projects/ghana-forest-investment-program-fip/

88 https://www.dgmglobal.org/ghana

89 https://www.worldcocoafoundation.org/initiative/cocoa-forests-initiative/

90 https://www.worldbank.org/en/news/press-release/2019/07/09/ghana-signs-landmark-deal-with-world-bank-to-cut-carbon-emissions-and-reduce-deforestation

The GFIP is implemented by the Ministry of Lands and Natural Resources, which focuses on forest protection and sustainable cocoa production. Out of the GFIP, a tree tenure and benefit-sharing framework have been adopted and 24 million tree seedlings planted in the cocoa landscape. Phase 2 of the GFIP would scale up the restoration of degraded landscapes and provide concessional loans to private plantation developers. CIF and DGM are private sector-led. Whiles CIF led by the World Cocoa Foundation, as a joint effort between Ghana and Cote D'Ivoire (two leading producers of global cocoa beans), seeks to promote deforestation-free cocoa supply chain among 34 cocoa and chocolate companies. DGM being implemented by Solidaridad[91] West Africa empowers local communities to get involved in the promotion of climate-smart landscape practices.

The Forest Plantation Development Programme (NFPDP) is a crucial mitigation measure in the forest sector. The NFPDP was launched in 2001 and implementation started in 2002 as a strategic initiative to restore forest cover of the degraded forest, reduce wood supply deficit, create jobs, enhance carbon stocks and contribute to food production. The NFPDP is a public-private joint programme targeting degraded lands in on-reserve and off-reserve areas. It has the following components:

- Modified Taungya System (MTS).
- Community Forest Management Project (CFMP)
- Government Plantation Development Programme (GPDP)
- Private developers on-reserve.
- Forest Services Division (FSD) Plantation.
- Forest investment programme.
- Expanded plantation programme.
- FC/Industry plantations fund.
- Large-scale off-reserve plantations.

The 2016-2040 Ghana Forest Plantation Strategy (GFPS)[92] seeks to establish 625,000 ha of forest plantations (translating into 25,000ha per annum), enrichment planting of 100,000 ha of poorly-stocked and degraded forest reserve compartments and, facilitate the incorporation of trees within farming systems (trees on-farms) covering 3.75 million (ha) of agricultural landscapes. The key achievements of the NFPDP so far include:

- more than 190,000 ha of tree plantation established under NFPDP from 2002 to date,
- over 3 million metric tonnes of food produced from the plantations for 2002-to-date.
- over 400,000 direct jobs since 2002 to-date.

Ghana also established a Forest and Plantation Development Fund (Act 583)[93] in 2000 to provide financial assistance for the development of private forest plantations on lands suitable for commercial timber production and research. Illegal mining (locally referred to as galamsey) is a significant driver of deforestation. The government has adopted a multi-sector strategy to tackle illegal mining which is being implemented through the Multi-Sectoral Mining Integrated Project (MMIP)[94] by the Ministry of Lands and Natural Resources.

[91] https://www.solidaridadnetwork.org/news/solidaridad-partners-with-world-bank-to-promote-resilient-landscapes-in-ghana

[92] https://www.fcghana.org/userfiles/files/Plantation%20Annual%20Report/Ghana%20Forest%20Plantation%20Strategy_24_01_16%20(2).pdf

[93] https://www.fcghana.org/library_info.php?doc=50&publication:Forest%20&%20Plantation%20Development%20Act,%202000.%20Act%20583&id=15#2

[94] http://mlnr.gov.gh/index.php/programs-projects/multi-sectorial-mining-integrated-project-mmip/

The policy covers the following areas: formalisation of artisanal and small-scale mining[95], streamlining mining regulations and strengthening compliance monitoring, restoration of areas affected by illegal mining, community involvement in mining and the establishment of an inter-ministerial task force to oversee efforts to curb illegal mining in Ghana.

4.2.4 Transport Sector Mitigation Policies and Measures

The transport sector mitigation strategy aims to promote low carbon mass transport mobility in the long-term. This strategy is anchored on the national transport policy. It focuses on electric mobility (e-mobility), fleet renewal, efficient vehicle inspections, and rail-based transit to realise GHG mitigation outcomes. E-mobility has recently received a strong policy push in the Transport and Energy Ministries. In the 2019 national budget (pp 190)[96], the government tasked the Ministries of Energy and Finance to come up with tax-free solutions for full-electric cars in Ghana. Furthermore, the Ministry of Transport is collaborating with the AFD to seek funding support for the Accra city electric bus project from the GCF. In line with the directive in the national budget, the Ministry of Energy launched the "Drive Electric Initiative" (DEI)[97] during the 5th renewable energy fair. The initiative aims to have at least one hundred electric vehicles, and at least ten public charging outlets in Ghana by 2020 to upscale renewable energy and contribute to the reduction of GHG emissions[98].

Another mitigation strategy in the Transport sector is the fleet renewal programme. As part of the fleet renewal efforts, the Ministry of Transport has introduced a facility to put 400 euro-3 high occupancy buses to service to increase mass ridership in cities. So far, one hundred buses are in operation whereas the remaining three hundred buses would start to operate in 2020. The Ministry of Transport also has a policy to improve the vehicle inspection regime to allow for private sector participation to bring innovation and efficiency. In line with the policy, the Ministry of Transport through the Driver Vehicle Licensing Authority (DVLA) has franchised twenty companies to undertake vehicle inspections to including vehicle emissions testing. The Ministry plans to add twenty more companies to expand the coverage nationwide. Regarding rail-based transit, Ghana has a flagship railway development programme and currently, the Ministry for Railway Development is implementing the National Railway Master Plan to modernise railway network nationwide by aiming at mobilising US$7.8 billion investments into 1,394 km of rail network.

4.2.5 Waste Sector Mitigation Policies and Measures

Biogas production and composting are the two main mitigation actions in the waste sector. The National Institutional Biogas Programme (NIBP) and the Renewable Energy Master Plan (REMP) neatly outline the strategies for the promotion of domestic and institutional biogas production. The NIBP aims at installing 200 biogas digester systems in public boarding schools, hospitals, and prisons. In the REMP, the target of the total number of biogas installations has increased to 900 units, of which 400 are for general and domestic use and the remaining 500 are institutional. Out of the 900 installation units, 160 biogas plants (100 institutional and 60 domestic/commercial) are in place. Under the Switch Africa Green initiative implemented by the Ghana National Cleaner Production Centre (GNCPC)[99], ten biogas plants have been constructed in seven Senior High Schools (SHS) within the Greater Accra Metropolitan Area.

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[95] The Mineral and Mining (Amendment), 2019 makes illegal mining a criminal offence with a mandatory minimum 15 years jail sentence

[96] https://www.mofep.gov.gh/budget-statements/2019

[97] http://www.energycom.gov.gh/public-notices?limit=1&start=9

[98] http://www.energycom.gov.gh/files/concept%20note%20Drive%20electric.pdf

[99] https://ncpcgh.org/index.php/projects/biogas-technologies-project

A total of 101 artisans have been trained and have commenced the building of biogas plants. The centre has also developed an excel template for the bio-digester calculator (capacities, feed, LPG equivalence and bill of quantities). Safisana Biogas Plant was established in 2017 to produce electricity, biogas, organic fertiliser, and seedlings[100]. The company has a power purchase agreement with the electricity company of Ghana to deliver green electricity to the national grid.

In 2018, Safisana generated 0.32 GWh of green electricity to the national network through sub-transmission connection translating into 144 tonnes of GHG savings. The composting initiative in Ghana is a collaboration between the local government authority and two major waste management companies. The two companies have established compost facilities that receive municipal solid waste from waste operators at an agreed tipping fee. The compost produced is sold as fertiliser, for agricultural business. The Accra Compost and Recycling Plant (ACARP) has constructed a 600 tonnes per day capacity compost plant and completed feasibility to expand the capacity to 1000 tonnes per day. ACARP plans to establish another 600 tonnes per compost plant in Kumasi. Jekora Ventures Limited produces JV Compsoil and Fortifier Compost for the local market. Since 2013, an average of 8,545.3 tonnes of compost have been produced annually and has led to 355.9 kt C/yr.

4.3 Government-Wide Mitigation Actions

There are governmental emissions mitigation efforts that cut across the ministries. Often such efforts do not directly translate to emissions reduction but create the enabling conditions for the implementation of the mitigation measures at scale. These include mitigation policy reforms, capacity development for mitigation, aimed at mobilising funding and the adoption or review of regulations that support GHG mitigation measures.

4.3.1 Policy and Regulatory Reforms Toward Achieving Mitigation Outcomes

Since 2015 when Ghana submitted its Third National Communication to the Convention, a wide range of policy and regulatory changes intended to enable more significant mitigation, and sustainable development outcomes have been adopted. A summary of the reforms are as follows:

4.3.1.1 Fossil-fuel subsidy reforms

Ghana has adopted a petroleum price liberalisation policy since 2006. The National Petroleum Authority (NPA) initiated automatic price adjustment formulae. The gradual removal of subsidies followed the adoption of the formulae until prices reached market levels over the period 2013-2015 except for premix fuel for local fishing. Ghana reformed subsidies on gasoline, diesel and LPG fuel and mitigated the effects by introducing livelihood policies to protect poor households. The removal of the support has reduced the expenditure and pressures on the public purse and served a positive signal for investments in climate change mitigation actions.

4.3.1.2 Tax, duty exemption and income tax for solar, wind and tree crops, feed-in-tariff for renewables

Starting in 1998, the Government reduced import duties and VAT on solar and wind generation systems and components. Presently, solar and wind energy generating systems are exempt from both import duties and Value-Added Tax (VAT). Components for use with solar and wind generation systems benefit from preferential import duty of 5%[101].

[100] http://www.safisana.org/what-we-do/ashaiman-factory/

[101] https://www.iea.org/policiesandmeasures/pams/ghana/name-24515-en.php?s=dHlwZT1yZSZzdGF0dXM9T2s,&return=PG5hdiBpZD0iYnJlYWRjcnVtYiI-PGEgaHJlZj0iLyISG9tZTwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy8iPlBvbGljaWVzIGFuZCBNZWFzdXJlczwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy9yZW5ld2FibGVlbmVyZ3kvIj5SZW5ld2FibGUgRW5lcmd5PC9hPjwvbmF2Pg

Reduced Corporate Income Tax (CIT) rates from the standard rate of 25% for tree crop farming (up to five years)[102]. In 2016, the Public Utility Regulatory Commission (PURC) published the gazetted revised feed-in-tariff rates to boost private sector investment in renewable energy[103].

4.3.1.3 Strengthening vehicle inspections

Efficient vehicle inspection is critical for high-performance of public and private transport. The main policy direction is to allow private sector participation in vehicle inspection. In line with the policy, the Ministry of Transport franchised the first twenty private vehicle inspection centres in the country. Under this initiative, vehicle inspections have become automated, and voluntary vehicle emissions testing is part of the examinations. Furthermore, the DVLA, EPA and the Ghana Standards Authority (GSA) have adopted a motor vehicle emission standard. The EPA has developed a regulation to back the implementation of the standards which is currently undergoing administrative reviews.

4.3.1.4 Sulphur in diesel regulations

Ghana has put in place low sulphur diesel standards to reduce vehicle emissions with a new sulphur content standard of 50 parts per million (ppm), down from 3,000 ppm[104]. This move positively affects 3 million residents in Ghana by reducing exposure to poor urban air quality.

4.3.1.5 Cookstove performance labelling

According to GLSS7, about 68% of Ghanaian households still rely on solid biomass as their primary cooking fuel, mostly using inefficient cookstoves. Most of these solid biomasses are harvested from the wild and carbonised using inefficient conversion technologies, leading huge vegetation cover losses and high carbon emissions. Hence, the policy decision to regulate the production and use of solid fuels for cooking and heating. The Government is harnessing successes chalked in implementing star-labelling energy efficiency schemes for electrical appliances to apply the same for improved biomass cookstoves. The national standard adopted for biomass cookstoves to be recognised as more efficient than baseline technologies is 20% thermal efficiency (as compared to an average of 18% for baseline technologies). Thresholds have also been adopted from the ISO voluntary performance standards for emissions ($PM_{2.5}$ and Carbon Monoxide) and safety under the labelling scheme, tested using the ISO test protocols. The Energy Commission has engaged several stakeholders on the draft regulations to implement the labelling scheme for biomass cookstoves and is working to finalise the regulations for submission to the Ministry of Energy by the end of 2020 for onward submission to the Parliament of Ghana. All the efforts are geared towards facilitating a faster transition to efficient biomass stove for cooking in households, institutions and commercial ventures.

4.3.1.6 No gas flaring legislation

In 2016, Ghana passed legislation (Petroleum Exploration and Development Act 919, 2016)[105] to restrict the flaring of gas in petroleum exploration and development unless the regulator grants permission. In practice, this legislation applies to flare and venting operations in petroleum exploration and operations of oil and gas fields, gas processes and oil refining.

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[102] https://www.gipcghana.com/invest-in-ghana/why-ghana/tax-regime-and-incentives.html

[103] http://www.purc.com.gh/purc/sites/default/files/fit_2016.pdf

[104] https://www.myjoyonline.com/news/2017/April-17th/ghana-to-reduce-sulphur-levels-in-fuel-to-50ppm-from-july-1.php

[105]http://www.petrocom.gov.gh/L&C_folder/Pet_register/laws/PETROLEUM%20(EXPLORATION%20AND%20PRODUCTION)%20ACT,%202016%20(ACT%20919).pdf

4.3.1.7 Building codes
The Ghana Standards Authority has issued the 2018 building codes (GS 1207: 2018) which seek to, among others, promote energy efficiency and green building practices in the design and construction of structures.

4.3.2 Mobilising Finance to Support Mitigation Measures
The government and its many collaborators mobilise funds to implement mitigation actions from several national and international sources. At the national level, the government allocates public funds in the national budget to finance mitigation investments in forest plantation development, fleet renewal, natural gas infrastructure, sustainable energy, and waste management. Summary of Ghana's efforts to raise the funding for mitigation actions are as follows:

4.3.2.1 Establishment of SDG delivery and green funds
The initiative is a joint effort between the government and the private sector SDG advisory group. The SDG delivery fund and Green fund was established in 2019 to raise funds to support the implementation of the country's SDG programme. The private sector has the target of establishing US$100 million SDGs Delivery Fund and a US$200 million Green Fund to complement government's efforts at tackling climate change and funding the implementation of the SDGs[106]. The fund would be raised over five years from the corporate social responsibility (CSR) budget to capitalise the fund.

4.3.2.2 Accessing mitigation finance from international earmarked funds
Ghana has mobilised mitigation finance from international funds such as Climate Investment Fund (CIF), Global Environment Facility (GEF) and the Green Climate Fund (GCF). Under the CIF[107], the Government and its partners are investing US$ 75 million to enhance the vitality of the forest landscape. An additional US$ 40 million is being invested in boosting the scaling up of renewable energy penetration. Similarly, the GEF has invested US$ 89 million in 32 national projects over the last two decades[108]. Ghana is yet to receive direct mitigation finance from the GCF. The GCF has approved funding for two adaptation projects worth US$ 46 million[109]. There are two mitigation projects on green cooling and shea landscape REDD+ seeking funding from GCF.

4.3.2.3 Result-based payment mitigation projects
Ghana is developing two Result-Based Payment (RBP) mitigation projects under the World Bank's Forest Carbon Partnership Facility (FCPF) and the International Transferred Mitigation Outcomes (ITMOs) under Article 6.2 of the Paris Agreement. Under the FCPF, Ghana is about to implement a result-based payment Cocoa REDD+ project to generate 10 million emissions reduction over six years. Ghana and Switzerland are about to pilot the National Clean Energy Access Programme (NCEP) under the ITMOs scheme. The NCEP[110] would seek to operationalise Article 6.2 in Ghana and transfer mitigation outcomes as ITMOs to Switzerland, thereby demonstrating the scalability of the conditional mitigation commitments. The NCEP would contribute to reducing GHG emissions by increasing access to distributed energy for qualified households and SMEs in Ghana. The programme would involve the nationwide installation and operationalisation of a wide range of renewable energy technologies.

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[106] https://www.presidency.gov.gh/index.php/briefing-room/news-style-2/1369-ghana-committed-to-reducing-her-carbon-footprints-president-akufo-addo
[107] https://www.climateinvestmentfunds.org/country/ghana
[108] https://www.thegef.org/country/ghana
[109] https://www.greenclimate.fund/countries/ghana
[110] https://www.international.klik.ch/en/Activities-and-impact/Mitigation-activities.287.html

It covers solar PVs, solar lanterns, solar home systems, and improved cooking systems to generate an estimated 2.2 million tonnes of carbon dioxide equivalent and increase access to more than 1 million green technology installations. An essential feature of the ITMOs activity is the integration of a Green Credit Line to streamline and scale-up investment. The carbon receivables would cushion SMEs to take up an ambitious expansion programme and reduce the payback risk to the local banks through credit guarantees.

4.3.2.4 Establishment of €30m Facility to Support the Implementation of Renewable Energy and Energy Efficiency Projects in Ghana

Agence Française de Développement (AFD) and the Energy Commission (EC) have signed a Technical Assistance Facility (TAF) to support local banks and energy businesses in Ghana. The facility, Sustainable Use of Natural Resources and Energy Finance (SUNREF) programme is one of the most significant green finance projects to be deployed in Ghana. SUNREF programme seeks to provide both technical assistance and green credit loans to local financial institutions for them to finance small and medium-scale renewable energy and energy efficiency projects in Ghana. The SUNREF programme has three pillars: credit lines of up to €30m from AFD disbursed through local banks; Technical Assistance Facility (TAF) of €1.88 million from the European Union Africa Infrastructure Trust Fund (EU-AITF); and an investment grant scheme €2.4m from the EU-AITF to provide additional incentives to green investments. The programme aim is to support small and medium-sized companies in Ghana to invest in renewable energy and energy efficiency interventions. It could contribute up to 7GWh per year reduction in energy consumption, increase the share of renewable energy in the overall energy mix and contribute to 3.2 ktCO_2 emissions saving each year.

4.4 Capacity Development for Enhanced Mitigation Actions

There are several on-going skill development initiatives that contribute to strengthening the mitigative capacities in the country. A brief overview of the mitigation related capacity development efforts is described in this section.

4.4.1 Skills Development Fund

Ghana has established the skills development fund (SDF) to provide funds to improve the productivity of the workforce through training. The Government of Ghana, the World Bank, and DANIDA provided funding for SDF. Priority is on enterprises in agribusiness/processing and sustainable energy. Under SDF, micro to large enterprises, universities, and technical universities can access funding for specialised training and acquire machinery. Through SDF, many artisans have been trained in solar installation and maintenance by the Energy Commission and Ghana Telecom University College[111]. The training also focused on technicians working on a solar system to upgrade their capacity in grid-connected solar PV installations. SDF provided GHS 1.6 million funding to put in place a technology centre at the Kumasi Technical University to promote renewable energy and energy efficiency technologies to businesses. The centre also conducts research and provides practical training to students in sustainable energy.

4.4.2 Technical Education and Institutional Training in Mitigation Related Disciplines

Training and research into renewable energy is a vital area in most universities and technical institutions in the country. KNUST has established The Energy Centre (TEC), Technology Consultancy Centre (TCC) and Land Use Centre to research and promote mitigation technologies in renewable energy and land use. The Energy Centre offers studies on policy engagement and organises short courses in renewable energy.

[111] https://www.sdfghana.org/fwindow.php?fid=8

The University of Energy and Natural Resources (UENR) established in 2012 delivers higher education, disseminate knowledge, and undertake energy-and-natural resources-related research. UENR has set up a regional centre for energy and environmental sustainability[112] to provide post-graduate training in Energy and Environment. Africa Institute for Sanitation and Waste Management is a collaboration between KNUST and Zoomlion Ghana Limited to establish specialised training bodies to train, study and promote innovative waste management technologies. The University of Ghana also has the Institute of Environment and Sanitation Studies and the Centre for Climate Change and Sustainability Studies to research and advocate for the adoption of mitigation technologies in the waste sector.

4.4.3 Certified Electrical Wiring

In 2012, Ghana's Parliament passed the Electrical Wiring Regulation (L.I. 2008)113 to govern electrical wiring and installation in Ghana. The Energy Commission has issued guidelines for the certification of electricians and curriculum for the examination and certification of electricians. The Commission has certified several institutions in the country to undertake pre-examination training in electrical wiring for prospective electricians. The Energy Commission has developed a database application (CEWP App) for certified electricians in Ghana. This App, which is available on the Google play store and the Apple app store, allows customers access to the database and allows them to use only certified electricians for their electrical wiring and installations.

4.4.4 Training of Biogas Technicians

The Ghana Cleaner Production Centre has a programme under the Switch Africa Green Project to train artisans in eight modules on the construction of biogas digesters. So far, the centre has trained 30 artisans who have been issued a Certificate of proficiency from the National Vocational Training Institute (NVTI). A biogas calculator has been developed to assist artisans in the estimation of materials required for biogas construction by the National Cleaner Production Centre.

4.5 Greenhouse Gas Mitigation Assessment

This section presents the steps used to conduct the GHG mitigation assessment, and the results are in two parts. Part one outlines the national arrangements for the mitigation assessment by addressing topics like key sectoral emission analysis, institutional mechanism for mitigation activities, methods and data sources, mitigation analysis archiving system and plans for further mitigation. The second part is on the mitigation assessment results. The results are presented for aggregate and individual measures in the energy and non-energy sectors. There is additional information on priority mitigation measures.

4.5.1 Categorisation of IPCC Greenhouse Gas Inventory Sectors for Mitigation Sectors

The mitigation assessment builds on GHG inventory estimates by mapping the results to suit key mitigation sectors. The first important step was to sort inventory results of the categories under the traditional IPCC sector into the mitigation sectors. The sorting allows for the inventory estimates to be expressed into sector classifications like the national GDP accounts. Aligning the GHG inventory results with the national account, helped to establish the linkages between GDP and emission trends. Table 24 presents the emissions according to the IPCC sectors, mitigation sectors, and national accounts.

[112] https://www.rcees.uenr.edu.gh

[113] http://www.energycom.gov.gh/licensing/electrical-wiring

Table 24: Categorisation of GHG inventory sectors to mitigation sectors and national accounts

GHG inventory sector	IPCC Codes	Mitigation sectors	National accounts	Historical emissions [$MtCO_2e$]		Share of 2016 national emissions (%)
				2010	2016	
Energy	1.A1	Electricity supply	Service	2.6	5.01*	11.98
	1.A3	Transport		4.88	7.08	16.93
	1.A4	Others		1.44	1.53	3.66
	1.B2	Fugitive		0.02	0.02	0.05
	1.A2	Manufacturing industry	Industry	1.78	1.05	2.51
Industrial Processes and Products Use	2.A, 2.B, 2.C, 2.D, 2F	Industrial process		1.09	1.04	2.49
AFOLU (livestock)	3A,	Agriculture	Agriculture	2.69	3.48	8.32
AFOLU (Land)	3B	Land-use change		12.98	12.87	30.77
AFOLU (Non-CO_2 and Aggregated sources)	3C	Aggregated Agric emissions		5.82	6.57	15.71
Waste	4A, 4B 4C	Solid waste	Services	1.04	1.33	3.18
	4.D1	Domestic wastewater management		1.08	1.21	2.89
	4.D2	Industrial wastewater management	Industry	0.42	0.62	1.48
Total				**35.84**	**41.81**	**100**

*Emissions from energy transformation (manufacture of solid fuels and refining) of 0.35 $MtCO_2e$ has been excluded from the 1.A1 in 2016 because it was not considered a significant emission source in the country. In 2010, 0.23 $MtCO_2e$ from the manufacture of solid fuels and refining, was not included under 1.A1.

4.5.2 Institutional Arrangement for Mitigation Assessment

Ghana's mitigation assessment has emerged from multisectoral efforts of line ministries. The information gives an overview of the existing institutional structure for mitigation assessment. It also identifies where there have been improvements since the submission of the third national communication and documents areas in the current institutional arrangement requiring further strengthening. The EPA is the designated mitigation assessment agency and the hosts of the UNFCCC focal point. The EPA has the responsibility to coordinate the planning, preparation, and reporting of the mitigation assessment in close collaboration with key government institutions.

Within the EPA, the climate change unit undertakes the day-to-day management of the mitigation assessment. The unit prepares a work plan for the sectoral mitigation teams, assists with data requests and ensures that the outputs of the mitigation assessment meet high-quality standards and are submitted on time. The EPA is also tasked to document all materials, including data and store them in a single location. Furthermore, the EPA identifies officers from the relevant institution to form the mitigation assessment team and prepares a memorandum of understanding to govern how they work within the broader framework of the assessment. A small sector group was formed out of the mitigation team to specifically focus on energy, transport waste management, land-use change, and cross-cutting issues.

Tables 25 and 26 give an overview of the existing institutional arrangements for the mitigation assessment. Table 26 highlights the relationships between the designated mitigation organisation and UNFCCC Focal Point; Table 27 gives details on the mitigation team members.

Table 25: Designated mitigation assessment agency

Designated National GHG Mitigation Assessment Preparation Agency	Describe the arrangements or relationship between Mitigation Assessment Agency/Organisation and UNFCCC Focal Point Agency	UNFCCC Focal Point and UNFCCC Focal Point Agency
Energy Commission Energy Centre, KNUST Ghana Atomic Energy	Member of the mitigation assessment team group responsible for energy.	Mr K. Y. Oppong Boadi, Environmental Protection Agency UNFCCC Focal Point Agency manages the mitigation assessment process from planning, preparation, and reporting.
Ministry Transport	Member of the mitigation assessment team, provided mitigation actions in the transport sector.	
Forestry Commission	Member of the mitigation assessment team and lead for the land-use change category. Provided data on REDD+ and forest plantation as input into the forest mitigation assessment.	
Economics Department, University of Ghana, Legon	Member of the mitigation assessment team, provided inputs into the economic analysis aspects. Instrumental in the construction of the marginal abatement revenues for the prioritised mitigation actions. Validated technology cost prices and the assumptions behind the GDP projection and the discount rates.	
Ministry of Environment, Science, Technology, and Innovation	Member of the mitigation assessment team and responsible for mitigation policy in the Environment sector include carbon markets.	
Environmental Protection Agency (Built Environment Department.)	Member of the mitigation assessment team, led in the assessment of mitigation opportunities in the landfill and compost.	
Environmental Protection Agency (Manufacturing Industry and Climate Change Unit.)	Member of the mitigation assessment team and was responsible for mitigation actions in industrial processes covering HFC phase-out and industrial wastewater management	

Table 26: National mitigation assessment team

Role	Name	Organisation	Contact Information	Comments
Mitigation Team Leader	Mr Simpson Attieku	Energy Commission	Email: attieku@energycom.gov.gh Tel: 0244872370	Dr Daniel Benefoh of Environmental Protection Agency was the alternate leader of the mitigation team.
Electricity Supply Lead	Mr Simpson Attieku	Energy Commission	Email: attieku@energycom.gov.gh Tel: 0244872370	The sector lead ensured strong linkages with the strategic national energy planning process.
Nuclear Power	Dr Seth Debrah	Ghana Atomic Energy Commission	Email: s.debrah@gaecgh.org Tel: 0243215604	The mitigation team member who focused on the mitigation assessment of the planned nuclear power.
Residential and Commercial Sector	Ms Paula Edze	Energy Commission	Email: pedze@energycom.gov.gh Tel: 0244487403	Coordinator, SEforALL Secretariat
Energy Efficiency in homes, commerce, and industry	Mr Kennedy Amankwa	Energy Commission	Email: kenamankwah@yahoo.co.uk Tel: 0242261212	Member of the national GHG inventory working group on energy and contributed to the assessment of mitigation opportunities in energy efficiency measures.
Industry Sector	Mr Joseph Baffoe	Environmental Protection Agency	Email: jabaffoe@gmail.com Tel: 0262373698	Mitigation action in the RAC sector with an emphasis on the HFC phase-down.
Land-use management	Thomas Gyambrah	Forestry Commission	Email: nanayaw239@yahoo.com Tel: 0249772820	Forestry mitigation measures on REDD+ and forest plantation
Solid Waste Management Lead	Mr Joy Hesse Ankomah	Environmental Protection Agency	Email: joy.ankomah@epa.gov.gh Tel: 0501301433	Waste mitigation action on landfill management, compost, and biogas
Economic/Integrated Analysis	Prof. Daniel Twerefou	University of Ghana Economics, Dept.	Email: twerefou@yahoo.co.uk Tel: 0244-603-676	Review of cost prices and the assumptions behind the GDP projection and the discount rates.
Sustainable development and mitigation policy	Mr Peter Dery	CDM/DNA, MESTI	Email: peterjdery@yahoo.co.uk Tel: 0243-646749	Linkages with carbon markets and environment sector mitigation actions.
Archive (Data and Document)	Dr Daniel Tutu Benefoh	Environmental Protection Agency	Email: dbenefor2000@gmail.com Tel: 0246114652	Member of the national GHG inventory-working group on energy.

Table 27 gives additional information on the roles and responsibilities at the sectoral level. It includes the specific task assigned to each member of the sector groups. They also teased out the crucial challenges the team encountered during the assessment and strategies to address them in the next mitigation assessment exercise. The mitigation assessment task broadly includes coordination of the assessment process; technical assessment; review of results and methodological choices, data collection and archive.

Table 27: Roles and responsibilities of the mitigation assessment team

Roles	Institutions	Contact(s)	Contact Information	Participated in the assessment meeting?	Comments
Mitigation assessment lead is responsible for the overall coordination of GHG mitigation assessment in the energy sector	Ghana Energy Commission and the Environmental Protection Agency	Mr Simpson Attieku and Dr Daniel Benefoh	Email: attieku@energycom.gov.gh Tel: 0244872370 Email: dbenefor2000@gmail.com Tel: 0246114652	Yes	EPA has an existing MOU arrangement with the institutions that are involved in the mitigation assessment. The MOU governs the relationship between EPA and institutions in terms of the data exchanges, finalisation of work plan and deliverables, and reporting lines. The team is also responsible for the coordination of a series of technical and stakeholder meetings to discuss the strategy on training, data collection, and work plans. Data collection is an integral part of the mitigation assessment. The Energy Commission and EPA led in the regular data collection throughout the assessment period.
Mitigation assessment team. The team conducts assessment for energy, transport, forestry, and waste management consistent with internationally recognised methodologies.	Energy Commission, EPA, Energy Centre, KNUST, Forestry Commission, Ghana Atomic Energy Commission and Ministry of Transport	Refer to Table 4	Refer to Table 4	Yes	The lead created smaller groups out of the mitigation team to focus on specific sector assessments in energy, transport, land-use change, industrial processes, and waste management. Each team had the responsibility to identify key data sources; collect and process mitigation assessment data, and choose appropriate tools to undertake the sector mitigation assessment and prepare sector reports. Energy Commission used the LEAP model to evaluate the mitigation opportunities in the energy and transport sectors.
Mitigation team responsible for ensuring policy linkages with the mitigation assessment. The team also reported on carbon markets and provided inputs into economic data used in the evaluation.	University of Ghana, Economics Dept. CDM/DNA-MESTI, EPA	Refer to Table 4	Refer to Table 4	Yes	The team ensured linkages between the mitigation assessment and key sustainable development policies. They also provided critical inputs in the review and selection of methodology for the assessment. The team also participated in the workshop to evaluate the initial results from the assessment.
Review of mitigation assessment methodology and results	UNEP-DTU Partnership	Jorgen Villy Fenhann	Email: jqfe@dtu.uk	Yes	The team worked with UNEP-DTU Partnership to undertake an economy-wide mitigation assessment using the GACMO model. UNEP-DTU originally developed the GACMO model.

	ISSER – University of Ghana, Legon	Dr Aba Obrumah Crenstil	Email: abaodoi@gmail.com Tel: +233 244363551	Yes	Participated in the mitigation assessment meeting to provide inputs into the methodology for the assessment.
Data providers	SPPD – Energy Commission	Mr Simpson Attieku	Email: attieku@energycom.gov.gh Tel: 0244872370	Yes	Supplied LEAP dataset for the analysis under the energy sector. Using the LEAP database ensured consistency with the Strategic National Energy Plan (SNEP). The EPA requested for the LEAP data as part of the collaboration with the Energy Commission. Both the EPA and Energy Commission team that worked on the SNEP also worked on the energy sector mitigation assessment.
	SEforALL Secretariat – Energy Commission	Ms Paula Edze	Email: pedze@energycom.gov.gh Tel: 0244487403	Yes	The SEforALL secretariat provided data on sustainable energy projects on the various energy institutions are implementing programmes in areas relevant to the mitigation assessment. The secretariat publishes a quarterly bulletin on sustainable energy interventions in Ghana.
		Mr Ebenezer Ashie	Email: ebenashie@gmail.com Tel: 0557349004	Yes	
	Energy Efficiency and Climate Change Unit– Energy Commission	Mr Kennedy Amankwa	Email: kenamankwah@yahoo.co.uk Tel: 0242261212	Yes	Provided data on significant energy efficiency interventions across the country that are useful to the mitigation assessment in the energy sector. The Unit also contributed to the screening and selection of the mitigation actions using multi-criteria analysis.
	Ghana Statistical Services (GSS)			No	Facilitated access to publicly available data on Ghana living standards surveys, housing, and multiple indicators cluster surveys. The GSS figures were useful in the household energy demand projections, waste disposal trends and industry waste outputs.
	National Development Planning Commission (NDPC)	Dr Felix Addo-Yobo	Email: felix.addo-yobo@ndpc.gov.gh Tel: 0505093954	Yes	NDPC has the mandate to set out the priority list of the government of the day in the national development plan. The key policy areas informed the mitigation assessment scenario. The Commission also regularly publishes the annual progress report and helps to track the implementation of key government policies and programmes.
	Forestry Commission	Mr Thomas Gyambrah	Email: nanayaw239@yahoo.com Tel: 0249772820	Yes	Forestry Commission provided data inputs on REDD+ and forest plantation. Participated in the mitigation

		Mr. Charles Sarpong Duah	Email: strongmanbowas@yahoo.com Tel: 0546419884	Yes	assessment meeting to offer data into the methodology for the assessment.
	Built Environment Department - Environmental Protection Agency	Mr Joy Hesse Ankomah	Email: ankojoyhesse@yahoo.com Tel: 0501301433	Yes	Provided data on solid waste management, including composting and landfill gas management.
	Climate Change Unit - Environmental Protection Agency	Mr Joseph Baffoe	Email: jabaffoe@gmail.com Tel: 0262373698	No	Provided data on HFC consumption in the country and input in the potential mitigation assessment.
Data Archiving		Dr Daniel Tutu Benefoh	Email: dbenefoh2000@gmail.com Tel: 0246-114-652	Yes	Documentation and archiving

4.5.2.1 Potential improvements in the institutional arrangement

Table 28 outlines the key identified areas in the existing institutional mechanisms needing further improvement in the subsequent assessments. The improvement areas are: increasing access to policy, technology, and financial/economic data; strengthening working relationships of the institutions involved in the evaluation; continuous capacity development; use of appropriate and comprehensive mitigation assessment tools and inclusion of additional stakeholders in the mitigation assessment.

Table 28: Potential improvements in the existing institutional arrangements for mitigation assessments

Mitigation sector/category	Strengths in the management structure of national mitigation assessments	Potential increases in the management structure of national mitigation assessments
Electricity Supply	Access to reliable plant-level current and projected electricity supply data from the LEAP model. The projections data on electricity supply are consistent with the SNEP. The independent power producers and the Volta River Authority supplied the primary data on electricity supply (process and fuels) to the Energy Commission. The Energy Commission regularly publishes the energy statistics annually in April. The statistics contain electricity to supply data and the source of power plants and the fuel used. This dataset is a useful source for the mitigation assessment in electricity supply. The team coupled electricity optimisation model results in the LEAP model to enhance the outputs.	Develop country-specific emissions factors that are representative of increasing diversification of electricity sources. Build on the CDM methodology for the development of grid emission factors. Continue working with Volta River Authority facility-level accounting and expand the programme to include independent power producers. Improve economic and technical forecast data in electricity supply in the short-term. Link the short forecast data with the annual electricity supply plan produced by the power sector players.
Demand-side Households, Commerce, and Industry	The regular supply of data on household energy use and expenditure from the Ghana living standard survey regularly published by the Ghana Statistical Service. The household energy demand projection is based on historical data on household energy consumption and expenditure, incomes and population trends and specific policy targets. The Energy Commission surveys data on energy demand and intensities for different fuels in commerce and industries. There is a right level of in-country capacities to run the LEAP model. The Energy Commission officially uses the LEAP model for strategic energy planning. The mitigation assessment builds on the LEAP model to ensure consistency.	Improve data on the relationship between economic and population forecast and household energy demand projection Ghana does not have country-specific data on technologies in the LEAP model. In this regard, the team relied on global prices in the mitigation assessment. There is a need to conduct a study to assess the cost of major climate-smart technology and the factors that drive the value over time.

Transportation (road transport)	Increased access to vehicle population data from the Ministry of Transport and the Driver Vehicle and Licensing Authority. The vehicle data include annual imports from Ghana Customs, Vehicle Registration, and Roadworthy certification from the private garages. The data covers vehicle model, technology class, fuel, and weight from 1995 to 2016.	Collaborate with DVLA and the private vehicle inspection garages to collect data on annual mileage. Survey to collect data on passenger or freight km in collaboration with the Ministry of Transport and DVLA. Improve data on the correlation between passenger/freight transport and sector GDP and motorisation rate. Organise additional training on transport modelling.
Industry Sector	Obtained data on industry from the Energy Commission, Ghana Statistical Service, and the Environmental Protection Agency.	Update data on industrial and commercial energy consumption through a survey. Expand the annual environmental report for the industry to include GHG estimation and the industry level projections. There are plans to establish an online reporting system for the industry. Include Association of Ghana Industries, Ministry of Trade and Industry and the Private Enterprise Federation in the mitigation assessment. Their involvement would be essential to add policy and regulatory dimensions to the assessment.
Land-use change	National plantation development programme annual report provides useful plantation data (area planted, target, and investment and food production).	Capacity development on mitigation assessment modelling in the land sector such as the ALU, Ex-ACT tool by FAO. Continue efforts towards ensuring consistency between the land BAU emissions (baseline) and the REDD+ forest reference levels.
Solid Waste Management	The team procured data from two compost facilities and the Ministry of Sanitation and Water Resources in the country for the assessment.	Collect landfill-specific or facility-level data on solid and liquid waste disposal and treatment. Collaborate with local government authorities in the ten regional capitals in Ghana to improve on the method of data collection, particularly, solid waste disposal.
Cross-sectoral	There is a collaboration between economic research, development and environment institutions which facilitated a greater exchange of data and experiences on economic forecast and sustainability options	Deepen the involvement of research and academic institutions in the financial forecast and analysis of market potentials of selected technologies. Collaborate with research and academic institutions to develop methodological tools that consider the real economic structure of Ghana. Develop simple to implement QA/QC and uncertainty template for the sectors.

4.5.3 Mitigation Assessment Methods and Data Sources

The proper documentation of information on the methodology, data and data sources and the underlying assumptions is critical to ensure greater transparency in the mitigation assessment. Such information would enable users who were not directly involved in the assessment and the future mitigation teams to understand the rationale for the methodological and data choices. The next mitigation assessment can refer to this documentation to determine the methods, tools and resources used. It would also help to improve transparency by explaining how the assessment was done and the challenges encountered. The documentation would also reduce the future effort teams would require to develop the mitigation assessments and provide a basis to ensure consistency in future reports. Table 29 provides an overall summary of the methods used for critical mitigation analysis tasks (BAU projection, mitigation scenario analysis).

Table 29: Methodological steps used for mitigation assessment in the energy and non-energy sectors

Analysis Task	Description of Methods	Who conducted the analysis?	Key Contact	Comments
Development of BAU Scenario	Energy sectors: Baseline emissions were projected along with the business as usual (BAU) trajectory for the period 2016-2030. BAU is analogous to without measures scenario (WtM) and covers the national and sector levels. The BAU generally represents the future emissions associated with the continuation of the status quo of government policies. In the energy sector, the BAU emission is consistent with the AEG scenario in the LEAP model. AEG is when the government implements its mitigation policy without adopting new ones. The 2016 baseline emissions projected to 2030 based on the economic (GDP), population and policies. The BAU emissions are the threshold below which emission reductions would occur due to the implementation of mitigation policies. It is also used as the reference for the measurement of performance of the individual or agreement mitigation policies. Non-energy sectors: In the non-energy sectors where specific data on future projections on the drivers of the future emissions do not exist, the team decided to use the mean for the last five years of the historical emissions to inform the BAU emission projections. The non-energy sectors included land-use change, waste management, and industry. Transportation was treated separately from the energy sector even though the LEAP model included it as one of the demand sectors.	Mitigation assessment team (Energy Commission and EPA)	Energy sector – Mr Simpson Attieku (Energy Commission), Dr Seth Debrah (Ghana Atomic Energy Commission and Dr Daniel Benefoh (Environmental Protection Agency)	In the energy sector, the assumption on economic growth, incomes, population trends, price variation, currency exchange rates, fuel prices, emission factors, discount and policy covered in the BAU, were consistent with the LEAP.

Identification and prioritisation (screening) of mitigation options	Several mitigation options have been identified for each sector based on existing programmes and the new policy direction. The team used a multi-criteria assessment (MCA) approach to screen the mitigation option to come up with a list of measures. The MCA tool is a spreadsheet that the team adopted to suit the unique planning situation of the country. The MCA approach was developed using qualitative and quantitative variables. The qualitative factors included the following: consistency with alignment with the sector, national priorities and SDGs, institutional ownership, technical effectiveness, capacity availability and ease of implementation whereas the quantitative factors were emission reduction, marginal cost, and investment outlay. The MCA is a Focused Group Discussion (FGD). Each criterion was scored and assigned overall weight. The participants did three rounds of scoring, individually and as a group. In each scoring round, the participants provided an objective score for each mitigation option using a "score sheet" in no order based on their disposition to specific field experience/ knowledge/ expertise. The group scoring was in two scoring rounds. Scoring was moderated by a facilitator who managed the group dynamics and ensured fairness. The co-solicitation was used to achieve objectives and transparent allocation of scores and reduction of bias. Allocation of scores for each criterion per mitigation option was agreed upon in two ways either through consensus scoring (where the participants agreed on a proposed score for a mitigation option after short discussions) or scoring by voting, (if no consensus after the participant's deliberations. When voting or agreement does not resolve the allocation of the score, the mitigation option was excluded from the list. The results of the individual score and group scores were averaged and allocated to the mitigation option. The MCA produced a priority list of mitigation options that were put together as policy packages under different mitigation scenarios (unconditional measures and conditional measures).	Mitigation assessment team (EPA team and workshop participants) facilitated by UNEP-DTU	Dr Daniel Tutu Benefoh, (Environmental Protection Agency)	Dr Daniel Twerefou of the Economics Department, University of Ghana, Legon) had used a similar MCA approach to prioritise low carbon development intervention in the country.

Macro-Economic Analysis	The macro-economic assessment was not conducted due to the lack of appropriate datasets to run Computational General Equilibrium (CGE) models.			There is a plan to undertake dynamic modelling of mitigation options in the subsequent assessments.
Mitigation Scenario Analysis (integration)	Economy-wide simulation for two mitigation scenarios (unconditional and conditional mitigation target) (GACMO model)	Mitigation team supported by the EPA and UNEP-DTU	Mr Jorgen Villy Fenhann UNEP-DTU Partnership Dr Daniel Tutu Benefoh, Dr Antwi-Boasiako Amoah	The GACMO model is an all-in-one mitigation assessment tool for all sectors. It is easy to use and flexible enough to suit Ghana's national circumstances. The tool has a robust and transparent methodological structure and can be portable to other models.
	Economy-wide simulation for energy mitigation scenarios (LEAP Model), expressed as "with measures (WM)" and "with additional measures (WAM)" and "with additional measures plus" depicting increasing levels of ambition. The different mitigation scenarios made of several policy measures compared to the without measures scenario (WtM).	Energy team and EPA	Mr Simpson Attieku (Energy Commission), Ms Paula Edze (Energy Commission), Mr Kennedy Amankwa (Energy Commission), Dr Seth Debrah (Ghana Atomic Energy Commission) and Dr Daniel Tutu Benefoh (EPA)	The LEAP database was initially developed by the Energy Commission to inform the strategic energy planning process. Several mitigation scenarios along different policy packages were created.
	Simulation of mitigation scenarios based on the forest plantation strategy and the REDD+ strategy (ALU and GACMO Model).	Land sector team and EPA	Mr Thomas Gyambrah (FC) Mr Charles Sarpong Duah (FC) and Dr Daniel Tutu Benefoh (EPA)	The GACMO focused on forest land. REDD+ projection was obtained from the forest reference level estimates.
	Simulation of mitigation scenarios in the solid and liquid waste categories. GACMO model.	Waste team and EPA	Mr Joy Ankomah Hesse, Mrs Juliana Bempah and Dr Daniel Tutu Benefoh all of EPA	The focus was on biogas and compost in the waste sector.
Marginal revenue curve	The GACMO model uses a spreadsheet to construct a marginal revenue curve for selected mitigation technologies.	EPA and UNEP-DTU.	Mr Jorgen Villy Fenhann (UNEP-DTU Partnership) Dr Daniel Tutu Benefoh (EPA), Dr Antwi-Boasiako Amoah (EPA)	Technology and fuel costs were obtained from international sources.

Tables 30-33 provide additional documentation on the tools and resources used for the specific mitigation assessment tasks, the rationale for using the selected tools and resources, and comments and suggestions for future analyses.

Table 30: Tools and methodologies used in the energy sector

Analysis Task(s)	Development of BAU and mitigation scenarios
Sector or scope	Economy-wide projections. The projections covered all the GHG inventory sectors from 2016 to 2030, but the emissions from agriculture and industry are not part of the mitigation commitments. The emission scenarios were as follows: "without measures (WtM)" and "with measures (WM)" and "with additional measures (WAM)." Without measures (WtM) - The scenarios corresponded to baseline (BAU emissions), unconditional and conditional mitigation projects reflecting increasing ambition. The WtM scenario represents future emissions trajectory projections along with status quo policy (trend of the existing policy remained unchanged in future, and none of the proposed or on-going government measures that have mitigation objectives is wholly or partially implemented). With measures (WM) - represented a future emissions scenario where proposed or on-going government policies and measures are implemented to achieve a lower mitigation goal. This scenario corresponds to the 15% unconditional mitigation commitment under the first nationally determined contributions. With additional measures (WAM) - a scenario with additional measures (mitigation scenario – where ambitious additional measures are undertaken with international support to achieve high ambitious emission reductions). This scenario is consistent with the 30% conditional mitigation commitment under the first nationally determined contributions.
Model/data source/tool	LEAP (Long-range Energy Alternative Planning) and the GACMO model
Describe why this resource was chosen	The LEAP model and GACMO are flexible and straightforward to use. Both are not data-intensive and can be adapted to suit the complexities of the national circumstances. There are significant in-country capacity levels to use the two models. The GACMO model has an in-built MRV component which allows for the tracking of the effects of the mitigation actions. The LEAP model has been the primary analytical tool for energy planning and mitigation assessment since 2005. The GACMO was officially adopted for the latest analytical work behind Ghana's NDC. Ghana would continue to use both tools in the future.
Contact	Energy team – Mr Simpson Attieku (Energy Commission), Ms Paula Edze (Energy Commission), Mr Kennedy Amankwa (Energy Commission) and Dr Seth Debrah (Ghana Atomic Energy Commission). Mr Jorgen Villy Fenhann, UNEP-DTU Partnership. Dr Daniel Tutu Benefoh and Dr Antwi-Boasiako Amoah all of EPA.
Other comments (e.g. usefulness, lessons, suggestions for future analysis)	The LEAP and GACMO tools allow the assessment in the energy and non-energy sectors. While the LEAP model is more energy-centric, the GACMO is an open-source spreadsheet that is simple but can be modified to suit complex assessments. There is reliable data on the cost of resources, fuels and technology, and the changes in them over time. So, in the LEAP, there was no cost information. In the GACMO, the cost information was obtained from international sources. The mitigation team plans to undertake a study to collect country-specific data on cost and investment on different mitigation technologies. The study results would improve on the data behind the marginal abatement revenues curves. Building the mitigation assessment on the LEAP model produced by the Energy Commission ensured greater consistency in the results because of the same dataset, assumptions, and mitigations scenario. Another important lesson is that the same team worked on both LEAP and the assessment and the plan is to pool them together in the future.

Table 31: Tools and methodologies used in the energy sector

Analysis Task(s)	Development of Marginal Abatement Revenue Curve
Sector or scope	Economy-wide
Model/data source/tool	GACMO tool
Why this resource was chosen	GACMO model uses a spreadsheet to construct a marginal abatement revenue curve for selected mitigation technologies. The curve automatically generates the marginal abatement revenues for each priority mitigation technology using their ex-ante emissions reduction potential (t) and the cost (in US$) of replacement.
Contact	Mr Jorgen Villy Fenhann UNEP-DTU Partnership, Dr Daniel Tutu Benefoh (EPA) and Dr Antwi-Boasiako Amoah (EPA)
Other comments (e.g. usefulness, lessons, suggestions for Future analysis)	The marginal abatement revenue curve is a histogram plot of emission savings (t) against the cost (US$) for each mitigation technology. The results are inputs of quantitative variables in the multi-criteria analysis for screening the mitigation options. The team collected data on technology costs from multiple international sources. It would be useful to collect additional country-specific technology cost data to improve the reliability of any future analysis. In the next assessment, the focus would be on energy mitigation technologies not covered in the current analysis. For instance, the team would investigate the detailed cost and mitigation assessment of nuclear technology because of the strong policy push for nuclear power.

Table 32: Tools and methodologies used in land-use change

Analysis Task(s)	Mitigation assessment for land-use change
Sector or scope	Forestry sector – carbon stock enhancement through forest plantation development and REDD+
Model/data source/tool	ALU and GACMO
Why this resource was chosen	With the ALU tool, it is possible to directly link the GHG inventory result for the forest land category to the mitigation assessment. The GACMO model allows calculating emission reduction potential and the cost for specific mitigation options (tree plantation and REDD+ in the same dashboard as other non-forest mitigation options). Both are flexible and less data-intensive. There is enough in-country capacity to use both models.
Contact	Mr Thomas Gyambrah (FC), Mr Charles Sarpong Duah (FC) and Dr Daniel Tutu Benefoh (EPA)
Other comments (e.g. usefulness, lessons, suggestions for Future analysis)	There are discrepancies in the forest reference level for REDD+ and the mitigation assessment results for the land sector. The variations were due to differences in the scope of activities in the forest reference level and mitigation. While the forest reference for the REDD+ includes activities (avoided deforestation and forest degradation), the mitigation assessment was limited to only carbon stock enhancement. In the next evaluation, the team would work to resolve differences in the baselines.

Table 33: Tools and methodologies used in solid waste management

Analysis Task(s)	Assessment of GHG mitigation potential for compost and biogas
Sector or scope	Waste sector
Model/data source/tool	Tool for calculating GHG in solid waste management (SWM) and GACMO
Why this resource was chosen	Simple, flexible modelling tool; adaptable to national circumstances,
Contact	Joy Ankomah Hesse (Built Environment Environmental Protection Agency)
Other comments (e.g. usefulness, lessons, suggestions for future analysis)	Explore opportunities to include GHG mitigation potential assessment for domestic and industrial liquid waste disposal

4.5.4 Mitigation Assessment Archiving System

In 2015, Ghana instituted a Climate Ambitious Reporting Programme (CARP) to facilitate national and international climate reporting. Documentation and archiving are some of the functional components of CARP. As a result, the EPA established[114] an online database to store GHG inventory and mitigation assessment data. The archive system keeps a record of references, the methods used, expert comments, data, and the location of the documents. The mitigation data archive has many benefits. It helps to facilitate easy retrieval of files and aid in the work of new teams in the future. It also makes the mitigation assessment process and the results more transparent and reproducible.

The team followed the documentation and archiving procedures. All the records from the assessment are in a single location online server hosted by the EPA. Having the files in a single location, in both soft and hard copies, would make it easy to retrieve by the future mitigation team. Besides, it can also serve as a reference source during technical reviews. An extra copy of the records is kept on hard drives to reduce the risk of losing them. The EPA assisted the mitigation team in collecting and processing data for the assessment. The mitigation team also used data available in NC2 and NC3 to ensure continuity.

Most of the administrative data the mitigation team obtained, were part of the data the technical institutions usually publish regularly. For instance, the Energy Commission supplied the energy sector data collected during the preparation of the strategic national energy plan. The Ghana Statistical Service and Energy Commission collected the household energy data. The EPA and the sector lead keep all materials (processed data, results, literature) in the assessment in hard and electronic formats. The stored dataset includes five spreadsheets, LEAP and ALU application database files. The file naming for each soft material follows the sector, last date saved and name of the expert who last worked on the file. Records of all comments, expert judgments, and assumptions are documented and incorporated into the separate files.

4.5.4.1 Making the archive system work

The first step of putting in place a data archive system has been successful through the CARP. In the reporting cycle, the focus would be on making the archive system work better than its current performance. In this regard, Ghana plans to streamline the role and responsibilities, standardise the archive procedures and above all, implement them. A description of the overview of some of the improvement areas in the archive system is provided below.

Defined the roles and responsibilities of archiving contact person

The EPA has played the role of archiving the assessment material. In the next assessment, the EPA intends to decentralise the task to the assessment institutions fully. The EPA would continue to act as the central point to coordinate the archiving functions. Each assessment institution must either appoint a separate archiving contact person or let the sector expert in the mitigation team act in the same capacity. Whichever option the sector chooses, the contact person would receive training on the archiving procedures at the beginning of the next assessment and assigned the responsibility to plan and implement the sector archive procedures. Generally, archiving contact person ensures that all archiving procedures are performed diligently throughout the assessment period including properly documenting and retaining mitigation assessment procedures, supporting documents, spreadsheets, and databases at every stage of the assessment.

[114] https://climatedatahubgh.com/

The person would also be responsible for clarifying who is responsible for carrying out archive procedures at various levels, as well as for ensuring that all team members know their archiving responsibilities. The archiving contact person has the following tasks:

- communicate archiving system plans, procedures, and responsibilities to other staff.
- Develop the archiving activities, and assign the task to the team members.
- Create a checklist of filing procedures for team members to follow.
- Ensure that the archive procedures go as planned.
- Serve as the keeper of the permanent archive and respond to future requests to view archive materials.

Revised archive procedures

The revisions of the existing archive procedures made it more effective by simplifying the archiving steps at every stage of the assessment. In the next evaluation, Ghana plans to continue to implement the changes in the archiving procedures. As much as possible, the mitigation team member would have the opportunity to learn about the new changes in the archive procedures before the beginning of the next assessment cycle. The latest change in the archive system would provide clear guidance on file management, data and document preservation, and storage.

File management

Throughout the mitigation assessment, the team handled multiple electronic file types. Different individuals or institutions create files from many sources. The team members also created files during the assessments. By the time the evaluation ended, the team had created several files. File management ensured the orderly naming, documentation and archiving of all data, reports, assumptions, databases, spreadsheets the assessment team had used. With regards to file naming, the group adopted a revised file saving convention to reflect the new changes in the assessment. The EPA team receives multiple files at different times. So, the team decided that the mitigation sector, source or destination, date, and the version of the file would distinctly separate all records when it was last saved and make it possible to pack all the shared files in a single folder for each sector. To get all the teams on board, the mitigation team has established a clear communication line on file management procedures and the naming convention. It is part of the orientation of the new entrants and part of the refresher training for the existing team members

Data retention

The team transferred all soft copies of data (spreadsheets, databases) used in the assessment to the custody of the archive contact person every six months and completely after the assignment. The team then archived the files listed by saving to a hard disk or other durable media and giving same to the archiving contact person. Where it was difficult for the team to store the data archive in electronic format, the team printed the files, catalogued, and placed it in the archive. The contents of the hard disk were labelled clearly for easy reference

- Source data, calculation spreadsheets and report files.
- Key sectoral emissions analysis spreadsheets.
- Draft and final electronic versions of the mitigation assessment document (for use as a starting point to update the assessment in the future).
- Updated documentation tools, which should be used to list and check references.
- The assumptions used in the assessment.
- Records of previous review comments and the actions taken to address them.

Document retention

All source documents and references used in the mitigation assessment were collected and transmitted to the archiving contact person. The materials must include vital information from publications, contacts, and the date. It also covered, at a minimum, the title page with the name of the author(s), pages of actual data used, pages explaining data used, and pages describing methodologies used. The document included:

- All new reference documents for the current mitigation assessment records file. The files retained in storage from any given analysis year are known as the mitigation analysis archive. The archiving contact person is responsible for reviewing the references cited in the mitigation assessment and collecting all new documents. It is not necessary to include duplicate copies of references that are already in the records file from the previous analyses.
- Draft versions (either electronic or hard copy) used for major internal and external peer reviews, as well as the final submitted versions of the analysis.
- The final version of the national mitigation assessment report (compilation of Key Sectoral Emissions Analysis, Institutional Arrangements for Mitigation Activities, Mitigation Analysis Archiving System, and National Mitigation Plan).
- Documents created to address comments received during any official review periods (or from expert reviews). These documents typically include both; comments received verbatim, as well as the response and subsequent actions taken by the mitigation-working group.

Storage platforms

The mitigation assessment data is stored in an online server, hard drive, and seldom in printed copies. The storage procedures are below:

- The master copies of the archive files are stored in the online server by a mitigation assessment leader.
- Duplicate copies of the archive files are stored in hard drive and lodge with the administrator of the online server at the EPA.
- All archive materials are duplicated (two copies of each document), catalogued and placed in the archive file. An index describing the contents of the archive should be placed at the front.

4.5.4.2. Additional archive procedures checklist

The archive contact persons must have clear steps to follow to achieve a high standard of archiving in the future. A checklist has been prepared for the archives contact persons to ensure that all archiving procedures are timely and complete. The checklist contains the list and schedule of all the archiving activities, responsibilities and timelines. The archiving contact person ensured that all the tasks are outlined before the start of any archive procedure. In every mitigation assessment round, the leader of the mitigation assessment team reviews the checklist and approves of it before sharing among the team members. During the inception meeting for the mitigation assessment team, the group discusses the list and confirms the responsibilities. The team also evaluates the practicality of the checklist by testing it on real-life examples. The team also agrees to document significant challenges encountered when using the checklist. Table 34 is the checklist for the archive task.

Table 34: Archive tasks, responsibilities, and schedules

No	Sub-task	Date Due	Task completed	
			status	date
Archiving contact person				
1	Created an official archive located in EPA's on the online server		√	
2	Communicated the archiving plan and set deadlines to all team members		√	
3	Collect copies of all data references		√	
4	Request missing references from sector leads			
5	Compile electronic versions of spreadsheets used to estimate emissions reductions by sector.		√	
6	Collect copies of final versions of the mitigation assessment document.		√	
7	Compile electronic versions of final versions of the mitigation assessment document.		√	
8	Collect copies of expert review comments response documents from each category lead.		√	
9	Catalogue all documents using a unique tracking number and index.			
10	Collect completed institutional arrangements for mitigation activities and documentation of mitigation assessment methods and data.		√	
11	Compile electronic versions of key sectoral emissions analysis.			
12	Save all electronic files on archived hard drives		√	
13	Distribute electronic files at the start of the next mitigation assessment update.		√	
Sector contact persons				
14	Send electronic versions of spreadsheets used to estimate net emissions to Mitigation lead (add "key" to the naming convention).		√	
15	Send final text documents for the sector to Mitigation lead.		√	
16	Send documentation of mitigation assessment and options reports for the sector.		√	
17	Create an index of draft documents and files for electronic and hard copy storage.			
18	Create an index of final documents and files for electronic and hard copy storage.			
19	Compile and send electronic versions of any key sectoral emissions analyses and documents to the mitigation lead (add "key" to the naming convention).		√	
20	Save all final electronic files on archive hard drive. Label as "FINAL" with the name of category/sector, date, and contact information, and send a copy to Mitigation lead.		√	

√ means task was successfully complemented under the current mitigation assessment

4.5.4.3 Plan for further mitigation assessment

The plan for additional mitigation assessment is a set of actions Ghana has identified to improve the mitigation assessments. The plan would guide any future efforts to increase the transparency, consistency, comparability, completeness, and accuracy of future inventories. It addresses many of the shortcomings of the previous mitigation assessment and would inform the next mitigation teams of needed improvements. The improvement areas identified in the evaluation of key sectoral emissions in Ghana include documentation of existing institutional arrangements, analyses of methods and data, and developing archiving systems. They are key areas the team encountered challenges that were not resolved during the assessment. Also, the areas for improvement have been informed by the comments from the technical review. The areas requiring improvement include institutional arrangement, technical gaps, capacity development, and outreach.

4.5.4.3.1 Improvements in institutional arrangement

The mitigation assessment is backed by a national system that governs the assessment process. It involves institutional and procedural arrangements Ghana has put in place to guide the assessment of mitigation potential of government policies and measures. In the preparation of the mitigation assessment report, the team identified and documented all the relevant contributors and their roles and incorporated them in the report. The information on the institutional arrangement is useful for improving the quality of the report. It also contributes to the efforts of institutionalisation of the mitigation assessment process into governmental structures. The information on the institutional arrangements also pinpoints the potential areas of weakness and opportunities to strengthen them. Table 35 presents the improvement areas in the existing institutional arrangement for mitigation assessment.

Table 35: Potential improvements in the mitigation assessment institutional arrangement

Category	Strengths in the management structure of mitigation assessment	Potential improvements in the management structure of mitigation assessment
Electricity supply	The energy sector team and the Energy Commission have strong work relationships. The leader of the modelling team for the strategic national energy planning also doubles as the leader of the energy group in the mitigation team. Both groups use the same primary dataset and projections. The mitigation team builds on the foundational data for the strategic energy planning for the country. The team also co-created capacity-building needs for their mutual benefits. Furthermore, there is an active collaboration among the key stakeholders that supply primary data to the Energy Commission. For instance, VRA, GRIDCo, Bui Power, Electricity Company of Ghana and the independent power producers regularly share data on electricity supply, losses, and expansion plans. Some of the datasets are published routinely in the annual energy statistics.	In the current assessment, the team has included the representative from the Ghana Atomic Energy Commission. The atomic energy expert led the modelling of nuclear energy into the future electricity mix. The team also started a collaboration with the Volta River Authority by developing a facility-specific greenhouse reporting tool. The plan is to continue the partnership and further strengthen it. There are also plans to initiate cooperation with other Independent Power Producers (IPPs).
Transport	The Ministry of Transport is part of the mitigation assessment team. The Ministry has a focal point and focuses on both policy and critical technical issues in the mitigation assessment. Transportation is considered as part of the energy demand sectors in strategic energy planning.	There is a need for the Ministry of Transport, Energy Commission, and the EPA to work together to ensure more significant synergies in the existing collaboration.
Residential	Ghana Statistical Service regularly shares household energy demand data from the Ghana Living Standards Survey with the Energy Commission. The Energy Commission uses the data in the LEAP model.	Need to further collaborate with Ghana Statistical Service to incorporate more relevant questions in their regular national living standards surveys.
Industry/ Commerce	Energy demand share, fuel intensity figures are obtained from the Energy Commission's survey.	Undertake additional commerce/industry surveys. Collaborate with the EPA's Manufacturing Industry Department to collect more data on industry/commerce.
Land-use management	The collaboration with the Forestry Commission team on the REDD+ and the Forestry Plantation Development helped to facilitate access to data.	Provide training to the Forestry Commission on land mitigation assessment.
Solid Waste Management	Some capacity within EPA to continue with any future mitigation assessment.	Start collaboration with the local government authority on regular data collection for mitigation options in the waste sector afresh.

4.5.4.3.2 Potential improvements in technical areas

The team has further identified the potential for future improvement through feedback and personal experiences. Tables 36 and 37 lists the challenges and potential improvements for the actions in the mitigation assessment process.

Table 36: Potential technical improvements in the assessment

Activity	Problem description	Potential improvements
Development of marginal abatement revenue curve	Inadequate data on technology-specific fuel consumption, unit cost, and duration. In the case where such data are missing, team members used expert judgment.	Collect specific data on fuel consumption, the market fuel cost, and lifetime through the household of market surveys.
Development of baseline emission	The baseline emissions in the ALU, LEAP and the GACMO models depended on different socio-economic and technical assumptions for energy and non-energy categories. The assumptions did not apply to all the baseline emissions.	In the current assessment, the team used the GACMO model to combine all the sectors into a single window. It helped to avoid using multiple tools for the assessment sectors. The next step is to further improve on the technical details of the GACMO and build the result of the individual tools into the GACMO model.
	The lack of clarity and a proper way to identify and incorporate government policies in the baseline scenario. Currently, the baseline cover policies outlined in the medium-term development plan and under implementation or more likely to continue in the future regardless of changes in government. However, in the assessment, the assumption is that once the national development plan captures the policy implementation would start within a reasonable timeframe. The baseline only represents a situation of full implementation of the already agreed government policies but not partially or non-implementation.	Design and adopt a practical approach for the selection of policies to include in the baseline consistently. This approach would allow for the inclusion of realistic policies in the baselines.
	The way of applying growth rates to different emission categories is consistent among the models.	Inconsistent projection rates are a vital source of uncertainty in the assessment. The team would investigate the possibility of applying consistent projections rates. The first step would be to explore the statistical relationship between the historical emission, demographic, macro-economic, fuel and technological indicators. In the next step, the team would further investigate how the projection rates would be applied consistently over the entire time series.
Development of mitigation projections	Mitigation commitment did not include the manufacturing industry and agriculture. With the new government policies, it would be essential to introduce new mitigation commitments in the missing categories.	Collect complete data specific to the manufacturing and agriculture to cover the new categories mitigation commitment would be introduced to in the next assessment.
Use of default emission factor for baseline and mitigation assessment in LEAP and GACMO models	The team relied on default IPCC emission factors for the baseline and mitigation scenarios for all categories. The use of default factors contributed to the high uncertainty levels of in the assessment	Undertake studies to develop country-specific emission factors by focusing on the key categories in the national greenhouse gas inventory. The future use of improved emission factors would improve the overall projections.
Marginal abatement revenue curves.	The use of international fuel prices, technology cost and lack of data on future cost contributed to the uncertainties in the projections.	Replace the international fuel prices with the price data published by the National Petroleum Authority. Conduct a national survey to collect data on climate technologies and factors that drive market prices.

Table 37: Potential improvements in the mitigation assessment archive system

Archive system task	Describe problem	Potential improvement
Define roles and responsibilities	Lack of clarity on the functional responsibilities and reporting line among the team members	Ask the mitigation assessment institutions to get a contact person to focus on the archive system. The person would work closely with the overall archiving contact person at the Environmental Protection Agency. The sector archive contact person would cover the documentation and archiving procedures in the sectors, whereas the one at the EPA would be responsible for national archiving. Train the contact persons on the archive checklist.
Storage location	The procedure for the retrieval of the storage data not well described in the QA/QC manual	Archiving contact person could ensure that the central point for archived documents stored in the short term must be easily retrievable.

Table 38 lists these potential improvements and identifies the level of priority associated with each (high, medium, and low).

Table 38: National mitigation priorities

Priority level	Improvements needed
High	Improve on the documentation and archiving at the sector and national level assessment.
High	Obtain more reliable data on the following: (a) energy - residential and commercial, (b) non-energy – solid waste management and liquid waste disposal.
Medium	Improve forestry mitigation and ensure linkages with REDD+ forest reference level.
Medium	Work more closely with institutions such as District Assemblies, power producers, Ministry of transport, private vehicle garages.
High	Incorporate new mitigation assessment for agriculture and manufacturing industries.
Low	Consider using other mitigation assessment tools that are more flexible and have a broader scope of coverage for different sectoral activities.
Medium	Develop country-specific emission factors for technologies in key category sectors.

4.5.5 Scope of Mitigation Assessment

There are two sets of results from the GACMO and LEAP tools. The GACMO assessment results covered all the mitigation sectors, whereas the LEAP is only on the energy sector. The summary of the assessment steps includes;

- Formulate baseline emissions
- Select and prioritise mitigation options
- Develop marginal abatement revenues and
- Construct mitigation projections

4.5.5.1 Baseline emission projections in the GACMO tool

The presentation of Ghana's emission projections is according to different sectors. The reported assessment sectors are energy (categorised into fossil fuel plants, others, manufacturing industry, and fugitive emission), industrial processes and product use, transport, agriculture (subdivided into livestock and aggregate Agric sources), land-use change and waste. Emissions by gas are expressed in terms of carbon dioxide equivalent using the 100-year global warming potentials contained in the IPCC's second assessment report. Ghana's emissions have already recorded a 60% increase between 1990 and 2016. The projected upward trend is likely to continue up to 75 $MtCO_2e$ in 2030, which is a three-fold increase over the 1990 levels.

The AFOLU and the energy sectors are the dominant sources of the emission throughout the forty years (1990-2030). Energy sector emissions are most likely to overtake that of AFOLU in 2027 as the government pushes for ambitious industrialisation policies (Figure 33).

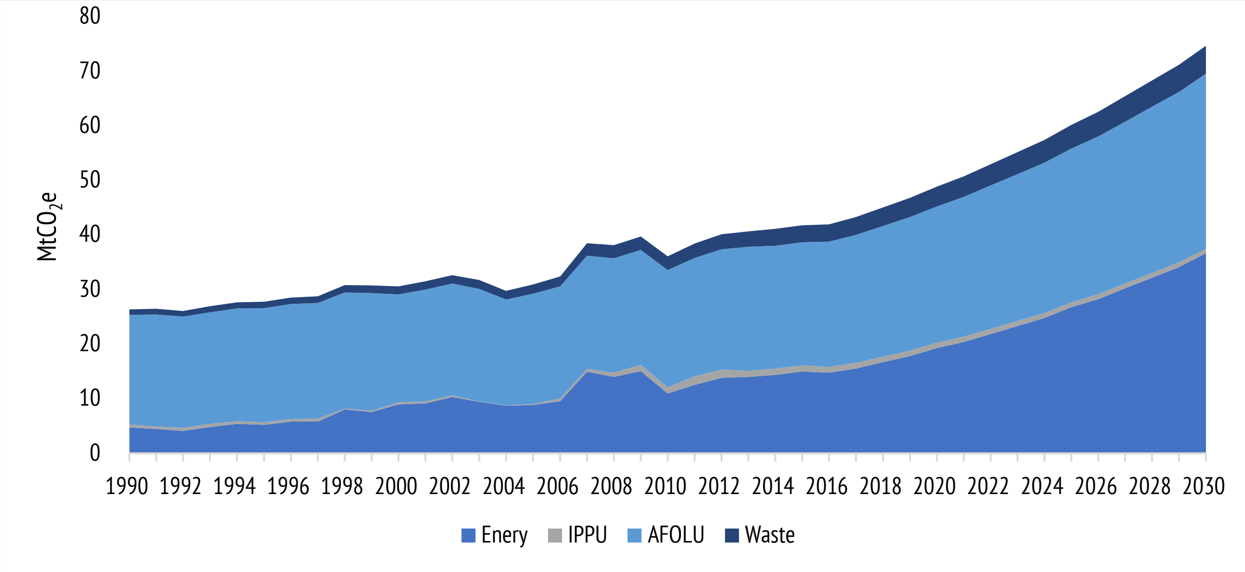

Figure 33: Project emissions by sector, 1990 to 2030

The emissions projection was further subdivided into the mitigation categories to reveal additional nuances in the business as usual trajectory. In figure 3, the emissions showed a similar upward trend of increase by 32.8 $MtCO_2e$ from 42 $MtCO_2e$ to 75 $MtCO_2e$ between 2016 and 2030. The observed growth in the electricity sector is due to the expected increase in thermal power capacity, transport led by car-centric strategies, fugitive emissions from the oil and gas fields and land from land-use change due to deforestation. Emissions from direct combustion (manufacturing industry and other sectors) would also grow correspondingly to the rolling out of the government industrialisation policies (Figure 34).

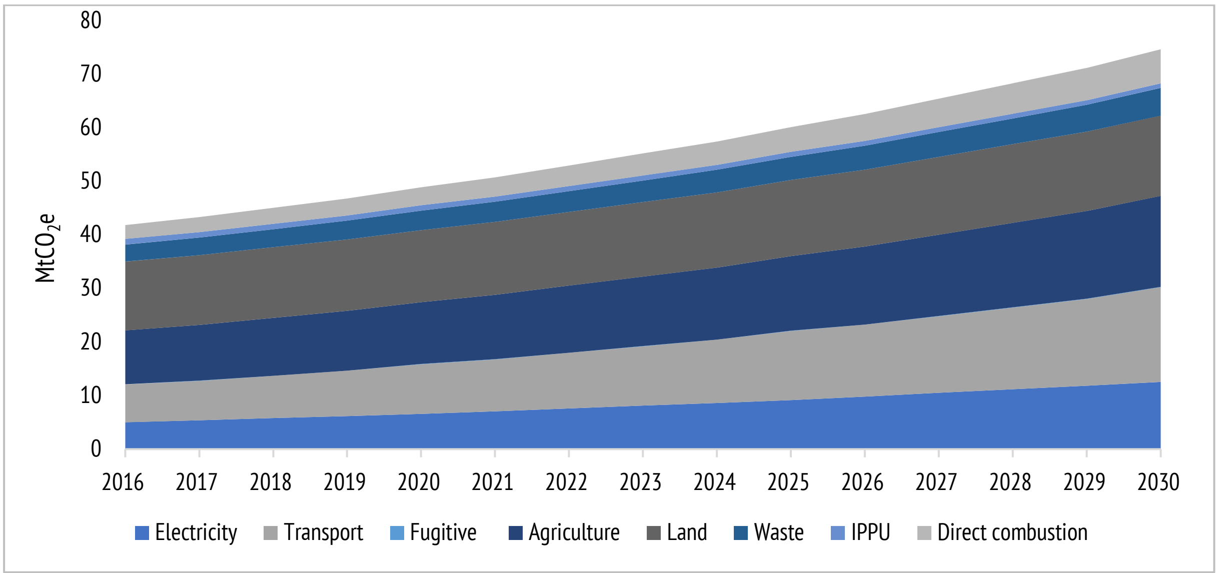

Figure 34: Projected emissions by sectors, 2016 to 2030[115]

[115] Direct combustion includes emissions from manufacturing industry, households, commerce, fisheries and agriculture; Agriculture includes livestock and aggregated emissions and non-CO_2 sources.

4.5.5.2 Description of the mitigation assessment steps

The mitigation scenario in the GACMO tool represents the counterfactual to the BAU emission pathway. The assessment came up with two distinct incremental ambition mitigation scenarios. The mitigation scenario "with measures (WM)" and "with additional measures" correspond to the unconditional (CUND) and conditional (CND) nationally determined contribution commitments. The "with measures" mitigation scenario represents a modest deviation from the BAU trajectory resulting from the government's unilateral effort to decarbonise the economy in the long run. The "with additional measures" scenario depicts the most ambitious mitigation trajectory towards rapid and higher decarbonisation outcomes. A consultative process was to identify and prioritise twenty mitigation options using a multi-criteria approach. The twenty mitigation options span energy, transport, industry, land, and waste. The prioritisation process led to the characterisation of two mitigation options under WM, and the remaining 18 fell in the WAM category.

4.5.5.3 Identification and prioritisation of mitigation options

The national stakeholder consultation meetings produced twenty mitigation measures in the energy, transport, forestry, waste and industry sectors. Out of the twenty mitigation measures, the highest of thirteen is in the energy sector, followed by three in the waste, two in forestry and one each in transport and the IPPU sectors. The selected mitigation options align well with existing national and sector policy or strategy documents (Table 39).

Table 39: List of mitigation options, their supporting policy/strategy, and priority status

Sector	Mitigation option	Supporting policy/strategy*	Status
Energy	Switch from fuel oil to natural gas	National Gas Master Plan	Unconditional
Forestry	Forest plantation	Forestry Plantation Strategy	
Energy	Efficient lighting with LEDs	National Energy Policy	Conditional
	Efficient wood stoves	SEforAll Action Plan	
	LPG stoves replacing wood stoves	SEforAll Action Plan LPG Promotion policy	
	Single-cycle to combined cycle	Strategic National Energy Plan	
	Power factor increase	National Energy Policy	
	Reduced flaring at the oil field	Petroleum Development and Exploration Act (Act 919)	
	Mini hydropower	Scaling Up Renewable Energy Penetration Investment Plan, Renewable Energy Master Plan SEforAll Action Plan	
	Solar PVs, large grid		
	Solar home PVs		
	Solar LED Lamps		
	Solar/diesel mini-grid		
	Wind turbines, on-shore		
Forestry	REDD+: Avoided deforestation	National REDD+ Strategy	
Transport	Bus Rapid Transit (BRT)	National Transport Policy	
Waste	Landfill gas flaring	National Environmental Sanitation Strategy, Renewable Energy Master Plan (REMP)	
	Institutional biogas	National Institutional Biogas Programme (NIBP), Renewable Energy Master Plan (REMP)	
	Compost	National Environmental Sanitation Strategy	
IPPU	HFC phase-down	HFC Phase-out Management Plan (HPMP)	

* Mitigation option (s) either been categorically identified in the stated policy/strategy or fit with the policy or strategy goal in the document.

