MALAWI'S FIRST BIENNIAL UPDATE REPORT TO THE CONFERENCE OF PARTIES (CoP) OF THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

MINISTRY OF FORESTRY AND NATURAL RESOURCES,
LILONGWE, MALAWI

NOVEMBER, 2021.

Environmental Affairs Department
Ministry of Forestry and Natural Resources
Lingadzi House, City Centre
Private Bag 394
Lilongwe 3
Malawi.

Tel: (265) (0) 1 771 111
Fax: (265) (0) 1 773 379

ISBN 978-99960-94-05-7

9 789996 094057

Correct Citation: Malawi's First Biennial Update Report to the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), Ministry of Forestry and Natural Resources, 2020, Lilongwe, Malawi.

Price: MK 20,000.00

Printing by: White Horse Designs

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Foreword

Climate change presents the biggest single threat to sustainable development in Malawi and around the world. Its associated widespread and unprecedented impacts disproportionately burden the poorest and most vulnerable including presenting adverse damage to economies and ecosystems. Malawi is considered a climate change "hotspot" country because of its vulnerability associated with a rapidly growing population, water scarcity and falling food production. The scale and intensity of climate related fold and drought events have devastating impacts on our already fragile economy. Governments that have signed, ratified and acceded to the 3 international treaties governing climate change namely; the Convention, Kyoto Protocol and Paris Agreement have an obligation to prepare periodic reports to the Conference of Parties (CoP) and Malawi is a signatory to all the 3 treaties. As a party to the UNFCCC, the Kyoto Protocol and the Paris Agreement, Government of Malawi is obligated to implement measures towards low carbon and climate resilience development pathways.

Climate shocks due to climate variability and climate change have increased in frequency and intensity over the last few decades. This has adversely affected key sectors of the country's economy. Agriculture, transport, health, water, forestry, energy and other key sectors have all been affected due to prolonged dry spells, erratic rainfall and floods which have been exacerbated by climate change and climate variability. As such, Government of Malawi realizes the importance of having robust measures and strategies to address the adverse effects of climate change in response to the Sustainable Development Goals and the National Development Agenda.

The First Biennial Update Report provides a comprehensive outlook of the status of sectoral climate change issues in the country and takes into consideration emerging issues since the Second National Communication. The Report has highlighted mitigation efforts that are feasible for Malawi, taking into consideration national circumstances and provisions of the various policy frameworks that guide environment and climate change management in the country. The Report also provides for an updated Greenhouse Gas inventory which establishes Malawi as a net emitter towards the global GHG emissions.

The BUR 1 is aimed at taking stock of the gaps, challenges and constraints encountered in the last submitted national communication and also provides an update on the actions taken by a party to implement the Convention.

Nancy G Tembo M.P.

MINISTER OF FORESTRY AND NATURAL RESOURCES

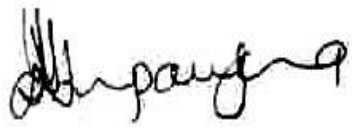
Preface

The country's economy, livelihoods and ecosystems are highly vulnerable to climate change and climate variability. In light of the above, it is imperative that appropriate measures and strategies are taken into account to ensure accurate predictions of weather and climate related changes and their associated adverse impacts on sectors of economic growth and vulnerable communities. We are fully aware that establishing the required management and response strategies is a daunting task because local climate change and variability are embedded in global climate systems that transcend national boundaries.

However, we take consolation in the realization that opportunities for managing and mitigating the adverse impacts of climate change are global endeavours, whose goals are ensuring a future that preserves the health and prosperity of the local and global communities, and that many countries in the world today strongly support efforts to combat global warming. It is in this regard that the Government and the people of Malawi wish to reaffirm their commitment to environmental protection in general, and climate change in particular, by preparing the First Biennial Update Report (BUR 1).

The Report takes stock of the gaps, challenges and constraints encountered in the last submitted National Communication and makes recommendations for improvement in the subsequent National Communication. It is aimed at fulfilling the obligations to the United Nations Framework Convention on Climate Change (UNFCCC) Article 12.The BUR 1 of Malawi gives information on; (i) national circumstances; (ii) greenhouse gases inventory for the period 2001-2017; (iii) programmes containing measures to mitigate climate change; (iv) Domestic Measurement, Reporting and Verification (DMRV); (v) other information considered relevant to the achievement of the objective of the Convention, (vii) constraints and gaps, and related financial, technical and capacity needs; and (viii) Information on the level of support received to enable the preparation of BUR.

These Reports play an important role in raising awareness at the national level of climate change issues. Awareness-raising activities should be prepared according to well-defined objectives and with the target audience clearly in mind. Essentially, they can be utilized by researchers, policy makers and various government departments and ministries.



Yanira M Ntupanyama, PhD.

SECRETARY FOR FORESTRY AND NATURAL RESOURCES

Acknowledgements

The Environmental Affairs Department (EAD) extends profound gratitude to the following institutions and individuals during the preparation of Malawi's First Biennial Update Report (BUR 1) for submission to the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC).

The GEF/UNEP for providing financial and logistical support; UNFCCC Secretariat for providing information and guidelines for preparing sectoral reports, thematic area reports and this BUR, and for supporting useful and relevant workshops; the Chairperson and Members of the National Technical Committee on Climate Change (NTCCC), National Climate Change Steering Committee (NCSC) for their valuable contributions and guidance; and the Climate Change Project Office for steering the preparation process; various national institutions, government departments, private sector organizations and the Universities of Malawi provided expertise and data which were used in the preparation of the various sectoral and thematic area reports, and contributed to the finalization of this Report.

Finally, but not least, the untiring efforts of the Project Manager, Ms Lusungu Ng'oma, Administrative Assistant, Ms Flora Guba Chiwale, the Project Coordination Team, National Team Leaders, National Experts, the International Experts, the Technical Preparation Team, and EAD Staff are greatly acknowledged. Timely production of this report would not have been possible without their unparalleled contributions.

I wish to express my heartfelt gratitude, and that of the Government and people of Malawi, to all those who have generously contributed in various ways in the production of this Report.

Tawonga Mbale-Luka
DIRECTOR OF ENVIRONMENTAL AFFAIRS

PROJECT MANAGEMENT, COORDINATION AND SECTOR CONTRIBUTIONS

Project Management: **Ms. Lusungu Ng'oma**, Project Manager, Environmental Affairs Department, **Ms. Flora Guba Chiwale**, Administrative Assistant, Environmental Affairs Department.

Project Coordination: **Ms. Tawonga Mbale-Luka**, National Project Director, Environmental Affairs Department, **Ms. Shamiso Najira**, Deputy Director, Environmental Affairs Department, **Mr. Evans Njewa**, National Project Coordinator, Environmental Affairs Department, **Mr. Golivati Gomani**, **Mr. Chimwemwe Yonasi**, **Ms. Hanna Siame** (Project Desk Officers), Environmental Affairs Department.

National Team Leaders: **Mr. Kenneth J. Gondwe**, National Peer Reviewer for Greenhouse Gas Inventory, Department of Mechanical Engineering, Malawi Polytechnic, University of Malawi**, Prof. Maurice Monjerezi**, National Team Leader for Mitigation and Abatement Analysis, Chancellor College, University of Malawi, **Dr. Cosmos Ngongondo**, National Team Leader for National Circumstances, Chancellor College, University of Malawi.

Executive Summary: **Mr. Kenneth J. Gondwe**, Department of Chemical Engineering, Malawi Polytechnic, University of Malawi.

Sector Contributions

National Circumstances: **Dr. Cosmos Ngongondo**, National Expert, University of Malawi, Chancellor College, **Dr. Mirriam Joshua,** National Expert, University of Malawi, Chancellor College**, Mr. Zuze Dulanya**, National Expert, Chancellor College, University of Malawi, **Mr. Bosco Rusuwa,** National Expert, University of Malawi, Chancellor College.

Greenhouse Gas Emissions: **Mr. Dingane Sithole**, Bees Consultancy Services (Zimbabwe), International Peer Reviewer for National Greenhouse Gas Inventory,
Dr. Suzgo Kaunda, National Expert, Energy and Transport Sector, University of Malawi, Polytechnic,
Mr. Mike Chirwa, National Expert, Forestry and Land Use Sector, Forestry Research Institute of Malawi (FRIM),
Mr. Henry Kadzuwa, National Expert,Forestry and Land Use Sector, Department of Forsetry, **Mr. Moses Njiwawo**, National Expert, Forestry and Land Use Sector, Department of Forestry,
Dr. Tembo Chanyenga, National Expert, Forestry and Land Use Sector, Forestry Research Institute of Malawi,
Dr. Eric Mbingwani, National Expert, Forestry Research Institute of Malawi,
Mr. Suzgo Chapa,National Expert, Agriculture Sector, Department of Livestock and Animal Health,

Mr. Geoffrey Longwe, National Expert, Agriculture Sector, Ministry Of Agriculture,

Mr. Boyd Mwafulirwa, National expert, Agriculture Sector, Ministry of Agriculture,

Mr. Phyllis Mkwezalamba, National Expert, Waste Sector, Lilongwe City Council,

Mr. Thokozani Mkaka, National Expert, Waste Sector, Lilongwe City Council,

Mr. Robert Kawiya, National Expert, Waste Sector,

Mr. Fredrick Munthali, National Expert, Waster Sector, National Commission for Science and Technology,

Mr. Christopher Mwambene, National Expert, Industrial Processes and Product Use, Shire River Basin Management Program,

Mr. Clement Phangaphanga, National Expert, Industrial Processes and Product Use, Ministry of Tourism, Industry and Trade.

Programmes Containing Measures to Mitigate Climate Change (Mitigation and Abatement Analysis):

Prof. Maurice Monjerezi, National Team Leader for Mitigation and Abatement Analysis, Industrial Processes and Product Use Sector,University of Malawi, Chancellor College,

Mr. Godfrey Mnesa, National Expert, Waste Sector, University of Malawi, Chancellor College

Mr. Mike Chirwa, National Expert, Forestry and Land Use Sector, Forestry Research Institute of Malawi,

Mr. Henry Kadzuwa, Forestry and Land Use Sector, National Expert, Department of Forestry

Dr. Suzgo Kaunda, National Expert, Energy Sector, University of Malawi, Polytechnic

Mr. Robert Kawiya, National Expert, Waste Sector,

Mr. Thokozani Mkaka, National Expert, Waste Sector, Lilongwe City Council,

Mr. Boyd Mwafulirwa, National Expert, Agriculture Sector, Ministry Of Agriculture,

Mr. Suzgo Chapa, National Expert, Agriculture Sector, Department of Livestock and Animal Health.

Domestic Measurement, Reporting and Verifcation:

Mr. Sipho Billiat, National Expert, National Planning Commission,

Ms. Chipo Masina, National Expert, Economic Planning and Development

Constraints and Gaps and related financial and capacity building needs:

Ms. Hanna Kasongo Siame, Sector Coordinator, Environmental Affairs Department,
Mr. Peter Magombo, National Expert, Environmental Affairs Department,

Information on the level of support received:

Mr. Evans Njewa, Chief Environmental Officer, Environmental Affairs Department,
Ms. Lusungu Ng'oma, Project Officer, Environmental Affairs Department,

Technical Preparation Team:

Ms. Tawonga Mbale-Luka, Director, Environmental Affairs Department,
Ms. Shamiso Najira, Deputy Director, Environmental Affairs Department,
Mr. Bennon Bibu Yassin, Deputy Director, Environmental Affairs Department,
Mr. Evans Njewa, Chief Environmental Officer, Environmental Affairs Department,

International Expert:

Mr. Dingane Sithole, International Peer Reviewer of the TNC NIR, Bees Consultancy Pvt Limited, Zimbabwe,
Mr. Walter Svinurai, International Peer Reviewer of the TNC NIR, Bees Consultancy Pvt Limited, Zimbabwe,
Ms. Veronica Gundu, International Peer Reviewer of the TNC NIR, Bees Consultancy Pvt Limited, Zimbabwe.

Acronymns and Abbreviations

A/R	Afforestation and reforestation
ADDs	Agricultural Development Divisions
AFOLU	Agriculture, Forestry and Other Land Use
AvGas	Aviation gasoline
BAU	Business as Usual
BERL	Bio Energy Resources Limited
BOD	Biological Oxygen Demand
CaCO3	Calcium carbonate
CEAR	Central and East Africa Railways
CH_4	Methane
CHP	Combined Heat and Power Generation
CKD	cement kiln dust
CO	Carbon monoxide
CO_2	Carbon dioxide
CO2eq	Carbon dioxide equivalent
COP	Congress of Parties
CTCN	Climate Technology Centre and Network
DAHLD	Department of Animal Health and Livestock Development
DEA	Department of Energy Affairs
EAD	Environmental Affairs Department
EF	Emission factor
EGENCO	Energy Generation Company (of Malawi)
EP&D	Economic Planning and Development
ESCOM	Electricity Supply Corporation of Malawi
ETHCO	Ethanol Company Limited
FAO	United Nations Food and Agricultural Organization
FCWSNET	Famine Early Warning System
FRA	Global Forest Resource
GEF	Global Environmental Facility
Gg	Giga grammes (10^9 g)
GHG	Greenhouse gas
GHG-IS	GHG-Inventory System
GoM	Government of Malawi
GoM	Government of Malawi
GWP	Global warming potential
Ha	Hectare
HFCs	Hydro fluorocarbons
HWP	Harvested Wood Products
IIED	Institute for Environment and Development
INC	Initial National Communication
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
Jet A1	Jet kerosene
Kcal	Kilo calorie
kToE	Thousand Tonnes of Oil Equivalent
kVA	Kilo-Volt Ampere (unit for measuring electricity energy)

LAMNET	Latin America Thematic Network on Bioenergy
LCCS	Land Cover Classification System
LEAP	Long Range Alternative Energy planning (an energy modelling software)
LED	Light emitting diode
LPG	Liquefied Petroleum Gas
MAI&WD	Irrigation and Water Development
MCF	Methane correction factor
MERA	Malawi Energy Regulatory Authority
MIC	manufacturing Industry and Construction
MIRTDC	Malawi Industrial Research and Technology Development Centre
MIT	Mitigation
MJ	Mega joule (10^6 J)
MMU	minimum mapping area or unit (),
MNEP	Malawi National Energy Policy
MoU	Memoranda of Understanding
MREAP	Malawi Renewable Energy Acceleration Programme
MSC	Malawi Shipping Company
Mt	Metric tonne
MTL	Malawi Telecommunications Limited
MToE	Million Tonnes of Oil Equivalent
MW	Megawatts (10^6 W)
N/A	Not applicable
N_2O	Nitrous oxide
NAMA	Nationally Appropriate Mitigation Action(s)
NCST	National Commission on Science and Technology
NE	Not estimated
NIR	National Inventory Report
NMVOCs	Non-Methane Organic Volatile Compounds
NOx	Nitrogen oxides
NSO	National Statistical Office
OVOP	One Village One Product
PAESP	Promotion of Alternative Energy Sources Programme (in Malawi)
PFCs	Perfluorocarbons
PM	Particulate Matter
ProBEC	Programme for Biomass Energy Conservation
QA/QC	Quality Assurance and Quality control
SAR	Second assessment report
SCL	Shayona Corporation Limited
SEforALL	Sustainable Energy for All
SF_6	Sulphur hexafluoride
SNC	Second national communication
SSA	Sub-Saharan Africa
SWDS	Solid waste disposal sites
TCRET	Testing and Training Centre for Renewable Energy Technologies
TJ	Terajoule (10^{12} J)
TNA	Technology Needs Assessment
TNC	Third National Communication
TNM	Telecommunication Network Malawi

UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USGS	United States Geological Survey

Executive Summary

ES 1 National circumstances

Malawi is a land-locked country in southern Africa that lies along the southern most arm of the great East African Rift-Valley System (EARS) between latitudes 9° 22' and 17° 03' south of the equator, and longitudes 33° 40' and 35° 55' east. It is bordered by Tanzania in the north and north-east; Mozambique in the south-west, south and the east; and Zambia in the west. The country is about 910 km long and varies in width from 60 to 161 km with a total surface area of 118,484 km^2. Of this total surface area, 94,787.2 km^2 (80%) is land and the remaining 23,696.8 km^2 (20%) is covered by water.

The location of the country within the EARS has profound impacts on the relief of the country. The process of rifting was responsible for the formation of a trough filled by Lake Malawi, one of the country's most conspicuous drainage feature and the third largest lake in Africa. The country falls into five main physiographic surfaces related to the different erosional cycles. The Rift valley floor is situated along the major drainage features of the country at about 30 – 500m asl, is very flat and is related to the Quaternary erosional cycle. Bordering the rift valley floors are the steep escarpments which are associated with major rift faults and related to the Post-African cycle. Above the escarpments are plains at an altitude of about 750-1300 m asl. These have a generally flat or rolling topography. The African surface is a relatively flat surface at 600-1400 m asl attitude. Slopes with moderate steepness at 1400-1500 are ascribed to the post-Gondwana and the Gondwana surfaces are above 1500 with steep slopes and generally have high plateaus 600 m.

ES 2 GHG Inventory

Malawi has prepared its First Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC). The Inventory covers Greenhouse gas (GHG) emissions for the period 2001 to 2017, with 2010 being the base year.

The Inventory includes five main Intergovernmental Panel on Climate Change (IPCC) sectors, namely: Energy, Industrial Process and Product Use (IPPU), Agriculture, Forestry and Other Land-Use (AFOLU), and Waste. The GHG emissions reported in this GHG inventory are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs). The 2006 IPCC Guidelines were used to compile the inventory. The methodology used was mainly tier 1.

GHG emissions

Table ES 1 presents the GHG emissions by sector in Malawi's BUR report. GHG emissions declined from 29,229.65 in 1994 to 3,613.53Gg in 2017. Malawi sequestered more CO_2 emissions that it emitted in the AFOLU sector. However, the emissions from Energy, IPPU and Waste, as well as non-CO_2 emissions from AFOLU exceeded the amount sequestered in AFOLU, resulting in Malawi being in a net emission position of 3,356.07GgCO_2eq in 2017.

At 1,364mtCO_2eq, the Energy sector contributed the largest proportion (36.76%) of emissions, closely followed by AFOLU with 1,205.02 mtCO_2eq (33.35%) and then Waste accounting for

1,004.06 $mtCO_2eq$ (27.79%). IPPU accounted for the least emissions at 40.01$mtCO_2eq$ representing 1.11% of the total GHG emissions in 2017.

There has been a significant decrease in emissions over time. Overall, the total emissions in 2010 represented a reduction of 87.64% from the 1994 emissions or 75.20% when compared with the emissions in 2000. Energy sector emissions declined by 70.71%, IPPU by 87.13%, AFOLU by 90.70% and Waste by 25.97% when compared with the 2000 GHG emissions reported in the SNC.

Table ES 1 National greenhouse gas emissions and removal trends (CO_2eq)

IPCC Category	Total emissions ($MtCO_2eq$)		
	1994 (INC)	2000 (SNC)	2010 (TNC)
Energy	7,798.34	4,658.58	1,364.44
IPPU	58.38	310.76	40.01
Agriculture	3,750.45	12,961.27	1,205.022
FOLU	17,517.37		
Waste	105.11	1,356.19	1,004.06
TOTAL	29,229.65	14,628.22	3,613.53
Memo items			8,658.56

In 2010 the highest CO_2 emissions were emitted from 1.A.3 - Transport, amounting to 616.96Gg, followed by 1.A.2 - Manufacturing Industries and Construction with 258.50Gg and then 3.C - Aggregate sources and non-CO_2 emissions from land accounting for 88.71Gg. In the same year, the largest CH_4 emissions were emitted from Livestoce-3A - amounting to 64.55Gg, followed by Solid Waste Disposal on Land (3A) with 20.16 Gg (13.18%) and then 1.A.4 - Other Sectors with 14.13Gg. In 2010 N_2O emissions were 1.61Gg, mainly coming from Livestock-3A with 0.66Gg (39.41%), Wastewater Treatment and Discharge -4.D 0.57 Gg (and Fuel Combustion activities-1A with 0.30Gg.

ES 3 Mitigation actions and their effects

As presented in the GHG Inventory Chapter, the latest national inventory data estimate total greenhouse (GHG) emissions excluding forestry and other land use (FOLU) at 9.33 million tonnes of carbon dioxide equivalent (tCO_2e) for 2017. Agriculture Sector accounted for by far the largest share of the total (5.07 million tCO_2e, 54% of total), followed by Energy (2.34 million tCO_2e, 25% of total) and waste (1.67 million tCO_2e, 18% of total). Emissions from industrial processes represented just 0.24 million tCO_2e, equivalent to around 3% of total emissions in 2017 (mainly associated with calcination CO_2 emissions from minerals production). Emissions from livestock represented the largest emissions source category, followed by emissions from managed soils in crop production. Following these agriculture sources, major sources included CO_2 emissions from fossil fuel use in transport, which accounted for 11% of the total, and methane emissions from unmanaged waste disposal site (dumps), which accounted for 13% of the total.

ES 4 Information on the level of support received

The Global Environment Facility (GEF) through United Nations Environment (UNE) which is the Implementing Agency for Malawi's BUR 1, has provided funds to a total of USD 352 000 to support Malawi prepare its BUR 1 for the fulfilment of its obligations under the United Nations Framework Convention on Climate Change (UNFCCC). The Environmental Affairs Department under the Ministry of Forestry and Natural Resources which is the Executing Agency provided in kind support, US $ 50,000, office space, government counterparts, and services of support personnel.

ES 5 Domestic Measurement, Reporting and Verification

The current medium term national development plan, the Malawi Growth and Development Strategy (MGDS) III, guides all development interventions from the year 2017 to 2022. This strategy continues to operationalize the Vision 2020 in attempting to realise its aspirations. Development priorities articulated in the plan have been isolated based on the linkages and the impact they have on the social and economic development of the country. Being agriculture based economy agriculture and other environment and natural resource related sectors have been given much priority in order to realise the country development potential. However the impacts of climate change have affected many sectors' productivity including agriculture such that attention is also given to multi-sectoral approach in managing climate change.

Even though large proportion of the resources comes from development partners, government is committed to increase financial resources for the environment and natural resource management in order to avert the various challenges that faces the sector. Some of the challenges include increasing population, land degradation, deforestation, soil loss, air and water pollution, water body siltation, and many other impacts of climate change.

Attention to climate change and environmental management has been demonstrated by various efforts including the development of National Climate Change Policy, National climate change programme, and National climate change investment plan. In order to implement the national investment plan effectively, an M and E framework was developed so as to ensure close monitoring and provision of advisory to the process of implementing the plan. Among the major areas of interest in the management of climate change there are adaptation, mitigation interventions and financing. These have received much effort and support in order to reduce the severity of the impacts and also build resilience among majority of the affected rural Malawians.

ES 6 Any other information relevant to the BUR process

Malawi has implemented a number of climate change related responses to changing socio-economic circumstances, including development and propagation of national policies, strategies and programmes. Specifically, this chapter presents information on: (i) Steps taken to integrate climate change into relevant socio-economic and environmental policies and strategies, (ii) transfer of technologies, (iii) climate change systematic observation, (iv) research programmes containing measures to mitigate, and to facilitate adequate adaptation to climate change, (v) education, training and public awareness on climate change, (vi) capacity building, and integrating climate change adaptation measures into medium- and long-term planning strategies, (vii) information sharing and networking, etc.

1 National Circumstances

This chapter provides information on Malawi's national circumstances that are relevant to climate change and to the implementation of the United Nations Framework Convention on Climate Change (UNFCCC), including the preparation of Malawi's Biennial Update Reports (BUR) to be submitted to the Conference of the Parties under the UNFCCC. It is a summary of the last submitted Third National Communication (TNC Report). These include: (i) Geographic profile (ii) Socio-Economic and Sector Profiles and (iv) Natural Resources.

1.1 Geographical Profile

1.1.1 Location and Land Area

Malawi is a land-locked country in southern Africa that lies along the southern most arm of the great East African Rift-Valley System (EARS) between latitudes 9^o 22' and 17^o 03' south of the equator, and longitudes 33^o 40' and 35^o 55' east. It is bordered by Tanzania in the north and north-east; Mozambique in the south-west, south and the east; and Zambia in the west. The country is about 910 km long and varies in width from 60 to 161 km with a total surface area of 118,484 km^2. Of this total surface area, 94,787.2 km^2 (80%) is land and the remaining 23,696.8 km^2 (20%) is covered by water.

1.1.2 Physiography and Relief

The location of the country within the EARS has profound impacts on the relief of the country. The process of rifting was responsible for the formation of a trough filled by Lake Malawi, one of the country's most conspicuous drainage feature and the third largest lake in Africa. The country falls into five main physiographic surfaces related to the different erosional cycles. The Rift valley floor is situated along the major drainage features of the country at about 30 – 500m asl, is very flat and is related to the Quaternary erosional cycle. Bordering the rift valley floors are the steep escarpments which are associated with major rift faults and related to the Post-African cycle. Above the escarpments are plains at an altitude of about 750-1300 m asl. These have a generally flat or rolling topography. The African surface is a relatively flat surface at 600-1400 m asl attitude. Slopes with moderate steepness at 1400-1500 are ascribed to the post-Gondwana and the Gondwana surfaces are above 1500 with steep slopes and generally have high plateaus 600 m.

1.1.3 Climate

The climate of the region is largely influenced by the northward and southward seasonal migration and intensity of the Inter-Tropical Convergence Zone (ITCZ), a low pressure belt within the Congo basin caused by tropical high pressure belts over both the Indian and Atlantic Oceans (Nicholson, 2001) and the Congo Air Boundary (CAB), that is controlled by sea-surface temperature (SST) anomalies such as the Indian Ocean Dipole (IOD) and El Niño/Southern Oscillation (ENSO) system (Saji et al., 1999; Abram et al., 2007).

Malawi has two main seasons, namely the cool dry season between May and October with mean temperatures of around 13 ^{o}C in June and July and the hot wet season between November and April with temperatures between 30^o - 35 ^{o}C. Rainfall is variable depending on altitude and ranges from 600 mm for the rift valley floors to 1600 mm per annum for the mountainous areas. Local differences in rainfall are caused by complex topography causing deflections of moisture-bearing winds that are responsible for precipitation and rain-shadow effects in various terrains.

1.1.4 Climate Trends and Extremes

Although Malawi may generally be described as receiving adequate rainfall, its distribution in space and time is not uniform and not predictable due to local environmental conditions or climate variability and climate change in general. This non-uniformity in distribution is responsible for climate extremes such as flooding and droughts which affect various parts of the country from time to time. Since 1961, Malawi has experienced considerable inter-annual and intra-annual climatic variations. These variations have resulted in the occurrence of extreme weather and related events, ranging from droughts (e.g. 1982/83, 1991/92 and 2015/16) to floods (e.g. 1996/97, 2014/15) and flash floods (e.g. 1990/91, 2000/01). For instance, when the Southern Region experienced extensive floods in the 1996/97 crop season, some parts of Karonga District in the north and the Lakeshore Plain were under drought conditions. In addition, there is evidence of increasing mean air temperature over Malawi.

Furthermore, the extreme weather events, especially floods and droughts, have also been increasing in intensity, frequency and magnitude. As a result of these, Malawi has experienced more than 40 weather-related disasters from 1970 to 2008, with 16 of these occurring between 1990 and 2008. These extreme weather events adversely impact on food security, water security, energy supply, infrastructure, human health and the sustainable livelihoods of family households. For example, in 1989, more than 400 people died in the Lower Shire Valley, whereas in 1991, over 1,000 people died in Phalombe due to flush floods. The Country lost over 24 million US Dollars from the 1991 Phalombe floods (Murray et al., 2016). In January 2015, floods caused by intense and prolonged rainfall period killed more than 106 person with over 172 reported missing. More than 1.1 million people were also affected by the floods resulting in 230,000 being internally displaced (Winsemus et al., 2015). The 2015 floods, categorized as most devastating in geographical coverage, resulted in an estimated total damage and loss of US$335 million and required a total of US$494 million for recovery and reconstruction (Winsemus et al., 2015). These are all signs that the climate is changing and strategies must be put in place to address its adverse impacts. Malawi's BUR document is therefore timely in this regard.

1.1.5 Lake Water Level Fluctuations

Lake Malawi water levels fluctuations is a good proxy barometer for the sensitivity of the climate regime due to climate change and variability, as it reflects the balance between water inflows from its tributaries, rainfall and outflow into the Shire River. Since 1900, oscillating patterns between and low lake levels are evident from the lake level hydrograph (Fig. 2.1). A period of low lake levels affected indicative of a general drier climate is reflected by declining levels between 1900 and 1915. The Lake experienced extremely low lake levels between 1915 and 1935 when outflows into the Shire River ceased. Increasing lake levels after 1915, due to a general wet climate regime, restored outflows into the Shire River in 1935. The lake levels continued with a general rising trend, peaking to around 477.16 m asl in May 1980 due to high rainfall of the immediate preceding years (Drayton, 1984).

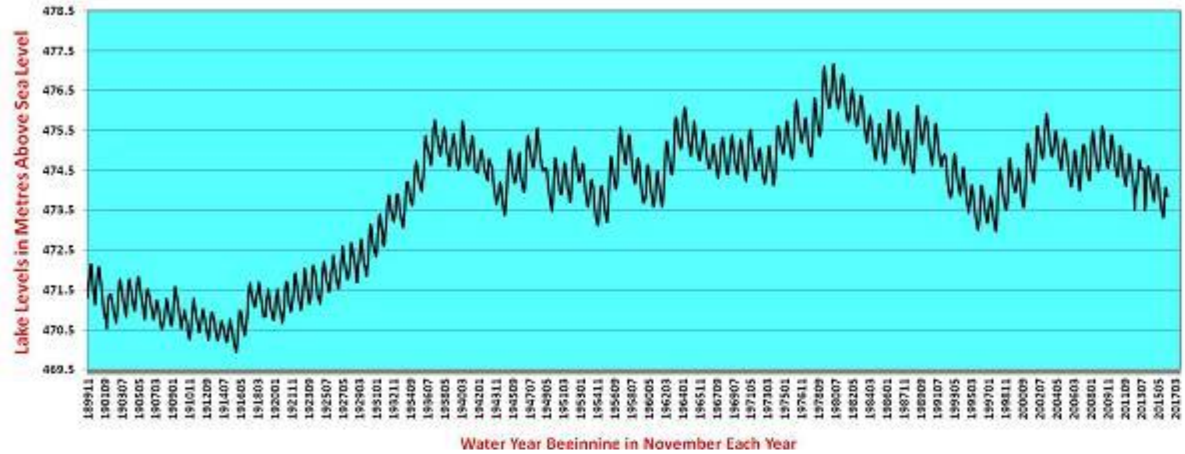


Figure1. 1: Lake Malawi water level hydrograph, 1899-2016
Source: Ministry of Agriculture, Irrigation and Water Development

The period 1979 to 1983 reported the highest recorded water levels for the Lake. These high lake levels caused a lot of damage along the lakeshore plain areas where floods damaged property and infrastructure, including hotels, chalets, buildings, settlements, roads, harbours and ports. However, during this period, there were years of low (drought) and high rainfall (floods), which resulted in low and high lake water levels, respectively. From the lake levels, a decreasing pattern is evident from 1980 to the present (2016) with an average lake level of 474.7 m.a.s.l. Since 1931, the lowest lake water levels of 472.9 m asl were recorded in November 1997 as a result of two severe droughts in the 1991/92 and 1994/95 rainy seasons. In the 2014/15 and 2015/16 rainy seasons, low rainfall caused by El Nino resulted in significantly low lake level which stood at 472.97 m.a.s.l as of 30 December 2016. This has affected electricity production along the Shire River resulting in massive load shedding.

These water level fluctuations equally affected the Shire River, the outlet of Lake Malawi to the Indian Ocean through the Zambezi River. The water level fluctuations for the Shire River (Fig 1.0.) are measured at Liwonde, which is the only outflow for Lake Malawi (Kidd 1983). The outflows, however, have been controlled on several occasions. From 1956 and 1957, the Shire River was blocked by a bund at Liwonde to allow for geotechnical investigations for the foundation of the present Kamuzu Barrage. The river was also blocked from 1965 to 1966 to allow for the construction of the Kamuzu Barrage. The Barrage was commissioned in the same year and has been used to regulate water flows in the late sixties, mid-seventies and early 1980s to facilitate installation of hydro-power plants on the Middle Shire River Valley. The Kamuzu Barrage has been effectively and efficiently regulated since 1992 to maintain a constant water flow rate for the generation of hydro-electricity on the Shire River. The prolonged regulation is to ensure adequate flows for hydro-power generation, in response to dwindling Lake Malawi water levels, resulting from low rainfall totals and declining groundwater resources. Further, the changing water levels have significant impact on the type and number of fish catches. Lake Malawi has an estimated total catchment area of 125,000 km^2 that includes a large network of rivers, such as the Songwe, North Rukuru, South Rukuru, Dwangwa, Linthipe and Bua on the Malawi side.