With the multi-criteria (MCA) screening tool, it was possible to categorise the mitigation options into unconditional and conditional status based on broad climate, economic and social criteria. The criteria were further divided into quantitative and qualitative sub-criteria. The quantitative sub-criteria were derived from emission reduction potential and the direct cost derived from the marginal abatement revenue curve. The qualitative factors included the following: consistency with alignment with the sector, national priorities and SDGs, institutional ownership, technical effectiveness, capacity availability and ease of implementation whereas the quantitative factors were emission reductions, marginal cost, and investment outlay. The Marginal Abatement Revenues (MAR) curve is calculated based on the value of the GHG emissions reduction options US$/t$CO_2$ (y-axis), and the impacts of the GHG emission reductions in kt/year (x-axis) (Figure 33).

To make the MAR curve legible, the options with minimal reduction impacts (values on the x-axis) or low marginal cost (values on the y-axis) are excluded from the curve (Tables 18 and 19). Seventeen options have been initially included in the MAR curve to evaluate the cost-effectiveness of emission reductions. They were purposefully selected to ensure a balanced representation of all the mitigation sectors. The options selection parameter was set to the following threshold: (a) thresholds for smallest value on x-axis (ktCO_2e/yr) = 100, (b) thresholds for smallest value on y-axis (US$/kt$CO_2$e) = 100, and thresholds for largest value on y-axis (US$/kt$CO_2$e) = 600. In all, the six options that were within the negative cost range had relatively smaller emission reduction potential. Single-cycle to combined cycle option recorded the highest negative cost and least emission reductions. The rest in a similar category are notably reforestation and LPG stove (Figure 35).

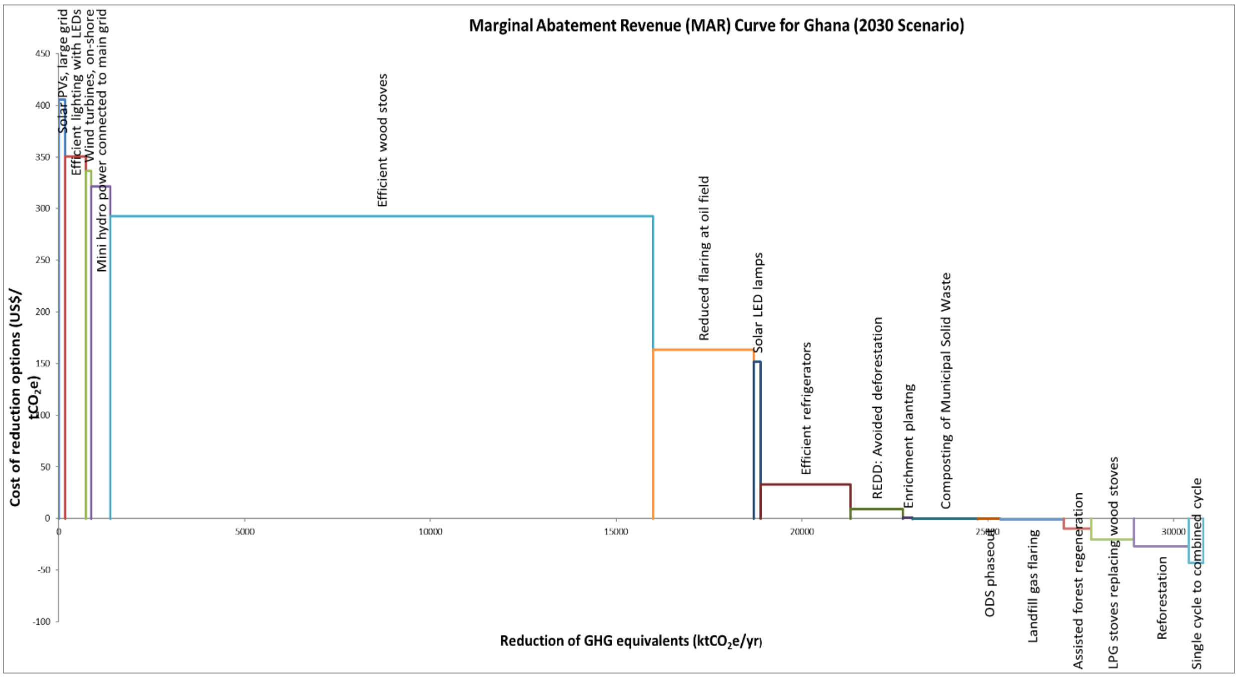

Figure 35: Marginal abatement revenue curve

On the other hand, Figure 35 presents the eleven mitigation options that showed positive upfront costs. Of the eleven, large solar PV, off-shore wind, LED bulbs, mini-hydro, efficient stoves, and reduced gas flaring were in the top six options with the highest reduction cost range. But from this list, efficient stoves, and reduced gas flaring have the most substantial GHG emission reduction potential. The rest in this category are solar lamps, avoided deforestation and compost.

Table 40: Options included in the MAR curve

Mitigation options	US$/tonCO$_2$	Emission reduction in 2030 per option kt/year
Solar PVs, large grid	405.37	177.94
Efficient lighting with LEDs	350.58	552.42
Wind turbines, on-shore	336.21	146.25
Mini hydropower connected to the main grid	321.22	516.00
Efficient wood stoves	292.48	14596.53
Reduced flaring at the oil field	163.03	2713.62
Solar LED lamps	151.55	187.82
Efficient refrigerators	32.75	2415.17
REDD: Avoided deforestation	9.04	1414.29
Enrichment planting	0.87	256.67
Composting of Municipal Solid Waste	0.02	1754.89
ODS phase-out	0.00	613.00
Landfill gas flaring	-1.28	1704.49
Assisted forest regeneration	-10.09	733.33
LPG stoves replacing wood stoves	-20.75	1158.87
Reforestation	-26.91	1466.67
Single-cycle to combined cycle	-42.96	398.46

Table 41: Options excluded in MAR curve

Mitigation options	US$/tonCO$_2$	Emission reduction in 2020 per option kt/year
Solar home PVs	413.33	64.06
Biogas at rural farms using kerosene	195.03	0.25
Biogas from Municipal Solid Waste	-0.26	7.07
Energy efficiency in industry	-1.17	32.79
Energy efficiency in service	-1.17	26.39
Power factor increase	-1.77	83.78
Efficient lighting with LEDs replacing CFL	-5.58	86.21
Solar/diesel mini-grid	-116.55	8.03
Bus Rapid Transit (BRT)	-125.30	395.10
Switch from fuel oil to natural gas in industry	-128.73	106.78

The twenty mitigation options are in nine priority areas in energy, transport, forestry, industry and waste sectors. Out of the twenty mitigation options, thirteen are in the energy sector, two in forestry, three in waste and one each in the transport and IPPU sectors (Table 40). Mitigation options in the agriculture and manufacturing industry are not part of the list (Table 41). The sectors are the mainstay of the economy and livelihoods of most rural households. Besides, their contributions to national emissions are not much. Also, there is no clear-cut policy that can be turned into mitigation commitment at this stage. However, with a renewed policy direction of the government of the day on rice, tree crops, and fertiliser, and an ambitious industrialisation drive, the next assessment would consider mitigation options from the agriculture and industrial sectors. The mitigation screening process prioritised switching from fuel oil to natural gas and forest plantation as the two mitigation actions under the "with measures (WM)" scenario. The remaining 18 mitigation options form the "with additional measure (WAM) scenario. They cut across technologies in the energy sector (mini-hydro, wind, solar, mini-grid, solar lanterns, improved cookstoves, LPG stoves, power factor correction devices et), forestry (REDD+, forests plantation, enrichment planting), climate-friendly and energy-efficient air-conditions, bus-based transit, railway transit, landfill gas management, compost and biogas (Table 42)

Table 42: Overview of overall screening and prioritisation of mitigation options

No	Mitigation policy/technology options	Abatement potential 2030($ktCO_2$/year)	Abatement cost 2030($/tCO_2)	Climate resilience	Institutional ownership	Technical effectiveness	Capacity availability	Ease of implementation	Employment	Resource access	Health	Education	Gender	Environmental Impact	Total Score
		Climate			Economic				Social						
1	**Switch from fuel oil to natural gas** (Replace crude oil with natural gas in thermal plants)	64.1	-128.7												
2	**Forest plantation** (Annual 25,000ha forest plantation up to 2030)	1466.7	-26.9												
3	**LPG for cooking** (Access by 2030, projected to 50%)	1158.9	-20.7												
4	**Efficient lighting with LED** (Ligting with 7 million LED bulbs)	552.42	350.6												
5	**Efficient woodstoves** (Distribute 2 million efficient stoves by 2030)	14597	292.5												
6	**Single cycle to combined cycle** (Add 330 MW of steam capacity by 2030)	398.46	-43.0												
7	**Power factor increase in buildings** (Installation of power bank in 1000 commercial and industrial buildings)	83.777	-1.8												
8	**Reduced flaring in oil fields** (Recover 120 MMSCF/day of natural gas from oil fields)	2713.6	163.0												
9	**Mini hydro power** (Install 300 MW mini hyro-dams connected to national grid)	516	321.2												
10	**Solar PV, Large grid** (250MW utility scale by 2030)	177.94	405.4												
11	**Solar home PV** (200,000 50W PV by 2030)	64.058	413.3												
12	**Solar LED Lamps** (2 million LED lamps by 2030)	187.82	151.5												
13	**Mini-grid** (Install 55 mini-grids - 300 MW by 2030)	8.03	321.2												
14	**On-shore wind turbines** (Install 150 MW by 2030)	146.25	336.2												
15	**Avoided deforestaton (REDD+)** (Avoid deforestation in 270,000ha)	1414.3	9.0												
16	**Bus Rapid Transit** (200km BRT line in Urban areas)	395.1	-125.3												
17	**Landfill gas flaring** (200 t/day plant nationwide)	1704.5	-1.3												
18	**Institutional biogas** (200 t/day plant nationwide)	7.1	-0.3												
19	**Composting of municipal waste** Domestic requirement for 20% by 2015 and 30% by 2040	1754.9	0.0												
20	**HFC phase-down** (All flourinated gases)	613	0.0												

Development Impact Visualation

key
- Highly positive
- Positive
- Neutral/Minor impact
- Negative
- Uncertain/ policy specific

4.5.6 Mitigation Projection Results

There are two scenarios under mitigation projection. The scenarios are "with measures" (WM) and "with additional measures" (WAM) with WAM representing a high ambition trajectory. The WM scenario consists of two mitigation options, whereas the remaining 18 are under WAM. When the two scenarios are put together, the overall cumulative mitigative effects of the twenty options is likely to be 45% lower than the BAU emissions 74 $MtCO_2e$ by 2030. The 45% target along the mitigation trajectory translates to 33.3 $MtCO_2e$ emission reductions in absolute over the 2017-2030 period. This trajectory is consistent with the total mitigation commitment in the NDC. All the twenty options underpin Ghana's NDC mitigation commitment and fall into the "IN" category. All other mitigation measures outside the prioritised twenty options or the NDC are classified as "OUT". Under the WM scenario, the potential mitigation amount to 11 $MtCO_2e$ representing 15% below the BAU emissions. The WM mitigation scenario corresponds to Ghana's unconditional NDC commitment. The WAM scenarios could potentially achieve an additional 30% emissions reduction relative to the BAU emissions. The savings represent a cumulative total of 22.2 $MtCO_2e$ over 2017-2030 and in sync with the conditional NDC commitment.

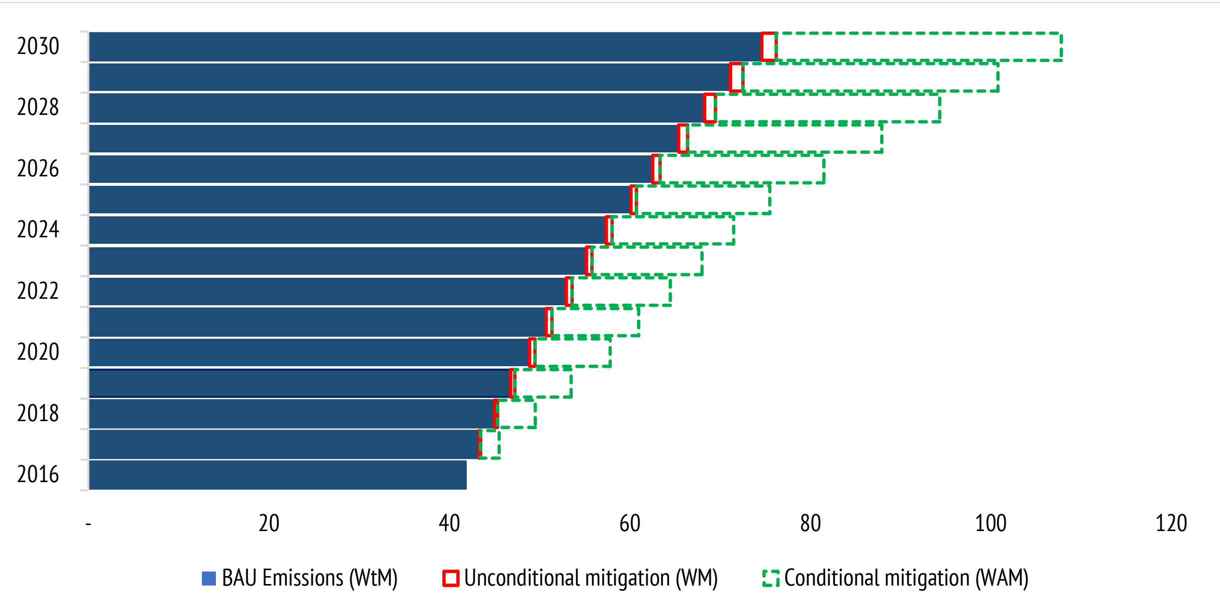

Figure 36: Mitigation scenario relative to BAU emissions

In Figure 36, the gold bar represents the baseline emissions for 2016, covering all the IPCC sectors and direct greenhouse gas obtained from the national GHG inventory. Multi-year blue bars from 2017 is the BAU pathway depicting emissions scenario associated with the status quo of the existing policies, would remain unchanged by 2030. The total potential effects of the twenty mitigation options would amount to 45% below the 2030 BAU emissions expressed in two tiers (red bold line bars and green-dash bars). The red bold line bars from 2017 to 2030 are the lower ambition mitigation pathway that corresponds to the 15% NDC unconditional commitment and expected from the implementation of fuel switch and forest plantation mitigation options. The green-dash bars (2017 to 2030) show the ambitious mitigation trajectory, which is consistent with the additional 30% emission reductions under the conditional mitigation commitment (Table 43).

Table 43: Breakdown of mitigation scenario by sectors, mitigation options and their corresponding emission reduction potentials between 2016 and 2030

Category		No. of mitigation options	Mitigation reduction potential	
			2017-2030	Annually
Mitigation scenario	With Measures (WM) and With Additional Measure (WAM) scenario	20	33 $MtCO_2e$	2.4 $MtCO_2e$
	WM scenario	2	11 $MtCO_2e$	0.8 $MtCO_2e$
	WAM scenario	18	22 $MtCO_2e$	1.6 $MtCO_2e$
Breakdown of mitigation options by sectors	Energy	13	14 $MtCO_2e$	1 $MtCO_2e$
	Forestry	2	9 $MtCO_2e$	0.6 $MtCO_2e$
	IPPU	1	1 $MtCO_2e$	0.1 $MtCO_2e$
	Transport	1	5 $MtCO_2e$	0.4 $MtCO_2e$
	Waste	3	4 $MtCO_2e$	0.3 $MtCO_2e$

4.5.6.1 Sector-by-sector baseline and mitigation projection results

The results obtained from the GACMO model for each sector are in Tables 44 to 47. Table 44 shows the energy sector mitigation figures. The energy sector BAU emissions would possibly quadruple to 36.6 $MtCO_2e$ by 2030. The emissions might reduce by 58% if the Government implements the thirteen identified WM and WAM mitigation options. The 58% translates to 21.1 $MtCO_2e$ potential emissions reduction in the energy sector alone, of which 20.9 $MtCO_2e$ would be associated with the twelve measures under WAM. The remaining 1.1 $MtCO_2e$ potential savings would be attainable with the options under the WM scenario. The efficient cookstove and reduced flaring mitigation options would by far have the massive emission reductions potential throughout the period. Mini-grid and solar home systems would contribute the least to the overall mitigation potential for the sector.

Emissions in the land-use sector would not grow as steep and as fast as the energy sector. The likelihood for emissions would rise by 9.1 $MtCO_2e$ to 31.9 $MtCO_2e$ by 2030 due to increasing deforestation and forest degradation (Table 45). Concerning the mitigation potential in the sector, implementing the two identified options could lead to a 12.1% emission reduction relative to the WtM emission by 2030. There are three plantation strategies (reforestation, assisted regeneration, and enrichment) that target enhancing carbon stock across degraded lands under the WM scenario. The other mitigation option relates to avoided deforestation. Reforestation, assisted regeneration, and enrichment fall under the WM scenario, and it is expected to mitigate 7.7% of the WtM by 2030. The WAM scenario covers REDD+: avoided deforestation is projected to generate 1.41 $MtCOe_2$ emission reductions which represent 4.4% below the 2030 WtM emissions. Table 46 shows the WtM emission trends from 2016 to 2030 for the IPPU sector.

The figures depict that the already declining trends in the IPPU sector emissions would continue to 2030 by 19%. There is only one mitigation option in the IPPU sector that would further reduce the emissions by 73% in the same period. The waste sector has three mitigation options all under the WAM scenario. They have the potential to reduce GHG emissions by 67% relative to the projected WtM emission by 2030. Landfill gas flaring and compost have the highest mitigation potential in the sector (Table 47).

Table 44: Mitigation projections for the energy sector

Sectoral - Energy	ktCO2e														
Years	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
WtM emissions (A)	14,694.1	15,549.2	16,671.7	17,794.2	19,266.8	20,388.4	21,860.1	23,331.8	24,803.5	26,761.7	28,260.4	30,208.9	32,157.3	34,105.8	36,669.8
WM and WAM emission reduction (B)	-	1,126.4	2,252.7	3,379.1	4,505.4	5,300.0	6,094.6	6,889.2	7,683.8	8,478.4	11,003.9	13,529.3	16,054.8	18,580.2	21,105.6
Adjusted WtM (A-B)	14,694.1	14,422.8	14,419.0	14,415.1	14,761.4	15,088.4	15,765.5	16,442.6	17,119.7	18,283.3	17,256.6	16,679.6	16,102.6	15,525.6	15,564.2
Energy mitigation relative to WtM (%)		7	14	19	23	26	28	30	31	32	39	45	50	54	58
Switch from fuel oil to natural gas	-	26.7	53.4	80.1	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8
Efficient lighting with LEDs	-	49.3	98.6	148.0	197.3	236.8	276.2	315.7	355.1	394.6	426.2	457.7	489.3	520.9	552.4
Efficient wood stoves	-	182.5	364.9	547.4	729.8	1,313.7	1,897.5	2,481.4	3,065.3	3,649.1	5,838.6	8,028.1	10,217.6	12,407.1	14,596.5
LPG stoves replacing wood stoves	-	21.7	43.4	65.1	86.8	156.3	225.7	295.1	364.6	434.0	579.0	724.0	868.9	1,013.9	1,158.9
Single cycle to combined cycle	-	99.6	199.2	298.8	398.5	398.5	398.5	398.5	398.5	398.5	398.5	398.5	398.5	398.5	398.5
Power factor increase	-	4.2	8.4	12.6	16.8	21.8	26.8	31.8	36.9	41.9	50.3	58.6	67.0	75.4	83.8
Reduced flaring at oil field	-	664.3	1,328.5	1,992.8	2,657.1	2,668.4	2,679.7	2,691.0	2,702.3	2,713.6	2,713.6	2,713.6	2,713.6	2,713.6	2,713.6
Mini hydro power	-	21.5	43.0	64.5	86.0	120.4	154.8	189.2	223.6	258.0	309.6	361.2	412.8	464.4	516.0
Solar PVs, large grid	-	8.9	17.8	26.7	35.6	49.8	64.1	78.3	92.5	106.8	121.0	135.2	149.5	163.7	177.9
Solar home PVs	-	4.0	8.0	12.0	16.0	19.2	22.4	25.6	28.8	32.0	38.4	44.8	51.2	57.7	64.1
Solar/diesel mini-grid	-	0.1	0.1	0.2	0.3	0.8	1.3	1.9	2.4	2.9	3.9	5.0	6.0	7.0	8.0
Solar LED lamps	-	11.7	23.5	35.2	47.0	56.3	65.7	75.1	84.5	93.9	112.7	131.5	150.3	169.0	187.8
Bus Rapid Transit (BRT)*	-	27.0	54.0	81.0	108.1	126.0	143.9	161.8	179.7	197.6	237.1	276.6	316.1	355.6	395.1
Wind turbines, on-shore	-	4.9	9.8	14.6	19.5	25.4	31.2	37.1	42.9	48.8	68.3	87.8	107.3	126.8	146.3

* The transport is included in the energy sector to ensure consistency with the IPCC inventory classification

Table 45: Mitigation projections for the land-use sector

Land-use sector	ktCO2e														
Years	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
WtM Emissions (A)	22,923.5	23,440.2	23,957.0	24,473.8	24,990.6	25,616.6	26,242.7	26,868.8	27,494.8	28,120.9	28,891.9	29,662.8	30,433.8	31,204.8	31,975.8
WM and WAM emission reduction (B)		307.7	615.5	923.2	1,231.0	1,372.4	1,513.8	1,655.2	1,796.7	1,938.1	2,324.7	2,711.2	3,097.8	3,484.4	3,871.0
Adjusted WtM (A-B)	22,923.5	23,132.5	23,341.5	23,550.6	23,759.6	24,244.2	24,728.9	25,213.5	25,698.2	26,182.8	26,567.2	26,951.6	27,336.0	27,720.4	28,104.8
Land-use mitigation relative to WtM (%)		1.3	2.6	3.8	4.9	5.4	5.8	6.2	6.5	6.9	8.0	9.1	10.2	11.2	12.1
WM scenario option	-	131.0	261.9	392.9	523.8	523.8	523.8	523.8	523.8	523.8	712.4	901.0	1,089.5	1,278.1	1,466.7
Reforestation	-	131.0	261.9	392.9	523.8	523.8	523.8	523.8	523.8	523.8	712.4	901.0	1,089.5	1,278.1	1,466.7
Assisted forest regeneration	-	65.5	131.0	196.4	261.9	261.9	261.9	261.9	261.9	261.9	356.2	450.5	544.8	639.0	733.3
Enrichment planting	-	45.8	91.7	137.5	183.3	220.0	256.7	293.3	330.0	366.7	344.7	322.7	300.7	278.7	256.7
WAM scenario options	-	65.5	131.0	196.4	261.9	366.7	471.4	576.2	681.0	785.7	911.4	1,037.1	1,162.9	1,288.6	1,414.3
REDD: Avoided deforestation	-	65.5	131.0	196.4	261.9	366.7	471.4	576.2	681.0	785.7	911.4	1,037.1	1,162.9	1,288.6	1,414.3

Table 46: Mitigation projections for the IPPU sector

IPPU sector	ktCO2e														
Years	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
WtM Emissions (A)	1,041.2	1,025.9	1,010.7	995.4	980.1	965.9	951.6	937.3	923.1	908.8	895.6	882.3	869.1	855.9	842.6
WM and WAM emission reduction (B)	-	30.7	61.3	92.0	122.6	159.4	196.2	232.9	269.7	306.5	367.8	429.1	490.4	551.7	613.0
Adjusted WtM (A-B)	1,041.2	995.3	949.4	903.4	857.5	806.5	755.4	704.4	653.3	602.3	527.8	453.2	378.7	304.2	229.6
IPPU mitigation relative to WtM (%)		3	6	9	13	17	21	25	29	34	41	49	56	64	73
WAM scenario option	-	30.7	61.3	92.0	122.6	159.4	196.2	232.9	269.7	306.5	367.8	429.1	490.4	551.7	613.0
HFC phase-down	-	30.7	61.3	92.0	122.6	159.4	196.2	232.9	269.7	306.5	367.8	429.1	490.4	551.7	613.0

Table 47: Mitigation projection for the Waste sector

Sector - Waste	ktCO2e														
Years	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
WtM Emissions (A)	3,167.50	3,284.97	3,402.45	3,519.92	3,637.40	3,775.58	3,913.75	4,051.93	4,190.11	4,328.28	4,493.83	4,659.38	4,824.92	4,990.47	5,156.01
WM and WAM emission reduction (B)	-	533.80	1,067.60	1,601.40	2,135.20	2,224.78	2,314.36	2,403.94	2,493.52	2,583.10	2,759.77	2,936.44	3,113.11	3,289.77	3,466.44
Adjusted WtM (A-B)	3,167.50	2,751.17	2,334.85	1,918.52	1,502.20	1,550.79	1,599.39	1,647.99	1,696.59	1,745.19	1,734.06	1,722.94	1,711.82	1,700.69	1,689.57
Waste mitigation relative to WtM (%)		16%	31%	45%	59%	59%	59%	59%	60%	60%	61%	63%	65%	66%	67%
WAM scenario options		533.80	1,067.60	1,601.40	2,135.20	2,224.78	2,314.36	2,403.94	2,493.52	2,583.10	2,759.77	2,936.44	3,113.11	3,289.77	3,466.44
Landfill gas flaring	-	93.31	186.62	279.93	373.25	462.82	552.40	641.98	731.56	821.14	997.81	1,174.48	1,351.15	1,527.82	1,704.49
Biogas from Municipal Solid Waste	-	1.77	3.53	5.30	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07	7.07
Composting of Municipal Solid Waste	-	438.72	877.44	1,316.17	1,754.89	1,754.89	1,754.89	1,754.89	1,754.89	1,754.89	1,754.89	1,754.89	1,754.89	1,754.89	1,754.89

4.5.6.2 Overall key sectoral emission assessment

Tables 48 to 50 present the overview of the emissions associated with WtM and the mitigation scenario over the 2016 to 2030 period.

Table 48: Projected emissions along with WtM scenario by 2030

Mitigation sectors		Emissions ($MtCO_2e$)			
		Base year	Intervening years		End year
		2016	2020	2025	2030
Electricity supply		5.01	6.58	9.13	12.55
Transport		7.08	9.29	12.94	17.71
Other sectors	Households	1.06	1.45	1.84	2.46
	Services and commerce	0.63	0.09	0.13	0.19
	Agric & fisheries	0.41	0.49	0.63	0.77
Fugitive		0.02	0.03	0.04	0.06
Manufacturing industry		1.05	1.43	2.05	2.94
Industrial process and product use		1.04	0.98	0.91	0.84
Agriculture (livestock)		3.48	3.94	4.58	5.34
Land-use change		12.87	13.45	14.20	15.00
Non-CO_2 and Aggregated emission sources	Rice cultivation	0.22	0.26	0.33	0.41
	N_2O from Agricultural soils	5.34	6.52	8.36	10.72
	Urea application	0.036	0.029	0.023	0.018
	Biomass burning	0.97	0.79	0.62	0.49
Solid waste	Solid waste	1.33	2.16	2.64	3.22
	Liquid waste	1.84	0.98	0.91	0.84

Table 49: Mitigation along with WM and WAM scenarios by 2030

Mitigation sectors	Emission Reductions ($MtCO_2e$)			
	Base year	Intervening years		End year
	2016	2020	2025	2030
WM and WAM	-	7.53	12.17	28.04
WM (unconditional)	-	0.63	0.63	1.58
Electricity supply	-	0.11	0.11	0.11
Land-use change	-	0.52	0.52	1.47
WAM (conditional)	-	6.89	11.54	26.46
Electricity supply	-	0.54	0.81	1.22
Households	-	0.83	4.12	15.82
Services/commerce	-	0.26	0.53	0.83
Fugitive emissions	-	2.65	2.71	2.71
Transport	-	0.11	0.19	0.39
Land-use	-	0.26	0.79	1.41
Industrial process and product use	-	0.12	0.31	0.61
Solid waste	-	2.12	2.07	3.46
Liquid waste	-	0.007	0.007	0.007

Table 50: Potential emission reductions under the mitigation scenario relative to the WtM

Year	Emissions ($MtCO_2e$)				Overall effects of mitigation options on BAU emissions	
	BAU Emissions	Mitigation scenario emissions				
	WtM [A]	WM [B]	WAM [C]	WM and WAM [D =B+C]	A-D [$MtCO_2e$]	D/A [%]
2016	41.82	-	-	-	-	-
2020	48.87	0.63	6.89	7.52	31.35	15.4
2025	60.12	0.63	11.54	12.17	47.95	20.2
2030	74.64	1.58	26.46	28.04	46.6	37.57

4.5.7 Detailed Mitigation Assessment in the Energy Sector

The energy sector is a key emissions source and has the highest number of mitigation options. As a result, Ghana has decided to conduct a detailed mitigation assessment for the sector with the LEAP tool. The assessment aims to enhance the transparency and reliability of the results. The additional assessment also sought to ensure consistency with the revised strategic energy planning (SNEP). The parameters of the LEAP are slightly different from the GACMO tool. Therefore, the energy results from the GACMO and LEAP tools are not comparable in several respects. First, the fundamental analysis of the LEAP is consistent with the categories in the SNEP. Secondly, the macro-economic, demographic and policy assumptions for the baseline and mitigation projections are fine-tuned to be compatible with SNEP parameters. There was a need for the refinement because of the vast variations in the scope of the activities in the covered methodology used and assumptions for forecasts.

Ghana has created comparable baseline scenarios to represent based on two plausible socio-economic trajectories. The Without Measures (WtM) scenario and the Accelerated Economic Growth (AEG) scenario. The WtM scenario depicts a low ambition future socio-economic situation based on a historical trend up to 2030. The parameters for the WtM include the following: population[116] would increase from 24.7 million in 2010 to 38 million in 2030 at an average annual growth rate of 2.17%; urbanisation rate is likely to increase from 50.9% in 2010 to 65.0% in 2030 at an average annual rate of 1.2%, and GDP would continue to grow from US$ 32.2 billion (in current prices) in 2010 at an average yearly rate of 7.1% to US$ 126.9 billion (current prices) in 2030[117].

The AEG represents a high ambition baseline. It incorporates emission implications of current government policies in the baseline. These are the Ghana Shared Growth and Development Agenda, Medium-Term National Development Policy Framework (2018-2021) and The Coordinated Programme for Economic and Social Development Policies (2017-2024), which included actions already taken and those yet to be undertaken by the government such as the 'One District-One Factory' industrial initiative and the 'planting for food' policy.

The specific parameters under the AEG are: the population would increase from 24.7 million in 2010 at an average annual rate of 2.09% to 37.4 million in 2030; urbanisation rate would increase from 50.9% in 2010 to 66.0% in 2030 at an average yearly rate of 1.3%, and GDP is expected to rise from US$ 32.2 billion (current prices) in 2010 at an annual average rate of 8.3% to US$ 158.6 billion (current prices) in 2030.

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[116] Ghana Statistical Service, Ghana Population Projection, October 2014

[117] In the Ghana Long Term National Development Plan (2018-2057) concept paper 2016, real GDP in 2030 would to be US$ 29.73 Also, the average annual growth rate of 7.1 from 2010 to 2030 for the WtM scenario is in line with the average annual growth rate 7.4 (with oil) and 5.6 (without oil) from 2017 to 2019 from Ministry of Finance (letter referenced MOF/RSD/ADMIN/03/17, dated 20th April, 2017).

The mitigation scenario represents the counterfactual trajectory of the baseline due to the various government policies that underpin the NDC measures. The PAMs have been packaged into two incremental mitigation ambition scenarios. These are the "With Measures (WM) scenario and the "With Additional Measures (WAM) scenario. The mitigation potential of the policies was determined by computing the relative differences between the emissions associated with AEG. The WM and WAM scenarios reflect the variety of policy options available to Ghana mitigation GHG in the long run. This approach further highlights the ground mitigation policy choice on climate and socio-economic imperatives. The LEAP results are in the sections below.

4.5.7.1 Business-as-usual emissions in the energy sector

The AEG emissions are plausible business-as-usual emissions in the energy sector associated with energy transformations and consumption in Ghana. The emissions are driven by the changing trends in macro-economic indicators, demography, and prevailing government policies. Thus, the effect of government mitigation policies would be calculated relative to the AEG as the reference case. AEG emissions have been divided into transformation and demand categories. The energy transformation category is subdivided into electricity generation, oil refinery, and charcoal production. Only the results cover emissions of electricity generation and charcoal production emissions under the AEG. Oil refinery emissions are excluded from the current assessment due to inadequate data. The demand side emissions divided along with residential and commercial/services (including agriculture), manufacturing and industry and transport.

The total energy sector emissions under AEG scenario, are projected to grow from 43.6 $MtCO_2e$ in 2020 to 82.5 $MtCO_2e$ in 2030 at an annual rate of 7.3%. The 2030 emissions would be 88% more than the 2020 levels. Throughout the assessment, the demand side category would contribute to much of the total emissions accounting for 72.9% while energy transformation emissions averagely make up 27.1% (Table 51). In all, the transport sector would constitute the most significant emissions source and expected to contribute to 36.6% of the total projected energy sector emissions. It would be trailed by residential emissions (24.7%), electricity generation (23.2%), Industry (9.9%), charcoal production (3.9%). The three top emission sources are likely to drive AEG emission trends over the 2016-2030 assessment period.

Table 51: Accelerated Economic Growth emissions for the period 2016-2030

Emission sources	Emissions ($MtCO_2e$)						% of the cumulative total
	2016	2020	2025	2029	2030	Cumulative totals	
Transport	10.8	15.0	22.3	30.6	33.2	301.9	36.6
Electricity Supply	7.3	9.3	14.5	19.1	20.6	191.1	23.2
Residential	11.5	12.4	14.2	15.8	16.2	203.9	24.7
Industry	3.3	4.2	6.2	8.0	8.5	81.6	9.9
Charcoal	1.8	2.1	2.2	2.3	2.4	32.3	3.9
Agriculture	0.4	0.6	0.9	1.3	1.4	12.5	1.5
Services	0.0	0.0	0.0	0.1	0.1	0.6	0.1
VALCo	0.0	0.1	0.1	0.1	0.1	1.3	0.2
Total	35.2	43.6	60.5	77.4	82.5	825.2	100.0%

Just as the emissions from all sources are likely to grow, the agriculture category emissions would follow a similar trend. The emissions are projected to record the highest growth of 141% over 2020-2030 at an annual rate of 10.3% followed by transport (122%) at 9.3% per annum, electricity generation (121%) at a yearly rate of 9.2% and industry (105%) at 8.3%.

The rest of the emissions sources would experience relatively slower growth over the same period. The emissions from residential areas and charcoal production would not grow as fast as the sources listed above. Residential emissions would increase by 31% over the ten years at a rate of 3% annually. In the same vein, emissions from charcoal production are expected to marginally grow at 15% over the same timeframe at the rate of 1.6% per annum. Generally, the emissions associated with energy use in agriculture are relatively low, but it would record the fastest growth. The Planting for Food and Jobs policy can drive the emissions up in the sector, particularly in the areas of mechanisation and irrigation.

The expected high growth in the industry category would correlate strongly with the government's accelerated industrialisation drive. Policy initiatives like the 1 District 1 Factory and the integrated aluminium industry, are going to influence industrial emissions strongly. Regarding transport, it would continue to be the dominant source of emissions for the sector. The emissions would rise sharply from 15 $MtCO_2e$ in 2020 to 33.2 $MtCO_2e$ (Figure 37). The anticipated increase in transport emissions is linked to the continued high motorisation rates and traffic congestion, especially in large cities in the country. The government's aggressive efforts to revive the railway industry would also contribute to transport emissions. Similar increasing emission trends are expected, in electricity and residential categories at varying rates.

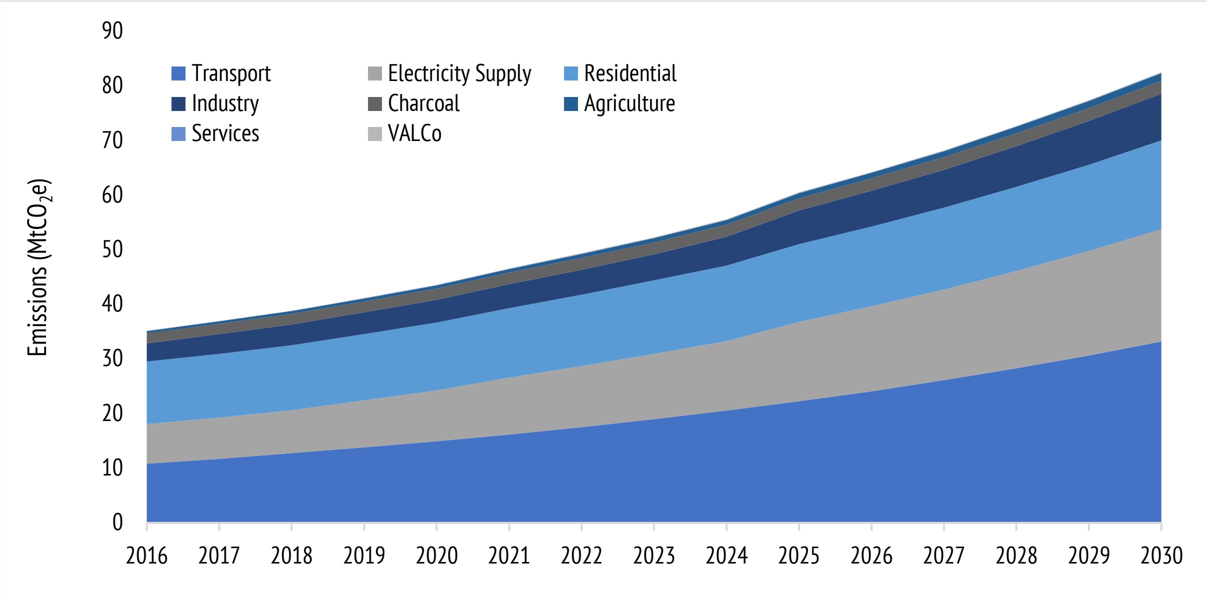

Figure 37: Total GHG emissions under the AEG scenario

Likewise, residential emissions would follow a similar rising trend as the other categories but at a relatively slower growth rate. Even though residential emissions would be among the four top emission sources in the country, the rate of increase would hover around 3.7%. The changes in household sizes would drive the expected emissions trend, electricity prices, changes in household energy preferences as living standards improve as a consequence of the government's economic empowerment and pro-poor policies.

4.5.7.2 Projected transport emissions

The transport sector would overtake the residential category to become the dominant emissions source in the country by 2030. The sector would account for 44.1% of the total final energy demand under the AEG scenario. The trend would correspondingly translate into emissions rising by 18.24 $MtCO_2e$ from 15 in 2020 to 33.2 $MtCO_2e$ at a yearly rate of 9%.

The lion's share of the transport emissions throughout the projected period would come from the road category (71.2%), followed by railways (26.7%) and then by domestic aviation (2.1%) (Table 52). Intracity, intercity, and train services would drive transportation emissions in the future. Among them, intracity passenger vehicle operations would be the primary emissions source making up 41.7% of the total transport section emissions. Emissions associated with diesel train operations would become the second-largest source of emissions in the sector. Emissions from diesel trains would be followed by inter-city operations (21.9%). The contributions of freight transport[118] to total emissions would hover around 7.5%. Long-distance freight transport would make up 4.6% of the entire transport emissions while that of local freight would be 3.%.

Table 52: Projected transport emissions under the AEG scenario

Transport modes	Emissions ($MtCO_2e$)											
	2016	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel Train	1.4	3.0	3.5	4.1	4.7	5.4	6.2	7.1	8.0	9.1	10.3	11.6
Intercity	3.3	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.1	5.3	5.6	5.8
Intracity	5.2	6.7	7.2	7.6	8.1	8.6	9.2	9.8	10.4	11.1	11.8	12.5
Local	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	1.0	1.1
Long-distance	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.3	1.4
Small Plane	0.1	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.8
Total	10.8	15.0	16.2	17.5	19.0	20.5	22.3	24.1	26.1	28.3	30.6	33.2

For the road category, a higher percentage (66%) would emanate from intra-city mobility, and the remainder (34%) would be associated with intercity operations. Intra-city emissions are forecasted to surge by 125% from 5.6 in 2020 to 12.5 $MtCO_2e$ by 2030. Generally, private petrol cars, LPG taxis, and petrol taxis would be the primary sources of emissions in the intra-city vehicle operations (Figure 38). Private petrol, LPG taxi, and petrol taxi cars would correspondingly contribute 33.2%, 36.8% and 15.2% respectively of the emissions from the intracity operations. Emissions from petrol taxis would record the highest percentage change between 2020 and 2030 at an annual rate of 23.3%.

[118] Freight transport by road was classified into urban or local freight transportation and long-distance freight transportation

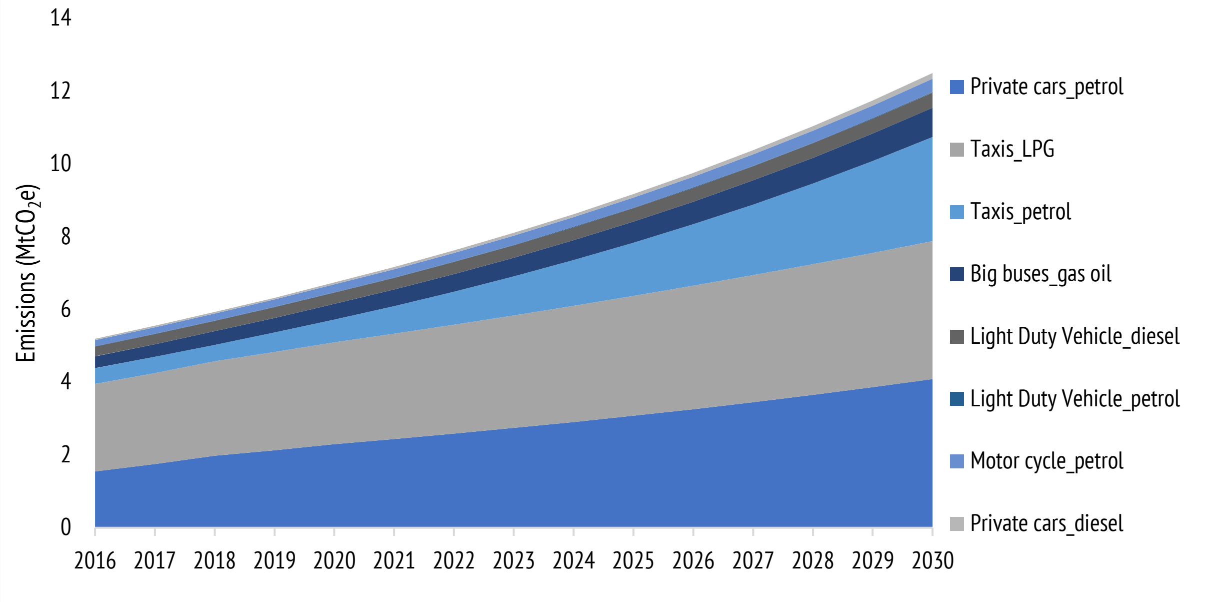

Figure 38: Projected emissions from intra-city vehicle operations under the AEG scenario

The final energy demand for intercity road passenger transportation under the AEG scenarios is projected to increase from 1,269 ktoe in 2020 at an average annual rate of 4.2% to 1,913 ktoe in 2030. Diesel would constitute the largest share (67.5%) of the final energy demand, and the gasoline (32.5%) leading to rising emissions. The emissions from inter-city transport are likely to grow by 20% from 3.8 to 5.8 $MtCO_2e$ between 2020 to 2030 at the rate of 4.5% per annum (Figure 39). Diesel buses and light-duty diesel vehicles would dominate the emissions from intercity passenger vehicle operations. These vehicles are usually used as high-occupancy public transport and run on diesel fuel. As the share of diesel buses and light-duty vehicles, road usage increases, there will be a corresponding rise in emissions. The big diesel buses usually ply the highways to connect passengers from one city to another.

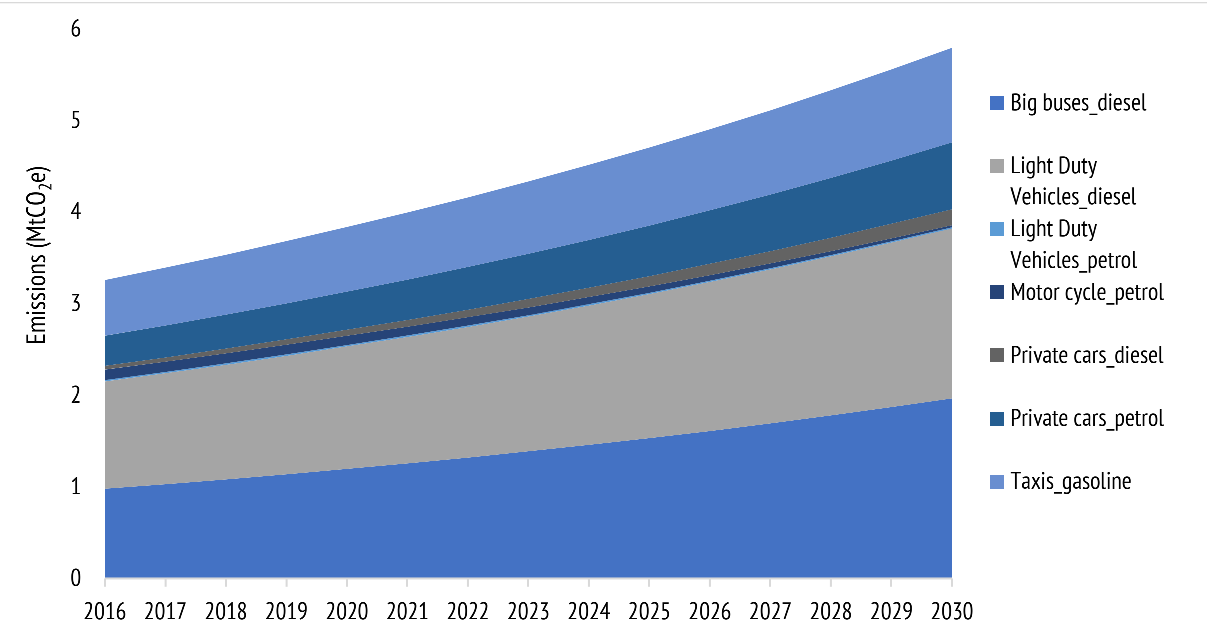

Figure 39: Emissions from intercity vehicle operation under the AEG scenario

The expected rise in road transport emissions could be due to the continued democratisation of cars and its attendant traffic congestion, especially in big towns and cities. With more than 60% of Ghanaians projected to live in urban areas, and steady growth in the economy, the demand for individual car ownerships would significantly drive future emissions in the transport category. Diesel is likely to be the main fuel for rail transportation in Ghana. It would increase from 631 kt in 2020 to 2,259 kt in 2030. The government policy drive to revitalise the railway industry would drive future emissions in Transport. Under the AEG scenario, diesel trains would be a significant part of the new fleet of trains government would put in service. That is why diesel train emissions would contribute actively to the transport sector. The emissions are expected to grow by 258% from 1.7 $MtCO_2e$ to 6 $MtCO_2e$ between 2020 and 2030. More diesel trains are likely to be commissioned on newly constructed rail lines. The rapid increase in the share of final energy demand for rail transportation is attributable to the government's policy to revamp the country's railway sector.

4.5.7.3 Projected emissions for households

The households have been divided into urban and rural to obtain homogenous energy use patterns consistent with the national statistics classification. The urban households are further classified into metro-urban (core areas of the city) and other-urban (peri-urban areas). Rural households are grouped according to ecological zones into savannah, forest and coastal and by electricity access. Household end-use energy applications are lighting, cooking, refrigeration, air-conditioning, water heating, clothes washing, dishwashing and miscellaneous uses. Emissions from electricity use in households have been excluded from the assessment to avoid double counting because electricity generation emissions are already part of the electricity category. The total household emissions may increase by 31% from 12.4 in 2020 to 16.2 $MtCO_2e$ 2030 at a 3% annual growth rate (Figure 40). Emissions from all the categories of households are likely to increase over the same period with "other urban" and "metro urban" households recording high growth rates. The share of the emissions from rural households (savannah, forest and coastal rural), would be relatively lower compared to the rest of the households.

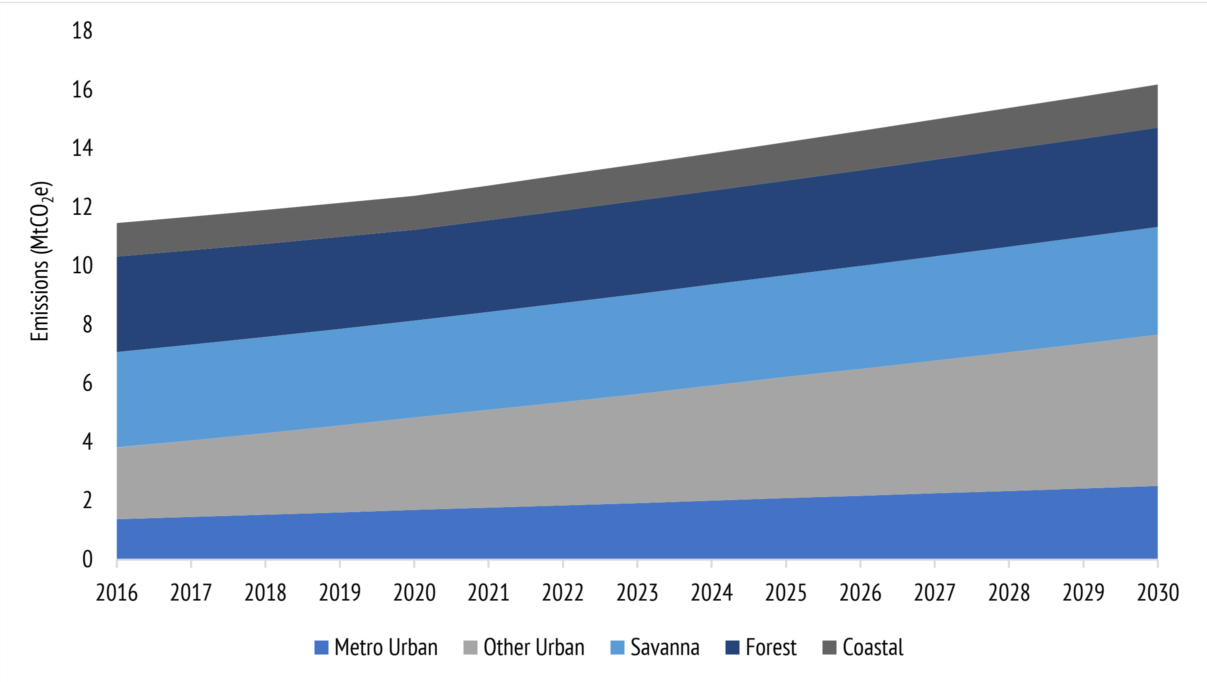

Figure 40: Projected household emissions under AEG scenario

The other urban households would contribute most to the emissions. It would account for 29% of the total household emissions for a forecasted decade. Other urban households would be followed by rural savannah (24.4%), rural forest (22.7%) and metro urban (14.7%) in the order of magnitude of contribution to the total household emissions. Coastal households would contribute the least to total household emissions. It would account for 9.2% of total emissions and grow from 1.2 to 1.5 $MtCO_2e$ for the 2020-2030 period at a 3% annual rate. The projected emission trends would correlate strongly with the energy consumption patterns of the various household categories. Urban households would account for 60.2% of the total household energy demand in 2030 compared to 47.4% in 2020. The reasons are that more than two thirds (68.9%) of households are expected to reside in urban localities by 2030. However, the final energy demand for urban households would be 2,268 ktoe in 2030, increasing from 1,609 ktoe in 2020 at an average annual growth rate of 3.5%. As stated earlier, the low growth rate is due to the decrease in urban household sizes, the shift from the use of charcoal to LPG for cooking and the penetration of energy-efficient appliances.

The final energy demand in rural forest households would account for 45.7% of the total energy demand in rural households, while the savannah and coastal rural households account for 36.0% and 18.3% respectively in 2020. The results indicate that cooking is the dominant household energy end-use activity, followed by lighting. Cooking would account for 81% of the household sector's total final energy demand in 2020. Firewood share would make up 9.3% of the urban household's aggregate energy demand compared to 7.2% in 2030. Similarly, charcoal demand could contribute 44.1% of the total final energy demand in 2020 compared to 39.1% in the same period. The share of LPG demand would increase from 13.2% of the total final energy demand in 2020 to 15.5% by the end of 2030. Total emissions from the urban areas would mainly come from cooking.

The 2020 emissions of 4.8 $MtCO_2e$ is forecasted to increase by 58% to 7.7 $MtCO_2e$ by 2030. Emissions would lead the growth from the traditional charcoal stoves (43.8%), followed by wood stoves (27.3%), improved charcoal stove (17.3%) and LPG stove (11.3%) (Figure 41). However, emissions from wood stoves would record the fastest growth of 12.1 per annum over the decade. In the same vein, emissions from LPG stoves would also grow at a relatively high rate of 4.8% annually. The rising trend corresponds with the upward trend in charcoal, wood and LPG demand. The demand for charcoal under AEG is forecasted to rise from 670 ktoe in 2020 to 775 ktoe due to favourable pricing and ready availability.

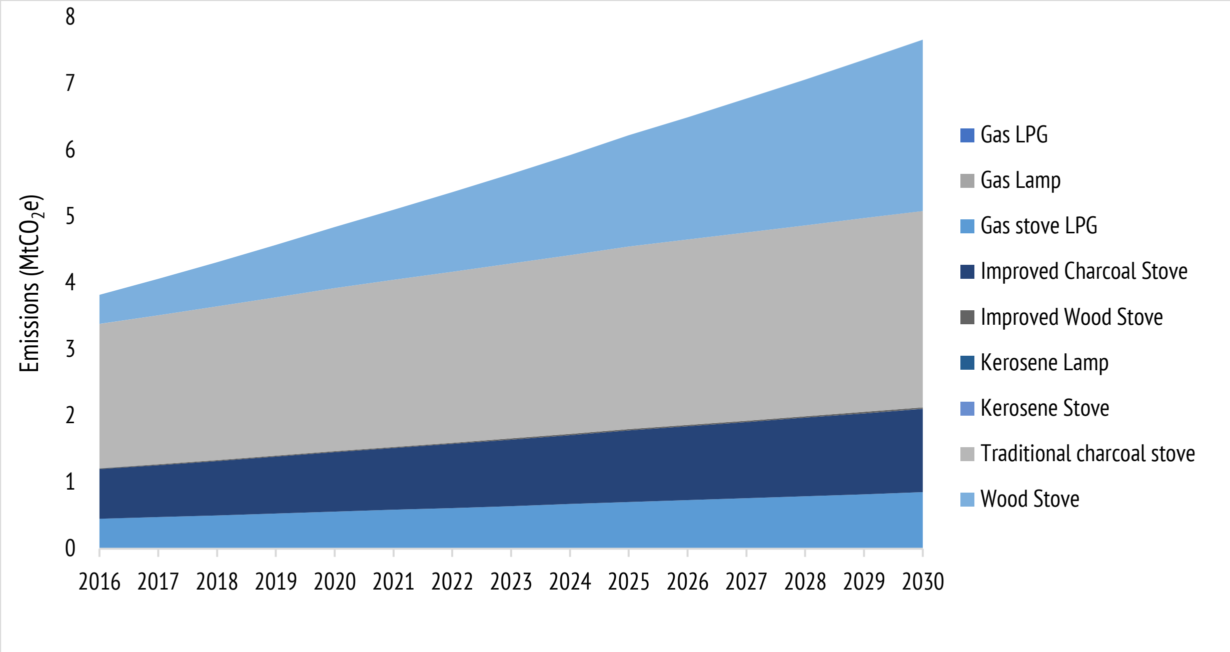

Figure 41: Projections of emissions for urban households by 2030 (Technologies not appearing in the graph means that they phased out of the local market)

On the contrary, the emissions from kerosene and wood stoves would record a drastic decline over the 10-year assessment period. The emissions share for kerosene lamps in urban households is expected to reduce by 8% by 2030. In the rural areas, woodstoves would account for 91.2% of the total emissions and then by the traditional charcoal stove (6.8%). Little emissions contribution would come from kerosene lamps for lighting. Emissions from wood stoves are to increase by 14% over the decade of 2020 to 2030 at a growth rate of 1.5% (Figure 42).

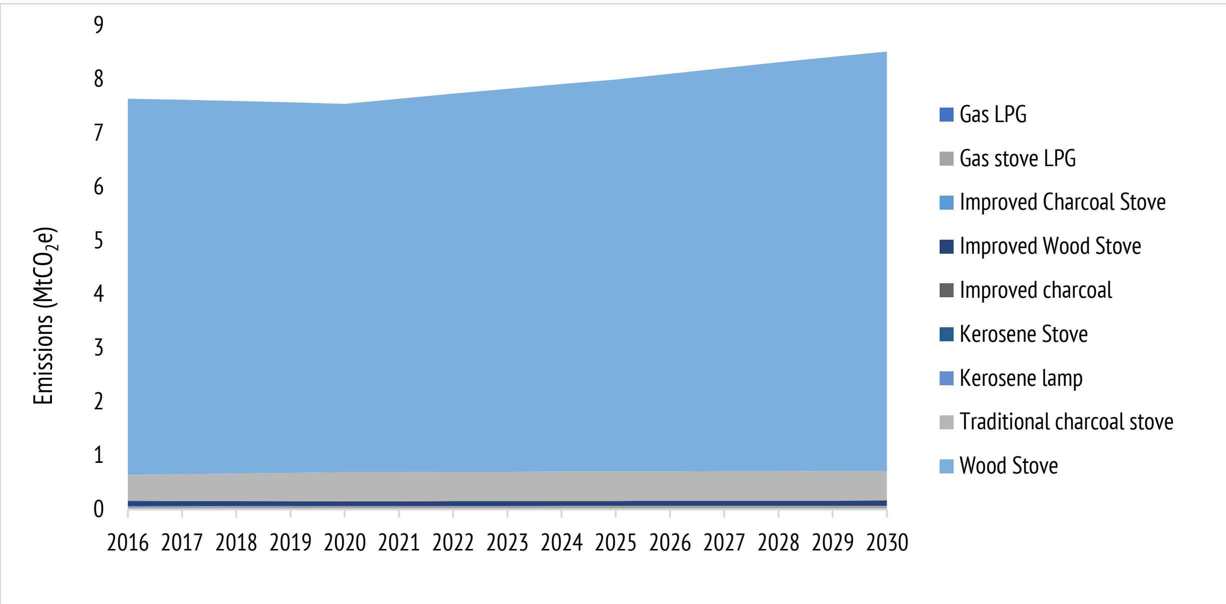

Figure 42: Projections of emissions in the urban household by 2030

Fuelwood would still be the dominant fuel for rural households between 2020 and 2030 for the AEG scenario. The fuelwood share may decrease from 80.7% in 2020 to 70.7% in 2030. However, the percentage of charcoal in the rural household's final energy demand could rise from 6.2% in 2020 to 7.5% in 2030. The portion of LPG demand in the total final energy demand in rural households is projected to increase from 1.8% in 2020 to 4.0% in 2030.

These energy demand dynamics in rural households could influence future emissions. While the emissions from kerosene lamps are expected to decrease by 25% and may lead to replacement with alternative forms of efficient lighting.

4.5.7.4 Projected emissions for energy use in industry

The industry sector includes manufacturing, construction, mining and quarrying, and water production activities. Generally, industrial emissions would grow by 105% from 4.2 to 8.5 $MtCO_2e$ over the 2020-2030 period at 8.3% annually. Throughout the assessment period, manufacturing would be the leading source of emissions, contributing 68% of the total industrial emissions, followed by mining and quarrying (27%) and construction (5%). The expected 19.3% annual increments would significantly influence the predicted high growth in the emissions in final energy demand. It would translate to a rise in final energy demand from 872 ktoe in 2020 to 5,092 ktoe in 2030. The higher final energy demand for the manufacturing sub-sector is due to the processing and refining of bauxite and iron integrated industries because of the government's proposed programs of Integrated Bauxite and Aluminium Industries; and Iron and Steel Integrated Industries. Within manufacturing, food processing, surface mining, and beverages would be the primary sources of emissions. Emissions from the food processing category would dominate and consistently account for 29.8% of industrial emissions throughout the period and are likely to be followed by surface gold mining (20.5%), beverages (7.8%) and textiles (5.4%) (Figure 43).

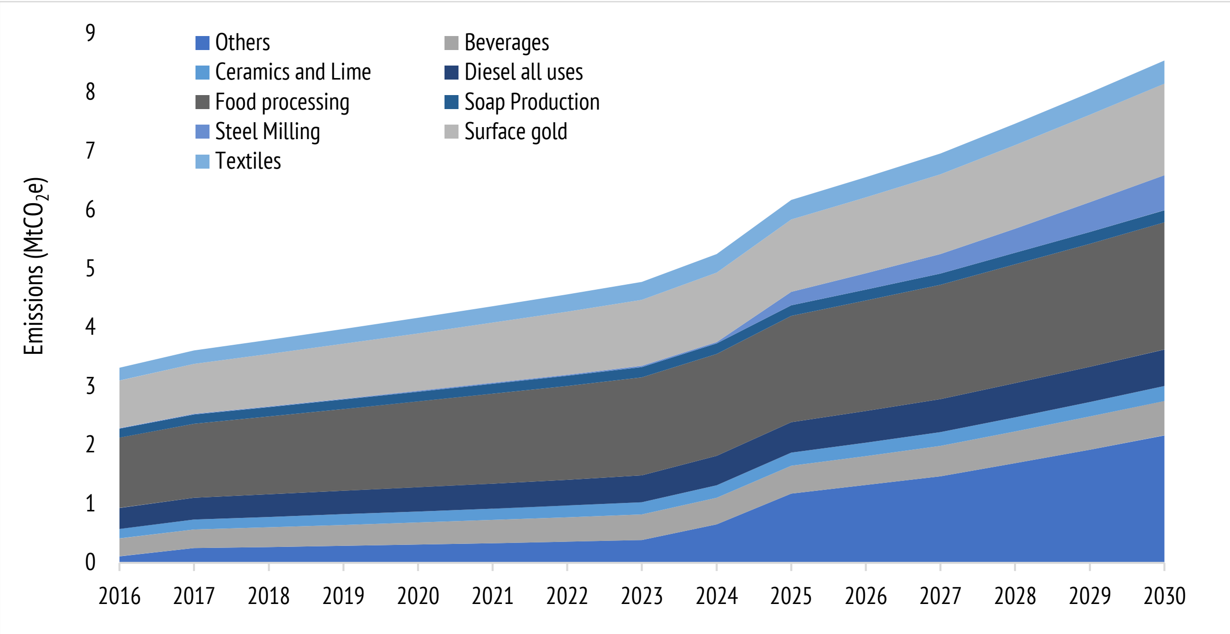

Figure 43: Emissions associated with the manufacturing under AEG

The dominant fuels in the final energy mix for the industrial sector would be diesel. The share of other petroleum products like RFO and LPG would be 5.6% and 1.8% respectively of the total final energy demand in 2020 compared to 6.6% and 2.4% in 2030. The manufacturing category promotes technology transfer, provides revenue and employment and as such, is very critical to the economy. It has been subdivided into formal and informal manufacturing and includes the production of cement[119], textiles, food and beverages, plastics, iron and steel, chemical and pharmaceutical products and the processing of wood lumber into other products. Mining and quarrying would be another important source of GHG emission in the country.

[119] Milling of clinker and gypsum

Under the mining and quarrying category, gold mining would drive the emission trends because it would account for 80% of the total energy demand for mining and quarrying. The mining emissions of 0.3 $MtCO_2e$ are likely to increase by 48% over the decade at an annual growth rate of 4.4% due to the projected increased use of diesel from 471 ktoe in 2020 and 531 ktoe 2030. Construction emissions are unlikely to be a significant contributor to industrial emissions as it has been predicted to account for only 5%. The total emissions for the manufacturing sector may grow by 381% from 0.7 to 3.2 $MtCO_2e$ in 2030 with food processing (19.5%), steel milling (12.8%), steel production (11.2%), pig iron production (10.2%), and beverages (10%) identified as the most significant sources (Figure 44). Natural gas would be the primary fuel for manufacturing in the next decade and would drive emissions upward. The high demand for natural gas as final energy use would be instigated mostly by the processing of extractive minerals such as iron to pig iron, limestone to clinker and bauxite to alumina.

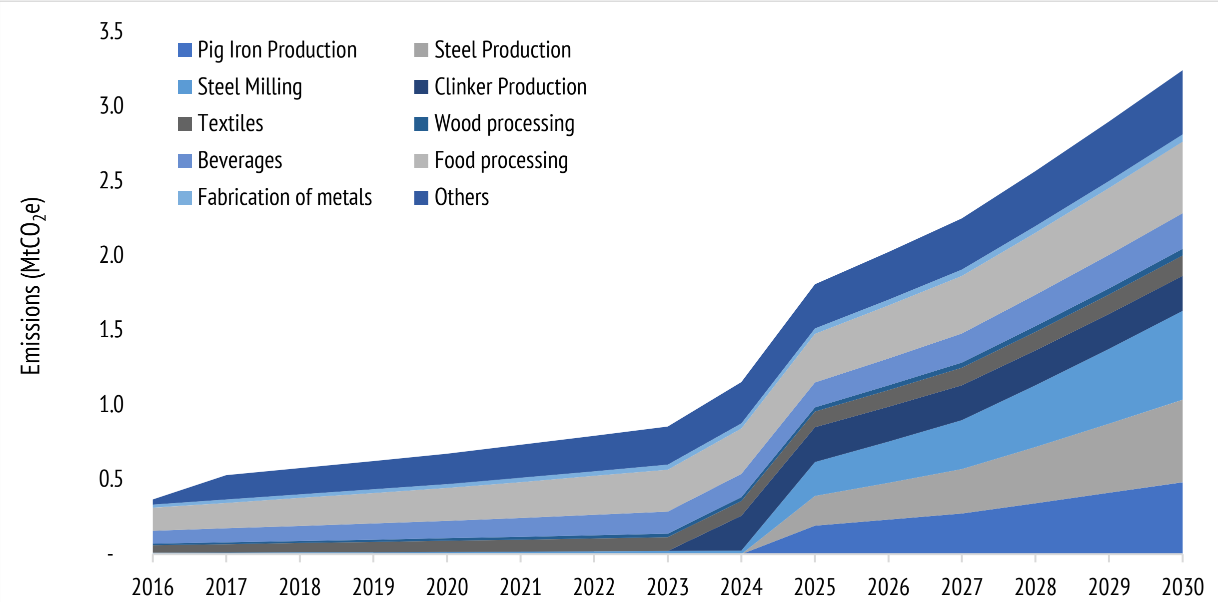

Figure 44: Manufacturing sub-sector emissions under AEG

The food processing industry annually accounts for about 15% of the total output of the manufacturing sector[120]. This industry comprises the large-scale processing of raw cocoa beans and oil-palm fruits into semi-finished and finished products, the manufacture of animal feeds, canned products, dairy products, food products, e.g. pasta, noodles and grain mill products, e.g. wheat flour. The total final energy demand for the food processing industry is likely to increase from 94 ktoe in 2020 at an average annual rate of about 8% to 203 ktoe in 2030. Demand for RFO, used in the formal food industry, would account for 42% of the final energy demand for food processing. The diesel fuel demand for food processing would go up by 25% under the AEG scenario. The steel production plants in the country use the Electric Arc Furnace technology to produce steel using scrap metals as feedstock. The total final energy demand for steel production would increase from 57 ktoe in 2020 at an average annual growth rate of 8.1% to 780 ktoe in 2030.

Diesel and RFO are projected to account for 40% and 7% share respectively of the total final energy demand for steel production. The corresponding emissions would increase from 0.2 $MtCO_2e$ in 2025 to 0.6 $MtCO_2e$ in 2030. Similar emission trends are likely for pig iron production. The beverage industry includes the large-scale manufacture of alcoholic (i.e. hard liquors, wines, and beers) and non-alcoholic (i.e. carbonated drinks, fruit juices, and water (sachet and bottled) drinks.

[120] Ghana Statistical Service: "Value Added Estimates of Sub-sectors of Manufacturing in the Revised 2011 GDP"

The total final energy demand of the beverage industry would increase from 44 ktoe in 2020 at an average annual growth rate of 7.2% to 76 ktoe and 89 ktoe in 2030. Residual fuel oil would account for 60.6% of the final energy demand. The final energy demand for the textile industry is projected to increase from 26 to 31 ktoe in 2020 at an average annual rate of 6.0% and 6.3% respectively to 47 ktoe. RFO would be the dominant fuel in the final energy mix of the textile industry. Metal fabrication, plastic production, wood processing, steel milling, and chemical industries would contribute less to the total emission.

4.5.7.5 Projected emissions for electricity generation

The future electricity generation under the AEG scenario is presented "with and without" coal to evaluate the emissions implications. Without the coal plant coming on stream, Ghana's total electricity generation may grow by 14% from 25,360.2 GWh in 2020 to 28,910.6 GWh in 2030. Sustainable energy contributions to the total electricity generation are estimated at 22.3% of which large hydro accounts for the largest share (Figure 45). The plausible generation scenario where the proposed coal plant comes online, total electricity production would likely see a quantum increase by 120% from 25,360.2 to 56, 139.8 GWh by 2030. The sustainable energy share under this scenario would constitute 14% over the decade.

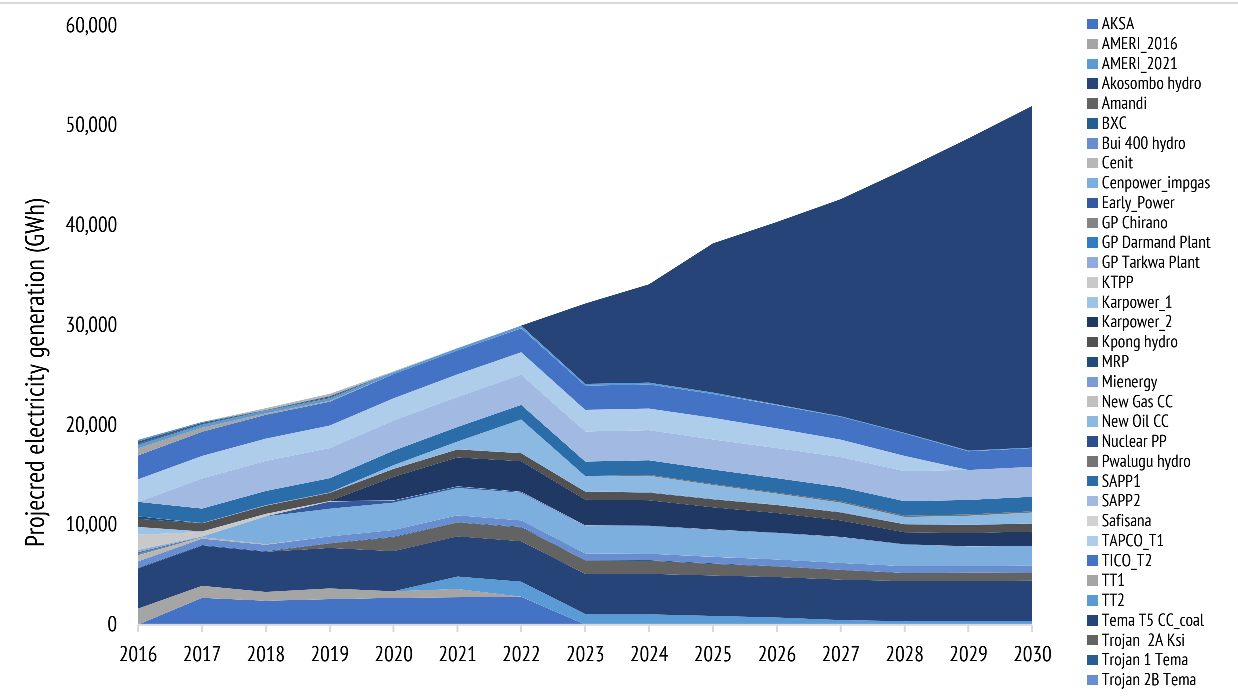

Figure 45: Projected electricity generation with coal under the AEG scenario with coal

The total fuel demand for electricity generation is anticipated to increase from 2,173.2 to 4,460.2 over the 2020-2030 timeframe. Natural gas would constitute the largest share of fuel demand making up 42% of the total fuel demand. The rest would be made-up of coal (39.6%), hydro (14.7%) and crude oil (3.3%) (Table 50).

Table 53: Projected fuel demand for electricity generation.

Fuels	Fuel Quantity (ktoe)						% of the cumulative total
	2016	2020	2025	2029	2030	Cumulative total (2020-2030)	
Natural gas	714.664	1645.84	1387.042	929.296	940.008	15060.7	42.1%
Diesel	176.6	9.1	0.8	0.8	0.8	21.0422	0.1%
LPG	44.2	17.1	3.2	2.2	1.9	56.3876	0.2%

Crude Oil	115.7	29.6	119.5	78.6	94.9	1193.24	3.3%
Hydro	471.4	471.4	481.5	481.5	481.5	5256.49	14.7%
Coal	-	-	1,283.8	2,688.7	2,941.0	14157.9	39.6%
Biomass	0.1	0.1	0.1	0.1	0.1	0.70426	0.0%
HFO	64.8	-	-	-	-	0	0.0%
Total	1,587.5	2,173.2	3,276.0	4,181.2	4,460.2	35746.5	100.0%

The installed generation capacity would almost double over the decade (2020-2030). About 5,014.14 MW of capacity may be added at an annual growth rate of 8.1% in the same period (Table 51). Should the coal plant come online as generally anticipated, it would make up about a quarter of the total installed capacity under the AEG scenario. It would be followed by the legacy hydro installations (Akosombo, Kpong, and Bui), making 17.2% of the installed capacity. The rest would be mainly natural gas and fuel oil-fired thermal plants and renewables.

Table 54: Projected installed electricity generation capacity under the AEG scenario

Power plants	Installed capacity (MW)				
	2016	2020	2025	2029	2030
Akosombo hydro	900.0	900.0	900.0	900.0	900.0
Kpong hydro	140.0	140.0	140.0	140.0	140.0
Bui 400 hydro	330.0	330.0	330.0	330.0	330.0
Pwalugu hydro	-	-	48.0	48.0	48.0
BXC	18.0	18.0	18.0	18.0	18.0
Mienergy	-	16.0	16.0	16.0	16.0
VRA Solar Plant	1.8	1.8	1.8	1.8	1.8
TAPCO_T1	305.0	305.0	305.0	-	-
TICO_T2	320.0	320.0	320.0	320.0	320.0
TT1	100.0	100.0	100.0	100.0	100.0
TT2	45.0	45.0	45.0	45.0	45.0
Cenit	100.0	100.0	100.0	100.0	100.0
MRP	40.0	-	-	-	-
KTPP	200.0	200.0	200.0	200.0	200.0
SAPP1	180.0	180.0	180.0	180.0	180.0
SAPP2	-	370.0	370.0	370.0	370.0
Cenpower	-	340.0	340.0	340.0	340.0
AMERI_2016	230.0	230.0	-	-	-
AMERI_2021	-	-	230.0	230.0	230.0
Karpower_1	213.0	-	-	-	-
Karpower_2	-	450.0	450.0	450.0	450.0
AKSA	-	375.0	-	-	-
Amandi	-	180.0	180.0	180.0	180.0
Early Power	-	377.5	377.5	377.5	377.5
Trojan 1 Tema	25.0	-	-	-	-
Trojan 2B Tema	20.0	20.0	-	-	-
Trojan 2A Kumasi	16.3	16.3	-	-	-
Trojan 3 Tema	-	49.9	-	-	-
GP Chirano	30.0	30.0	30.0	30.0	30.0
Safisana	0.1	0.1	0.1	0.1	0.1

GP Darmand Plant	25.5	25.5	25.5	25.5	25.5
GP Tarkwa Plant	33.0	33.0	33.0	33.0	33.0
New Gas combined cycle	-	-	-	-	-
New Oil combined cycle	-	224.0	1,211.1	1,501.8	1,790.3
Nuclear power plant	-	-	-	-	-
Tema T5 combined cycle coal	-	-	2,005.2	4,237.4	4,637.9
Total	**3,272.7**	**5,377.1**	**7,956.2**	**10,174.1**	**10,863.1**

Under the option with coal, there is the possibility of ultimately adding 4,600 MW to the existing electricity generation capacity. The coming on stream of the coal plant is anticipated to start 2025 with 2000 MW and later ramped up to the projected optimal capacity. Although the possibility of incorporating coal-fired plants in the generation mix is intrinsically indicative at this stage, it is essential to note that it would require appropriate policy, regulatory and investment justification before coming online. The projected shift in the electricity generation mix to base more on natural gas, hydro and renewables and the option to plug in coal, would influence the future GHG emission trends. The changing electricity mix is expected to translate to a total emissions increment of 270% from 9.6 $MtCO_2e$ in 2020 to 35.4 $MtCO_2e$ in 2030 (Figure 46).

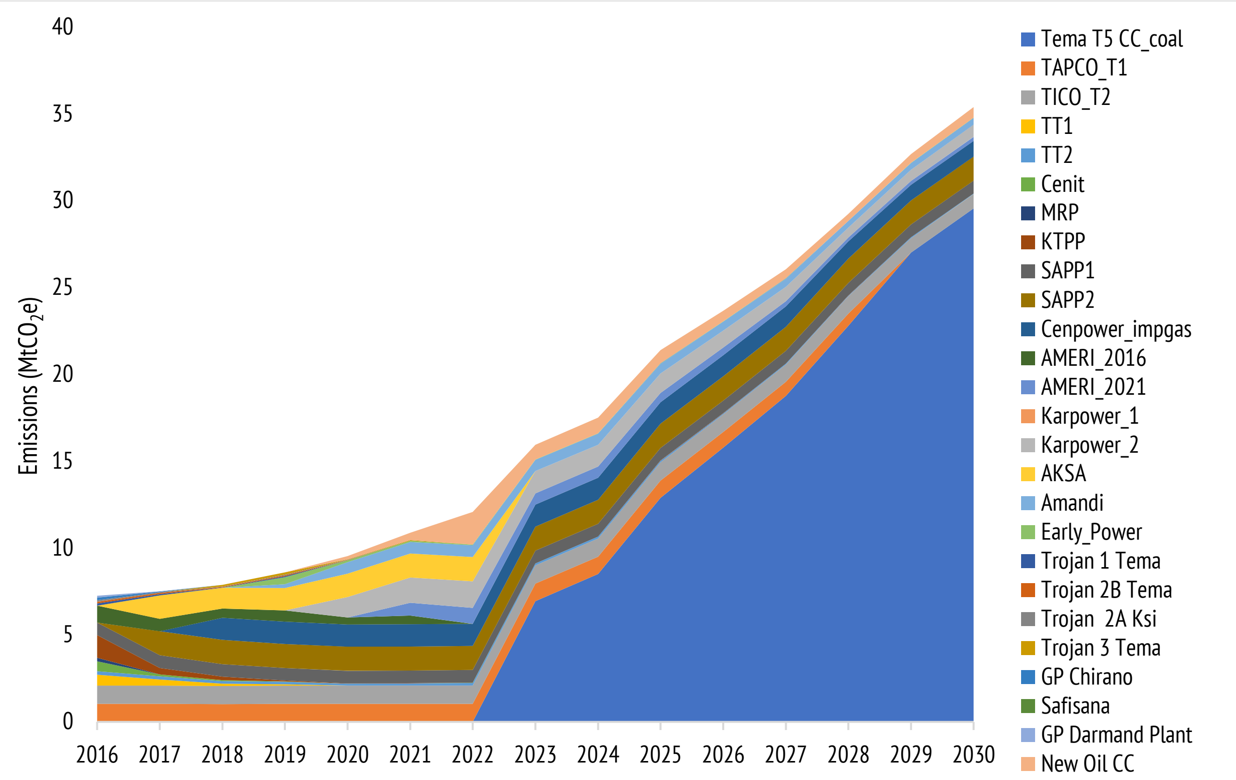

Figure 46: Projected emissions associated with electricity generation under the AEG scenario

4.5.7.6 Projected emission for charcoal production

Charcoal production is a major source of greenhouse emissions because of inefficient carbonisation and demand for charcoal. The charcoal production technology is predominantly earth mound pit and mud beehive. The process efficiencies of the technologies are less than thirty per cent. The dominant use of the inefficient earth mound pit and mud beehive technologies presents an opportunity to optimise the thermal efficiencies and contribute to reducing GHG emissions. As charcoal would remain a significant part of the final energy demand in households, the production process provides a viable opportunity to modernise the charcoal production process and mitigate greenhouse emissions. The assessment showed that GHG emissions from charcoal production are likely to increase by 15.1% over the ten years (2020-2030) from 2.1 to 2.4 $MtCO_2e$ at a rate of 1.6% per annum. Earth mound pit technology would contribute 85% of the total charcoal production emissions compared to mud beehive kiln of 15% over the same timeframe. While the mud beehive emissions are likely to exhibit an increasing trend, that of the earth mound pit would decline. The share of mud beehive emission would increase by 269% over the decade; on the other hand, the earth mound pit emission is expected to decline by 0.5% in the same period.

4.5.8 Assessment Mitigation Potential in the Energy sector

Assessing the mitigation potential involved the evaluation of the greenhouse gas effects of the prioritised energy mitigation options listed in Table 52 relative to the AEG. The assessment of the potential mitigation effects of the alternatives was done as individuals and together as an aggregate package. Two aggregate mitigation scenarios, With Measures (WM), With Additional Measures (WAM) made of two or more measures, are evaluated to estimate the overall GHG effects. The measures under the WM and WAM scenarios corresponded with the unconditional and conditional mitigation commitment in Ghana's NDCs and further showed the increasing ambition of GHG effects. Table 55 shows the list of mitigation options modelled under the mitigation scenario.

Table 55: List of mitigation options, their NDC status, and mitigation scenario

Mitigation options	Mitigation policy package	NDC status	Mitigation scenario
Switch from fuel oil to natural gas	Low carbon electricity	Unconditional commitment	WM
Single-cycle to combined cycle	Low carbon electricity	Conditional commitment	WAM – included in LEAP
Solar PVs, large grid	Low carbon electricity	Conditional commitment	WAM
Wind turbines, on-shore	Low carbon electricity	Conditional commitment	WAM
Nuclear plant	Low carbon electricity	Not included in NDC 1*	WAM
Efficient lighting with LEDs	Efficient lighting	Conditional commitment	WAM
Efficient wood stoves	Clean cooking	Conditional commitment	WAM
LPG stoves replacing wood stoves	Clean cooking	Conditional commitment	WAM
Efficient home appliances	Efficient lighting	Not included in NDC 1**	WM
Power factor increase	Industrial efficiency	Conditional commitment	Not modelled in the LEAP
Mini hydro-power	Low carbon electricity	Conditional commitment	WAM
Solar home PVs	Distributed solar	Conditional commitment	WAM
Solar/diesel mini-grid	Mini-grids	Conditional commitment	Not modelled in the LEAP
Solar LED lamps	Efficient lighting	Conditional commitment	WAM
Bus Rapid Transit (BRT)	Low carbon mass mobility	Conditional commitment	WAM
Electric mobility	Low carbon mass mobility	Conditional commitment	WAM
Railway mobility	Low carbon mass mobility	Conditional commitment	WAM
Reduced flaring at oil fields	Low carbon oil and gas production	Unconditional commitment	Not included in NDC 1**
Fuel switch in pig iron production	Sustainable industrial production	Not included in NDC 1*	WAM
Fuel switch in alumina production	Sustainable industrial production	Not included in NDC 1*	WAM

* Measure was not initially included in the NDC 1 published in 2016. Ghana intends to incorporate measures as part of the conditional NDC commitment during next year's updates as a result of the new government policy direction. ** Measure was being implemented at the time of the NDC but omitted due to a lack of data. With the availability of new dataset, Ghana would be able to incorporate as an unconditional commitment

4.5.8.1 With measures mitigation scenario

The WM includes mitigation options considered under the current unconditional NDC commitment. It also covered the options that were excluded from the NDC due to a lack of data but are eligible to be part of the unconditional commitment. The measures are "fuel switch from fuel oil to natural gas in thermal plants" and "efficient home appliances".

The fuel switch measure aims at replacing fuel oil (crude oil, HFO, DFO, and Diesel) with natural gas in existing and new thermal power plants. The mitigation effects would result in the avoided use of fuel oil for natural gas in thermal electricity generation in line with the policy of the state-run power producer (Volta River Authority) to cease the use of fuel oil as the primary fuel for their thermal plant. Efficient home appliances underpin the country's energy efficiency improvement strategy, but their GHG effects are not part of the NDC due to data challenges. In the LEAP tool, the efficient homes appliance package focused on electrified homes and included penetration of efficient technologies for refrigeration, space cooling and heating, and washing.

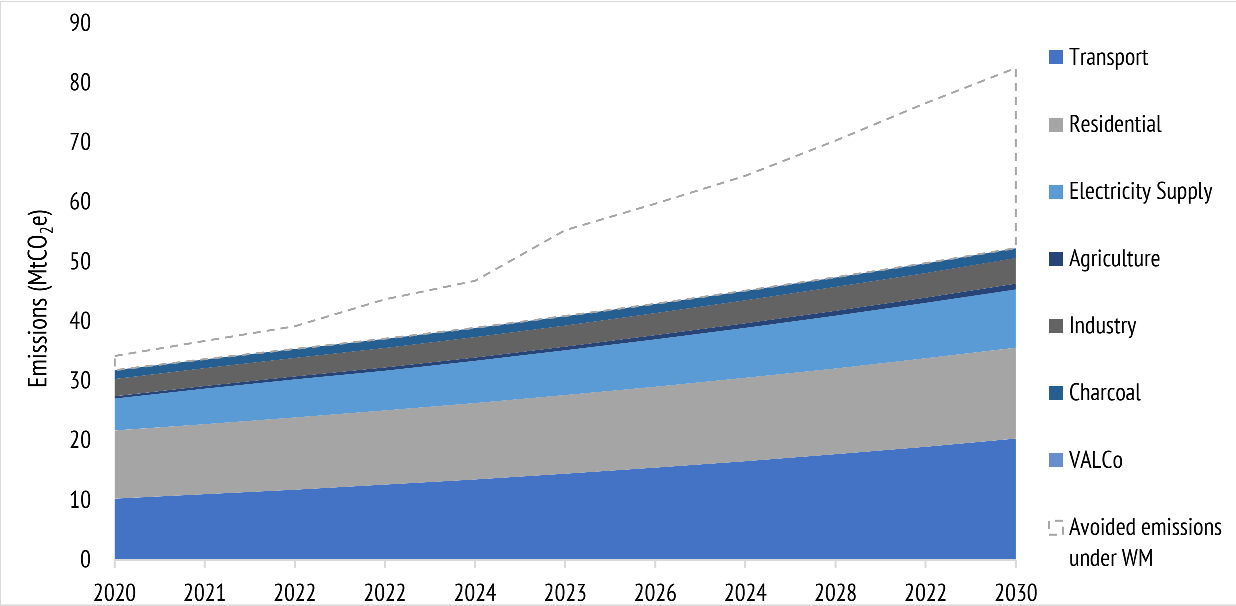

Figure 47: GHG emission reductions potential under the with measures mitigation scenario

The WM scenario compares the incremental benefits of the fuel switch in fossil-fuel power plants and efficient home appliances against the projected AEG emissions. The assumption is that the two identified mitigation options would be implemented in addition to the policies driving the AEG emissions trajectory. The potential aggregate GHG effects of the mitigation options under WM is estimated at 25% relative to the projected emissions of AEG by 2030 (Figure 47). The expected emission reductions under WM scenario translate to an average of 14 $MtCO_2e$ per year. The breakdown of the contributions of individual mitigation options under WM is reported relative to the AEG emissions for households and electricity generation. Regarding the efficient appliance measure in households, the estimated emission savings would be 4% lower than the AEG emissions. It would translate into an annual savings rate of 0.6 $MtCO_2e$ over the assessment period (Figure 48).

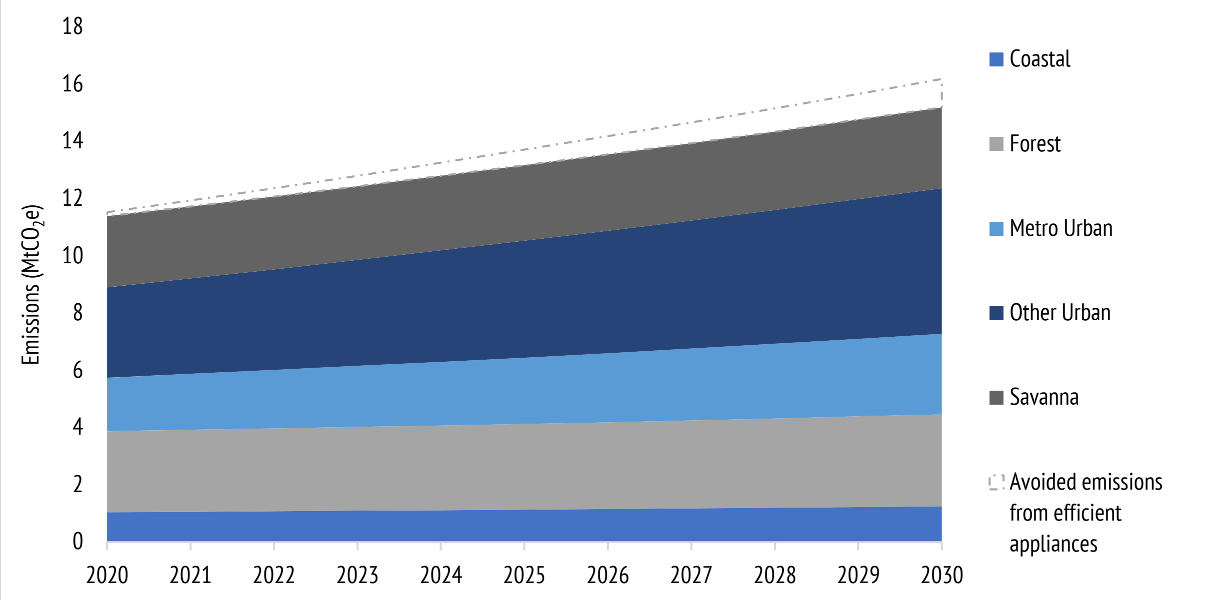

Figure 48: GHG emissions reduction for efficient appliances under with measures mitigation scenario

In the same vein, the replacement of fuel oil with natural gas for the fossil-fuel power plant could lead to an estimated 50% reduction relative to the projected AEG emissions for the electricity category. The potential savings would increase from 2.1 $MtCO_2e$ in 2020 to 21.53 $MtCO_2e$ by the end of the decade. The cumulative total of the effect would amount to 117.5 $MtCO_2e$ by 2030, with an annual average of 29.6 $MtCO_2e$ (Figure 49).

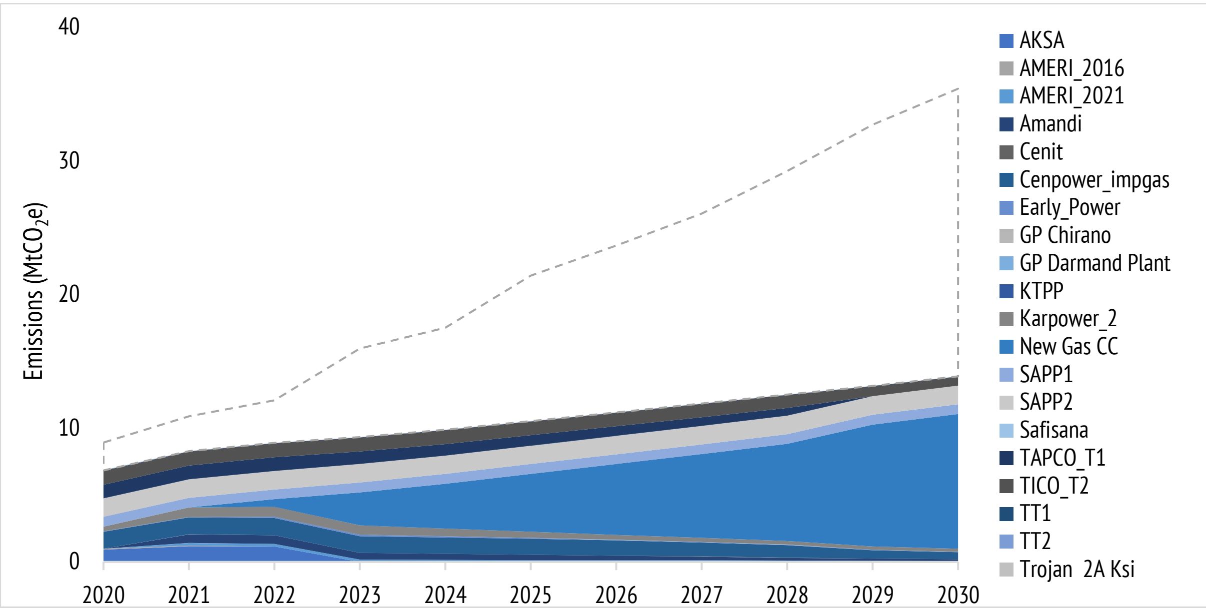

Figure 49: GHG emissions reduction for fuel switch measure under with measures mitigation scenario

4.5.8.2 With additional measures mitigation scenario

The "with additional measure" is the ambitious mitigation scenario and is made up of eighteen options in the energy sector. The eighteen options cover a combination of a wide range of mitigation technologies focusing on households, transport, industry, and electricity categories. WAM represents a mitigation scenario where the NDC commitments are fully achieved, which represent a significant increment over the WM and AEG emissions trajectory.

Two WAM mitigation packages focus on the household category. The first set is on clean cooking and includes the penetration of improved charcoal stoves, improved wood stoves, and LPG stoves. The second cluster of household mitigation options target clean and efficient lighting in electrified and non-electrified households.

Efficient lighting component is on the distribution of LED lamps in the electrified households, whereas clean lighting focuses on the replacement of kerosene lamps with solar and dry cells in non-electrified households. Under the WAM scenario, the assessment identified three transport mitigation options. These are the introduction of electric vehicles, electric trains and high occupancy bus services (Bus Rapid Transit - BRT). Electric mobility mitigation options would focus on adopting electric vehicles for private and commercial use in major cities in the country. Concerning trains, even though the government may introduce diesel trains under the AEG, mitigation scenarios would evaluate the emissions if 20% of the passenger-km is on electric trains.

The BRT is a bus-based mitigation option in intra-city transport. BRT is already under implementation under the current transport policy; the WAM scenario would seek to expand the coverage of the BRT to more cities. The plan is to import 400 high occupancy buses to augment the existing fleet. But the envisaged emission reductions cannot be achieved without dedicated lanes for the buses. In Industry, the focus would be on mitigating GHG emissions from pig iron and alumina production.

Both industries are linked to the government integrated aluminium industry agenda. The mitigation strategy would concentrate on the promotion of substitute fuels for the iron and alumina industry. For pig iron production, the aim is to quantify emissions from the alternative use of natural gas instead of traditional coal. In the same vein, the focus is on assessing the implications of adopting natural gas as an alternative fuel of residual fuel oil. On the electricity side, the assessment aims at evaluating the GHG effects for adopting additional measures on utility-scale solar and wind installation as an alternative to natural gas-fired thermal plants. The assessment also estimated the emission reductions potential associated with the scenario of introducing nuclear power on the utility grid scheduled to come online by 2030. The cumulative GHG emissions reductions under the WAM scenario are estimated at 181.1 $MtCO_2e$ covering the ten years (2020 to 2030). This figure is 29.7% lower than the projected AEG emissions of 610 $MtCO_2e$ (Figure 50).

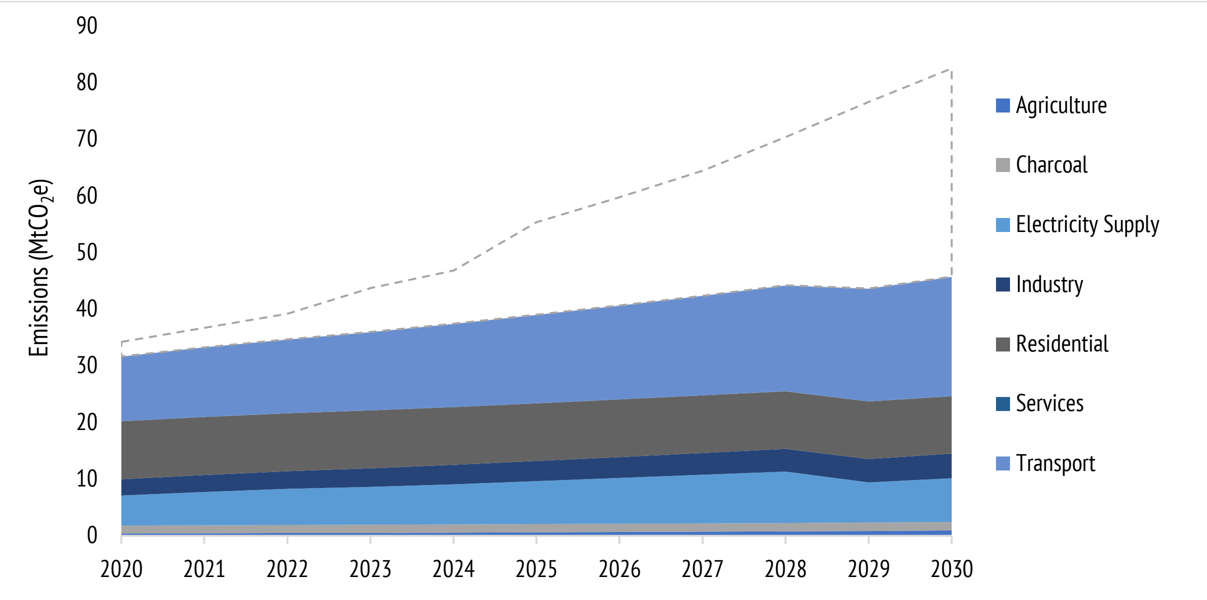

Figure 50: GHG emission reductions potential under the WAM mitigation scenario

The individual mitigation options would contribute differently to the aggregate mitigation potential under the WAM scenario. Under the household, there are three broad options in the areas of clean cooking (improved stoves and replacement of LPG fuel), LED lighting and solar lamps. The improved cookstove mitigation strategy captures the penetration of charcoal and wood stoves as well as LPG stoves. A cumulative total of 30.2 $MtCO_2e$ is expected to be achieved for all the mitigation options in the household category. The emission reduction would be about 19.9% below the AEG emission for the household (Figure 51). The annual average savings are likely to hover around 0.91 tCO_2e every year.

Among the household mitigation measures, the improved cookstove option is expected to achieve the highest emission reductions of 19.4 $MtCO_2e$, which would represent about 12.8% deviation from the AEG emissions. LED bulbs strategy involved the replacement of less efficient CFL and incandescent bulbs with LED. The total emission savings from this measure would amount to 6.4 $MtCO_2e$ for the entire assessment period. The emission reduction figure is 4.2% less than the projected AEG emissions for the household category. The savings would occur at a rate of 0.58 per annum. The solar PV mitigation option would contribute the least to the overall emissions reduction in the category. In all, 4.4 $MtCO_2e$ of greenhouse gas emissions would be avoided as the result of the solar PV interventions. The projected mitigation effect of the solar PV option would be 2.9% lower than the AEG emissions by 2030.

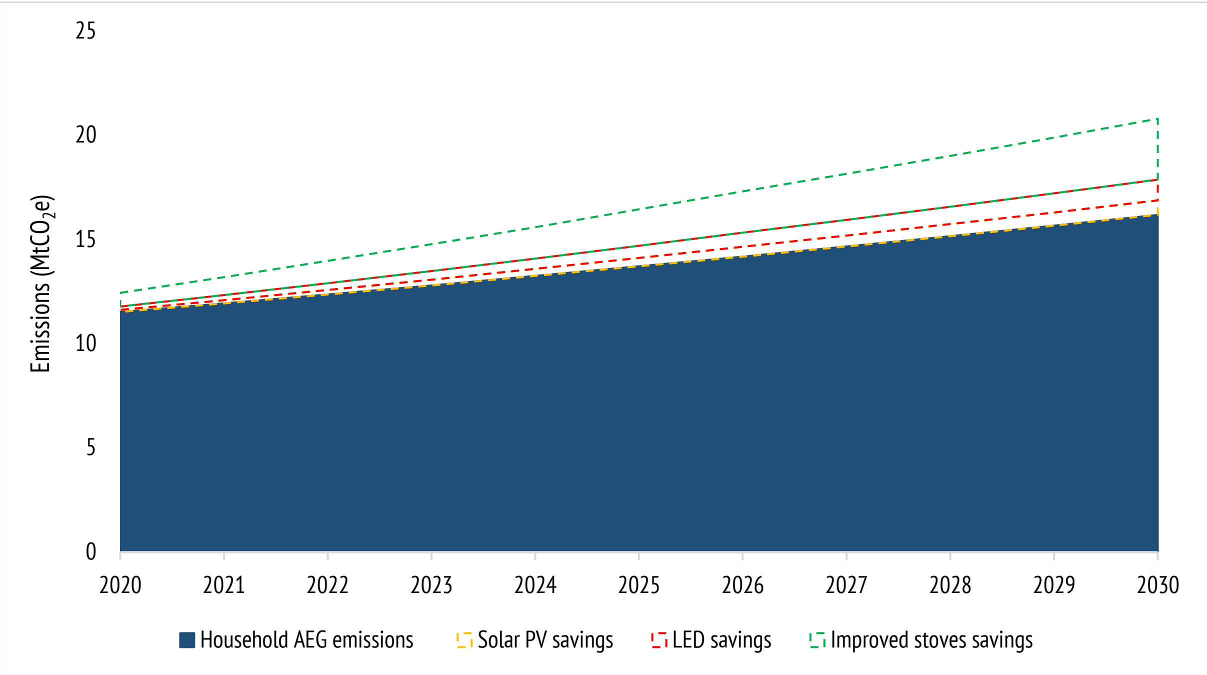

Figure 51: GHG emission reductions potential under the WAM mitigation scenario for households

The next set of mitigation options under WAM scenario is in the transport sector and includes three multi-modal shift mitigation measures. These are electric vehicles, BRT and electric buses. The highest reduction contributions of 34.8 $MtCO_2e$ would come from the high-occupancy BRT system in major cities and projected to be 13.8% below the AEG emissions

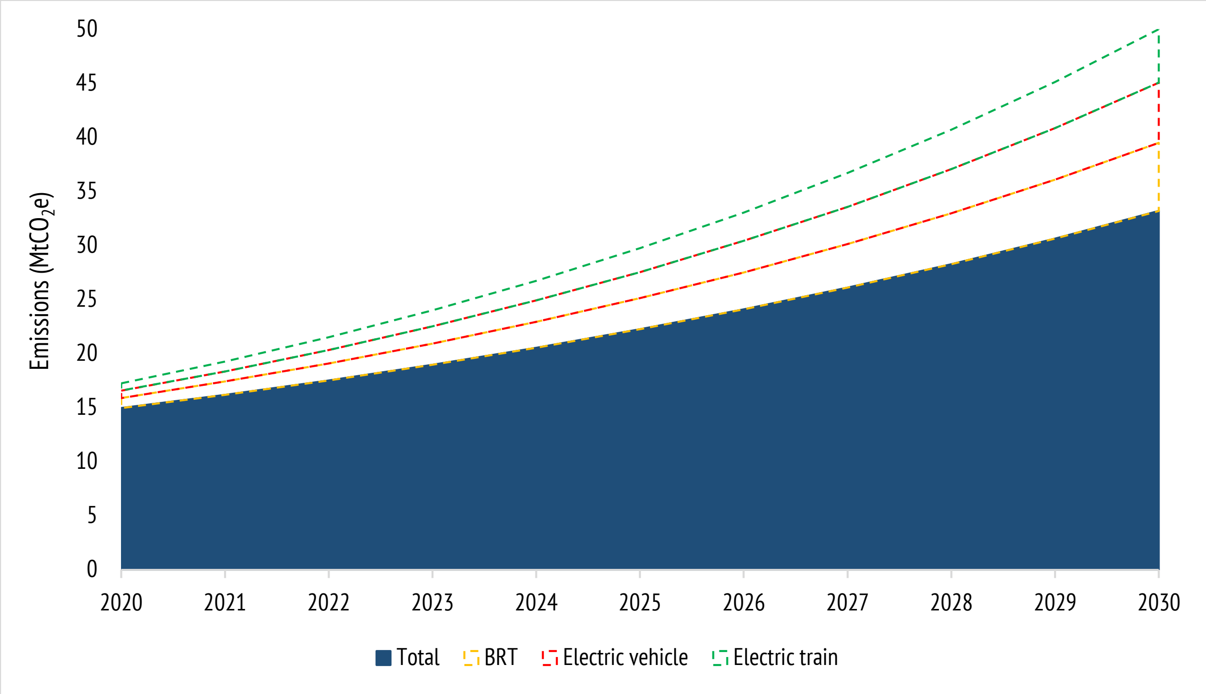

Figure 52: GHG emission reductions potential under the WAM mitigation scenario for the transport sector

The mitigative effects of electric vehicles and electric trains could lead to emission reductions of 29.7 $MtCO_2e$ and 26.9 $MtCO_2e$, respectively. For electric vehicles, the projected emission savings would be 11.7% deviation from the AEG emissions (Figure 52). In the same vein, an electric train alternative is a plausible option for the proposed diesel train strategy. It is projected that, if 20% of the passenger-km of the proposed diesel train initiative is replaced with electric trains, it would lead to cumulative total emission savings of 26.9 $MtCO_2e$ which is 10.6% below the AEG emissions for the transport sector. Under the industrial sector, improved alumina and pig iron production are two main mitigation options. They would focus on the replacement of residual fuel oil and coal with natural gas to achieve the mitigation objective in the assessment period. Both options would be part of the government's industrialisation agenda.

4.5.8.3 Mitigation effects of the AEG, WM and WAM scenarios

The evaluation of the overall mitigation effects of the selected options, the emissions associated with WM and WAM scenarios have been compared with the AEG. Generally, the emissions under the WAM trajectory would be the lowest as expected, relative to the WM and AEG scenarios. While the total cumulative emissions along the AEG trajectory is estimated to be 278.9 $MtCO_2e$, the WM emissions would deviate by 28% to 217.3 $MtCO_2e$ and further decline below by 40% to 199 $MtCO_2e$ on the WAM scenario (Figure 53)

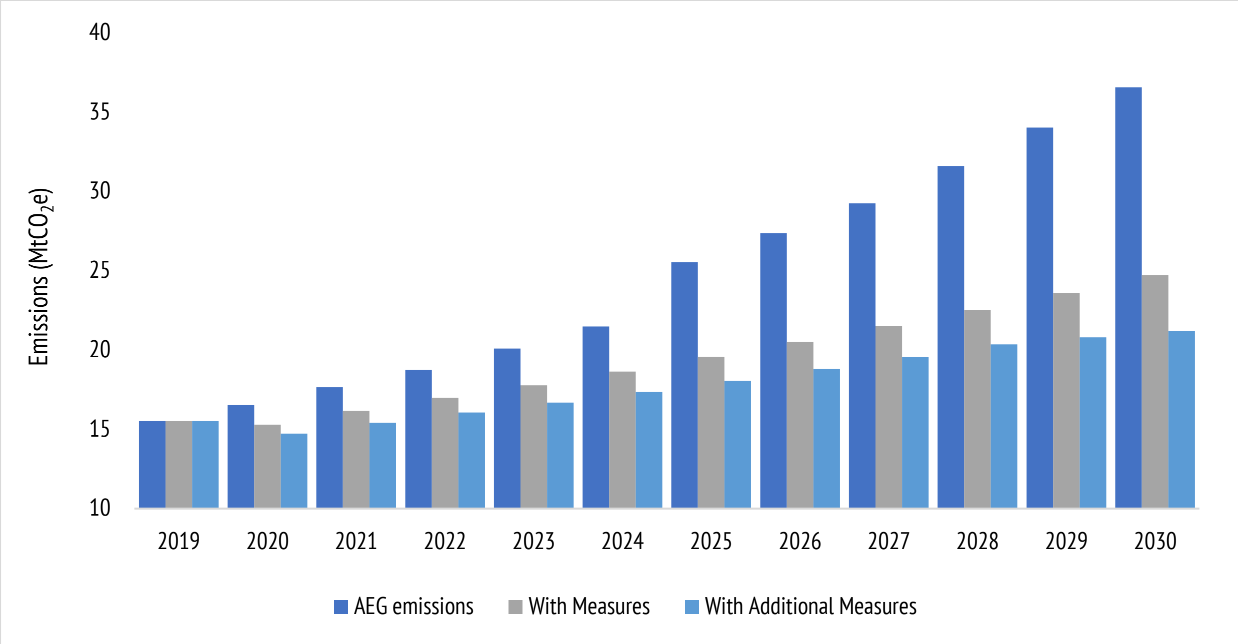

Figure 53: Comparison of emissions under AEG, WM, and WAM scenarios

4.5.9 Strategies for Implementing Mitigation Options

The rolling out of the mitigation options cannot be successful without coherent policies, capable and well-coordinated institutional roles, access to necessary investments and technology. Ghana would prioritise advocacy for the consistent implementation of existing policies as a concrete way to achieve its mitigation goals. Table 56 provides an overview of some of the critical actions that need to be implemented to achieve the mitigation objectives. It captures information on significant barriers, investment cost, abatement potentials, sustainable development benefits, lead agency and alignment with national policy.

Table 56: Further steps toward implementation of selected mitigation options

Mitigation Options	Line Ministries	Supporting Agencies	Investment costs for implementation to 2030 (US$)	Estimated split between the public-private sector and consumer investments*	Abatement potential and sustainable development impacts	Priority Barriers	Alignment with National Policy/Programme removing barriers
Clean cooking (Improved biomass cookstoves and LPG Cookstoves)	Ministries of Energy and Ministry of Land and Natural Resources, Local Government and Rural Development	Energy Commission National Petroleum Authority Forestry Commission District Assemblies	US$ 0.65billion Improved cookstoves (UDUS$0.16billion) LPG stoves (US$ 0.49billion)	Improved cookstoves: about 70% consumer costs and 30% public support costs, LPG stoves: about 80% consumer cost and 20% public support	- Abatement potential to 2030 of 15.8 $MtCO_2e$ - Health benefits from reduced indoor air pollution. - Lower woodfuel demand and deforestation. - Potential cost savings to households	- inadequate production and distribution capacity; - limited expertise to design and produce more efficient technologies; - the sector is not attractive to financial institutions;	Policy target: 50% LPG penetration by 2020. Reduce wood fuel demand from 72% to 50% by 2020. Programmes – SEforALL Action plan.
Utility-scale solar	Ministry of Energy	Energy Commission, Private sector	US$ 169 million[121]	80% of the total cost expected to come from the private sector	- 11 $MtCO_2$ - 1,169 jobs prospects	- The challenging investment climate, - Uncertainty of available resources, - Limited technological capacity. - Insufficient experience in renewable energy development - Information and awareness barriers	Renewable Energy Act. Renewable Energy Master Plan SREP Investment Plan
Solar lanterns	Ministry of Energy	Energy Commission, Private sector	US$ 300 million	Private sector involved in importation, distribution, sales and installation of LED lamps	- 947 $ktCO_2e$/year - Health benefits from reduced indoor air pollution.	- Inadequate resource availability - The incentive for manufacturers or importer of efficient LED lamps. - The disposal of inefficient bulbs is a potential source of mercury emissions.	National Energy Policy Light for all initiative (distribution of 12 million LEDs)

[121] Renewable Energy Master Plan

Switch from liquid fuel to natural gas in thermal power plants	Ministry of Energy	Volta River Authority, Ghana Gas Company	US$ over 1 billion	About 80% investment in gas infrastructures by GNGC. The private sector contributes 20% gas production and distribution cost	- Potential to generation 145 ktCO_2e/year	- Irregular flow of natural gas from the West Africa Gas Pipeline	National Gas Master Plan
Forest plantation development	Ministry of Lands and Natural Resources	Forestry Commission Private sector	US$ 4.1 billion investment cost, projected income of US$ 9.4 billion	The shared cost between public and private sector plantation development companies.	- Potential to generate 2,456.67 kt/year. - 2.8 million job prospects for over 25 years.	- Lack of sustainable financing framework for plantation development. - Lengthy land acquisition processes. - Weak legal and institutional framework for plantation development. - Lack of a unified legal framework for regulating plantation development, benefits sharing, financing.	National forest and wildlife policy. Forest Plantation Strategy Forest Plantation Development Fund REDD+ Strategy
Ghana Forest Cocoa REDD+ Programme	Ministry of Lands and Natural Resources	Forestry Commission, Ghana Cocoa Board Private sector	US$ 50 million results-based payment model.	The results-based payment scheme is expected to leverage an additional over US$ 200 million investment into the cocoa landscape.	- Potential to generate 1414.29 kt/year. -	- Difficulty in the sourcing of funds for implementation. - Inadequate capacity to use state-of-the-art GIS technology to map and monitor existing plantations spatially. - Threats from illegal mining.	National forest and wildlife policy. REDD+ Strategy Forest Plantation Strategy Forest Plantation Development Fund
High Occupancy Buses	Ministry of Transport, Infrastructure, and local government	Ministry of Transport	(US$ 0.35 billion)	About 70%-80% public investment cost for infrastructure and 20%-30% private costs for vehicle stock	- Abatement potential to 2030 of 1.63 MtCO_2e. - Reduced traffic congestion - Improved local air quality - Improved road safety - Job creation	Difficult to regulate informal transport service providers. - Inadequate funding. - Lack of consistent political commitment. - Integration of BRT in road development. - Lack of clarity in regulation and enforcement.	National Transport Policy Policy target: 80% of all trips in the Urban Area should be done through the public. Mass Transit Systems

Institutional biogas	Ministries of Energy, Education and Health	Ministry of Energy	(US$ 0.11 billion)	About 55% public investment through rebate scheme 45% private costs for cost institutional biogas	- Abatement potential to 2030 of 0.024MtCO_2e. - Reduction in indoor pollution - Improved sanitation - Reduction in out-pocket-expenditure on cooking fuels - Job creation and increased incomes	- Lack of access to finance, including microfinance. - Limited local professional artisans. - High upfront cost. - Non-existing public capital incentives. - Standardisation of biomass plants and registration of firms to ensure efficient monitoring. - There is a need to equip the EC and GSA to ensure proper standardisation.	SEforALL Action Plan. Renewable Energy Act. Renewable Energy Master Plan.
Scale-up market share of climate-friendly and energy-efficient conditioners to 70% by 2030	Ministry of Environment, Science, Technology and Innovation	Environmental Protection Agency, Energy Commission	US$ 15.5 million	Private sector involvement in the importation of efficient conditioners	- Potential to reduce the emission of 900 kt/year.	- Industry refusal, backing from other national agencies needed. - Inadequate funding	HFC phase-out management plan
Avoided methane from the disposal of solid waste through composting	Ministry of Sanitation and Water Resources	Private companies	Not estimated	Private sector-led	- Potential to reduce 1,754.9 kt/year	- Mixed waste stream introduces the extra cost of processing. - Limited market scope and application of compost. - Limited compost production capacity	Double the current waste to compost capacity of 200tonnes/day to 400tonnes/day by 2030
Landfill gas management	Local government, waste, environment	Ministry of Local Government and Rural Development	(US$ 0.51 billion)	About 30% public investment to equity, 70% private capital cost	- Abatement potential to 2030 of 0.4MtCO_2e/yr. - Reduce the incidence of fire at landfills. - Additional energy generated - Improve sanitation	- High upfront transaction cost. - No landfill gas collection obligation - Challenges in the operational management of landfills	National Environmental Sanitation Policy Renewable Energy Act

4.5.10 Updates on Implementation of Mitigation Options

Updates on the implementation of mitigation measures since the submission of the second biennial update report to the Convention was reported in 2018. The reported information is along the lines of the mitigation policy options outlined in this communication and consistent with the mitigation commitment in the NDC. Only mitigation measures, the implementation of which has meaningfully progressed on the ground, and new information have been collected, are reported. This section of the report must be read together with the mitigation actions and their effects in Ghana's BUR2 to appreciate the bigger picture (Table 57).

Table 57: Updates on the implementation of mitigation options since the submission of BUR2

Mitigation options	Category	Updates since the submission of BUR2 to the UNFCCC
Households sector	Clean cooking	The clean cooking measures include the dissemination of improved charcoal and woodstove and the adoption of LPG for cooking. The Ministry of Energy and National Petroleum Authority lead in the implementation of the LPG related interventions, and the Energy Commission leads in the application of the biomass associated interventions. Clean cooking interventions are supported by development partners like the UNDP, the Clean Cooking Alliance, Netherlands Development Organisation, and the World Bank. The following are the updates of the significant steps taken and achievements made since the submission of the second biennial update report to the UNFCCC: The Ministry of Energy has successfully launched Ghana's 500,000 improved cookstove project in collaboration with the Korean Investors. The project is expected to deliver not less than 4,000 kt of emissions reductions (ERs) every year. The ERs are to be transferred to the Korean Carbon Market under rules of the amended Kyoto Protocol and subsequently within the framework of the Paris Agreement Article 6. Ghana is the host of fourteen improved cooking stove program activities with a potential average of 151.1 kt/year each in the first period.
	LED lighting	The Ministry of Energy has introduced the "light for all initiative" in which 12 million LED lights are to be distributed nationwide under a cost-recovery programme led by local banks. This initiative has the potential to reduce energy consumption by 50% from the current compact fluorescent bulbs' usage and 0.96 Mt of carbon emission savings. Three million LED lights are to be distributed to public institutions by the Ministry of Energy, which is expected to reduce 0.24Mt carbon savings. Part of the 2.4million US$ under the Energy Efficiency & Demand Side Management (EEDSM) project implemented by MiDA is being used to replace existing high-energy consuming streetlights as part of the effort to save energy and enhance security within the Greater Accra Region. A total of 1,800 energy efficiency streetlights would be installed ed under the project. Part of the funds would also be used to finance 3 Energy Auditing Centers in selected tertiary institutions for the building of capacity for energy auditors who would work towards the reduction in wastage in the energy supply systems in Ghana. Other activities include curriculum and development of standards for most appliances.
Transport	High-occupancy buses	Fleet renewal. The Ministry of Transport plans to import 400 high occupancy Euro 3 buses. One hundred high-occupancy buses (Euro 3) are already in the country. Additional 300 would be imported to add to the fleet. Efficiency in testing and improved roadworthiness - Private sector participation in-vehicle testing. Nearly twenty private garages in operation - Accra, Tema, Kumasi, Somanya, Winneba, Koforidua. Twenty more to be added to cover the northern sector.
	Electric vehicles	The Ministry of Energy has launched an e-drive initiative to promote electric vehicles in Ghana. The Ministry of Transport, Private sector and AFD are developing Accra city vehicle project to seek funding from the Green Climate Fund.

Sustainable energy	Solar programme	The Volta River Authority has launched a renewable energy programme. Phase 1, VRA is constructing 17MW Upper West Regional Solar Power Project, 76 MW Wind Power Project -1 and 76.5MW Wind Power Project -2. In phase 2, VRA plans a 200MW Solar Power project to be built in different stages, including 18MW Upper West Regional Solar Power Project & 40MW Bongo Solar Power Project, 200MW Wind Power Project, 75kWp. Volta River Authority Head office Cafeteria Building Solar-PV Rooftop Project, 28kWp Akuse Solar PV Rooftop Project, 40.2kWp Akuse Institutional office buildings Solar PV Rooftop Project.
Low carbon electricity	Conversion of a single cycle to combined cycle thermal plant	Conversion of the 220MW Simple Cycle Kpone Thermal Power Station to 330MW Combined Cycle Plant. A total 400kt CO_2e annual savings envisaged when operational.
	Fuel switch in fossil-fuel thermal plant	VRA has introduced a corporate policy to utilise natural gas solely for power generation from the thermal power plant.
Lowering deforestation and restoration of degraded lands	Forest Cocoa REDD+	Ghana signed an agreement with the World Bank to cut carbon emissions and reduce deforestation[122]. Ghana's five-year Emission Reductions Payment Agreement with the Forest Carbon Partnership Facility (FCPF) Carbon Fund, which is administered by the World Bank, unlocks performance-based payments of up to US$50 million for carbon emission reductions from the forest and land-use sectors. In Ghana's ERPA, the FCPF Carbon Fund commits to making initial results-based payments for emission reductions of 10 million tons of CO_2 emissions (up to US$50 million).
	Forest plantation development	Youth in Afforestation programme. 65,000 youth recruited under the programme has planted about 10 million seedlings of different species across the country since 2018[123].

[122]https://www.worldbank.org/en/news/press-release/2019/07/09/ghana-signs-landmark-deal-with-world-bank-to-cut-carbon-emissions-and-reduce-deforestation
[123] https://www.graphic.com.gh/daily-graphic-editorials/ghananews-afforestation-programme-needs-the-push.html

Climate vulnerability, impacts and adaptation assessment

Cover photo source: CNES/Airbus Image over Keta from Google Earth

5. Updates on Climate Vulnerability, Impacts and Adaptation Assessment

This section of the NC4 presents a unified consolidation of information on climate scenarios, vulnerability assessment, and adaptation. It is structured into four parts. Part one is on the updates on climate scenarios including reviewing climate modelling initiatives. Information on data, methodology and the results from the climate projection analysis are covered as well. Part two is on spatial vulnerability, explaining the data points and the methods for the vulnerability assessment. The visualised results are in thematic maps covering the entire country. In part three, the results from climate projections and the spatial vulnerability assessment are used as input in the revision of the information on impacts assessment and adaptation planning. Part four synthesises the key messages from the climate scenarios, spatial vulnerability, and adaptation planning into summaries for policymakers and end-users.

5.1 Description of Climate Projections

Climate projections and the underlying analysis provided evidence on the current and future climate change in Ghana. The projections give a lead on the past and future characteristics of climate variables per each agro-ecological zone. Often, the results serve as inputs in climate change vulnerability, impacts, and adaptation assessments. Here, the report lays out the methodology, analysis, and results of climate projections. The results also reveal the trend of current and future climate change. The projection of the future climate outlook has a great deal of reliability since it was derived from the pattern of 34-year historical climate records.

Presentation of results is at the national scale and for different agro-ecological zones to make it easy to understand and user-friendly. The climate projections are a useful reference for potential end-users involved in engineering, policy and grassroots work, particularly for multiple stakeholders in water resources management, urban infrastructure planning, agriculture, and climate adaptation planning. It also serves as reference material for academics and students involved in climate change-related activities. The updated climate projections are improvements of the previous information reported in the NC3. The team made the following changes:

- RCPs instead of SRES[124] to ensure consistency with the current IPCC report. The IPCC AR5 recommended the use of RCPs as best practice.
- CORDEX[125] models, instead of the AMMA model[126] due to its high resolution and better performance over Africa.
- Added two gauged stations to the previous 22 stations managed by Ghana Meteorological Agency[127].
- The baseline was 1980-2014, an improvement of the previous 1981-2010 for a longer baseline.

The changes introduced in the current projections contributed to making the results more robust for the climate assessment based on emission scenarios of the Fifth Assessment Report (AR5)[128] by the Intergovernmental Panel on Climate Change.

[124] Special Report on Emissions Scenarios – SRES. sedac.ciesin.columbia.edu/ddc/sres/
[125] Coordinated Regional Climate Downscaling Experiment. The downscaling is performed using multiple regional climate models.
[126] African Monsoon Multidisciplinary Analysis. https://www.amma2050.org/
[127] www.meteo.gov.gh/website/
[128] https://www.ipcc.ch/assessment-report/ar5/

5.1.1 Methodology for the Climate Projections

5.1.1.1 Summary of climate projection steps

Long-term observed historical climate data was used in the projections. The climate projection team obtained data from the Ghana Meteorological Agency (GMet), which has the mandate to collect and manage climate data for the country. The data included daily rainfall, minimum and maximum temperature for thirty-four years (1980-2014). Three GCM ensembles from Coupled Model Intercomparison Project Phase 5 (CMIP5) were used in the downscaling to drive five regional climate models data from CORDEX. The analysis covered two timeframes. The baseline was the period 1980-2014, whereas the future projections are sliced into three epochs: 2015-2040, 2041-2060, 2061-2080.

5.1.1.2 Description of weather stations data

The GMet was established in 1957 to provide efficient and reliable meteorological information by collecting, processing, archiving, analysing and disseminating findings/meteorological information to end-users. In line with their mandate, GMet:

- undertakes daily national weather forecast on radio and television.
- Collects, processes, stores, and disseminates meteorological information.
- Undertakes research and publications.
- Collaborates with relevant agencies (Agricultural, Water Resources, Aviation, Energy, Adaptation programmes) on issues of weather and climate.
- Provides expert advice on climate issues.
- Provides meteorological information to meet international set standards.
- Renders other meteorological services on routine/requests.

Currently, GMet regularly publishes agrometeorological, flood and drought monitoring bulletins for informed medium-term planning. The primary data source for the climate projection was GMet's meteorological records from 1980 to 2014. The data on climate variables used for the predictions were obtained from the twenty-four nationwide meteorological stations managed by the GMet[129].The twenty-four weather stations have a good spread across the country but not evenly distributed (Figures 54 and 55).

[129] www.meteo.gov.gh/website/

Figure 54: Ghana Meteorological Agency outdooring a new automatic weather station

Figure 55: Automatic weather station in Accra

The selected data for the projections were gauged weather stations with high inter-annual data availability and of high quality. The selected stations offered a good spread of climate data across the country for rigorous assessment. The deciduous zone has the most stations with eight stations followed by the coastal savanna with five stations. The transitional and the guinea savanna zones have three stations, whereas rainforest was the least with a one-gauge station (Figure 56).

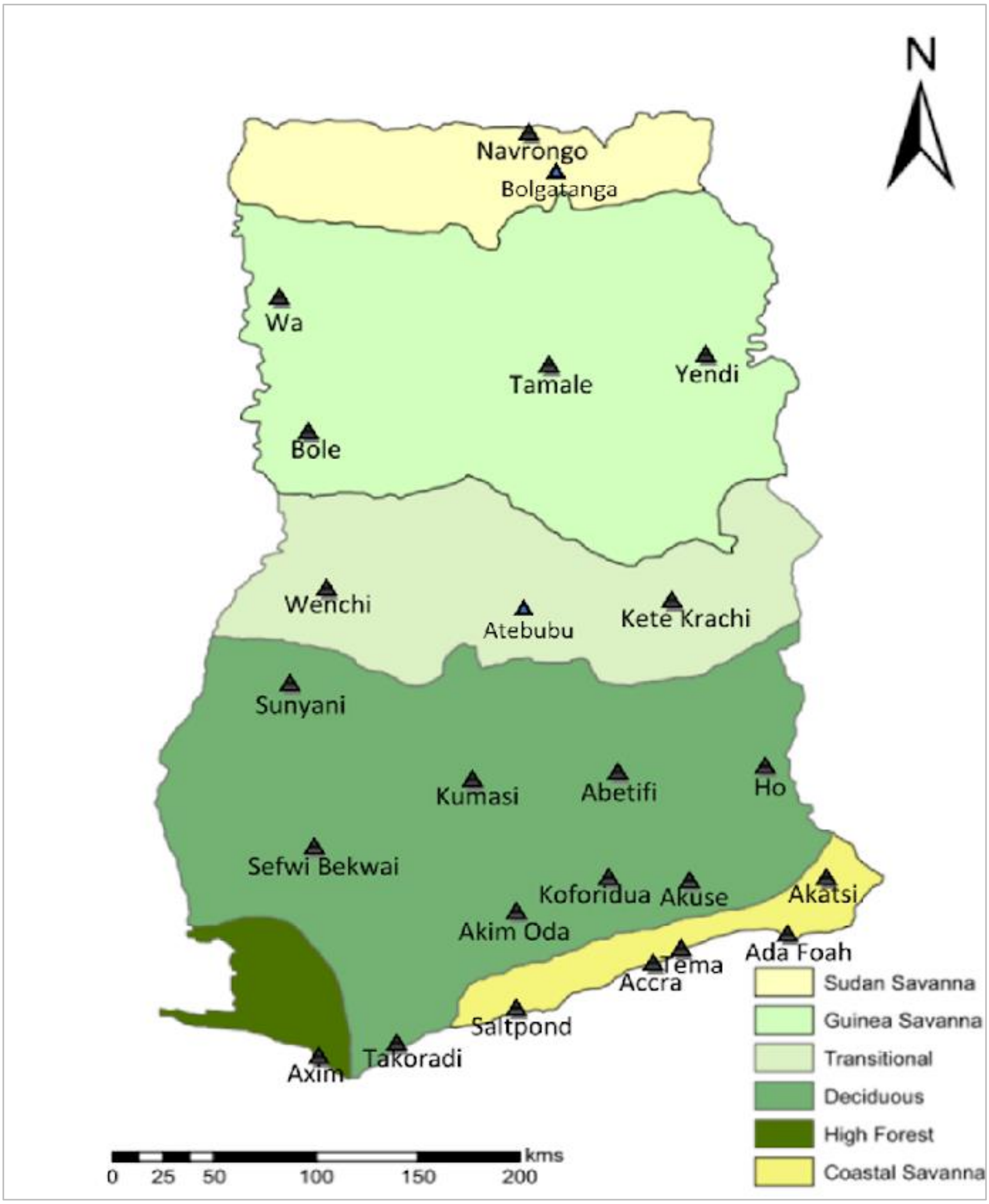

Figure 56: Spatial distribution of the 24 weather stations in six agro-ecological zones

The twenty-four selected stations had complete climate data with minimal gaps. The selected stations had at least 85 per cent data availability for the period 1980-2014 for rainfall, minimum and maximum temperatures.

5.1.1.3 Description of the climate projection method

The team followed three main steps in the climate projection (Table 58). The broad overview of the climate projection steps is summarised below:

5.1.1.3.1 Data collection for climate projection

Data collection is the first important step for climate projection. It involved scanning through the existing national climate records available at least for thirty years' time-series. The use of thirty years or more observational climatological data as a baseline is to allow for the detection of patterns in climate variability and change. In this assignment, gauged 34-years' time-series data from twenty-four weather stations were used as the baseline. The data covered climate variables such as daily rainfall, and minimum and maximum temperature recorded between 1980 and 2014. The data was cleaned by eliminating outliers and inaccuracies resulting from administrative or transposition errors. After the cleaning, the data was used in further analysis during the simulation and downscaling stage.

5.1.1.3.2 Simulation and downscaling

The team downscaled daily rainfall, maximum and minimum temperature data using quantile-quantile transformation method. Ten projections (corresponding to ten different combinations of GCMs and RCMs) were produced for each station per ecological zone and for RCPs 2.6 and 8.5 emission scenarios. The downscaled data was transformed into annual averages of rainfall and temperatures for each station and plotted. The yearly averages were calculated for the period 1980-2014, 2015-2040, 2041-2060 and 2061-2080.

5.1.1.3.3 Analysis of downscaled results

The country is subdivided into six agro-ecological zones representative of the sites where the data was recorded. The ensemble averages of the ten projections of each of the stations in the climatic zones were calculated for 2015-2040, 2041-2060 and 2061-2080. The rainfall changes were calculated by subtracting the historical mean (1980-2014) from the zonal mean projection. Decadal change and the spread of variability per each zone were determined. The observed and projected data were gridded to produce individual spatial maps.

Table 58: Summary of the climate projection steps

Activity	Description of Activity		Tools used/Source	Remarks
Data collection	Minimum and maximum temperature and rainfall for 24 synoptic stations.		Ghana Meteorological Agency	Records of daily weather observations.
Quality control	Identification and removals of outliers, key entry errors, negative precipitation values, spatial and temporal checks.		R-Climdex, Climate Data Tool (CDT).	Improved data integrity
Selection of models	GCMs SMHI REMO	RCMs MPI-ESM-LR CNRM-CM5 GFDL-ESM2G CM5A-LR MIROC5	CORDEX models	Readily available and dataset tested over West Africa.
Selection of emission scenarios	RCP 2.6 and RCP 8.5		IPCC (2015)	Robust for West Africa projected economic development scenario

Period for scenarios	Baseline – 1980-2014 Scenario years 2015-2040 (near future) 2041-2060 (mid future) 2061-2080 (far future)		Near to far-future scenarios for segmented policy planning
Downscaling Methodology	Quantile-Quantile transformation (statistical downscaling)	Personal Computer (PC)	Allow projections to the local scale
Analysis of the model results	Calibration and validation	Historical data from GMet	Cancelling out biases and outliers
	Ensemble mean of results	RCMs	
	Analysis of change of climate variables (period and ecological zones)	R Software version 3.5	
	Observed data were gridded	SURFUR/ARCGIS	

5.1.2 Projection Results
This section presents the model results from the projections.

5.1.2.1 Model performance
The overall climate model performance was good on the observed data. It performed as expected in the prediction of future climate with a high degree of confidence. There was strong statistical confidence for predicting the near and mid-future climate compared to far-future climate, which recorded high uncertainty. The high confidence in the model was validated with the accurate prediction of the extreme events of reduction in rainfall that occurred in 2015. The extreme events resulted from the severe El Nino of 2015. The models were sensitive to local climate effects which led to the over-estimation of urban heat effects and urban induced-precipitation.

5.1.2.2 Past, present, and future rainfall pattern
Figure 57 presents the results of rainfall distribution for six agro-ecological zones under RCP 2.6 and RCP 8.5. Generally, the widespread rainfall distribution in the country would not substantially shift but would show high variability across all the six agro-ecological zones (Figure 55). The rainfall under both RCP 2.6 and RCP 8.5.

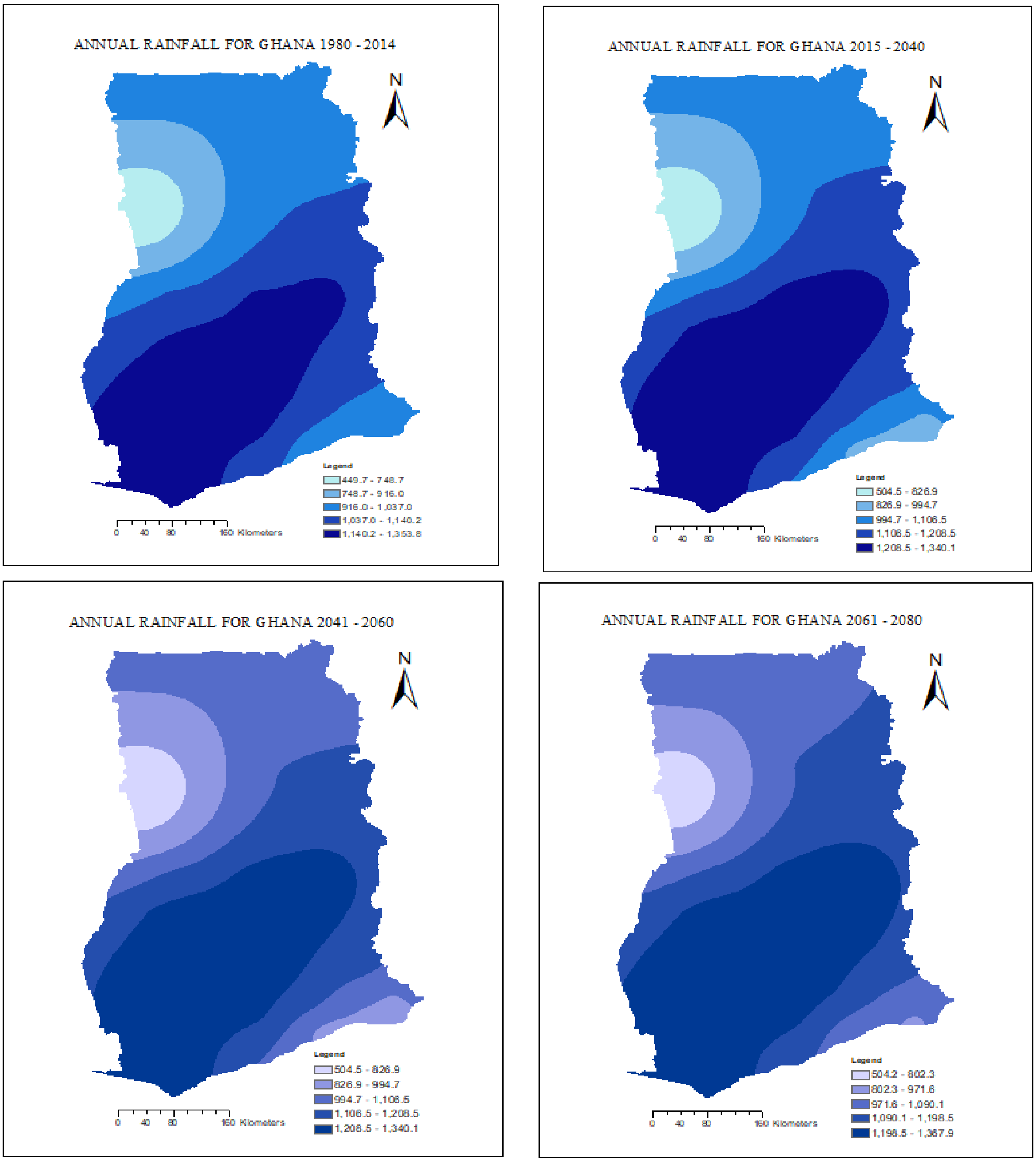

Figure 57: Maps of past and future rainfall patterns in Ghana (RCP 2.6)

The coastal zone projections indicate a likely reduction in rainfall at varying degrees over the analysis period. The level of reduction would be smaller in the near future. The rainfall reduction is likely to be larger in the mid-future, whereas the far future would experience a marginal decline. In the deciduous forest, rainfall is projected to be high for both scenarios. In the Guinea savanna, the overall rainfall is likely to increase but very high in the far future. Rainfall patterns in the rain forest are expected to decline significantly. Like the projected rainfall pattern in the Guinea savanna zone, the significant increase in the rainfall amount is expected with a higher amount for RCP 8.5 than RCP 2.6. In the transitional area, only a marginal increase in rainfall is projected for both RCP 2.6 and RCP 8.5 (Figure 57)

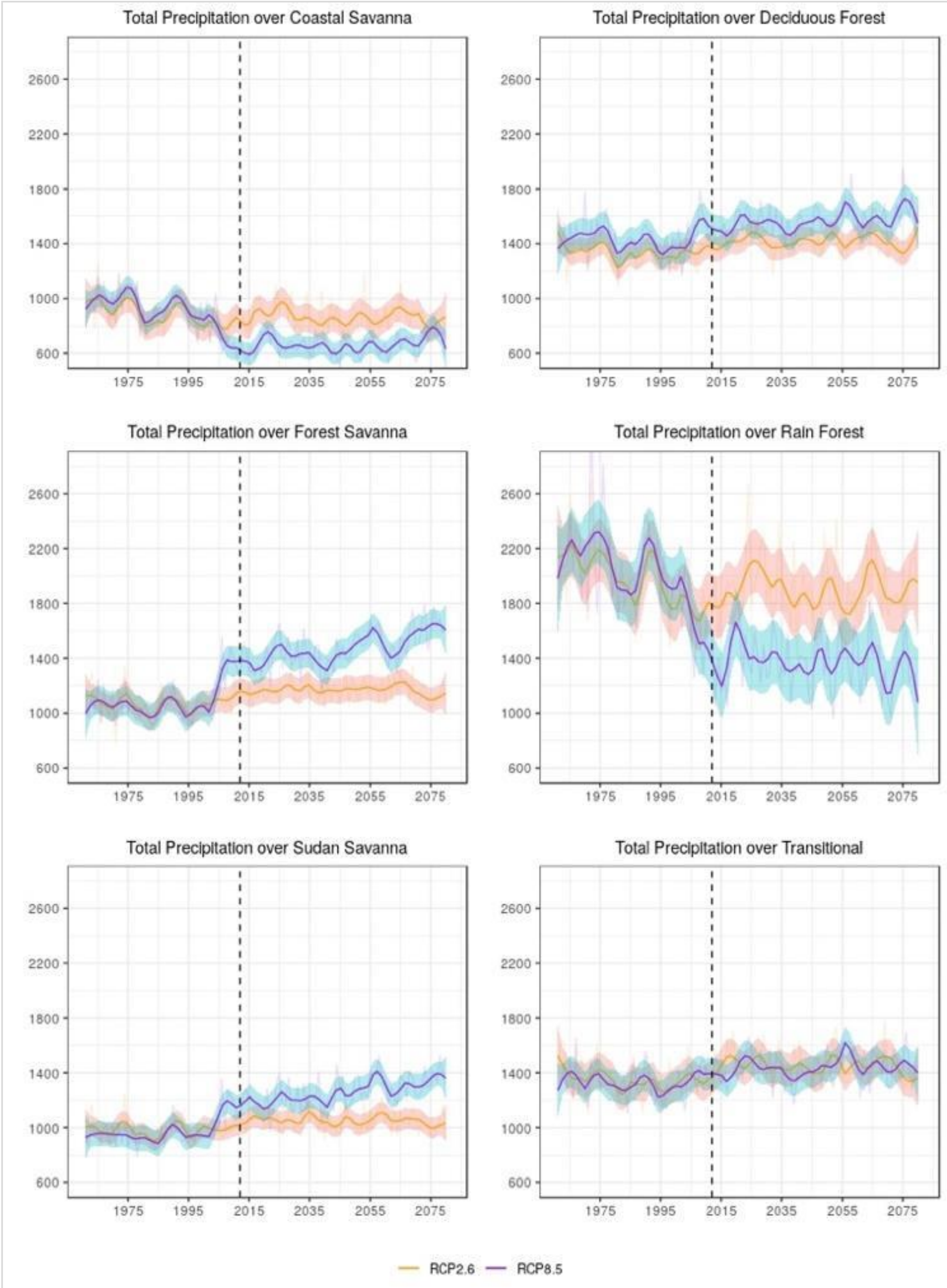

Figure 58: Past and future rainfall patterns in six agro-ecological zones of Ghana. The pink and blue lines are showing the mean trend in rainfall. The enveloped around mean line shows the degree of variability of change in the past and future climate as indicated by the dotted vertical line.

5.1.2.3 Past, present, and future temperature pattern

Figure 59 shows the projected average temperature over Ghana. Figure 60 further revealed a high likelihood of temperature increases by an average of 3°C across all the agro-ecological zones by the year 2080.

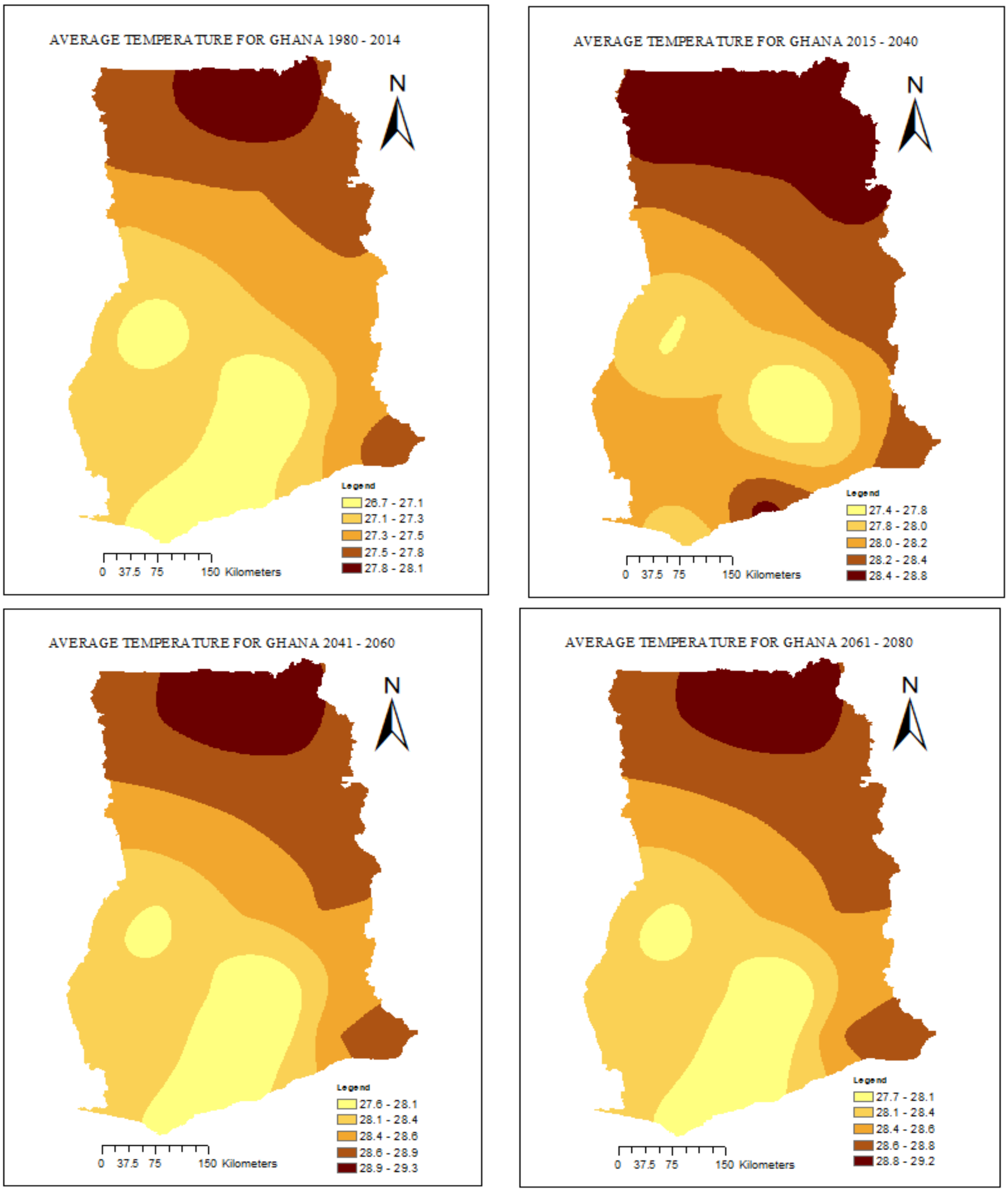

Figure 59: Maps of the past, current and future temperature patterns in Ghana under RCP 2.6

Towards the far future, the coastal savanna and Sudan savanna areas are likely to record average temperatures of above 30 °C under RCP 8.5 scenario.

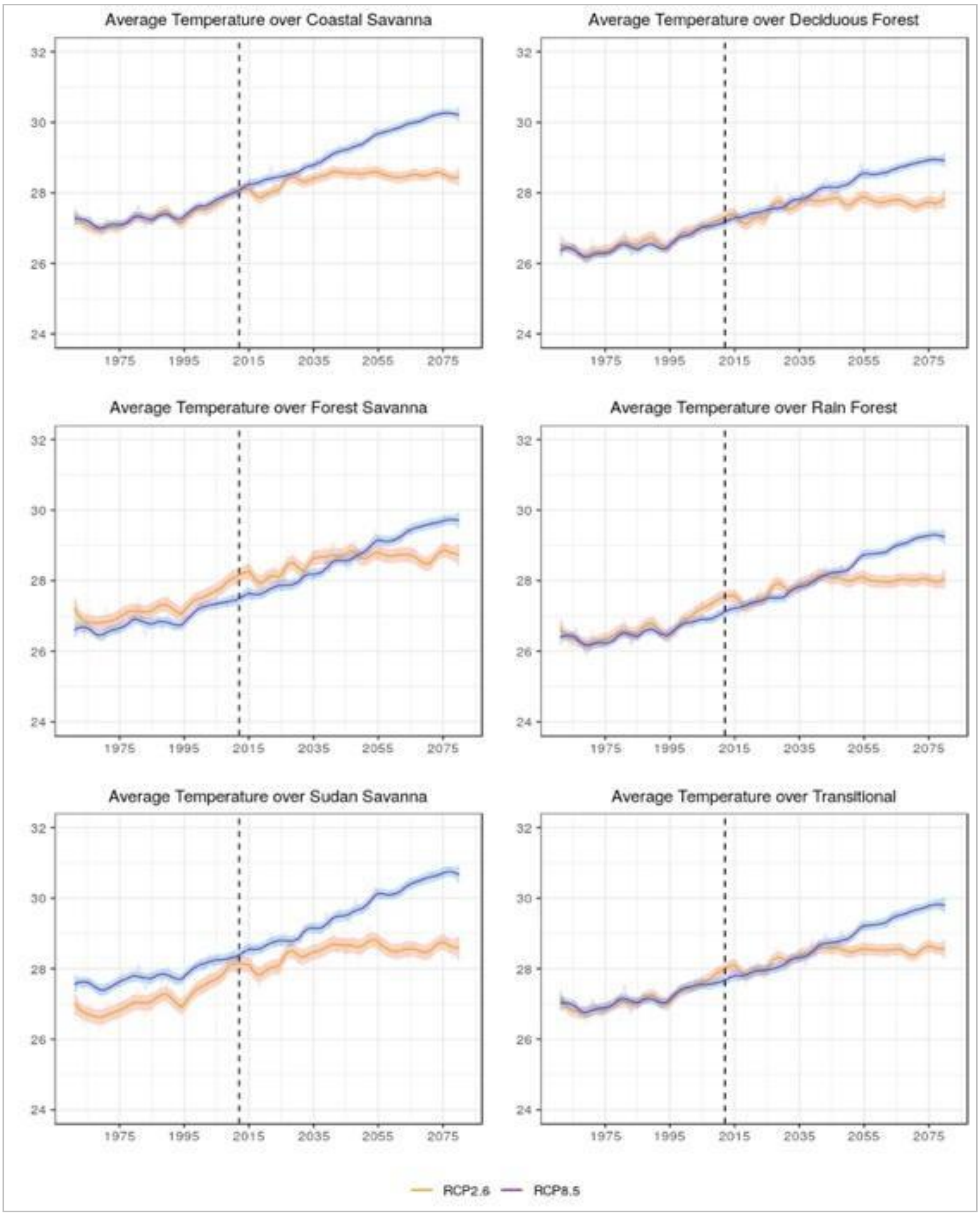

Figure 60: Past and future rainfall patterns in six agro-ecological zones of Ghana. The pink and blue lines show the mean trend in rainfall. The enveloped around mean line shows the degree of variability of change in the past and future climate as indicated by the dotted vertical line.

Overall, the temperature increases would be similar under both RCP 2.6 and RCP 8.5 until the late century, where temperature increase under RCP 2.6 stabilises while the temperature RCP 8.5 scenario continues to increase in all the agro-ecological zones (Figure 60).

5.1.2.4 Decadal trends for temperature and rainfall

5.1.2.4.1 Multi-decadal rainfall pattern

The far future rainfall is predicted to have a decadal increase with projected decadal variability for all the ecological zones until 2080. Although the coastal zone shows a general decline in rainfall, the decadal trends show substantial increases after 2050. In the past, under RCP 8.5, the worst drop of 27.9% is unlikely to reoccur. Instead, the likely anticipated decline is within the range of 1-13% until the end of the century (Figure 61). Similarly, the rainforest agro-ecological zone toes the line of the coastal area with a likely decrease in the last decade. The general decadal increases in this zone are between 5% and 26%. There are a consistent increase in decadal rainfall for Sudan-savanna, deciduous and forest-savanna ecological zones compared to the transition zone where there is a high likelihood of a decline in rainfall in the near future. However, decadal rainfall begins to increase after 2050.

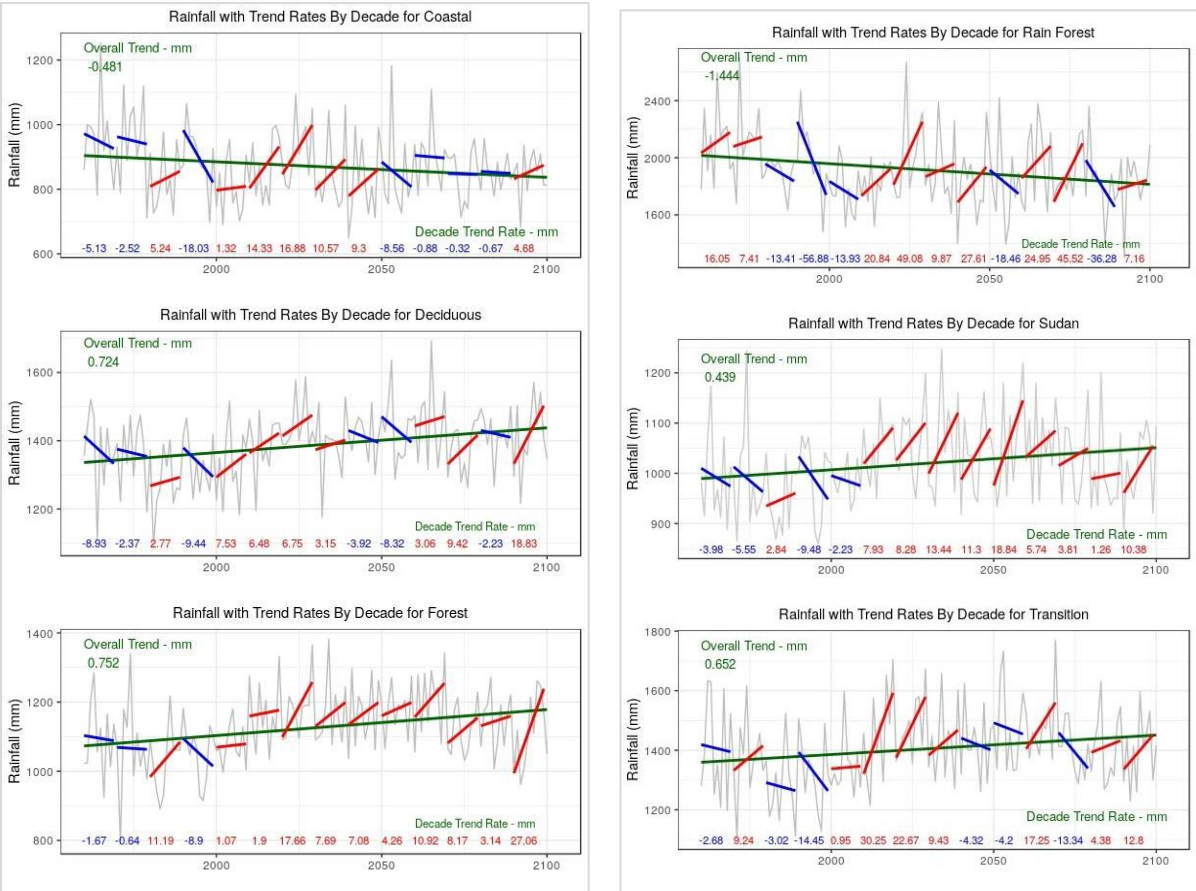

Figure 61: Multi-decade rainfall trends for six ecological zones in Ghana. The green line represents the general trend of rainfall expressed in grey for the entire period. The red and blue strikes show the decadal trends of increases and decrease respectively

5.1.2.4.2 Decadal maximum temperature trend

In conformity with global trends, the decadal maximum temperatures for all agro-ecological zones are projected to increase. The rate of increases would range from 0.01% to 0.07%. In terms of mean decadal averages, the maximum rainforest temperature is unlikely to exceed 33 ^{0}C, but the rest of the country is likely to increase beyond 34 ^{0}C (Figure 62).