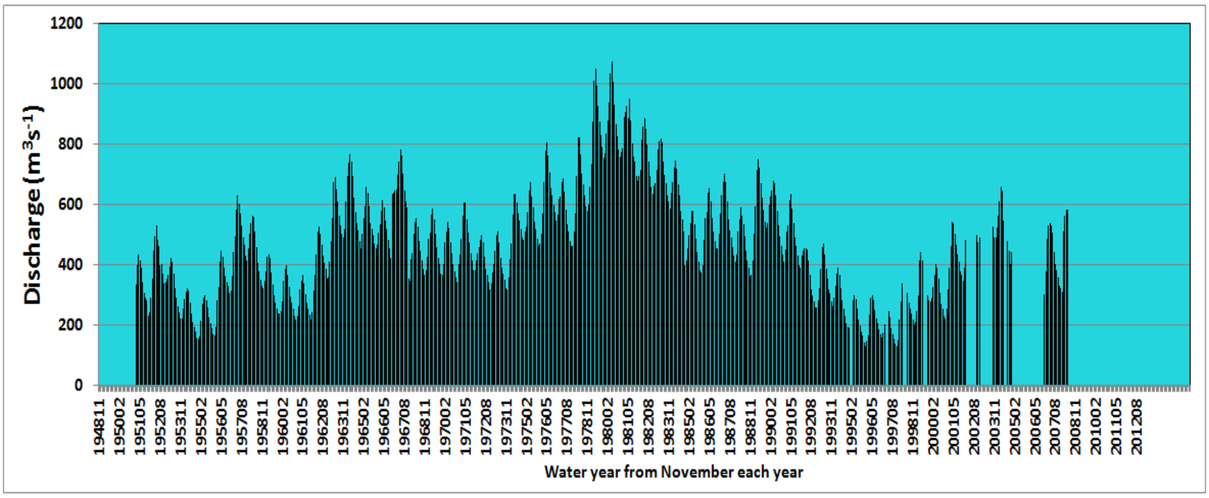


Figure1. 2: Shire River monthly flows at Liwonde, 1948-2008
Source: Ministry of Agriculture, Irrigation and Water Development

1.2 Socio-Economic Profile

1.2.1 Population Profile

Malawi's current official population is estimated at 15,805,240, up from 13,066,320 people in 2008, representing an overall population increase of 21% that has been growing almost constant at the rate of 2.8% per annum up to 2013, rising up to 3.1% in 2014 (NSO, 2008, & 2015). The population density is 168 persons /km^2, up from 139 in 2008, making Malawi one of the most densely populated countries in the world. The spatial population distribution in the country indicates that 48.3%, 39.5% and 12.2% of the people live in the south, centre and north of the country, respectively. Women and men comprise 51% and 49% of the population respectively, the same as reported in the 1998 and 2008 Population and Housing Census Reports (NSO, 2002, 2008, & 2015). The population of those 18 years and above is about 48% of the total population suggesting a dominance of the young population (52%) of which 48% are below 15 years (NSO, 2015). The overall average life expectancy as of 2017 is about 57 years, up from 48.5 years in 2008 (NSO, 2015). Despite this improvement, this is below the 2015 average life expectancy for Africa which was estimated at 60 and 71.4 years respectively (http://www.who.int/gho/mortality_burden_disease/life_tables/situation_trends_text/en/.
Some basic demographic, health and economic indicators are given in Tables 1.0a to c.

Table 1. 1 Malawi basic demographic indicators, 2008-2014

Indicator	2008	2012	2014	Unit
Population	13.1	14.0	15.81	Million
Urban population	15.4	15.2	14	% of total
Rural population	84.6	84.8	86	% of total
Population density	139	157	188.6	Persons per km^2
Population growth	2.8	2.8	3.1	%/year
Life expectancy at birth (male)	47.4	52	62	Years
Life expectancy at birth (female)	50.6	54.9	59.9	Years

Indicator	2008	2012	2014	Unit
Fertility rate	6.3	5.7	4.4	Birth per woman
Female headed households	25	23.9	30	% of all households
Literacy	56	73.6	71.8	% of total population
Average household size	4.8	4.6	4.5	Number of people

Source: NEC (2003); NSO (2000, 2008, 2014, 2015); RBM (2005); GoM (2011, 2012, 2014); World Bank (2017)

Table 1. 2 Malawi Basic Health indicators, 2008-2014

Indicator	2008	2012	2014	Unit
Infant mortality	87	66	42	Per 1,000 live births
Mortality rate, under-five	140	112	64	Per 1,000 live births
HIV prevalence	14	8.8	8.8	% of females aged 15-24
HIV and AIDS mortality rate	700			Per 100,000 people
Illiteracy	36	35	45.2	% of total population
Illiteracy rate (males)	25.5	26	54.8	% of males 15 years and over
Illiteracy rate (females)	53.5	43		% of females 15 years and over
Illiteracy rate (urban)		11		% of total population 15 years and over
Illiteracy rate (rural)		39		% of males 15 years and over
Poverty rate	52	50.7		% of total population

Source: NEC (2003); NSO (2000, 2008, 2014, 2015); RBM (2005); GoM (2011, 2012, 2014); World Bank (2017)

Table 1. 3 Malawi basic economic indicators, 2008-2014

Indicator	2008	2012	2014	Unit
Gross Domestic Product (GDP)	5.125	5.653	4.26	Billion (US $)
GDP per Capita	432	385	494	US $ per head
Gross National Income (GNI) per Capita	170	340	320	US $
GDP growth	1.7	1.9	2.9	% over preceding year
Population in poverty (%)	65	50.7	51	% of total population
Population in absolute poverty	29	24.5		% of total population

Source: NEC (2003); NSO (2000, 2008, 2014, 2015); RBM (2005); GoM (2011, 2012, 2014); World Bank (2017)

1.2.2 Population Growth

The population of Malawi has grown exponentially over the last hundred years, from a meagre 737,200 in 1901 to the present estimate of 17.2 million in 2017 (Fig. 2.3). However, the population growth rates have fluctuated between 2.0% (1998) and 3.7% (1987), mainly because of the Mozambican civil war refugees, who peaked at 1.0 million people at the height of the influx in the 1980s. Presently, all the Mozambican refugees have been repatriated, so that the present high population growth rate can be ascribed to a high average fertility rate of about 5 children per woman (GOM, 2000a, 2005a; NSO 2014, 2015). The statistics suggest that the country's population is increasing by about half a million per year. The population density increased from 105 persons/ km^2 in 1998 to 139 in 2008, and is presently at 168 persons/km^2.

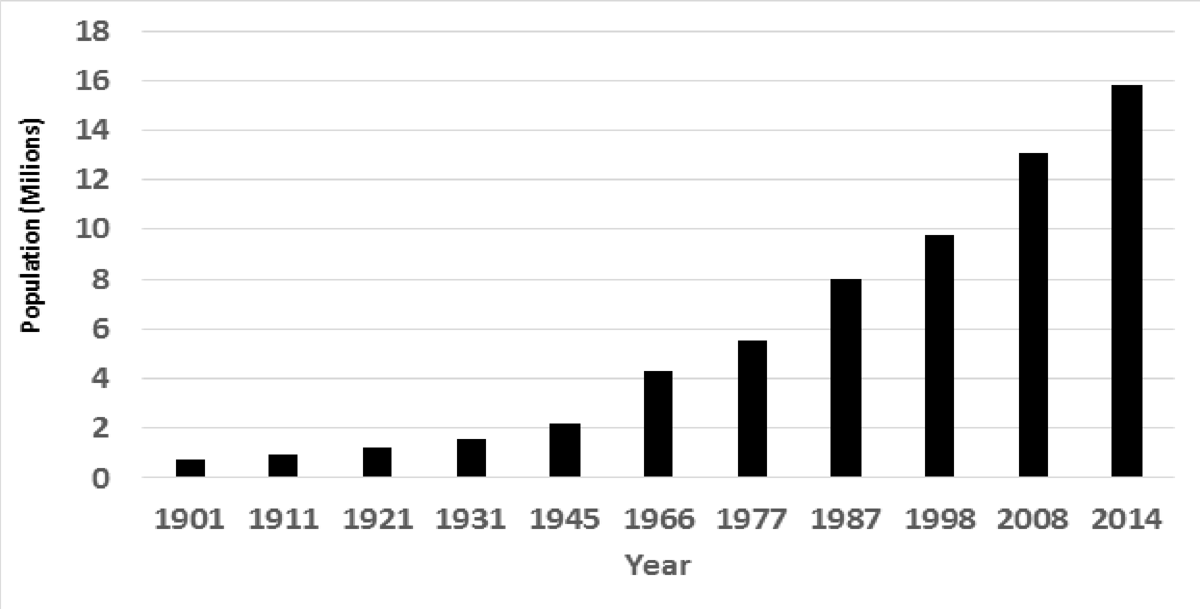


Figure1. 3 Population growth of Malawi, 1901-2014

1.2.3 Fertility Rates

Women in Malawi as of 2016 had an average of 4.4 children per woman showing a decline from 6.7 children reported in 1992 (Fig 1.2). The 2015-2016 rate is lower than the average for African region (4.4). However, these fertility rates are still ranked as some of the highest (UN, 2015) - they are beyond the replacement fertility rates of 2.5 to 3.3 for developing countries – taking into account high death rates. Fertility rates in Malawi are higher for rural areas (4.8 children per woman) than for urban areas (3 children per woman). Fertility also declines with income showing that wealthy household have, on average, less number of children than poor households.

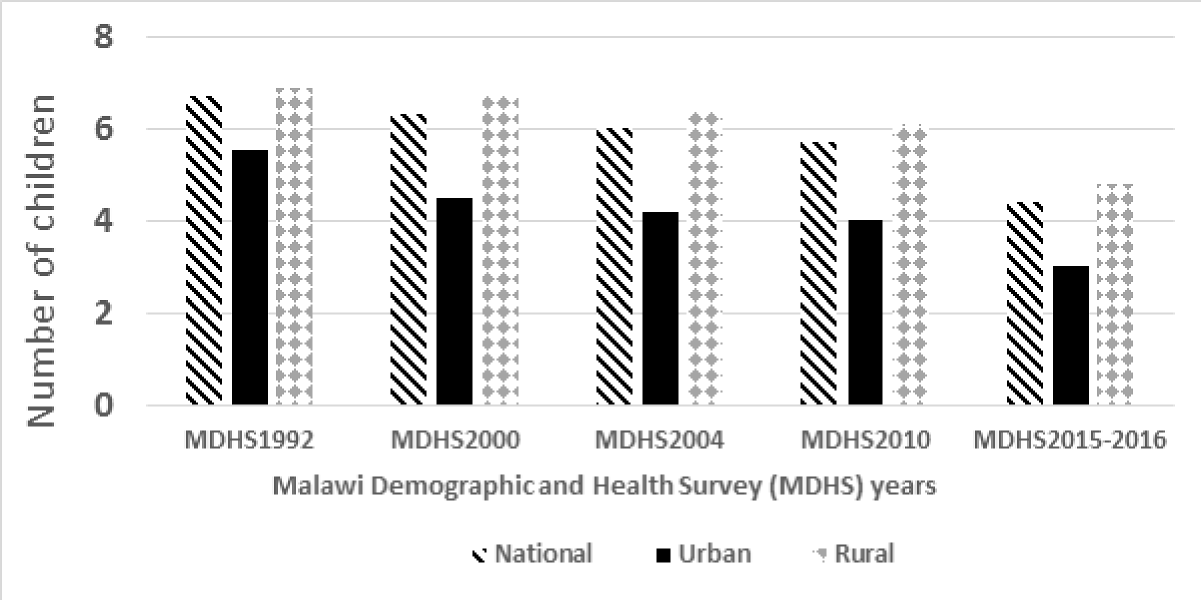


Figure1. 4 Trends in fertility rates, 1992-2015

1.2.4 Population Distribution

Malawi population is predominantly rural with about 86% living in the rural and the remainder (14%) in urban. This urban proportion makes Malawi one of the least urbanised nations in Southern Africa (UN-DESA, 2012). The spatial distribution of population is further unequal among the three regions. The southern Region hosts the highest proportion (almost half) of the national population followed by the Centre. The 2008 census showed that 45% of the population was in the southern region while the central and the northern regions recorded 42% and 13% of the total respectively. The percentage of the population residing in the southern region declined from 47% from 1998 while in the corresponding figures for the central and northern regions increased from 41% and 12% respectively. In terms of regional growth, highest growth rates were recorded in the north with 3.3% growth recorded while the centre and the south recorded growth rates of 3.1% and 2.4% respectively. The percentage distribution of population per region is shown in the Fig. 1.4. These trends have continued up to 2014.

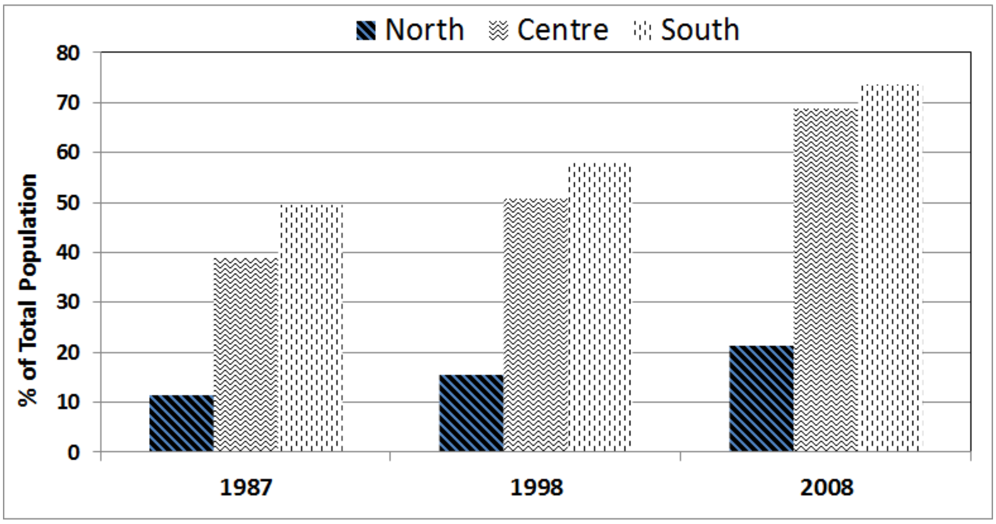


Figure1. 5 Population distribution by region in Malawi, 1987, 1998, 2008 and 2015*

Source: NSO (2002, 2008, 2015a).
*Note: 2015 shows the MDG Endline population distribution based on the population living in households, whereas the rest of the years shows Census distribution based on the entire population, i.e. including the institutional population and other negligible non-household populations (NSO, 2015a).

1.2.5 Infrastructure

Infrastructure is important for the achievement of Government's strategic objectives of poverty alleviation and food and water security as stipulated in the Malawi Growth and Development Strategy (MGDS) of 2006 and 2011(GoM, 2006; 2011). Malawi's infrastructure development strategy focuses on the following: (i) transport (road, rail, air and water), (ii) energy, (iii) water and sanitation, (iv) telecommunication technologies, (v) information technology, (v) science and technology, and (vi) buildings or built environment. The aim is to ensure: (i) easy access to markets, hospitals and schools, and (ii) reduce the incidence of water borne diseases, land and environmental degradation, air and water pollution, and the adverse impacts from poor water usage and sanitation. However, all these areas are highly vulnerable to climate change, especially in the form of high intensity rainfall, landslides, mudslides, floods, droughts, cyclones and strong winds.

1.2.6 Transport

Transport infrastructure is vulnerable to climate change and variability due to their exposure to environmental conditions (Chinowsky et al., 2017). Malawi is a landlocked country surrounded by Tanzania, Mozambique and Tanzania. Transport facilities (roads, rail, water and air) are generally inadequate and in poor condition to adequately meet the needs of a growing and vibrant population estimated at 15.852 million in 2015 by the National Statistics office and estimated at 17.2 million in 2017 by the World Bank. Being landlocked, Malawi has been promoting the development of transport corridors through the neighbouring countries of Tanzania and Mozambique to the Indian Ocean (e.g. Mtwara Corridor) as one way of facilitating the transportation of goods and services, and attracting investments into the country. Consequently, most of the country's imports are shipped via the sea ports of Dar es Salaam in Tanzania, Nacala and Beira in Mozambique or as road cargo via Mwanza and Mchinji.

1.2.7 Road Transport

The road sector is the most widely used, with a total of 437,416 registered vehicles in 2014 up from 96,146 in May 2007 and 20,000 in 1992 (Tables 1.2 and 1.3).

Table 1. 4 Trends in registered number of private vehicles by category between 2007 and 2014Vehicle category registered vehicles Percentage (%)

		Total Number of Registered vehicles				
		2007	2011	2012	2013	2014
Serial	**Vehicle category**	96,146	19,199	22,152	29,443	27,508
1	Motorcycle (less than 3 wheels)	8,018	2,033	2,235	2,460	2,837

2	Motor Tricycle	641	Included in 1	Included in 1	Included in 1	Included in 1
3	Light passenger vehicle (less than 12 persons)	38,796	9,613	11,978	16,467	15,779
4	Heavy passenger vehicle (12 or more persons)	8,312	1,562	1,389	1,669	1,518
5	Light load vehicle (GVM 3500 kg or less)	22,452	2,555	3,419	4,509	3,579
6	Heavy load vehicle (GVM>3500 kg, not to draw & equipped to draw)	14,467	2,757	2,781	3,695	3,177
7	Agricultural tractor & trailers	1,283	258	214	196	183
8	Trailers & other	2,177	402	136	447	435

Sources: Malawi Road Traffic Directorate (2007, 2014); NSO (2015)

Table 1. 5 Government motor vehicle registration by type 2011 to 2013

Serial	Vehicle category	Year		
		2011	2012	2013
	Total	821	436	1291
1	Saloon and Estate Cars	197	92	188
2	Land Rovers	0	133	312
3	Commercial and Goods Vehicles	8	33	232
4	Motor Cycles	324	153	141
5	Other Vehicles and Plants	292	25	19

Sources: Plant and Vehicle Hire Organisation (PVHO, 2013); NSO (2015)

1.2.8 Water Transport

Water transport is characterised by underexploited and inadequate access to ports. Lake Malawi provides the main water transport from Mangochi in the south to Karonga in the north, with port facilities at Monkey Bay in Mangochi, Chipoka in Salima, Nkhota Kota, Likoma Island, Nkhata Bay, and Chilumba in Karonga. Apart from the four development corridors cited above, Malawi is presently exploring the practical possibility of linkages to the Indian Ocean through the Shire and Zambezi Rivers, under the Shire-Zambezi Waterway (SZW) Initiative. The realization of the SZW will be one of the major breakthroughs in the 21st century that will enable Malawi to have direct access to the Indian Ocean, and Malawi will no longer be a "land locked country" in the southern Africa region.

1.2.9 Rail Transport

Rail transport is yet to develop to full capacity. There are some 2,382 km of railway line track in Malawi. The railway line links Nsanje in the south with Mchinji in the centre through Chiromo, Lunchenza, Blantyre, Balaka, Salima and Lilongwe. This railway line also connects Malawi to the port of Beira in Mozambique. Unfortunately, the portion between Nsanje and Beira has been out of order since the beginning of the civil war in Mozambique in the 1970s. In addition, most of the Nsanje-Mchinji line has remained unusable over the years because of the poor state of the infrastructure due to washed-away bridges among other reasons. There are recent efforts by both the government to rehabilitate this railway line. The Moatize-Nacala line was recently constructed by Vale Mining Company of Brazil with the purpose to haul coal from their operation base in Mozambique to the port of Nacala trough Malawi.

1.2.10 Air Transport

Malawi has five main airports: (i) Chileka in Blantyre, (ii) Kamuzu International Airport (KIA) in Lilongwe, (iii) Mzuzu Airport in Mzuzu, (iv) Karonga Airport in Karonga, and (vi) Club Makokola in Mangochi. There are also some aerodromes, which are presently rarely used, such as Chitipa, Mzimba, Likoma, Kasungu, Dedza and Nsanje. However, aircraft operation is affected by heavy rains, fog and clouds that interfere with aircraft navigation. These climatic calamities are expected to increase in frequency and magnitude in the future in response to changes in climate.

1.2.11 Water Supply and Sanitation

Recent statistics suggest that the proportion of households with access to safe water of drinking have improved from about 79% (Table 1.4) in 2012 to 86%, 99% and 84% at national, urban and rural level respectively in 2014/15 (NSO 2014; 2015) and 87%, 98% and 85% respectively in 2016 (NSO 2016). At regional level, estimates are 90.2% for the North, 83.8% for the centre and 87.1% for the south (NSO 2015). The statistics further show "use of improved source of drinking water increases with increasing education level of household head and increasing household wealth" (NSO 2015 p94). Households with household head with secondary education and in those in the richest wealth index quintile have almost universal access to improved sources of drinking water (NSO 2015).

Table 1. 6 Proportion of household with access to improved sources of drinking water, 2011

Year	**Area**	**Proportion (%) with access to improved source**	**Source of drinking water**				
			Improved sources			Unimproved sources	
			Piped into dwelling (%)	Piped into yard/communal stand pipe (%)	Protected well in yard/public well/borehole (%)	Open well in yard/open public well (%)	Spring/river/stream/lake/dam/rainwater (%)
2012	National	78.7	2.9	16.7	59.1	15.4	5.8

	Urban	78.7	14.0	61.6	3.1	20.0	1.2
	Rural	78.7	0.8	8.4	69.5	14.6	6.7
	Rural North	82.9	0.8	8.2	73.9	7.5	9.6
	Rural Central	73.5	0.8	4.8	67.9	22.2	4.4
	Rural South	82.1	0.9	11.6	69.6	10.0	7.9
2015/16	National	87.2	2.4	18.5	66.1	8.0	4.8
	Urban	98.0	13.5	72.3	12	1.6	0.5
	Rural	85.2	0.4	8.7	75.9	9.2	5.6

Source: GoM (2012a)

1.2.12 Information, Communication and Technology

Current ICT facilities include radio, television, postal services, internet, mobile phone and e-mail services. Table 2.5 shows the proportions of Malawians having access to the various ICT facilities, according to MACRA (2015, http://www.macra.org.mw/wp-content/uploads/2014/09/Summary-National-Survey-on-Access-and-Usage-of-ICT-Services-in-Malawi.pdf).

Table 1. 7 Proportion of Malawians with access to ICT facilities

Service	**Rural (%)**	**Urban (%)**	**Malawi**
Radio	42.2	61.7	44.5
Television	6.2	46.3	10.9
Mobile Phones	42	85.1	45
Fixed Phone	0.5	4.2	1
Post Box	1.9	5.6	2.3
Pay TV	0.9	17.8	2.9

Although the situation is improving, access to ICT facilities is still on the lower side due to high costs particularly for low income earners, erratic power supply and poorly developed ICT infrastructure, especially in the rural areas. This needs urgent attention as ICT facilities have important implications for weather forecasting initiatives and providing early warning systems to agriculturists and policymakers, and to farming communities in areas prone to floods, such as the Shire Valley and areas along the Lakeshore Plain.

1.2.13 Science and Technology

Malawi has remained largely an under-developed country because it has not fully embraced or harnessed her human and physical resources to use science and technology to develop and utilize modern technologies for technological advancement. There is need to put science into action, and research findings into technologies.

1.2.14 Buildings and Other Urban Structures

These include all types of buildings and structures, such as urban dwelling and commercial houses, public and industrial buildings, pavements and roads. These buildings are built with different types of materials, which either absorb or reflect solar radiation. Some 34% of the buildings are made of permanent or semi-permanent materials, such as iron sheets, which highly reflect solar radiation (NSO, 205b; 2008). However, 66% of the houses in Malawi are built of traditional materials, such as tree poles and are thatched with grass, which, unfortunately also contribute to deforestation. The effect of cutting down trees for construction purposes is twofold: (i) carbon dioxide (CO2) emissions into the atmosphere, which contributes to global warming, and (ii) the removal of trees which absorbs CO2 c from the atmosphere, hence reduces global warming.

1.2.15 Economic and Sector Profiles

1.2.16 Economy

Malawi's economy is largely agro based (Fig. 1.5), with the sector supporting about 80% of rural people's livelihoods and contributing about 30% to GDP and 80% of export revenue. Performance of the other sectors is dependent on agriculture which is largely rainfed and hence highly vulnerable to climate change and climate variability

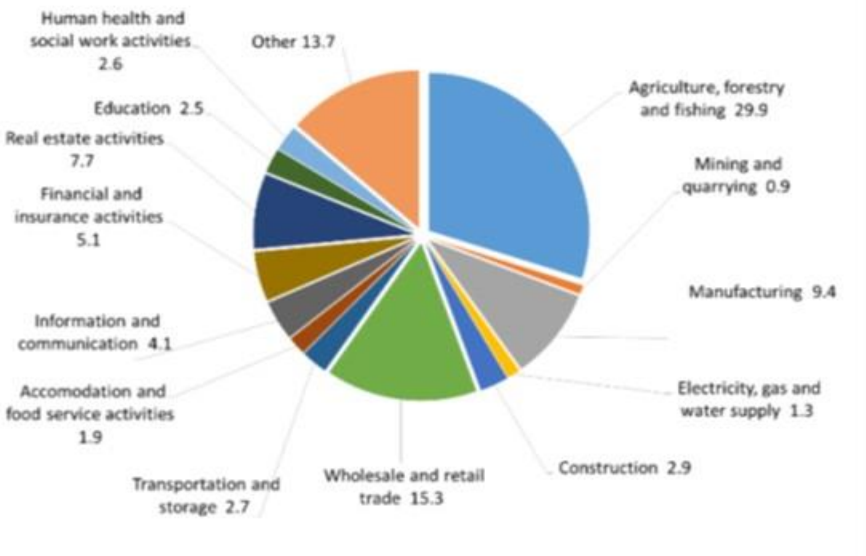


Figure1. 6 GDP Shares of the Malawi Economy, 2015
Source: National Statistical Office and Ministry of Finance, Economic Planning and Development data

1.2.17 Current Policies and Strategies

Since the late 1990s, development in Malawi has been guided by the following national and sectoral policy and strategy documents: (i) Vision 2020 of 2000, (ii) Malawi Poverty Reduction Strategy (MPRSP) of 2002, (iii) Malawi Economic Growth Strategy (MEGS) of 2004, (iv) Malawi Growth and Development Strategy (MGDS) of 2006, Malawi Growth and Development Strategy (MGDS) of 2011 (v) National Environmental Action Plan (NEAP) of 1994 and revised in 2002, and (vi) National Environmental Policy of 1996, (vii) National Climate Change Management Policy, (viii) and related policies including the National

Transport Policy, National Climate Change Investment Policy, Mines and Minerals Policy, National Biodiversity Strategy and Action Plan II, National Disaster Risk Management Policy and National Agriculture Policy.

1.2.18 Poverty and Social Profiles

Poverty headcount had steadily decreased from 2005 to 2010 but the trend reversed in 2011 (GoM, 2007, 2008, 2009, 2009a, 2010, 2012; NSO, 2015; UNDP, 2010) suggesting persistent high poverty rates in Malawi (Table 2.2). About half (50.7%) of population in Malawi are poor and 24.5% are in absolute poverty. Similar trends are present at place of residence. By place of residence, high poverty rates are prevalent among the rural population (GoM, 2012; NSO, 2015) – registers about 94% of the poor population in Malawi (GoM, 2012). Southern region remains the poorest region as it has the highest poverty rate (63%) relative to Central (49%) and Northern region (60%). Ultra poverty trends show similar regional picture (Table 2.6). Rural poverty is estimated at 57% and urban, 17%. Further variations at seen at district level (Table 1.6) for statistics of poverty incidence at national level).

Table 1. 8 Poverty incidence in Malawi and selected areas, 1998 - 2011

Area	Estimate (%)						
	1998	2005	2006	2007	2008	2010	2011
Proportion poor							
National	54	52.4	45	40	40	39	50.7
Urban	19	25.4	24	11	13	14	17.3
Rural	58	55.9	53	47	44	44	56.6
North	56	56.3	51	46	35	31	59.9
Centre	48	46.7	46	36	40	41	48.7
South	68	64.4	60	51	51	51	63.3
Proportion ultra-poor							
National	24	22	21	15	15	15	24.5
Urban	5	8	8	2	2	3	4.3
Rural	26	24	23	17	17	17	28.1
North	25	26	21	17	18	9	25.6
Centre	16	16	16	11	11	13	18.9
South	35	32	30	22	24	23	29.5

Sources: GoM (2007, 2008, 2009, 2009a, 2009b, 2010, 2011, 2012); NSO (2015, 2016); UNDP (2010); Mussa and Pauw (2011)

These high poverty levels increases the vulnerability of Malawian households "to a number of shocks that may increase their likelihood of being poor" including climatic shocks – with severe implications on the dominant county's rain-fed agricultural production systems and resulting household welfare (Mussa and Pauw, 2011). Severe weather shocks are seen as one of determinants of poverty in Malawi as they "often drag households below the poverty line and limit the extent to which they can invest in inputs for the next production cycle" (Mussa and Pauw, 2011).

1.2.19 Sector Profiles

Malawi's economy is largely agro based, with the sector supporting about 80% of rural people's livelihoods and contributing about 30% to GDP and 80% of export revenue.

Performance of the other sectors is dependent on agriculture which is largely rain fed and hence highly vulnerable to climate change and climate variability.

The MGDS II identified six broad thematic areas, namely; Sustainable Economic Growth; Social Development; Social Support and Disaster Risk Management; Infrastructure Development; Improved Governance; and Cross-Cutting Issues. Within these six thematic areas, the MGDS II isolates nine key priority areas (KPAs), namely; Agriculture and Food Security; Transport Infrastructure and Nsanje World Inland Port; Energy, Industrial Development, Mining and Tourism; Education, Science and Technology; Public Health, Sanitation, Malaria and HIV and AIDS Management; Integrated Rural Development; Green Belt Irrigation and Water Development; Child Development, Youth Development and Empowerment; and Climate Change, Natural Resources and Environmental Management. The selection of the key priority areas was meant to sustain and accelerate economic growth within the available resources.

Through the nine key priority areas and the six thematic areas, the MGDS II maintained a balance among economic, social and environmental components of the economy for sustainable economic growth and development. This was expected to reduce poverty and bring about prosperity in the medium term while accelerating attainment of the Millennium Development Goals (MDGs).

1.2.20 Human and Public Health Profile

The Human Health situation for Malawi is still declining as shown by the 2015-2016 Demographic and Health Survey (DHS) (See Table 1.5). According to the World Health Organization, life expectancy as of 2015 remained at 57 years for males and 60 years for females. The country was spending about 11.5% of its GDP on health as of 2015 (http://www.who.int/countries/mwi/en/).

Infant and under 5 mortality rates are at 42 and 63 deaths per 1000 live births (DHS 2015-16). This means that out of every 16 Malawian children, one does not survive. Child mortality rates are higher for rural areas (77 deaths per 1000 live births) than for urban areas (60 deaths per 1000 live births). The maternal mortality rate for Malawi is at 439 deaths per 1000 live births. About 4 to 5 women aged between 15 and 49 die during pregnancy, childbirth or within 42 days after child birth.

Malaria continues to be one of the killer diseases in Malawi posing a risk mostly to under 5 children. While the DHS 2015-16 recorded that 57% of households own at least one insecticide treated mosquito net, only 39% reported to have slept under one during the night before the day of the survey. Further to this, only 24% of the households had enough nets to cover the whole household.

HIV prevalence rate for the country was at 8.8% for Malawians aged between 15-49 years. HIV prevalence is lowest in Salima (3%) and highest in Mulanje (20%). The prevalence rate is higher for women (10.8%) than for men (6.4%).

1.2.21 Gender

Gender issues have been mainstreamed into Malawi's development strategies. The development agenda for the country acknowledges the fact that gender inequalities in accessing productive resources, development opportunities and decision making affect economic growth and development. Women in Malawi constitute about 51% of the population. However, despite being the majority, they are marginalized socially and economically affecting their ability to effectively participate in social, economic and political development of the country.

Education is one of the important factors that should enhance women empowerment. In Malawi, literacy levels for men stand at 74% and 57% for women. Further to this, IHS3 reported that 23% of women in Malawi had never attended school while only 14% of men reported to have never attended school.

1.3 Transfer of Technologies and Funding Mechanisms

This is the information that is considered relevant to the achievement of the United Nations Framework Convention on Climate Change (UNFCCC), especially as it relates to Article 4.8, 4.9 and 4.10 of the Convention. Article 4 is about commitments, and sections 4.8, 4.9 and 4.10 cover funding, insurance and the transfer of technologies. The other relevant information include: (i) education, training and public awareness, (ii) research and systematic observation, (iii) communication, and (iv) scientific and technical research and learning institutions.

1.4 Institutional Arrangements for Climate Change

1.4.1 Institutional Arrangements

Current policies and strategies recognize the importance of cross-cutting issues, such as climate change, gender and HIV and AIDS, as important components of an over-arching and sustainable development strategy. The Ministry of Natural Resources, Energy and Mines is responsible for preparing and implementing environmental policies and relevant legislation.

It comprises an Environmental Directorate, which among other things, is responsible for the preparation and coordination of environmental policy and climate change issues. It is responsible for enforcing any contravention against environmental laws and policies. It is also responsible for giving guidance on environmental issues, and serves as the Secretariat for the National Climate Change Committee (NCCC). In each of the twenty-eight districts in the country, there is an Environmental Officer (EO) who is responsible for coordinating and overseeing environmental issues, and preparing "District State of Environment Reports" that are further consolidated into the "National State of the Environment Report". Recent developments include the finalization of the National Climate Change Management Policy, National Climate Change Management Policy, National Climate Change Investment Policy and the National Disaster Risk Management Policy.