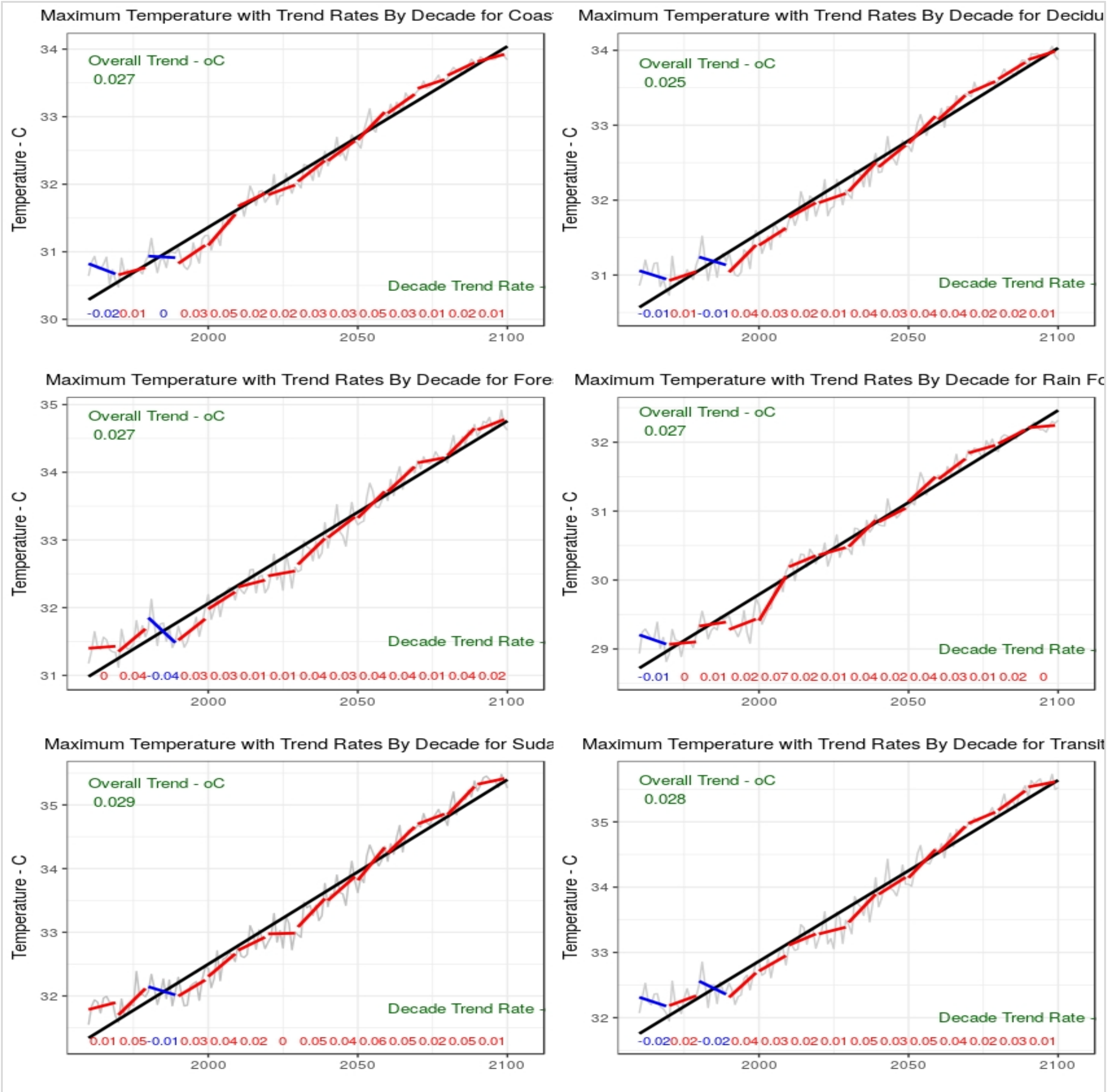

Figure 62: Multi-decade rainfall trends for six ecological zones in Ghana

5.1.3 Limitations in the Projections

Although the models performed well in the prediction of future climate over the country, there were data quality and analytical challenges. The data issues mainly related to incomplete data due to time series gaps and limited spatial coverage of the observation data. Another area of concern was the use of RCP 2.6 and 8.5 scenarios in the projections. The team considered RCP2.6 and RCP8.5 as the most suitable emission scenario to fit Ghana's future economic growth scenario. However, there is the real possibility that the Ghanaian economy may grow beyond or below the set thresholds for the selected RCPs. Concerning the efforts to improve on data quality, the focus had been on the strategy to increase coverage of the observation stations. In the last five years, the GMet has made efforts to modernise its observations capability, and as a result, about ten automatic stations have been established across the country to augment the existing observation infrastructure. The dataset from the ten automatic stations was not used in the current climate projections because of the lack of long-term historical data. Besides, low station density and missing data are still operational issues that GMet continues to address. Increasing the number of stations with adequate and routine maintenance would improve the quality of data for future projections.

5.2 Climate Modelling and Adaptation Assessment Initiatives

Climate modelling and adaptation assessment studies continue to receive attention from academia and the practice community. Most of the studies are either part of a research package or a specific project activity. For instance, the World Bank and USAID conducted studies involving climate projections and subsequently used the results in thematic impact assessments. Besides, there have been many peer-reviewed publications on climate modelling, impact assessments and adaptation since 2015. The list of climate modelling and adaptation initiatives show that climate projections have been produced in ten government-led initiatives.

The latest climate modelling and adaptation assessment initiatives led by USAID and World Bank centred on energy resources and climate and economic analysis (Table 59). The USAID study was part of the Ghana Integrated Resource and Resilience Planning Programme being implemented by ICF International. The modelling results fed into the assessment of the impacts of projected climate change on power systems in Ghana. The analysis concluded that the projected increases in extremes (drought, flood, or heat stress) have the most significant potential to impose negative impacts across the power system. The reason is that they have the potential to increase demand while diminishing generation (hydropower) as well as transmission and distribution capacity. At the same time, there may be beneficial opportunities, such as increasing solar capacity due to an increase in irradiation.

Conversely, the results of the World Bank study led[130] to the IBRD/IDA credit facility for the implementation of the Greater Accra Resilient and Integrated Development (GARID) project. The Ministry of Works and Housing is leading the implementation of the GARID project. Another study was the climate projections that was conducted as part of the feasibility study for the preparation of the climate-resilient landscapes for sustainable livelihoods project in northern Ghana to the Green Climate Fund, led by the EPA and the Ministry of Food and Agriculture with technical support from UN Environment. Generally, climate modelling and adaptation studies have become more prevalent in the academic community in Ghana. A keyword search in "google" and "google scholar" in February 2019 returned about 3 million and 25,000 results, respectively in Ghana.

For 2018 alone, over 2,600 scientific papers were published covering a wide variety of topics in peer review journals. The high levels of research show a significant interest in climate modelling and adaptation research in the country. Some of the joint research areas included climate projections, vulnerability and impacts assessment on specific ecosystems as well as the geographic regions and adaptation strategies. Universities and some research institutions have introduced climate change courses to contribute to the development of human capacities. For instance, the Physics Department of Kwame Nkrumah University of Science and Technology has undergraduate and graduate degree courses in meteorology and atmospheric science. In 2016, the CSIR College of Science and Technology (CCST)[131] started a course on climate change and integrated natural resources management. Some of the climate change topics in the course include climate modelling and adaptation.

[130] Ghana multi-sectoral investment framework for climate and disaster risk management
[131] https://www.csir.org.gh/index.php/latest-news/114-csir-to-start-private-university

Table 59: Matrix of climate modelling efforts, related initiatives and capacity needs in Ghana

Initiative	Background		Climate modelling components	Remarks
	Scope, Objectives, Outputs	Implementing institutions	Climate variables, Models, timeframe and scale	
1. Government of Ghana Efforts				
NCAP 2	Climate scenarios & sectoral impacts assessments	EPA, KNUST, UG, CSIR, GMET, CRIG, Netherlands	**Variables**: Monthly mean daily temperatures. **Model**: GCMs, ECHAM4, CSIRO **Timeframe**: 30-year mean centred at 2020, 2050 and 2080. **Scale**: Ghana & immediate offshore waters	Graduate training for one GMet staff. Sea level rise data obtained. Rainfall, temperature projections. The results were used for V and A of the Health, Tuber, Fisheries, Cereal and Cocoa.
Africa Adaptation Programme	Inform climate adaptation decisions and practices.	EPA, UNDP, and Japan	**Scale**: National and pilot districts	The community of practice for climate modelling. Automatic weather stations for GMe.t Leadership and skills development. Strengthening early warning systems.
Innovative insurance products for adaptation to climate change	Drought index insurance.	National Insurance Commission, Germany	**Scale**: Northern Ghana	Cereals in Sudan savanna. Expanded network of weather stations. The project helped to reduce the climate-induced risk for crop production in northern Ghana.
Climate Change Adaptation through Integrated Water Resources Management	Assess floods and drought disasters on the biophysical environment,	Water Resources Commission. DANIDA.	**Scale**: White Volta basin	Trained 700 people in 15 districts of the three northern regions. The project established an innovative Adaptation Learning Resource Centre. Developed Disaster contingency plans for three communities.
Climate Change Adaptation: Water Security and Flood Risk Reduction	Long-term water security in northern Ghana.	Water Resources Commission. DANIDA.	**Scale**: Northern Ghana	Increased water security for both domestic and productive uses.
Climate-proofed Water Conservation Strategies in Northern Ghana	Promote the transfer of knowledge and skills on the sustainable management of water resources	Water Resources Commission. Centre for Human and Environmental Security and Geo-hydrodynamics Limited	**Scale**: Three northern regions	Increased resilience and strengthened adaptation.

Managing water in the urban-rural interface for a climate change resilient city	Integrated urban water management in Accra.	IWMI, DFID, CSIR	**Variable**: Rainfall trends. **Model**: Nested fine-grid Accra area atmospheric model. Reg CM3-4 downscaling models. **Scale**: Densu basin	Increased resilience in Accra to climate change and water security
Community Resilience through Early Warning Project	Implement hazard mapping, early warning, and vulnerability assessment and reduction	Government of Norway through UNDP and implemented by NADMO		Integrated early warning system. The project help to build capacities within the country to reduce disaster risk.
Building Stronger Universities in Developing Countries Phase III	Capacity development in climate change	University of Ghana Danish Foreign Ministry		PhD programme in Climate change
Ghana Integrated Resource and Resilience Planning Programme	Risk and Resiliency in Ghana's Electric Power Sector.	USAID/Ghana IRRP Project by ICF	**Variables**: Temperature, rainfall, extreme events, and sea-level change. **Models**: Climate projections were from climate resource aggregators. **Timeframe**: 1986-2015 2040-2065. **Scale**: Electricity supply at the national level	Sea level rise data obtained. The study established that the South-east and South-west zones of Ghana are wetter and subject to changes in sea level and storm surge.
Ghana multi-sectoral investment framework for climate and disaster risk management	Foster climate-resilient infrastructure investments and promote climate-smart policy choices	World Bank as part of the 17th IDA	**Scale**: Climate change and economic analysis	Led to Greater Accra Resilient and Integrated Development Project. Facilitated the World Bank's investment decision in building resilience. Review of climate change impacts, adaptation, and DRR
2. Africa level initiatives				
WASCAL	Strengthening climate change research and capacity in West Africa.	MESTI, UG, KNUST German Government.		Contribute to evidence or knowledge-based system. Masters and PhD in climate modelling and land management
AMMA	West African Monsoon variability and impacts on communities.	GMet, French Government	**Variables**: Rainfall, temperature, wind, pressure. **Models**: Different Regional models	Funds and research on climate modelling

CORDEX	Provide regional climate scenarios for impact assessment	UCC, UG	**Variables**: Rainfall, temperature, wind, pressure. **Models**: CORDEX models	Local capacity building trained three Ghanaians
Global Change System for Analysis Research and Training	Contribute to strategic place-based regional research			Support to regional research and fellowships. Few Ghanaians have benefited from the programme.
African Centre of Meteorological Application for Development	Facilitate the implementation of the sub-regional strategy for disaster management	Ghana among 53 African countries, African Development Bank, WMO, UNDP, ECA		Coordinate training and capacity building and resource mobilisation. Climate watch and early warning. Disseminates products regularly for African countries.
GCRF African-SWIFT	Build capacity within African forecasting agencies and improve communication links to forecast users.	4 African countries including Ghana, UK Research and Innovation Global Challenges Research Fund.		PhD training. One staff from GMet undergoing PhD Training at the University of Leeds, UK. Enhance climate service delivery
3. Studies and Publications				
Climate and Society Community of Practice	Focus on climate change data collection, analysis, and generation of information.	Early warning system under AAP project	**Variables**: Rainfall, temperature, wind, pressure. **Models**: RCMs. **Timeframe**: 2050s and 2080. **Scale**: Sisala East and Mamprusi West districts	High rainfall volume can instigate floods. Multi-disciplinary training for COP members. Early warning information for rainfall. .
Climate Change and Variability in Ghana: Stocktaking	Holistic literature on climate change and variability in Ghana.	Asante and Anuakwa-Mensah, 2015. Climate, Volume 3	**Variables**: Impacts and projections of climate change and variability. **Scale**: Focus on agricultural, health and energy.	This initiative revealed that the impacts of climate change had worsened the plight of the poor.
Climate change impact under alternate realisations of climate scenarios on maize yield and biomass in Ghana	An estimate of the effects of climate variables on potential maize productivity.	Srivastava et al., 2018 Agricultural Systems Volume 159, January 2018, Pages 157-174	**Variables**: Climate impacts assessment on Maize. **Models**: RCP 4.5 and RCP 8.5 and LINTUL5. **Timeframe**: 2000, 2030 and 2080 **Scale**: Ashanti and Brong Ahafo Regions	Positive effect of CO_2 reduced water stress. The average increase in maize yield and aboveground biomass by 57% and 59% respectively under RCP 8.5 by 2030

Modelling Impact of Climate Change on Water Resources and Agriculture Demand in the Volta Basin and other Basin Systems in Ghana	Assess the impacts of projected climate change on water availability.	Amisigo et al., 2015 Sustainability 2015, 7(6), 6957-6975	**Variables**: Impacts on water resources. **Models**; CliRun water balance model, AquaCrop, WEAP. **Scale**: Volta Basin and the rest of Ghana river basins	Call for the evaluation of groundwater. All water demands cannot be simultaneously met currently, or under any of the scenarios used, including the wet scenarios.
Changes in expectations and extremes in the rainfall climatology of Accra, Ghana, 1895–2005	Reviews one of the longest continuous monthly rainfall records in West Africa for evidence of longer-term periodic behaviour of annual and seasonal rainfall totals using a sliding, rather than the discrete, thirty-year window.	Peter Waylen and Kwadwo Owusu	Variable: Rainfall Model: Time series and correlations analysis. Timeframe: 1895–2005 Scale: Accra	Rains during the short dry spell and minor rainy seasons are controlled by SSTs in the Gulf of Guinea and to a lesser extent the equatorial Atlantic. The effects of ENSO are most pronounced at the height of the significant rains.
Daily characteristics of West African summer monsoon precipitation in CORDEX simulations	Intercompare the performance of a set of ten regional climate models (RCMs).	Klutse et al. Theoretical and Applied Climatology January 2016, Volume 123, Issue 1–2, pp 369–386	**Variable**: Precipitation. **Models**: RCMs **Scale**: West Africa	Though not generalised, multi-model ensemble outperforms individual RCM member in the prediction of the range of precipitation variables
Simulation of the Rainfall Regime over Ghana from CORDEX	Demonstrate how well nine CORDEX models can capture the spatial and temporal rainfall seasonality.	Owusu and Klutse 2013	**Variable**: Rainfall. **Model**: RCMs **Timeframe**: 1989 to 2008 **Scale**: Ghana	Research conducted by Ghanaians and published. Historical analysis of rainfall over Ghana
Effective Adaptation Options to Climate Change Impacts in Ghana	Investigate and gain an improved understanding of climate variability and climate change and devise effective adaptation measures.	PhD Thesis by Emmanuel Tachie-Obeng, 2012	**Variables**: Rainfall and Temperature. **Models**: GCMs **Timeframe**: 2050s and 2080s **Scale**: Wa and Wenchi	The projection for rainfall and temperature. Post-graduate training in climate change. Thesis completed and published. The study revealed adaptation options for Maize.
Predicting the impacts of Climate change on the cocoa-growing regions in Ghana and Cote D'Ivoire.	Determine which environmental variables drive the climate suitability of an area to grow cocoa, predict the change in climate for the cocoa-growing areas in Ghana.	International centre for tropical agriculture with support from Bill & Melinda Gates Foundation	**Variables**: Rainfall and temperature (mean, max, min, and precipitation). **Models**: 19 downscaled GCMs **Timeframe**: 2030s and 2050s **Scale**: Ghana (30 arc seconds)	Research conducted by non-Ghanaians. The results were useful for long-term planning for the cocoa sector in Ghana.

UNDP Climate Change Country Profiles	Ghana's profile on climate scenarios.	University of Oxford & Tyndall Centre for Climate Change Research	**Variables**: Rainfall and temperature. **Models**: GCMs **Timeframe**: 2030, 2060, 2090 **Scale**: Ghana	Ghanaians did not directly partake in the research. Provide a sound basis for vulnerability and impact assessment
West Africa Agriculture and Climate Change study	Research-based on scenarios from economic global climate change models.	MoFA and IFPRI	**Variable**: Annual changes in rainfall. **Models**: Four GCMs **Timeframe**: 2050 **Scale**: Agriculture	
BSc course in meteorology and climate science in 2008	Human capacity building in meteorological and climate science.	Physics Department, Kwame Nkrumah University of Science and Technology		Award BSc. Degree. The first batch has been graduated.
Regional Institute of Population Studies	Climate change adaptation research and training capacity for development	RIPS, IDRC Canada		Climate change modelling short course. Training on real-time numerical model and uncertainties of climate projections.
Undergraduate and postgraduate meteorology and atmospheric science	Increase human capacity in climate science.	The University of Cape Coast. Physics Department		BSc and MPhil in Physics with Meteorology.
Partnerships for Enhanced Engagement in the Research science project	Support research in climate and agriculture	The University of Cape Coast. Physics Department	**Variables**: Rainfall and Temperatures **Scale**: Ejura, Wenchi, Saltpond	Supports Physics Dept. in teaching and research of climate modelling. Purchase of automatic weather station.
Post-graduate students undertaking research in climate-related disciplines	Human Capacity Development	Geography and Resource Management Department, University of Ghana, Legon		BSc and MSc degrees in Geography.
Building Capacity to Meet the Climate Change Challenge in Ghana	Aim at mainstreaming climate change issues into university courses and enhancing the pool of climate change experts.	University of Ghana		Award MSc and MPhil degrees in Climate Change Adaptation. Established Centre for Climate change and sustainability studies.
Building Climate Resilience into Basin Water Management in the Pra and Densu River Basins in Ghana	Create a knowledge base and capacity for integrating climate change, shared socioeconomic pathways	Water Research Institute, CSIR		PhD in climatology and climate change, land-use/cover modelling starting in 2019.

5.3 Climate Change Vulnerability Assessment

This section discusses the assessment of Ghana's vulnerability to climate change in two parts. Part 1 presents work on the assessment of spatial climate change vulnerability, whereas part 2 focuses on Ghana's flood and drought vulnerability maps. In both cases, the rationale, methodology, results and the main conclusions have been provided in the applicable sections.

5.3.1 Spatial Climate Change Vulnerability

The vulnerability of communities and ecosystems to climate change is a vital determinant in adaptation planning. The IPCC defines climate change vulnerability (CCV) as "the degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes"[132]. This definition implies that vulnerability is determined by the character, magnitude, and rate of variation in climate parameters to which a system is exposed, and the sensitivity and adaptive capacity of the system in question[133]. Therefore, within the CCV context, four primary factors influence the extent to which a system is vulnerable to climate change (Figure 63). These factors are elaborated below:

- Exposure is the nature and degree to which a system is exposed to significant climatic variations[134].
- Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct or indirect[135].
- A combination of exposure and sensitivity determines the potential impact.
- Adaptive capacity is the ability of a system to adjust to climate change – including climate variability and extremes – to moderate potential damages, to take advantage of opportunities, or to cope with the consequences[136].

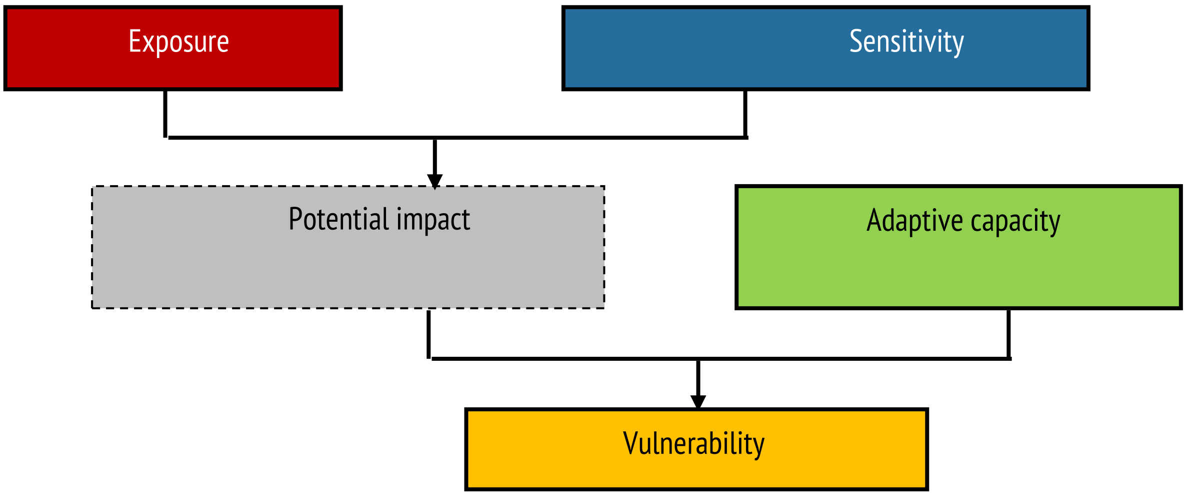

Figure 63: Interactions among the determinants of climate change vulnerability

[132] McCarthy JJ et al. eds. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

[133] McCarthy JJ et al. eds. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

[134] McCarthy JJ et al. eds. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

[135] McCarthy JJ et al. eds. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

[136] McCarthy JJ et al. eds. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

5.3.2 Description of Climate Change Vulnerability Methodology

An assessment was conducted to calculate CCV for the administrative districts of Ghana quantitatively. The assessment was built on the workflow and data generated from the study on climate-resilient landscapes for sustainable livelihoods in Northern Ghana. Data for the assessment was obtained from national institutions that have the mandate to publish government data, literature and inter-governmental bodies. The data was processed and used to generate parameters to quantify the variables for exposure, adaptive capacity and sensitivity components of CCV (Figure 61).

Exposure was divided into current exposure to climate change and variability; and predicted future exposure to climate change and variability. Three parameters on the present shift in temperature and rainfall were used to quantify the current exposure of each district in Ghana. For future exposure scores, nine rainfall and temperature parameters were split into a total of thirty-six sub-parameters to account for predicted medium- and long-term changes (2060 and 2080) under two different scenarios (RCP 2.6 and RCP 8.5) of future climate change (Table 58). The districts in the country were ranked for every parameter and sub-parameter relating to exposure to current and predicted absolute changes in climate[137].

Sensitivity to current and future climate change was quantified as a percentage of the population per administrative region currently employed in the agricultural sector (Table 60). It was assumed that people operating in this sector would be the most sensitive to changes in the climate (as reflected in increasing temperatures and decreasing and variable rainfall patterns) as the agricultural sector rain-fed and inherently climate-dependent. Employment information was only available at the regional level, and therefore, all districts within a region received the same sensitivity score in the assessment. No data were available to predict future sensitivity based on projected changes in agricultural employment. Therefore, it was assumed that sensitivity would remain relatively constant in the coming decades. Districts were ranked according to percentage agricultural employment, where a more significant percentage suggested a higher sensitivity to climate change[138].

Table 60: Population employed in Agriculture per region

Region[139]	# households	Mean household size	Agri households	Agric population (Est)
Western	553,635	4.2	275,975	1,159,095
Central	526,764	4	270,854	1,083,416
Greater Accra	1,036,426	3.8	68,715	261,117
Volta	495,603	4.2	291,224	1,223,141
Eastern	632,048	4.1	374,257	1,534,454
Ashanti	1,126,216	15.3	412,055	6,304,442
Brong Ahafo	490,519	4.6	336,097	1,546,046
Northern	318,119	7.7	240,238	1,849,833
Upper East	177,631	5.8	148,660	862,228
Upper West	110,175	6.2	84,931	526,572

The adaptive capacity of people within each district in Ghana was quantified using seven parameters relating to i) economic activity; ii) education, (iii) sanitation, (iv) rural water availability, (v) health, (vi) security and

[137] See Table 59 for a description of the ranking methodology.
[138] See Table 59 for a description of the ranking methodology.
[139] The data were collected at the time Ghana had ten regions. In 2019, the Regions were further divided into sixteen.

governance effectiveness; and (vii) poverty. As for exposure and sensitivity, each district received adaptive capacity ranks for each of the seven parameters[140]. No data were available to predict future adaptive capacity based on projected changes in economic activity, district development or poverty. Therefore, it was assumed that adaptive capacity would remain relatively constant in the coming decades. District-specific exposure, sensitivity and adaptive capacity were calculated as the sum of the ranks of parameters divided by the maximum possible component score. District-specific CCV was calculated using the IPCC equation:

CCV = (Exposure x Sensitivity) – Adaptive Capacity   Equation 1

The resulting CCV scores range from -1 (low vulnerability) to 1 (high vulnerability). Table 58 is a simplified illustration of how CCV was calculated for the districts of Ghana. GIS layers of the vulnerability parameters were created for each district and subsequently overlaid using Equation 1. When putting the maps together, equal weights were assigned to each layer. The parameters are shown in Table 61.

Table 61: Vulnerability of parameters and the GIS data

Vulnerability parameters	Scale	Variables	Spatial data
Exposure	Current change per district	Temperature seasonality	Temperature variability
		Mean annual rainfall	Trend
	Future climate (RCP 2.6 and 8.5 per district	Mean rainfall	2060 and 2080
		Mean temperature	
		Mean rainfall in wettest month	
		Mean rainfall in the driest month	
		Number of dry months	
		Rainfall seasonality	
		Annual minimum temperature	
		Annual maximum temperature	
Sensitivity	District	Population	Agricultural employment
Adaptive capacity		governance effectiveness	District capacity
		economic activity	Night light distribution
		Poverty	Percentage in poverty
			Number in poverty
			Poverty Depth
			Severity (derived from poverty depth)
			Gini

The map that emerged from the overlay of the individual GIS layers was the CCV map for each district. The CCV score for each district was derived using the concept, and the variable described in Tables 62 and 63.

[140] Ibid

Table 62: Description of the parameters used to calculate climate change vulnerability for the administrative districts and regions of Ghana

Component	Parameter	Rationale and data description	Ranking methodology
Current/recent exposure to climate change and variability.	Variation in annual average temperature[141]	The measure of current temperature variability. Calculated as the current district-specific standard deviation over monthly average temperature values.	Greater variation = higher exposure ranking
	Variation in mean annual rainfall[142]	It provides a measure of current rainfall variability. Calculated as the current district-specific standard deviation over monthly average rainfall values.	Greater variation = higher exposure ranking
	Changes in mean annual rainfall[143, 144]	Current and recent changes in rainfall would affect among other things: i) the frequency and intensity of climatic hazards such as droughts and floods; ii) agricultural productivity; iii) ecosystem function; and iv) human health. Calculated as the absolute district-specific change in rainfall as measured by a linear trend from 1981–2016.	Greater absolute change = higher exposure ranking
Predicted future exposure to climate change and variability[145, 146, 147, 148].	Percentage change in mean annual rainfall	Future changes in rainfall would affect among other things: i) the frequency and intensity of climatic hazards such as droughts and floods; ii) agricultural productivity; iii) ecosystem function; and iv) human health. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) mean annual rainfall.	Greater absolute percentage change = higher exposure ranking
	Percentage change in rainfall variability	Future changes in rainfall variability (seasonality) would affect among other things: i) the frequency and intensity of climatic hazards such as droughts and floods; ii) agricultural productivity; iii) ecosystem function; and iv) human health. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) rainfall variability.	Greater absolute percentage change = higher exposure ranking
	Percentage change in mean rainfall of the wettest month	Future changes in rainfall in the wettest month would affect agricultural productivity during the most vital period of the growing season.	Greater absolute percentage change = higher exposure ranking

141 Data are from: www.worldclim.org; Hijmans, R.J., Cameron S.E., Parra J.L., Jones P.G., Jarvis A. 2005. Very high-resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978.
142 Data are from: www.worldclim.org; Hijmans, R.J., Cameron S.E., Parra J.L., Jones P.G., Jarvis A. 2005. Very high-resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978.
143 Data are from the CHIRPS v2.0 dataset, available at http://chg.geog.ucsb.edu/data/chirps/.
144 Funk C., Peterson P., Landsfeld M., Pedreros D., Verdin J., Shukla S., Husak G., Rowland J., Harrison L., Hoell A., Michaelsen J. 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Scientific Data 2, 150066. doi:10.1038/sdata.2015.66 2015.
145 All future climatic predictions were calculated using an ensemble of 10 general circulation models downscaled using five regional climate models. Four sub-parameters were produced, including percentage change by: i) 2060 under RCP 2.6; ii) 2060 under RCP 8.5; iii) 2080 under RCP 2.6; and iv) 2080 under RCP 8.5. This accounted for medium- and long-term changes under two different scenarios of future climate change.
146 Current climate data are available at www.worldclim.org; Hijmans, R.J., Cameron S.E., Parra J.L., Jones P.G., Jarvis A. 2005. Very high-resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978.
147 Future climate data are available at www.york.ac.uk/environment/research/kite/resources/; Platts P.J., Omeny P.A., Marchant R. 2015. AFRICLIM: high-resolution climate projections for ecological applications in Africa. African Journal of Ecology 53, 103-108.
148 Exposure to sea-level rise, salt water intrusions and/or coastal erosion was not considered in this assessment. This was to ensure that all parameters were comparable across Ghana and were not region-specific.

		Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) mean rainfall in the wettest month.	
	Percentage change in the number of dry months	Futures changes in the number of dry months would affect agricultural productivity through changes to the length of the growing season. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) number of dry months where a dry month is a month with moisture index <0.5.	Greater absolute percentage change = higher exposure ranking
	Percentage change in mean annual average temperature	Futures changes in annual average temperature would affect, among other things: i) agricultural productivity, and ii) ecosystem function. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) mean annual average temperature.	Greater absolute percentage change = higher exposure ranking
	Percentage change in mean annual minimum temperature	Futures changes in annual minimum temperature would affect, among other things: i) agricultural productivity, and ii) ecosystem function. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) mean annual minimum temperature.	Greater absolute percentage change = higher exposure ranking
	Percentage change in mean annual maximum temperature	Futures changes in annual maximum temperature would affect, among other things: i) agricultural productivity, and ii) ecosystem function. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) mean annual maximum temperature.	Greater absolute percentage change = higher exposure ranking
	Percentage change in mean potential evapotranspiration	Future changes in potential evapotranspiration would affect, among other things: i) agricultural productivity, and ii) ecosystem function. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) mean potential evapotranspiration.	Greater absolute percentage change = higher exposure ranking
	Percentage change in mean moisture index	Future changes in the moisture index would affect, among other things: i) agricultural productivity and ii) ecosystem function. Calculated as the district-specific absolute percentage difference between predicted future (2060 & 2080) and current (1980–2014) mean moisture index.	Greater absolute percentage change = higher exposure ranking
Sensitivity to current and future climate change	Percentage of the population employed in the agricultural sector[149]	The agricultural sector is considered one of the most sensitive sectors to climate change. Therefore, the assumption was made that the percentage of people working in the agricultural sector in each district would be a good indicator of how sensitive people in that district are to climate change. Employment data were only available at the regional level. Therefore, all districts within a region have the same percentage of employment in the agricultural sector.	Larger percentage employed in the agricultural sector = higher sensitivity ranking
Adaptive capacity	District League Table score[150]	The DLT incorporates measures of education, sanitation, rural water availability, health, security, and governance effectiveness to assess development across Ghana's 216 districts. These factors are considered good indicators of the capacity of private citizens and local governments to adapt to a changing climate[151].	Lower score = lower adaptive capacity ranking

[149] Data are from: Ministry of Food and Agriculture. 2010. Agriculture in Ghana: Facts and Figures.
[150] Data are from: UNICEF – 2016 – District League Table 2016: Calling for central government to better target district support.
[151] GIZ – 2014 – A framework for climate change vulnerability assessments.

	Night-time light intensity[152]	Night-time light intensity is a good proxy for economic activity[153]. Economic development and activity are a useful measure of adaptive capacity as it relates to the ability of people to diversify their livelihoods and incomes when and if necessary.	Lower value = lower adaptive capacity ranking
	Percentage of the population under the poverty line[154]	People under the poverty line are assumed to have reduced capacity to adapt to climate change as they have fewer financial resources to moderate damages and take advantage of the benefits of climate change. District district-specific estimate of the percentage of people below the poverty line of GH₵1,314 per person per year.	Greater percentage = lower adaptive capacity ranking
	Number of people under the poverty line[155]	The number of people under the poverty line accounts for the number of people with reduced adaptive capacity. District district-specific estimate of the number of people below the poverty line of GH₵1,314 per person per year.	Greater number = lower adaptive capacity ranking
	Poverty Depth[156]	Poverty depth is used in addition to percentage poverty to measure adaptive capacity. Where the percentage poverty parameter considers all people below the poverty line equally poor, poverty depth measures the intensity of poverty. District-specific average poverty gap in the population as a proportion of the poverty line.	Greater depth = lower adaptive capacity ranking
	Poverty Severity[157]	The square of district-specific poverty gaps to provide further attention to the needs of the poor.	Greater severity = lower adaptive capacity ranking
	Gini coefficient[158]	The district-specific measure of inequality.	Greater Gini = lower adaptive capacity ranking

[152] The Visible Infrared Imaging Radiometer Suite (VIIRS) data are from U.S. National Oceanographic and Atmospheric Administration (NOAA).
[153] Mellander C., Lobo J., Stolarick K., Matheson Z. 2015. Night-Time Light Data: A Good Proxy Measure for Economic Activity? PLOS One. https://doi.org/10.1371/journal.pone.0139779.
[154] Data are from: Ghana Statistical Service. 2015. Ghana Poverty Mapping Report.
[155] Data are from: Ghana Statistical Service. 2015. Ghana Poverty Mapping Report.
[156] Data are from: Ghana Statistical Service. 2015. Ghana Poverty Mapping Report.
[157] Data are from: Ghana Statistical Service. 2015. Ghana Poverty Mapping Report.
[158] Data are from: Ghana Statistical Service. 2015. Ghana Poverty Mapping Report.

Table 63: Example of the method used to calculate district-specific Climate Change Vulnerability

District	Region	Exposure			Sensitivity		Adaptive capacity			
		Predicted change in mean annual rainfall[159] (ranking)	Predicted change in mean annual average temperature (ranking)	Score	% agricultural employment (ranking)	Score	% below the poverty line (ranking)	District League Table (ranking)	Score	CCV
Adansi North	Ashanti	5.91% (2)	16.14% (2)	0.67[160]	43.8 (2)	0.67[161]	18.4 (2)	58.61 (2)	0.67[162]	-0.22[163]
Accra Metropolis	Greater Accra	1.84% (1)	14.56% (1)	0.33	10.5 (1)	0.33	2.6 (3)	65.03 (3)	1.00	-0.89
Wa East	Upper West	8.85% (3)	17.03% (3)	1.00	73.2 (3)	1.00	83.8 (1)	54.96 (1)	0.33	0.67

[159] By 2080 under RCP 8.5.

[160] [Rainfall change rank (2) + Temperature change rank (2)] / [Max. possible rainfall change rank (3) + Max. possible temperature change rank (3)] = 0.67

[161] [% agricultural employment rank (2)] / [Maximum possible % agricultural employment rank (3)] = 0.67

[162] [% below poverty rank (2) + District League Table rank (2)] / [Max. possible % poverty rank (3) + Max. possible District League Table rank (3)] = 0.67

[163] [Exposure score (0.67) * Sensitivity score (0.67)] - [Adaptive capacity score (0.67)] = -0.22

5.3.3 Spatial Climate Change Vulnerability Results

The CCV assessment revealed that the vulnerability of Ghana's districts generally increases from the coast[164] into the transition zone and the northern savannas (Figure 62). On average, the Upper West Region is the most vulnerable in the country (Figure 64). The ten districts with the highest CCV scores were all from the Upper West Region (Figure 64)[165], and Wa East was the most vulnerable district to climate change with a CCV of 0.68. Wa East's neighbouring district – and the home of the regional capital, Wa Municipal, had the lowest CCV in the Upper West Region.

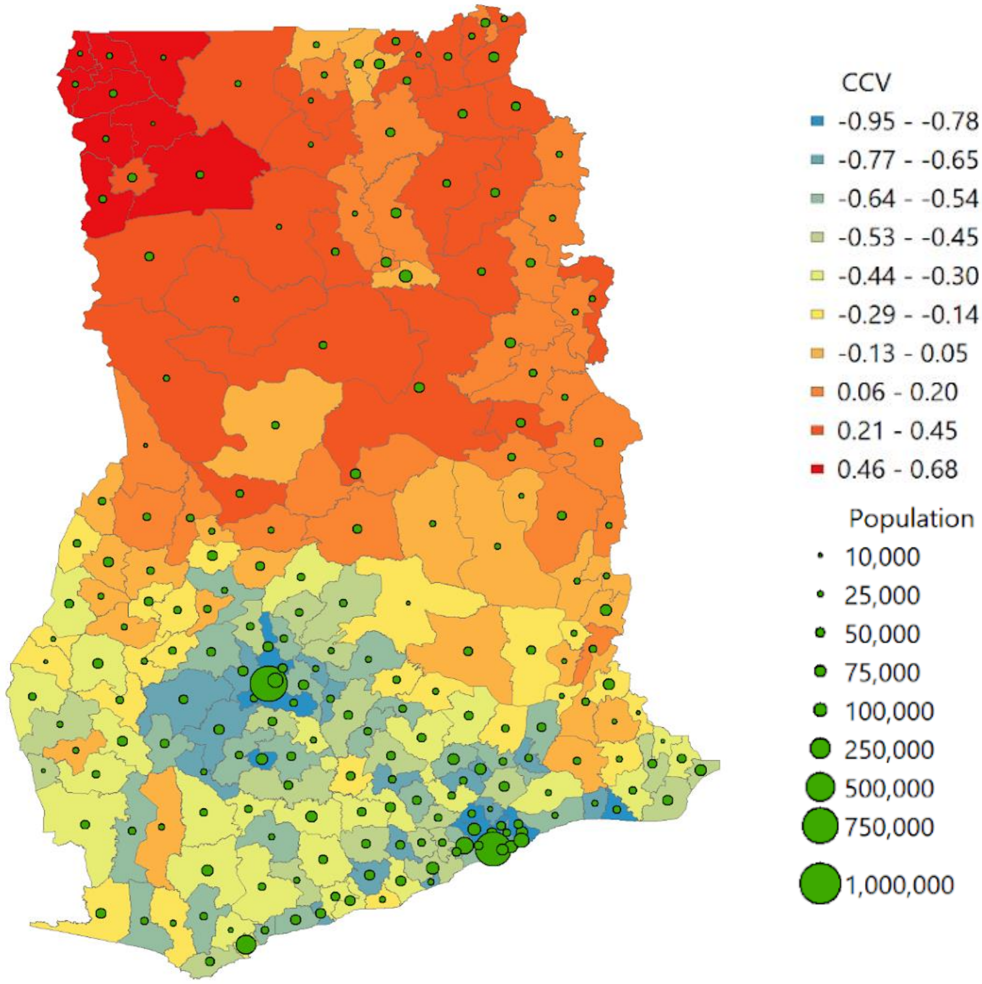

Figure 64: Climate change vulnerability scores for Ghana's 216 districts

The Northern and Upper East Regions were the second and third most vulnerable regions, respectively (Figure 65). In the Northern Region, the Sawla-Tuna-Kalba District on the borders of Côte d'Ivoire and Burkina Faso had the highest CCV. Garu Tempane on the Togolese border had the highest climate change vulnerability in the Upper East Region. The three least vulnerable regions were the Greater Accra (average CCV = -0.78), Ashanti (-0.61) and Central Regions (-0.51) (Table 64). The four districts with the lowest CCVs were all in the Greater Accra Region, and the La Dade Kotopon District had the lowest CCV (-0.95) in Ghana (Figure 63).

[164] Although exposure to coast-specific climate impacts (e.g. sea level rise) were not considered in this assessment.

[165] See Table 8 in Supporting Information for the districts of Ghana ranked according to CCV

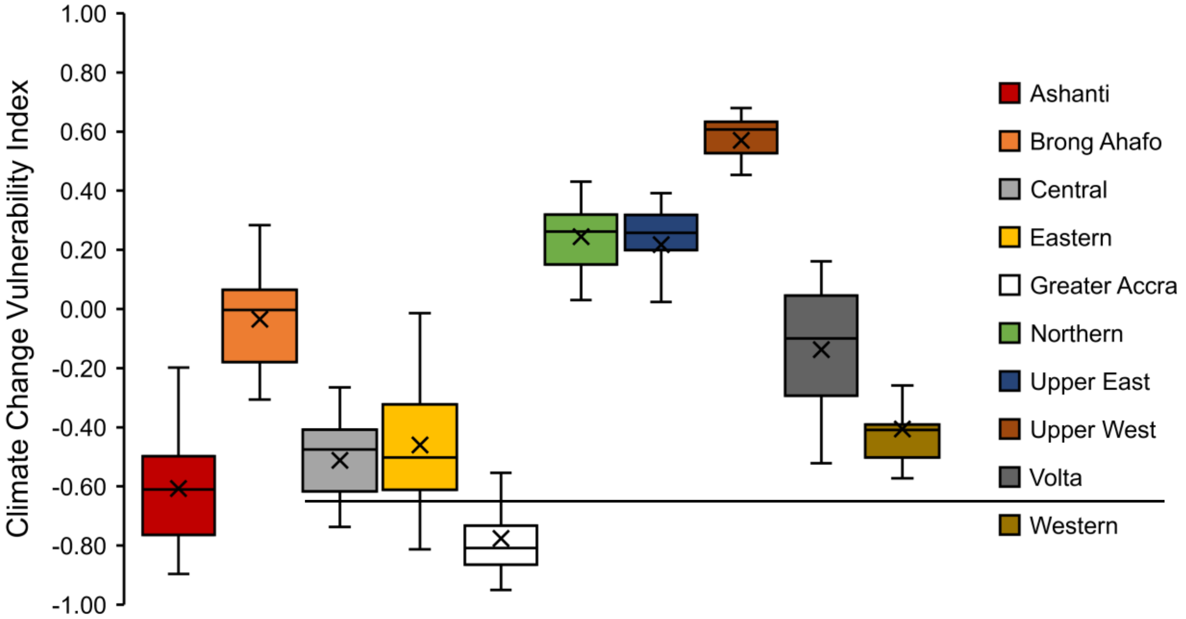

Figure 65: District climate change vulnerability scores aggregated at the level of administrative regions. "Xs" are mean values

Based on the results of the CCV assessment, it is evident that climate change adaptation interventions are urgently required to enhance climate resilience in most parts of the country, especially in the northern regions of Ghana.

Table 64: District breakdown of climate change vulnerability parameters

District	Region	Sensitivity	Exposure	Adaptive capacity	CCV
Adansi North	Ashanti	0.08	0.46	0.66	-0.62
Adansi South	Ashanti	0.08	0.41	0.54	-0.51
Afigya Kwabre	Ashanti	0.08	0.63	0.84	-0.78
Afigya Sekyere	Ashanti	0.08	0.68	0.63	-0.58
Ahafo Ano North	Ashanti	0.08	0.50	0.33	-0.29
Ahafo Ano South	Ashanti	0.08	0.63	0.67	-0.62
Amansie Central	Ashanti	0.08	0.49	0.64	-0.60
Amansie West	Ashanti	0.08	0.50	0.82	-0.77
Asante Akim Central Municipal	Ashanti	0.08	0.44	0.79	-0.75
Asante Akim North	Ashanti	0.08	0.52	0.59	-0.54
Asante Akim South	Ashanti	0.08	0.43	0.57	-0.53
Asokore Mampong Municipal	Ashanti	0.08	0.46	0.84	-0.80
Atwima Kwanwoma	Ashanti	0.08	0.46	0.93	-0.90
Atwima Mponua	Ashanti	0.08	0.57	0.71	-0.66
Atwima Nwabiagya	Ashanti	0.08	0.55	0.81	-0.77
Bekwai Municipal	Ashanti	0.08	0.48	0.56	-0.52
Bosome Freho	Ashanti	0.08	0.48	0.44	-0.40
Bosomtwe /Atwima / Kwanwoma	Ashanti	0.08	0.43	0.92	-0.88
Ejisu Juaben	Ashanti	0.08	0.50	0.67	-0.63

Ejura SekyeDumase	Ashanti	0.08	0.58	0.39	-0.34
KMA	Ashanti	0.08	0.47	0.71	-0.67
Kwabre	Ashanti	0.08	0.57	0.90	-0.86
Mampong Municipal	Ashanti	0.08	0.63	0.54	-0.48
Obuasi Municipal	Ashanti	0.08	0.54	0.85	-0.80
Offinso Municipal	Ashanti	0.08	0.66	0.52	-0.46
Offinso North	Ashanti	0.08	0.65	0.62	-0.57
Sekyere Afram Plains	Ashanti	0.08	0.65	0.55	-0.50
Sekyere Afram Plains North	Ashanti	0.08	0.52	0.24	-0.20
Sekyere Central	Ashanti	0.08	0.56	0.54	-0.50
Sekyere East	Ashanti	0.08	0.59	0.72	-0.68
Asunafo North	Brong Ahafo	0.74	0.49	0.67	-0.30
Asunafo South	Brong Ahafo	0.74	0.52	0.58	-0.19
Asutifi North	Brong Ahafo	0.74	0.48	0.47	-0.12
Asutifi South	Brong Ahafo	0.74	0.47	0.59	-0.24
Atebubu Amantin	Brong Ahafo	0.74	0.54	0.26	0.14
Banda	Brong Ahafo	0.74	0.59	0.25	0.19
Berekum	Brong Ahafo	0.74	0.59	0.52	-0.08
Dormaa East	Brong Ahafo	0.74	0.53	0.35	0.05
Dormaa Municipal	Brong Ahafo	0.74	0.50	0.68	-0.31
Dormaa West	Brong Ahafo	0.74	0.47	0.58	-0.23
Jaman North	Brong Ahafo	0.74	0.64	0.51	-0.03
Jaman South	Brong Ahafo	0.74	0.57	0.58	-0.16
Kintampo North	Brong Ahafo	0.74	0.53	0.36	0.03
Kintampo South	Brong Ahafo	0.74	0.71	0.24	0.28
Nkoranza North	Brong Ahafo	0.74	0.66	0.41	0.08
Nkoranza South	Brong Ahafo	0.74	0.63	0.44	0.03
Pru	Brong Ahafo	0.74	0.51	0.25	0.14
Sene East	Brong Ahafo	0.74	0.50	0.32	0.05
Sene West	Brong Ahafo	0.74	0.54	0.35	0.05
Sunyani Municipal	Brong Ahafo	0.74	0.56	0.60	-0.18
Sunyani West	Brong Ahafo	0.74	0.61	0.45	0.00
Tain	Brong Ahafo	0.74	0.60	0.26	0.19
Tano North	Brong Ahafo	0.74	0.55	0.61	-0.20
Tano South	Brong Ahafo	0.74	0.60	0.44	0.01
Techiman Municipal	Brong Ahafo	0.74	0.68	0.69	-0.18
Techiman North	Brong Ahafo	0.74	0.70	0.62	-0.10
Wenchi	Brong Ahafo	0.74	0.65	0.33	0.15
Abura / Asebu / Kwamankese	Central	0.23	0.27	0.48	-0.42
Agona East	Central	0.23	0.27	0.54	-0.48

Agona West	Central	0.23	0.27	0.76	-0.70
Ajumako-Enyan-Essiam	Central	0.23	0.27	0.72	-0.65
Asikuma / Odoben / Brakwa	Central	0.23	0.32	0.54	-0.47
Assin North	Central	0.23	0.42	0.46	-0.37
Assin South	Central	0.23	0.35	0.45	-0.37
Awutu Senya	Central	0.23	0.27	0.52	-0.45
Awutu Senya East Municipal	Central	0.23	0.26	0.65	-0.59
Cape Coast Metro	Central	0.23	0.27	0.80	-0.74
Effutu	Central	0.23	0.26	0.73	-0.67
Ekumfi	Central	0.23	0.23	0.32	-0.26
Gomoa East	Central	0.23	0.24	0.59	-0.53
Gomoa West	Central	0.23	0.23	0.46	-0.41
Komenda Edna Eguafo / Abirem	Central	0.23	0.28	0.62	-0.55
Mfantsiman	Central	0.23	0.28	0.47	-0.41
Twifo Atti-Morkwa	Central	0.23	0.46	0.71	-0.60
Twifo Lower Denkyira	Central	0.23	0.35	0.55	-0.47
Upper Denkyira East	Central	0.23	0.54	0.51	-0.39
Upper Denkyira West	Central	0.23	0.47	0.82	-0.71
Akuapem North	Eastern	0.33	0.45	0.64	-0.50
Akuapem South	Eastern	0.33	0.38	0.78	-0.65
Akyem Mansa	Eastern	0.33	0.35	0.28	-0.16
Asuogyaman	Eastern	0.33	0.36	0.70	-0.58
Atiwa	Eastern	0.33	0.55	0.56	-0.38
Ayensuano	Eastern	0.33	0.36	0.48	-0.36
Birim Municipal	Eastern	0.33	0.40	0.54	-0.42
Birim North	Eastern	0.33	0.41	0.75	-0.61
Birim South	Eastern	0.33	0.40	0.44	-0.31
Denkyembour	Eastern	0.33	0.45	0.88	-0.73
East Akim	Eastern	0.33	0.54	0.79	-0.61
Fanteakwa	Eastern	0.33	0.62	0.62	-0.42
Kwaebibirem	Eastern	0.33	0.47	0.66	-0.51
Kwahu Afram Plains North	Eastern	0.33	0.41	0.31	-0.17
Kwahu Afram Plains South	Eastern	0.33	0.45	0.16	-0.01
Kwahu East	Eastern	0.33	0.59	0.34	-0.14
Kwahu South	Eastern	0.33	0.64	0.36	-0.15
Kwahu West	Eastern	0.33	0.51	0.73	-0.57
Lower Manya	Eastern	0.33	0.37	0.78	-0.66
New Juaben Municipal	Eastern	0.33	0.46	0.86	-0.71
Nsawam Adoagyiri	Eastern	0.33	0.26	0.90	-0.81
Suhum Municipal	Eastern	0.33	0.43	0.84	-0.70

Upper Manya	Eastern	0.33	0.45	0.37	-0.22
Upper West Akim	Eastern	0.33	0.29	0.55	-0.45
West Akim	Eastern	0.33	0.45	0.71	-0.56
Yilo Krobo	Eastern	0.33	0.50	0.71	-0.55
Accra Metropolis	Greater Accra	0.00	0.26	0.81	-0.80
Ada East	Greater Accra	0.00	0.21	0.81	-0.81
Ada West	Greater Accra	0.00	0.22	0.70	-0.70
Adenta	Greater Accra	0.00	0.29	0.74	-0.74
Ashaiman	Greater Accra	0.00	0.27	0.93	-0.93
Ga Central Municipal	Greater Accra	0.00	0.31	0.84	-0.83
Ga East	Greater Accra	0.00	0.32	0.84	-0.84
Ga South	Greater Accra	0.00	0.26	0.57	-0.57
Ga West	Greater Accra	0.00	0.27	0.81	-0.81
Kpone Katamanso	Greater Accra	0.00	0.29	0.90	-0.90
La Dade Kotopon	Greater Accra	0.00	0.26	0.95	-0.95
La Nkwantanang Madina	Greater Accra	0.00	0.31	0.94	-0.94
Ledzokuku / Krowor	Greater Accra	0.00	0.26	0.86	-0.85
Ningo Prampram	Greater Accra	0.00	0.24	0.56	-0.55
Shai Osu Doku	Greater Accra	0.00	0.32	0.37	-0.37
Tema Metropolis	Greater Accra	0.00	0.25	0.81	-0.81
Bole	Northern	0.87	0.62	0.20	0.35
Bunkpurugu Yonyo	Northern	0.87	0.75	0.27	0.39
Chereponi	Northern	0.87	0.71	0.47	0.15
East Gonja	Northern	0.87	0.57	0.13	0.37
Gonja Central	Northern	0.87	0.62	0.27	0.26
Gushiegu	Northern	0.87	0.70	0.29	0.32
Karaga	Northern	0.87	0.69	0.33	0.27
Kpandai	Northern	0.87	0.54	0.21	0.26
Kumbungu	Northern	0.87	0.65	0.42	0.15
Mamprugu Moagduri	Northern	0.87	0.63	0.26	0.29
Mamprusi East	Northern	0.87	0.75	0.33	0.32
Mion	Northern	0.87	0.64	0.25	0.31
Nanumba North	Northern	0.87	0.63	0.40	0.15
Nanumba South	Northern	0.87	0.60	0.38	0.14
North Gonja	Northern	0.87	0.75	0.32	0.33
Saboba	Northern	0.87	0.62	0.34	0.20
Sagnerigu	Northern	0.87	0.67	0.44	0.15
Savelugu Nanton	Northern	0.87	0.68	0.39	0.20
Sawla/Tuna/Kalba	Northern	0.87	0.79	0.26	0.43
Tamale North Sub Metro	Northern	0.87	0.66	0.55	0.03

Tatale	Northern	0.87	0.62	0.29	0.25
Tolon	Northern	0.87	0.66	0.28	0.29
West Gonja	Northern	0.87	0.73	0.33	0.30
West Mamprusi	Northern	0.87	0.68	0.42	0.17
Yendi Municipal	Northern	0.87	0.61	0.43	0.10
Zabzugu	Northern	0.87	0.60	0.37	0.15
Bawku Municipal	Upper East	0.68	0.79	0.34	0.20
Bawku West	Upper East	0.68	0.74	0.19	0.32
Binduri	Upper East	0.68	0.77	0.18	0.34
Bolgatanga Municipal	Upper East	0.68	0.70	0.45	0.03
Bongo	Upper East	0.68	0.76	0.21	0.31
Builsa North	Upper East	0.68	0.64	0.24	0.20
Builsa South	Upper East	0.68	0.62	0.09	0.33
Garu Tempane	Upper East	0.68	0.78	0.14	0.39
Kassena Nankana East	Upper East	0.68	0.68	0.44	0.02
Kassena Nankana West	Upper East	0.68	0.74	0.60	-0.10
Nabdam	Upper East	0.68	0.73	0.24	0.26
Pusiga	Upper East	0.68	0.81	0.27	0.28
Talensi	Upper East	0.68	0.69	0.21	0.26
Daffiama Bussie	Upper West	1.00	0.76	0.13	0.64
Jirapa	Upper West	1.00	0.75	0.14	0.61
Lambussie Karni	Upper West	1.00	0.76	0.10	0.66
Lawra	Upper West	1.00	0.72	0.20	0.52
Nadowli-Kaleo	Upper West	1.00	0.74	0.17	0.58
Nandom	Upper West	1.00	0.74	0.20	0.54
Sissala West	Upper West	1.00	0.76	0.13	0.63
Sissala East	Upper West	1.00	0.74	0.29	0.45
Wa East	Upper West	1.00	0.75	0.07	0.68
Wa Municipal	Upper West	1.00	0.76	0.40	0.36
Wa West	Upper West	1.00	0.72	0.11	0.61
Adaklu	Volta	0.56	0.31	0.27	-0.10
Afadzato South	Volta	0.56	0.61	0.25	0.09
Agotime Ziope	Volta	0.56	0.32	0.33	-0.15
Akatsi North	Volta	0.56	0.26	0.51	-0.36
Akatsi South	Volta	0.56	0.26	0.67	-0.52
Biakoye	Volta	0.56	0.59	0.36	-0.03
Central Tongu	Volta	0.56	0.26	0.44	-0.29
Ho Municipal	Volta	0.56	0.50	0.52	-0.24
Ho West	Volta	0.56	0.43	0.28	-0.04
Hohoe Municipal	Volta	0.56	0.70	0.35	0.05

Jasikan	Volta	0.56	0.68	0.35	0.03
Kadjebi	Volta	0.56	0.69	0.23	0.16
Keta Municipal	Volta	0.56	0.24	0.64	-0.51
Ketu North	Volta	0.56	0.28	0.57	-0.41
Ketu South	Volta	0.56	0.27	0.64	-0.49
Kpando Municipal	Volta	0.56	0.57	0.50	-0.18
Krachi East	Volta	0.56	0.48	0.14	0.13
Krachi Nchumuru	Volta	0.56	0.48	0.14	0.13
Krachi West	Volta	0.56	0.43	0.34	-0.10
Nkwanta North	Volta	0.56	0.54	0.20	0.10
Nkwanta South	Volta	0.56	0.67	0.25	0.12
North Dayi	Volta	0.56	0.47	0.36	-0.10
North Tongu	Volta	0.56	0.28	0.20	-0.05
South Dayi	Volta	0.56	0.40	0.50	-0.28
South Tongu	Volta	0.56	0.23	0.53	-0.40
Ahanta West	Western	0.45	0.30	0.65	-0.51
Aowin	Western	0.45	0.41	0.60	-0.42
Bia East	Western	0.45	0.48	0.47	-0.26
Bia West	Western	0.45	0.51	0.64	-0.41
Bodi	Western	0.45	0.43	0.31	-0.11
Ellembelle	Western	0.45	0.30	0.70	-0.57
Jomoro	Western	0.45	0.26	0.41	-0.29
Juabeso	Western	0.45	0.50	0.70	-0.47
Mpohor	Western	0.45	0.38	0.59	-0.42
Nzema East	Western	0.45	0.34	0.43	-0.28
Prestea / Huni Valley	Western	0.45	0.44	0.61	-0.41
Sefwi-Wiawso	Western	0.45	0.43	0.59	-0.39
Sefwi Akontombra	Western	0.45	0.44	0.59	-0.40
Sefwi Bibiani-Anhwiaso Bekwai	Western	0.45	0.49	0.80	-0.57
Sekondi Takoradi	Western	0.45	0.36	0.56	-0.40
Shama	Western	0.45	0.34	0.72	-0.57
Suaman	Western	0.45	0.42	0.64	-0.45
Tarkwa Nsuaem	Western	0.45	0.40	0.76	-0.57
Wassa Amenfi Central	Western	0.45	0.49	0.30	-0.08
Wassa Amenfi East	Western	0.45	0.52	0.63	-0.40
Wassa Amenfi West	Western	0.45	0.45	0.77	-0.57
Wassa East	Western	0.45	0.39	0.56	-0.39

5.3.4 Limitation of the Spatial Climate Change Vulnerability Assessment

Using GIS techniques to produce a spatially-explicit climate change vulnerability map at the district was mostly successful because it was the first significant attempt to link climate and socioeconomic variables. Nevertheless, some inherent limitations need to be addressed to make the methodology robust and the results more useful to target users. The significant fundamental barriers are listed below:

- Using the districts as the minimum mapping unit may have masked the inherent variabilities in climate change vulnerability at specific spots.
- Sensitivity to the impacts of climate change is not only limited to agricultural livelihood. There is a wide range of sensitivities across the country. For example, the major vulnerability along the coast due to coastal erosion is driven by the threat to infrastructure, fishing livelihoods and marine ecology. Sensitivity was limited to agricultural livelihood due to lack of data on sensitivity parameters of communities and ecosystems.
- Sensitivity levels were assumed to be constant in the current and future climate scenarios. This assumption must be interrogated to identify areas where improvements can be made to add more rigour to the methodologies for future assessment.
- The variables in each CCV parameter were assigned the same weight. There is a lot more nuance to the parameters than the ways it has been represented in the CCA framework.
- The CCV assessment combines specific vulnerabilities to extreme events such as floods and drought. It is important to isolate them for effective planning and targeting.
- The interpretation of the CCV results must be made with caution to recognise the limitations of the analysis, as stated above.

5.4 Flood and Drought Hazard Mapping

In addition to the CCV map, Ghana has also prepared current (2010), and future (2050) flood and drought hazard maps to have a general idea of most susceptible areas in the country[166]. The future maps depict the likelihood of an area to experience increased or decreased flooding or drought. The maps are used to inform national policy for managing extreme climate events in the country.

5.4.1 National Flood Hazards

The Height Above Nearest Drainage (HAND) method was used to characterise the probability of flooding in an area. The HAND method uses the relative height of a specific area (expressed in pixels) about the local drainage network. It also includes slopes and drainage patterns. At the national level, the HAND method is based on data from the Shuttle Radar Topography Mission (SRTM)-DEM. The calculation of the HAND-index follows the steps below:

- Derive flow direction raster.
- Classify the stream network according to the upstream area and the height of the stream according to the DEM.
- Define the upstream areas for each stream pixel with the same height as the downstream stream pixel.
- Derive the HAND index by calculating the difference between the outcomes of step 3 and step 2.

[166] Risk Assessment & Mapping under the CREW initiative implemented by NADMO

The method validated several common and well-known flood areas. The validation shows that the hazard levels are strongly dependent on the quality of the elevation data and the raster size used. In urban areas, the level of detail of the 90m SRTM-DEM seems to be too coarse, whereas the high hazard inundation areas of Lake Volta and the White Volta are well represented with the 90m SRTM-DEM.

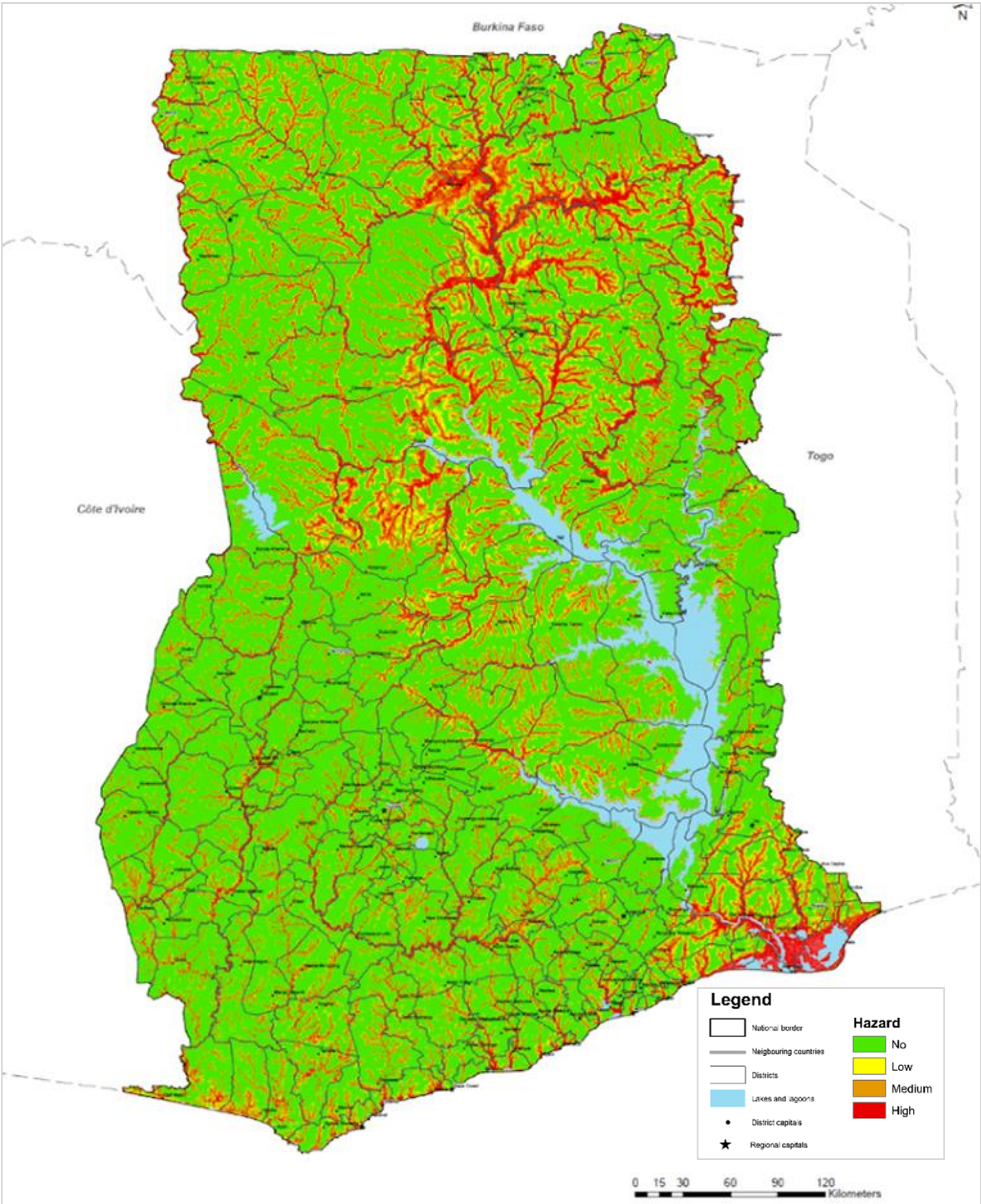

Figure 66: Flood hazard map showing the distribution of the likelihood of an area to experience a flood in 2010

The future flood hazard map for 2050 was produced based on IPCC's A1B and A2 emission scenario projections (Figure 67). The emission scenarios are the corresponding emissions associated with the likely future economic development situation for the country.

The findings in Figures 66 and 67 unanimously point to the fact that the areas that are likely to experience floods would remain unchanged if no remedial measures are adopted. Both maps also reinforced the notion of a flood is controlled in part by the drainage pattern of the area in question. It further revealed the high likelihood of the occurrence of floods in low-lying areas that are close to existing water bodies.

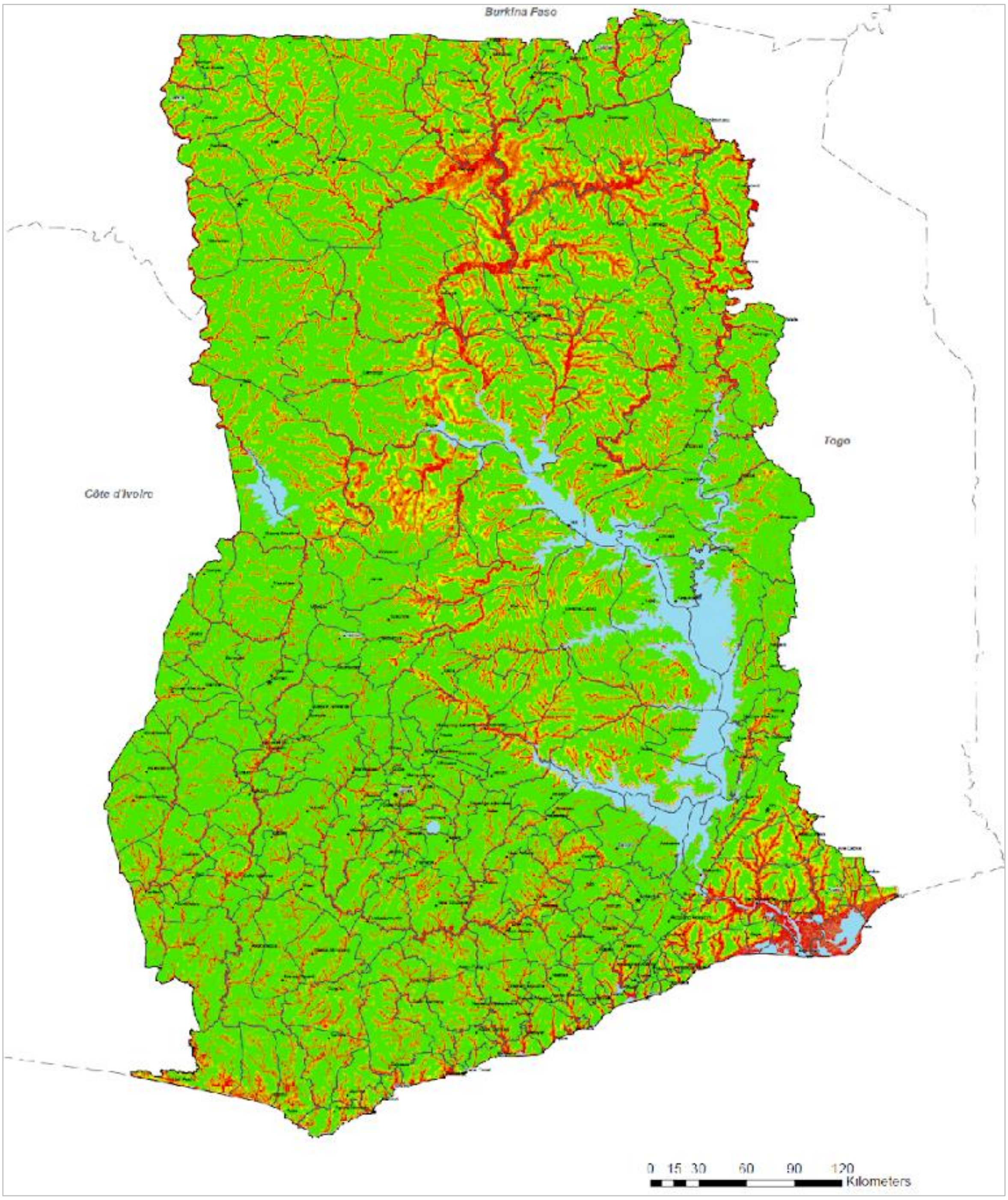

Figure 67: Flood hazard map showing the distribution of the likelihood of an area to experience a flood in 2050

The maps above indicate that about 10% of the country falls within high (28,640km^2), medium (30,753 km^2) and low hazard (24,137 km^2) regions, with most of the hazard zones located along the White Volta and downstream of the Akosombo dam. The rest of the regions are categorised as no hazards (155,413 km^2).

5.4.2 National Drought Hazards

The areas that experience drought were pinpointed by the spatial variability of meteorological parameters and the physical properties of the land surface. In this regard, mapping out the potential drought hazard at the national scale was performed using data on meteorological drought (e.g. rainfall deficit) without hydrological factors like the phreatic groundwater level. Using this approach made it possible to incorporate climate change variables (rainfall and temperature) into the assessment. Under this method, cumulative rainfall deficit (evapotranspiration minus rainfall) is an essential primary variable.

Parameters like cumulative rainfall, cumulative potential evapotranspiration, and the resulting cumulative rainfall deficit are plotted. The threshold value for rainfall deficit and the number of days that the threshold value is exceeded within each year, are also counted. Input data from global datasets are used to produce drought hazard maps for the current climate situation. The advantages are that the:

- Same data is used nationwide, which makes the results more consistent
- Global datasets show a better representation of the spatial variability than the data from the national synoptic stations, mainly for rainfall and
- Problems of data gaps within time series are resolved.

Based on the drought hazard classification and the map with the 14-year average of the number of days that the deficit threshold of 600 mm exceeded the final drought hazard map, the current climate situation was produced for 2010. For drought, changes in rainfall and potential evapotranspiration are of interest, as these two variables determine the rainfall deficit. The future drought hazard map was produced based on the rainfall changes associated with the IPCC's A1B and A2 emission scenarios. Potential evapotranspiration was from data derived from Obuobie, 2014 based on the Hargreaves method (Allen et al., 1998) and which is like the CGIAR method for determining global evapotranspiration.

The results show that the northern part of Ghana has a high hazard; the eastern and south-eastern parts show low and medium hazard (Figures 68 and 69). The southwest part of Ghana shows no hazard for drought. The results provide a well-founded assessment of the likelihood of the occurrence of the drought phenomenon based on 14-year averages. It should be noted that this does not mean that in areas rated as 'no hazard', there would never be a drought problem, nor does this mean that areas with 'high hazard' would suffer from drought every year.

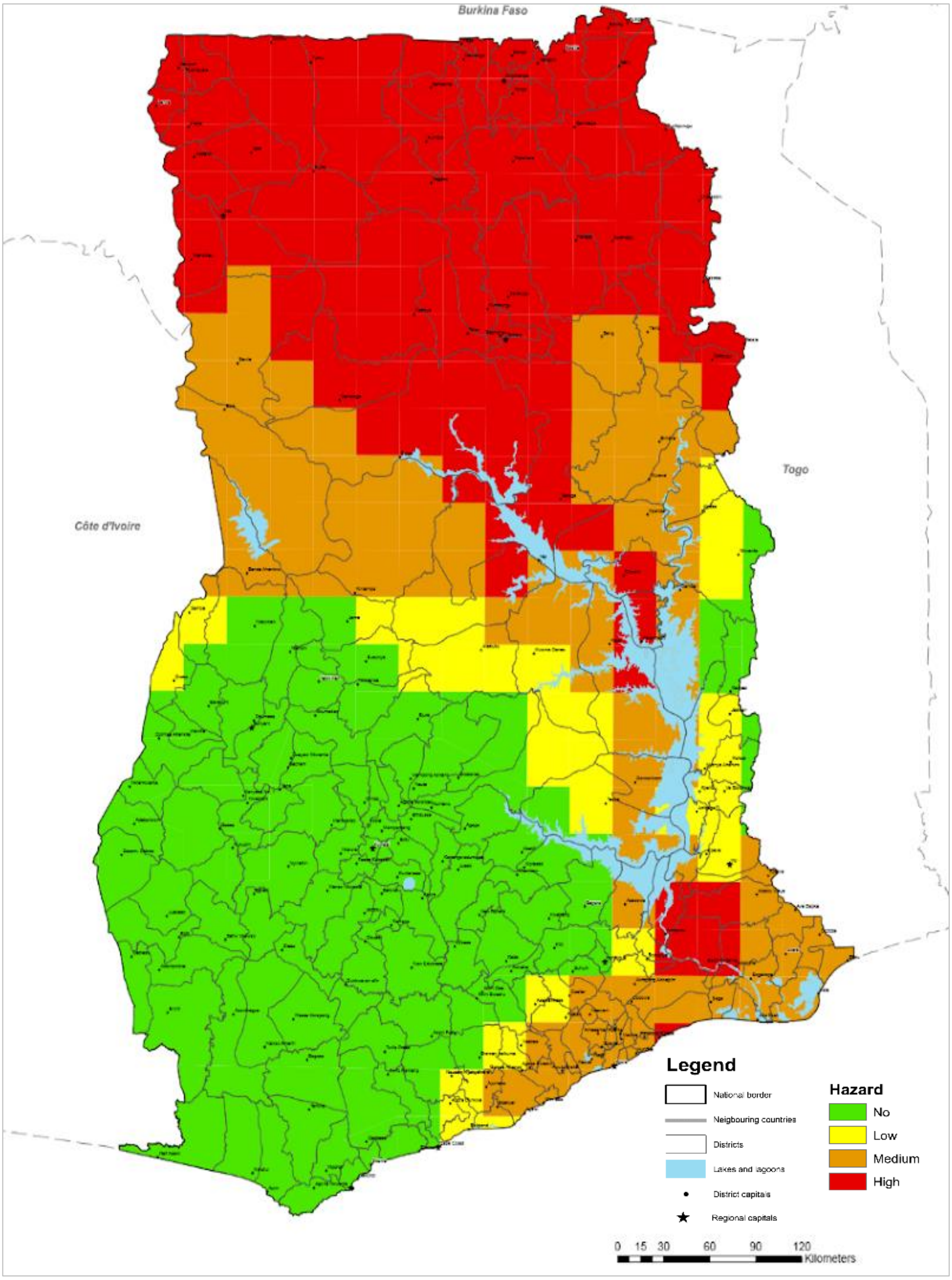

Figure 68: National drought hazard map for 2010

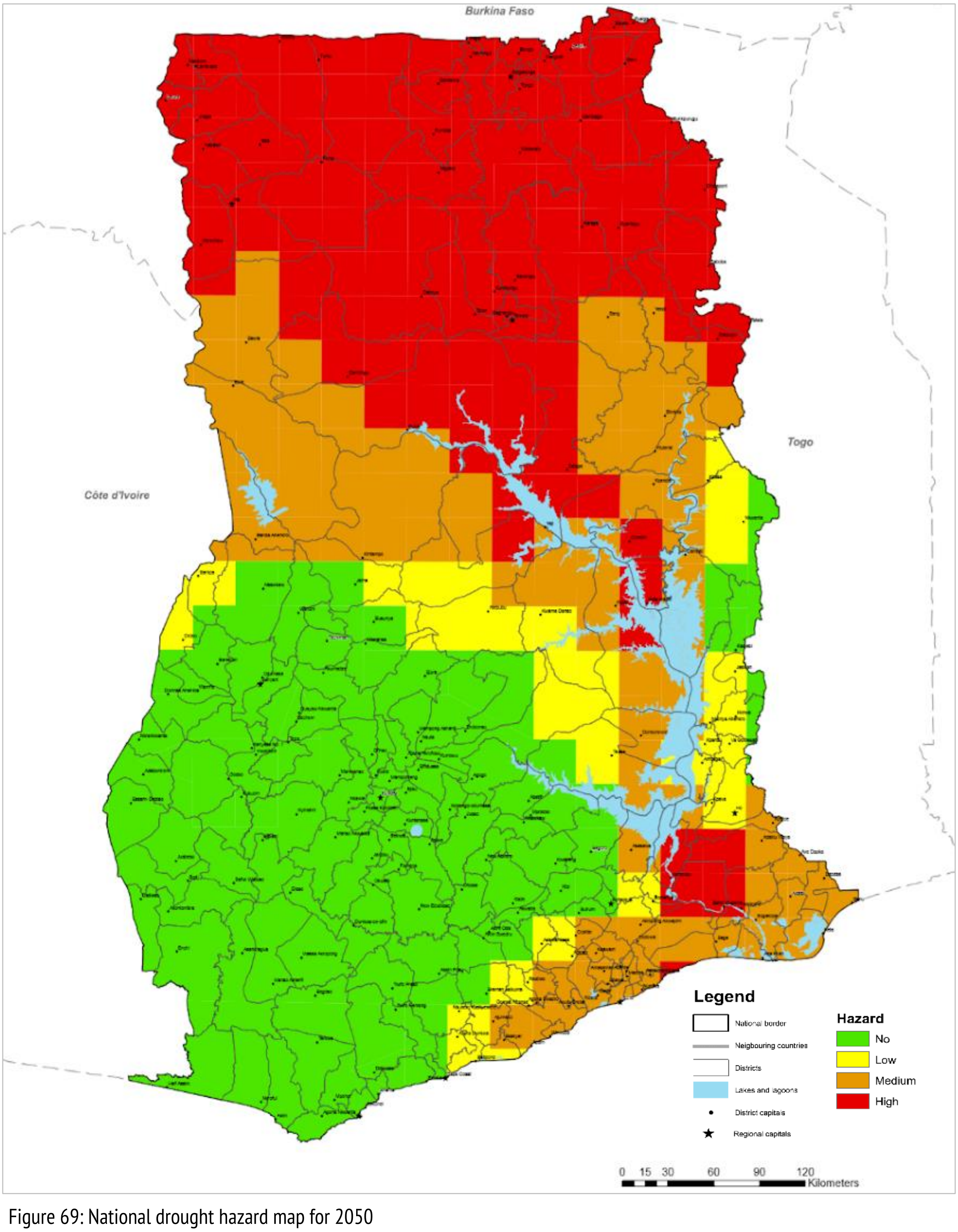

Figure 69: National drought hazard map for 2050

5.5 Climate Change Impacts and Adaptation

This section is divided into two parts. Section 1 is on actual and potential climate impacts assessment. The second section focuses on adaptation interventions. Under section 1, updates on significant climate hazards and extreme events in the country have been presented. The update covers the period after Ghana submitted its Third National Communication. The information includes major climate-related events that have occurred during the reporting period and the system for climate data management. Emphasis has been placed on the critical climate events that happened during the period and sectoral impacts assessment. Then, in the next section, the emphasis is on adaptation interventions in terms of the actions being taken and the planning aspects. The information on the adaptation actions has been reported by sectors or themes, including information on specific adaptation programmes that have been or are being implemented by the various institutions. The report also covered the national efforts on adaptation planning at all levels.

5.5.1 Recent Climate Hazards and Extreme Events

Ghana has experienced many climate hazards[167] over the past five decades (Figure 70). The climate hazards comprise at least three droughts and nineteen floods (Table 62), which have cumulatively affected over sixteen million people and resulted in at least four hundred and forty-four deaths – excluding the undocumented numbers of deaths resulting from droughts. The occurrence of climate disasters has a major negative impact on the standard of living of people in the country[168]. Given Ghana's reliance on rain-fed agriculture, drought poses a significant threat to the agricultural sector, with the most immediate consequence being a decrease in the production of staple crops – especially sorghum, millet, maize, and groundnuts. These losses negatively impact the livelihoods of smallholder farmers, particularly in the northern savanna zones[169]. When crops fail, farmers often resort to selling livestock to supplement their incomes. As the food-deficit increases, farmers are forced to sell more valuable livestock, including draught and transport animals such as oxen and donkeys[170], reducing the adaptive capacity of farmers in the long-term, which leads to maladaptation[171]. Drought also affects fodder production, leading to weight reduction and deaths among livestock.

Overall, these factors reduce the output capacity of the agricultural sector, potentially leading to socio-economic stress, food insecurity, and famine. For example, a severe drought in 1983 affected 12.5 million people across the country, resulting in severe hunger and the deaths of hundreds of people, mostly children[172]. The most affected regions of the 1983 drought were the Upper East, Upper West and Northern regions, southern Brong-Ahafo and northern Ashanti, where the decrease in rainfall severely reduced the output of maize and other cereals, including the loss of ~60,000 hectares of cocoa trees[173].

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[167] UNISDR 2009. Terminology on Disaster Risk Management. Available at: https://www.unisdr.org/we/inform/terminology. – defined as natural phenomena that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation.

[168] Okyere C.Y, Yacouba Y and Gilgenbach D. 2012. The problem of annual occurrences of floods in Accra: An integration of hydrological, economic and political perspectives. Interdisciplinary Term Paper, Universitat Bonn.

[169] Choudhary V, Christienson G, D'Alessandro S.P, Josserand H.P. 2016. Ghana: Agricultural Sector Risk Assessment. World Bank Agriculture Global Practice Note.

[170] Toulin C. 1986. Drought and the farming Sector: Loss of Farm Animals and Post-drought Rehabilitation. Alphan- African Livestock Analysis Network 10

[171] Antwi-Agyei, P.; Dougill, AJ.; Stringer, L.C.; Codjoe, S.N.A. (2018) Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. Climate Risk Management, 19, 83–93.

[172] Agency for International Development 1984. Disaster Case Report: Ghana – Food Shortage. Available at: http://pdf.usaid.gov/pdf_docs/PBAAB318.pdf

[173] Choudhary V, Christienson G, D'Alessandro S.P, Josserand H.P. 2016. Ghana: Agricultural Sector Risk Assessment. World Bank Agriculture Global Practice Note.

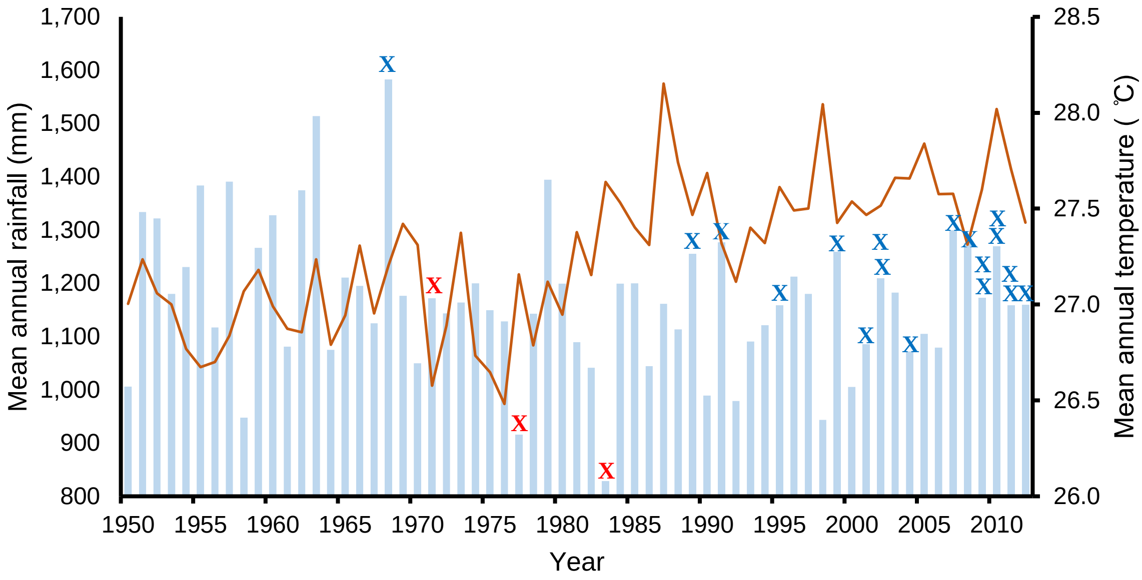

Figure 70: Extreme climate events (droughts and floods) relative to mean annual rainfall (left-hand y-axis; bars) and mean annual temperature (right-hand y-axis; line) in Ghana from 1950 to 2012.

Furthermore, the dry conditions resulting from the drought and prolonged dry winds from the Sahara largely contributed to the spread of extensive bush fires in the north, destroying up to 35% of total food production in some regions. The severity of this 1983 drought ranks it as the fourth highest impacting climate disaster in Africa over the past 35 years[174]. The impact of droughts can also be compounded by heat stress. During heat waves, plants open their stomata to allow for cooling by evapotranspiration. However, during droughts, plants are unable to do this, leading to increased leaf temperatures. The phenomenon can shorten the duration of growth of leaves and grains and thus limit the ability of the plant to accumulate enough carbohydrate necessary for substantial grain growth[175]. The combination of drought and heat stress can, therefore, have detrimental effects on the growth and productivity of crops[176]. Smallholder farmers are the most vulnerable to the impacts of drought as they have few assets to sell to supplement income or purchase food when crops fail.

Additionally, farms based away from reliable water sources such as rivers are at higher risk from droughts, than farmers with a reliable nearby supply of water because they rely on rainwater for crop production. However, farmers living close to large water sources, while being more resilient to the adverse effects of droughts, may be more vulnerable to the impacts of floods. The occurrence of floods is more common than droughts in Ghana – with at least 11 flood events occurring in the past decade – and can cause widespread damage to infrastructure and farmland, impacting the livelihoods of many Ghanaians. For example, a flood in the Greater Accra Region in 1991 affected about two million people and caused over US$12 million worth of damage. Besides, floods have had significant impacts on Ghana's agricultural sector, including among other things: i) the loss of crops – such as cassava, rice, yams, and groundnuts – and livestock; ii) the destruction of farmlands, houses, bridges, schools and health facilities; iii) damage to water supply infrastructure and irrigation facilities, and iv) damage to food storage and post-harvest processing facilities[177].

[174] UNISDR 2008. Africa- Disaster Statistics. PreventionWeb. Available at: http://www.preventionweb.net/english/countries/statistics/index_region.php?rid=1
[175] Farrell A. High temperature stress. University of West Indies. Available at: http://plantsinaction.science.uq.edu.au/book/export/html/158
[176] Mittler R. 2006. Abiotic stress, the field environment and stress combination. TRENDS in Plant Science 11(1): 1360–1385
[177] Armah F.A, Yawson D.O, Yengoh G.Y, Odoi J.O, Afrifa E.K.A. 2010. Impact of Floods on Livelihoods and vulnerability of Natural Resource Dependent Communities in Northern Ghana. Water 2(2): 120–139.

The existing technical and financial capacity among relevant stakeholders in the agricultural sector of northern Ghana to address such risks or cope in their aftermath, is severely limited. The extent of the impacts of floods in Ghana is exemplified by the severe floods that affected northern Ghana in 2007, which led to the Government pronouncing the three northern regions and some parts of the Afram Plains and Keta Area as a disaster zone (Figure 71). These floods claimed 56 lives, damaged ~500 km of roads, destroyed 69 bridges and displaced ~332,000 people.

Additionally, ~34,000 homes, ~ ten schools, 51 health facilities and ~70,500 hectares of farmland were severely affected by the floods[178][179]. The floods also caused the loss of an estimated 144,000 metric tonnes of food crops – including maize, sorghum, millet, groundnuts, yam, cassava, and rice. The loss in production, coupled with the restricted access to markets because of damaged roads and bridges, led to negative growth in the agricultural sector for the first time since 1994[180].

Figure 71: Floods in Atiwlame, in the Afram Plains North District in 2018[181]

Another example of the impacts of flooding in Ghana is the floods that occurred in parts of northern Ghana, Accra and the Agona District in 2010. Intense rainfall, inadequate drainage systems, and spill-over from dams resulted in the loss of human life, livestock and farmland, as well as extensive damage to infrastructure. Such flooding events often lead to significant impacts on, among other things, agriculture, education, health, water and sanitation sectors of the affected regions, districts and communities[182].

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[178] Government of Ghana 2007. Joint assessment report of flood disasters in the three northern regions of Ghana. Inter-ministerial Disaster Relief Committee and UN Country Team.

[179] Armah F.A, Yawson D.O, Yengoh G.Y, Odoi J.O, Afrifa E.K.A. 2010. Impact of Floods on Livelihoods and vulnerability of Natural Resource Dependent Communities in Northern Ghana. Water 2(2): 120–139.

[180] Choudhary V, Christienson G, D'Alessandro S.P, Josserand H.P. 2016. Ghana: Agricultural Sector Risk Assessment. World Bank Agriculture Global Practice Note.

[181] https://africafeeds.com

[182] Okyere C.Y, Yacouba Y and Gilgenbach D. 2012. The problem of annual occurrences of floods in Accra: An integration of hydrological, economic and political perspectives. Interdisciplinary Term Paper, Universitat Bonn.

Table 65: List of climate hazards and their impacts in Ghana between 1968 and 2017[183].

Year	Disaster description	Regions affected	Total deaths	Total people affected	Total damage (US$)
1968	Flood	Central	--	25,000	74,00,000
1971	Drought	Countrywide	--	12,000	100,000
1977	Drought	Northern, Upper East, Upper West	--	--	--
1983	Drought	Countrywide	--	12,500,000	--
1989	Flood	Northern	7	2,800	--
1991	Flood	Greater Accra	5	2,000,000	--
1995	Flood	Greater Accra	145	700,000	12,500,000
1999	Flood	Northern, Upper East, Upper West	52	324,602	21,000,000
2001	Flood	Greater Accra	12	144,025	--
2002	Flood	Greater Accra	--	200	--
2002	Flood	Greater Accra	4	2,000	--
2007	Flood	Northern, Upper East, Upper West	56	332,600	--
2008	Flood	Northern	--	58,000	--
2009	Flood	Greater Accra, Ashanti, Volta, Western, Central, Eastern	16	19,755	--
2009	Flood	Northern	24	139,790	--
2010	Flood	Greater Accra, Central, Volta	45	7,500	--
2010	Flood	Brong Ahafo, Eastern, Western, Upper East, Upper West, Northern	18	9,674	--
2011	Flood	Eastern	6	12,571	--
2011	Flood	Greater Accra, Eastern, Volta	14	81,473	--
2013	Flood	Northern, Volta	5	25,000	--
2015	Flood	Greater Accra	25	5,000	12,000,000
2016	Flood	Greater Accra	10	--	--

Between 1991 and 2011, the country experienced seven significant floods. In 2010, floods in the White Volta River Basin affected hundreds of thousands of people and destroyed many of their livelihoods. Urban floods also regularly impact key cities, with the last major event occurring in Accra in June 2015 (Table 65). Ghana has a 550km coastline. The coastal zone is inhabited by more than one-quarter of Ghana's population and about 80% of its industrial activities such as oil and gas production, port operations, thermal electricity generation, coastal agriculture, sand winning, hydroelectricity generation, and fishing. These activities have led to coastal erosion and compounded by the rising impacts of sea-level rise closely linked to climate change (Figure 72). Although the entire coastline is eroding at varying intensity, the eastern section has been identified as the most vulnerable.[184]

[183] EM-DAT 2016. Disaster List for Ghana. Available at: http://emdat.be/disaster_list/index.html
[184] theconversation.com/why-ghana-needs-a-new-approach-to-stop-the-erosion-of-its-coastline-44018

Figure 72: Fuveme in Keta municipality (between the Gulf of Guinea and the Keta Lagoon) of the Volta region is prone to sea erosion[185]

5.6 Sectoral Impacts Assessment

This section is dedicated to summarising the key messages from the sectoral vulnerability and impact assessment to climate change. It highlights the types of study, the key findings and the corresponding adaptation measures and the implementation status.

5.6.1 Cross-Sectoral Impacts Assessment

Climate change impacts contribute to the worsening drought conditions, flooding from heavy and incessant rains, sea level rise and erosion (Figure 72). To address these challenges, Ghana's policy response to climate change emphasises on building a resilient economy and ecosystems. Ghana's policy response is informed by the evidence of climate change and the associated vulnerability. Ghana's NC3 reported on assessment studies on roots and tubers, cocoa, fisheries, land management, health, poverty and gender that fed into the development of the national adaptation strategy. The NC4 reports on three additional sub-sectors including energy, water and migration. For the agriculture sector, the impact assessment separates the conditions for agriculture in the north from the southern sectors of the country since the two have different climatic conditions and adaptation mechanisms.

The assessment reports on the methods and tools, critical vulnerabilities and the proposed adaptation measures in each sector. In addition, it examines the key policy instruments that anchor the sector measures and whether they are in line with the adaptation actions in the NDC. Table 66 presents Ghana's adaptation assessment studies and the corresponding adaptation measures.

[185] https://www.bbc.com/news/world-africa-36257360

Table 66: Sectoral adaptation assessment and linkages with the on-going adaptation measures

Sector	Scope	Methods/Tools	Key identified vulnerabilities	Proposed adaptation measures	On-going adaptation	NCCAS Priorities	Policy alignment		
							Ghana's NDCs	NCCP	Sector policies
Agriculture (Roots and tubers)	Roots and tuber as an alternative livelihood in the middle and southern belts of Ghana	Socio-economic survey for economic and household data. Baseline studies using quantitative and qualitative methods. Secondary data (production statistics) used for natural yield variability. Crop model – DSSATv4 used to evaluate root crops vulnerability, Implications for future climatic change and project expected magnitude of impacts. Computer-aided modelling, Scenario analysis, Simulation gaming. The participatory and qualitative assessment used for interactions between impacts of climate change on root and tuber crop yields and national policies	Unreliable, irregular and unpredictable rainfall patterns. Indiscriminate deforestation. Poor or degraded soils because of intensive and harmful cultivation practices. Prolonged drought increases the population of variegated grasshoppers, which destroy cassava. Generally, the low-income status of root & tuber farmers. Heavy dependence on root and tuber on rainfall. Reduction in production due to high temperatures.	Improved Farming technologies or practices Varieties with different maturity periods. Introduce drought-resistant varieties. Integrated nutrient management under various crops. Afforest degraded Forest lands. Alternate cropping Post-harvest technologies Alternate livelihood, especially off farming activities. Irrigation under root crops production	Root and Tuber Improvement and Marketing (RTIMP) – MoFA. Promoting a value chain approach to climate change adaptation in agriculture in Ghana (ProVACCA). The main goal of the project is to reduce the vulnerability of the food supply system to the deleterious impacts of climate change and climate-induced risks in the cassava value chain. West Africa Agricultural Productivity Programme. Lessons from Conservation Agricultural Practices – CARE International	Programme Area 7: minimising climate change impact and socio-economic development through Agricultural Diversification	Modified community-based conservation agriculture adopted in 43 administrative districts	Strategic Themes: Food and Agriculture Strategic Focus: Focus Area 1: Development of climate-resilient agriculture and food systems Programme Areas 1.2 Develop and promote climate-resilient cropping systems 1.5. Support for water conservation and irrigation systems 1.6. Risk Transfer and Alternative livelihood Systems 1.7 Improved Postharvest Management	FASDEP II CSA and Food security action plan

Agriculture (Fisheries)	Marine and inland fisheries as sustainable alternative livelihood and climate change adaptation	A survey study on fish species regarding catch, physical conditions, and socio-economic dynamics. Physical (canoco 4), Biomass dynamic model, Artificial Neural Network (ANN) for meteorological and fishery data.	Increasing variability in marine fish stock, reduction in catch rate due to rising seas temperature, decreases in freshwater landings, generally low incomes in fishing communities.	Aquaculture development; restocking of the fingerlings; reliable extension services including dissemination of weather information; monitoring diseases; education		Programme Area 10: Adapting to climate change, sustainable livelihoods through enhanced fisheries resource management	Scale-up penetration of climate-smart technologies to increase livestock and fisheries productivity by 10%.	Strategic theme: Food and Agriculture Focus area 1: development of climate-resilient agriculture and food system Programme area: support adaptation and risk reduction in the fisheries sector	
Agriculture (Cocoa)	Cocoa as a cash crop for subsistent livelihood activity within the agricultural sector in Ghana.	CASE2 (Cacao Simulation Engine2) Informal semi-structured and formally structured surveys (individual interviews). Key informant interviews, group interviews Focus group interviews of selected farmers and other stakeholders.	Erratic rainfall patterns in cocoa-growing areas. Generally, the low-income status of cocoa farmers is due to the small size of farms. Increased degradation of land in cocoa-growing areas. Generally low and unreliable prices of cocoa An ageing population of cocoa farmers. Traditional farming practices within the cocoa sector.	Drought tolerant and high yielding cocoa varieties. Zero tillage non-burning of vegetation and mulching for the conservation of soil moisture. Incorporate shade trees to moderate micro-climatic and edaphic conditions of the cocoa environment. Supplementary water application through irrigation.	Pro-poor REDD+	Programme area 6: managing water resources as climate change adaptation to enhanced productivity and livelihoods.	Governance reform for utilisation of forest resources for sustainable energy use and biodiversity business. Modified community-based conservation agriculture adopted in 43 administrative districts	Strategic Theme: Natural resources management Strategic focus: increase carbon sink Programme areas 4.4: Conservation of trees through sustainable agroforestry and on-farm practices	FASDEP II CSA and Food security action plan National Tree Crop Policy

				Rehabilitation and restoration of degraded areas. Development of off-farm income-generating activities					
Agriculture	Agriculture as the livelihood in the northern savannah zone	IPCC Climate change vulnerability assessment GIS techniques	A differentiated vulnerability across the agro-ecological zones with the highest intensity in the savannah zones	Ecosystem-based adaptation alternative climate-resilient livelihoods	Sustainable land and water management project. Upscale sustainable land management practices. Adaptation Fund project focuses on providing access to water to smallholder farmers in the Savannah Drylands.	Policy area 7: minimising climate change impacts and socio-economic development through agricultural diversification	Modified community-based conservation agriculture adopted in 43 administrative districts	Strategic theme: Food and Agriculture Focus Area 1: development of climate-resilient agriculture and food systems Programme Areas: 1.2: develop and promote climate-resilient cropping system. 1.5: support to water conservation and irrigation systems. 1.6: Risks transfer and alternative livelihood systems. 1.7: Improved post-harvest management.	FASDEP II CSA and Food security action plan (CSAFSAP) Tree crop policy

Energy	Power sector (generation, transmission, and demand)	Integrated Planning Model (IPM)	Increased temperatures and extremes could lead to increased demand by competing water users can reduce water available for power generation	Modify operations of reservoirs and spillways to include variable and changing flow amounts. Develop improved hydrological forecasting techniques and adaptive management operating rules Protect watersheds to secure an adequate water supply to reduce silt loading and attenuate peak flow. Employ sediment expulsion technology. Implement erosion control measures to reduce siltation and sedimentation Modify spillway capacities and install controllable spillway gates to flush silted reservoirs.	Volta river basin project. The aim is to promote a more sectorally coordinated management approach based on integrated water resource management principles both at the national and regional levels with a strong emphasis on an expanded role for all stakeholders.	Programme area 6: managing water resources as climate change adaptation to enhance productivity and livelihoods Programme area 9: developing demand and supply-side measures for adapting the national energy system to impacts of climate change	Integrated water resources management Renewable energy: scale-up renewable energy penetration by 10% by 2030	Programme area 7: minimise the impact of climate change on access to water and sanitation	Renewable energy Act 832 (2011) Electricity generation masterplan Renewable energy master plan
Migration	Migration as adaptation to climate change	A mixed-method was used and comprised quantitative and qualitative surveys and	Deltaic regions and semi-arid regions in Ghana are	Promotion of resilient alternative livelihood interventions.	Deltas, vulnerability and climate change: migration and		Building standards for strategic coastal	Focus area 9: Address climate	National migration

		Geographic Information System.	vulnerable to climatic impacts. Examine why populations would continue to live in places where environmental thresholds have been exceeded and how migration has been used as an adaptation to climatic impacts.	Establishment of an integrated coastal and northern development authorities to promote economic opportunities on the coast and the savannah.	adaptation (DECCMA) project Adaptation at scale in semi-arid regions (ASSAR) project Northern development authority (NODA)		infrastructure adopted.	change and migration	policy for Ghana Revised National Population Policy of Ghana, 2014
Gender (focus on Women livelihoods	Gender and climate change in the Southern and Northern Ghana	A qualitative survey using questionnaires including focus Groups to a small group of twenty women in a locality selected from the three study areas Sustainable livelihood framework. The procedure for the qualitative survey described by Roger Climate Vulnerability and Capacity Analysis (CVCA)	Women experiencing discrimination under customary Law and practices. Time spent in collecting or buying firewood. Indoor air pollution through cooking. The increased workload of women and children who collect firewood. Reduction in fishery resources. Competition from big fishing trawlers. Inadequate and poor access to financial credit facilities	Facilitating equitable access to land. Security tenure and protection of land rights. Ensure planned land use. Develop sufficient institutional capacity and capability. Increase access to health services. Improve the efficiency of health service delivery.	Southern Voices on Adaptation (SVA): Increase advocacy and public awareness of gender issues. ABANTU for Development and the Gender Action on Climate Change for Equality and Sustainability with support from Care International Adaptation Learning Programme –increase the capacity of vulnerable groups such as women and children to adapt to increasing and uncertain climate	Programme Area 2: Alternative livelihood: Minimising climate change impact for the poor and vulnerable	Implementation of community-led adaptation and livelihood diversification for vulnerable groups	Strategic Theme: Equitable Social Development Strategic Focus Focus Area 6: Addressing Impacts of Climate Change on Human Health Programme area 6.7 Social protection and improved access to healthcare, e.g. NHIS	The National Gender Policy (2015) Social Protection Policy (2015) Child and Family Welfare Policy (2015) National Ageing Policy (2010) Ghana Disability policy (2010)

				Foster partnership with other agencies in improving health by: Addressing inequalities based on gender, poverty, and disability; Expand water availability, sanitation, and the healthy environment Improve nutritional status.	change and climate variability				
Climate change and health	Climate change and health in different ecological zones in Ghana: Ashanti Region (Southern Ghana), Northern Region - Malaria, Diarrhoea, Guinea Worm and Cerebral Spinal Meningitis	Desktop review, questionnaire administration, focus group discussion, key informant interviews and observations, epidemiology survey, household case studies Multiple regression analysis among climate variable and the three diseases, sustainable livelihood approach for socio-economic health impacts, ANN, MIASMA (Modeling framework for the Health Impact Assessment of Man-Induced Atmospheric changes) MODEL Version 2.0	Measles cases would increase by the year 2080 because of increased mean air temperature and reduced rainfall amount. However, measles is on the decrease under the present climate condition. The gradual rise in the incidence of meningitis cases over the range of months where cases of meningitis are high. Risk of increased diarrhoea cases due to a reduced rainfall amount and	Break the transmission cycle. Destroy breeding grounds of mosquitoes Destroy the larvae to break the life cycle. Break the host-vector contact and protect the host. Destroy the Cyclops to break the life cycle. Break the host-vector contact and protecting the host, Reduce Cyclops host contact through;		Programme Area 8: Minimizing climate change impacts on human health through improved access to health care Programme Area 5: Developing and implementing environmental sanitation strategies to adapt to climate change	Managing climate-induced health risks	Strategic Themes: Equitable social development Strategic focus Focus area 6: Addressing Impacts of Climate Change on Human Health Programme 6.3 Strengthen disease surveillance and response systems 6.4 Improve public health measures	National health policy. National Health Insurance Policy Framework.

		or LEMRA (Local Eco-epidemiological Malaria Risk Assessment)	increased mean air temperature.	Provision of safe drinking water, Filtration of water to remove Cyclops Chemical destruction of crustaceans. Vaccination of high-risk groups. Increased input to vaccination campaigns, Proper housing, and ventilation. Effective case management and Education.				(immunization, improved drainage, sanitation, and hygiene) especially in vulnerable communities 6.5. Emergency health preparedness, e.g. provision of ambulances in vulnerable areas 6.6. Collaboration and partnership for improved nutrition, water, and sanitation	
Water	Climate change Adaptation: Water Resource Management in Upper East, Upper West and Northern Regions of Ghana Protection of Beaches and Environs against Encroachment by the Sea	Construction and structural development of water systems Human resource capacity building and training Hydrological modelling and testing with ground data while performing future scenario demonstration on exceedance Surveys and target farm group interactions	Limited access to water services in urban, peri-urban, rural and small towns Un-harmonised Water, sanitation and hygiene education Farming practices close to water bodies resulting in uncontrolled catchment degradation Flood and drought affect on-farm productivity	Develop and improve early warning systems for flood and drought monitoring Increase and improve hydrological and meteorological gauge stations for the collection and reporting of accurate and timely data Enforce regulations on pollution control of	Increased Resilience to Climate Change in Northern Ghana through the Management of Water Resources and Diversification of Livelihoods Sea Defense / Coastal Erosion Project Flood Recession Agriculture for food security in the white Volta River Basin	Programme Area 1: Integrated Water Resources Management Strengthen regulatory framework Improve access to water resources knowledge base Improve institutional and	Strengthen equitable distribution and access to water for 20% of the population living in climate change risk communities	Strategic Theme: Disaster Preparedness and Response Strategic Focus: Focus Area 2: Build Climate Resilient Infrastructure Program Areas 2.1 Build capacity to design climate-resilient infrastructure	National Water Policy - 2007 (NWP) National Riparian Buffer Zone Policy – 2011 (NBZP) Urban Water Supply Investment Plan - 2007 (UWSIP)

	Early warning system for monitoring Flood and Drought in selected Basins (OTI, White Volta Diversification of livelihood Un-serviced urban, peri-urban, rural and small towns		Loss of livelihood	surface and groundwater resources Construct sea defence and coastal erosion systems Improve access to safe, affordable, adequate and regular water supply	Community Resilience through Early Warning (CREW) project (NADMO, UNDP) Flood Hazard Assessment (WRC, UNDP, NADMO, HSD, and GMet) Disaster Risk Management (WRC, UNDP, NADMO, HSD, and GMet) Completed OTI Flood Hazard Assessment (WRC, UNDP, NADMO, HSD, and GMet) Improving the resiliency of crops to drought through strengthened early warning within Ghana. (WRC, GMet)	human resources capacity Enhance public awareness and education Enhance trans-boundary an international corporation		2.2 knowledge management and coordination 2.3 climate-resilient sectorial and local development planning 2.5 Flood prevention activities 2.7 Protection of coastal resources and communities Focus Area 3: Increase Resilience of Vulnerable Communities to climate-related risks Programme area 3.1 Early warning mechanism	Rural Water Supply Investment Plan – 2007 (RWSIP) National Integrated Water Resource Management Plan - 2012 (NIWRMP) Water Sector Strategic Developmen t Plan - 2014 (WSSDP) 2012 - 2025
Poverty Linkages	Addressing climate change and poverty linkages across the country (Nationwide)	Use of secondary data. Supplemented by primary sources of data. Data mainly from national government publications and unpublished reports such as Ghana Poverty Reduction	Heavy reliance agriculture and other livelihood ventures on rainfall. Inadequate irrigable lands.	Reforestation. Devise flood/drought early warning systems.		Programme Area 2: Alternative livelihood: Minimizing climate change impact the poor and vulnerable	Agriculture resilience building in climate-vulnerable landscapes	Strategic Themes: Disaster Preparedness and Response Strategic Focus:	

		Strategy. Ghana Living Standards Survey. Draft national documents. Core Welfare Indicators Questionnaire (CWIQ) surveys Qualitative and quantitative with the aid of a statistical tool, Statistical Package for Social Science (SPSS), Analysis of Variance and Correlation, the use of tables, charts, and maps.	A progressive loss of non-timber forest products. Increased land degradation and loss of cropable land. Disruption in industry productivity due to possible crises in the energy sector. Disruption in the supply of raw materials. Disruption of rainfall patterns would affect the Akosombo dam (30% of our energy sources). Potential risk from sea-level rises, such as coastal inundation and erosion. Disruption of sources of livelihoods, e.g. fishing and agriculture Population displacement Lack of and inadequate credit facility (e.g. small loans to small scale farmers and petty traders)	Negotiate regional water-sharing agreements; Providing efficient mechanisms for disaster management; Planting mangrove belts to provide flood protection; Planting salt-tolerant varieties of vegetation Establishing setback policies for new developments; Encourage the use of setback policies for all underdeveloped areas within the coastal zone. This would prevent the construction of stable structures within hazard areas. Development of woodlots Promote and develop energy-efficient technologies			Value addition-based utilization of forest resources Integrated water resources management Resilience for gender and the vulnerable	Focus Area 3: Increase Resilience of Vulnerable Communities to Climate-related risks Programme areas 3.3. Rapid Response and Disaster Management 3.5 Financial Support and Insurance Schemes 3.6 Provision of Social	

				Promotion of energy conservation, especially in large energy-consuming industries. Promote and develop alternative energy sources, institute credit schemes to promote small scale enterprises and businesses as alternative livelihood ventures.					

5.6.2 Climate Hazards and Economic Analysis

A climate hazard and economic study have been undertaken as part of the multi-sectoral investment framework for climate and disaster risk management[186]. The purpose was to review climate change impacts, adaptation and disaster risk reduction opportunities in Ghana. The study identified three areas of concern. These are: (a) managing resilient urban transitions; (b) erratic earnings from the cash crops sector; and (c) increasing pressure on the electricity system.

5.6.2.1 Managing resilient urban transition

Most cities are particularly vulnerable to the consequences of recurrent flooding. The increasing vulnerabilities in Ghanaian urban centres are the result of a complex chain of interconnected vulnerabilities, involving climate-related disasters, development constraints, and policy failures. Key climate hazards have impacts, notably from floods with the 2015 floods leading to several hundred casualties and severely disrupted business activities. There are also distributional differences in exposure and impacts: informal settlements are more susceptible to risks, due to lower building standards and the fact they are often located in high-risk areas. The economic impacts of these floods (including the direct damage and losses, as well as the indirect effects on transport, services.) lead to macroeconomic impacts (Figure 73).

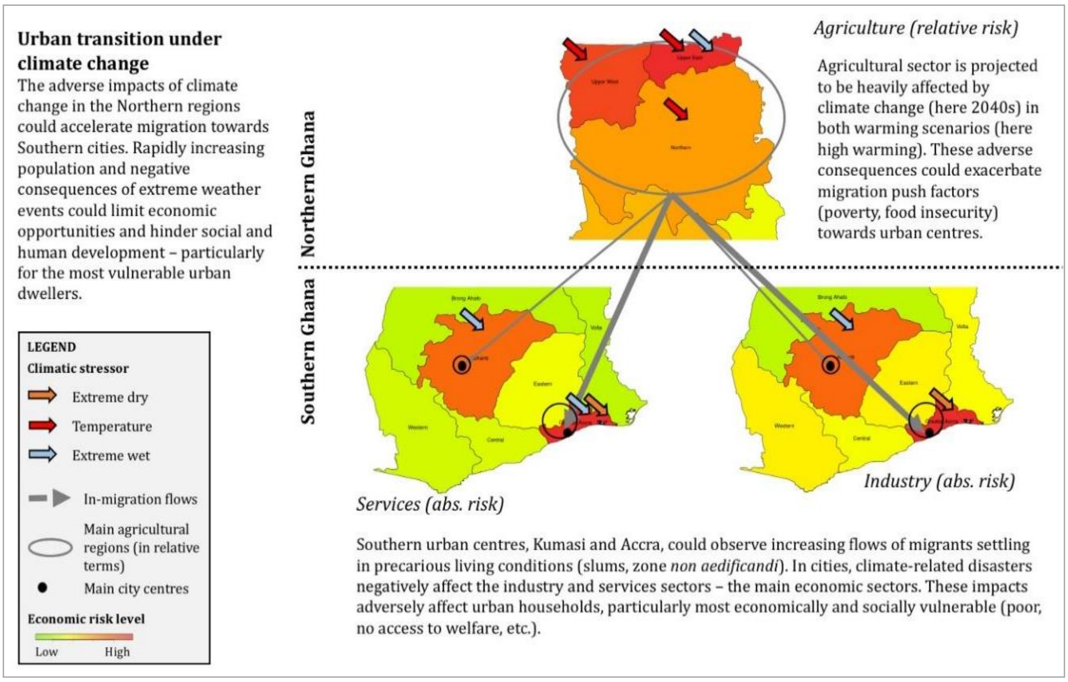

Figure 73: Climate change and urbanisation scenario

5.6.2.2 Erratic earnings from cash crops

Increases in irregular rainfall patterns have the potential to reduce crop yields, threatening both subsistence and commercial farmers. A reduction in cocoa yields, one of Ghana's most significant exports would negatively affect national output, reduce overall agricultural capacity, and threaten livelihoods of the poor and vulnerable. Because of the decreasing and erratic production of cocoa, the whole cash crop value chain (transportation, trading) in both the services and industry sectors could be affected. Decreasing exports and reduced government revenues could also affect macroeconomic stability (Figure 74).

[186] This study was part of the World Bank IDA and Ministry of Works and Housing work on investment framework on climate hazards and economic analysis

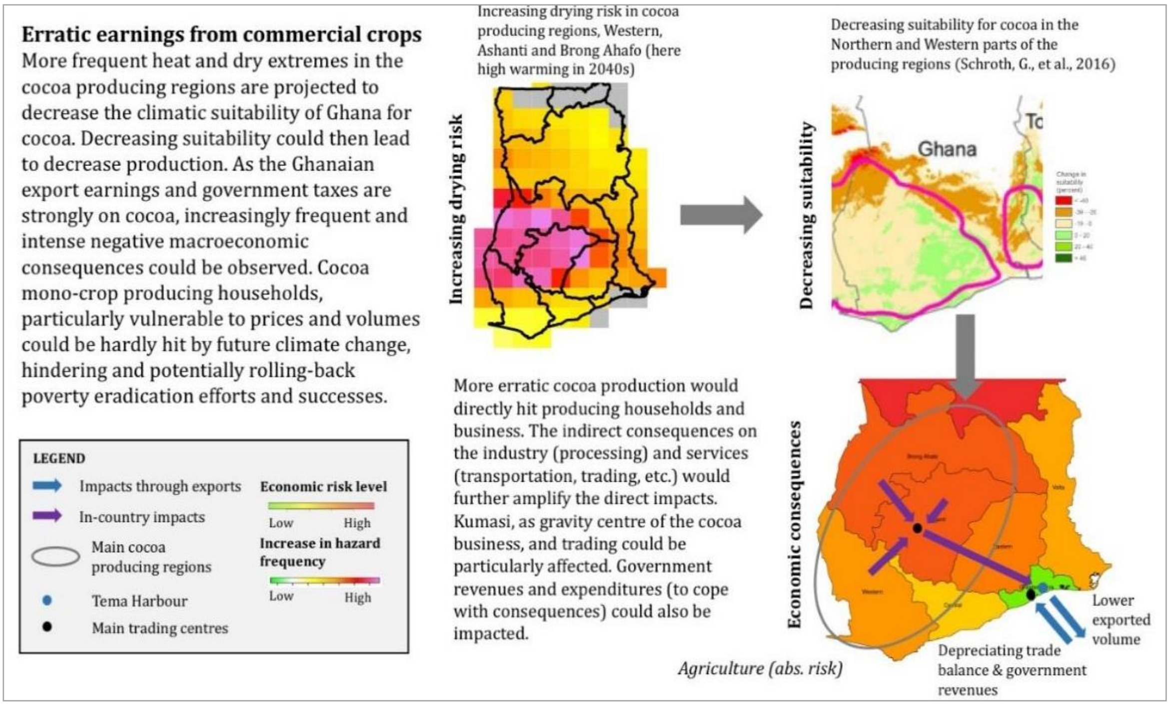

Figure 74: Climate change and commercial crop scenario

5.6.2.3 Pressures on the electricity system

Climate-driven pressures would influence Ghana's energy generation options on water availability for cooling (thermal power plants) and production (hydropower)[187]. The projected increase in the frequency of extreme events could worsen the impacts on the power system. Heat and dry extremes could further accentuate the vulnerability of the already pressured electricity production and distribution system (Figure 75).

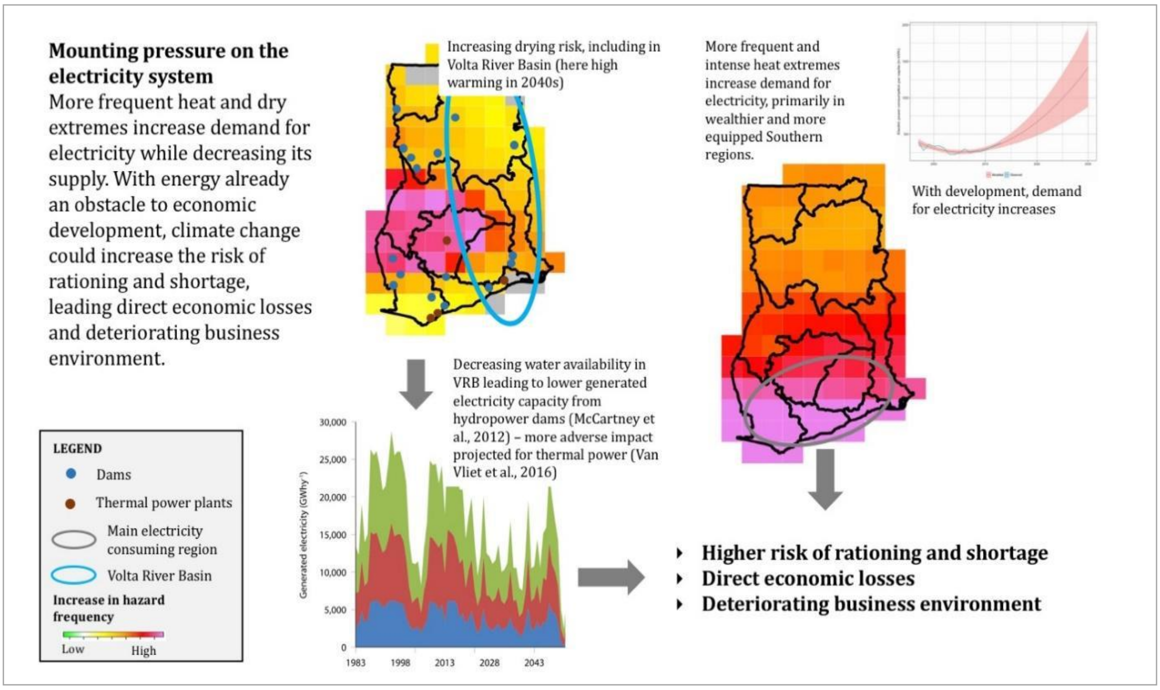

Figure 75: Climate change and electricity system scenario

[187] Ghana multi-sectoral investment framework for climate and disaster risk management

Flooding events and storms are likely to affect electricity distribution and transmission. On the demand side, increasing temperature could also increase electricity demand for cooling, increasing peak demand and putting additional pressure on the limited capacity. The study concludes that:

- New energy generation infrastructure projects should consider climate-related disasters and long-term climate change in their design and development.
- Enhancing the climate resilience of energy infrastructure could lead to a significant increase in cost and, given the need to include future uncertainty changes in the initial design.

5.7 Updates on Adaptation Planning and Actions

Several national, sector and district policies support climate adaptation. Policy alignment is critical because it is the surest way to demonstrate government support for adaptation as a priority area. It is also a practical approach to secure government funds to implement adaptation programmes. When the adaptation issues are incorporated into the national medium-term development framework, it behoves on the line ministries and the district assemblies to reflect them in their medium-term plans. Incorporating the adaptation into the individual plans could be the justification for implementation. Therefore, this section provides updated information on adaptation actions in Ghana. It focuses on adaptation planning efforts and the status of adaptation actions being implemented in the country.

5.7.1 Adaptation Planning

Adaptation planning has been contextualised into policy alignment and mainstreaming efforts. The policy alignment aspects reflect the status of the national efforts to incorporate adaptation issues into national, sectoral and district plans. It addresses the critical adaptation policy interventions and the subsequent mainstreaming efforts at all levels.

5.7.1.1 Adaptation-related policies and strategies

5.7.1.1.1 Cross-sectoral policies and strategies

There are several adaptation-related policies and strategies the government has adopted to build resilience to climate change. The first category of policies is cross-sectoral in nature with a national scope. Usually, the cross-sectoral adaptation policies set out the broad priority areas and the strategies to guide implementation. Then, the sector-specific strategies draw on the priority areas identified in national policy to develop concrete programmes for the ministry or district.

Medium-Term Development Policy Framework (2018-2021)

The national medium-term plans often recognise climate change issues. The previous plans (Ghana Shared Growth Development Agenda 1 and 2)[188] and the most recent one has incorporated climate change issues into them. The latest medium-term plan (dubbed the Agenda for Jobs)[189] outlined strategies to domesticate Ghana's commitment under the Paris Agreement. Climate change and variability issues have been captured under the "Environment, Infrastructure and Human Settlement" section.

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[188] https://s3-us-west-2.amazonaws.com/new-ndpc-static1/CACHES/PUBLICATIONS/2018/11/08/GSGDA+II+December+1++2014.pdf
[189] https://s3-us-west-2.amazonaws.com/new-ndpc-static1/CACHES/PUBLICATIONS/2018/08/23/Medium-term+Policy+Framework-Final+June+2018.pdf

The NDPC facilitates the preparation of the national development framework in line with the broad vision set out in the current administration's coordinated programme of economic and social development policies. The NDPC performs the plans formulation and coordination functions under Act 480. The issues that are covered in the national plan cover adaptation measures outlined in the national climate change policy and the nationally determined contributions. Once the medium-term development framework captures adaptation issues, the line ministries and the district assemblies are expected to reflect them in their respective development plans.

Ghana National Climate Change Policy (NCCP, 2015–2020)[190]

The NCCP and the master plan are Ghana's flagship climate change policy to respond to climate change within the sustainable context. The policy highlights the government commitments to tackle climate change and strategies to institutionalise implementation of the programmes in it. The policy identifies effective adaptation as the top priority area of government in addition to the low carbon growth and social development objectives. The following seven pillars have been included in the policy:

- governance and coordination
- capacity building
- science, technology, and innovation
- finance
- International cooperation
- information, communication and education
- monitoring and reporting

Furthermore, four thematic areas have been identified to address adaptation issues. These are energy and infrastructure; natural resources management; agriculture and food security; and disaster preparedness and response. NCCP is implemented by the Ministry of Environment, Science, Technology, and Innovation (MESTI). Broad action areas have been identified to guide the implementation of the policy at the sectoral and decentralised levels. MESTI has established the climate change implementation committee to coordinate the rolling out of the NCCP interventions.

Ghana National Climate Change Adaptation Strategy (NCCAS, 2012)[191]

The NCCAS predates the NCCP but builds upon it. The "effective adaptation" goal in the NCCP is a further elaboration of the priority actions in the NCCAS. It emerged from an earlier sectoral vulnerability study conducted in 2008. Ghana's NCCAS seeks to increase climate resilience and decrease the vulnerability of local communities. Its adopted goal is to enhance Ghana's current and future development by strengthening its adaptive capacity and building the resilience of communities and ecosystems to the impacts of climate change. The strategy prioritised eight areas for adaptation actions: (i) livelihoods; ii) energy; iii) agriculture; iv) health; v) early warning; vi) fisheries management; vii) land use, and viii) water.

[190] Ministry of Environment, Science and Technology (MESTI), Republic of Ghana. 2014. Ghana National Climate Change Policy. Available at: https://s3.amazonaws.com/ndpc-static/CACHES/NEWS/2015/07/22//Ghana+Climate+Change+Policy.pdf

[191] UN Environment and UNDP. 2012. National Climate Change Adaptation Strategy. CC DARE. Available at: https://s3.amazonaws.com/ndpc-static/CACHES/PUBLICATIONS/2016/04/16/Ghana_national_climate_change_adaptation_strategy_nccas.pdf

The actual implementation of the NCCAS is through the sub-national institutions, including the District Assemblies under the supervision of the National Climate Change Committee. The Town / Area Councils would prepare plans which would be submitted to the District Assemblies. Many ground interventions emerged from the implementation of the NCCAS. For example, the Ministry of Health implemented climate change and health project on the back of the NCCAS. Additionally, the MESTI's Adaptation Fund Project is addressing the livelihood, agriculture and water aspect of the NCCAS.

Ghana's Nationally Determined Contributions (NDC, 2020-2030)[192]

In 2015, Ghana submitted its intended nationally determined contributions in response to the Lima Call for Action. The intended nationally determined contributions automatically turned into NDC when Ghana ratified the Paris Agreement in 2016. The nationally determined contributions comprised thirty-one climate actions covering seven priority areas. The thirty-one climate actions consisting of twenty mitigation, and eleven adaptation actions are consistent with the broadly stated objectives of the medium-term development plan and the national climate change policy. These programmes of actions would be the strategic focus of a "10-year post-2020 enhanced climate action plan" currently under development. The long-term adaptation goal set out in the NDC, is to increase climate resilience and decrease vulnerability for enhanced sustainable development. Table 67 outlines the priority adaptation plans that would be implemented to achieve this goal.

Table 67: Priority adaptation policy actions to be implemented to achieve Ghana's NDC adaptation goal

Sector	Strategic Area	NDC Policy Actions	Number of Programmes of Action
Agriculture and food security	Sustainable land use	Agriculture resilience building in climate-vulnerable landscapes	3
Sustainable forest resource management		Value addition-based utilisation of forest resources	2
Resilient infrastructure in the built environment	Climate-resilient strategic infrastructure	City-wide resilient infrastructure planning	1
		Early warning and disaster prevention	1
Climate change and health	Equitable social development	Managing climate-induced health risk	2
Water resources		Integrated water resources management	1
Gender and the vulnerable		Resilience for Gender and the Vulnerable	1

5.7.1.1.2 Sector-specific adaptation strategies

Once the national medium-term plan, NCCP, NCCAS, and the NDCs identified climate adaptation as a priority, the line ministries and the district assemblies are expected to incorporate them into their sector/district plans. Consequently, during the preparation of the current sector/district plans, some of the MDAs and MMDAs reflected adaptation issues in them. Others have even adopted a climate-specific strategy to deal with the issues in the sector.

Sector strategic Medium-term Plan for the Ministry of Works and Housing (2018-2021)[193]

The Ministry of Works and Housing (MWH) has prepared a sector strategic medium-term plan for the period 2018-2021.

[192] Government of Ghana. 2015. Ghana's intended nationally determined contribution (INDC) and accompanying explanatory note. UNFCCC. Available at: http://www4.unfccc.int/ndcregistry/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf

[193] https://www.mwh.gov.gh/wp-content/uploads/2018/05/SECTOR-MEDIUM-TERM-DEVELOPMENT-PLAN-2018-2021.pdf

The plan was in response to the Environment, Infrastructure and Human Settlement theme under the national medium-term development framework (Agenda for jobs: creating prosperity and equal opportunity for all). The plan identified the following as the key development issues to address:

- the rapid growth of **slums** in cities and towns
- recurrent incidence of **flooding**
- the vulnerability of the **coastal zone** on the impact of climate change
- the potential rise in **sea level** resulting in wetland flooding

The plan further indicated the broad policy objectives in the national medium-term plan relevant to the MWH operations and the adaptation measures as follows:

- Promote resilient urban development
- Address recurrent devastating floods
- Promote proactive planning for disaster prevention and mitigation
- Enhance climate change resilience

The targets set for the Plan period that relate to adaptation are:

- 20% upgrade of existing slums by December 2021 and zero tolerance of new ones.
- 20 % increase in infrastructure investment for Sea defence projects.
- Effective Early Warning System for effective flood control established by December 2021.

Some of the specially adapted relation intervention include:

- Development of a coastline master plan for protection
- Construction of fifteen sea defence projects in Western, Central and Greater Regions.
- Renovation of 75 river gauging stations and changing of automatic water level recorders.
- Develop 10 Regional Drainage Master Plans and construction of primary drains.
- Develop 20 District Drainage Master Plans.
- Implement the Annual Emergency National Flood Control programme.
- Gazetting of the Building Code and the review of the Building Regulations

Ghana Plan of Action for Disaster Risk Reduction and Climate Change Adaptation (2012)[194]

The Ghana Plan of Action for Disaster Risk Reduction and Climate Change Adaptation (2012) summarises strategic support for Disaster Risk Management (DRM) from the government and its development partners. NADMO has a new law, Act 2016 (Act 927) that strengthens its mandate to enforce disaster risk reduction regulation and coordinate all related activities. NAMDO is also the lead institution in the implementation and localisation of the Sendai Framework for Disaster Risk Reduction (SFDRR) (2015-2030) and the African Regional Strategy for Disaster Risk Reduction.

[194] http://nadmo.gov.gh/images/NADMO_documents/2015_documents/GHANA%20PLAN%20OF%20ACTION%20ON%20DRRCCA%202011-2015.pdf

National Climate-Smart Agriculture and Food Security Action Plan (2016-2020)[195]

The Food and Agriculture Sector Development Policy (FASDEP 2) is the primary document from which agriculture adaptation strategy is derived. FASDEP 2 is accompanied by a Medium-Term Agricultural Sector Investment Plan (METASIP 2). The National Climate-Smart Agriculture and Food Security Action Plan was adopted by the Ministry of Food and Agriculture in 2016 to provide additional details on the strategies to align agricultural adaptation issues in the NCCP to the FASDEP 2. Thus, the main goal of the action plan is to facilitate the NCCP in effectively integrating climate change considerations into the food and agricultural sectors' development policies and programmes

The specific aims of the Action Plan are to:

- develop climate-resilient agriculture and food systems for all agro-ecological zones;
- develop human resource capacity for climate-resilient agriculture; and
- elaborate on the implementation framework and the specific climate-smart agriculture activities to be carried out at the respective levels of governance.

MoFA is responsible for the implementation of the Action Plan, with the Environment and Climate Change Unit (ECCU) having direct responsibility for the dissemination, capacity building and coordination of the implementation. The ECCU works in collaboration with the Ministerial Climate Change Task Force to ensure that relevant activities are integrated into the annual work-plans and budgets for all national Directorates of MoFA. At a decentralised level, the Departments of Agriculture of the Metropolitan, Municipal and District Assemblies would be responsible for the implementation of on-the-ground activities. At the community level, farmers and farmer groups take responsibility for the implementation of activities on their management units.

The Ghana Irrigation Policy (2011)[196]

The Ghana Irrigation Policy plans to achieve sustainable growth and enhanced performance of irrigation while contributing fully to the objectives of the Ghanaian agriculture sector. The policy has four objectives namely: i) accelerating the performance and growth in Ghana's agricultural land under irrigation; ii) removing current constraints on land and water resources to promote balanced socio-economic engagement in the water sector; iii) raising the environmental performance of all types of irrigation and related agricultural practices; and iv) enhancing services which extend cost-effective, demand-driven irrigation services to public and private irrigators through a series of economic incentives for farmer participation.

The target of the policy is to: i) improve national food security; ii) intensify and diversify production of agricultural commodities; iii) increase livelihood options; iv) optimise natural resource usage; v) reduce negative environmental impacts, and vi) expand investment space for irrigated production. The implementing units are the Ghana Irrigation Development Authority (GIDA) under the MOFA, the District Assemblies and the Water Resources Commission, working together with the Department of Cooperatives, the private sector, NGOs and farmer associations. The policy commits to decentralising irrigation services and encouraging private sector participation from individual farmers and commercial operators.

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[195] Essebey G.O, Nutsukpo D, Karbo N, and Zougmore R. 2015. National Climate-Smart Agriculture and Food Security Action Plan of Ghana (2016-2020). Working Paper 139. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: www.ccafs.cgair.org

[196] Ministry of Food and Agriculture. 2011. National Irrigation Policy, Strategies and Regulatory Measures. Available at: http://mofa.gov.gh/site/wp-content/uploads/2011/07/GHANA-IRRIGATION-DEVELOPMENT-POLICY1.pdf

5.7.1.2 Mainstreaming Adaptation

The past adaptation mainstreaming efforts mostly focused on incorporating them into the national development framework. Integrating adaptation into the national, sectoral and district plans is an essential first step. The next step is to make sure that the adaptation issues in the sectors and district plans are implemented. Since 2015, the NDPC, EPA, MESTI and other actors have embarked on continuous training of district assemblies on the mainstreaming of adaptation into their district plans. The training was on understanding the common physical and socio-economic vulnerabilities of the district and how to address them in the district medium-term plans (Table 68).

Table 68: Some Interventions to address the capacity gap for climate resilience building at the sub-national level

Name of Intervention	When/Institutions	Beneficiary	Funding Source	Strategic Intention
Climate change mainstreaming capacity needs assessment at the district level.	March 2018 EPA/NDPC/ICF	22 District Assemblies in the Western Region	USAID	Addressing climate change adaptation capacity gaps at the district level.
Training workshops to enhance institutional capacity to address climate change adaptation at the district level.	April 2018 EPA and ICF	About 100 officers (coordinating directors, planning officers, budget officers, engineers) from 22 district assemblies in the Western region	USAID/EPA (government of Ghana) co-funding	Addressing climate change adaptation capacity gaps at the subnational(district) level
Training workshops to enhance capacity for integration of climate change adaptation into environmental assessment processes at all levels.	July 2018 EPA and ICF	About 60 officers from the EPA.	USAID/EPA (government of Ghana) co-funding	Addressing capacity gaps of EPA officers for effective integration of climate change adaptation into environmental assessment processes in Ghana
Regional Road Show on Ghana's NDC under the Paris Agreement	September-October 2016 MESTI	681 participants[197] from Ashanti, Central and Eastern Regions.	UNDP/ Government of Ghana	Raising awareness of Ghanaians on Ghana's commitments under the Paris Agreement
Regional Road Show on Ghana's NDCs under the Paris Agreement	May 2016 MESTI	More 100 participants[198] from Northern, Upper East, and Upper West Region	UNDP/ Government of Ghana	Raising awareness of Ghanaians on Ghana's commitments under the Paris Agreement
Training of District Development Planning	September 2017 MESTI/NPDC	138 people participated[199] in the	UNDP/ Government of Ghana	Facilitate mainstreaming of NDCs in the

[197] Participants in the Southern Zone include: Regional Ministers, Regional /District Coordinating Directors (R/DCD), Metropolitan, Municipal and District Chief Executives (MMDCE), Members of the Eastern, Central and Ashanti Regional House of Chiefs comprising Paramount Chiefs, Queen Mothers and their attendants and sub-chiefs, Heads of Government Departments, Non-Governmental Organisations, Muslim and Christian Council members, Media, Security Personnel, Drivers, Staff of EPA Regional Offices, Registrars of House of Chiefs, Staff of Regional Coordinating councils.

[198] Same list of participants as 178

[199] The participants included District Coordinating Directors, District Planning Officers, District Budget Officers, District Engineers, District Finance/Procurement Officers, District Development Officers, EPA officials and some Regional Coordinating Council officials. The districts are Savelugu, Zabzugu and Bole districts in the Northern Region; Bawku Municipal, Bawku West, Bongo and Builsa South in the Upper East Region and Nandom, Nadowli and Sissala East in the Upper West Region. The first training took place in Tamale, second and third in Bolgatanga and Wa respectively.

Officers on the Use of the Checklist for Mainstreaming NDCs into National Development Plans		training programme from 10 adaptation Districts		formulation district plans.
Training of selected MDAs on climate finance tracking tool	Ministry of Finance/ISSER	Twenty-six people from 20 MDAs trained on the tools.	UNDP/ Government of Ghana	Support budgeting for climate change activities in their annual plan.
Training on Mainstreaming of Climate Change and Green Economy Related SDG Indicators into the National Development Plans	May 2018 MESTI	A total of 138 people participated in the training programme from 10 adaptation districts.	UNDP/UNEP	Support M & E of Climate Change and Green Economy Issues in the district planning

5.7.1.3 National adaptation planning

Adaptation planning is an integral component of the Ghana climate change strategy. Ghana has given considerable attention to climate change mainstreaming in the past. The current strategy is to focus on deepening the adaptation planning efforts and bringing on board the private sector. The section provides a concise overview of the GCF readiness support on national adaptation planning.

5.7.1.3.1 National adaptation plan framework

Ghana has initiated steps to undergo National Adaptation Planning (NAP) and seek funding from the GCF with support from UNEP. The NAP proposal has been submitted to the GCF secretariat awaiting approval of the board. Ghana's NAP aims to provide the enabling framework for the planning and implementation of adaptation actions highlighted in the NCCP, NCCAS and NDCs, all done within the context of sustainable development. Improving adaptation planning through the NAP process would help build local adaptive capacity to address climate change (SDG13), which would reduce poverty (SDG1), thereby enhancing livelihood opportunities (SDG1) and improving gender equality (SDG5). The purpose is to provide an overall framework to guide adaptation planning and implementation by clarifying the overarching vision and structure that would drive the NAP process. The NAP process seeks to promote community-based and ecosystem-based approaches and works to ensure that it delivers multiple co-benefits to sustainable development, poverty reduction and climate change adaptation[200]. The NAP framework describes the benefits of the NAP process in the context of Ghana while ensuring that the NAP does not unnecessarily contribute to the proliferation of planning processes and related documents. Specifically, the objectives of this NAP framework are to:

- Clarify Ghana's approach to its NAP process - This includes an articulation of the country's vision of climate change adaptation, its adaptation objectives and principles, the roles to be played by stakeholders within the national government, and priority adaptation actions to be undertaken. It also provides a reference point for bringing together various adaptation planning efforts from different sectors, sub-national structures, and scales of decision-making;
- Align the NAP process with existing policies, strategies and adaptation research;
- Identify specific themes that are particularly relevant and unique to the country context; and
- Serve as a basis for stakeholder engagement.

[200] MEST and EPA, 2018 - Ghana's National Adaptation Plan Framework

Private sector involvement in the NAP Process

The Private Investment for Enhanced Resilience (PIER) project has selected Ghana to receive technical assistance. The support would focus on NDC Private Sector Strategy; private sector engagement; and integrating climate risk into portfolio management by the private banks. The modalities of the PIER project are being worked out to firm up the scope and mode of delivery of the support. The NAP framework highlights the need to engage the private sector in the NAP process for the implementation of climate adaptation actions in the country.

5.7.2 Adaptation actions

5.7.2.1 Government flagship programmes that support climate adaptation

The government is implementing major development programmes that support the realisation of adaptation goals in the NCCP, NCCAS and the NDCs. These are One village One Dam (1V1D), One district one Warehouse (1D1W), Planting for Food and Jobs, Planting for Export and Rural Development and Rearing for Food and Jobs (Table 69).

Table 69: List of government flagship programme supporting adaptation in the NCCP, NCCAS and the NDC

Name of programme	Lead Ministry	Objectives	Scope	Achievements	Supporting adaptation area
One village on Dam (1VID)	Ministry of Special Development Initiatives[201]	Provide all-year availability of water for smallholder farmers in communities, particularly in the three northern regions	Construction of small dams and dugouts across communities of the three Northern Regions	Five Hundred Seventy small dams and dugout constructed or rehabilitated in Northern (310), Upper East (150) and Upper West (110) Regions in 2018	Building resilience vulnerable landscapes
One district one Warehouse (1D1W)		Reduce post-harvest losses among smallholder farmers across the country.	Constructing fifty[202] 1,000 metric tonnes warehouses across the country.	50,000 food storage capacity added in 2018	Minimising post-harvest loss
Planting for Food and Jobs (PFJ[203]). (2017- 2020) at an estimated cost of US$ 717.5 million	Ministry of Food and Agriculture	Enhance the productivity of crops of significance for food and feed in Ghana through integrated services on farming and marketing	Seed and fertiliser supply. Improved extension services.	Five hundred seventy-seven thousand farmers were supplied with subsidised fertilisers and seeds for the 2018 cropping season[204]. 183,000mt of fertilisers, 7,600mt of seeds and cassava planting	Promotion of conservation agriculture practices

[201] http://www.msdi.gov.gh/1D1A.html
[202] http://www.msdi.gov.gh/1D1W.html
[203] http://mofa.gov.gh/site/wp-content/uploads/2018/03/PFJ%20document%20New%20New.pdf
[204] https://www.mofep.gov.gh/sites/default/files/budget-statements/2019-Budget-Statement-and-Economic-Policy_.pdf

				materials were distributed. Improved extension service delivery. Two thousand seven hundred extensions, other and relevant staff are being recruited.	
Planting for export and rural development	Ministry of Food and Agriculture	Decentralise tree crop programme to promote rural economic growth and farmer incomes	Support to one million farmers in 170 districts with certified free planting materials to cover over one million hectares of farmlands and engage 10,000 young graduates as crop specialised extension officers.		Economic and incomes diversification
Rearing for Food and Jobs (RFJ)	Ministry of Food and Agriculture	To develop a competitive and more efficient livestock industry over the period 2019-2023	Breed improvement, Productivity, and production, Development of infrastructure, feed production and conservation of forage, animal health and disease control, development of communal grazing lands, commercialisation of livestock production and entrepreneurship development, and application of e-agriculture in livestock production.	So far, 53,500 livestock (sheep, pigs, cockerels and guinea fowls) have been distributed as at June 2019	Climate-smart livestock production

5.7.2.2 Cities and local actions

Cities and local governments are the hubs of climate actions now. Many of them are gearing up with innovative solutions to deal with climate issues in their jurisdiction and at the same time contributing to national efforts. Three significant initiatives stand out and are worthy of mentioning. These are: (a) Greater Accra Resilient and Integrated Development project (GARID); Local Climate Adaptive Living (LoCAL) project and C40 Partnership with Accra Metropolitan Assembly (Table 70).

Table 70: Selected adaptation-related interventions in the cities and location actions category

Project name	Institution	Funding	Funding agency	Objectives	Components	Supporting adaptation areas	Impacts
Greater Accra Resilient and Integrated Development Project (GARID- 2019-2025) [205]	Ministry of Works and Housing	US$ 200 million credit facility	World Bank/IDA	Improve flood risk management and solid waste management in the Odaw River Basin and improve access to necessary infrastructure and services in the targeted communities within the Basin.	Climate-resilient drainage and flood mitigation measures. Solid waste management capacity improvements Participatory Upgrading of Targeted Flood Prone Low-income communities, and Local Government	Flooding Building resilience cities and towns	The number of people protected by improved flood mitigation infrastructure. Number of people in targeted low-income communities with improved solid waste collection services
Local Climate Adaptive Living (LoCAL) project[206]	Ministry of Rural Development and Local Government		UN Capital Development Fund	Enables local governments to cope with the increased cost of building resilience against climate change and natural disasters.	Performance-based Climate Resilient grants with technical and capacity support	Mobilising adaptation funding	Delivered 2.3 million climate grants to 3 local governments
C40 Partnership with Accra Metropolitan Assembly	AMA		C40 Cities Initiative		Accra to develop a climate change action plan	Building resilience cities and towns	Adopted Accra Resilience strategy
GIZ/Alliance Develop Insurability Project[207]	AMA, Ga West, and the Ga East Municipal		BMZ and Allianz Climate Solutions GmbH (ACS)	Help municipalities make contingency plans to help reduce the impacts of anticipated hazards and disasters, including flooding.		Climate risk transfer	Contribute to addressing annual flooding in Accra

[205] Documents.worldbank.org/curated/en/548841552863167300/Project-Information-Document-Integrated-Safeguards-Data-Sheet-Greater-Accra-Resilient-and-Integrated-Development-Project-P164330
[206] https://www.uncdf.org/ghana
[207] http://www.ghananewsagency.org/social/stakeholders-meet-over-perennial-flood-disaster-in-district-assemblies-150757

5.7.2.3 Strengthening climate services

The Ghana Meteorological Agency is the lead institution in-charge of systematic observation and offers climate services to a wide range of multiple users. The data used for the climate projection analysis in this report was primarily sourced from GMet. Like many public institutions, GMet keeps working on improving the efficiency of meteorological stations across the country. The GMet focus has been on the modernisation and automation of weather observation stations. The GMet has improved data collection by recently procuring ten automatic weather stations to augment the available weather stations. This is meant to aid the Agency in receiving climate data in real-time for climate risk management decisions. Another significant initiative is the provision of location-specific climate data within every 4km radius in Ghana by merging satellite and gauge data. This was achieved through the Enhancing National Climate Services (ENACTS) initiative. Ghana is a partner to the Rainwatch Alliance.

Rainwatch (rainwatch-africa.org) is an open-access platform for rainfall monitoring which further provides useful information for decision making. The GMet has also improved on the dissemination of the forecast information they generate for multiple applications. It is worthy to note that GMet issues flood, drought, and Agromet bulletins to inform adaptation planning[208]. The Remote Sensing and Climate Center of the Ghana Space Science and Technology Institute[209] has been in partnership with the Ghana Meteorological Agency in engaging and training key science actors and, Agric Extension Agents to use climate information from the Rainwatch platform for climate risk management decisions and adaptation planning in the agricultural sector.

5.7.2.4 Enhancing early warning system /disaster risk management

Apart from enacting Act 927 in 2016 to strengthen the mandate to coordinate disaster related-activities, NADMO established a climate change and disaster risk reduction department. The new department is to see to the implementation of climate change and disaster risk reduction activities in the areas listed in Table 71.

Table 71: Early warning/disaster risk reduction initiative implemented by NADMO

Project name	Institution	Funding amount (US$)	Funding Agency	Objectives	Components or achievements	Supporting adaptation area
Community Resilience through Early Warning (CREW) project[210] (2013 – 2017)	NADMO	5,162,667	Norway via UNDP	Reduction of economic and human losses and damages from priority disasters; Establishment of adequate early warning and communication for priority hazards to reduce disaster risks in the ten pilot sites by 2016.	Developed multi-hazard Early warning system and EWS master plan to benefit roughly 6 million people. Early warning communication equipment has been installed at the NADMO HQ and in 20 subnational offices.	Early warning system to manage extreme events

[208] http://www.meteo.gov.gh/website/
[209] https://gssti.gaecgh.org/remote-sensing-gis-and-climate-centre/
[210] http://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/crew.html

					Floods and droughts, hazards, vulnerability and risk maps at current (2010) and future scenarios (2050) have been developed for the country and the ten pilot districts.	
Promoting Integrated Climate Risk Management and Transfer (ICRM) (2015 to 2019)	NADMO Ministry of Finance	Unknown	German Government via GIZ	Put climate risk management strategy in place to protect smallholders and commercial agribusinesses against the financial risks associated with an extreme weather event.	Appropriate agricultural practices for adaptation. Africa Climate Insurance	Risk transfer associated extreme event (drought and flooding)

The Water Resources Commission is also involved in the early warning and disaster reduction efforts. During the period under review, the commission has implemented projects in the areas listed in Table 72.

Table 72: Early warning/disaster risk reduction initiative implemented by the Water Resources Commission

Name of Initiative	Implementing organisation(s)	Time Frame	Sponsor of Initiative	Amount (US$)	Scope of Initiative	Objectives	Main Outcomes / Impacts	Main tools used	Beneficiaries	Supporting Adaptation Area
Flood recession agriculture for food security in the white Volta River Basin	HSD	June 2016 – December 2016	International Water Management Institute	Unknown	White Volta Basin in the Northern Region	Supervision of gauge readers. Validate, digitise and transmit gauge values.	Monitored and transmitted accurate data during the 2016 flood season. Trained and supervised gauge readers.	Training	Data collection professionals	Building resilience in the vulnerable landscape
Flood Hazard Assessment	WRC, UNDP, NADMO, HSD, and GMet	2010 - 2012	World Bank	1 million	White Volta Basin	Flood hazard assessment of the White Volta Basin	Flood Hazard maps	Hydrological models	Vulnerable communities within the basin	Early warning system
Disaster risk management	WRC, UNDP, NADMO, HSD and GMET	2014 - 2016	World Bank Global facility for disaster reduction and recovery	1.3 million	White Volta Basin	Development risk management procedure and services for the White Volta	Development of flood early warning system for the white Volta. Development of flood risk maps. Flood forecasting model.	Training Hydrological Models	Vulnerable communities	Early warning system
OTI flood hazard assessment	WRC, UNDP, NADMO, HSD, and GMet	2016 - 2017	World Bank	1.2 million	OTI Basin		Development of flood maps. Flood Early Warning system developed	Hydrological models	Communities within the OTI Basin	Early warning system (flood)
Improved the resiliency of crops to drought through strengthened early warning within Ghana.	WRC, GMet	2016 - 2017	Climate Technology Centre and Network (CTCN)[211]	250,000	White Volta	Drought Early Warning system enhance data accessibility, climate forecasting, and adaptation planning and communication	Online Portal for climate data. Drought and Flood forecast system	Hydrological models, Training	Communities within the White Volta Basin. Improving the resiliency of crops to drought through strengthened early warning within Ghana.	Early warning system (drought)

[211] https://www.ctc-n.org/content/improving-resiliency-crops-drought-through-strengthened-early-warning-within-ghana

5.7.2.5 Building resilience in climate-vulnerable landscapes

Landscapes provide critical support to ecology, rural livelihood and the national economy. Climate change can negatively affect landscape vitality. It can compromise the quality of ecosystem services for the people that derived their livelihoods from it. The savannah and transitional ecosystem and the people that live there are the most vulnerable to climate change. It is because the livelihoods of most people living in the savannah and transitional ecological zones are intricately linked to the climate. So, any significant change in the prevailing climate can cause severe disruption to the way they live. In this regard, significant attention has been given to the savannah and transitional zones when it comes to climate change adaptation interventions. The summary of the interventions is listed in Table 73.

Table 73: Climate adaptation investments in climate-vulnerable landscapes

Project name	Institution	Funding / Funding Agency	Objectives/Scope/Location	Components	Supporting adaptation area and results
Sustainable Land and Water Management Project (SLWMP)	MESTI, MoFA FC and EPA	US$ 44,000,000 (2011–2020) GEF via World Bank	Demonstrate improved sustainable land and water management practices aimed at reducing land degradation and enhancing the maintenance of biodiversity in selected micro-watersheds. Twelve districts in Upper East, Upper West, and Northern Regions.	Tree plantation. Input supply. Extension services. Promotion of SLM technologies. Watershed management. Village saving schemes. Payment of Environmental Services.	More than 10,000 farmers benefited Strengthening the resilience of smallholder farmers
Increased Resilience to Climate Change in Northern Ghana through the Management of Water Resources and Diversification of Livelihoods	MESTI, WRC, EPA	US$ 8,293,972 (2015-2020) Adaptation fund via UNDP	Enhance the resilience and adaptive capacity of rural livelihoods to climate change impacts, and threats to water resources in the northern regions of Ghana. Ten districts[212], across the Upper East, Upper West and Northern regions.	Improve water access in these regions. Increase the institutional capacity for climate-resilient management of surface and groundwater. Diversify the livelihoods of rural communities[213].	Strengthening the resilience of smallholder farmers
Adaptation of Agro-Ecosystems to	Ministry of Food and Agriculture	US$ 3,900,000 (2012–2017)	Reduce climate-related crop losses in the savanna and transitional regions of Ghana through pilot measures.	Develop climate-smart farming systems. Deliver climate-smart extension services; Adopting climate-smart policies	Planted drought-resistant maize varieties in demonstration plots in the 16 pilot communities.

[212] Builsa, Bongo, Bawku West, Bawku, Sissala East, Lawra, Nadowli, Bole, Zabzugu-Tatale and Savelugu.