1.4.2 Institutional Arrangements for Preparing National Communications and BURs and Climate Change work in Malawi

Following the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in April 1994, Malawi conducted several studies aimed at fulfilling her obligations under the Convention with funding from GEF through UNDP. This culminated in the preparation and submission of the INC to COP of the UNFCCC in December 2003, and the preparation of several other climate change related documents, including: (i) Research and Systematic Observation in 2005 (EAD, 2005), (ii) Technology Transfer and Needs Assessment in 2003 (EAD, 2003), (iii) National Adaptation Programmes of Action (NAPA) in 2006 (EAD, 2006), and (iv) National Capacity Self-Assessment in 2006 (EAD, 2006).

The Environmental Affairs Department (EAD) in the Ministry of Forestry and Natural Resources is the executing agency for the TNC process. The EAD has the overall mandate of monitoring the project to meet the objectives of the study, achieving results (outputs) and impact; and accounting for all financial resources to UNEP. The National Climate Change Technical Committee (NCCTC) provides technical guidance. Each Team comprising various and complementary experts was headed by a National Team Leader. The team members comprised a pool of experts that were involved previously in the preparation of the INC and the SNC as well as new experts. The national experts were drawn from key relevant sectors from Government ministries/departments, academic institutions, researchers, private sector organisations and NGOs.

The Malawi Government considers environmental management as an integral component of food and water security, poverty alleviation and socio-economic growth and development as central pillars of national development policies and strategies. Addressing climate change forms part of the Government's strategy to spur economic growth and development, thereby reducing poverty, and encouraging sustainable development. The EAD in the Ministry of Forestry and Natural Resources, is responsible for preparing and implementing environmental policies and relevant legislations. It is also responsible for enforcing the regulations and providing guidance on environmental issues, including climate change. In each of the twenty-eight districts, there is a District Environmental Officer (DEO) responsible for coordinating and overseeing environmental issues and the preparation of the district State Of Environment Reports, (SOER). EAD, in collaboration with the Department of Metrological Services (DoMS), is responsible for coordinating climate change issues in the country.

The major policy thrust includes the coordination and proper management of the environment and the natural resource base in collaboration with line ministries and departments, the private sector, NGOs, select communities, and other relevant stakeholders at district, national, regional and international levels. Further, officers responsible for environmental management usually create in the people of Malawi what is known as "legitimate expectations", which are protected by Section 43 of the Constitution of Malawi. The principles of administrative law are utilized as a tool for quality decision– making to ensure sustainable management of the environment.

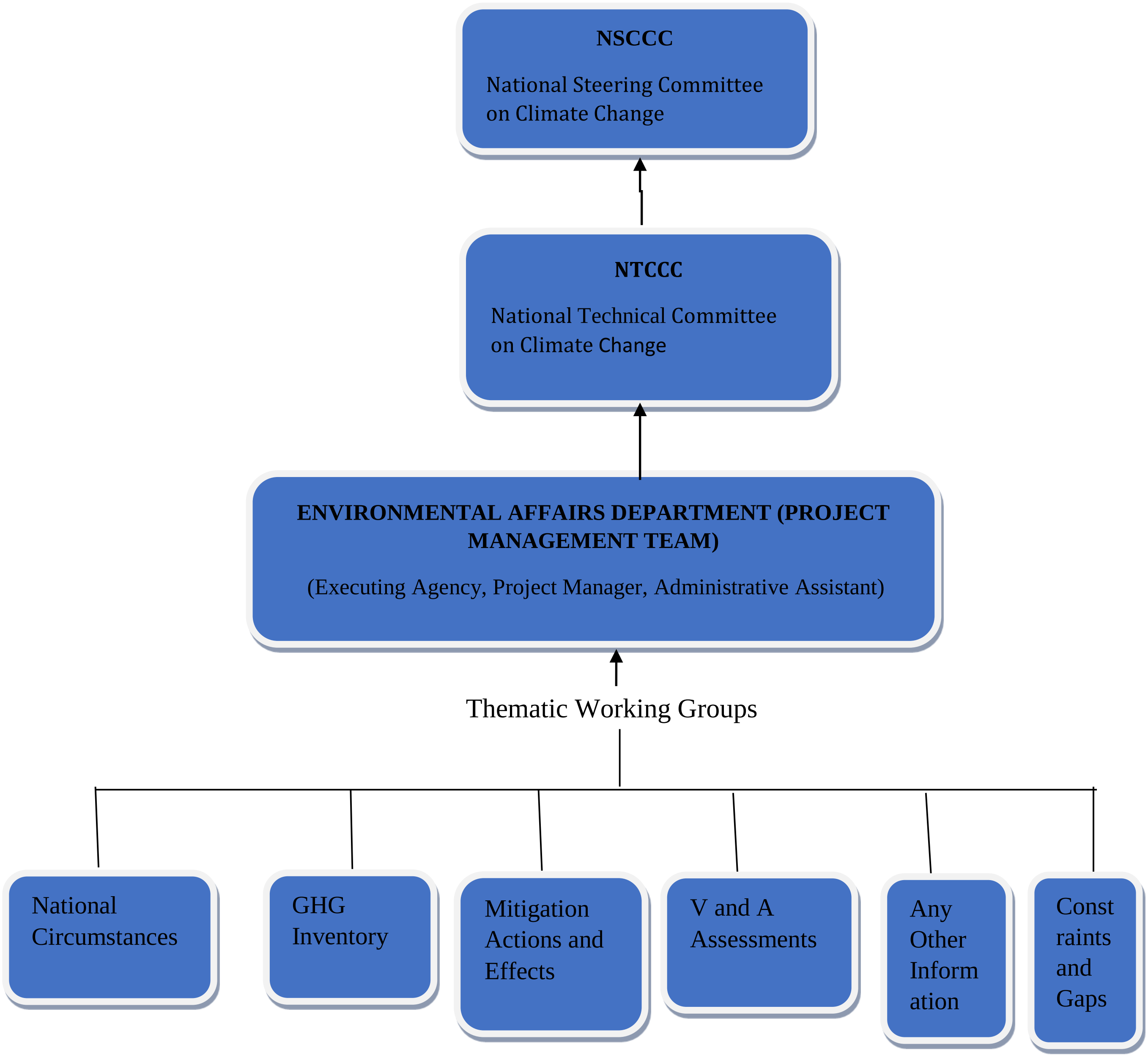


Figure1. 7 Institutional arrangements for preparing National Communications (NCs) and Biennial Update Reports (BURs) and Climate Change Work in Malawi

1.5 Natural Resources

1.5.1 Geology and Mineral resources

Malawi broadly lies near the southern end of the western branch of the EARS. The geology is dominated by Metamorphic rocks of Precambrian to lower Palaeozoic age which are the oldest rocks. These oldest rocks are overlain by sedimentary rocks and intruded upon by a variety of Alkaline rocks of Jurassic to Cretaceous age. These are overlain by younger sediments (Tertiary to Quaternary area) deposited in the major drainage basins of the country.

The country is endowed with a variety of mineral resources with high potential for exploitation. The rare earth metals are a particularly distinctive feature of Malawi geology. There is potential for Oil, Gas and potentially unconventional hydrocarbons in the Tertiary to recent sediments of Lake Malawi. Mineral and hydrocarbon deposits in Malawi can be grouped into four major associations, summarised in Table 1.9.

Table 1. 9 Major Mineral groups in Malawi

Rock association	Potential Mineral Deposits
Residual weathering, placer and rift-related sedimentation	Bauxite, Nickel, Titanium/REE/Zr, Gold and gemstone placers
Sedimentary and volcanic cover rocks	Coal, Uranium, industrial minerals, gemstones
Alkaline Magmatism	Rare Earth metals, Coltan, metals, nuclear metals, phosphate
Basement metamorphic and igneous rocks	Precious and base metals, industrial minerals, gemstones

Source: British Geological Survey (2009)

Mining in Malawi is currently dominated by small scale operators. Principal commodities exploited include gemstones, sand, rock aggregate, coal and limestone. The majority of the mineral deposits are not exploited. However, following the opening of the Kayerekera Uranium mine by Paladin Africa in 2009, a number of both local and international companies have shown interest in the country's mining industry. To date, there are few medium to large-scale mining operations. However, a number of small scale operations exist including some collieries to the north of the country and a number of gemstone and limestone miners. The Kanyika Niobium, The Songwe REE, and the Duwi Graphite prospects are some of the major deposits currently undergoing advanced feasibility studies for possible exploitation in the near future. Other than these, the majority of Malawi's major mineral deposits are at preliminary exploration stages.

In general, there have been minimum negative environmental impacts arising from the exploration and mining activities owing to their underdevelopment i.e. most of them are at exploration stages. Lack of proper regulation and/ or enforcement thereof are key concerns for the safety and environmental conservation in areas where these operations are taking place.

1.5.2 Land resources

Malawi's total land area of 9.4 m ha is presently supporting a human population of 13.1 m people that is growing at the rate of 2.8% with a population density of 139 persons km^{-2} (NSO, 2008). Out of the 9.4 m ha, (i) 3.70 m ha is forests and woodlands, (ii) 1.85 m ha is permanent pastures, (iii) 3.85 m ha is total agricultural land (0.13 m ha is permanent crops and 1.88 m ha is arable land, and (iv) 7.41 m ha is non-arable land (GoM, 2000a; NSO, 2008)

Thus, only 31% of the country's total land area is suitable for rain-fed agriculture at traditional level of management, which is highly influenced by topography, slope, rainfall, temperature, soil type and soil depth, a clear indication of the limited nature of the land resource base that is heavily utilized and prone to environmental degradation, hence also highly vulnerability to climate change.

About 56% of the family households own and cultivate small land holdings of less than 1.0 ha, most of which is under the customary land tenure system. However, Malawi's land resource base is under threat from increasing human and livestock population pressures, and the expending agricultural production to marginal areas. These pose the challenges of land and environmental degradation.

Soil development in Malawi is linked to both geologic and geomorphic development of the country as a product of prolonged periods of weathering and soil deposition within the drainage basins. Although there are many soil subgroups, they can generally be categorized according to their physiographic unit. Alluvial and colluvial soils with subordinate vertisols and calcimorphic soils are the main soil types associated with all the major drainage feature and are common within the rift valley floor. The escarpments and the plains have deep well-drained profiles of latosols. The High plateaus have thin developments of soils and mostly have lithosols.

The country's economy is heavily dependent on agriculture for sustenance and foreign exchange earnings. Agricultural production in the country is largely from small scale farming which contributes to over 80% of the breadbasket. Tobacco and tea are the two largest foreign exchange earners with the former contributing to nearly 60% of the total earnings. Of late, government has been trying to diversify its economic base from agriculture to other areas like mining, tourism and manufacturing. Although this is the case, it will still be a long way before the diversification in the economy will yield results because to the majority of Malawi's dominantly rural population, land is the most important asset which they possess.

As a consequence of the foregoing, land and natural resources in Malawi are under severe stress to sustain the rapid population growth. This is leading to rapid environmental degradation and resources depletion among other impacts. Soil erosion ranks as one of the most acute environmental problem in Malawi and has been exacerbated by a number of factors such as deforestation, rapid population with consequences on reduced land holding size, poor farming practises and cultivation in marginal lands and over reliance on the agricultural sector for the country's economy.

The other factors that contribute to land degradation include: (i) insecure and unforeseeable property rights leading to open access exploitation for agricultural production, (ii) limited information on the costs of land degradation and the benefits of conservation, (iii) lack of access to credit for soil conservation and management practices, and (iv) poor agricultural production practices. However, the new Malawi Land Policy (MG, 2007) is addressing some of these constraints.

1.5.3 Water Resources

The Water Resources Sector is one of the most important sectors for the socio-economic growth and development. "Water is life", as the popular saying goes. In addition, Malawi's water resources support navigation, the fishing industry, tourism, wildlife, and above all rain-fed agriculture, which is the engine of economic growth. Presently, domestic water demand is estimated at 125 litres per day per capita or 157,500 m^3 per day or about 57.6 m m^{-3} per year. Urban areas are estimated to use some 200-360 litres per day per capita, whereas rural areas are estimated to use 27 litres per day per capita. However, the available water supply and improved sanitation services are only accessible to an estimated 73% and 61% of the population, respectively.

The water resources of Malawi are stocked in the country's rich water systems comprising a network of rivers, streams, lakes and groundwater reservoirs. The most dominant water body is Lake Malawi, the third largest lake in Africa and one of the world's important centres of biodiversity, which has a mean water level of 474.2 m asl, and an annual mean live storage capacity of 101 km^3 of water. It has an estimated catchment area of 97,740 km^2 (66% of which is in Malawi, 27% is in Tanzania and 7% is in Mozambique). The lake itself occupies an area of some 28,760 km^2, and is 590 km long varying from 30 to 80 km in width. The other lakes include: Chilwa, Chiuta, Malombe and Kazuni. The mean annual rainfall over Lake Malawi is estimated at 1,549 mm per year, with a total surface inflow of approximately 920 m^3/s, of which, 400 $m^3 s^{-1}$ is from Malawi, 486 m^3s^{-1} from Tanzania and 41 m^3s^{-1} from Mozambique. The Shire River is the second dominant water body with an average flow rate of some 400 m^3/s as it leaves Lake Malawi. It passes an annual average of some 18 km^3 of water out of the country as it enters into the Zambezi River on its way to the Indian Ocean. Other important rivers include Songwe, North Rukuru, South Rukuru, Dwangwa, Diamphwe, Lilongwe, Linthipe, Bua, Shire, Ruo, Phalombe and Mwanza. Except for the Lake Chilwa catchment basin, the rest of the drainage systems in Malawi are part of the Zambezi watershed.

There are two main groundwater resources: (i) the extensive but low yielding (1-2 litres per second) weathered basement aquifer of the Middle Altitude Plateau, and (ii) the high yielding (> 15 litres per second) aquifer of the Lakeshore Plain and the Lower Shire Valley. Both surface and groundwater resources depend on rainfall inputs, and they support important wetlands, especially those along the shores of Lake Malawi and Lake Chilwa, Vwaza Marsh near Lake Kazuni, and Ndindi and Elephant Marches in the Shire River Valley, which are habitats for various flora and fauna.

The country's water resources are used for domestic and industrial purposes, generating electricity and for irrigation purposes. A conservative estimate indicates that there are about 90,000 ha of land that is suitable for irrigation with an estimated water demand of about 178 million m^3 per year. However, about 40,000 ha are presently are under irrigation and use an estimated 80 million m^3 per year. The main reason for the low use of irrigation water include (i) lack of an irrigation culture by Malawians, and (ii) inadequate water resources in rivers and streams during the dry season. Some 280 MW of electricity are generated from hydro-power plants constructed on the Shire River. This is more than 99% of the electricity used in the country, and its generation requires an estimated 250-400 $m^3 s^{-1}$, or a maximum of about 12.6 km^3 per year. There is still a further potential to harness about 740 MW on the Shire River, with about 64 MW already installed at Kapichila Hydro-power Station. However, the current and future hydro-power developments depends on maintaining flow rates of at least 250-400 m^3s^{-1} on the Shire River, which has not always been guaranteed. This is because flow rates lower than these have been recorded on the Shire River in the past, such as during the 1996/97 rainy season. It is against this background that the Kamuzu Barrage was constructed at Liwonde with the aim of regulating lake water levels and river flow rates, thereby minimising the likelihood of having flow rates that are lower than those required for generating hydro-electricity down stream on the Shire River.

Although the abundant ground and surface water resources of Malawi are presently sufficient for domestic, agricultural, commercial and industrial use, they are slowly and steadily getting degraded due to many interrelated factors including: (i) ground and surface water pollution from faecal concentrations, industrial and hazardous wastes, untreated municipal wastes and agro-chemical run-off, (ii) sedimentation or siltation from suspended particles and soil erosion, and (iii) drying of perennial rivers from low rainfall and dwindling groundwater resources. All these factors combine in space and time to reduce both water quantity and quality, painting a brink picture for the future against a backdrop of climate change.

1.5.4 Energy

The country relies heavily on biomass fuel and has one of the least per capita consumption of energy in sub-Saharan Africa (Taulo et al, 2015). Biomass fuel accounts for nearly 93% of the energy needs, petroleum products account for 3.5%, hydro-electricity constitutes 2.3% while coal constitutes 1% of the energy consumed. The remaining 0.2% comes from renewable energy sources (REIAMA, MEP).

Inadequate supply due to ageing infrastructure, high demand due to rapid population growth coupled with environmental degradation climatic extremes are some of the problems rocking the country's power sector. As a way to improve the situation, there have been efforts to explore and exploit some of the existing the alternative energy sources and reduce the energy production monopoly by ESCOM, the country's sole electricity producer by bringing in independent power producers to supplement the efforts by the country's sole supplier. The Millennium Challenge Account (MCA) is at the moment supporting Energy sector reforms including splitting the roles of generation and distribution which are seen as one way to improve the efficiency of the power suppliers.

1.5.5 Alternative Energy Resources

Malawi is well endowed with a variety of sources of energy: biomass, coal, many perennial rivers for hydropower generation, solar energy for heat and electricity generation, wind energy for water pumping and other minor applications, hot springs for geothermal power and uranium deposits for nuclear power generation. Petroleum products are exclusively imported (MEP, 2002).

Biomass and bio-energy

Biomass in the form of wood fuel is the largest form of primary energy consumed in Malawi, accounting for 97% of the total primary energy supply in the country (GoM, 2010b). Major sources of biomass available include fuelwood and forestry and agricultural residues, animal dung, energy crops and municipal wastes. Forest reserves are the main sources of fuelwood and contribute nearly 75% of the total biomass supply (Jumbe and Angelsen, 2011). Forests cover 3.2 million hectares, approximately 36% of the total land area with total available biomass resources being 275.5 million tonnes (Kambewa and Chiwaula, 2010). Sustainable fuel wood supplies from forests are estimated to be 42.4 million cubic metres of solid wood equivalent. Total demand for biomass energy is estimated at 8.92 million total wood equivalent or 13.38 million cubic metres solid wood.

Total bio-energy potential in Malawi is estimated between 0.1 and 0.5 EJ/year (Zyl *et al*, 2010). Crop residues have the biggest energy potential about 161, 910 TJ/year, followed by forest residues (48,744 TJ). In addition, there are approximately 23 million animals (cattle, goats, sheep, pigs and chickens) and their manure can be used for the production of biogas (FAO, 2010). This number of animals gives a theoretical potential for biogas production of 1,387,195 m^3 of biogas per day corresponding to 1100 GWh_{el}/year of electricity or 914.5 GWh_{th}/y of heat, assuming an average of 2.25 kWh/m^3. This is about 74% of the electricity consumed in Malawi (electricity consumption amounted to 1,478 GWh in 2012). In view of rising consumption, which is expected to quadruple over 2008 to 2030, using biogas to generate electricity could be a sensible way of improving electricity supply mix in Malawi.

Annual average production of sugarcane in Malawi is estimated at 2.5 million tons/year leaving behind over 950 000 tons baggase which is a significant power source. There are two sugar mills in Malawi having potential to generate 62 MWe of electricity but currently only 18 MWe has been utilised. Bagasse-based electrical generation estimated at 251GWh, corresponds to about 25% of national electricity generation (UNEP, 2013). The country can also explore biogas potential of municipal solid waste (MSW) as well. Current estimated municipal solid waste (MSW) generation per day is 720 tons which gives theoretical potential for biogas production of 32,683 m^3/day corresponding to 70.6 MWh_{el}/y or 58.8 MWh_{th}/y (Karekezi *et al.*, 2003).

Moreover, agricultural residues such as rice straw, sugarcane and cassava pulp have the potential to produce approximately 46.5 million litres ethanol production for the country. This could possibly displace over 40% of Malawi's 2011 petrol consumption as transport fuel. Alternatively, the same amount of residue could provide 18.1 million litres per year of diesel to potentially offset 9.5% of natural diesel consumption in the transport sector. Presently, molasses-based ethanol amounting to 18 million litres/year, is being marketed as 10% blend with petrol. The total demand for ethanol is expected to be 33.6 million litres against present availability, resulting in scarcity of 15.6 million litres ethanol in the year 2015. Furthermore, biodiesel produced from energy crops such as *Jatropha curcas*, soya beans, cotton, sunflower and groundnuts has the potential to produce 50 million litres of biodiesel, equivalent to 583, 530 TJ/year of energy.

1.5.6 Coal

Coal is Malawi's most abundant fossil resource with probable coal reserves estimated at 1 billion metric tonnes and 22 million of which are proven reserves of a bituminous type. The coal deposits are scattered in various coal fields to the north and south of the country. The Ngana coal field with estimated proven reserves of 16 MT is the largest but with probable reserves estimated at 70 million tonnes (GoM, 2010c). Further exploration work might increase the total reserves of coal in the country.

A number of collieries in the northern and southern coal field mine the coal. Total annual production increased from about 34 000 metric tons in 2001 to about 80000 metric tons in 2010 (GoM, 2010c). Presently, the main consumers of the coal in Malawi are the tobacco processing, textile and sugar production, and beer brewing and cement industries. However due to inadequate supplies of electricity from hydro, feasibility studies are underway to establish two coal-fired all two coal-fired power stations at Zalewa and Salima with capacity of 300 MW and 100 MW respectively (Chiyembekeza, 2013). Due to the abundance of the coal resources in Malawi and its low prices, it could be the energy for the future for Malawi.

1.5.7 Hydrocarbon resources

Malawi does not have oil deposits, and relies entirely on imported petroleum products. However, previous work has shown geological successions and structures that have potential to host these resources within the Malawi Rift. Surestream and Simkara are some of the exploration companies that are currently carrying out exploration activities for hydrocarbons.

Malawi imports 97% of its refined petroleum products with the remaining 3% coming from locally-produced ethanol (NCST, 2011). The transport sector is the major consumer of the liquid fuels accounting for nearly 90% of the total consumption. The remaining 10% is used in the domestic, agricultural and manufacturing sectors.

Uranium

Malawi uranium reserves in sedimentary basins in the north of the country the largest one is at Kayerekera. The known recoverable resource of uranium in Malawi at Kayelekera Mine is estimated at 63 000 tons, which is equivalent to 378 tons of U-235 (GoM, 2003). The deposit at Kayerekera was actively mined from 2009- 2014 when it went under care and maintenance due to the global decline in Uranium prices. In 2010, when the mine was fully operational, annual production output was estimated at 790 tons of uranium (U_30_8). Another deposit which is yet to be quantified is at Illomba in Chitipa district.

Due to the small sizes of the deposits, environmental concerns and the high costs associated with development of nuclear reactors, Uranium may not be the energy resource of choice for the near future of the country.

1.5.8 Renewable energy resources

Malawi has a large potential for renewable energy exploitation in a number of areas, the significant ones being solar energy, biomass, and hydropower with potential for geothermal and wind energy. Except for large scale hydropower, which serves as a major source of electricity, the current state of exploitation and utilization of the renewable energy sources in the country is very low, limited largely to pilot and demonstration projects. This section gives a review on the available energy potential of different renewable energy sources and the current status of exploitation is presented.

Hydro

Malawi has an estimated gross theoretical potential of 1670 MW and the average power generation of 15 000 GWh/year. The technical and economically feasible hydro capacity has been estimated at 6 000 and 7 000 GWh/year, respectively (Taulo, 2007). Current hydropower generation is about 17% of the nation's hydropower potential and represents 98% of total installed grid-connected electricity generation capacity. Hydropower potential of Malawi is concentrated on the Shire River. The capacity ranges from 18 to 140 MW. The estimated hydro potential of the Shire River is about 600 MW, equivalent to an annual production of 3500 GWh (ibid). In addition, several smaller rivers such as the Songwe, South Rukuru, Dwangwa and Bua, have limited potential at a number of sites estimated to total about 300-400 MW (WEC, 2002).

In addition, Malawi also has huge untapped small hydropower potential (with capacities of less than 10 MW each) which are spread out across the country. The gross theoretical small hydro potential of the country is 150 MW, out of which only 4.5 MW of the economically feasible potential has been developed (MEM, 1997). The exploitability of these is limited by their projected costs, but they could be useful for off-grid or stand-alone-mini grid electrification.

Solar energy

Solar energy presents considerable potential that can contribute to a large extent to fill the gap of energy needs in Malawi. The country receives about 2138 to 3087 hours of sunshine and 2133 kWh/m^2/year. The global solar radiation on a horizontal surface ranges between 4.3 kWh/m^2/day minimum and 7 kWh/m^2/day maximum. The annual daily mean global solar radiation is about 5.86 kWh/m^2/day, equivalent to 250 million tonnes of oil equivalent. Maximum irradiation of 6.5-7.0 kWh/m^2/day occurs in September - October and the minimum of 4.3-4.6 kWh/m^2/day occurs in January-February or in June-July according to location. Peak hourly solar radiation is more than 1000 kWh/m^2 during November to December (Chima, 1998). Considering that many parts of the country receive 8 to 12 hours of sunshine per day of 244 W/m^2, the potential for using solar for electricity generation is very high. The total available solar energy potential over the total geographical area (i.e. 94,280 km^2), of Malawi is calculated to be 356,284,837 MWh/year.

The solar resource in Malawi has been employed for various applications. Solar water heaters have been developed and are manufactured locally for domestic purposes. Total amount of installed solar water heaters in the country is estimated to have reached approximately 4 855 square meters. In addition, photovoltaic systems are also finding increasing use for various purposes such as lighting, water pumping, telecommunications repeater stations, refrigeration, and other appropriate applications. At present, there are more than10 000 photovoltaic systems installed in various parts of the country, with a total capacity of 165 kWp (CSR, 2005). There has been further growth, though small, in the SHS but no accurate figures are currently available. Six solar-wind hybrid systems have also been installed with Department of Energy Affairs support in Thyolo, Chiradzulu, Nkhata Bay, Mzimba, Nkhota-kota and Ntcheu (12 kW, each providing power for about 150 households). More recently, an 870 kWp solar photovoltaic plant has been commissioned at Lilongwe International Airport.

Wind energy

Wind energy has been used on a small scale to supply water for both livestock and irrigation in Malawi. Although there is a dearth of information on the wind energy characteristics of the country, it seems the wind speeds are moderate to low, typically in the range of 2.0-7.0 metres/ second (GoM, 2003). Preliminary results from studies conducted by Malawi's Meteorological Department suggest that the wind resource in Malawi cannot contribute significantly to a firm power generation; and that low speed aero-generators could be operated for various applications such as milling of grains, pumping water and even lighting purposes in small remote villages around Malawi. It is particularly suited to water pumping as intermittent wind could still supply the needs when an adequate storage facility is incorporated. However, such assertion is contrasted by recent research findings which indicate that there is considerable potential for wind in the country. At present, the DoEA is collaborating with Malawi Renewable Energy Acceleration Programme (M-REAP) at the University of Malawi, an initiative funded by the Scottish Government, to undertake detailed wind measurements at five strategic sites as part of developing Malawi's wind atlas.

Geothermal energy

Geothermal energy has been extensively used for power generation and direct power applications in many countries of the world (Fridleifsson, 2003). As a consequence of Malawi's location in the East African Rift System (EARS), the country is endowed with significant potential reserves of geothermal energy. There are approximately 55 geothermal spots in Malawi, but three major ones identified for detailed investigation are: Chiweta, Mwankeja, and Nkhotakota. The combined geothermal potential from these major areas is 200 MWe (Gondwe *et al.,* 2012). As for geothermal projects, some studies have been conducted to design a prototype Geothermal Power Plant for producing electricity. One of the ongoing related projects is a 30 MW Geothermal Power Plant at exploring stage in Nkhotakota, to be upgraded to 100 MW depending on the results of exploration drilling.

1.5.9 Fish Resources

The fishes of Malawi, particularly those in Lake Malawi, are one of the most diverse species assemblages in the world with more than 800 species of cichlids alone (Genner and Turner, 2005; Genner and Turner, 2015). Malawian fish species represents about 15% of the global total number of fresh water fish species and approximately 4% of the world's number of fish species (Konings, 1990; Ribbink, 2001). Most of the Malawian cichlid fishes have evolved in this lake within a geologically short period and occur nowhere else in the world as natives (Genner and Turner, 2005). The main fish types found in Lake Malawi include *Oreochromis karongae, Oreochromis squamipinnis, Oreochromis lidole* (collectively known as Chambo), *Oreochromis shiranus* (makumba), *Bagrus meridionalis* (Kampango), *Lethrinops spp* (Chisawasawa), *Clarias gariepinus* (Mlamba), *Bathyclarias* spp (Bombe), *Labeo mesops* (Ntchila), *Opsaridium microlepis* (Mpasa), *Opsaridium microcephalum* (Sanjika), *Engraulicypris sardella* (Usipa), *Rhamphochromis* spp (Ncheni), *Diplotaxodon* spp. (Ndunduma), various types of small brightly coloured rocky shore-dwelling cichlids like *Maylandia zebra* and *Labeotropheus trawavasae* (collectively called mbuna), *Dimidiochromis kiwinge* (Mayani) and *Copadichromis spp* (Utaka).

Close to 30 fish species abound within the river cosystems of Malawi, mostly types that are also widely distributed on the African Continent. The main fish families represented include the Cyprinidae, Cichlidae, Mormyridae, Clariidae, Bathyclariidae, Bagridae, Distichodontidae, Protopteridae, Malapteruridae and Mochokidae Amphilidae, Alestidae, Mastacembelidae and the introduced family Salmonidae (Likongwe, 2005; Kadye et al., 2008; Tweddle and Skelton, 2008). While the fish diversity of the country's largest lake (Lake Malawi), mostly comprise of cichlids, cyprinids dominate in the rivers that drain into this lake (Likongwe, 2005; Kadye et al., 2008). Most of the large cyprinids of the genera *Barbus*, *Labeo*, and *Opsaridium* undertake seasonal migrations upstream into the tributary rivers for spawning at the onset of or in the rainy season (Tweddle and Skelton, 2008; Limuwa et al., 2012).

1.5.6 Biodiversity and Wildlife Resources

Malawi has a spectrum of habitats and ecosystems in form of woodlands, montane grasslands, wetlands and fresh water bodies of diverse sizes. These ecosystems are home to a rich variety of plants and animals. The spatial distribution of these ecosystems is highly variable and influenced by topography, climate, vegetation type and, more importantly, human activities. Within these ecosystems there are more than 6000 plant species, 122 of which are endemic and over 248 of which are threatened (among which 14 are endangered, 89 are vulnerable and 25 are critically endangered) according to the 2013 International Union of Conservation of Nature (IUCN) Red list data. About 114 plant species are known to occur only in few places in Malawi, none of which is formally protected. Malawi has only eleven plant species under legal protection. There are over 8,500 invertebrate species, mostly insects. The invertebrate species count is dominated by nematodes, crustaceans and insects while earthworms, myriapods and arachnids are poorly represented. The country has about 280 species of non-insect aquatic invertebrates that include mollusks, nematodes, crustaceans, rotifers, annelids and acarins. Chironomids, insect nymphs of various taxa as well as water mites are also widespread. Eighty three amphibian species occur in Malawi, most of which are frogs and toads. Over 120 reptile species occur in the country, twelve of which are natives. Malawi harbours about 648 bird species, 94 of which occupy a restricted geographical range in one or a few biomes. A hundred and ninety two species of mammals also abound in Malawi, the majority of which are small mammals. About 83 species of amphibians have been recorded in Malawi, 7 of which are endemic. Malawi has 145 species of reptiles spread across 19 families and 72 genera. The majority of these reptiles are snakes of the family Colubridae (43 species) and lizards of the families Scincidae (20 species) and Geckonidae (16 species). Although estimates of endemism in invertebrates are not well established, it is generally thought that approximately 47 species of mollusks and 12 species of reptiles are endemic to Malawi.

Wetland Resources: Malawi has several most important wetland ecosystems, the main ones of which include the following areas: (i) Lake Chilwa in Machinga, Zomba and Phalombe districts (ii) Elephant and Ndindi Marshes along Shire River in Chikwawa and Nsanje districts (iii) Vwaza Marsh at Lake Kazuni in Mzimba and Rumphi districts, (iv) Lake Chiuta in Machinga district and (v) Lake Malawi lakeshore districts. These wetlands constitute 20% of the country's territorial area and are rich in flora and fauna. Wetlands such as Elephant Marsh and Lake Chilwa play are ecologically important as bird sanctuaries and resting destinations for migratory birds that seasonally traverse the African continent from the north to the south and vice-versa. In 1996, Malawi ratified the Ramsar Convention and Lake Chilwa was designated a wetland of international importance in 1997 because of its physical, biological, ecological and socio-economic attributes to people and the environment. The lake Chilwa wetland contains over 3,500 to 4,000 plant species, and more than 1,000 species of animals and micro-organisms. The wetland is also important as it is a sanction for migration birds. Recently, in 2017 Elephant Marsh was also designated with same status, a wetland of international importance under the Ramsar Convention. Climate change, especially in the form of droughts, has huge potential of adversely affecting the fauna and flora of these wetlands. Although these ecosystems are a hub of biodiversity, they are a source of natural methane (CH4), a greenhouse gas whose emissions contributes to global warming.