[213] UNDP 2015. The Increased Resilience to Climate Change in Northern Ghana through the Management Water Resources and Diversification of Livelihoods project proposal. Adaptation Fund. Washington DC. USA. Available at: https://www.adaptation-fund.org/wp-content/uploads/2015/09/RESUBMISSION_Ghana-AF_proposal_-29-January-2015.pdf

Climate Change (AAESCC)		German Federal Ministry for Economic Cooperation via GIZ	Sixteen communities in eight districts of the Brong-Ahafo and Northern regions.		Six hundred farmers – 300 in each region – receive weather forecasts by mobile phone, which has improved their ability to manage and plan agricultural activities. GMet being equipped with automatic weather stations in the eight project districts, which has improved weather forecasting for the region.
Climate Change Adaptation in Northern Ghana Enhanced[214] (CHANGE)	Regional Advisory and Information Network Systems. Trade Aid Integrated. Tumu Deanery Regional Integrated Development Programme.	US$ 3,000,000 2013–2015 Government of Canada via the Department of Foreign Affairs, Trade and Development (DFATD).	Assist smallholder farmers in improving their adaptive capacity and in building their resilience to the impacts of climate change on agriculture, food security and livelihoods 17 communities in Savelugu-Nanton, Bolgatanga, Sissala East Districts in the Northern, Upper East, and Upper West regions	CSA agricultural practices and conservation agriculture. Sustainable soil and water management practices. Effective use of agriculture data. Storage and prevention of post-harvest losses	100% of FBO leaders reported an increased understanding of climate change. About 95% of farmers attended at least one training module. 93% – 66% female – of farmers tested one or more CSA method, far exceeding the target of 75%. 95% – 66% female – of farmers who implemented CSA strategies reported increased agricultural productivity[215].
Innovative Insurance Products for the Adaptation to Climate Change (IIPACC)	National Insurance Commission	€3,832,000. German Federal Ministry of Environment, Nature Conservation and Nuclear Safety via GIZ. 2009–2014[216]	Support the development of sustainable agricultural insurance system by introducing demand-orientated crop insurance products to protect against financial risks caused by extreme weather events, and other forms of climate change.	Drought index insurance product for maize, soya and sorghum farmers. An area-yield-index product was introduced in three pilot districts for smallholder farmers. The multiple-peril crop insurance product was introduced for commercial farmers	Agricultural insurance solutions for farmers in Upper East, Upper West, and Northern Regions.

[214] Canadian Feed the Children. 2015. Change project stakeholder learning forum: Project Wrap-Up Summary. Available at: http://www.canadianfeedthechildren.ca/downloads-projects/CHANGE-Project-Summary-of-Results.pdf.
[215] Canadian Feed the Children. 2015. Change project stakeholder learning forum: Project Wrap-Up Summary. Available at: http://www.canadianfeedthechildren.ca/downloads-projects/CHANGE-Project-Summary-of-Results.pdf.
[216] Gille S. 2013. The case of Ghana – Innovative insurance products for the adaptation to climate change. MCII-GIZ Workshop, Bonn. Available at: http://www.climate-insurance.org/fileadmin/mcii/documents/20130411_MCII-GIZ_Workshop_SGille.pdf

Ghana Agricultural Sector Investment Programme (GASIP);[217]	MoFA	IFAD loan of US$ 71.6 million Adaptation for Smallholder Agriculture Programme grant of US$10 million 2015–2020 – first two cycles of three years each, more are planned in the long-term, (US$113 million)	Agribusiness, including smallholders, has enhanced its profitability and climate change resilience. Nation-wide	Value chain development Rural value chain infrastructure. Knowledge management, harmonisation and policy support[218].	Contribute to sustainable poverty reduction in rural Ghana
Support Transition Towards Climate-Smart Agriculture Food Systems	FAO	(2015–2016), Government of Norway	Ensure food security by improving smallholder farmers' resilience to climate change-induced hazards	Assist Ghana to create the required policy and economic environment for CSA. Provide smallholder farmers with access to resources and knowledge to implement CSA. Engage stakeholders to encourage the uptake of CSA practices[219].	Facilitated the scaling up of climate-smart agriculture (CSA) in Ghana
Towards Pro-poor REDD+ Project	IUCN ARocha Codesult Network	Phase 1: 2009–2012 with US$4,610,960, Phase 2: 2013–2016 with US$4,610,960, DANIDA)[220] Ghana, Cameroon, Uganda, Indonesia and Guatemala	Communities are surrounding Mole National Park. Wassa Amenfi forests	Pilot and assess pro-poor benefit-sharing mechanisms for performance-based REDD+. Identify and promote policy and institutional arrangements required to deliver performance-based payments equitably and efficiently for REDD+ activities. Generate and promoting lessons about the design and implementation of pro-poor REDD+ benefit-sharing mechanisms.	Improved adaptation planning

[217] IFAD. 2015. GASIP Fact Sheet. Available at: https://www.ifad.org/topic/resource/factsheet.
[218] Programme Management Department. 2014. Ghana Agricultural Sector Investment Programme (GASIP) Design Report.
[219] FAO. 2016. FAO Project list. Available at: http://www.fao.org/ghana/programmes-and-projects/project-list/en/
[220] The REDD desk. 2017. IUCN towards pro-poor REDD+ project. Available at: http://theredddesk.org/countries/initiatives/iucn-towards-pro-poor-redd-project.

Promoting a value chain approach to climate change adaptation in agriculture in Ghana	MoFA by the Roots and Tubers Improvement and Marketing Programme (IFAD Project)[221].	GEF SCCF Grant US$2.5 million, IFAD loan. US$8.5 million, Government of Ghana. US$0.3 million and US$0.2 million as beneficiary contribution	Reduce climate-induced risks to the cassava value chain; Achieve food security, and generate income for rural pilot communities in Ghana[222]. Ashanti, Brong-Ahafo, Northern and Volta regions	Awareness-raising on climate change and capacity building to address its impacts along the cassava chain; Support adaptation to climate change in cassava production; Promote innovative adaptation solutions along agricultural value chains.	Targeted individuals and groups of women, men and youth living in remote rural areas who are involved in cassava processing, production, and marketing activities.
Resilient Landscapes for Sustainable Livelihoods (RLSL) [223]	MoFA	US$ 3,360,000 (2013–2016) via UNDP, FAO, and WFP	Develop the capacity of national and local institutions; Strengthen the resilience of districts and communities in northern Ghana to climate change and disaster risks through the development, and Implement sustainable land management approaches Ten communities in the three northern regions of Ghana – Northern, Upper East, and Eastern.	The social component involved the development of community cooperatives. Technical component focused primarily on agricultural practices and interventions and the establishment of community-based seed production units to supply rural farmers with farming inputs; and iii) the training of rural farmers on Sustainable Land and Water Management interventions. The financial component involved the establishment of revolving funds to assist with the provision of farming inputs and diversification into additional livelihood activities.	Building the resilience of vulnerable farmers
Water, Climate and Development Project (WACDEP)	African Ministers Council on Water the Ghana Water Partnership and the Volta Basin Authority [224].	Austrian Development Cooperation, DANIDA; United Kingdom; and other Global Water Partnership financing partners. US$17.8 million. 2011–2016,	Integration of water security and climate resilience in development planning processes. West Gonja district - Northern Region – and in the Bakwu and Binduri districts – Upper East Region.	Investments in regional and national development. Innovative green solutions. Knowledge and capacity development Partnership and sustainability	WACDEP promoted water as a key part of sustainable regional and national development and contributed to climate change adaptation for economic growth and human security.

[221] GEF. 2016. Promoting value chain approach to adaptation in agriculture. Available at: https://www.thegef.org/project/promoting-value-chain-approach-adaptation-agriculture.
[222] IFAD. 2015. Ghana: Promoting a value chain approach to climate change adaptation in agriculture in Ghana. Available at: https://www.ifad.org/documents/10180/b0c49e3d-5d00-454d-9d40-c78f79f5150b.
[223] Ministry of Food and Agriculture. 2012. Resilient Landscapes for Sustainable Livelihoods Project Proposal.
[224] Global Water Partnership. 2011. WACDEP Flyer. Available at: http://www.gwp.org/WACDEP.

5.7.2.6 Coastal protection

Coastal protection is a major adaptation intervention Ghana is pursuing to safeguard the integrity of the shoreline from climate-induced sea erosion. They are built parallel to the shore and aim to hold or prevent sliding of the soil while protecting from wave action. Several Sea defence projects have been initiated and are at various stages of development. Five of them are on-going, three have been completed, and four have been planned[225](Table 74).

Table 74: Coastal protection projects in Ghana

Name of Initiative	Implementing organisation	Time Frame	Status	Sponsor	Amount (Currency)	Scope of Initiative	Objectives	Major Impacts
New Takoradi SDP[226]	HSD	2016 – 2018	ongoing	Mostly GoG*	35m (US$)	Protection of beaches and environs against encroachment by the sea	Construction of sea defence systems for the coastal areas of the country to preserve lives. Protect communities that suffer the rage of the sea periodically.	Initial findings completed and main construction to begin
Adjua	Amandi	2016	ongoing	Mostly GoG	51 m (US$)			Reclaimed 15km of coastal bed
Aboadze	Messrs Xara Developers	2016	ongoing	Mostly GoG	28.5m (US$)			
Ada SDP[227]	Dredging International and International	2013 - 2016	ongoing	Mostly GoG	183.4m (€) / 240[228]m (€)			Reclaimed 15 km of coastal bed lost along the Atlantic Ocean
Axim Coastal Protection Works - Western Region	Makam Plant Hire Ltd	2019	ongoing	Mostly GoG				
Keta Sea Defence Project			Completed		US$52m			Protected three communities
Sakumono Sea Defence Project	Amandi Holding Limited	2015	completed	Mostly GoG	60 m	A gravity wall of length 550m and construction of two groynes of length 70 metres.	Protect the Sakumono coastal stretch belt	5,000 m stretch

* GoG - Government of Ghana

[225] Amanful Kumar Coastal Protection works, Dixcove Coastal Protection Works, Komenda Coastal Protection Works and Nkontompo Coastal Protection Works (Phase 2) - Western Region

[226] SDP – Sea Defence Project

[227] http://www.ghana.gov.gh/index.php/media-center/news/2377-ada-sea-defence-project-completed, https://www.graphic.com.gh/news/general-news/work-on-240-million-ada-coastal-protection-project-completed.html

[228] Value for the two-phase project

5.7.2.7 Irrigation development

Ghana has 136,000 km^2 agricultural lands of which 58,000 km^2 is under cultivation and 11,000 hectares under irrigation[229]. Agriculture in Ghana is dominated by small-scale farms. About 60% of all farms in the country are less than 1.2 hectares in size, 25% are between 1.2 to 2.0 hectares, with 15 % above 2.0 hectares. There are about 3 million smallholder farmers, with an average farm size between 0.5 and 2 hectares and produce 95 per cent of the country's food crops[230]. Smallholder farming is primarily rain-fed, using traditional, subsistence methods. It exposes the smallholder farmers to significant climate risk when seasonal changes and droughts occur.

The use of irrigation technology, although currently not widespread, has a vital role to play in reducing the climate-induced vulnerability and improving production. Therefore, having access to water throughout the year for farming is a critical adaptation intervention. Ghana Irrigation Development Authority (GIDA) under the Ministry of Food and Agriculture has the mandate to formulate, develop and implement irrigation and drainage plans for all-year-round agriculture production in a sustainable environment. GIDA does so by "identifying possible irrigation projects, and in some instances involved in the management and maintenance of irrigation schemes"[231]. Furthermore, GIDA plays a significant role in the implementation of the Ghana Irrigation Development Strategy and the master plan. Below are some of the achievements from the implementation of policy and the master plan:

- Twenty-two Irrigation Projects all over the country constructed by GIDA covering a total of 6,505 hectares.
- An additional 22 schemes have been constructed under the Small-scale Irrigation Development Project (SSIDP) and six schemes under the Small Farms Irrigation Project (SFIP). Each of these projects is less than 1,000 ha in size except the Tono and Kpong Irrigation Projects, which have about 2,500 ha.
- Thirteen irrigation schemes have been completed, increasing the irrigable area by 325 hectares, out of 44,490 hectares.
- Two Hundred and Eighty irrigation farmers trained in the management of irrigation systems.
- Phase I of the rehabilitation of the Tono Irrigation Scheme is completed. It involved 25,870 metres of left branch canal, 12,880 metres of the right branch and 1,800 metres of infill canals. Farmers are already cropping.
- Draft feasibility studies for the entire 200,000 hectares and detailed design for 5,000 hectares completed.
- A total of 897 pump sets and 266 sprinkler sets have been distributed to all ten regions of Ghana, and installation of the same is on-going.
- Rehabilitation of 3,000 ha of the Kpong Right Bank Irrigation Project and the extension of new irrigation infrastructure and services to a proposed additional 8,000 hectares under the New Development Irrigation Scheme (NDIS) is underway232. This US$ 90 million initiative is part of the Accra Plains Irrigation Project.

[229] http://www.fao.org/ghana/fao-in-ghana/ghana-at-a-glance/en/
[230] http://www.fao.org/3/a-i4158e.pdf
[231] http://mofa.gov.gh/site/?page_id=2976
[232] http://www.ppp.mofep.gov.gh/project/78/accra-plains-irrigation-project

5.7.2.8 Climate change adaptation research and skills development

The Council for Industrial and Scientific Research (CSIR) and the Universities are involved in different aspects of adaptation research. The research focuses on broad themes such as (a) development of improved seeds; (b) climate change and population dynamics; (c) climate change impacts on agriculture and water. They are also training students at the graduate and postgraduate levels. Table 75 presents some selected climate change adaptation research in the country.

Table 75: List of climate change adaptation research works in Ghana

Research Projects	Objective	Recipient Institution	Location /scope	Funding	Time frame	Outputs	Targets/ Outcomes
DEltas, vulnerability and Climate Change: Migration and Adaptation (DECCMA)	Assess migration as an adaptation in deltaic environments	RIPS, University of Ghana, Legon	Volta delta. Ketu South, Ketu North, Keta Municipality, South Tongu, Central Tongu, Ada East, Ada West, Ningo Prampram and Akatsi South.	CAD 1,000,000 from IDRC	2014-2018	Formation of a National Expert Advisory Group.Used Unmanned Aerial Vehicles (UAVs) / drones to provide visual evidence of coastal erosion and flooding at Fuvemeh, communities in Keta.	Scholarship for PhD students. Publications in journals
Cities and Climate Change	Improve the management of flood risks and enhance resilience in Accra's readiness for future floods by developing an integrated climate-smart flood management framework and catalysing evidence-based policy action.	RIPS, University of Ghana, Legon	Selected districts in the Greater Accra Region[233]	CAD 1,000,000	2016-2019	Community Scoping and Sensitization on Flooding and Climate Change. Understanding State Institutions and Flood Management	
Building Research Capacity for sustainable water and food security in drylands of sub-Saharan Africa (BRECcIA)	Develop research capacity across institutions that are self-sustaining and focused on improving food and water security for the poorest of society.	RIPS, University of Ghana, Legon	Drylands in Ghana (Northern part of Ghana)	£5.4 Million Global Challenges Research Fund (GCRF)	2017-2021		Dryland communities in northern Ghana
Building Capacity to Meet the Climate	Develop the University of Ghana as a centre of	The University of Ghana and	Academic development	Unknown	On-going	Introduced Masters course in	Graduate and Post-graduate training

[233] Greater Accra Metropolitan Area; Adentan Municipal Assembly; Accra Metropolitan Assembly; Ashaiman Municipal Assembly; Kpone Katamanso Municipal Assembly; La Dade Kotopon Municipal Assembly; Ledzokuku Krowor Municipal Assembly and Tema Metropolitan Assembly

Change Challenge (B4C-Ghana)	excellence in global environmental change, with capabilities to contribute effectively to Ghana's ability to adapt to climate change by building training and research capacity in the long-term.	includes the Ghana Wildlife Society and Centre for African Wetlands		Open Society		Climate Change and Sustainable Development Trained three batches (16 students) of graduate students in climate change	Established Centre for climate change and sustainability studies at the University of Ghana, Legon
Building climate-resilience into basin water management	Adopt an interdisciplinary and cross-disciplinary approach to studying the trade-offs among climate, land use and socio-economic changes in Water Resource Management in two key river basins in Ghana.	Water Research Institute	Pra and Densu Basins	11,998,167 DKK Danish Government	2019-2024	Not yet	Not yet
Building Stronger Universities: Environment and Climate Change Platform Building Stronger Universities, Phase III 2017-2021	Environment and climate change theme of the Project	University of Ghana and KNUST	Academic Development	KNUST – 13 million DKK UG - 13 million DKK DANIDA	On-going	Not yet	Not yet
Climate Smart Cocoa Systems for Ghana (CLIMCOCOA)	Develop a comprehensive understanding of the impacts of climate change on the socio-biophysical bases of cocoa systems in Ghana, and assess the role of agroforestry as a model for climate-smart agriculture in Ghana	Geography Department University of Ghana, Legon	Academic and Knowledge Development	9.99 million DKK DANIDA	On-going	Not yet	Include 3 PhD. Students and one post-doctoral training.

5.8 Enabling Implementation of Adaptation Actions in Ghana

5.8.1 Mobilising Adaptation Finance

Funding for adaptation actions come from the national government and development partners. The government allocates funds for adaptation-related investments through the national budget. Additional funding comes from different donor countries and organisations. Currently, Ghana has developed two adaptation-specific projects on the resilience landscape and the national adaptation plan for funding from the Green Climate Fund. Both projects have been submitted to the secretariat and are waiting for investment decisions by the board.

5.8.2 Removing Barriers for Adaptation in Ghana

Even though Ghana's development policies and strategies address climate change issues, there are significant barriers that hinder the widespread adoption of climate change adaptation technologies and practices. The barriers have retarded the potential of past and ongoing adaptation efforts to elicit transformational change toward building a resilient society. Therefore, to build the climate-resilience of vulnerable communities sustainably, these barriers and ways to overcome them should be explicitly considered during the design of adaptation interventions. Some of the barriers identified through interviews and literature review are in Table 76

Table 76: Barriers to adaptation measures in Ghana

Barrier	Description of issues	Efforts to address barriers
Limited institutional and technical capacity	Limited institutional capacity within the Government to effectively strengthen climate-resilience on the ground. It is particularly pertinent at the regional and district levels, where limited coordination and collaboration between sectors of government prevents the effective management of adaptation interventions. Government staff is not adequately trained to integrate climate change adaptation into local development planning and to coordinate the implementation of interventions. Often too few extension officers to adequately cover a district, limiting their ability to interact effectively and transfer information to the communities they serve.	Reviving the District and Regional Environmental Management Committees Recruitment of extension service officer PFJ[234] Continue training of district assembly staff. Refer to table 13.
Limited integration of climate change adaptation into district development planning.	District and community development plans do not consider climate change impacts and do not include provisions for the implementation of climate change adaptation. Districts and communities do not receive support for the design and implementation of locally appropriate climate change adaptation interventions.	Continue training of district assembly staff. Refer to Table 13. LoCAL project (Table 15) encourages district assemblies to address climate change by providing performance-based climate-resilient grants with technical and capacity support.
Limited spatial and population coverage of climate change adaptation projects	Climate change adaptation projects in Ghana have generally been focused within a limited geographic area and target a limited number of target communities. It is mainly due to inadequate access to additional funding to expand initiatives, relying mostly on donor funding with limited local investment.	Incorporate adaptation projects into the mainstream operations of government to ensure long-term sustainability and upscaling of project outcomes. The management model of the SLWM project is a

[234] Government Recruits 1,000 Agric Extension Officers -To Support 'Planting for Food and Jobs' Policy. http://www.peacefmonline.com/pages/local/news/201702/307280.php

	The limited geographic extent and population coverage of the interventions restrict the spread of adaptation technologies across Ghana and therefore inhibit transformational change.	classic example of de-projectisation of adaptation measures.
Low private sector participation	Adaptation is considered a risky venture because it is tilted towards addressing border social outcomes rather than profits. The private sector tends to shy away from investing in adaptation actions.	Private Investment for Enhanced Resilience (PIER) would explore ways to attract the private sector into adaptation.

Other information

Source: Lake Bomsumtwi in Ghana. Picture by Kobe Subramaniam on Unsplash

6. Climate Technology Development and Transfer in Ghana

Reporting on climate technology development and transfer in the NC4 covers a wide range of topics. It presents new updates of the information in the NC3 in three ways. Firstly, when no further substantial information on climate technology is available, the text in the NC3 is still considered relevant, then the report captures a regurgitative summary. Secondly, where there are gaps in the previous report, new information is presented to fill them to make it complete.

Finally, NC4 also captures newly discovered information and recent developments as updates. The chapter starts with updates on technology needs assessment. It covers information on the progress of implementing the previous technology assessments and areas that need additional effort in the wake of the NDC.

The next section is on information on the efforts to enable climate technology transfer and diffusion in Ghana, the challenges and the opportunities to enhance NDC technology penetration. In this regard, the report has given a broad overview of the NDC technologies and the strategies Ghana is implementing to advance climate technology solutions and to remove the barriers impeding greater adoption. Furthermore, the report highlights the mechanism for climate technology transfer in Ghana. It provides information on the various models for facilitating climate technology exchanges in the country.

6.1 Technology Needs Assessment

Ghana has conducted two Technology Needs Assessments (TNA) in 2003[235] and 2013[236]. Both assessments produced priority mitigation and adaptation technologies for tackling climate change. The 2003 exercise was the first-generation assessment that highlighted critical mitigation technology options in the energy and waste sectors. On the other hand, the 2013 TNA focused on adaptation technologies in the water and agriculture sectors. Even though the EPA carried out the two assessments with different lenses, the approach followed a similar style. In the two TNAs, national stakeholders and experts were involved in the consultation to identify and prioritise the technology portfolios using a set of nationally agreed criteria on climate protection.

Apart from the fact that the 2013 TNA was on adaptation, it also sought to build on the best practices of the 2003 TNA despite the decade long lag. It was also a way to ensure the completeness of the technology package since the 2003 TNA was limited to mitigation options. However, some of the identified technologies in both assessments did not make it to the final priority list. Table 77 presents the top priority technology options 2003 TNA. The options that were mentioned in the stakeholder identification process but not selected were consistent with the 2003 TNA list. Most of the technologies are also consistent with the National Climate Change Policy, National Energy Policy. The 2013 TNA is the most current version in Ghana (Table 78). It is nearly seven years old and needs to be updated to reflect the current technology status of the country.

[235] http://www.un-gsp.org/sites/default/files/documents/ghana_tna.pdf

[236] https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2013/12/technologyneedsassessmentreport-ghana-13.pdf

Table 77: Climate technology options identified in 2003 TNA and the links with policy

Priority technology portfolios	2003 TNA	Policy aligned	Comments
Biofuels	x		
Industrial energy efficiency improvement	x	x	Consistent with Ghana's NDCs[237]
Energy efficiency lighting	x	x	Aligns with 12 prioritised NAMAs[238] and Ghana's NDCs, strategic national energy plan[239]
Solar PVs	x	x	Aligns with Ghana's SEforALL Action Plan[240]; 12 prioritised NAMAs, renewable energy master plan[241], strategic national energy plan and Ghana's NDCs, internationally transferred mitigation outcomes (ITMOs)[242],
Natural gas combined cycle and Natural gas distribution system	x	x	The technology aligns with Ghana's NDCs, national gas master plan.[243]
Management technologies and efficiency improvement in transport sub-sector or BRT	x	x	The technology aligns with Ghana's NDCs, national transport policy.
Wind Energy	x		The technology aligns with Ghana's NDCs, renewable energy master plan, strategic national energy plan, scaling up of renewable energy penetration investment plan (SREP-IP).[244]
Solar water heater	x	x	Renewable energy master plan, strategic national energy plan, Ghana's SEforALL Action Plan, SREP-IP
Small and mini-hydro	x		The technology aligns with the renewable energy master plan, strategic national energy plan, SEforALL Action Plan, SREP-IP and NDCs.
Biomass for power generation (co-generation from sawmill residues)	x		The technology aligns with the renewable energy master plan, SEforALL Action Plan.
Landfill methane gas capture for power generation	x	x	The technology aligns with Ghana's NDCs, renewable energy master plan.
Anaerobic and CH_4 generation technologies for wastewater handling (Biogas technologies)	x	x	The technology aligns with Ghana's SEforALL Action Plan, 12 prioritised NAMAs, renewable energy master plan and Ghana's NDCs.
Incineration	x	x	
LPG and improved stoves		x	Aligns with Ghana's SEforALL Action Plan, strategic national energy plan, LPG promotion policy, renewable energy master plan, national gas master plan, clean development mechanism (CDM), NDCs, and ITMOs.
Efficient fridges		x	Strategic national energy plan and the NDCs.

[237] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf
[238] https://www.pef.org.gh/documents/Ghana%20NAMA%20Investor%20Guide_final_web.pdf
[239] http://www.energycom.gov.gh/files/SNEP%20Demand%20Oct2019_SNEP2030_Final.pdf
[240] http://energycom.gov.gh/files/SE4ALL-GHANA%20ACTION%20PLAN.pdf
[241] http://www.energycom.gov.gh/files/Renewable-Energy-Masterplan-February-2019.pdf
[242] https://www.international.klik.ch/en/Activities-and-impact/Mitigation-activities.287.html
[243] https://www.thegasconsortium.com/documents/GMP-Final-Jun16.pdf
[244] https://www.climateinvestmentfunds.org/sites/cif_enc/files/srep_13_4_srep_investment_plan_for_ghana_0.pdf

Similarly, the top technology lists in the 2013 TNA aligns with the National Climate Change Policy[245], National Climate Change Adaptation Strategy[246], National Disaster Management Plan[247], Nationally Determined Contribution and the Strategic Medium-term Development Plan for the Ministry of Works and Housing[248]. Some of the sectoral policies covering the selected technologies are consistent with include: Planting for Food and Jobs; Food and Agriculture Sector Development Policy II, National Water Policy and the National Climate-Smart Agriculture Action Plan. Table 78 presents the top five list of adaptation technology options and the linkages with relevant policy documents.

Table 78: Climate technology options identified in 2013 TNA and the links with policy

Priority technology portfolios	Sector	2013 TNA	Policy aligned	Comments
Rainwater collection from ground surfaces	Water	x	x	The technology aligns with the national water policy[249]
Post-construction support for community-managed water systems	Water	x	x	The technology aligns with the national water policy
Improving the resilience of protected wells to flooding	Water	x	x	The technology aligns with the national water policy
Demarcation and protection of buffer zones for water bodies	Water	x	x	The technology aligns with the riparian buffer zone policy[250]
Rainwater harvesting from roofs	Water	x	x	The technology aligns with the national water policy
Community-based extension model	Agriculture	x	x	The technology aligns with Ghana's NDC, planting for food and jobs, with the climate-smart agriculture action plan.
Water user associations	Agriculture	x		
Integrated soil nutrient management	Agriculture	x		The technology aligns with the Food and Agriculture sector development policy II and the climate-smart agriculture action plan.
Ecological pest management	Agriculture	x	x	The technology aligns with the climate-smart agriculture action plan, Ghana's NDCs.
Seed and grain storage	Agriculture	x	x	Aligns with Ghana's NDC, planting for food and jobs (one district one warehouse programme).

Table 79 presents the key barriers associated with the priority technology options ranging from technical to economic constraints.

245 https://www.un-page.org/files/public/ghanaclimatechangepolicy.pdf

246 https://www.adaptation-undp.org/sites/default/files/downloads/ghana_national_climate_change_adaptation_strategy_nccas.pdf

247 http://nadmo.gov.gh/images/NADMO_documents/2015_documents/Disaster%20Magt%20Plan.pdf

248 https://www.mwh.gov.gh/wp-content/uploads/2018/05/SECTOR-MEDIUM-TERM-DEVELOPMENT-PLAN-2018-2021.pdf

249 https://www.gwcl.com.gh/national_water_policy.pdf

250 http://www.wrc-gh.org/documents/acts-and-regulations/

Table 79: Prioritised adaptation technology options and key barriers

Sector	Technology Portfolio	Technology Description	The target of technology diffusion	Scale/estimated Cost (US$)	Technical and Economic Barriers	Comments
Water	Rainwater collection from ground surfaces (RCS).	Collection, storage and use of rainfall that lands on the ground as opposed to collection from roofs with the intention for multi-purpose use in the communities. In many water-poor areas, small-scale runoff collection infrastructure can contribute significantly to the volume of freshwater available for human consumption and other versatile applications.	Addresses insufficiency of water to support livelihoods of rural communities resulting in poor community health and poor school attendance, particularly for the girl-child	Water-poor communities in Savannah areas and Afram Plains. US$ 6,000,000	High construction and maintenance cost. The high cost of feasibility. Few technicians and artisans to undertake construction and maintenance of water systems. High production and import cost. Inadequate government incentives. Policy uncertainty.	Contained in TAP & PIR. It was selected using consultative MCA. Technology diffusion is projected to take ten years.
	Post-construction support for community-managed water systems (PCS).	Facilitates community ownership, management and maintenance of water systems promotes women participation in their management and improves system performance and sustainability.	Increasing the success and sustainability of community-managed water systems through existing government initiatives.	500 communities nation-wide. US$ 8,500,000	Inadequacy of funds available to communities for emergency repairs and general maintenance of their water systems.	Contained in TAP & PIR. It was selected using consultative MCA.
Agriculture	Integrated Nutrient Management (INM)	Make efficient use of both synthetic and natural plant nutrient sources to enhance soil fertility towards improving and preserving soil productivity.	Appropriate application and conservation of nutrients and transfer of knowledge to farmers.	Pilot in selected farming communities nation-wide (100, 000 farmers) US$ 9,300,000	The high cost of credit. Low farmer income. Inadequate availability of technical information and low access to extension services to end-users of the technology.	Contained in TAP & PIR. Selected using consultative MCA
	Community-Based Extension Agent (CBEA)	Provide specialised and intensive technical training to identified people in rural communities to promote a variety of technologies and offer professional services with support and review from an extension organisation	Training of service providers in climate data collection, analysis and dissemination within their areas of operation to enable communities to select appropriate response strategies.	Pilot in 500 farming communities nation-wide US$ 4,200,000	Lack of motivation for available personnel. Lack of budgetary allocation to support CBEA because it is not an integral part of the national extension structure	Contained in TAP & PIR. Selected using consultative MCA

6.2 Technology Requirements for Ghana's Nationally Determined Contributions

Since the establishment of the Clean Development Mechanism (CDM) under the Kyoto Protocol, the Convention has adopted mechanisms to enhance mitigation ambition and address adaptation needs that promote climate technologies (Figure 76). Most of the priority technologies from the TNAs informed the climate actions Ghana put forward in the NDC. Improved cookstove technology is the highest of registered projects under the CDM in the country. Similarly, the five top measures in the nationally appropriate mitigation actions (NAMAs) align well with priority technology options selected from the 2013 TNA.

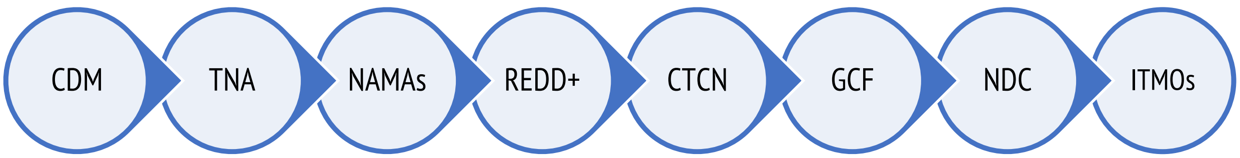

Figure 76: Diagramme showing some of the international climate processes relevant for TNA

The NDC is the latest global mechanism that has built on TNA selected technologies. Currently, under the Green Climate Fund (GCF) Ghana has received readiness support funding to develop an early warning drought and forecasting system through the UNFCCC Climate Technology Centre and Network[251]. Ghana is seeking additional funds from the GCF to finance the scaling up of solar and conservation agriculture technologies. Also, cookstove and solar technologies would be part of the first-ever pilot of Internationally Transferred Mitigation Outcomes (ITMOs) in the country. Ghana's NDC contains thirty-one adaptation and mitigation technologies in seven priority areas including energy, transport, water, agriculture, climate services, early warning system and forestry (Figure 77).

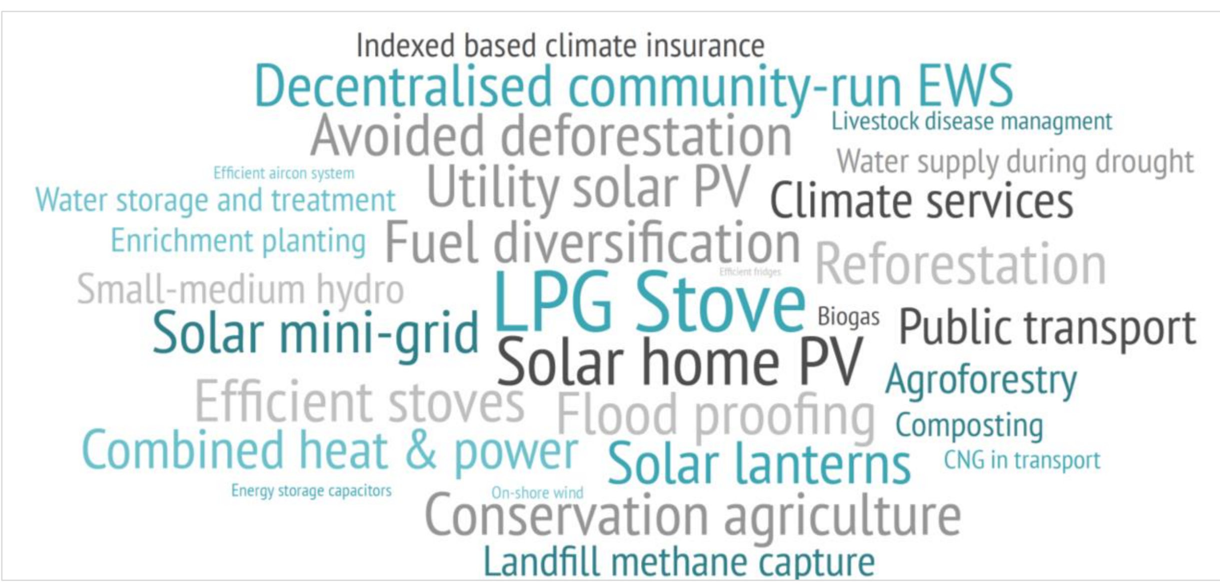

Figure 77: Snapshot of climate technologies in Ghana's nationally determined contribution

[251] https://www.greenclimate.fund/documents/20182/466992/Readiness_proposals_-_Ghana__UNEP_-_CTCN__Strategic_Framework.pdf/9db7f031-6892-40c0-afd9-5e71028c87ed

6.3 Making Climate Technology Transfer and Diffusion Work

Creating the enabling conditions for technology penetration is a crucial aspect of Ghana's climate strategy. It focuses on removing persistent barriers and strengthening efforts to make them work. This section reports Ghana's progress toward enabling climate technology transfer and diffusion at all levels.

6.3.1 Addressing Policy, Regulatory and Fiscal Barriers

Undoubtedly, enough climate technologies exist in the global space, but market barriers prevent smooth transfer and adoption in the country and across the sub-region. The constraints are in the areas of policy, regulations, economic, technical and socio-cultural. In response, the government is rolling out some reforms to help address policy and economic barriers that hamper technology transfer and diffusion. The strategies to deal with the challenges are focused on policy and regulation, fiscal incentive skill and infrastructure development. The plan is to drive fast transfer and assimilation of innovative and affordable climate technologies embedded with strong local business content. In implementing this strategy, Ghana is mindful of the need to safeguard local businesses' interest in being competitive and to avoid technology dumping in the open market. Table 80 shows an overview of the strategies to remove technology barriers in the country.

Table 80: Selected policy, technical and financial reforms to enable technology transfer and diffusion

Strategy	Focus area	Technology targets	Type of instruments	Comments
1. Policy and regulatory reforms				
Renewable Energy Act	Renewable Energy target	Renewable Energy Technology	Policy	Policy target for RE electricity generation share
	Renewable Energy Fund		Fiscal	Access to credit
	Feed-In-Tariff (FIT) scheme		Fiscal	Incentives for the private sector to generate grid-scale RE electricity
	competitive bidding		Fiscal	Renewable Energy Act is undergoing an amendment to replace the FIT scheme with a competitive bidding model.
Local content and local participation	Regulations, 2017 (L.I., 2354). Local Content and Local Participation) (Electricity Supply Industry (ESI).	Electricity supply and distribution Electronic appliances	legal	Minimum of fifty-one per cent equity participation in wholesale supply and distribution in the electricity supply industry in Ghana and 60% local content and development of capacity in the manufacturing industry for electrical cables, solar cells, conductors, accessories,
Electricity tariff rationalisation	Automatic price adjustment policy	Grid-connected electricity supply and consumption	Fiscal	An incentive for independent power producers.
Standards and guidelines	Standards for improved stoves	Cookstove market	Regulatory	Development phase by Energy Commission and CSIR

	Appliance standards and labelling	Appliance import market		Ensure quality and energy-efficient appliance in the local market
	Ghana Landfill guidelines	Landfill methane capture		Regulate landfill construction and management by EPA
	Law on the ban on importation of used fridges and air-conditioners	Refrigeration and Air-conditions		Ban on import of old refrigeration
Investment Promotion Act	Technology Transfer Regulations, 1992 (L.I. 1547)	All technologies	Legal	Facilitate technology transfer
2. Skills and infrastructure development				
Skills development fund[252]	Skills development	Technician and artisans	Training and Awareness	Funding for technicians and artisans in RE installation and maintenance (Solar & Biogas)
National Research Endowment Fund	Technology research and development	R& D institutions	Research and Development	National Science, Technology and Innovation Policy.
3. Financial and market reforms				
Free zone enclave	Incentives for businesses to produce at minimum cost for export.	Industrial technology enclave	Regulatory and Fiscal	Relief from double taxation for foreign investors and employers; 100% exemption from payment of direct and indirect duties and levies on all imports for production and exports from free zones.
SDG delivery fund	Private sector vehicle for technology financing	Environmentally sound technologies	Fiscal	Private sector contribution through corporate social responsibility
Ghana Infrastructure fund[253]	Funding for large infrastructure	Energy and transport infrastructure	Fiscal	Mobilise capital and provide credit to businesses.
Akoben industry performance disclosure mechanism	Promotion of technology adoption in industry and the hospitality sectors.	Environmentally sound technologies	Regulatory	Annual public disclosure of industry performance.
Rebate scheme	An incentive for efficient electronic appliance adoption and market reforms	Refrigeration and air-conditioners	Regulatory and Fiscal	Top up for poor households to buy new efficient Fridges.
Over-aged vehicle tax	Tax incentive based on polluter pays principle	Vehicles of all technology categories	Fiscal	Reduce import of poorly performing engine

[252] https://www.sdfghana.org/

[253] http://www.odekro.org/Images/Uploads/Ghana%20Infrastructure%20Investment%20Fund%20Act,%202014.pdf

6.3.2 Skills Development for Technology Development, Transfer and Adoption

Skills development is a crucial element for speedy technology adoption at all levels. In this regard, capacity development is at the core of Ghana's technology strategy. The focus is on increasing the capacities of frontline adapters of climate technologies (farmers, engineers, technicians and artisans) and sustaining their awareness through knowledge dissemination. It is an essential step towards mobilising the critical mass of technology users and developers. Consequently, Ghana has come up with formal and informal capacity development programmes, as shown in Table 81.

Table 81: Technology related capacity building initiatives in Ghana

Initiative	Type of technology capacity building	Comments
Ghana Energy Development and Access Programme (GEDAP)	Operational Manual for Matching Grants modified to incorporate in Renewable Energy Business	Capacity building for rural bank staff and solar company's on-going.
Sustainable land and water management project	Hands-on training on soil and land management technologies	Target –20 communities in the arid regions. More than 10 000 farmers have benefited from this programme.
Skill Development Fund (SDF)	Training of technicians and artisans on installation and maintenance of solar PVs	Ghana Technology University College; Energy Commission; Kumasi Technical University All these institutions have benefitted from the SDF to conduct training and construct the infrastructure to facilitate research into renewable energy.
Human resource development for disseminating solar PV	Technical Guidelines for PV Rural Electrification in Ghana, Solar PV Resting Manual, Solar PV system Technical Service Guidelines and Community Agent Manual.	An effort to support tertiary institutions which are already offering courses in renewable energy to build the capacity of students.
Master courses In renewable energy	Formal training on renewable energy	Two-year MSc degree in the Mechanical Engineering Department, Kwame Nkrumah University of Science and Technology.
Established the University of Energy and Natural Resources	Skilled labour for the energy market	Fully-fledged energy training institution to produce high skilled labour on energy technologies.
HND courses In Renewable energy	Technical training on renewable energy	Renewable energy system engineering (Koforidua Polytechnic), Renewable energy & Energy Efficiency (Accra Polytechnic) and Renewable energy and efficient technologies (Kumasi Polytechnic).

6.3.3 Technology Development and Transfer Institutions

Institutions play various roles in technology development and transfer in the country. In this section, the report highlights on-going efforts by institutions to support climate technology.

6.3.3.1 Science and Technology Policy Research Institute

The CSIR[254] is the leading hub for climate technology development and dissemination in the country. CSIR has specialised institutions that research into technologies in agriculture, forestry and industry. The Science and Technology Policy Research Institute (STEPRI) under CSIR has the mandate to conduct knowledge-based research that contributes to the formulation and implementation of policies and programmes for socio-economic development.

6.3.3.2 Ghana Technology Transfer and Marketing Centre[255]

The Ghana Atomic Energy Commission has established a Technology Transfer and Marketing Centre (TTMC). The centre aims to collaborate with the private sector to facilitate climate technology transfer. TTMC also undertakes an analysis of the potential commercial market for each innovation. They also help literature and patent searches to help assess patentability and support scientists and private sector companies to source for funding.

6.3.3.3 Technology Consultancy Centre[256]

The KNUST established a Technology Consultancy Centre (TCC) in 1972. The centre works with KNUST's academic departments to research, co-develop and transfer technology to support small and medium scale industries in Ghana. The work of the centre relevant to climate change relates to cookstove testing. The centre serves as one of the cookstove testing and expertise laboratories and conducts a training programme on climate technologies such as biogas and, cookstove. Its "Suame Intermediate Technology Transfer Unit" collaborates closely with the informal garage operators to facilitate industry technology.

6.3.3.4 University of Ghana Technology Development and Transfer Centre[257]

The University of Ghana has established a Technology Development and Transfer Centre (TDTC) to facilitate technology commercialisation and intellectual property (IP) protection of research products from the University. TDTC's core mandate is to connect the University of Ghana to industry through close collaboration with the Association Ghana of Industries (AGI) and the Private Enterprise Federation (PEF). Some of the centre's activities include exhibitions, registration of IP, building technology databases and awarding grants.

6.3.3.5 Clean cookstove market in Ghana

There are more than seventy national and international organisations that provide a variety of services in the clean cookstove value chain.[258] They are involved in the cookstove design/manufacture/assembly or distribution/retail segment of the niche market. The latest innovation in the market is the establishment of clean cooking marketing online platform[259] to aid in the retail of clean stove and solar lighting devices to consumers across the globe (Figure 78).

[254] https://www.csir.org.gh/
[255] https://gaecgh.org/technology-transfer/
[256] https://tcc.knust.edu.gh/
[257] https://www.ug.edu.gh/tdtc/
[258] https://www.cleancookingalliance.org/partners/directory.html?alpha=&region=1&country=3&type=&fuel=&area=1&area=3&submit=Submit
[259] https://cleancookingmarket.com/shop/

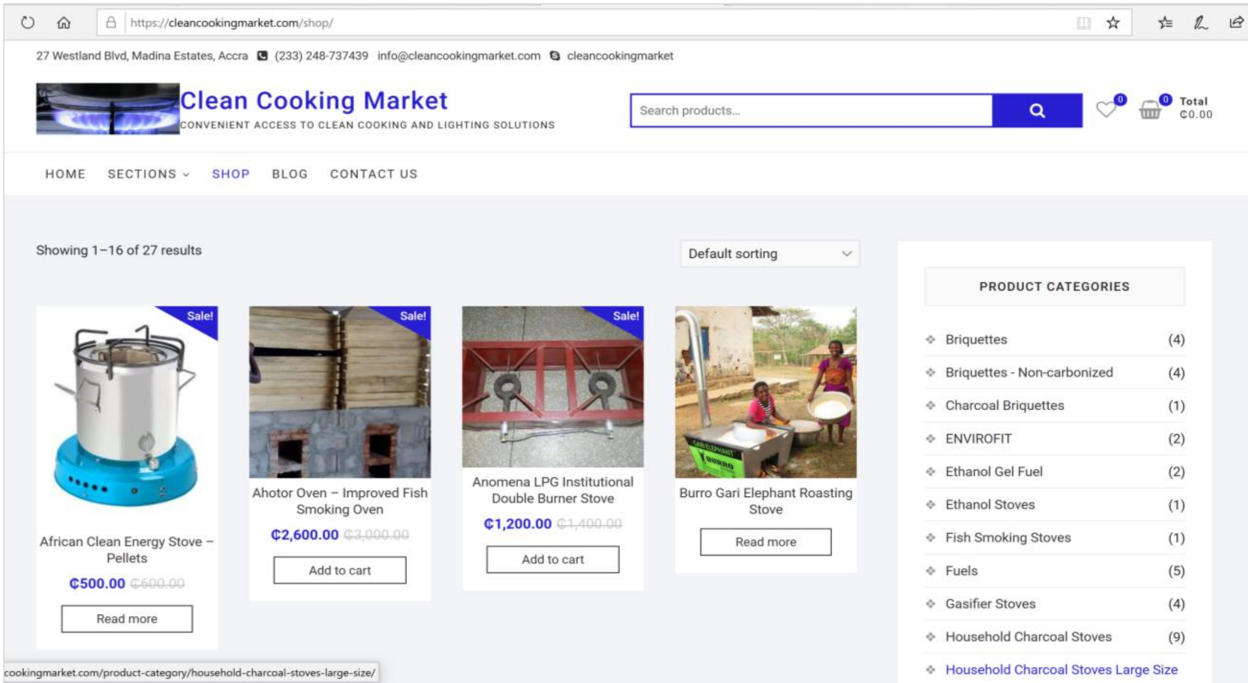

Figure 78: Interface of the online platform for clean cooking market

6.4 Technology Transfer Mechanism

In Ghana, technology is not only acquired from international markets. Some conventional and indigenous climate technologies can be acquired locally through research and development and farmer innovation. The mode of technology transfer and diffusion is through one or a combination of the mechanisms listed below. Often, the dictates of the markets at supplier and user's end determine the route and dynamics of the technology transfer. Some of the technology exchange mechanisms in Ghana are described below with examples.

- **South-south technology exchange** – This channel for exchanging technology is growing among developing countries. The China-Ghana south-south cooperation on renewable energy technology transfer[260] is the latest model in the country. The partnership aims to ensure a more holistic transfer of renewable energy expertise and technology from China to Africa, building on China's unique development experience. The collaboration did not only support the transfer of hardware but focussed on the institutional framework and capacity required to make the local absorption of renewable energy technologies effective. The Government of Denmark sponsored the partnership between the Energy Commission of Ghana and the Ministry of Science and Technology China and managed by the UNDP. Some of the accomplishments of the cooperation include the publication of two reports on "renewable energy policy review" and "barriers to renewable energy technology transfer", development of the Renewable Energy Masterplan (REMP).

[260]https://www.gh.undp.org/content/ghana/en/home/operations/projects/environment_and_energy/china-ghana-south-south-cooperation-on-renewable-energy-technolo.html

- **Multilateral development cooperation –** The Ghana Climate Innovation Centre[261] involves a multiple institutional collaboration between Ghana and the Danish Government through the World Bank and implemented by a private sector consortium. The centre is a clean technology hub that promotes SMEs to commercialise and scale innovative solutions. The work of the centre has led to the receipt of over US$1.4 million received by businesses as a grant leading to 1,129 $MtCO_2$ avoided emissions. The UNDP is also collaborating with Ghana Cocoa Board to register trees in the off-reserve areas in the cocoa landscape. In this regard, the UNDP launched a mobile application for tree registration in cocoa landscapes[262].

- **Private sector initiatives** – Private sector is at the forefront when it comes to innovation and technology adoption by farmers and within communities. Esoko[263] is a leader in connecting farmers to the market and technology services. The company has created an ecosystem that connects farmers to information services (crop prices, weather forecast, crop tips), market opportunities, financial and payment services. TechnoServe Ghana is a technology solution company that links smallholder farmers to lucrative markets[264]. Gratis foundation[265] is an indigenous hardware technology manufacture company in Ghana. The company researches, designs, develops, manufactures and markets appropriate technology-based products and services for micro, small and medium enterprises.

- **Pilot-to-scale and replication (GEF-Approach)** – The refrigeration market transformation project uses GEF funding model of piloting and testing technology to stimulate the future market. After the project, the efficient registration market has scaled with the private sector taking the lead.

- **Climate technology centre and network** – The CTCN aims to connect countries to climate technology solutions. The EPA of Ghana is the national designated entity for the CTCN. Ghana received technical assistance from the CTCN on improving the resiliency of crops to drought through strengthened early warning within Ghana with funding from the GCF. The technology support received responded to the nationally determined contributions in the areas of water, early warning and disaster prevention as well as vulnerable agricultural landscapes[266].

6.5 Funds received to Support Technology Transfer

Funding is critical for the implementation of technology transfer and to make them work. The section below gives an overview of the financial and non-monetary support received for climate technology transfer in Ghana.

6.5.1 Funding from National, Multilateral and Annex II Parties to Support Technology Transfer

Funding for technology transfer comes from multiple sources. Chief among the funding sources are governmental, multilateral and Annex II Parties.

[261] http://www.ghanacic.org/
[262] https://www.gh.undp.org/content/ghana/en/home/presscenter/pressreleases/2018/Tree_Mobile_App.html
[263] https://esoko.com/digital-farmer-services/
[264] https://www.technoserve.org/our-work/where-we-work/ghana/
[265] http://gratis.gov.gh/
[266] https://www.ctc-n.org/technical-assistance/projects/improving-resiliency-crops-drought-through-strengthened-early-warning

Generally, the support to Ghana from Annex 11 parties, is dominated by technology transfer financing but delivered through different channels (Table 82). However, in terms of economic value, the government made the most substantial investment in natural gas recovery and processing technology. Also, the government provides co-finance as a matching fund for donor support.

Table 82: List of technology transfer funds received over the period 2011-2019

Name	Type support	Source of Funding	Channel of support	Financial Support Amount (US$)	Capacity support	GOG indicative co-financing
Ghana Climate Innovation Center	Grant	Government of Denmark and others	Multilateral (World Bank)	17.6million	Target 500 businesses	-
Ghana Energy Development and Access Programme	Grant, Concessional Loans, non-concessional loans	Multiple sources	Multilateral (World Bank)	235.28 million	-	77.28 million
Promotion of Appliance of Energy Efficiency and Transformation of the Refrigerating Appliances Market in Ghana	Grant	GEF	Multilateral	6.1 million	-	4.4million
China-Ghana South-South Cooperation on Renewable Energy Technology Transfer	Grant	Government of Denmark	Bilateral (UNDP)	2.72 million	-	-
Millennium Development Challenge Account Compact 2 – Ghana Power Pact	Grants	United State Government	Bilateral	498.2 million	-	37.4 million
Facilitating Implementation and Readiness For Mitigation	Grant	Government of Denmark	Bilateral through UNEP-DTU Partnership	0.35 million	Capacity to develop two technology-based NAMAs and low carbon development strategy	
Technology Needs Assessment	Grant	GEF	Multilateral through UNEP-DTU Partnership	0.07 million	-	-
Human Resource Development for disseminating solar PV	Non-cash support	Government of Japan	Bilateral through JICA	Unknown	Training Materials	-

Sustainable Land and Water Management Project	Grant Loan	GEF World Bank	Multilateral	13.25million	-	4.5million
Forest Preservation Programme	Cash and Technical Support	Government of Japan	Bilateral	8.5million	Spatial Infrastructure and training	-
Ghana Urban Transport Project (BRT)	IDA Credit Grant	GEF, World Bank, and AfDB.	Multilateral	29 million	-	2 million
Ghana Gas Infrastructure Plant	Commercial Loan from China	Government of China	China Development Bank	**1,000 million		Ghana Government 100% funded
Low Emission Capacity Building Project: BRT and power factor correction) technologies	Grant	EU Australia	Multilateral through UNDP	0.882million	Capacity to develop two technology-based NAMAs	-
Community resilience through early warning	Grant	Government of Norway	Bilateral through UNDP	5.2 million	-	-
Hand pollination under cocoa productivity programme	Grant	Ghana Government	National Budget	Unknown		Ghana Government 100% funded
Drought Early Warning and forecasting system: Improving the resiliency of crops to drought through strengthened early warning within Ghana[267]	Grant	Green Climate Fund	Multilateral through CTCN, UN Environment	300,150	Technical training on drought early warning technology	
Green cooling Initiative (refrigeration and air conditioning technology)[268]	Grant	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU) as part of the International Climate Initiative (IKI)	Bilateral			

** Initial estimate. Total capital expenditure could be more than conservative estimates.

[267] https://www.greenclimate.fund/documents/20182/466992/Readiness_proposals_-_Ghana__UNEP_ _CTCN__Strategic_Framework.pdf/9db7f031-6892-40c0-afd9-5e71028c87ed

[268] https://www.giz.de/en/worldwide/28042.html

7. Research and Systematic Observation

The section is in two parts. Part one reports on the update of climate research in Ghana and its relevance to policy. The second part is on the status of systematic observation infrastructure in the country and Ghana's participation in international climate science programmes.

7.1 Climate Change Research

Research is the bedrock for evidence-based climate change decision-making at all levels. That is the reason the national climate change policy and the NDC recognise research as a strategic pillar for policy and practice. But the research needs are substantial and cover several topics. The main research interest gathered through a nation-wide survey broadly include the following:

- technology adoption pathways
- pathways for indigenous knowledge transfer
- socio-economic impacts on local communities
- documenting past and on-going ecological and social dynamics
- policy-research diagnostics
- climate finance
- institutional coordination
- vulnerability assessment
- climate adaptation issues

The survey further revealed that climate change research in Ghana is often project-driven and donor-funded. The major challenge Ghana faces with climate change research is inadequate funding from the Government. Because funding from the government is not adequate, most of the academic and research institutions that are involved in climate change research rely on external funding sources. The donor funding for climate research has been useful, but an increase in government funding in research areas that have a direct response to national priorities would be necessary. That said, the ongoing research contributes immensely to informing the climate change strategy development in the country. Consequently, the EPA has developed a climate change research database to collate and synthesise research findings to inform climate actions. Many on-going studies address different aspects of climate change, namely: landscape dynamics, climate change and biodiversity, climate change and society, climate modelling and cross-cutting research.

7.1.1 Landscape Dynamics

7.1.1.1 West Africa Science Centre on Climate Change and Adapted Land Use (WASCAL)[269]

WASCAL is a large-scale research-focused climate service centre mandated to help tackle the challenges of climate change in West Africa with funding from the Government of Germany. Ghana is among 10 West African nations benefiting from WASCAL and hosts the headquarters and the Land-use Centre at KNUST. In Ghana, the collaborating institutions of WASCAL are the University of Ghana, Kwame Nkrumah University of Science and Technology, Ghana Meteorological Agency and MESTI. WASCAL has organised around three main components,

[269] https://wascal.org/

namely – (a) Competence centre and Observation Network, (b) Core Research Programme and (c) Graduate studies programme. WASCAL has six core research clusters: (a) climate and weather; (b) landscape dynamics, (c) agricultural systems; (d) markets and livelihoods; (e)risk management; and (f) integrated assessment. The research programme cluster has produced extensive datasets and peer-reviewed papers on vegetation structure, hydrology, farming systems and innovations, soils and landscape dynamics. These products are useful to support evidence-based policy and practice on climate change. Since its inception in 2012, 390 masters and doctoral students have benefited from the WASCAL scholarship programme. Currently, Ghana chairs the board of governors of WASCAL.

7.1.1.2 Improving Food Security in Africa Through Increased System Productivity Of Biomass-Based Value Webs (BiomassWeb)[270]

Ghana is involved in BiomassWeb research with funding from the German Government. The research partner institutions in the country include; CSIR-crop research institute, KNUST, WASCAL, University of Cape Coast, Forum for Agricultural Research in Africa (FARA), ISSER, West Africa Regional Office of International Network for Bamboo and Rattan (INBAR). BiomassWeb aims to provide concepts to increase the availability of and access to food in Ghana through greater and higher-value biomass for food and non-food purposes in the next decades. The research themes cover analysis of biomass demand, supply and related value webs, research innovations, and implementation, including capacity and network building. The study sites are in Ashanti, Brong-Ahafo, and Upper East Regions. The research was implemented from 2013 to 2018. Some of the publications relevant to Ghana from BiomassWeb are as follows:

- Is Africa ready to develop a competitive bioeconomy? The case of the cassava value web in Ghana
- Socioeconomic Indicators of Bamboo Use for Agroforestry Development in the Dry Semi-Deciduous Forest Zone of Ghana.
- Making Contract Farming Arrangements Work in Africa's Bioeconomy: Evidence from Cassava Out-grower Schemes in Ghana.
- Rapid and easy carotenoid quantification in Ghanaian starchy staples using RP-HPLC-PDA.
- Why do maize farmers in Ghana have a limited choice of improved seed varieties? An assessment of the governance challenges in seed supply.
- Climate change impact under alternate realisations of climate scenarios on maize yield and biomass in Ghana.
- Potentials of Bamboo-Based Agroforestry for Sustainable Development in Sub-Saharan Africa: A Review.
- Impact of climatic variables on the spatial and temporal variability of crop yield and biomass gap in Sub-Saharan Africa – a case study in Central Ghana.
- Comparative life cycle analysis of producing charcoal from bamboo, teak, and acacia species in Ghana

7.1.1.3 CLIMAFRICA[271] – (Crop Research Institute of CSIR)

CLIMAFRICA is an EU-sponsored research programme in which Ghana is participating with 10 European and 8 African Countries. The research focuses on developing improved climate prediction on seasonal to decadal climatic scales; assess impacts in the water and agricultural sector of the economy;

[270] https://biomassweb.org/
[271] https://www.climafrica.eu/cons_part_en.jsp

evaluate the vulnerability of the ecosystems and civil population; suggest and analyse new adaptation strategies; develop a new concept of monitoring and forecasting warning systems. The research site is the communities around the Ankasa Forest Reserves. The research project was conducted for the period 2010 – 2014. The other partners are Soil Research Institute of CSIR and Forestry Research Institute of Ghana of CSIR.

7.1.1.4 Savannah Forest Boundary Transition in West Africa - Coupling The Energy Balance and Hydrology and Carbon Cycles Across the Biome Zot - Forestry Research Institute of CSIR)[272]

The European Union provided funds for the research programme, which focused on the assessment of the energy balance and carbon fixation regime in savannah vegetation in the forest savannah zone of Ghana. The research partners are FORIG and Wageningen University. The research delivered PhD thesis, scientific publications and presentations both locally and internationally at workshops and seminars. It also established thirty-five permanent plots in the forest, forest-savanna (mixed) and savanna sites within the reserve to aid in research in carbon cycles.

7.1.1.5 Does Shifting Carbon Use Efficiency Determine the Growth Rates of Intact and Disturbed Tropical Forests? Gathering New Evidence From African Forests – (Forestry Research Institute of CSIR)[273]

The research is a collaborative effort between FORIG and the University of Oxford with funding from the United Kingdom through its Natural Environment Research Council. The research studied the relative importance of photosynthesis and autotrophic respiration in determining forest function in intact and disturbed tropical African forests. To achieve this large carbon cycle assessment, plots have been established and replicated across two different countries in Africa, namely, Ghana (West Africa) and Gabon (Central Africa). The research sites are the Bobiri Forest Reserve and Kogyae Strict Nature Reserve (KSNR).

7.1.1.6 Forest 2020[274]

Ghana, through the Faculty of Renewable Natural Resource of KNUST, is among the six participating countries in the Forest 2020 research. Ecometrica manages the project with expert contributions from UK institutions (Edinburgh University and Leicester University, and Carbomap). The contributions from the project would help address forest monitoring needs in the areas of REDD+ and forest plantation development. Forest 2020 project in Ghana would test spatial technologies to distinguish tree crops from the natural forest as well as to detect deforestation near real-time. Currently, the Forest 2020 team is using drones to capture and develop three dimensional (3D) images. The 3D photos would help to map the cocoa-growing region by highlighting the difference between natural forest and shaded cocoa accurately.

7.1.1.7 Climate Smart Cocoa Systems for Ghana, CLIMCOCOA (University of Ghana, Legon)[275]

The Department of Geography and Resource Development, University of Ghana is collaborating with the University of Copenhagen, Roskilde University, World Agroforestry Center (ICRAF), and International Institute of Tropical Agriculture (IITA) to implement the CLIMCOCOA research project.

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[272]https://csir-forig.org.gh/projects/donor-funded/138-savanna-forest-boundary-transition-in-west-africa-coupling-the-energy-balance-and-hydrology-and-carbon-cycles-across-the-biome-zot.

[273]https://csir-forig.org.gh/projects/donor-funded/139-does-shifting-carbon-use-efficiency-determine-the-growth-rates-of-intact-and-disturbed-tropical-forests-gathering-new-evidence-from-african-forests.

[274] https://ecometrica.com/space/forests2020.

[275] https://www.ug.edu.gh/geography-climcocoa/node/5.

The Government of Denmark funds CLIMCOCOA and aims to develop a comprehensive understanding of the impact of climate change on the socio-biophysical basis of cocoa systems in Ghana and assesses the role of agroforestry as a model for climate and carbon smart agriculture. The research output would contribute to improving farmer's resilience to the changing climate. It would also build the capacities of local researchers to use modelling tools to assess climate change impacts. The project would train three PhDs in cocoa and climate change.

7.1.1.8 The Planning for Drought (P4D) Project[276]

The Institute of Environmental and Sanitation Studies of the University of Ghana is leading the P4D research in Ghana on water management for vulnerable communities in the Upper West Region of Ghana. Other partners of the project include the University for Development Studies, Ghana Irrigation Development Authority, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Mali and the University of East Anglia. The project would run from October 2018 – June 2020 under the auspices of the Africa-EU Innovation Alliance for Water and Climate (AfriAlliance) with funding from the European Union's Horizon 2020 Research and Innovation Programme. P4D is to promote dry season farming in semi-arid Ghana by enhancing the capacities of vulnerable farmers and local agriculture stakeholders (extension officers, input dealers and marketers).

7.1.2 Climate Change and Society

7.1.2.1 Building climate resilience through risk communication in Ghana's growing coastal cities - Regional Institute for Population Studies (RIPS), University of Ghana, Legon

The objective of this research was to promote the use of climate change risk factors as common indicators for integrating climate compatible development and policy processes in Ghana. This involved: risk and vulnerability assessments; testing of a vulnerability identity matrix method; evaluating and testing the sensitivity of policy frameworks to respond to community-level climatic risks; understanding specific drivers of risk reduction; and disaster contingency planning. The research also helped to strengthen human capacity in risk assessment and management of critical impacts of climate change. The outcome aimed to guide the mainstreaming of climate science, policy and people. The United Kingdom Government, through the Climate and Development Knowledge Network (CDKN) Innovation Fund, supported the project and ended in 2013.

7.1.2.2 DEltas, Vulnerability and Climate Change; Migration and Adaptation - DECCMA[277], (RIPS)

DECCMA is collaborative applied research on adaptation options, limits and potential in deltaic environments to current weather variability and extremes, as well as climate change. Project countries are Ghana, India and Bangladesh and selected partners in the United Kingdom and the FAO. In Ghana, RIPs led the implementation of the project at the Volta delta. Some of the scientific publications of DECCMA relevant for Ghana are as follows:

- Adjei, P.O-W., Cazcarro, I., Arto, I., Ofori-Danson, P.K., Asenso, J.K., Asmah, E.A., Appeaning Addo, K., Codjoe, S.N. and Amponsah, S.K. 2019. Comparative analysis of the socio-economic characteristics of Delta and Non-Delta spaces of Ghana: An input-output approach. African Review of Economics and Finance 11 (1), 53-75.

[276] http://iess.ug.edu.gh/projects/institutional/planning-drought-p4d-project
[277] http://www.deccma.com/deccma/team/

- Appeaning-Addo, K., Jayson-Quashigah, P-N., Codjoe, S.N.A. and Martey, F. 2018. Drone as a tool for coastal flood monitoring in the Volta Delta, Ghana. Geoenvironmental Disasters 5, 17.
- Appeaning-Addo, K., Nicholls, RJ., Codjoe, S.N.A. and Abu, M. 2018. A Biophysical and Socioeconomic Review of the Volta Delta, Ghana. Journal of Coastal Research 34(5), 1216-1226.
- Cazcarro, I., Arto, I., Hazra, S., Bhattacharya, R.N., Adjei, P.O-W., Ofori-Danson, P.K., Asenso, J.K., Amponsah, S.K., Khondker, B., Reihan, S. and Hosser, Z. 2018. Biophysical and socioeconomic state and links of deltaic areas vulnerable to climate change: Volta (Ghana), Mahanadi (India) and Ganges-Brahmaputra-Meghna (India and Bangladesh). Sustainability 10(3), 893.
- Owusu-Daaku, K.N., 2018. (Mal)Adaptation opportunism: when other interests take overstated or unintended climate change adaptation objectives (and their unintended effects). Local Environment. The International Journal of Justice and Sustainability 23(9), 934-951.

7.1.2.3 Building Climate-Resilience into Basin Water Management[278] (CSIR-Water Research Institute -WRI)

CSIR-WRI is leading a consortium of institutions in Ghana and Denmark on this research project. DANIDA is funding the project from 2019 to 2024. The project sites are Pra and Densu basins, and integrated approaches are adopted to evaluate the consequences of climate change, land-use changes and changes in socio-economic and political development. The output from the analysis can inform water resource management decision-making.

7.1.2.4 Climate Change Resilience in Urban Mobility (CLIMACCESS)[279]

DANIDA is also funding the CLIMACCESS research and capacity building project from 2018 to 2022. The research partners are the University of Copenhagen, University of Ghana (Department of Geography and Resource Development) and the CSIR. The purpose of the project is to identify strategies for increasing climate change resilience within urban mobility, accessibility and transport in Accra, Ghana. CLIMACCESS would train three PhD students. There are three workstreams on: (a) climate change and urban flooding, (b) urban planning and accessibility analysis, and 3) mobility patterns and livelihood vulnerability.

7.1.2.5 Building Resilience on Lake Bosumtwi to Climate Change (RELAB)[280]

The University of Energy and Natural Resources, Aarhus University and the University of Ghana are implementing the RELAB research project from 2018 to 2022. The project would resolve the complex interactions at the ecosystem and watershed scale and investigate the dynamics within the socio-ecological system. This information would be used for policy and management of the Lake Bosumtwi watershed. With high-resolution monitoring of lake physics, biogeochemistry, primary production, fisheries, land-use changes, sedimentation and livelihood adaptive mechanisms, the project aims to collect the most comprehensive dataset in West Africa. The deliverables of the research are: (i) assess various land use responses to fisheries decline, (ii) determine land-use changes using remote sensing techniques and (iii) set up a SWAT model for Lake Bosumtwi watershed. RELAB would support the training of four PhDs and MPhil studies.

[278] http://drp.dfcentre.com/project/building-climate-resilience-basin-water-management

[279] https://ign.ku.dk/english/climaccess/

[280] https://www.relabproject.uenr.edu.gh/

7.1.2.6 Effects of Climate Change on Volta Lake Resources (VOLTRES)[281]

VOLTRES seeks to improve the understanding of the physical and biogeochemical functioning of Lake Volta and how the lake and its resources (fish) would respond to climate change. VOLTRES aims to strengthen local research capacity using new research approaches such as ecosystem and biophysical modelling; to ensure early preparedness and response to climate change effects in the lake environment and to contribute to the effective management of the entire lake system. VOLTRES is a joint project between CSIR Water Research Institute, Ghana and Aarhus University, Department of Bioscience, Denmark, which was implemented from May 2014 to April 2017. The research was supported by Danida (13-P04-GHA).

7.1.3 Climate Change Scientific Publications

The number of scientific research publications on climate change has recorded a significant increase in recent years. Most of the research works that took place in the country in most cases produced scientific papers or grey reports. The publications are vital for gathering evidence to inform climate change policy and fill the scientific knowledge gap. Keyword search[282] on "climate+change+ghana" from 2015 to 2019 in google scholar, ScienceDirect and Francis and Tylor online returned 23,700, 3,641 and 8,258 publications respectively. Many of the reviewed articles are on climate modelling and adaptation in human and natural systems. The adaptation topics ranged from perception surveys, vulnerability and impacts assessment, gender and climate change, adaptation pathways, and mainstreaming at the local and national levels. Few of the publications focused on climate finance and mitigation, particularly on green building, renewables, REDD+, agroforestry.

Table 83 shows selected scientific and grey literature publications on climate change in Ghana for the period 2011-2019. The information in the table is the updates of the list reported in Ghana's NC3. The list of publications since 2015 is lengthy, so only a representative sample of the literature to reflect the diversity of current knowledge in the country is presented. As much as possible the list has captured new research topics and study sites. Although the literature covers both reviewed and grey publications, most of them are journal grade.

Table 83: Selected scientific and grey literature publications on climate change in Ghana for the period 2011-2019

Authors (s)	Title of publication	Sponsor/Collaborators	Relevance	Specific areas
Präger et al. 2019	Biomass sources for sustainable energy supply in Ghana – A case study for Sunyani. Renewable and sustainable energy reviews. Volume 107, June 2019, Pages 413-424	Hochschule für Forstwirtschaft Rottenburg, Schadenweilerhof	Energy mitigation	Biomass contributions to mitigation actions
UNU-INRA	Africa's development in the age of stranded assets. Discussions paper	United nations university	Oil and gas and mitigation action	Study in seven African countries including Ghana
Nana Asare Obeng-Darko, 2019	Why Ghana would not achieve its renewable energy target for electricity. Policy, legal and regulatory implications. Volume 128, May 2019, Pages 75-83	UEF Law School, University of Eastern Finland	Energy mitigation actions	Renewables and NDC.

[281] https://projects.au.dk/voltres/

[282] The keyword search on both Google Scholar, ScienceDirect and Francis and Tylor online were on 12th December, 2019

Bunn et al. 2019	Recommendation domains to scale-out climate change adaptation in cocoa production in Ghana. Climate services 16 (2019) 100123	Cocoa research institute	Climate change and agriculture	Cocoa and climate change impacts
Dwomoh et al. 2019	Forest degradation promotes fire during a drought in moist tropical forests of Ghana, Forest Ecology and Management, Volume 440, 15 May 2019, Pages 158-168.	The University of Oklahoma	Forest mitigation	REDD+
Adzawla et al. 2019	Effects of climate change and livelihood diversification on the gendered productivity gap in Northern Ghana. Climate and Development, 2019	WASCAL	Economics of climate and gender	Northern Ghana
Abokyi et al. 2019	Industrial growth and emissions of CO_2 in Ghana: The role of financial development and fossil fuel consumption	Department of Economics, Universita' Politecnica delle Marche, Italy	Emissions and industry growth	Industrialisation and climate change
Nuamah et al. 2019	Understanding climate variability and change: analysis of temperature and rainfall across agroecological zones in Ghana, Heliyon, Volume 5, Issue 10, October 2019.	Pan African University, Cameroon	Climate vulnerability assessment	Climate modelling
Antwi-Agyei, P. et al. (2017)	Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana, Climate Risk Management, 9, 83-93.	Dept. of Environmental Science, KNUST	Adaptation strategies	Adaptation in food systems in northern Ghana
Antwi-Agyei, P. et al. (2016)	Perceived stressors of climate vulnerability across scales in the Savannah zone of Ghana: a participatory approach, Regional Environmental Change, 17(1), 213-227	Dept. of Environmental Science, KNUST	Climate vulnerability assessments	Vulnerability assessments in northern Ghana
Antwi-Agyei, P. et al. (2015)	Impacts of land tenure arrangements on the adaptive capacity of marginalized groups: the case of Ghana's Ejura Sekyedumase and Bongo districts, Land Use Policy, 49, 203–212	Dept. of Environmental Science, KNUST	Climate adaptation barriers	Ghana's Ejura Sekyedumase and Bongo districts
Antwi-Agyei, P. et al. (2014)	Livelihoods adaptations to climate variability: insights from farming households in Ghana, Regional Environmental Change, 14(4) 1615-1626.	Dept. of Environmental Science, KNUST	Climate adaptations	Adaptations in Upper East and Central Ghana
Antwi-Agyei, P. et al. (2012).	Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data, Applied Geography, 32(2), 324-334	Dept. of Environmental Science, KNUST	Climate vulnerability assessment	Whole country
Mensah Owusu & Melissa Nursey-Bray, 2018	Socio-economic and institutional drivers of vulnerability to climate change in urban slums: the case of Accra, Ghana. Climate and Development, Volume 11, 2019 - Issue 8	Department, of Geography, Environment and Population, University of Adelaide	Climate change and cities	Climate vulnerability of Accra
Wood et al. 2019	Examining climate change and food security in Ghana through an intersectional framework. The Journal of Peasant Studies	North Carolina State University	Climate change and food security	Whole country

Tetteh et al. 2019	Perceptions of weather variability and climate change on goat producers' choice of coping and adaptation strategies: evidence from climate-smart and non-climate-smart villages in the Jirapa and Lawra district. Climate and Development, 2019.	University of Development Studies	Adaptation strategies	Goat producers in Jirapa and Lawra district
Musah-Surugu et al. 2018	Mainstreaming climate change into local governance: financing and budgetary compliance in selected local governments in Ghana. Development in Practice, 28:1, 65-80,	The University of Ghana, Department of Geography and Resource Development	Climate change mainstreaming	Local government finance
Asiedu et al. 2017	Aquaculture in troubled climate: Farmers' perception of climate change and their adaptation. Cogent Food & Agriculture, Volume 3, 2017 - Issue 1	The University of Energy and Natural Resources	Adaptation in fisheries	Sunyani Aquaculture Zone
Ahenkan, A., & I.J. Musah-Surugu, 2014	Financing climate change adaptation and mitigation in Ghana: Challenges and prospects	University of Ghana	Climate finance	
Tachie-Obeng, E., P.B.I. Akponikp & S. Adiku, 2013	Considering effective adaptation options to the impacts of climate change for maize production in Ghana. Environmental Development 5 (2013) 131–145.	University of Ghana and EPA	Agriculture adaptation option	Maize in Northern Ghana
Fosu-Mensah et al	'Modelling Impact of Climate Change on Maize (Zea mays L.) yield under Rain-fed Condition in Sub-Humid Ghana', UNU-INRA Working Paper No 1/11	UNU-INRA	Agriculture adaptation option	Maize under rain-fed conditions
Afful-Koomson et al. 2012	Governance Challenges for Promoting the Green Economy in Africa' In J.A. Puppim de Oliveira (ed), Green Economy and Governance for Sustainable Development: Opportunities, Promises and Concerns. Tokyo: United Nations University Press	UNU-INRA	Green economy	Africa-wide
Emmanuel Tachie-Obeng, et al. 2014	Downscaled Climate Change Projections for WA District in the Savanna Zone of Ghana. Journal of Disaster ResearchVol.9No.4, 2014	University of Ghana	Climate modelling	District scale
Codjoe, S.N.A. et al. 2015	Geophysical, socio-demographic characteristics and perception of flood vulnerability in Accra, Ghana. Natural Hazards.	RIPS, Legon	Flood vulnerability	Accra
Codjoe, S.N.A. et al. (2015)	Climate change/variability and schistosomiasis transmission in the Ga District, Ghana. Climate and Development.	RIPS, Legon	Climate change and health	Schistosomiasis transmission in GA district
Codjoe, S.N.A. et al. (2014)	Climate change and cerebrospinal meningitis in the Ghanaian meningitis belt. International Journal of Environmental Research and Public Health, 11 (7), 6923-6939.	RIPS, Legon	Climate change and health	CSM and climate change
Codjoe, S.N.A. et al. (2014).	Climate change and internal migration intentions in the forest-savanna transition zone of Ghana. Population and Environment, 35, 341-364.	RIPS, Legon	Climate change and migration	Savannah-forest movement

Codjoe, S.N.A. et al. (2013).	Economic analysis of climate variability impact on malaria prevalence: The case of Ghana. *Sustainability,* 5(10): 4362-4378.	RIPS, Legon	Climate change, health, and economies	The economic cost of climate-induced malaria
Tanner et al. 2015	Political Economy of Climate Compatible Development: Artisanal Fisheries and Climate Change in Ghana.	Institute of Environment and Sanitation Studies	Fisheries and climate change	Artisanal fisheries
Tompkins et al. 2013	An investigation of the evidence of benefits from compatible climate development	Institute of Environment and Sanitation Studies	Cross-cutting issues for climate planning	National climate change policy
Obuobie et al. 2012	Assessment of the vulnerability of river basins in Ghana to water stress conditions under climate change	CSIR-Water Research Institute	Climate change and water	Vulnerability assessment
Obuobie et al. 2013	Impact of climate change on streamflow in selected river basins in Ghana	CSIR-Water Research Institute	Climate change and water	Vulnerability assessment
Bawakyillenuo, S., et al. 2014	Exploring the autonomous adaptation strategies to climate change and climate variability in selected villages in the rural Northern Savannah Zone of Ghana. Local Environment: The International Journal of Justice and Sustainability).	Institute for Statistical, Social and Economic Research (ISSER)	Climate change adaptation strategy	Rural adaptation
Koforobour K. et al., 2013	Climate change adaptation mainstreaming at the sub-national level development planning: A Case of the Sekondi-Takoradi Metropolitan Assembly (STMA), Ghana. Journal of Economics and Sustainable Development www.iiste.org ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online) Vol.4, No.11, 2013	Department of Geography and Regional Planning, University of Cape Coast, Cape Coast, Ghana	Climate change mainstreaming	Local government
Klutse et al. 2014	Assessment of Patterns of Climate Variables and Malaria Cases in Two Ecological Zones of Ghana Open Journal of Ecology, 4, 764-775	Centre for African Wetlands, University of Ghana	Climate change and health	Climate-induced malaria pattern
Owusu et al. 2014	Changes in Expectations and Extremes in the Rainfall Climatology of Accra, Ghana, 1895-2005. *Applied Geography* Vol.52, 99-109	Geography and Resource Development, University of Ghana	Climate modelling	Changing rainfall pattern
Klutse et al. 2014	Rainfall variability over Ghana: model versus rain gauge observation. *International Journal of Geosciences* Vol 5, 673-683	University of Ghana, Ghana Atomic Agency, and others	Climate modelling	Comparison of rainfall variability
Owusu et al. 2013	Simulation of the Rainfall Regime over Ghana from CORDEX. International Journal of Geosciences Vol. 4, 785-791	University of Ghana, Ghana Atomic Agency	Climate modelling	Rainfall projections
Owusu et al. 2013	Identification of historical shifts in daily rainfall regime, Wenchi, Ghana. Climatic Change Vol. 117 (1-2) 133-147	Geography and Resource Development, University of Ghana	Climate modelling	Changing rainfall patterns in Wenchi

Owusu et al. 2013	The changing rainy season climatology of mid-Ghana. Theoretical and applied Climatology Vol. 112 (3-4) 419-430	Geography and Resource Development, University of Ghana	Climate modelling	Rainfall seasonality
Agarko et al. 2019	Removing barriers and promoting demand-side energy efficiency in households in Sub-Saharan Africa: A case study in Ghana. Energy policy	Energy Commission	Energy mitigation strategy	Energy efficiency
Cárdenas et al. 2018	Policy coherence for climate-sensitive planning in Ghana	Sustainability Research Institute	Climate policy	NDCs
Atiah et al. 2019	The Spatio-Temporal Variability of Rainfall over the Agro-Ecological Zones of Ghana. 2019. Atmospheric and Climate Sciences, 9, 527-544.	Physics Department, KNUST	Climate modelling	Rainfall variability in Ghana
Asare 2017	Assessing climate-driven malaria variability in Ghana using a regional scale dynamical model, J. Climate, 5(1)	Physics Department, KNUST	Climate change health	Sectoral impacts assessment of climate change

7.2 Systematic Observations

7.2.1 National Meteorological Observation Network

The Ghana Meteorological Agency[283] manages the national systematic observation infrastructure and provides climate services to the public, agriculture application, civil aviation, commercial airlines, military aviation and maritime (Figure 79). The synoptic and automatic network of meteorological and radar stations support the systematic observation infrastructure. The synoptic and automatic weather stations cover about 95% of Ghana's territory for the measurement and monitoring of atmospheric phenomena. The meteorological radar located in Accra covers the remaining 5% of the country. The recent addition of radar monitoring and automatic stations to the system observation network infrastructure has boosted observation capabilities of the GMet.