2 National GHG Inventory

2.1 Introduction

This chapter represents a summary of the GHG inventory for the period 2001 to 2017 submitted in the Third National Communication (TNC) Report. The Republic of Malawi signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 at Rio de Janeiro, Brazil, during the United Nations Conference on Environment and Development (UNCED). Being a party to the Convention, the country is mandated to submit its National greenhouse gas (GHG) emissions inventory report (NIR) to UNFCCC as a component of the Biennial Update Report to UNFCCC.

2.1.1 Emissions/removal inventory sectors and gases

The BUR includes five main IPCC sectors, namely: Energy, Industrial Process and Product Use (IPPU), Agriculture, AFOLU, and Waste. The emissions reported in this GHG inventory are carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O).

2.1.2 Methodology

The 2006 IPCC Guidelines were used to compile the BUR. Table 2.1 presents the methodologies used to compile the NIR.

Table 2. 1 Methodologies used

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Method
1A1.Energy industries	T1
1A2.Manufacturing industries and construction	T1
1A 3.Transport	T1
1A 4.Other sectors	T1
1A 5.Other	T1
1B 1.Fugitive emissions from Solid fuels	NO
1B 2. Fugitive emissions from Oil and natural gas	NO
1C. CO_2 transport and storage	NO
2A.Mineral industry	T1
2B.Chemical industry	T1
2C.Metal industry	T1
2F.Product uses as ODS substitutes	NE
3A.Enteric fermentation	T1
3B.Manure management	T1
3C.Rice cultivation	T1
3D.Agricultural soils	T1
3E.Prescribed burning of savannas	T1
3F.Field burning of agricultural residues	T1
3G. Liming	T1
3H. Urea application	T1
3I.Other carbon-containing fertilizers	T1
3J.Other	T1
4A. Forest land	T1
4B. Cropland	T1
4C. Grassland	T1
4D. Wetlands	T1
4E. Settlements	T1
4F. Other land	T1
4G. Harvested wood products	T1
4H. Other	T1

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Method
5A.Solid waste disposal	T1
5B.Biological treatment of solid waste	NE
5C.Incineration and open burning of waste	NE
5D.Waste water treatment and discharge	T1
5E.Other	T1

2.1.3 Use of IPCC Inventory software

Estimation of GHG emissions as well as calculation of key category analysis were done using the 2006 IPCC GHG Inventory Software Version 2.54. The software is basically a spreadsheet, created based on the mathematical formulations presented in the 2006 IPCC Guidelines for National Greenhouse Inventories. It is authored by IPCC Taskforce on Greenhouse gas Inventories and is available on IPCC website (http://www.ipcc-nggip.iges.or.jp/software/). The software, uses default emission factors, as given in the 2006 IPCC Guidelines. However, for some sectors like Energy, IPPU and Waste sectors, it is possible to replace the default values, making the software possible to estimate emissions using Tiers 2 and 3 approached. The software covers all inventory categories in the five sectors but can also be used for management of specific sectors. To validate whether the software produced accurate results, the sample results were compared with the manually calculated values.

2.1.4 National inventory for 2017

Table 2.2 presents the GHG emissions in units of mass (Gg) for the reporting year of 2010. GHG emissions were reported for the CO_2, CH_4 and N_2O. In 2010 the highest CO_2 emissions were from 1.A Fuel Combustion Activities with 936.58Gg followed by 3.C Aggregate sources and non-CO_2 emissions sources on land with 88.71Gg and then Mineral Products (2A) accounting for 40.01Gg. In the same year, the largest CH_4 emissions were from 3A Livestock amounting to 64.55Gg, followed by 1.AFuel Combustion Activities with 20.79Gg and closely followed by Solid Waste Disposal (4A) with 20.16 Gg . Total N_2O emissions were 1.68Gg mainly coming from the Livestock manure (0.66Gg) and Energy (0.37Gg).

Table 2. 2 GHG emissions by mass

Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO	NOx	NMVOCs	SOx
Total National Emissions	468.71	1.61	1.61							
1 - Energy	939.02	0.30	0.30				NA	NA	NA	NA
1.A - Fuel Combustion	936.58	0.30	0.30				NA	NA	NA	NA
1.A.1 - Energy Industries	3.12	0.10	0.10				NA	NA	NA	NA
1.A.2 - Manufacturing Industries and	258.50	0.122	1				NA	NA	NA	NA
1.A.3 - Transport	647.47	0.13	0.03				NA	NA	NA	NA
1.A.4 - Other Sectors	27.49	14.13	0.16							
1.A.5 - Non-Specified	NO	NO	NO							
1.B - Fugitive emissions										
1.B.1 - Solid Fuels	NE	9.97	NE							
1.B.2 - Oil and Natural	NO	NO	NO				NO	NO	NO	NO
1.B.3 - Other emissions	NO	NO	NO				NO	NO	NO	NO
1.C - Carbon dioxide										
1.C.1 - Transport of CO2	NO			NO	NO	NO	NO	NO	NO	NO
1.C.2 - Injection and	NO		NO	NO	NO	NO	NO	NO	NO	NO
1.C.3 - Other										
2 - Industrial Processes	40.01	NE	NE							
2.A - Mineral Industry	40.01	NE								
2.A.1 - Cement production	16.07	NE								
2.A.2 - Lime production	23.84	NE								
2.A.3 - Glass Production	NO	NO								
2.A.4 - Other Process Uses	0.10	NO								
2.A.5 - Other (please	NA	NA								
2.B - Chemical Industry	NO	NO	NO	NA	NA	NA				
2.C - Metal Industry	NO	NO	NO	NA	NA	NA				
2.D - Non-Energy Products from Fuels and	NO	NO	NO				NO	NO	NO	NO
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F - Product Uses as Substitutes for Ozone	NE		NE	NE	NE	NE				
2.G - Other Product	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.H - Other	NA	NA	NA							
3 - Agriculture, Forestry,	-519.45	71.87	0.69				NA	NA	NA	NA
3.A - Livestock		64.55	0.66				NA	NA	NA	NA
3.B - Land	-562.58	NE	NE				NA	NA	NA	NA
3.C - Aggregate sources and non-CO2 emissions	88.71	7.32	0.03				NA	NA	NA	NA
3.D - Other	-45.58						NA	NA	NA	NA
4 - Waste	9.13	38.25	0.62				NA	NA	NA	NA
4.A - Solid Waste Disposal		20.16	NE				NA	NA	NA	NA
4.B - Biological Treatment		NE	NE				NA	NA	NA	NA
4.C - Incineration and	9.13	3.82	0.05				NA	NA	NA	NA
4.D - Wastewater		14.26	0.57				NA	NA	NA	NA
4.E - Other (please	NA	NA	NA				NA	NA	NA	NA
5 - Other	NA	NA	NA				NA	NA	NA	NA

The Global Warming Potentials (GWP) from the IPCC Second Assessment Report (SAR) were used to convert the GHG emissions to CO_2eq. The GWPs from the SAR are presented in Table 2.3.

Table 2. 3 SAR GWP values for 100-year time horizon

Gas	Chemical formula	GWP
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide 310	N_2O	310

Source: IPCC SAR

The GHG emissions in CO_2eq for 2010 are shown in Table 2.4.

Table 2. 4 GHG emissions in CO_2eq

Categories	Net CO_2	CH_4	N_2O	Total
Total National Emissions and Removals	468.71	2,644.47	500.35	3,613.53
1 - Energy	**939.02**	**332.02**	**93.40**	**1,364.44**
1.A - Fuel Combustion Activities	936.58	315.55	93.40	1345.54
1.A.1 - Energy Industries	3.12	16.02	31.53	50.67
1.A.2 - Manufacturing Industries and Construction	258.50	0.12	1.00	259.62
1.A.3 - Transport	647.47	2.72	9.87	660.07
1.A.4 - Other Sectors	27.49	296.69	51.00	375.18
1.A.5 - Non-Specified	NO	NO	NO	NO
1.B - Fugitive emissions from fuels	2.44	16.46	NE	18.90
1.B.1 - Solid Fuels	2.44	16.46	NE	18.90
1.B.2 - Oil and Natural Gas	NO	NO	NO	NO
1.B.3 - Other emissions from Energy Production	NO	NO	NO	NO
1.C - Carbon dioxide Transport and Storage	NE	NE	NE	NE
1.C.1 - Transport of CO2	NE	NE	NE	NE
1.C.2 - Injection and Storage	NE	NE	NE	NE
1.C.3 - Other	NO	NO	NO	NO
2 - Industrial Processes and Product Use	**40.01**	**0.00**	**0.00**	**40.01**
2.A - Mineral Industry	40.01	NE	NE	40.01
2.A.1 - Cement production	16.07	NE	NE	16.07
2.A.2 - Lime production	23.84	NE	NE	23.84
2.A.3 - Glass Production	NE	NE	NE	NE
2.A.4 - Other Process Uses of Carbonates	0.10	NE	NE	0.10
2.A.5 - Other (please specify)	NO	NO	NO	NO
2.B - Chemical Industry	NO	NO	NO	NO
2.C - Metal Industry	NE	NE	NE	NE
2.D - Non-Energy Products from Fuels and Solvent Use	NO	NO	NO	NO
2.E - Electronics Industry	NE	NE	NE	NE
2.F - Product Uses as Substitutes for Ozone Depleting Substances	NE	NE	NE	NE
2.G - Other Product Manufacture and Use	NO	NO	NO	NO
2.H - Other	NO	NO	NO	NO
3 - Agriculture, Forestry, and Other Land Use	**-519.45**	**1509.29**	**215.18**	**1,205.02**
3.A - Livestock	NE	1355.61	205.29	1560.89
3.B - Land	-562.58	NE	NE	-562.58
3.C - Aggregate sources and non-CO2 emissions sources on land	88.71	153.68	9.90	252.29
3.D - Other	-45.58	NE	NE	-45.58
4 - Waste	**9.13**	**803.17**	**191.77**	**1,004.06**
4.A - Solid Waste Disposal	NE	423.42	NE	423.42
4.B - Biological Treatment of Solid Waste	NE	NE	NE	NE
4.C - Incineration and Open Burning of Waste	9.13	80.28	15.59	104.99
4.D - Wastewater Treatment and Discharge	NE	299.47	176.18	475.65
4.E - Other (please specify)	NO	NO	NO	NO
5 - Other	NO	NO	NO	NO

2.1.5 Key Category Analysis

The key category analysis was performed using the 2006 IPCC GHG Inventory Software and shown in Table 2.5 (level).and Table 2.6 (trend).

Table 2. 5: Key category analysis by level

IPCC Category code	IPCC Category	GHG	2010 Ex,t (Gg CO_2 eq)	|Ex,t| (Gg CO_2 eq)	Lx,t (%)	Cumulative Total of Column F(%)
3.B.1.a	Forest land Remaining Forest land	CO_2	-2498.48	2498.48	27.50	27.50
3.B.2.b	Land Converted to Cropland	CO_2	1589.39	1589.39	17.50	45.00
3.A.1	Enteric Fermentation	CH_4	1246.56	1246.56	13.72	58.72
1.A.3.b	Road Transportation	CO_2	616.96	616.96	6.79	65.52
4.A	Solid Waste Disposal	CH_4	423.42	423.42	4.66	70.18
1.A.4	Other Sectors – Biomass	CH_4	401.23	401.23	4.42	74.60
4.D	Wastewater Treatment and Discharge	CH_4	299.47	299.47	3.30	77.89
3.B.3.b	Land Converted to Grassland	CO_2	261.89	261.89	2.88	80.77
3.A.2	Manure Management	N_2O	205.29	205.29	2.26	83.03
3.B.6.b	Land Converted to Other land	CO_2	188.29	188.29	2.07	85.11
4.D	Wastewater Treatment and Discharge	N_2O	176.18	176.18	1.94	87.05
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CO_2	154.05	154.05	1.70	88.74
3.B.1.b	Land Converted to Forest land	CO_2	-128.45	128.45	1.41	90.16
3.C.7	Rice cultivations	CH_4	122.40	122.40	1.35	91.50
3.A.2	Manure Management	CH_4	109.05	109.05	1.20	92.71
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO_2	104.45	104.45	1.15	93.85
3.C.3	Urea application	CO_2	88.71	88.71	0.98	94.83
4.C	Incineration and Open Burning of Waste	CH_4	80.28	80.28	0.88	95.72
1.A.4	Other Sectors – Biomass	N_2O	71.52	71.52	0.79	96.50
3.D.1	Harvested Wood Products	CO_2	-45.58	45.58	0.50	97.00
1.A.1	Energy Industries – Biomass	N_2O	31.52	31.52	0.35	97.35
3.C.1	Emissions from biomass burning	CH_4	31.28	31.28	0.34	97.70
1.A.3.a	Civil Aviation	CO_2	29.88	29.88	0.33	98.02
1.A.4	Other Sectors - Liquid Fuels	CO_2	27.49	27.49	0.30	98.33
3.B.5.b	Land Converted to Settlements	CO_2	24.78	24.78	0.27	98.60
2.A.2	Lime production	CO_2	23.84	23.84	0.26	98.86
1.B.1	Solid Fuels	CH_4	16.46	16.46	0.18	99.04
2.A.1	Cement production	CO_2	16.07	16.07	0.18	99.22
1.A.1	Energy Industries – Biomass	CH_4	16.01	16.01	0.18	99.40
4.C	Incineration and Open Burning of Waste	N_2O	15.59	15.59	0.17	99.57
3.C.6	Indirect N2O Emissions from manure management	N_2O	9.69	9.69	0.11	99.68
1.A.3.b	Road Transportation	N_2O	9.61	9.61	0.11	99.78
4.C	Incineration and Open Burning of Waste	CO_2	9.13	9.13	0.10	99.88
1.A.1	Energy Industries - Liquid Fuels	CO_2	3.12	3.12	0.03	100.00
1.A.3.b	Road Transportation	CH_4	2.72	2.72	0.03	99.91
1.B.1	Solid Fuels	CO_2	2.44	2.44	0.03	99.94
1.A.2	Manufacturing Industries and Construction - Solid Fuels	N_2O	0.75	0.75	0.01	99.95
1.A.3.d	Water-borne Navigation - Liquid Fuels	CO_2	0.64	0.64	0.01	99.95
1.A.3.a	Civil Aviation	N_2O	0.26	0.26	0.00	99.96
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.26	0.26	0.00	99.96
3.C.5	Indirect N2O Emissions from managed soils	N_2O	0.20	0.20	0.00	99.96
2.A.4	Other Process Uses of Carbonates	CO_2	0.10	0.10	0.00	99.96
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.09	0.09	0.00	99.96
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.08	0.08	0.00	99.96
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.07	0.07	0.00	99.97
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CH_4	0.03	0.03	0.00	99.97
1.A.1	Energy Industries - Liquid Fuels	N_2O	0.01	0.01	0.00	99.97
1.A.3.d	Water-borne Navigation - Liquid Fuels	N_2O	0.01	0.01	0.00	99.97
1.A.3.a	Civil Aviation	CH_4	0.00	0.00	0.00	99.97
1.A.1	Energy Industries - Liquid Fuels	CH_4	0.00	0.00	0.00	99.97
1.A.3.d	Water-borne Navigation - Liquid Fuels	CH_4	0.00	0.00	0.00	99.97

2.B.6	Titanium Dioxide Production	CO_2	0.00	0.00	0.00	99.97
1.A.1	Energy Industries - Solid Fuels	CO_2	0.00	0.00	0.00	100.00

Table 2. 6 Key category analysis by trend

	2000 Emissions	2017 Emissions	KCA by trend
IPCC Source category			
1.A - Fuel Combustion Activities	1683.824698	1724.820992	3.4360
1.A.1 - Energy Industries	756.1572252	59.3262153	3.8008
1.A.2 - Manufacturing Industries and Construction	0	211.0804378	
1.A.3 - Transport	927.6674725	933.8367847	0.0000
1.A.4 - Other Sectors	0	520.5775545	
1.B - Fugitive emissions from fuels	0	15.5530302	
1.B.1 - Solid Fuels	0	15.5530302	
2.A - Mineral Industry	55.2292	80.5771	0.1072
2.A.1 - Cement production	55.2292	0	0.1257
2.B - Chemical Industry	4.07535E-07	0	0.0000
3.A - Livestock	0	2330.005506	-
3.B - Land	-2600.204442	1964.002716	0.0000
3.C - Aggregate sources and non-CO2 emissions sources on land	8.04648805	252.6911865	12.7874
3.D - Other	-34.64651801	0	0.0146
4 - Waste	0	675.0743526	0.0000
4.A - Solid Waste Disposal	0	675.0743526	0.0000

2.1.6 General Quality Assurance and Quality Control

In accordance with the IPCC requirements, all GHG Inventories should undergo Quality Assurance and Quality Control. Malawi's National GHG Inventory has undergone a number of reviews on a number of levels by internal and external reviewers outside EAD. It has also undergone international peer reviews by reviewers recognized by UNFCCC both local and international to ensure Quality Assurance and Quality Control. In addition, it has also undergone international peer review by experts from the UNFCCC who came up with a number of recommendations to improve the draft inventories and these were shared with the Team of Reviewers from Zimbabwe, Bees Consultancy Services. The inventory was also presented to national stakeholders for review, comments and validation. The Inventory was thereafter finalized once all the comments were addressed.