[283] http://www.meteo.gov.gh/website/

Figure 79: Automatic weather station installed in Accra by GMet under the e-transform project source: GMET website

Now, GMet is implementing critical reforms to improve service efficiency. Some of the changes include data commercialisation to increase internally generated funds, capacity development and modernisation of the observation network. Nevertheless, the Agency is still facing numerous challenges, including:

- Underfunding for the operations and maintenance of the observation network
- Outdated technology for the gathering and forecasting of climate information.
- No interconnectivity of weather stations.
- Inadequate automatic weather stations.
- Inefficient climate service product dissemination.

7.2.2 Earth Observation Research and Innovation Centre[284]

The University of Energy and Natural Resources, Sunyani, established Earth Observation Research and Innovation Centre (EORIC) to research into the earth and atmospheric observation. The centre researches, trains and provides services in carbon flux monitoring, aerial and satellite operations and fire monitoring. EORIC observation infrastructure enables researchers to deliver cutting-edge satellite operations, weather and climate monitoring and unmanned aerial services. The earth and meteorological observation infrastructure include:

- **Carbon flux tower** – EORIC is collaborating with the Global Change Research Institute, Czech Academy of Sciences to establish a carbon flux tower in the Bia Tano forest reserve at Gambia Number 1 in Mim to monitor terrestrial carbon exchanges throughout the year.

[284] https://www.eoric.uenr.edu.gh/about-us/

- **Earth observation satellite-direct broadcast –EOS-DB ground station (UNER)** - Installed in 2015 to acquire earth observing satellite-direct broadcast data from Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) Satellites (Figure 80).

Figure 80: EOS-DB ground station mounted at the University of Energy and Natural Resources source: EORIC website

- **EUMETCast-GEONETCast Reception Station** – GEONETCast is a global network of satellite-based data dissemination systems providing environmental data to a world-wide user community.

- **COSMIC[285]-2 Ground Station** - The 3m X/Y Fibre antenna system was installed in 2016 to support COSMIC-2 satellite operations (acquisition of data and Telemetry, Tracking and Command-TT&C). The station is part of the network of nine (9) COSMIC-2A (Equatorial) Baseline Ground Station Architecture to support the COSMIC-2 project. EORIC is hosting the ground station through a partnership agreement between the University of Energy and Natural Resource and Atlas Space Operation Inc., USA.

- **Global Navigation Satellite System – GNSS Referencing Station** - The GNSS receiving station was installed in 2018 to support the COSMIC-2 program and other applications. The University of Energy and Natural Resources and University Corporation for Atmospheric Research (UCAR) jointly operate the station through a partnership (Figure 81).

[285] Constellation Observing System for Meteorology, Ionosphere, and Climate

Figure 81: GNSS referencing station mounted at the compound of the University Energy and Natural Resources

- **Automatic weather stations** - EORIC established a network of automatic weather stations in 2014 to collect daily weather data for agro-meteorological and climate change applications in the Bono region.

7.2.3 Centre for Remote Sensing and Geographic Information Services (CERSGIS)[286]

The Centre for Remote Sensing and Geographic Information System (CERSGIS) provides specialised services on geo-information on earth observation monitoring and mapping on land and coastal resources. The centre is competent in web mapping, GPS mapping, optical and radar applications and skills training. CERSGIS has a 20-seat capacity training laboratory equipped with modern equipment and resource library. CERSGIS is a partner in the Ghana Agricultural GIS online Platform[287] (Figure 82). The platform gives access to cross-sectional data and GIS data collected by projects including USAID funded ADVANCE and TIPCEE, ADRA Ghana Food Security Programme, the Ministry of Food & Agriculture and GIZ/MOAP projects. Application of GIS technologies in agriculture helps to provide essential information such as locations of smallholder farms, aggregators, processors, tractor service providers, warehouses and weather stations.

To achieve a meaningful developmental impact, it has become necessary to share data among various stakeholders. This GIS online Platform has become the most appropriate means to make data available to specific end-users and potentially to the public. This is expected to increase the efficiency of all value chain actors and industry leaders who, as managers base critical management decisions on reliable data. Ultimately, Ghana's agricultural industry would become competitive in the domestic, regional and international markets. Data on this platform is available for six commodity value chains: Mango, Citrus, Maize, Rice, Soybean and Cashew. Most data here are for public interest and free. However, a fee is charged for premium dataset upon request.

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[286] https://cersgis.org/

[287] http://gis4agricgh.net/

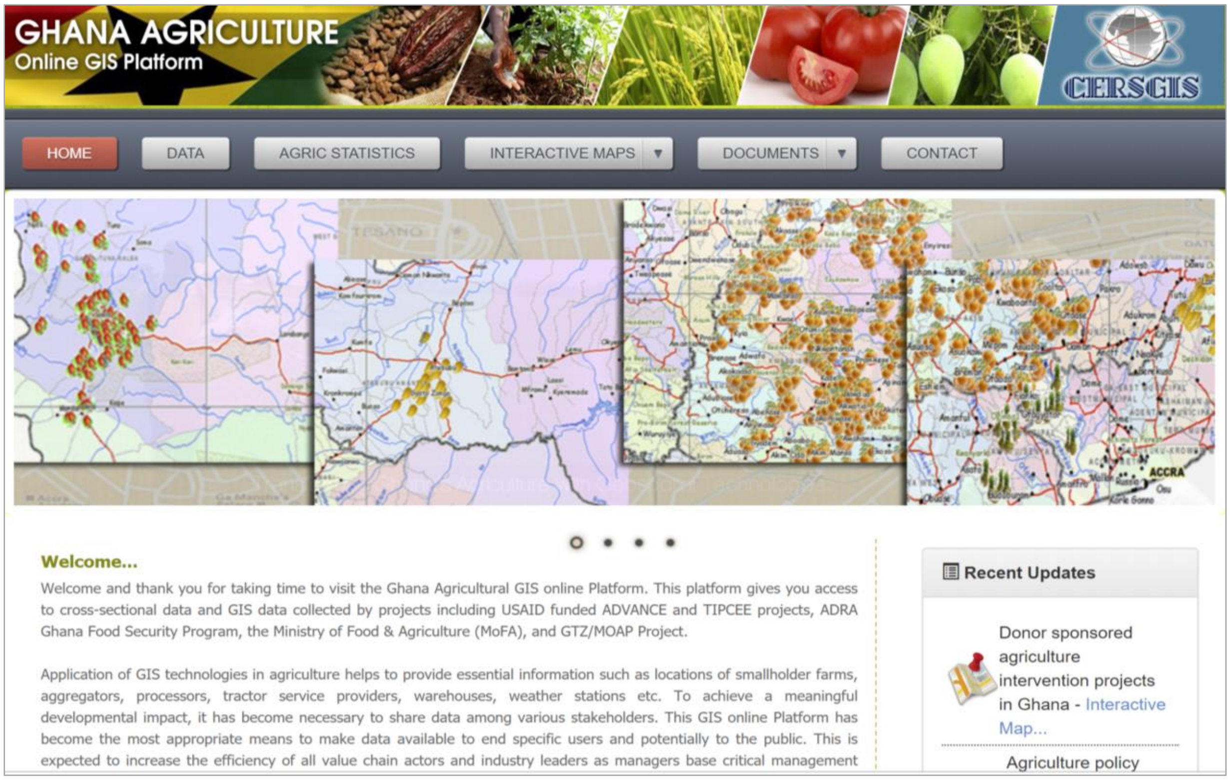

Figure 82: Ghana Agriculture online GIS platform

CERSGIS is also the leading SERVIR-West Africa partner[288] in Ghana. The platform has a host of decision-aid tools and applications for local actors dealing with climate-induced issues such as disasters, water management, agriculture, land-use and ecosystem protection. In this regard, the SERVIR platform has three information portals that monitor and reports illegal mining[289], land-use and land-cover dynamics[290] and tree cover change and charcoal production[291].

7.3 Participation in international climate change activities

This section presents information on Ghana's involvement in climate change programmes at the continental and global levels.

7.3.1 Continent-Wide Level (Africa Union Level)

Africa-wide climate change initiatives – Climate change is a top priority for the African continent. That is why Africa Union is a champion in advocating for African governments to pay attention to climate change. Some of the climate-related initiatives are below:

[288] http://servir.cersgis.org
[289] http://tethyscer.servirglobal.net/apps/ssmportal/
[290] http://tethyscer.servirglobal.net/apps/landdegradation/
[291] http://tethyscer.servirglobal.net/apps/charcoalportal/

- **Climate for Development in Africa Programme (ClimDev-Africa)**[292] – It was put together by AfDB, UNECA and the Africa Union Commission. Ghana is a regular participant in the annual ClimDev dialogue that assembles stakeholders to discuss climate change issues about the continent.

- **Africa NDC hub**[293] – The AfDB hosts the Africa NDC hub as a resource pool to support countries in the implementation of their Paris Agreement commitments. Currently, the hub assists countries in fostering long-term climate action, mobilising means for implementation and coordination, advocacy and Partnerships.

- **African Adaptation Initiative (AAI)**[294] **-** Ghana is receiving support from AAI through the World Bank to develop an investment strategy to back the implementation of the adaptation component of Ghana's NDC. AAI focuses on enhancing climate information services, strengthening policies and institutions, enhancing ground action and climate finance and investments.

- **African Renewable Energy Initiative (AREI)**[295] – AREI is a continental initiative set to achieve at least 10 GW of new and additional renewable energy generation capacity by 2020, and mobilise the African potential to generate at least 300 GW by 2030. In Ghana, the Ministry of Energy is the focal point for AREI. Ghana is yet to benefit from the Africa Renewable Energy Facility initiative.

Participation in Africa Ministerial Conference on the Environment (AMCEN) – Ghana is an active member of AMCEN, which is hosted by UNEP. Ghana participated in the seventeenth regular session of AMCEN in Durban South Africa. The conference discussed issues on greening the economy in Africa; advancing the circular economy; the development of a blue economy; biodiversity loss; land degradation; desertification, drought and climate change. AMCEN and the Committee of African Heads of State and Government on Climate Change (CAHOSCC) ultimately shaped the African position at the UNFCCC negotiations.

African Group of Negotiators (AGN) [296]- The AGN consists of technical negotiators of every African country. One country is selected to chair the group for two years; Egypt currently chairs the AGN. Ghana is an active member of the AGN. Experts from Ghana coordinate issues on loss and damage, long-term review and global stock in the UNFCCC negotiation on behalf of the AGN.

African Climate Policy Centre (ACPC)[297] -The ACPC is a hub for knowledge generation on climate change in Africa. It addresses the need for greatly improved climate information for Africa and strengthening the use of such information for decision making, by improving analytical capacity, knowledge management and dissemination activities. The ACPC is an integral part of the Climate for Development in Africa (ClimDev-Africa) programme, which is a joint initiative of the African Union Commission (AUC), the United Nations Economic Commission for Africa and

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[292] https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/climate-for-development-in-africa-climdev-africa-initiative
[293] https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/africa-ndc-hub
[294] https://africaadaptationinitiative.org/
[295] http://www.arei.org/
[296] https://africangroupofnegotiators.org/
[297] https://www.uneca.org/acpc

the African Development Bank. ClimDev-Africa has been mandated to influence continental climate policy at regional meetings of African Heads of State and Government, as well as by Africa's Ministers of Finance, Ministers of Planning and Ministers of Environment. Ghana, as a member of the Africa Union, contributes to the activities of the ACPC.

United Nations University – Institute for Natural Resource in Africa (UNI-INRA)[298] – The University of Ghana is the host of UNU-INRA. UNI-INRA conducts research relevant to Africa and offers training in natural resource management, including topics on climate change. The institute recently published a climate change study on stranded assets in Africa within the context of emerging global climate policy. In 2019, the Institute together with the University of Ghana hosted the IPCC Outreach Programme on the Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels

7.3.2 International Level

UNFCCC and Climate Change Negotiations - Ghana actively participates in the Climate Change negotiations both at the UNFCCC, regional and the sub-regional levels. The country has contributed to the advancement of multilateral structures and mechanisms in the negotiation process. Ghana has contributed immensely to the Africa Group level by leading negotiations on behalf of the Africa Group, especially on Technology Transfer, REDD+ and Climate Change Adaptation. At the regional and sub-regional levels, Ghana has contributed to the formulation and advancement of common African positions on various negotiation issues, as well as participating in activities to develop a joint climate change framework for the ECOWAS sub-region. Ghana is on the ECOWAS climate change committee. Ghana has also previously served on the following "groups" of the convention as a member or alternate member: (a) Adaptation Fund Board (ADF)–Alternate member, (b) Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention (CGE) – Member; (c) Expert Group on Technology Transfer (EGTT) – Former Member; (d) Standing committee on Finance.

Besides, Ghana contributes to some of the technical activities of the UNFCCC secretariat such as the annual reviews of national GHG Inventory from Annex 1 Parties and the technology committee. So far, Ghana has produced three lead reviewers, three energy experts, two industrial process experts, one agriculture expert and two waste experts. In 2018, one LULUCF expert qualified as a reviewer of National Forest Reference Level for REDD+. Additional Ghanaian experts also participate in the review of national communications and biennial update reports from Annex 1 parties. In all, four national experts are involved in the reviews of national communications and biennial update reports.

Intergovernmental Panel on Climate Change (IPCC) - Ghana is also present in the IPCC process. Under the Sixth Assessment Report (AR6), Ghanaian scientists are working in Working Group II (WG II) and Working Group III (WG III) as lead and contributing authors.

[298] https://inra.unu.edu/

Ghanaian scientists contributed to the IPCC Special Reports on climate change and land, and the impacts of global warming of 1.5 °C above pre-industrial levels[299]. Ghana is also a member of the IPCC's Task Group on Data Support for Climate Change Assessments (TG-Data)[300].

7.3.3 Global Climate Change Partnerships

In line with Ghana's strategy to contribute to efforts to combat climate change, the country has joined several international partnerships. Joining such alliances offers the platform for like-minded countries to advance issues of mutual interest at the global and national levels. The platforms also allow Ghana to work together with other countries to raise funds and above all, share practical experiences on relevant climate change topics. The partnerships are listed below:

Partnership on Transparency in Paris Agreement (PATPA)[301] - The Partnership for Transparency in Paris Agreement (PATPA) is an informal forum on climate transparency matters and NDC implementation. Ghana joined the partnership in 2012 with the view to learn and exchange practical knowledge on MRV and transparency issues. PATPA also provides technical assistance to countries. Ghana has implemented the information matters project[302] to support the preparation of Ghana's first biennial update report and the international consultation analysis. Besides, the country is also a regular participant of the annual partnership retreats.

Climate and Clean Air Coalition (CCAC)[303] - Ghana is one of six countries that formed the CCAC in 2012. Currently, the coalition consists of more than 50 state and non-state members. Ghana joined the coalition at the early stages to demonstrate the country's seriousness to take concrete action on SLCPs. The CCAC supports country partners to accelerate and scale-up mitigation actions through its eleven initiatives. The Ministry of Environment, Science, Technology and Innovation is the focal point of CCAC in Ghana and coordinates CCAC activities. The EPA acts as the alternate focal point and provides a technical backstop to MESTI and other stakeholders involved in CCAC related activities. As the focal point, MESTI leads Ghana's contribution to the activities of the coalition at the international level and facilitates the mobilisation of national efforts for integrating short-lived climate pollutants mitigation measures into the overall national development process.

Ghana is participating in four of the 11 CCAC initiatives, and these are:

- Urban Health Initiative (Ghana Health Services and WHO).
- Reducing SLCPs from Household Cooking and Domestic Heating (Global Cookstove Alliance);
- Promoting SLCP National Action Plans (SNAP) (MESTI and EPA)
- Reducing Black Carbon Emissions from Heavy-Duty Diesel Vehicles and Engines (Ghana Port Authority, including the promotion of soot-free buses by EPA and UNEP).
- Ghana is a sitting member of the CCAC steering committee until 2021.

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[299] https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

[300] https://www.ipcc.ch/data/

[301] https://www.transparency-partnership.net/

[302] https://www.transparency-partnership.net/network/information-matters

[303] https://www.ccacoalition.org/en

NDC Partnership[304] - The partnership has a focus on advancing the implementation of development and climate actions. MESTI is Ghana's focal point for the partnership and works closely with the UNDP to coordinate donor support for the implementation of Ghana's NDC. The country foresees its engagement with the NDC partnership would be efficient if it is worked through the existing institutional collaboration to avoid duplication.

Coalition for Rainforest Nations (CfRN)[305]**-** Ghana is among the twenty-three African REDD+ countries that are part of the CfRN. With the support of CfRN, Ghana improved its GHG inventory for the AFOLU sector by receiving quality assurance checks by the Independent Panel review of the Reporting for Results-based REDD+ (RRR+) project. The coalition has been a fulcrum for developing forest nations to champion their views in the UNFCCC negotiations.

Global Methane Initiative (GMI)[306] – Ghana is a steering committee member of GMI and has representatives on the biogas, agriculture and waste technical groups under the biogas sector as well as the committee on oil and gas systems. GMI is an international public-private initiative that advances cost-effective, near-term methane abatement and recovery and use of methane as a clean energy source.

UN-REDD[307] – UN-REDD is also active in Ghana and has provided support to the country under the Warsaw Framework for REDD+. The support was on "governance and synergies between REDD+ and FLEGT, as well as on national forest carbon inventories in West Africa". Currently, Ghana serves as a member of the UN-REDD board.

7.4 Capacity Building Needs

The EPA conducted an online survey[308] from state and non-state actors to assess the capacity requirements for effective implementation of climate change programmes in Ghana. In all fifty-five institutions were surveyed, of which 70% responded to the questionnaire. Below are the key findings from the survey:

An unexpectedly high number of "cross-cutting" institutions – Majority of the respondents identified as cross-cutting organisations making up 63.2% (Figure 83). The large proportion of cross-cutting institutions include those that are not directly working in the line ministries such as the Universities, CSO, private sector companies and the coordination organisations (Ministry of Finance, National Development Planning Commission, Ministry of Environment, EPA). Besides, the rest of the respondent institutions were mostly from the energy and forestry sectors.

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[304] https://ndcpartnership.org/

[305] https://www.rainforestcoalition.org/

[306] https://www.globalmethane.org/about/index.aspx

[307] https://www.unredd.net/regions-and-countries/africa/ghana.html

[308] The team used survey monkey instrument for the exercise

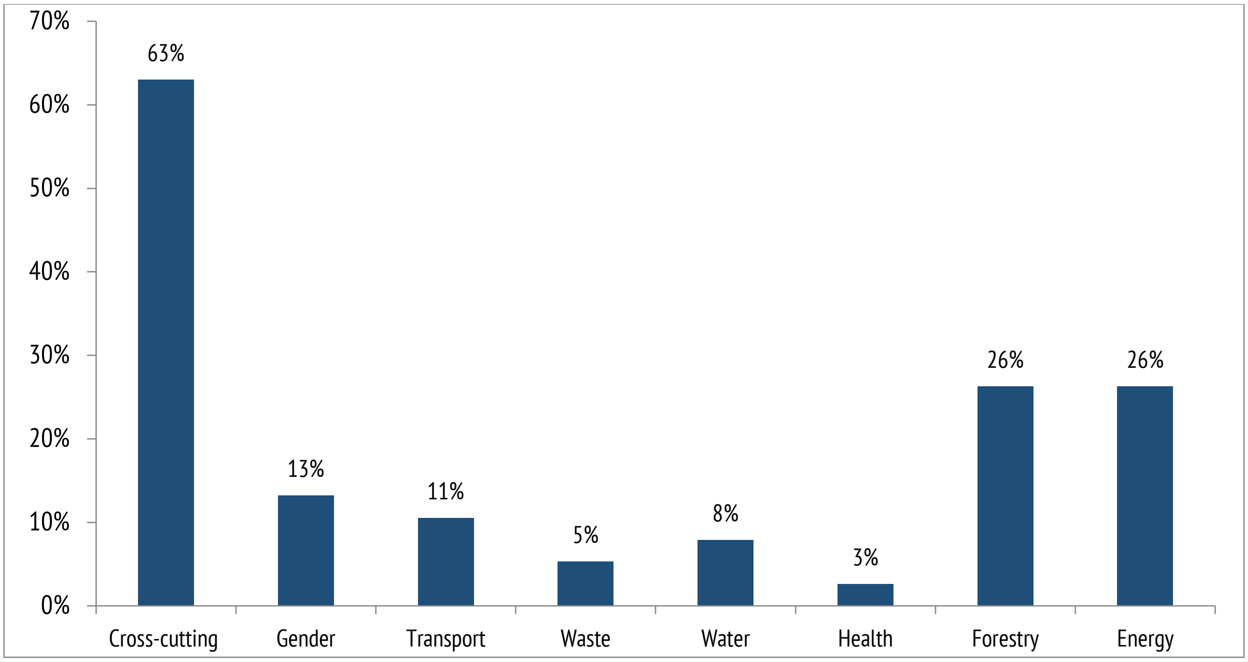

Figure 83: Working sectors of respondent institutions

A high number of respondent institutions are involved in climate change – more than 90% of the respondents had participated in the preparation of the actual NDC or the implementation plan as sector lead, supporting or contributing institutions. More than half (55%) of the total number of institutions indicated their involvement as sector lead. Sector leads are organisations that have the overall responsibility of coordinating climate change activities in each line ministry.

For example, the institutional arrangement in the energy sector is characterised by three levels of involvement in climate change. While the Ministry of Energy as the lead government institution in the sector provides broad support and policy directions, the Energy Commission and the Volta River Authority operate at the regulatory (supporting) and facility-level (contributor) respectively. The involvement of a wide range of institutions in climate change activities is a good sign of meaningful collaboration to work together as a whole community (Figure 84). It also shows the potential for further strengthening of the partnership that already exists among actors.

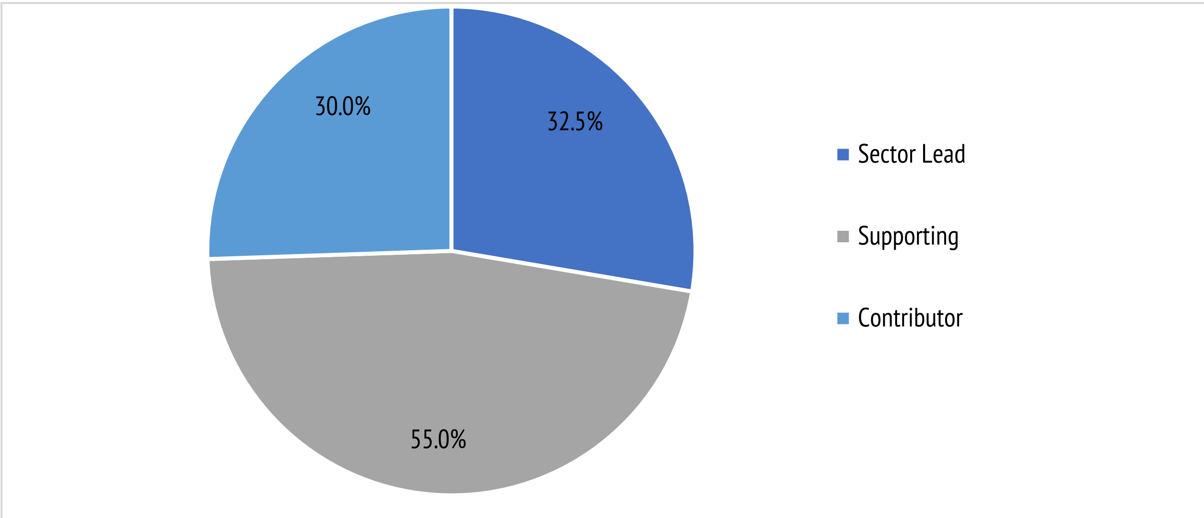

Figure 84: Description of the types of institutional involvement in climate change in Ghana

Segment and prioritise capacity needs - the institutions indicated that addressing the top capacity needs of most of the actors would require greater participation in the implementation of climate change policies and programmes. The survey identified some of the institutional and individual capacity gaps as follows:

- Inadequate understanding of climate negotiations.
- Difficulty in accessing international climate finance.
- Insufficient capacity for preparing bankable climate projects and fundraising.
- Limited skills for undertaking vulnerability and mitigation assessment, economic modelling, emission projections, policy evaluations.
- Inadequate capacity to develop viable investment plans.
- Reduced visibility of climate change issues or climate awareness of high-level decisions makers

Furthermore, the institutions further suggested priority capacity needs:

- Develop a national climate change capacity-building plan to guide the sourcing and coordination of capacity support.
- Organise climate change clinics for high-level technical and political office holders at the national, sector, district and community levels.
- Develop tools for tracking the progress of implementation of climate change policies and programme and train stakeholders on how to use them.
- Organise regular training on topics on project preparation, climate fundraising, vulnerability and mitigation assessment, policy evaluation, economic and emission projection.
- Support local experts to participate in international and national climate training organised by reputable academic and non-academic organisations.
- Develop a national programme on international experiential training for learning-on-the-job training for local experts.
- Prepare standard reporting template and an associated guidance tool.

8. Information on Action for Climate Empowerment (ACE)

Information on Action for Climate Empowerment (ACE) is the UNFCCC's comprehensive programme on Articles 6 of the UNFCCC and Article 12 of the Paris Agreement. The overall goal is to engage the whole society through education, training, public awareness, public participation, public access to information, and international cooperation. Ghana's ACE agenda is delivered through the EPA's environmental education strategy and coordinated by the ACE national focal point. The ACE focal point at the EPA collaborates closely with the Environmental Education, Public Affairs Departments and other national stakeholders. The updates on the implementation of Ghana's ACE programme are below:

8.1 Efforts to Promote Access to Public Information

8.1.1 Installing Automatic Weather Stations in Senior High Schools

In 2015, the EPA signed a memorandum of understanding (MOU) with African hydro-meteorological Observatory (TAHMO)[309] to install Automatic Weather Stations (AWS) in Senior High schools across the country (Figure 85). The objective of the programme is to make climate data accessible to students and to keep them abreast with changes in the climate, and available technology to educate students. As part of the EPA climate change education in school's programme, TAHMO Initiative in collaboration with the KNUST and Delft University of Technology (TU-Delft), local NGOs, student and traditional authorities, launched the first automatic weather station at Accra Academy Senior High School. The launching marked TAHMO initiative of establishing weather stations across Ghana for improved access to accurate climate data in schools and the sustainable development of agriculture, weather forecasting, as well as climate modelling in Africa.

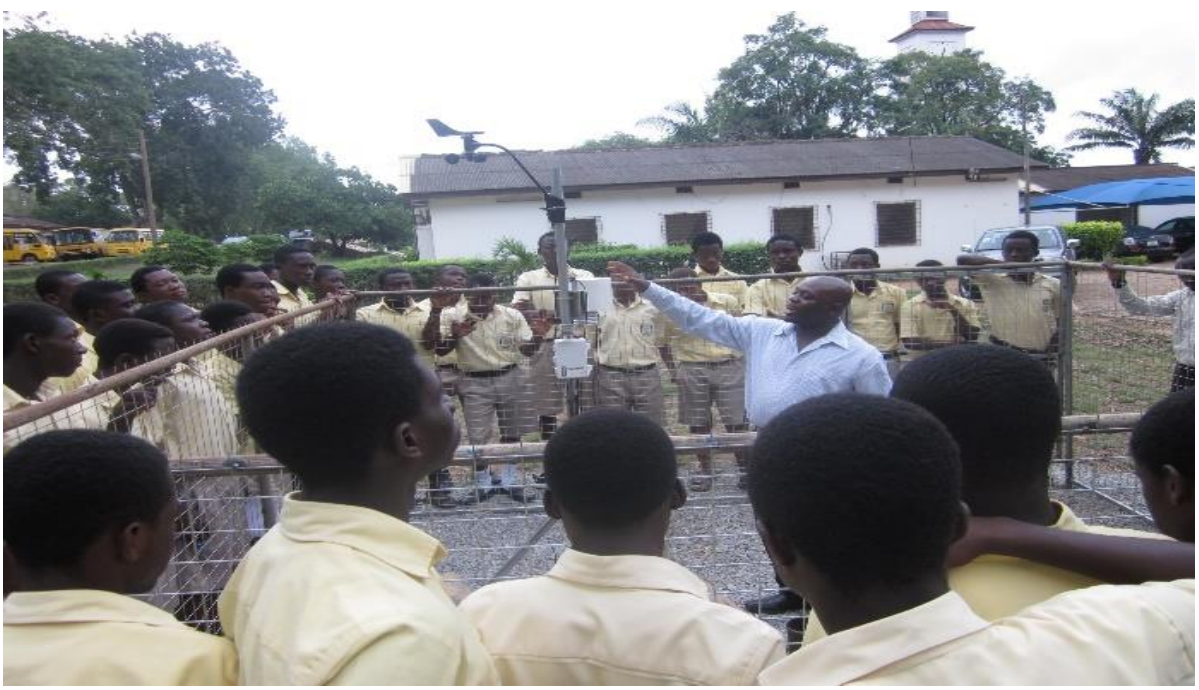

Figure 85: Commissioning of Automatic weather station at Accra Academy senior high school

[309] https://tahmo.org/

So far, the TAHMO initiative has installed more than 20 automatic weather stations nation-wide as part of the school-to-school programme. The beneficiary schools expect to put the AWS to good use with the view to (a) encourage and stimulate the interest in climate change learning in schools, (b) conduct climate change education in senior high schools, (c) provide data and information for climate change learning and (d) form climate change clubs to manage AWS and sustain the programme.

8.1.2 Climate Change Information Sharing Platforms

Public access to climate information is essential to promote public interest in climate change activities. The enactment of the Right to Information Act would further bolster the flow of climate information to the wide society. Below are the relevant electronic climate information sharing platforms in the country:

8.1.2.1 Climate change data hub[310] - Environmental Protection Agency

The EPA established an online database to serve as a climate change information depository. The hub, with five portals, contains data on greenhouse gas inventory, project registry, policies and measures, NDC and GCF. The URL for the hub is https://climatedatahubgh.com/ (Figure 86). The GHG portal hosts data on the latest GHG inventory, including the activity data, emission factors, inventory results and all relevant documentation.

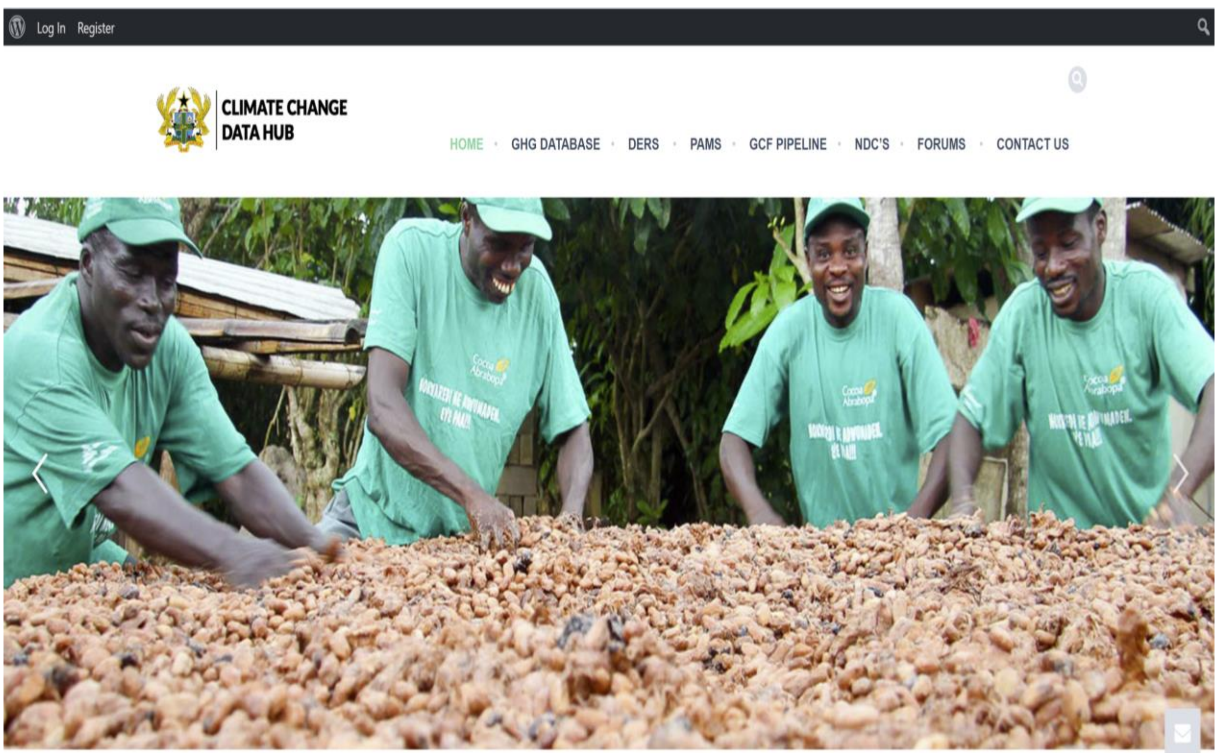

Figure 86: Screenshot of Ghana's climate data hub

The project registry contains information about climate actions and effects, and the financial support received. The dynamic search function allows users to look for specific project information on the fly. The policies and measures portal is the dashboard for tracking the implementation and achievement of climate change programmes.

[310] https://climatedatahubgh.com/

The new additions to the hub are the NDC and GCF pipeline portals. The NDC portal is to report information on the implementation of NDC actions per sector. The GCF page presents a central point to host GCF pipeline projects allowing developers and the public to track the status of an application under the GCF. There are plans to add an adaptation portal in the coming months as part of the national adaptation planning initiative.

8.1.2.2 National energy data processing and information centre[311] - Energy commission

The Energy Commission's database is a one-stop energy data platform and managed by the national energy data processing and information centre (NEDPIC). The platform visualises information on electricity, renewable energy and energy efficiency, natural gas, and petroleum industries in the country. The NEDPIC web page is under construction and would build on the previous Ghana Energy Access Database (GhEA Database). The GhEA database supplies information to aid sustainable energy planning in the country. The GhEA database can be accessed via this web address http://energycom.gov.gh/GhEAdatabase/dataset/ (Figure 87).

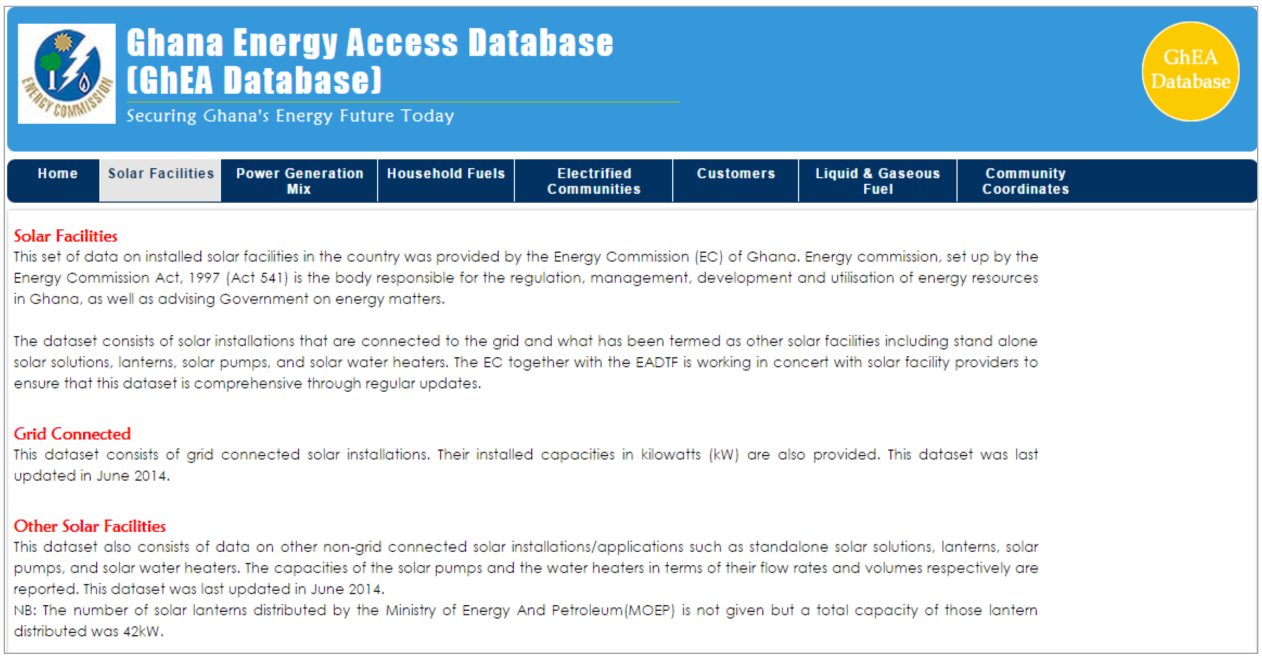

Figure 87: Screenshot of the Ghana energy access database

8.1.2.3 Climate change and resilience information centre – Care International[312]

Ghana is one of Care International's climate change operation hubs. The climate change and resilience information centre contain critical information on the communities in Ghana within Care International's project areas (Figure 88).

[311] http://www.energycom.gov.gh/planning/data-center/nedpic

[312] https://careclimatechange.org/

Figure 88: Screenshot of Care International's Climate change and resilience information centre

8.2 Efforts to Promote Public Participation

8.2.1 National School Drawing Contest on Climate Change[313]

Ahead of COP21 in Paris, the National Focal Point for climate change education in Ghana, in collaboration with the European Union, organised a national climate change contest to prepare unique drawings to highlight the vulnerability of climate change in Ghana to the global community at COP 21 in Paris. The competition was under the theme "seed for change; plant your idea to deal with climate change in Ghana". It was structured in three categories according to the age of pupils, with each group focussing on an aspect of climate change observation, impact and solution. The aim was to step up the climate change awareness outreach in Ghana to build a coalition ahead of the COP21 to be held in Paris at the end of November and December. It also helped to raise the profile of EU Climate Diplomacy to maximise the chances of success in COP21 and build up the awareness of all key interest groups in Ghana on the impact of climate change in the country and possible measures to adopt. Over 4,000 school children participated in the information sessions of the contest, resulting in 1, 866 drawings received from 493 schools. The nine best drawings were used as illustrations in a brochure and presented during Ghana Day at COP 21 in Paris. Some of the award-winning portraits are shown in Figure 89.

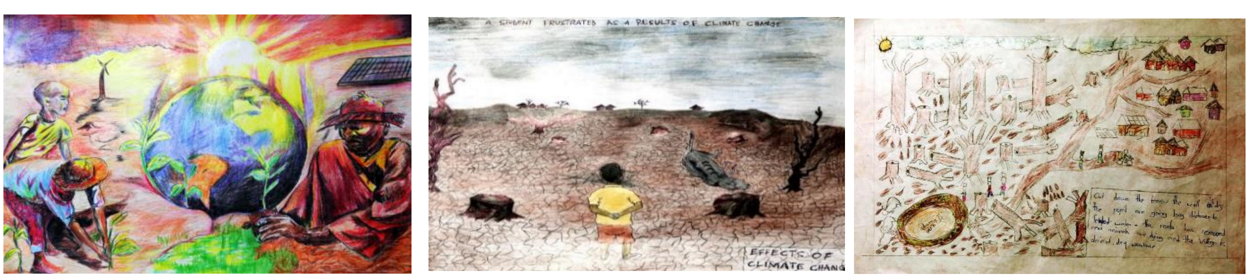

Figure 89: Award-winning drawings from the national contest

[313] https://newsghana.com.gh/eu-climate-change-schools-drawing-contest-towards-cop21/

The best Award Winner had a two weeks study tour in France. The Former President of Ghana H.E John Agyekum Kufuor presented the awards at Alliance Francaise, Accra (Figure 90).

Figure 90: National contest award ceremony

8.3 Efforts to Promote Public Awareness

8.3.1 Climate Change Week[314]

Ghana is implementing climate change and green economy learning strategy. In line with the plan, the EPA introduced climate change and the green economy week in 2016. The first climate change week took place from 24th to 30th of October 2016 to coincide with the month of the global climate change week. Activities of the week included a procession on the principal streets of the capital city of Ghana with placards. There was also a national symposium, community durbar, and political dialogue under the theme "climate change, a concern for all". The week helped to reach the wider Ghanaian audience and to create awareness of climate change and improve understanding of opportunities for green developments. About 5,000 participants took part in the week, including school children, civil society, academia, private sector, MDAs and the general public (Figure 91).

[314] https://www.uncclearn.org/news/ghanaians-celebrate-climate-change-and-green-economy-week

Figure 91: Pictures from the maiden climate change week in Ghana

8.3.2 REDD Eye Campaign[315]

In 2015, the Forestry Commission launched the REDD Eye to raise awareness among the Ghanaian youth on the need to plant and nurture trees as one of the ways to mitigate climate change. The Forestry Commission organised a national summit to engage the youth nationwide to educate them about REDD+. As part of the programme, "REDD EYE" clubs were formed in the various schools to undertake sensitisation on tree-planting programmes across the country. Besides, the Forestry Commission organised the national REDD+ forum to sensitise Ghanaians and solicit their support in the implementation of the national REDD+ programme.

The theme of the forum was "Conserving Our Forests for Better Lives and a Better Climate". The second national REDD+ forum[316] took place in 2017 at the Accra International Conference Centre (Figure 92) with the theme "strengthening law enforcement for effective REDD+ implementation". The forum brought together over a thousand stakeholders ranging from students, development partners, private sector, community leaders, traditional authorities and government officials. The government affirmed its support to combat deforestation. Further, it urged local communities to get involved in the fight against illegal logging and mining. The Judiciary also reiterated the meaningful role of law enforcement in dealing with deforestation.

[315] https://www.fcghana.org/events.php?events=69

[316] https://www.myjoyonline.com/news/2017/October-10th/forestry-commission-to-hold-second-national-redd-forum.php

Figure 92: Picture from the second REDD+ National Forum

8.3.3 Climate Change and Population Conference on Africa[317]

The University of Ghana's Regional Institute for Population Studies (RIPS) introduced the CPOP in 2012. Since then, RIPS has hosted seven CCOPs in Accra. CCOPs seeks to assemble climate change stakeholders to share value and experiences in tackling climate change in Africa. The seventh CCOP was held in 2019 at the Accra Metropolitan Assembly, Accra, Ghana with the theme "transforming cities' resilience to climate change". After the official opening, selected participants made oral and panel presentations of scientific papers under the following sub-themes.

- Population – climate nexus
- Population, health and climate change
- Climate change and energy
- Coastal zones and green growth
- Cities and climate change
- Climate finance and investment
- Climate change negotiations and diplomacy
- Adaptation and mitigation
- Food security and agricultural/rural communities
- Climate change and poverty
- Sustainable development goals
- Water resources management

The research findings and the issues elicited in the presentations informed the panel discussions and the conference conclusions.

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[317] https://www.ccpopghana.org/

8.3.4 Africa Climate Change Week[318]

The Ghana Government successfully convened the 2019 Africa Climate Week (ACW) at the Accra International Conference Centre under the Nairobi Partnership Framework. The theme for the week was "African Climate Action; A Race We Can Win". More than 2000 governments, businesses and CSOs joined the ACW. The conference called on countries and non-state actors to rally around the collective agenda of fighting climate change at all levels. During the high-level opening, Ghana's President, HE Nana Addo Dankwa Akufo-Addo indicated that the urgency needed for tackling climate change would require the involvement of the whole society. The ACW helped to raise the level of awareness of the public on climate change (Figure 93).

Figure 93: Picture from the NDC investment forum during the 2019 Africa Climate Week

8.3.5 Renewable Energy Fair[319]

In 2015, Ghana instituted the renewable energy fair to promote investment opportunities for scaling up renewables in line with Act 832 and as a climate change mitigation strategy. So far, the Ministry of Energy, Energy Commission and their partners have organised five renewable energy fairs at the International Conference Centre, Accra. The fair provides the platform for policy and academic discussions, an exhibition of innovation and trending renewable energy technology, and business-to-business partnership. The 2019 edition had the theme "opportunities for renewable energy and energy efficiency in a constrained energy sector". Often the fair involved a symposium[320] and exhibition[321]. However, in 2019, the organisers introduced a "high school renewable energy challenge[322]" for selected schools in the Greater Accra region.

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[318] http://mesti.gov.gh/ghana-launches-2019-africa-climate-week-celebration/

[319]http://ghanarefair.com/en/

[320] https://www.facebook.com/REFairGH/photos/a.313824722699073/331844430897102/?type=3&theater

[321] https://www.facebook.com/REFairGH/photos/a.107505169997697/548010399280503/?type=3&theater

[322] https://www.facebook.com/REFairGH/photos/a.539936886754521/539940900087453/?type=3&theater

The 2019 renewable energy fair brought together more than two thousand participants, twenty speakers and about thirty exhibitors to assess the progress, evaluate opportunities and challenges in the scaling up of renewables (Figure 94).

Figure 94: Photo from the high-level segment of the 5th renewable energy fair

8.3.6 Accra SDG Investment Fair[323]

The Ministry of Finance, the SDG Advisory Unit of the Presidency, the Ministry of Planning and Ghana Investment Promotion Centre established the Accra SDG investment fair to promote awareness on the SDGs and encourage private sector investments. Two investment fairs took place in 2018 and 2019 at Kempinski Hotel Gold Coast City, Accra. More than two hundred participants attended the 2019 SDG fair, which focused on a panel discussion on "blended financing for sustainable development." A breakout group followed panel discussion and treated topics like "local level financing of the SDGs, developing bankable projects for impact financing and achieving the SDGs: using a market approach (Figure 95).

[323] https://accrasdgsinvestmentfair.mofep.gov.gh/

Figure 95: Photo from the 2nd Accra SDG Investment Fair

8.3.7 Climate Chance Summit - Africa[324]

The Ministry of Local Government and Rural Development led a coalition of local and international partners to organise the second edition of the climate chance summit- Africa in Accra in 2019. The summit brought together 2,000 participants representing 50 different nationalities (including 34 African nationalities) and a variety of non-state actors engaged in the fight against climate change: local governments, businesses, unions, environmental NGOs, farmers, Women and Youth organisations, researchers (Figure 96).

Figure 96: Picture of the partners of the climate chance summit in Ghana

[324] https://www.climate-chance.org/en/climate-chance-africa-summit-2019/

The President of the Republic of Ghana who opened the summit announced the implementation of two funds with a total value of US$300 million for the fight against global warming. The Government has established an Advisory Group of prominent, private sector chief executives, who are setting up a US$100 million SDGs Delivery Fund and a US$200 million Green Fund, to complement the government's efforts at tackling climate change and funding the implementation of the SDGs.

8.3.8 Climate Change Dialogue with Political Parties and Parliamentarians

Ghana has a holistic strategy to address climate change. The immediate priority is to feature climate change issues in national development plans regardless of which political party is in government. Therefore, the engagement with political parties and the parliamentarians is critical to ensuring that climate change remains in the development plan of the country. In this regard, the EPA held a series of engagements with political parties and parliamentarians before Ghana's 2016 general elections to assess how political parties have integrated climate change and green economy issues into their manifestos. Those engagements also provided an opportunity for the UNDP, in collaboration with MESTI and EPA, to build their capacities and stimulate their interest in climate change and green economy[325]. At these discussions were eight representatives of political parties and the select committee. The meeting resulted in a fruitful debate among the representatives of the political parties on how their manifestos address climate change issues. The major political parties took turns to highlight their climate change commitments in their manifestos[326][327] (Figure 97).

Figure 97: The NPP and NDC political parties highlighting climate issues in their manifestos

8.3.9 National Climate Change and Green Economy Learning Strategy

In 2016, the MESTI launched the Climate Change and Green Economy Learning Strategy (CCGELS) to promote climate change education, awareness and learning in Ghana. The multi-sectoral Learning Strategy was developed by MESTI and the EPA, with technical support from the UNDP and United Nations Institute for Training and Research with funding support from the Swiss Government through the One UN Climate Change Learning Partnership (UN CC Learn).

[325] https://www.gh.undp.org/content/dam/ghana/docs/Doc/Demgov/Undp_GH_Report%20of%20UNDP%20Nkitahodie%20Policy%20Dialogue%20on%20Climate%20Change.pdf

[326] http://myjoyonline.com/docs/124542016%20npp%20manifesto%20highlights.pdf

[327] http://myjoyonline.com/docs/88222016-manifesto.pdf

The Multi-sectoral Learning Strategy is a capacity-building component of the Climate Change Master Plan in Ghana. It also seeks to promote awareness creation and help to build national capacity for the implementation of Ghana's NDC. The overall objective of the Climate Change and Green Economy Learning Strategy is to foster systematic and country-driven processes to enhance climate change and green economy learning. The 10-year learning strategy (2016-2026) was estimated to be implemented with a budget of US$ 103,073,000.

8.3.10 Integrated School Project on Clean Cooking Energy[328]

World Education Incorporated (WEI) responded to a call from the Clean Cooking Alliance, CCA (formerly Global Alliance for Clean Cookstoves) to design and implement a pilot project on Clean Cooking Energy. The project dubbed INSPOCCE (Integrated School Project on Clean Cooking Energy) was implemented in two communities within the Amasaman Municipal Assembly in the Greater Accra Region (GAR). The rationale was to provide the education sector with a programme to reach teachers, students and communities to mitigate the risk associated with using traditional cookstoves. It also built capacity within the sector to support and sustain the programme.

The project educated Junior High School students about the dangers of cooking over open fires and the existence of cleaner, more efficient solutions. As part of this pilot project, CCA through WEI designed and implemented an integrated curriculum that was tested and evaluated against several outcomes such as increased knowledge and positive attitudes towards clean cooking solutions. The project also raised awareness about the negative impact of traditional cooking practices among Ghanaian youth. It provided opportunities for girls and boys to be part of the change as their households transitioned to cleaner cooking solutions and enhanced their leadership skills.

The INSPOCCE pilot project worked closely with Curriculum Research Development Division (CRDD) of Ghana Education Service (GES), the National Council for Curriculum and Assessment (NaCCA), The Amasaman Municipal Education Directorate, the Municipal Assembly, traditional and religious leaders from both Christian and Islamic faiths, opinion leaders, the Global Alliance for Clean cookstoves' Ghana Team and the Ghana Alliance for Clean Cookstoves and Fuels (GHACCO)

Highlights of INSPOCCE

- 30 Community-Based Peer Educators trained in INSPOCCE's entrepreneurial component to meet the rising community demand and sale of clean cooking energy solutions.
- 181 School-Based Peer Educators successfully trained for in-school and out of school educational sessions.
- Three thousand seventy-six students (1,506 males and 1,570 females) reached through classroom teaching and in-school peer education sessions.
- Twenty-four thousand one hundred twenty-seven community members (9,648males, 14,479 females) participated in clean cookstoves and fuel awareness activities.
- A draft clean cooking education curriculum that increases the awareness and knowledge levels of JHS Students in Ghana has been developed to be integrated into the GES Basic School Education curriculum.
- The capacity of teachers in implementing schools built to effectively integrate cookstoves and fuel issues into the basic education curriculum.

[328] https://worlded.org/WEIInternet/international/project/display.cfm?ctid=na&cid=na&tid=40&id=23341

- Developed a scale-up strategy for integrating the teaching and learning of clean cooking and household energy into the national curriculum. Currently working with the National Council for Curriculum and Assessment to develop content in various subject areas for a national scale-up.

The I-SKIP Project[329] was a follow-on to the INSPOCCE Project but focused on transforming school kitchens from traditional ones to cleaner ones. The overall project objectives were twofold. Firstly, the project sought to transform traditional cooking school kitchens to clean cooking school kitchens, and secondly, to develop a scale-up strategy for implementing a national school kitchen improvement project. The concept of Clean cooking kitchens developed in I-SKIP had two purposes: as a pilot to establish best practices for adoption, integration and to scale up the use of clean cooking technology in school kitchens, and promote clean cooking technology as a living laboratory where students, teachers and all other staff can observe and learn about benefits of clean cooking technology and energy efficiency in schools.

Highlights of I-SKIP

- 10 implementing school kitchens in the Northern and Southern parts of the country presently use clean cookstoves for cooking. Each school has one highly efficient firewood (efficiency of 80%) stove and 3 LPG stoves installed.
- Health-related issues experienced by kitchen staff have reduced to about 50% with the improved stoves.
- All kitchen staff agree that clean cookstoves use less fuel, produce less smoke and little ash, are easier to use, and helps to maintain a cleaner kitchen environment.
- 100% of kitchen staff know about clean cooking solutions while 80% presently use an IC at home.
- 78% of teachers use LPG, and 40% use an improved charcoal stove.
- 85% of pupils have knowledge of improved cookstoves.
- 80% of the pupils are aware of the negative environmental and health effects of using traditional cookstoves.
- 72% of pupils got to know of a clean cooking solution through ISKIP.

8.4 Efforts to Promote Education

Climate change education is a central pillar of Ghana's ACE agenda. The strategy is to get the whole society to embrace the necessity to deal with climate change head-on if Ghana wants to achieve sustainable development goals. Therefore, Ghana's climate change education targets both the formal and informal segment of society. While the formal education programme focuses on developing the critical skills base from primary to tertiary school training, the informal aspect highlights the need for increased public awareness on climate change with an emphasis on behavioural change and community action.

8.4.1 Formal Climate Change Education

8.4.1.1 Integration of climate change into school curricula

In September 2019, all primary schools across Ghana started teaching climate change (Figure 98). The EPA, in close collaboration with the National Council for Curriculum and Assessment (NaCCA) and Ghana Education

[329] https://worlded.org/WEIInternet/international/project/display.cfm?ctid=na&cid=na&tid=40&id=32623

Service, has incorporated climate change issues into school curricula. Currently, climate change is taught as part of the following subjects in lower and upper primary: English Language[330], Science[331], Our World and Our People[332], Creative Arts[333] and Religious and Moral Education[334]. Integrating climate change into school curricula is in line with the implementation of Ghana's National Learning Strategy. Furthermore, climate change teaching and learning materials (TLMs) in the form of posters, tailored to the new curricula have been developed by EPA and NaCCA to enhance practical training and learning. The EPA is currently training primary school teachers across the country to improve their understanding of climate change and how to use the materials. The integration of climate change into school circular benefitted from the foundation work of Ghana's Climate Change and Green Economy Learning Strategy. The UNDP and the UNITAR supported the technical process for preparing the strategy as part of the CC learn to programme. Work is underway to facilitate the integration of climate change into school curricula of junior and senior high schools.


Figure 98: National stakeholders during the initial meeting on the development of climate change school curricula

[330] https://nacca.gov.gh/wp-content/uploads/2019/06/ENGLISH-B4-B6.pdf

[331] https://nacca.gov.gh/wp-content/uploads/2019/04/SCIENCE-UPPER-PRIMARY-B4-B6.pdf

[332] https://nacca.gov.gh/wp-content/uploads/2019/06/OUR-WORLD-AND-OUR-PEOPLE-B4-B6-1.pdf

[333] https://nacca.gov.gh/wp-content/uploads/2019/06/CREATIVE-ARTS-B4-B6-.pdf

[334] https://nacca.gov.gh/wp-content/uploads/2019/04/RELIGIOUS-AND-MORAL-EDUCATION-B1-B6.pdf

8.4.1.2 Tertiary climate change education

Many public tertiary institutions offer courses on climate change as a stand-alone or integrated subject and as a graduate programme. The University of Ghana, Legon and Kwame Nkrumah University of Science and Technology, Kumasi have introduced graduate programmes on “climate change and sustainable development” and “climate science and meteorology” respectively. Also, WASCAL has introduced graduate and post-graduate programmes on climate change. Some of the specialised areas are natural resources management, energy, economics, agriculture, geography and recently, international development. These programmes have produced skilled young natural and social scientists who can contribute to tackling climate change in Ghana. Besides, the University of Cape Coast, University of Development Studies and the University of Energy and Natural Resources have bachelor and graduate programme course structures to cover topics on climate change and sustainable development. Table 84 shows the tertiary institutions in Ghana that teach climate change and related courses at the degree level.

Table 84: Overview of climate change and related courses offered by Tertiary Institutions in Ghana

Course/Programme	Institute/Department	University	Comments
MSc and MPhil in Climate Change and Sustainable Development	School of social sciences, Business School	University of Ghana, Legon	Multi-disciplinary
Bachelor in Geography	Department of Geography and Resources Development	University of Ghana, Legon	Climatology
MSc. Climate Science and Meteorology	Department of Physics	KNUST	Relevant for climate modelling
MSc. Environmental, Science, Policy and Management	Department of Urban and Environmental Management	Institute of Local Government Studies, Accra and Tamale	Climate change to inform decision-making processes
Post-graduate studies	Institute of Environmental Studies and Sanitation	University of Ghana, Legon	Climate Change Adaptation
Post-graduate studies	Regional Institute for Population Studies	University of Ghana, Legon	
MSc. Renewable Energy	Mechanical Engineering and Energy Centre	KNUST	Climate mitigation
MA in Environment and Resource Management	Faculty of Integrated development studies	University of development studies	Climate change policy
M.PHil/ PhD. Environmental Management and Sustainability	Navrongo campus	University of development studies	Climate change policy
MA Geography and Regional Planning	Department of Geography and Regional Planning	University of Cape Coast	Climate Adaptation and mainstreaming issues, Climatology
MSc Sustainable Energy Management	Department of Energy and Environmental Engineering	The University of Energy and Natural Resources	Low carbon development
Dual Degree Programme in Master of Science in Bio-Economy and Natural Resources	Forest Research Institute (FORIG) and KNUST	University of East Finland	REDD+, Carbon Trading
HND Renewable Energy Systems Engineering	School of Engineering	Koforidua Technical University[335]	Climate change mitigation

[335] https://foe.ktu.edu.gh/programmes/programmes-renewable-energy-systems-dept/

Masters Programme in Sustainable & Integrated Rural Development	College of Agriculture and Natural Resources Department of Agricultural Economics, Agribusiness and Extension,	KNUST	Climate-smart agriculture policies
MPhil - Natural Resource & Environmental Governance	Department of Silviculture and Forest Management	KNUST	Forest mitigation
MPhil Geography & Rural Development	Department of Geography & Rural Development	KNUST	Climate change policy
BSc. Environmental Science	Department of Environmental Science	KNUST	Climate change policy
MPhil/PhD in Environmental Science	Department of Environmental Science	KNUST	Climate change adaptation, impacts and policy
MPhil/PhD Social Forestry and Environmental Governance	School of Graduate Studies	The University of Energy and Natural Resources	Climate change policy
MSc./MPhil Climate Change	School of Graduate Studies	The University of Energy and Natural Resources	Climate change policy and climate modelling
MSc./PhD Sustainable Energy Management	School of Graduate studies	The University of Energy and Natural Resources	Climate change policy
MPhil Environmental Science	Department of Environmental Science	University of Cape Coast	Climate change policy

8.4.2 Informal Climate Change Education

Informal education generally targets the broader section of the Ghanaian society. Most of the informal education Programmes on climate change are delivered in mass and print media such as radio and TV interviews, jingles, documentaries, community durbars, information vans and dissemination of educational materials. Social media has also become a useful tool in communicating with the public on climate change issues. Table 85 shows selected institutions and their climate change awareness programmes.

Table 85: Institutions, public awareness and training programmes

Institutions	Public Awareness Programme	Level/Target
Centre for African Wetlands, University of Ghana and Ghana Wildlife Society	Local community fora and stakeholder consultative meetings organised to seek and exchange views with communities concerning climate-related issues.	Community and district levels
Crop research institute	CLIMAFRICA; community members around the Ankasa forest reserve were involved in an awareness Programme on the identification of climate change coping strategies and development of adaptation strategies.	Community-level
Forestry Research Institute of CSIR	FORIG trained fifty-four communities around the Ankasa conservation area on forest carbon assessment	Community-level
Forestry Commission	Series of sensitisation workshops organised for various levels of stakeholders to enhance understanding of climate change issues targeting	The private sector, NGOs, CBOs, local communities and traditional authorities and Government agencies including frontline staff of the Forestry Commission.
Environmental Protection Agency	District capacity programme	
	Climate Change awareness in ICT	Second cycle institutions

	Environmental programmes in secondary school / Climate change education in Schools programme.	
	Number of radio and TV interviews	General public
University of Ghana Business School (UGBS)	Series of sensitisation programmes for students on climate change issues	First and second cycle institutions
	Number of regional level-Radio discussion	General public
Africa Centre for Energy Policy (ACEP)	Developed a demonstration project using solar energy to undertake irrigation farming for the deprived community in Karaga District of Northern region of Ghana. The essence is to highlight the potential of using solar energy as opposed to fossil fuel sources to draw water for irrigation purposes	Communities
	Currently developing animation concepts and articles to promote climate change adaptation using social media	General public
Greener Impact International (GII)	Instituted a biannual conference dubbed Ghana Youth Conference on Climate Change and Sustainable Development to provide a platform for learning and share ideas and experiences on issues related to climate change	Youth
	Training and capacity building workshops focused on Climate Smart Agricultural (CSA) Techniques to enhance the resilience of Anloga Community to the threats of climate change	Women and youth farmers
HATOF Foundation, Abibiman Foundation, and Agorvie Youth for Sustainable Development	Collaborative, consultative workshop to assess and outline climate adaptation actions for the youth, challenges young people face and how to overcome these challenges and feed results into the Global Commission on Adaptation Flagship Programme[336]	Youth
CARE International in Ghana	Climate policy and adaptation/resilience technical training under the "Yen Sore" natural resources governance programme and "GCF-CSO Readiness Project	CSOs and local communities
Centre for Capacity Improvement for the Wellbeing of the Vulnerable - CIWED	Conducted several sensitisation and training workshops on good agronomic practices on Feed the Future Agriculture Technology Transfer project, climate change, and gender.	community level
HATOF Foundation	Capacity building and knowledge management workshops for CSOs towards the implementation of Multilateral Environmental Agreement – climate change, and national environmental policies, legal frameworks, and climate finance[337]	NGOs, CBOs, private sector, women and youth groups.
	Training and capacity building workshop for selected media house towards the effective reporting and communication of climate change and climate finance[338]	Journalist
Abibiman Foundation	Training on climate-smart agricultural techniques and methods for farming chilli pepper	Women groups

[336] https://citinewsroom.com/2019/03/workshop-on-youth-in-climate-adaptation-held-in-accra/

[337] https://drive.google.com/open?id=0B90e9V2nuzitaWwwekFtR0VyQkQ3Q2pkT2hoS0ZoQ1lzRnlN

[338] https://citinewsroom.com/2019/03/climate-change-would-retard-ghanas-development-gains-if-not-tackled-analyst/

	Sensitisation and awareness creation on climate change among students	First and second cycle schools
	Tree planting exercise for the establishment of woodlots.	Youth
Concern Health Education Project	Training and outreach campaign on climate change and renewable energy and sensitisation of schools and communities on Adaptation and Mitigation Plans	Students and local communities
Agency for Health and Food Security (AHEFS)	Embarked on in-school and out-of-school education on climate mitigation and adaptation behaviours using stakeholder engagement, public addressing, behavioural change communication, participatory learning and action, and social change techniques[339].	Schools
Strategic Youth Network for Development (SYND	Organised training for youth leaders on climate change bringing them to speed on national plans and how they can contribute to the processes using their skills, energies, and abilities	Youth
Private Enterprise Federation, MESTI, EPA and UNDP in collaboration with the Centre for Climate Strategies[340]	One-year certification program on building the capacities of the Private Sector on financial de-risking measures for the implementation of Ghana's NDC.	Private sector

8.4.2.1 Capacity Building for media practitioners

In the NC3, the following priority challenges were identified through the EPA's media survey on environmental training needs assessment for journalists:

- Inadequate understanding of the concepts and terminologies used by scientists to discuss the issue of environmental management and policies on climate change and chemicals.
- Inadequate of training in skills to convert scientific information presented by environmental scientists and experts into everyday parlance for the average Ghanaian, and
- Inadequate knowledge of sources and sometimes resource persons on environmental management.

In addressing these challenges, the EPA organised three training workshops on enhancing knowledge and advocacy of core Journalists on environmental issues for editors, producers and presenters on the topic "Demystifying Environmental Issues: The Role of Media Editors" in 2019 at the Institute of Environmental Studies (IES), Amasaman Accra, Ghana. The workshop aimed at improving the understanding of the participants on environmental issues and policies, including chemicals and climate change issues, and to empower them, as advocates for environmental protection/ management in Ghana. The training enhanced the knowledge of journalists on environmental issues to equip them with the skills and materials needed to educate Ghanaians on the need to protect and sustain our environment to guarantee the quality of human life. In all, about ninety media persons from state and private media took part in the training. The participating journalists appreciated the breadth and depth of the topics covered and the strategies for reporting on environmental issues.

[339] http://www.ghananewsagency.org/social/csos-call-for-stronger-partnerships-to-help-achieve-sdgs-1365648
[340] http://www.climatestrategies.us/international_actions/international_actions/view/53

The resource persons noted, with excitement, an increase in media reports on different environmental and EPA issues immediately following the training. At the end of the training, EPA signed a Memorandum of Understanding with the Ghana Journalists Association to sponsor the Best Environmental Journalist annually for three years and equip and give knowledge on pertinent and emerging environmental issues and environmental reporting for 20-25 fresh graduates from the Ghana Institute of Journalism and other accredited communication training institutions annually (Figure 99).

Figure 99: Group picture of Editors and sub-editors and resource persons

9.0 Ghana's first summary of information on how safeguards for REDD+ are being addressed and respected

In May 2019, as mandated by Decision 12/CP. 19 paragraphs 3-4, Ghana voluntarily provided its first summary of information (SOI) on how safeguards for REDD+ are being addressed and respected via the UNFCCC website[341]. To further strengthen the effective implementation of REDD+, Ghana has established an online safeguard information system (SIS) to meet the national environmental regulations, Cancun, World Bank, and GCF safeguard requirements. With the establishment of the SIS, Ghana wishes to update the SOI submitted to the UNFCCC consistent with Decision 12/CP. 19. The URL reference to SIS is http://reddsis.fcghana.org/ (Figure 100).

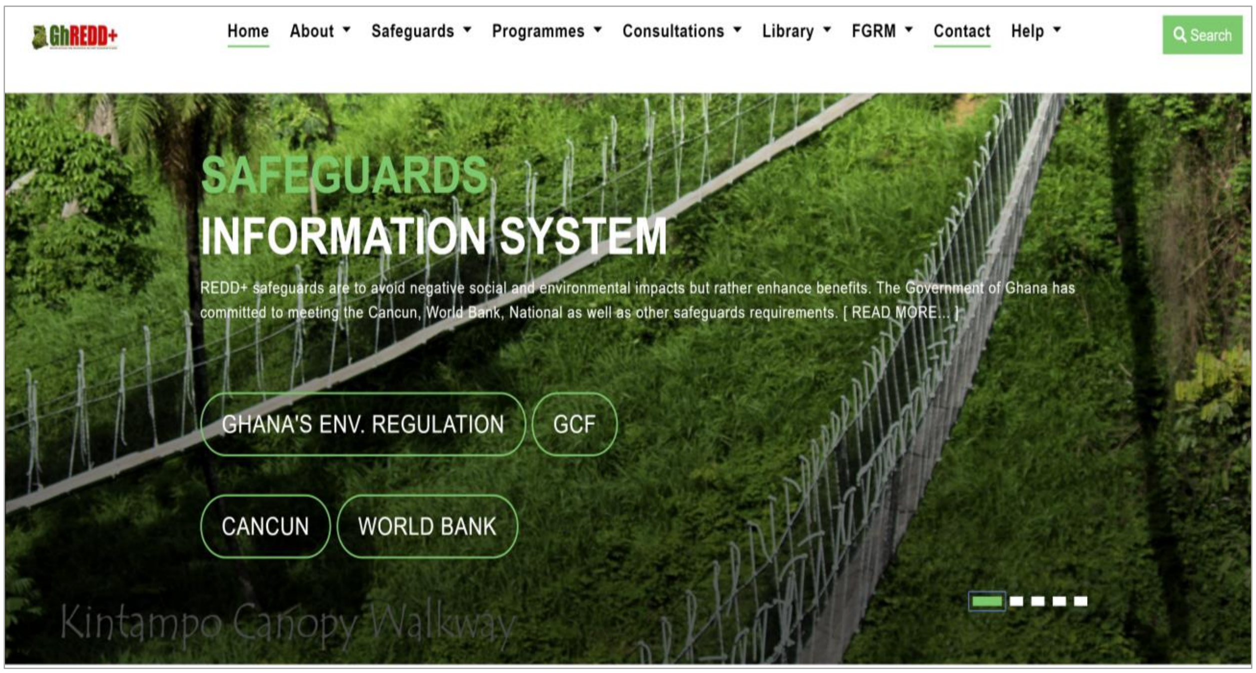


Figure 100: Screenshot of Ghana's safeguard information system

[341] https://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf

10. Ghana's Experience on Response Measures

Decision 2/CP.17 adopted guidelines in Annex III that determined objectives for the development of guidelines for Biennial Update Report for non-Annex I Parties that included issues of Response Measures (RM) and in so doing facilitating the reporting to take cognisance on any economic and social consequences of response measures.

Decision 3/CMA.1 (matters related to the implementation of PA) also states that each Party with an NDC that consists of adaptation action and/or economic diversification plans resulting in mitigation co-benefits, to submit information on how the economic and social consequences of response measures have been considered in developing the nationally determined contribution. Furthermore, decision 18/CMA.1 also states that each Party with an NDC that consists of adaptation actions and economic diversification plans resulting in mitigation co-benefits shall provide the information necessary to track progress on the implementation and achievement of the domestic policies and measures implemented to address the social and economic consequences of RM, including:

- sectors and activities associated with the response measures;
- social and economic consequences of the response measures;
- challenges in and barriers to addressing the consequences;
- actions to address the consequences.

Each Party is encouraged to provide detailed information, to the extent possible, on the assessment of economic and social impacts of response measures. Therefore, Ghana opted to report RM information in its BUR2 and has further provided an update in this NC4 as follows:

10.1 State of Response Measures Efforts in Ghana

There are a series of climate and green policies, strategies and initiatives which have been implemented in recent years in Ghana. It is believed that the climate and green policies initiative would contribute to the broader social and economic development plan. There was the need for a planning tool that can assess how green and climate policies affect job creation, for women and youth, income distribution, skills development and economic growth.

Therefore to provide for better planning and coherence of policies with multiple objectives, and to maximise job growth and minimise losses, and protect those in transition to sustainable development and a Just Transition for All, EPA partnered the International Labour Organisation (ILO) to offer support in the provision of the tool-Green Jobs Assessment Model (GJAM). This partnership provides quantitative and qualitative employment estimates for evidence-based decision making using the tool GJAM. The tool, currently being used by Ghana has provided for better planning and coherence of Ghana's climate change policies with multiple objectives.

10.2 Responding to the Gaps

A training was organised from 11th to 14th March 2019 with the overall objective to help the country better understand the social and employment implications of climate policies and their NDC. The training targeted nineteen institutions and twenty-nine persons from research, statistics, labour, employment, Union, Policy, Financial, Pensions Fund, Ministries and Agencies. Most of the institutions listed are members of the Response Measures Technical Working Group (Figure 101).

10.2.1 What Has Been Done So Far

- ILO and core climate change negotiators have built the capacity of the response measures technical working Group on global perspective and contextual issues of climate change and the UNFCCC process.
- ILO has developed a Green Jobs Assessment Model for Ghana following the methodology as described in the "Guidebook on How to Measure and Model Social and Employment Outcomes of Climate and Sustainable Development Policies
- ILO has built the capacity of the response measures technical working group on the elements of the Input-Output Table model, interpretation of multipliers and basic applications. Also, the expansion of a traditional Input-Output table with physical quantities.
- Build capacity of the technical working group of the NDC to model and measure the job impacts of national climate plans and policies (focusing on NDCs).

10.2.2 Challenges

- Lack of current data for the model - The current Supply and Use Table (SUT) for Ghana was constructed in 2004. The oil and gas sub-sector under the mining and quarrying sector is not part of 2004 SUT since Ghana started producing commercial quantities of oil in 2010.
- Lack of data on the green and conventional Industries

Figure 101: Participants in the ILO-EPA training workshop on response measures

10.2.3 Activity for the Next Steps to Address the Gaps

- Development and update of SUT/IOT/SAM to latest GDP.
- Data collection of Green industry structure in terms of intermediate demand, import, value-added and employment and spilt of ISIC into green and conventional industries (Small sample survey of Green industry from Ghana Statistical service business register (out of a total of 638,000 establishments).
- Data collection of additional labour, social and environmental statistics, cleaning and interpolation in concordance with ISIC and Green Industry extension of SUT/IOT.

- Yearly SUT/IOT baseline business as usual projection up to next 10-15 years, such as up to 2030 or aligning to the national development plan, using IMF or another forecast.
- Review of climate and green policies, developing several scenarios and quantification of those in terms of investment and final demand up to 2030.
- Yearly SUT/IOT 'green' projection up to 2030 using IMF forecast but modelling structural shift and considering quantified green and climate policies.
- Analysis of employment, social and the environment, such as CO_2 outcomes of policies, a model report in a spreadsheet, a summary of the report and technical report.
- Report and relevant policy briefs.
- Presentation and discussion of results in a national workshop.

10.2.2 Targeted Groups for the Presentations and Discussion of the Findings:

- NDPC Commissioners
- Media
- Parliamentary Select Committees on Environment; Employment; Energy; and Land;
- Economic Management Team
- Financial, Investment and Pensions Institutions; and the
- Leaderships of relevant Workers and Employment Organisations

Constraints, gaps, related financial, technical and capacity needs

Source: https://unsplash.com/photos/Y5biRJCR-Q4 Kakum Canopy, Cape Coast, Ghana

11. Updates on Financial, Technical and Capacity Needs

The preparation of the national communication has been beneficial in many ways to Ghana. First and foremost, the involvement of national experts in the compilation processes has led to substantial capacity improvements in climate change. Since 2000, more than 100 experts have received training on the UNFCCC guidelines for the preparation of national communication. It has also contributed to raising a high level of awareness and visibility of key climate change issues. Besides, national communication helps to highlight the critical problems for policy-makers to act on.

One unique characteristic of the national communication process is the ability to use the networks that have been created over the past ten years to collect feedback on ways to improve the national communication process continuously. It is also possible to use the existing network to monitor the implementation of activities and measures envisaged under the convention and the challenges confronting them. Nonetheless, the country faces technical and financial difficulties in implementing climate change activities and preparing national communications. In this regard, the EPA conducted a national survey to collect data on constraints and gaps in implementing climate change activities and the preparation of the national communication. The exercise revealed a wide range of issues in the following areas:

11.1 Financial Constraints, Gaps, and Needs

Access to finance and capacities are vital ingredients for climate actions and reporting. They are critical aids in implementing climate interventions and preparing national communications. Therefore, during the survey, stakeholders pinpointed some of the significant financial and capacity needs the NC4 must highlight as follows:

- **Difficulty in tracking climate financial inflows** – several organisations in the country receive climate funding from multiple sources that do not pass through the Ministry of Finance. It is because most of the programmes take place at different levels and unless it is held at the national level, it is difficult to track. The Ministry of Finance and the EPA are putting in place a national climate finance tracking tool that would sufficiently track all climate support expenditure from the Ghana government and donors. So far, the Ministry of Finance is finalising the work on developing budget codes for monitoring government expenditure on climate change. The EPA has incorporated the climate finance portal into the climate change hub.

- **Duplication of activities and funding** – weak institutional coordination within government and among donors, leads to duplication of climate change interventions, and in most cases, resources are not applied to where they are needed most. In Ghana, regular sharing of information among donors is already paying off in building synergies and avoiding duplication.

- **Lack of transparency on reporting on non-financial support for training and technical assistance** – It is difficult to monitor and report non-monetary supports. Many institutions receive training and technical assistance support from donors without financial disclosure because the source of funding is part of the global budget. When such situations arise, it becomes difficult to report because the recipient organisation does not have full access to the funding and accounting information.

- **Inadequate financial allocation in national budget** –funding for climate change activities, including preparation of national communication in the country, is mostly donor-driven and project-based. Domestic financing of climate change activities is difficult to estimate over a given time frame. This is because in the national budget, there is no clear demarcation of climate expenditure items, and this leads to challenges in tracking actual expenditures during the implementation of climate change activities and Programmes. The Ministry of Finance has collaborated with the ISSER, the University of Ghana to undertake Climate Public Expenditure and Institutional Review (CPEIR), which is expected to streamline how climate change expenditure issues are addressed.

11.2 Technical and Capacity Constraints and Gaps including Needs

Climate change capacity needs vary widely. In 2005, Ghana undertook capacity self-assessment for Global Environmental Management with support from GEF. The assessment informed the selection of priority capacity improvement areas in climate change that required considerable attention. The areas that were identified were used in subsequent capacity planning in the country. Since then, many institutions have benefited from several capacity development programmes (Table 86). Most of the programmes are either packaged into a more significant project or tailor-made to meet specific needs. The challenges that confront Ghana borders on the inability to monitor capacity and technical assistance regularly.

It, therefore, means that information on the capacity that is reported is not detailed enough to help in future capacity planning. Additionally, there is a problem with retention of enhanced capacity and usually arises from institutions where individuals who received capacity leave their jobs without transferring the capacity to another person. The country is currently making efforts to reduce the risk of creating gaps in institutions by making sure that at least two or more people benefit from training so that in the event one leaves, the other can transit smoothly to take over.

Table 86: Summary of the technical and capacity constraints and gaps

Activity	Capacity needed	Capacity received	Source of support
Use of 2006 IPCC guidelines and ALU software for AFOLU GHG Accounting	Data processing and management strategies	Training on AFOLU data collection and management.	RRR+ Project, Rainforest Coalition Nations
	QA/QC Protocols & Management of Uncertainty Management	Workshop on QA/QC and Uncertainty Assessment.	
		Development of LULUCF standard operating procedures.	Forest Carbon Partnership Facility, World Bank
		Training on Land use mapping using Google map engine tool.	West Africa GHG Management Project
Improvements in GHG national system	Strengthening national system for GHG	Development of GHG Manual.	Low Emission Capacity Building Project, UNDP
		Development of QA/QC Plan and Uncertainty Assessment Plan.	
	GHG and mitigation action data management and institutional arrangement	Establishment of an online climate change data hub.	
		Development of sector-specific MRV.	NDC Support Programme, UNDP
		Introduce corporate carbon accounting to VRA.	NDC Support Programme, UNDP Integrated Resource and Resilience

			Planning, USAID, IRRP
		NDC progress tracking tool	NDC Support Programme, UNDP and ICAT Project
Development of marginal abatement cost curve	Training on marginal abatement curves	Training on GACMO tool for the development of marginal abatement curves	ICAT Project, UNEP-DTU Partnership
Continuous training of GHG Experts	Training new technical expert on GHG at the international level	One expert participated in training Annex 1 GHG review and qualified as LULUCF reviewer	UNFCCC GHG Review Training Programme
Development of mitigation scenario for the non-energy sector	Improving on emission baselines	Training on mitigation assessment using LEAP-IBC tool	Stockholm Environment Institute (SEI)
Climate impacts assessment	Use of statistical and dynamic crop and hydrological modelling model	-	-
Monitoring and evaluation of climate adaptation actions	Methodology for monitoring adaptation action	-	-

11.3 GEF, Annex II Parties, multilateral/bilateral financial contributions

11.3.1 Data collection

The Government of Ghana and many donors have committed resources to support Ghana to meet the cost of addressing climate change. As a result, direct and indirect climate change supports had seen significant increases in the last ten years in Ghana. Most of the support Ghana received came through several development aid channels. Data on financial contributions from GEF, Annex II Parties, and multilateral/bilateral agencies and the Government of Ghana have been collected through a national survey and the website of donors. The data collected covered one hundred and one climate-specific projects (direct climate benefits) for the period 2011-2019. The projects that are not considered climate-relevant (indirect climate benefits) have been excluded because of the lack of clarity on the definition of scope and sources of funding.

In future, Ghana is planning through the Ministry of Finance and the EPA to put in place an efficient tracking and disclosure database system which would be available online. In the analysis of the data, the following assumptions were made; (a) to ensure consistency in the unit of analysis, non-US dollar-denominated projects have been converted to US$ using averages of exchange rates for each year and the period 2011 to 2019; (b) projects without adequate funding information are excluded; (c) for projects classified as active, "committed fund" is reported. Actual amounts disbursed may differ; (d) for projects classified as complete, total funds disbursed is reported; and (e) projects that are less than US$ 30,000 are excluded because of incomplete data.

11.3.2 Analysis of financial contributions

The financial contributions have been analysed "with" and "without" loans, Ghana has contracted to invest in the development of the gas industry. Except explicitly stated, all the financial flows are reported without the loan investment in the development of the national gas market. Total climate-related financial inflows for the period 2011-2019 amounts to US$ 15.5 billion (the equivalent of GHC 29.7 billion). The financial investment in the natural gas industry development alone amounts to US$14.2 billion in three oil and gas fields and processing plants. When the loan investments in the natural gas industry development are excluded, total climate inflows for the period hover around US$ 1.3 billion (GHC 2.5 billion). Of the total amount of climate finance for the period, the grant component made up the largest share of 72.1% and followed by loans (19.1%), national budget (8.5%) and result-based payments (0.4%)(Figure 102).

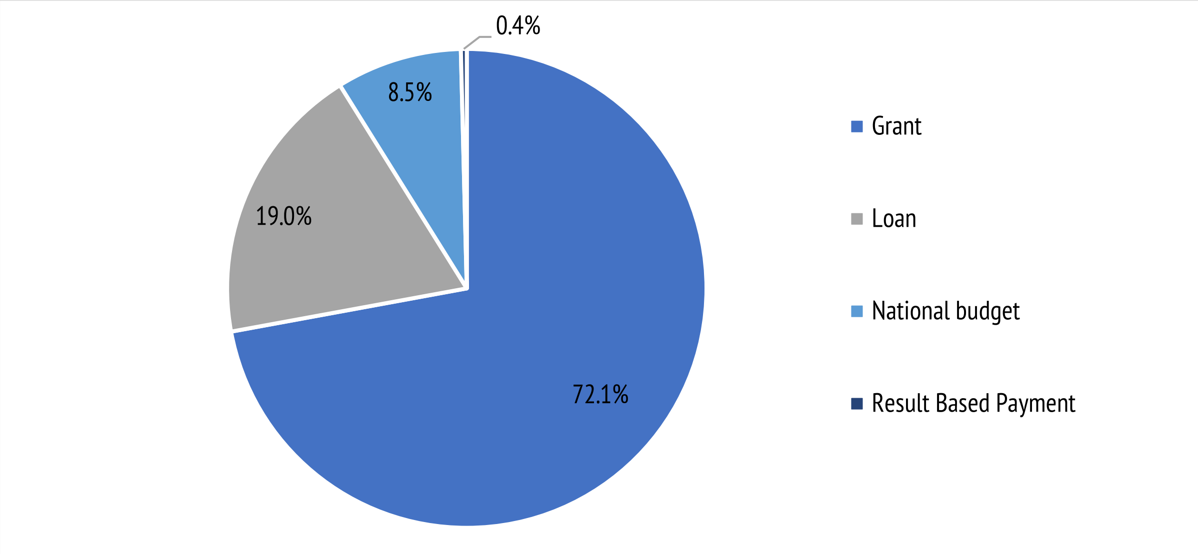


Figure 102: Share of climate financial inflows for the period 2012-2017

As shown in Table 87, the financial flows through bilateral channels were the largest (45.1%), followed by multilateral (29%), global projects (11.6%), national funds (7.1%), GEF (4.4%). The remaining 2.8% are private foundations (1.3%), private sector (0.13%) and technical cooperation (0.02%).

Table 87: Breakdown of climate change finance flows for the period 2011-2019

Climate finance flow channels	Grant	Loan	National budget	Result-based payment	total
Bilateral	**591,529,884**				**591,529,884**
Adaptation	7,979,847				7,979,847
Adaptation (MOI**)	1,113,558				1,113,558
Mitigation	516,648,586				516,648,586
Mitigation (MOI)	48,581,393				48,581,393
SD* (MOI)	17,206,500				17,206,500
Co-financing	**-**		**18,000,000**		**18,000,000**
Mitigation	-		18,000,000		18,000,000
GEF	**58,366,182**				**58,366,182**
Adaptation	13,418,182				13,418,182
Adaptation (MOI)	70,000				70,000
Enabling Activities	1,678,000				1,678,000
Mitigation	43,200,000				43,200,000
Global Project	**152,000,000**				**152,000,000**
Mitigation	152,000,000				152,000,000
Multilateral	**125,348,308**	**249,500,000**	**-**	**5,200,000**	**380,048,308**
Adaptation	22717296				22,717,296
Mitigation	68499128.24	249500000		5,200,000	323,199,128
Mitigation (MOI)	31020894				31,020,894

Finance (MOI)	938,679				938,679
Adaptation (MOI)	68,966				68,966
SD	50,000				50,000
SD (MOI)	2,053,345				2,053,345
National Funds	**-**		**93,280,000**		**93,280,000**
Mitigation	-		93,280,000		93,280,000
Private Foundations	**16,921,063**				**16,921,063**
Adaptation (MOI)	16,445,100				16,445,100
Mitigation (MOI)	475,963				475,963
Private Sector	**1,700,000**				**1,700,000**
SD (MOI)	1,700,000				1,700,000
Technical Cooperation	**249,000**				**249,000**
Grand Total	**946,114,437**	**249,500,000**	**111,280,000**	**5,200,000**	**1,312,094,437**

* SD: Sustainable development, **MOI: Means of Implementation

In terms of sectors, the energy sector is leading in the receipt of climate inflows. The total climate funds to the sector projects over the eight years amounted to US$ 758.8 million, making up 57.8% of total funds committed (Table 88). Almost all the funds allocated to the energy sector went to mitigation interventions. The forestry sector is the second biggest recipient (25.7%) of the climate funds for the same period. In the same vein, mitigation activities had more than the rest. Agriculture is the third biggest sector recipient of climate inflows over the same period.

Table 88: Overview of committed climate fund per sectors

Sectors	Adaptation	Adaptation MOI	Enabling Activities	Mitigation	Mitigation MOI	Finance MOI	SD	SD MoI
Agriculture	18,844,847			31,550,004	392,000			
Development Planning	6,000,000							
Education		16,509,965						
Energy				756,060,574	2,720,000			
Environment	11,054,629	1,142,558	1,678,000		3,787,633		50,000	18,059,845
Finance					5,000,000	938,679		2,900,000
Forestry		45,100.00		268,717,135	68,178,616			
Health	1,918,182							
Interior	5,162,667							
Transport				90,000,000				
Water	1,384,000							
Grand Total	44,364,324	17,697,623	1,678,000	1,146,327,714	80,078,250	938,679	50,000	20,959,845

Generally, there is considerable disparity between mitigation and adaptation of the climate fund allocations. Mitigation inflows constituted 87.4% of the climate inflows, followed by adaptation (3.4%). The remainder went into supporting means of implementation activities, especially capacity-building efforts. Table 89 indicates that the majority (92%) of the climate flows went through government organisations. Out of the total that was committed to the government, the public cooperation and the ministries received the largest share.

Besides, international NGOs operating in the country and the Universities followed with 3.3% and 2.6% shares respectively. Regarding their status, about 75% of the projects are still under implementation. Also, 23.5% of the projects are closed, whereas 1.6% is planned.

Table 89: Breakdown of the committed climate funds according to institutions

Organisations	Project status				Total
	Active	Complete	Phased-out	Pipeline	
Government Corporations	708,742,004	252,244,849		10,400,000	971,386,853
Government Ministries	199,890,834	14,250,312	3,527,571	9,147,317	226,816,034
Government Regulators	18,213,657	70,000		1,100,000	19,383,657
International NGO	5,500,000				5,500,000
NGO International	9,100,224	33,605,400			42,705,624
NGO Local		521,063			521,063
Private	3,500,000				3,500,000
Research National	658,716	7,974,990			8,633,706
University	33,606,500	41,000			33,647,500
Total	979,211,935	308,707,614	3,527,571	20,647,317	1,312,094,437

12. Concluding Remarks

Preparing the NC4 had been another opportunity to fortify the national arrangements for climate reporting. On this reporting round, more institutions and experts joined the NC4 to provide data and underwent training in the country and abroad. The training covered topics on vulnerability and adaptation assessment, GHG emission projections and evaluation of mitigation actions. Despite taking the initial commendable steps to devolve climate reporting to the relevant key line ministries, the institutionalisation process has not reached the desirable levels. So, during the NC4, the team took meaningful steps to get the line ministries to incorporate climate reporting into their annual work plans.

Another critical area that the preparation process afforded the team to focus on is the strategies for the policy uptake of the NC4 findings. This issue is vital when it comes to the discussion of the long-term sustainability of climate reporting. About the way forward, the team considered two aspects. First, the NC4 methodology and findings must be credible before policy-makers can confidently use them to inform policy. The team also recognised that NC4 results must be properly packaged for widespread dissemination to create the desired awareness among policy-makers so they can factor them into future climate policy planning. In this regard, the team plans to vigorously engage the potential users of the NC4 on how best to package the findings for future use, including through the preparation of infographics for dissemination. Additionally, there will be policy engagements with key stakeholders.

High-integrity data and adequate financing are the lifelines for the regular preparation of national communications. Regarding access to data, Ghana would continue to support the effort at strengthening the national data platforms and work closely with the Ghana Statistical Service to improve regular data collection. The GEF enabling fund is the primary funding source for the preparation of the national reports. Presently, Ghana does not provide direct funding to support national communications but covers some of the operational cost through in-kind contributions. The current level of funding arrangement is not enough to cover the full costs of running an efficient national system that can produce high-quality national reports timeously. 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 considering is the possibility to raise funding from the national budget through collaboration with the key line ministries and the Ministry of Finance.

13. Annexes

13.1 Annex 1: Summary Table A (2016)

Categories	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)			Emissions (Gg)				
	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NOx	CO	NMVOCs	BC	PM2.5
Total National Emissions and Removals	27,285.46	309.99	24.86	613.00	33.32	-	121.26	1,751.42	270.49	234.80	598.86
1 - Energy	13,973.47	31.34	1.24	-	-	-	97.21	1,207.71	261.00	234.53	594.74
1.A - Fuel Combustion Activities	13,965.23	30.58	1.24	-	-	-	97.21	1,207.71	261.00	234.53	594.74
1.A.1 - Energy Industries	5,098.01	1.70	0.23				9.16	320.71	108.18	1.29	8.88
1.A.2 - Manufacturing Industries and Construction	1,065.70	0.31	0.04				7.73	37.35	5.36	23.85	1.66
1.A.3 - Transport	6,918.61	1.68	0.68				66.52	270.64	37.41	87.76	236.00
1.A.4 - Other Sectors	882.90	26.89	0.28				13.80	579.01	110.05	121.63	348.20
1.A.5 - Non-Specified	-	-	-				-	-	-	-	
1.B - Fugitive emissions from fuels	8.24	0.76	0.0001	-	-	-	-	-	-	-	
1.B.1 - Solid Fuels	-	-	-				-	-	-	-	
1.B.2 - Oil and Natural Gas	8.24	0.76	0.0001				-	-	-	-	
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	394.89	-	-	613.00	33.32	-	-	-	-	-	
2.A - Mineral Industry	334.08	-	-	-	-	-	-	-	-	-	
2.A.1 - Cement production	21.85						-	-	-	-	
2.A.2 - Lime production	-						-	-	-	-	
2.A.3 - Glass Production	-						-	-	-	-	
2.A.4 - Other Process Uses of Carbonates	312.23						-	-	-	-	
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	-	-					-	-	-	-	
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	58.74	-	-	-	33.32	-	-	-	-	-	
2.C.1 - Iron and Steel Production	3.87	-					-	-	-	-	
2.C.2 - Ferroalloys Production	-	-					-	-	-	-	
2.C.3 - Aluminium production	54.86				33.32		-	-	-	-	
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	-	-	-	613.00	-	-	-	-	-	-	
2.F.1 - Refrigeration and Air Conditioning				613.00			-	-	-	-	
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					-	-	-	-	-	-	
2.G.2 - SF6 and PFCs from Other Product Uses					-	-	-	-	-	-	
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	12,908.42	156.76	21.69	-	-	-	22.00	527.75	-	-	
3.A - Livestock	-	121.14	3.03	-	-	-	-	-	-	-	
3.A.1 - Enteric Fermentation		114.66					-	-	-	-	
3.A.2 - Manure Management		6.48	3.03				-	-	-	-	
3.B - Land	12,872.05	-	-	-	-	-	-	-	-	-	
3.B.1 - Forest land	(4,668.07)						-	-	-	-	
3.B.2 - Cropland	8,331.46						-	-	-	-	
3.B.3 - Grassland	8,804.18						-	-	-	-	
3.B.4 - Wetlands	30.48		-				-	-	-	-	
3.B.5 - Settlements	173.75						-	-	-	-	
3.B.6 - Other Land	200.25						-	-	-	-	
3.C - Aggregate sources and non-CO_2 emissions sources on land	36.37	35.62	18.66	-	-	-	22.00	527.75	-	-	
3.C.1 - Emissions from biomass burning		25.18	1.42				22.00	527.75	-	-	
3.C.2 - Liming	-						-	-	-	-	
3.C.3 - Urea application	36.37						-	-	-	-	
3.C.4 - Direct N_2O Emissions from managed soils			13.36				-	-	-	-	
3.C.5 - Indirect N_2O Emissions from managed soils			3.68				-	-	-	-	
3.C.6 - Indirect N_2O Emissions from manure management			0.19				-	-	-	-	
3.C.7 - Rice cultivations		10.44					-	-	-	-	
3.C.8 - Other (please specify)		-	-				-	-	-	-	
3.D - Other	-	-	-	-	-	-	-	-	-	-	

3.D.1 - Harvested Wood Products	-						-	-	-	-	
3.D.2 - Other (please specify)	-	-	-				-	-	-	-	
4 - Waste	8.68	121.89	1.93	-	-	-	-	-	-	-	
4.A - Solid Waste Disposal	-	55.01	-	-	-	-	2.06	15.96	9.49	0.27	4.12
4.B - Biological Treatment of Solid Waste	-	2.45	0.15	-	-	-	-	-	-	-	
4.C - Incineration and Open Burning of Waste	8.68	2.75	0.04	-	-	-	2.06	15.96	9.49	0.27	4.12
4.D - Wastewater Treatment and Discharge	-	61.69	1.75	-	-	-	-	-	-	-	
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	346.56	0.0031	0.01	-	-	-	-	-	-	-	
1.A.3.a.i - International Aviation (International Bunkers)	339.06	0.002	0.01				-	-	-	-	
1.A.3.d.i - International water-borne navigation (International bunkers)	7.50	0.001	0.0002				-	-	-	-	
1.A.5.c - Multilateral Operations	-	-	-	-	-	-	-	-	-	-	

13.2 Annex 2: Energy sectoral table (2016)

	Emissions (Gg)							
Categories	CO_2	CH_4	N_2O	CO	BC	NOx	NMVOC	$PM_{2.5}$
1 - Energy	13,973.47	31.34	1.24	912.21	116.25	109.16	202.37	300.92
1.A - Fuel Combustion Activities	13,965.23	30.58	1.24	912.21	116.25	109.16	202.37	300.92
1.A.1 - Energy Industries	5,098.01	1.698	0.23	320.80	1.29	9.13	108.18	8.88
1.A.1.a - Main Activity Electricity and Heat Production	4,785.57	0.16	0.03	1.75	0.67	8.41	0.12	0.32
1.A.1.a.i - Electricity Generation	4,785.57	0.16	0.03	1.75	0.67	8.41	0.12	0.32
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				-	-	-	-	-
1.A.1.a.iii - Heat Plants				-	-	-	-	-
1.A.1.b - Petroleum Refining	252.70	0.007	0.0013	0.12	0.0018	0.12	0.00004	-
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	59.74	1.53	0.20	318.94	0.63	0.59	108.07	8.56
1.A.1.c.i - Manufacture of Solid Fuels		1.53	0.20	318.94	0.63	0.59	108.07	8.56
1.A.1.c.ii - Other Energy Industries	59.74	0.0018524	0.000326	0	-	-	-	-
1.A.2 - Manufacturing Industries and Construction	1,065.70	0.31	0.04	40.0616	25.3341	7.82469	6.083	
1.A.2.a - Iron and Steel	4.53	0.00018	0.00002	0.00402	0.118525	0.03128	0.0015	0.027389
1.A.2.b - Non-Ferrous Metals				-	-	-	-	-
1.A.2.c - Chemicals	6.68	0.0193	0.0026	2.71035	1.486875	0.09233	0.3831	-
1.A.2.d - Pulp, Paper and Print	4.31	0.0001	0.00002	0.0027	0.000262	0.01	0.0006	0.010619
1.A.2.e - Food Processing, Beverages and Tobacco	93.38	0.2079	0.0280	30.2611	0.281384	1.10261	4.1623	0.381761
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	694.74	0.02813	0.00563	0.61878	19.3852	4.8096	0.2344	-
1.A.2.j - Wood and wood products	32.20	0.00130	0.00026	0.02868	0.004986	0.22294	0.0109	0.203526
1.A.2.k - Construction	163.35	0.00661	0.00132	0.14549	0.025293	1.13086	0.0551	1.0323811
1.A.2.l - Textile and Leather	7.80	0.0249	0.0033	3.49442	1.698952	0.11188	0.4937	0.0092812
1.A.2.m - Non-specified Industry	58.73	0.0214	0.0030	2.79609	2.332629	0.3085	0.7414	-
1.A.3 - Transport	6,918.61	1.6800	0.6837	272.929	87.3847	83.1755	40.1217	292.0438

1.A.3.a - Civil Aviation	56.72	0.0004	0.0016	0.0357	0.1728	1.2511	1.4405	3.1024
1.A.3.a.i - International Aviation (International Bunkers) (1)								
1.A.3.a.ii - Domestic Aviation	56.72	0.00040	0.0016	0.0357	0.172769	1.25108	1.4405	3.102408
1.A.3.b - Road Transportation	5,918.52	1.63	0.32	269.75	87.02	66.52	37.32	239.16
1.A.3.b.i - Cars	2,844.40	0.935	0.137	126.932	37.732	30.819	17.986	123.231
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	129.99	0.047	0.02	11.28	0.42	1.25	1.44	7.33
1.A.3.b.i.2 - Passenger cars without 3-way catalysts	2,714.42	0.89	0.12	115.65	37.31	29.57	16.55	115.90
1.A.3.b.ii - Light-duty trucks	922.07	0.167	0.069	33.848	15.646	10.142	4.675	41.054
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts	37.21	0.02	0.00	3.23	0.12	0.36	0.41	2.10
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	884.86	0.15	0.07	30.62	15.52	9.78	4.26	38.95
1.A.3.b.iii - Heavy-duty trucks and buses	1,235.64	0.09	0.07	29.42	30.67	16.74	4.50	23.16
1.A.3.b.iv - Motorcycles	916.41	0.44	0.04	79.55	2.97	8.82	10.16	51.71
1.A.3.b.v - Evaporative emissions from vehicles				-	-	-	-	-
1.A.3.b.vi - Urea-based catalysts				-	-	-	-	-
1.A.3.c - Railways	941.96	0.05	0.36	3.14	0.15	15.37	1.36	49.71
1.A.3.d - Water-borne Navigation	1.41	0.0001	0.00004	0.0032	0.0369	0.0344	0.0012	0.0743
1.A.3.d.i - International water-borne navigation (International bunkers) (1)								
1.A.3.d.ii - Domestic Water-borne Navigation	1.41	0.00013	0.00004	0.00325	0.03693	0.03443	0.0012	0.074306
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	882.90	26.89	0.28	278.41	2.24	9.03	47.98	-
1.A.4.a - Commercial/Institutional	36.94	1.12	0.01	19.06	0.13	0.40	1.26	-
1.A.4.b - Residential	436.67	25.72	0.27	259.35	2.11	8.64	46.72	-
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	409.29	0.0577515	0.003465	-	-	-	-	-
1.A.4.c.i - Stationary	0.43	0.0001	0.000003	-	-	-	-	-
1.A.4.c.ii - Off-road Vehicles and Other Machinery	170.53	0.0239	0.0014	-	-	-	-	-
1.A.4.c.iii - Fishing (mobile combustion)	238.34	0.0338	0.0020	-	-	-	-	-
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	8.24	0.76	0.0001	-	-	-	-	
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 CO_2	-	-		-	-	-	-	
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	8.24	0.7599	0.0001	-	-	-	-	
1.B.2.a - Oil	8.24	0.76	0.00013	-	-	-	-	
1.B.2.a.i - Venting				-	-	-	-	
1.B.2.a.ii - Flaring	8.24	0.01	0.0001	-	-	-	-	
1.B.2.a.iii - All Other		0.75		-	-	-	-	
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		0.75		-	-	-	-	
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	0.0020	-	-	-	-	-	
1.B.2.b.i - Venting				-	-	-	-	
1.B.2.b.ii - Flaring				-	-	-	-	

1.B.2.b.iii - All Other	0.00	0.0020	-	-	-	-	-		
1.B.2.b.iii.1 - Exploration				-	-	-	-		
1.B.2.b.iii.2 - Production				-	-	-	-		
1.B.2.b.iii.3 - Processing	0.000820	1.406E-06	-	-	-	-	-		
1.B.2.b.iii.4 - Transmission and Storage				-	-	-	-		
1.B.2.b.iii.5 - Distribution	0.00006	0.00204	-	-	-	-	-		
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 CO_2	-			-	-	-	-		
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	-			-	-	-	-		

13.3 Annex 3: IPPU sectoral table (2016)

Categories	(Gg)			CO_2 Equivalents (Gg)			
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors
2 - Industrial Processes and Product Use	394.81	-	-	613.00	33.319	-	-
2.A - Mineral Industry	334.08	-	-	-	-	-	-
2.A.1 - Cement production	21.85						
2.A.2 - Lime production	-						
2.A.3 - Glass Production	-						
2.A.4 - Other Process Uses of Carbonates	312.23	-	-	-	-	-	-
2.A.4.a - Ceramics	-						
2.A.4.b - Other Uses of Soda Ash	0.02						
2.A.4.c - Non-metallurgical Magnesia Production	-						
2.A.4.d - Other (please specify)	312.22						
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	-	-					
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				-			
2.B.9.b - Fugitive Emissions							
2.B.10 - Other (Please specify)							
2.C - Metal Industry	58.65	-	-	-	33.32	-	-
2.C.1 - Iron and Steel Production	3.79	-					
2.C.2 - Ferroalloys Production	-	-					
2.C.3 - Aluminium production	54.86				33.32		
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	-	-	-	613.00	-	-	-
2.F.1 - Refrigeration and Air Conditioning	-	-	-	613.00	-	-	-
2.F.1.a - Refrigeration and Stationary Air Conditioning				613.00			
2.F.1.b - Mobile Air Conditioning				-			
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	-	-	-	-	-	-	-
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 - SF6 and PFCs from Other Product Uses	-	-	-	-	-	-	-
2.G.2.a - Military Applications					-	-	
2.G.2.b - Accelerators					-	-	
2.G.2.c - Other (please specify)					-	-	
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)			-				
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)							

13.4 Annex 4: AFOLU sectoral table (2016)

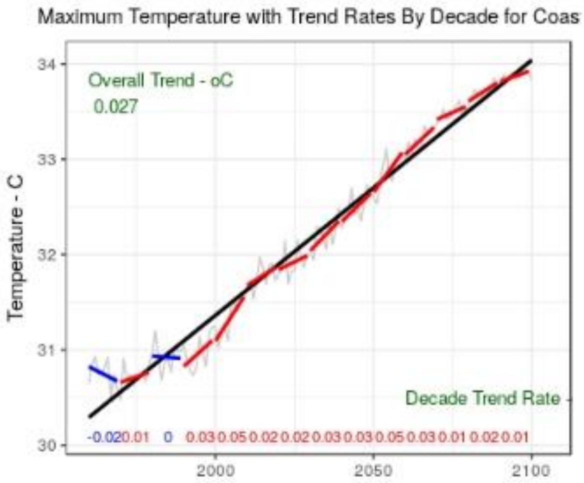
Categories	(Gg)					
	Net CO_2 emissions / removals	Emissions				
		CH_4	N_2O	NOx	CO	NMVOCs
3 - Agriculture, Forestry, and Other Land Use	12,908.42	156.76	21.73	0	0	0
3.A - Livestock	-	121.14	3.07	0	0	0
3.A.1 - Enteric Fermentation	-	114.66	-	-	-	-
3.A.1.a - Cattle	-	56.27	-	-	-	-
3.A.1.a.i - Dairy Cows		-		-	-	-
3.A.1.a.ii - Other Cattle		56.27		-	-	-
3.A.1.b - Buffalo		-		-	-	-
3.A.1.c - Sheep		23.72		-	-	-
3.A.1.d - Goats		33.70		-	-	-
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		0.78		-	-	-
3.A.1.j - Other (please specify)		-		-	-	-
3.A.2 - Manure Management (1)	-	6.48	3.07	-	-	-
3.A.2.a - Cattle	-	1.82	1.36	-	-	-
3.A.2.a.i - Dairy cows		-	-	-	-	-
3.A.2.a.ii - Other cattle		1.82	1.36	-	-	-
3.A.2.b - Buffalo		-	-	-	-	-
3.A.2.c - Sheep		0.95	0.71	-	-	-
3.A.2.d - Goats		1.48	0.95	-	-	-
3.A.2.e - Camels		-	-	-	-	-
3.A.2.f - Horses		0.01	0.00	-	-	-
3.A.2.g - Mules and Asses		0.02	0.00	-	-	-
3.A.2.h - Swine		0.78	0.02	-	-	-
3.A.2.i - Poultry		1.43	0.03	-	-	-
3.A.2.j - Other (please specify)		-	-	-	-	-
3.B - Land	12,872.05	-	-	-	-	-
3.B.1 - Forest land	(4,668.07)	-	-	-	-	-
3.B.1.a - Forest land Remaining Forest land	(3,562.51)			-	-	-
3.B.1.b - Land Converted to Forest land	(1,105.57)	-	-	-	-	-
3.B.1.b.i - Cropland converted to Forest Land	(465.91)			-	-	-
3.B.1.b.ii - Grassland converted to Forest Land	(603.22)			-	-	-
3.B.1.b.iii - Wetlands converted to Forest Land	(1.24)			-	-	-
3.B.1.b.iv - Settlements converted to Forest Land	(31.84)			-	-	-
3.B.1.b.v - Other Land converted to Forest Land	(3.37)			-	-	-
3.B.2 - Cropland	8,331.46	-	-	-	-	-
3.B.2.a - Cropland Remaining Cropland	(506.42)			-	-	-
3.B.2.b - Land Converted to Cropland	8,837.88	-	-	-	-	-
3.B.2.b.i - Forest Land converted to Cropland	10,334.45			-	-	-
3.B.2.b.ii - Grassland converted to Cropland	(1,182.72)			-	-	-
3.B.2.b.iii - Wetlands converted to Cropland	2.17			-	-	-
3.B.2.b.iv - Settlements converted to Cropland	(302.83)			-	-	-
3.B.2.b.v - Other Land converted to Cropland	(13.19)			-	-	-
3.B.3 - Grassland	8,804.18	-	-	-	-	-
3.B.3.a - Grassland Remaining Grassland	0			-	-	-

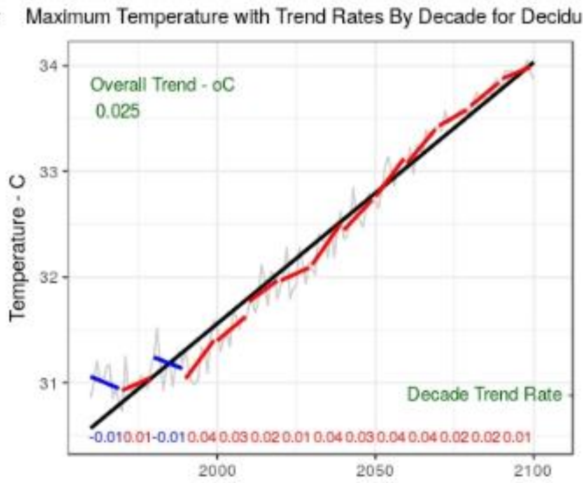
3.B.3.b - Land Converted to Grassland	8,804.18	-	-	-	-	-
3.B.3.b.i - Forest Land converted to Grassland	10,847.35			-	-	-
3.B.3.b.ii - Cropland converted to Grassland	(1,951.47)			-	-	-
3.B.3.b.iii - Wetlands converted to Grassland	(8.59)			-	-	-
3.B.3.b.iv - Settlements converted to Grassland	(52.51)			-	-	-
3.B.3.b.v - Other Land converted to Grassland	(30.59)			-	-	-
3.B.4 - Wetlands	30.48	-	-	-	-	-
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	30.48	-	-	-	-	-
3.B.4.b.i - Land converted for peat extraction			-	-	-	-
3.B.4.b.ii - Land converted to flooded land	-			-	-	-
3.B.4.b.iii - Land converted to other wetlands	30.48			-	-	-
3.B.5 - Settlements	173.75	-	-	-	-	-
3.B.5.a - Settlements Remaining Settlements	-			-	-	-
3.B.5.b - Land Converted to Settlements	173.75	-	-	-	-	-
3.B.5.b.i - Forest Land converted to Settlements	88.98			-	-	-
3.B.5.b.ii - Cropland converted to Settlements	71.54			-	-	-
3.B.5.b.iii - Grassland converted to Settlements	13.23			-	-	-
3.B.5.b.iv - Wetlands converted to Settlements	-			-	-	-
3.B.5.b.v - Other Land converted to Settlements	-			-	-	-
3.B.6 - Other Land	200.25	-	-	-	-	-
3.B.6.a - Other land Remaining Other land				-	-	-
3.B.6.b - Land Converted to Other land	200.25	-	-	-	-	-
3.B.6.b.i - Forest Land converted to Other Land	136.04			-	-	-
3.B.6.b.ii - Cropland converted to Other Land	37.22			-	-	-
3.B.6.b.iii - Grassland converted to Other Land	26.99			-	-	-
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)	36.37	35.62	18.65	-	-	-
3.C.1 - Emissions from biomass burning	-	25.18	1.42	-	-	-
3.C.1.a - Biomass burning in forest lands		2.30	0.21	-	-	-
3.C.1.b - Biomass burning in croplands		14.17	0.42	-	-	-
3.C.1.c - Biomass burning in grasslands		8.71	0.79	-	-	-
3.C.1.d - Biomass burning in all other land		-	-	-	-	-
3.C.2 - Liming	-			-	-	-
3.C.3 - Urea application	36.37			-	-	-
3.C.4 - Direct N2O Emissions from managed soils (3)			13.36	-	-	-
3.C.5 - Indirect N2O Emissions from managed soils			3.68	-	-	-
3.C.6 - Indirect N2O Emissions from manure management			0.19	-	-	-
3.C.7 - Rice cultivations		10.44		-	-	-
3.C.8 - Other (please specify)				-	-	-
3.D - Other	-	-	-	-	-	-
3.D.1 - Harvested Wood Products	-			-	-	-
3.D.2 - Other (please specify)				-	-	-

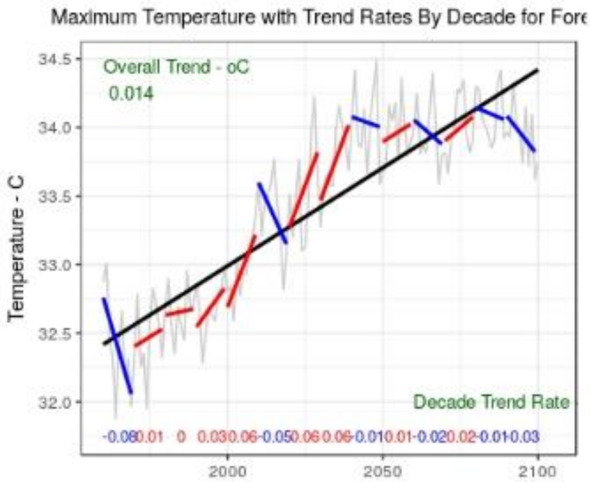
13.5 Annex 5: Waste sectoral table (2016)

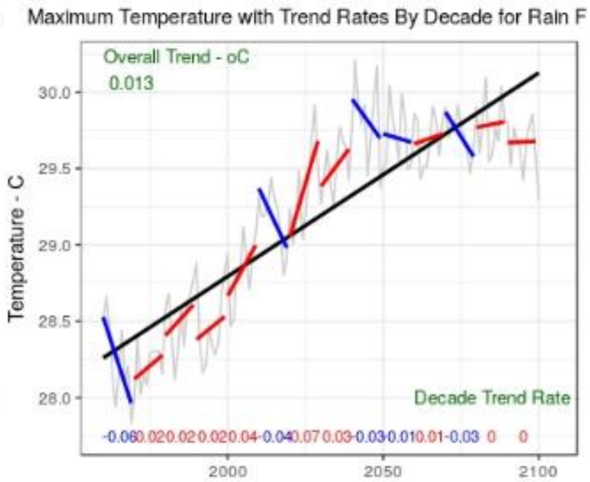
Categories	Emissions [Gg]						
	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO2
4 - Waste	8.68	121.89	1.93	-	-	-	-
4.A - Solid Waste Disposal	-	55.01	-	-	-	-	-
4.A.1 - Managed Waste Disposal Sites				-	-	-	-
4.A.2 - Unmanaged Waste Disposal Sites				-	-	-	-
4.A.3 - Uncategorised Waste Disposal Sites				-	-	-	-
4.B - Biological Treatment of Solid Waste		2.45	0.15	-	-	-	-
4.C - Incineration and Open Burning of Waste	8.68	2.75	0.04	-	-	-	-
4.C.1 - Waste Incineration	2.16	0.02	0.00	-	-	-	-
4.C.2 - Open Burning of Waste	6.52	2.73	0.04	-	-	-	-
4.D - Wastewater Treatment and Discharge	-	61.69	1.75	-	-	-	-
4.D.1 - Domestic Wastewater Treatment and Discharge		32.04	1.75	-	-	-	-
4.D.2 - Industrial Wastewater Treatment and Discharge		29.65		-	-	-	-
4.E - Other (please specify)				-	-	-	-

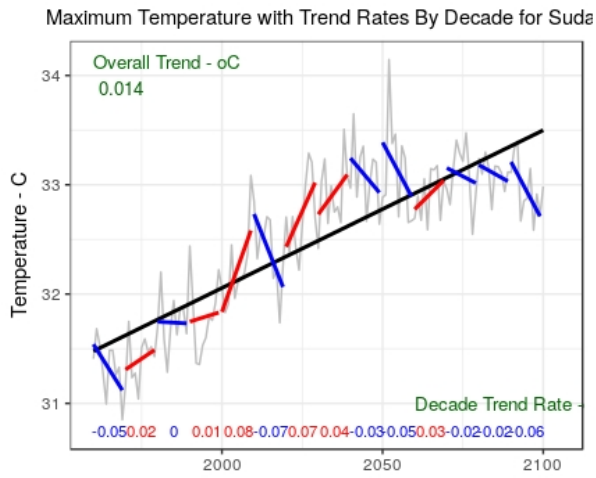
13.6 Annex 6: Multi-decade minimum and maximum temperature trends

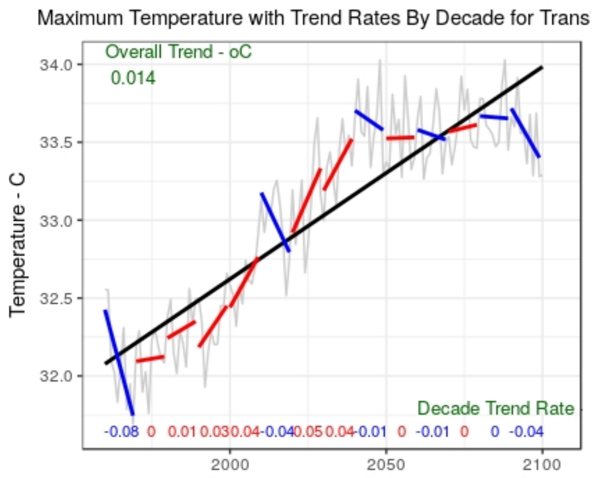


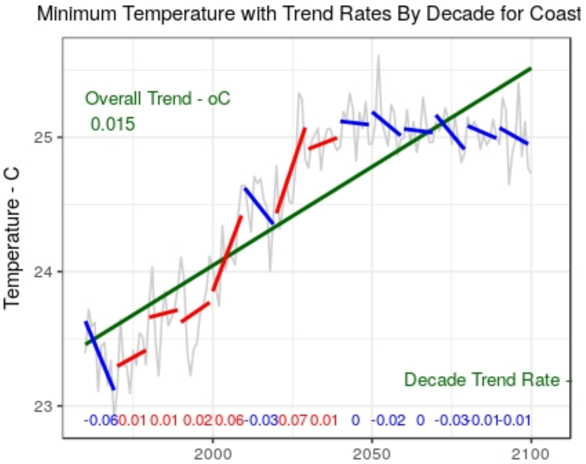


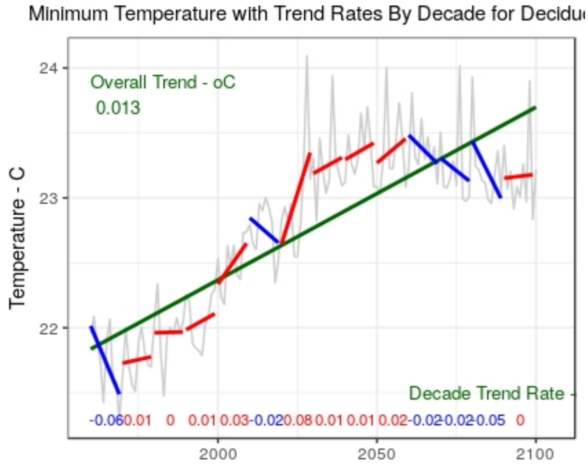


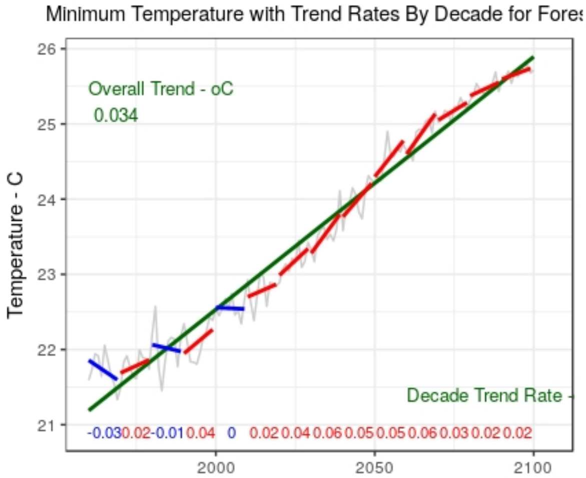


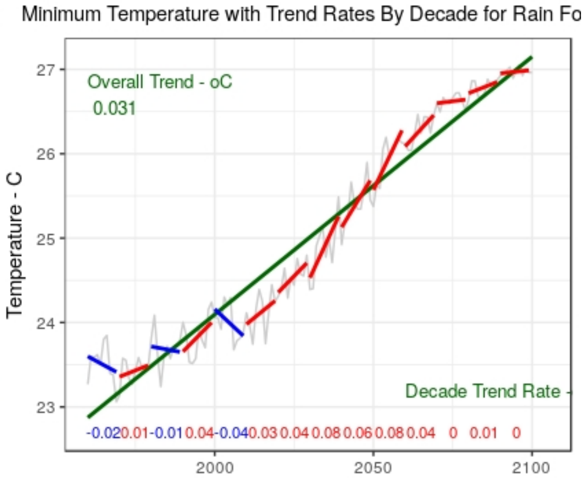


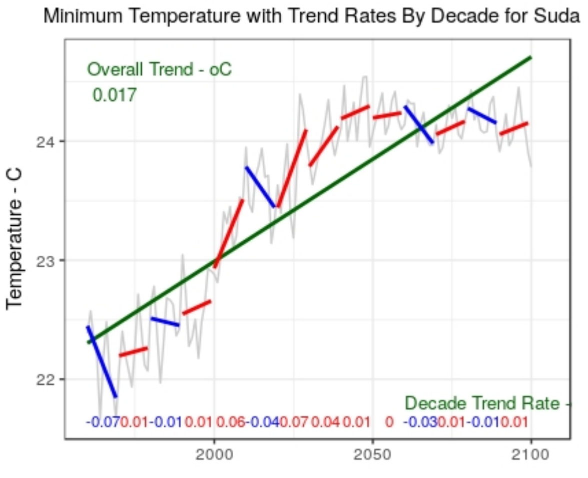


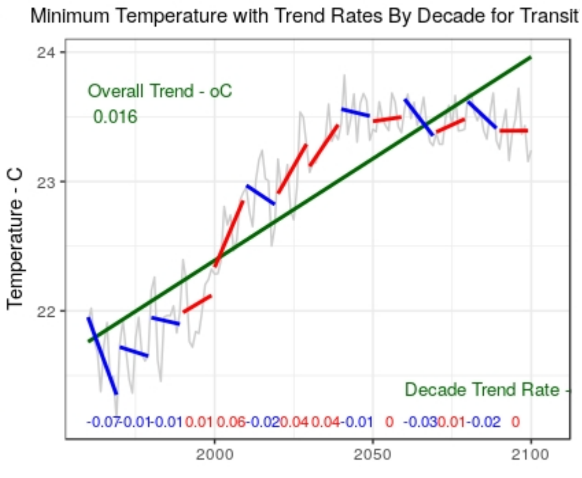

Minimum Temperature with Trend Rates By Decade for Coast
Overall Trend - oC
0.015
Decade Trend Rate
-0.06 0.01 0.01 0.02 0.06 -0.03 0.07 0.01 0 -0.02 0 -0.03 -0.01 -0.01
Temperature - C
23
24
25
2000
2050
2100


Minimum Temperature with Trend Rates By Decade for Decidu
Overall Trend - oC
0.013
Decade Trend Rate
-0.06 0.01 0 0.01 0.03 -0.02 0.08 0.01 0.01 0.02 -0.02 -0.02 -0.05 0
Temperature - C
22
23
24
2000
2050
2100


Minimum Temperature with Trend Rates By Decade for Fores
Overall Trend - oC
0.034
Decade Trend Rate
-0.03 0.02 -0.01 0.04 0 0.02 0.04 0.06 0.05 0.05 0.06 0.03 0.02 0.02
Temperature - C
21
22
23
24
25
26
2000
2050
2100


Minimum Temperature with Trend Rates By Decade for Rain Fo
Overall Trend - oC
0.031
Decade Trend Rate
-0.02 0.01 -0.01 0.04 -0.04 0.03 0.04 0.08 0.06 0.08 0.04 0 0.01 0
Temperature - C
23
24
25
26
27
2000
2050
2100


Minimum Temperature with Trend Rates By Decade for Suda
Overall Trend - oC
0.017
Decade Trend Rate
-0.07 0.01 -0.01 0.01 0.06 -0.04 0.07 0.04 0.01 0 -0.03 0.01 -0.01 0.01
Temperature - C
22
23
24
2000
2050
2100


Minimum Temperature with Trend Rates By Decade for Transit
Overall Trend - oC
0.016
Decade Trend Rate
-0.07 -0.01 -0.01 0.01 0.06 -0.02 0.04 0.04 -0.01 0 -0.03 0.01 -0.02 0
Temperature - C
22
23
24
2000
2050
2100

13.7 Annex 7: Analysis of committed bilateral financial flows for the reporting period 2011-2019

Name of Project	Sector	Climate relevance	Means of Implementation (MoI)	Recipient	Start Date	End Date	Donor Institution	Implementing Agency	Channel	Amount (US$)	Type	Status	Supporting Policies
Promotion of integrated approaches for climate risk management and transfer	Multiple	Adaptation		MoF	2015	2018	BMUB, Germany	GIZ	Bilateral	Unknown		Active	FASDEP 2
Energizing Development (EnDEV) - Energy Access Program	Energy	Mitigation		SNV	2006	2018	BMZ, Germany	GIZ	Bilateral	Unknown	Grant		National Energy Policy
Adaptation of Agro-Ecological Systems to Climate Change	Agriculture	Adaptation		MoFA	2012	2017	BMUB, Germany	GIZ	Bilateral	3,448,276	Grant	Active	FASDEP 2
PEER Science Project	Education	Adaptation MoI	Capacity Building	UCC	2012	2014	USAID, United States	USAID	Bilateral	41,000	Grant	Complete	National climate change policy
Ghana Energy Development and Access Project (GEDAP)	Energy	Mitigation		ECG	2007	2017	Switzerland	WB	Bilateral	11,000,000	Grant	Complete	Renewable Energy Act
Millennium Development Challenge Account Compact 2 – Ghana Power Pact	Energy	Mitigation		Ministry of Energy	2014	2019	United States	MiDA	Bilateral	498,200,000	Grant	Active	National Energy Policy
Energy, Poverty and Gender in Agro Processing (EPGAP)	Energy	Mitigation		SNV	2014	2015	Netherlands	SNV	Bilateral	517,241	Grant	Active	Renewable Energy Act
Developing Sustainable Energy Value Chains in Fish Smoking Markets in Ghana	Energy	Mitigation		SNV	2014	2015	Netherlands	SNV	Bilateral	747,126	Grant	Active	Renewable Energy Act
Integrated Clean Cookstoves and Biomass Fuel Market Assessment Project	Energy	Mitigation		SNV	2014	2015	Netherlands	Sustainable Energy Solutions for Africa	Bilateral	206,897	Grant	Active	Renewable Energy Act
Solar Lantern Saving scheme for Ghana	Energy	Mitigation		SNV	2014	2015	Netherlands	Sustainable Energy	Bilateral	206,897	Grant	Active	Renewable Energy Act

								Solutions for Africa					
Energy, Poverty and Gender (EnPoGen)	Energy	Mitigation		SNV	2013	2013	Netherlands	SNV	Bilateral	172,414	Grant	Complete	Renewable Energy Act
Ghana Climate Innovation Centre (GCIC)	Environment	Sustainable Dev. MoI	Finance	Ashesi Uni. SNV, EY, UNU-INRA	2014	2019	DANIDA, Denmark	WB	Bilateral	17,206,500	Grant	Active	Climate finance
Ghana Climate Change and Environmental Governance	Environment	Mitigation MoI	Technical Assistance	MESTI	2012	2013	DFID, United Kingdom	DFID	Bilateral	274,075	Grant	Complete	Climate strategy
Green Facility	Environment	Mitigation MoI	Finance	MESTI	2011	2014	Denmark	UNEP-DTU Partnership	Bilateral	96,000	Grant	Complete	Climate strategy
Forest Preservation Programme	Forestry	Mitigation MoI	Technical Assistance	FC	2012	2014	Japan	JICA	Bilateral	8,500,000	Grant	Complete	National Forest & Wildlife Policy
Coastal Sustainable Landscapes Project	Forestry	Mitigation		US$A/USAID	2013	2016	United States	USAID	Bilateral	3,500,000	Grant	Active	Forest and Wildlife Policy
Does shifting Carbon Use Efficiency determine the growth rates of intact and disturbed tropical forests? Gathering new evidence from African forests	Forestry	Mitigation MoI	Finance	FORIG	2011	2014	Natural Environment Research Council, United Kingdom		Bilateral	134,280	Grant	Complete	National Forest & Wildlife Policy
Mapping forest landscape restoration in Ghana	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2010	2012	Germany	GIZ	Bilateral	97,701	Grant	Complete	National Forest & Wildlife Policy
Pro-poor REDD+ initiative in Ghana	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2009	2012	Denmark	DANIDA	Bilateral	504,598	Grant	Complete	National Forest & Wildlife Policy
Facilitating countries and communities in the design of pro-poor REDD+ Benefit Sharing Schemes	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2013	2015	Germany		Bilateral	703,448	Grant	Active	National Forest & Wildlife Policy
Towards Pro-Poor REDD+ Project (Phase II): Promoting Rights-based Approaches to Strengthen the Conservation,	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2014	2017	Denmark		Bilateral	3,961,655	Grant	Active	National Forest & Wildlife Policy

Governance and Sustainable Management of Landscapes in Cameroon, Ghana, Guatemala, Papua Province of Indonesia and Uganda													
Advancing REDD+: mobilising private investment for community-based, carbon-intensive landscape restoration	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2013	2015	Norway		Bilateral	658,949	Grant	Active	National Forest & Wildlife Policy
Climate Change Adaptation in Northern Ghana	Water	Adaptation		WRC	2009	2012	Denmark	DANIDA	Bilateral	884,000	Grant	Complete	National Water Policy
Assets Creation for Resilience	Agriculture	Adaptation	Construction	MOFA	2013	2017	Government of Canada	WFP	Bilateral	3,527,571.00	Grant	Phased-out	National Water Policy
Advancing REDD+: Mobilising private investment for the community - based, carbon-intensive landscape restoration NORAD PILAR)	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2013	2017		NORAD	Bilateral	464,330.00	Grant	Complete	National Forest & Wildlife Policy
Support transition towards climate-smart agriculture food system	Agriculture	Adaptation	Finance	MoFA	2015	2017	Norway	FAO	Bilateral	120000	Grant	Complete	
REDD+ benefit-sharing Project	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2013	2017		BMUM	Bilateral	772230	Grant	Complete	National Forest & Wildlife Policy
Towards Pro-Poor REDD+ Project	Forestry	Mitigation MoI	Finance	IUCN-Ghana	2013	2017		DANIDA	Bilateral	31,594,127	Grant	Complete	National Forest & Wildlife Policy
Partnership for Productivity, Protection & Resilience in Cocoa Landscapes (PPPRCL)	Agriculture/Forestry	Mitigation		SNV, NCRC, FC and Touton			DFID, United Kingdom	Touton SA	Bilateral			Active	REDD+ strategy
Operationalising National Safeguards for Results-	Forestry	Mitigation		SNV	2015	2018	BMZ, Germany	SNV	Bilateral	496,315	Grant	Active	REDD+ strategy

Based Payments from REDD+													
Full Sun to Shaded Cocoa Agroforestry Systems (SCAFS)	Forestry	Mitigation		SNV	2016	2018	BMZ, Germany	SNV	Bilateral	1,601,697	Grant	Active	REDD+ strategy
Forest Governance, Markets and Climate	Forestry	Mitigation		Forestry Commission	2011	2021	UKAID, United Kingdom	DFID	Bilateral			Active	Forest and Wildlife Policy
Nationally determined contribution-support programme (NDC-SP)	Environment	Mitigation MoI	Capacity Building	MESTI	2017	2019	Germany	UNDP	Bilateral	820,000	Grant	Active	National climate change policy
UN CC: Learn Initiative	Environment	Adaptation MoI	Capacity Building	MESTI	2015	2017	Switzerland	UNDP	Bilateral	1,072,558.00	Grant	Complete	National climate change policy
Green Cooling Initiative I	IPPU	Mitigation	Technology transfer/capacity building	EPA/MESTI	2016	2018	BMUB, IKI	GIZ	Bilateral	Unknown			
Green Cooling Initiative II	IPPU/Energy	Mitigation	Technology transfer/capacity building	EPA/MESTI	2018	2021	BMUB, IKI	GIZ	Bilateral	Unknown			

13.8 Annex 8: Analysis of committed multilateral financial flows for the reporting period 2011-2019

Name of Project	Sector	Climate relevance	Type of MoI	Recipient	Type institution	Start Date	End Date	Donor Institution	Implementing Agency	Channel	Amount (US$)	Status	Supporting Policies
CARE Adaptation learning programme for Africa	Development Planning	Adaptation		Care International	Research, National	2010	2014	DFID, DANIDA, Finland	DFID	Multilateral	6,000,000	Complete	National climate change policy
CLIMAFRICA Project	Education	Adaptation MoI	Capacity Building	CSIR, CRI, SRI & FORIG for Ghana	Research, National	2010	2014	European Union	EU	Multilateral	68,966	Complete	FASDEP 2
Ghana Energy Development and Access Project GEDAP (formerly) Development of Renewable Energy and Energy Efficiency	Energy	Mitigation		ECG	Govt. Implementation	2007	2017	IDA	WB	Multilateral	100,000,000	Complete	Renewable Energy Act
Ghana Energy Development and Access Project GEDAP (formerly) Development of Renewable Energy and Energy Efficiency	Energy	Mitigation		ECG	Govt. Implementation	2007	2017	Africa Catalytic Growth Fund	WB	Multilateral	50,000,000	Complete	Renewable Energy Act
Ghana Energy Development and Access Project GEDAP (formerly) Development of Renewable Energy and Energy Efficiency	Energy	Mitigation		ECG	Govt. Implementation	2007	2017	AFDB	AFDB	Multilateral	18,250,000	Complete	Renewable Energy Act
Ghana Energy Development and Access Project GEDAP (formerly) Development of Renewable Energy and Energy Efficiency	Energy	Mitigation		ECG	Govt. Implementation	2007	2017	Global Partnership on output-based aid	WB	Multilateral	6,250,000	Complete	Renewable Energy Act

China-Ghana South-South Cooperation on Renewable Energy Technology Transfer	Energy	Mitigation MoI	Finance	Ministry of Energy	Govt. Regulatory	2015	2018	Denmark	UNDP	Multilateral	2,720,000	Active	Renewable Energy Act
Institutional Support to the Implementation of the Sustainable Energy for All (SE4ALL) Action Plan	Energy	Mitigation	Finance	EC	Govt. Regulatory	2013	2018	UNDP	UNDP	Multilateral	730,000	Active	National Energy Policy
Low Emission Capacity Building Project (LECBP)	Environment	Mitigation MoI	Finance	MESTI	Govt. Ministry	2013	2017	EC, Germany, Australia	UNDP	Multilateral	1,072,558	Active	Climate strategy
Africa Adaptation Programme	Environment	Adaptation	Finance	EPA	Govt. Regulatory	2010	2013	Japan	UNDP	Multilateral	2,760,657	Active	Climate strategy
Integrating Green Economy into Ghana's Medium-Term Development Plan	Environment	Sustainable Dev.	Finance	MESTI	Govt. Ministry	2014	2015	Netherlands	UNDP	Multilateral	50,000	Active	National Environment Policy
Facilitating Implementation & Readiness For Mitigation	Environment	Mitigation MoI	Finance	MESTI	Govt. Ministry	2013	2015	Denmark	UNEP/DTU	Multilateral	300,000	Active	Climate strategy
Green Climate Fund Readiness Programme	Environment	SD MoI	Finance	MESTI	Govt. Ministry	2015	2016	Germany	UNDP/UNEP/WRI	Multilateral	853,345	Pipeline	Climate finance
Increased Resilience to Climate Change in Northern Ghana Through the Management Of Water Resources and Diversification of Livelihoods"	Environment	Adaptation		MESTI	Govt. Ministry	2015	2019	Adaptation Fund Board	UNDP	Multilateral	8,293,972	Pipeline	National Water Policy
Support for Development and Operation of COCOBOD's Ghana Cocoa Platform	Finance	SD MoI	Finance	Cocoa Board	Govt. Implementation	2013	2015	UNDP/UN-REDD and Mondelēz Cocoa Life.	UNDP	Multilateral	1,200,000	Active	National Forest & Wildlife Policy

Natural Resource and Environmental Governance Program Technical Assistance	Finance	Mitigation MoI	Technical Assistance	MoF	Govt. Regulatory	2014	2016	World Bank	WB	Multilateral	5,000,000	Active	Natural Resource Sectors
Forest Investment Program (FIP)	Forestry	Mitigation		MLNR	Govt. Ministry	2015	2020	Climate Investment Funds	WB	Multilateral	29,500,000	Active	National Forest & Wildlife Policy
Forest Investment Program (FIP)	Forestry	Mitigation		MLNR	Govt. Ministry	2015	2020	Africa Development Fund	AFDB	Multilateral	15,000,000	Active	National Forest & Wildlife Policy
Forest Investment Program (FIP)	Forestry	Mitigation		MLNR	Govt. Ministry	2015	2020	Climate Investment Funds	IFC	Multilateral	10,000,000	Active	National Forest & Wildlife Policy
REDD+ R-PP Implementation	Forestry	Mitigation MoI	Finance	FC	Govt. Implementation	2010	2013	Word Bank, FCPF	WB	Multilateral	3,400,000	Active	National Forest & Wildlife Policy
FCPF REDD+ Readiness Additional financing	Forestry	Mitigation MoI	Finance	FC	Govt. Implementation	2015	2017	Word Bank, FCPF	WB	Multilateral	5,200,000	Pipeline	National Forest & Wildlife Policy
Ghana Cocoa REDD+ Programme	Forestry	Mitigation		FC	Govt. Implementation	2015	2016-2036	World Bank	WB	Multilateral	5,200,000	Pipeline	National Forest & Wildlife Policy
Advancing REDD+ in Ghana: Preparation of REDD Pilot schemes in Off-Reserve Forests and Agro-Forests	Forestry	Mitigation MoI	Finance	FORIG	Research National	2013	2014	ITTO	ITTO	Multilateral	366,954	Complete	National Forest & Wildlife Policy
Reducing Emissions from Deforestation and Forest Degradation through Collaborative Management with Local Communities	Forestry	Mitigation	Finance	FORIG	Research National	2010	2014	ITTO	ITTO	Multilateral	760,408	Complete	National Forest & Wildlife Policy

Capacity building for CDM forestry in the framework of SFM emphasizing community forests and poverty alleviation in Ghana	Forestry	Mitigation MoI	Finance	FORIG	Research National	2011	2014	ITTO	ITTO	Multilateral	644,382	Complete	National Forest & Wildlife Policy
REDD through stakeholder engagement	Forestry	Mitigation		CSIR-FORIG	Research National	2009	2012	ITTO	ITTO	Multilateral	658,716	Active	National Forest & Wildlife Policy
Community Resilience through Early Warning	Interior	Adaptation	Finance	NADMO	Govt. Implementation	2012	2017	Norway	UNDP	Multilateral	5,162,667.00	Complete	National Disaster Risk Reduction Action Plan
Ghana Urban Transport	Transport	Mitigation		MoT	Govt. Ministry	2005	2015	FDA	WB	Multilateral	20,000,000	Active	National Transport Policy
Ghana Urban Transport	Transport	Mitigation		MoT	Govt. Ministry	2005	2015	IDA	WB	Multilateral	45,000,000	Active	National Transport Policy
Forest Carbon Partnership Facility	Forestry	Mitigation MoI		FC	Govt. Regulatory	2015	2018	FCPF	World Bank	Multilateral	5,200,000	Active	REDD+ strategy
Ghana Forest Investment Programme	Agriculture/ Forestry	Mitigation MoI		COCOBOD, MLNR, FC	Govt. Implementation	2015	2020	CIF	World Bank/ AfDB	Multilateral	392,000	Active	
Capacity Building for Transparency Initiative (CBIT)	Environment	Mitigation MoI	Capacity Building	EPA	Govt. Regulatory	2019	2021	GEF	UNEP	Multilateral	1,100,000	Pipeline	Nationally determined contributions
Environmentally Sustainable Production Practices in Cocoa Landscapes (ESP II)	Agriculture/ Forestry	Mitigation		Ghana Cocoa Board	Govt. Implementation	2016	2020	Mondelēz Cocoa Life	UNDP	Multilateral	1,850,004	Active	FASDEP 2, REDD+ Strategy
Advocacy and capacity building for disaster risk reduction and preparedness in Ghana	Water	Adaptation		NADMO	Govt. Implementation	2015	2016	World Bank	UNDP	Multilateral	500,000	Complete	National Adaptation Strategy
Green Climate Fund Readiness Programme	Finance	Finance MoI	Finance	MESTI	Govt. Ministry	2015	2017	BMUB	UNDP	Multilateral	938,679	Complete	National climate change policy

Dedicated Grant Mechanism for Local Communities	Forestry	Mitigation MoI	Capacity Building	Solidaridad	International NGO	2017	Unknown	World Bank	World Bank	Multilateral	5,500,000	Active	REDD+ strategy
Ghana Energy Sector Transformation Initiative Project	Energy	Mitigation		MOE	Govt. Ministry	2018	2022	World Bank	World Bank	Multilateral	20,000,000	Active	National Energy Policy
Initiative on Climate Action Transparency	Environment	Mitigation MoI	Capacity Building	EPA	Govt. Regulatory	2017	2019	Multiple donors	UNEP DTU Partnership	Multilateral	125,000	Active	National climate change policy

13.8 Annex 9: Analysis of GEF financial flows for the reporting period 2011-2019

Name of Project	Sector	Type of MoI	Recipient	Start Date	End	Implementing Agency	Donor Institution	Amount (US$)	Type	Status	Supporting policies
Expanded Sustainable Land and Water Management Project	Agriculture		MESTI	2011	2020	WB	GEF	29,700,000	Grant	Active	FASDEP 2
Promoting the value chain approach to climate change adaptation in Ghana	Agriculture		MoFA_RTIMP	2012	2017	IFAD	GEF /IFAD	11,500,000	Grant	Complete	FASDEP 2
Ghana Energy Development and Access Project GEDAP (formerly) Development of Renewable Energy and Energy Efficiency	Energy		ECG	2007	2017	WB	GEF	6,500,000	Grant	Complete	Renewable Energy Act
Technology Needs Assessment (TNA) update	Environment	Finance	EPA	2012	2013	UNEP/DTU	GEF	70,000	Grant	Complete	Climate strategy
Third National Communication to UNFCCC	Environment	Finance	EPA	2011	2014	UNEP	GEF	500,000	Grant	Active	Climate strategy
First Biennial Update Report to UNFCCC	Environment	Finance	EPA	2013	2014	UNEP	GEF	352,000	Grant	Active	Climate strategy
Climate Change and Health Project	Health		MoH	2010	2013	UNDP	GEF	1,918,182	Grant	Complete	National Adaptation Strategy
Ghana Urban Transport	Transport		MoT	2005	2015	WB	GEF	7,000,000	Grant	Active	National Transport Policy
Fourth National Communication/BUR2 to UNFCCC	Environment	Capacity Building	EPA	2016	2019	UNEP	GEF	826,000	Grant	Active	Climate strategy
Capacity Building Initiative for Transparency	Environment	Capacity Building	EPA	2020	2022	UNEP	GEF	1,100,00	Grant	Active	Climate strategy

13.10 Proposed projects for funding

Project idea - Rainwater collection from ground surfaces

Project description - Provision of 100 run-off storage facilities (dug-outs and small reservoirs) each of 1 million m3 maximum storage capacity for 100 rural communities to provide water for such multiple uses as domestic, livestock watering, vegetable irrigation, fish production and other income-generating activities in the communities.

Targets – 100 mainly farming rural communities and fisher folks in the Savannah regions (the three northern regions and the Coastal Savannah regions) of the country

Duration - Ten years

Total Cost - US US$ 12.2 million

Proposed funding sources - Government of Ghana, Development partners, Savannah Accelerated Development Authority (SADA)

Project deliverables

- 100 dugouts/small reservoirs;
- 100 community management committees trained in water systems management and maintenance; and
- 500 artisans trained in maintenance works

Main activities to implement the project

- Project co-ordination setup
- Selection of sites, feasibility studies and design of the runoff collection systems
- Construction of 100 run-off storage facilities
- Ensuring post-construction management and maintenance system,
- Sensitisation and awareness creation in beneficiary communities and district assemblies
- Setup and training of water systems management committees in the communities
- Training of artisans for systems maintenance
- Setup and training of monitoring and supervisory teams at the district assemblies

Stakeholder mapping

- Project co-ordination - MLGRD
- Project monitoring and evaluation (MWRWH as lead; other members from MLGRD, MESTI, WRC, GIDA and EPA)
- Beneficiary communities - for direct management, operation and maintenance of the systems
- District Assemblies – for training, monitoring and supervision of communities

Project idea: Post-construction support (PCS) for community-managed water systems

Project description - Empowering rural communities to properly manage to operate and maintain their water systems through technical training and capacity building in financial and systems management at the district and community levels.

Targets - Rural communities made up of mainly farmers and fisherfolks across the country with active water systems for multi-use.

Duration - Five (5) years

Total Costs - US$ 12.2 million

Proposed funding sources - Government of Ghana, Development partners, Savannah Accelerated Development Authority (SADA)

Project deliverables

- 500 rural communities trained in the technical and financial aspects of management, operation and maintenance of multi-use community water resource systems;
- Start-up capital provided to 500 rural communities for emergency water systems repairs;
- Monitoring and supervisory teams, set up at the district assemblies to monitor and supervise communities in the use and management of their water systems

Main activities to implement the project

- Selection of communities and water systems, identification of training needs of district assemblies, developing technical procedures/manuals for water facility operations and management, developing book-keeping and financial procedures/manuals;
- Training district assemblies and communities;
- Setup of management systems including coordination, monitoring and evaluation at all levels – community, district, regional and national;
- Provision of starter capital for the 500 communities.

Stakeholder mapping

- Project co-ordination – Ministry of Local Government and Rural Development (MLGRD)
- Project monitoring and evaluation (Ministry of Water Resources and Sanitation as lead; other members from MLGRD, MESTI, WRC, GIDA and CWSA)
- Beneficiary communities - for direct management, operation and maintenance of the systems.
- District Assemblies – for training, monitoring and supervision of communities.

Project idea - CBEA model in Ghana nationwide, training community-based extension agents for the transfer of knowledge and innovation into agricultural practices

Target - Crop and livestock farmers, fisherfolks and other agricultural producers in rural communities

Duration - Five years

Total Costs - US$ 13 million

Proposed funding Sources- Government of Ghana and development partners

Project Deliverables

- 500 rural communities participating in the CBEA project
- 5,000 CBEA trained in their agricultural practices and providing extension services to other farmers in their communities.
- Farmers in the project communities benefiting from the community-based extension services.
- Publications on the CBEA project

Main activities to implement the project

- Selection of 500 communities in all the ten regions of Ghana to participate in the project;
- Identification and selection of CBEAs to be trained for the various communities;
- Training of agricultural extension officers in the regions and respective districts;
- Training of CBEAs for the communities;
- Facilitating the extension service provision of the CBEAs in their communities;
- Setting up of project office for co-ordination, monitoring and evaluation at all levels – community, district, regional and national.
- Research and development to support the extension services.

Stakeholder mapping

- Project co-ordination – Ministry of Food and Agriculture
- Oversee implementation of the project in communities – District Assemblies
- Research and development – Research team from research institutes and universities
- Organisation of targeted agricultural producers – beneficiary communities

Project idea - Demand- and Supply-Side Measures for Adapting the National Energy System to Impacts of Climate Change

Project Context - Ghana's energy supply is vulnerable to climate change. At present, 67% of electricity generation comes from hydropower and by 2020 as much as 41% could still be derived from hydropower. This dependence on hydropower also makes it vulnerable to fluctuations in supply due to changes in annual precipitation and increased evapotranspiration. At the same time, hydroelectric generation limits the country's vulnerability to oil price shocks as well as its greenhouse gas emissions. This project proposes both demand-side measures, through increased efficiency of electricity use, and supply-side measures, through increased use of low-head run-of-river hydro and other renewable energy sources, to make the national electricity supply more resilient to climate change.

Rationale and Justification - The electricity supply is currently vulnerable to climate change. At present 67% of electricity generation in the country is from hydropower. The vulnerability of the hydroelectric sector to climate change is highlighted by the output of hydroelectricity in 2003, a mainly dry year. The output was 3,885 GWh, or about 60% of the level of 6,610 GWh in 2000, which was a relatively wet year. An emergency supply of thermally generated electricity was brought online in 2003 to compensate for the decrease in hydroelectric generation partially. If average rainfall decreases, and temperature increases, as is expected under climate scenarios, then runoff would decrease, with consequences for hydroelectric generation. According to the National Energy Plan for 2006-2020, the electricity supply is expected to continue to rely heavily on hydropower into the future, even as demand expands and the electricity supply becomes diversified. In the scenario where the contribution is lowest, 31% of electricity would be generated from hydropower in 2020. However, the Plan did not take reduced runoff through climate change into account, and instead maintained the installed capacity at a constant level in the simulations. Despite the upgrade of the turbines at the Akosombo hydroelectric dam, which increased output, changes in average annual flow from climate change could make it challenging to meet the National Energy Plans goals.

Project Description - The proposed project focuses primarily on small-scale initiatives through the off-grid generation and efficiency improvements. These initiatives should lead to an improved economic situation for the potential beneficiary, which raises the question of why the beneficiaries have not made the necessary investments themselves. The reason is that both off-grid generation and efficiency improvements represent investments that have multi-year payback periods. Where capital is scarce, and access to credit is limited, it is not sufficiently economically attractive to make the necessary investments.

Overall goal and objectives - The overall goal is to enhance the resilience of the national energy systems to climate change impacts through the implementation of demand and supply-side measures. Within the pilot communities, the objectives are to:

- Increase the use of off-grid alternative energy resources;
- Increase the use of efficient domestic appliances;
- Develop low-head run on hydroelectric river schemes.

At the national and system level, the objective is to encourage large-scale energy conservation

Development context - This project supports one of the strategic targets in the National Energy Plan for 2006-2020, which is that by 2020 there would be 100% universal electrification, with 30% penetration of rural electrification via renewable energy technologies. The project is geared toward increasing the resilience of both local communities and the national electricity supply through diversification of energy supply and increased efficiency. While the focus is on adapting to climate change, the proposed measures would make the system more resilient to current climate variability, changes in trans-boundary river flow, and fluctuations in global energy prices. The environmental impacts of the proposed activities should be minimal compared to alternative electricity generation options but are still present.

Short-term output - Short-term outputs refer to the outputs produced during the project, which is expected to run for five years

- Run-of-river hydro implemented in five communities;
- Buy-back scheme for inefficient appliances;
- Provide off-grid wind and solar installations;
- Rural energy-efficiency improvement scheme;
- Whole-Country Educational Programme on Energy Efficiency Labelling.

Duration: 5 years implementation-horizon. This is a conservative estimate.

Financial resources - Conservative cost estimates of the project (investment, implementation and transaction costs) ranges between US$ 4million and US$ 5million.

Stakeholders - Ministry of Power, Volta River Authority, Environmental Protection Agency, Electricity Company of Ghana, Ghana GRIDCo Company and District Assemblies.

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