2.1.7 Quality Control

Malawi's GHG Inventory has undergone Quality Control checks in terms of the calculations, data processing and completeness of the data. In situations where data was not available notational keys have been inserted to indicate as such. The quality control process has been undertaken with reference to the Good Practice Guidance which ensures data completeness, correctness and integrity and also identify errors and omissions. The GHG Inventory was reviewed by international recognised peer reviewers both from the UNFCCC and independent Consultants.

2.1.8 Uncertainty assessment

Uncertainty assessment was conducted using the IPCC Inventory software (Table 2.7). The highest combined uncertainties emanated from the Energy sector, largely driven by solid and liquid fuels use in that sector.

Table 2. 7 Uncertainty analysis for the reporting year, 2010

2006 IPCC Categories	Gas	Year T emissions or removals (Gg CO_2 eq)	AD Uncertainty (%)	EF Uncertainty (%)	Combined Uncertainty (%)
1.A.1.c.i - Manufacture of Solid Fuels – Biomass	N_2O	31.52	5.00	304.55	304.59
1.A.4.b - Residential – Biomass	N_2O	71.52	5.00	297.73	297.77
1.A.1.c.i - Manufacture of Solid Fuels – Biomass	CH_4	16.01	5.00	245.45	245.51
1.A.3.b - Road Transportation - Liquid Fuels	CH_4	2.72	5.00	244.69	244.74
1.A.4.b - Residential - Liquid Fuels	N_2O	0.07	5.00	236.36	236.42
1.A.1.a.i - Electricity Generation - Liquid Fuels	N_2O	0.01	5.00	228.79	228.84
1.A.4.b - Residential – Biomass	CH_4	401.23	5.00	227.27	227.33
1.A.3.b - Road Transportation - Liquid Fuels	N_2O	9.61	5.00	209.94	210.00
1.A.4.b - Residential - Liquid Fuels	CH_4	0.08	5.00	200.00	200.06
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	N_2O	0.26	5.00	150.00	150.08
1.A.3.d.ii - Domestic Water-borne Navigation - Liquid Fuels	N_2O	0.01	5.00	140.00	140.09
2.A.1 - Cement production	CO_2	16.07	35.00	0.00	35.00
1.A.4.b - Residential – Biomass	CO_2	7671.45	5.00	18.69	19.35
1.A.1.c.i - Manufacture of Solid Fuels - Biomass	CO_2	2846.89	5.00	18.69	19.35
2.A.2 - Lime production	CO_2	23.84	15.00	0.00	15.00
1.A.4.b - Residential - Liquid Fuels	CO_2	27.49	5.00	6.14	7.92
1.A.1.a.i - Electricity Generation - Liquid Fuels	CO_2	3.12	5.00	6.14	7.92
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CO_2	154.05	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction - Liquid	CO_2	104.45	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	N_2O	0.75	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction - Liquid	N_2O	0.26	5.00	5.00	7.07
1.A.2 - Manufacturing Industries and Construction - Liquid	CH_4	0.09	5.00	5.00	7.07

2006 IPCC Categories	Gas	Year T emissions or removals (Gg CO_2 eq)	AD Uncertainty (%)	EF Uncertainty (%)	Combined Uncertainty (%)
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CH_4	0.03	5.00	5.00	7.07
1.A.3.d.ii - Domestic Water-borne Navigation - Liquid Fuels	CO_2	0.64	5.00	4.30	6.60
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CO_2	29.88	5.00	4.17	6.51
1.A.3.b - Road Transportation - Liquid Fuels	CO_2	616.96	5.00	3.07	5.87
1.B.1.a.i.1 – Mining	CO_2	2.14	0.00	0.00	0.00
1.B.1.a.i.1 – Mining	CH_4	16.46	0.00	0.00	0.00
3.A.1.a.i - Dairy Cows	CH_4	87.28	0.00	0.00	0.00
3.A.1.a.ii - Other Cattle	CH_4	668.84	0.00	0.00	0.00
3.A.1.c – Sheep	CH_4	31.72	0.00	0.00	0.00
3.A.1.d – Goats	CH_4	408.86	0.00	0.00	0.00
3.A.1.h – Swine	CH_4	49.86	0.00	0.00	0.00
3.A.2.a.i - Dairy cows	N_2O	5.17	0.00	0.00	0.00
3.A.2.a.ii - Other cattle	N_2O	199.10	0.00	0.00	0.00
3.A.2.a.i - Dairy cows	CH_4	0.89	0.00	0.00	0.00
3.A.2.a.ii - Other cattle	CH_4	21.58	0.00	0.00	0.00
3.A.2.c – Sheep	CH_4	1.27	0.00	0.00	0.00
3.A.2.d – Goats	CH_4	35.45	0.00	0.00	0.00
3.A.2.h – Swine	CH_4	49.86	0.00	0.00	0.00
3.B.1.a - Forest land Remaining Forest land	CO_2	-2498.48	0.00	0.00	0.00
3.B.1.b.i - Cropland converted to Forest Land	CO_2	-106.45	0.00	0.00	0.00
3.B.1.b.ii - Grassland converted to Forest Land	CO_2	-9.30	0.00	0.00	0.00
3.B.1.b.iii - Wetlands converted to Forest Land	CO_2	-12.70	0.00	0.00	0.00
3.B.2.b.i - Forest Land converted to Cropland	CO_2	1589.38	0.00	0.00	0.00
3.B.2.b.iii - Wetlands converted to Cropland	CO_2	0.01	0.00	0.00	0.00
3.B.3.b.i - Forest Land converted to Grassland	CO_2	261.89	0.00	0.00	0.00
3.B.5.b.i - Forest Land converted to Settlements	CO_2	24.78	0.00	0.00	0.00
3.B.6.b.i - Forest Land converted to Other Land	CO_2	188.29	0.00	0.00	0.00
3.C.1.a - Biomass burning in forest lands	CH_4	27.15	0.00	0.00	0.00
3.C.1.b - Biomass burning in croplands	CH_4	0.18	0.00	0.00	0.00
3.C.1.c - Biomass burning in grasslands	CH_4	3.95	0.00	0.00	0.00
3.C.3 - Urea application	CO_2	88.71	0.00	0.00	0.00
3.C.5 - Indirect N2O Emissions from managed soils	N_2O	0.20	0.00	0.00	0.00
3.C.6 - Indirect N2O Emissions from manure management	N_2O	9.69	0.00	0.00	0.00
3.C.7 - Rice cultivations	CH_4	122.40	0.00	0.00	0.00
3.D.1 - Harvested Wood Products	CO_2	-45.58	0.00	0.00	0.00
4.A - Solid Waste Disposal	CH_4	423.42	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	CO_2	9.13	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	CH_4	80.28	0.00	0.00	0.00
4.C.2 - Open Burning of Waste	N_2O	15.59	0.00	0.00	0.00
4.D.1 - Domestic Wastewater Treatment and Discharge	CH_4	299.47	0.00	0.00	0.00
4.D.1 - Domestic Wastewater Treatment and Discharge	N_2O	176.18	0.00	0.00	0.00

2.1.9 Inventory management system

The EAD has responsibility for the inventory. A number of relevant agencies and organizations were involved in providing data. Focal persons were appointed in the key institutions. Key public institutions and companies that prided data provision included the National Statistical Office (NSO), Department of Mines, Department of Economic Planning and Development, Ministry of Commerce, Trade and Industry, Shayona Cement Limited. AFOLU: Activity data was collected from public and private sector organizations.

Sector focal points have been place at EAD to collect and archive data from data providers for a continuous process of data management and archiving.

2.1.10 Key institutions and their roles

Table 2.8 presents the key institutions that were involved in the BUR.

Table 2. 8 Key institutions and their roles

Institution	**Role(s)**
Environment Affairs Department	Overall responsibility for inventory
Department of Energy Affairs	Data provider-Energy
Malawi Energy Regulatory Authority	Data provider-Energy
National Statistical Office	Data provider-All sectors
Department of Mines	Data provider-Energy
Department of Economic Planning and Development	Data provider -All sectors
Ministry of Commerce, Trade and Industry	Data provider-IPPU
Shayona Cement Limited	Data provider-IPPU
Department of Mines	Data provider-Energy
Malawi Revenue Authority	Data provider -All sectors
Ministry of Agriculture	Data provider-AFOLU
Irrigation and Water Development	Data provider AFOLU
Irrigation and Water Development (MAI&WD).	Data provider AFOLU
Department of Animal Health and Livestock Development (DAHLD)	Data provider AFOLU
and Agricultural Development Divisions (ADDs).	Data provider AFOLU
Famine Early Warning System (FEWSNET)	Data provider AFOLU
Agriculture Organization Databank	Data provider AFOLU
Karonga town Council	Data provider-Waste
Mzuzu City Council	Data provider-Waste
Kasungu town Council,	Data provider Waste
Central Region: Lilongwe City Council,	Data provider Waste
Salima town/district Council,	Data provider Waste
Dedza town Council	Data provider Waste
Blantyre City Council,	Data provider Waste
Zomba City Council,	Data provider Waste
Mulanje town Council	Data provider Waste
Mangochi town Council	Data provider Waste
Balaka	Data provider Waste
Machinga town Council.	Data provider Waste

2.1.11 Data management and archiving

EAD will establish and document the process for making the inventory a continuous process. Arrangements will be put in place between the inventory compilers and data providers. The arrangements may be legal instruments, Memorandum of Understanding (MoUs), or any formal arrangements, as applicable. EAD will also document and archive all information relating to the planning, preparation, QA\QC and management of inventory activities. The GHG Inventory management system has been put in place and its main objective is to collect and archive data on a continuous basis.

2.1.12 Inventory improvement plan

Table 2.9 presents the planned improvements.

Table 2. 9 Improvement plan

Identified gap	Planned improvement	Status
The type of arrangements established between data providers and inventory compilers or the role of involved institutions were not described.	Include a description of the arrangements and institutions involved in the inventory process	EAD to establish and document the process for making the inventory a continuous process. Arrangements have been put in place between the inventory compilers and data providers. The arrangements will be legal instruments, MoUs, or any formal arrangements, as applicable. MOUs yet to be signed between EAD and the inventory compilers.
The processes for archiving the data and outputs of the inventory processes, for instance, inventory planning, preparation, and management of inventory activities and QC activities, were not reported.	Document and archive all information relating to the planning, preparation, QA\QC and management of inventory activities.	The GHG Inventory management system has been put in place and its main objective is to collect and archive data on a continuous basis.
Malawi Energy sector is dominated by biomass (85.6%), but non-CO_2 emissions from biomass were not estimated.	Estimate CO_2 emissions, but should not be included in national CO_2 emissions from fuel combustion. Include other GHG emissions from biomass fuel should be included in the national total.	This will be rectified in the Fourth National Communication.

2.1.13 Summary Information table of Inventories previously submitted

Table 2. 10 Summary Report of National Greenhouse Gas Inventories for 1994 (Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_X	CO
Total National Emissions and Removals	**19247.28**	**-1016.00**	**187.90**	**7.77**	**26.31**	**951.80**
1. Energy - Sectoral Approach (Not done)						
- Reference Approach (Below)	**660.88**	**0.00**	**135.09**	**0.71**	**24.03**	**879.58**
2. Industrial Processes	**58.38**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
3. Agriculture	**0.00**	**0.00**	**48.50**	**7.05**	**2.24**	**72.20**
4. Land Use Change and Forestry	**18528.02**	**-1016.00**	**0.02**	**0.01**	**0.04**	**0.02**

5. Waste	**0.00**	**0.00**	**4.29**	**0.00**	**0.00**	**0.00**

Table 2. 11 Total emissions in terms of carbon dioxide equivalent for the period 1995 to 2000**.**

	1995	1996	1997	1998	1999	2000
1 Energy Sector						
1A Fuel combustion activities	742.88	752.41	807.69	843.27	781.83	726.13
1B Fugitive emissions from fuels	0.57	0.57	1.02	0.95	0.58	0.68
1C Carbon dioxide transport and storage	NA	NA	NA	NA	NA	NA
2 Industrial Processes and Product Use (IPPU)						
2A Mineral Industry	59.53	46.59	37.93	48.04	57.30	59.18
2B Chemical industry	NA	NA	NA	NA	NA	NA
2C Metal Industry	NA	NA	NA	NA	NA	NA
2D Non-energy products from fuels and solvent use	0.07	0.16	0.73	0.31	0.42	0.50
2E Electronics industry	NA	NA	NA	NA	NA	NA
2F Product uses as substitutes of ODS	NE	NE	NE	NE	NE	NE
2G Other product manufacture and use	NA	NA	NA	NA	NA	NA
2H Other (Please specify)	NA	NA	NA	NA	NA	NA
3 Agriculture, Forestry and other land use						
3A Livestock	747.30	730.69	664.63	762.31	740.90	810.75
3B Land	17800.00	18089.00	18377.00	18666.00	18954.00	19243.00
3C Aggregate sources and non-CO2 emissions sources on land	2459.669	2406.592	2514.025	2195.056	2174.688	2280.547
3D Other	NE	NE	NE	NE	NE	NE
4 Waste						

4A Solid waste disposal	150.20	156.59	163.08	169.84	176.65	184.57
4B Biological treatment of solid waste	NE	NE	NE	NE	NE	NE
4C Incineration and open burning of waste	83.60	87.32	91.36	94.97	99.36	105.90
4D Waste water treatment and discharge	14.79	15.44	16.07	16.80	17.50	18.29
4E Other (please specify)	NE	NE	NE	NE	NE	NE
Overall Total Emissions	23108.80	23342.38	23840.55	23776.20	23559.389	23294.50

Table 2. 12 Summary of GHG Emissions in units of mass for 2010

Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO	NOx	NMVOCs	SOx
Total National Emissions and	468.71	1.61	1.61							
1 - Energy	939.02	0.30	0.30				NA	NA	NA	NA
1.A - Fuel Combustion	936.58	0.30	0.30				NA	NA	NA	NA
1.A.1 - Energy Industries	3.12	0.10	0.10				NA	NA	NA	NA
1.A.2 - Manufacturing Industries and Construction	258.50	0.122	1				NA	NA	NA	NA
1.A.3 - Transport	647.47	0.13	0.03				NA	NA	NA	NA
1.A.4 - Other Sectors	27.49	14.13	0.16							
1.A.5 - Non-Specified	NO	NO	NO							
1.B - Fugitive emissions from										
1.B.1 - Solid Fuels	NE	9.97	NE							
1.B.2 - Oil and Natural Gas	NO	NO	NO				NO	NO	NO	NO
1.B.3 - Other emissions from	NO	NO	NO				NO	NO	NO	NO
1.C - Carbon dioxide										
1.C.1 - Transport of CO2	NO			NO	NO	NO	NO	NO	NO	NO
1.C.2 - Injection and Storage	NO		NO	NO	NO	NO	NO	NO	NO	NO
1.C.3 - Other										
2 - Industrial Processes and	40.01	NE	NE							
2.A - Mineral Industry	40.01	NE								
2.A.1 - Cement production	16.07	NE								
2.A.2 - Lime production	23.84	NE								
2.A.3 - Glass Production	NO	NO								
2.A.4 - Other Process Uses of	0.10	NO								
2.A.5 - Other (please specify)	NA	NA								
2.B - Chemical Industry	NO	NO	NO	NA	NA	NA				
2.C - Metal Industry	NO	NO	NO	NA	NA	NA				
2.D - Non-Energy Products from Fuels and Solvent Use	NO	NO	NO				NO	NO	NO	NO
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F - Product Uses as Substitutes for Ozone	NE		NE	NE	NE	NE				

Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO	NOx	NMVOCs	SOx
2.G - Other Product	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.H - Other	NA	NA	NA							
3 - Agriculture, Forestry, and	-519.45	71.87	0.69				NA	NA	NA	NA
3.A - Livestock		64.55	0.66				NA	NA	NA	NA
3.B - Land	-562.58	NE	NE				NA	NA	NA	NA
3.C - Aggregate sources and non-CO2 emissions sources	88.71	7.32	0.03				NA	NA	NA	NA
3.D - Other	-45.58						NA	NA	NA	NA
4 - Waste	9.13	38.25	0.62				NA	NA	NA	NA
4.A - Solid Waste Disposal		20.16	NE				NA	NA	NA	NA
4.B - Biological Treatment of		NE	NE				NA	NA	NA	NA
4.C - Incineration and Open	9.13	3.82	0.05				NA	NA	NA	NA
4.D - Wastewater Treatment		14.26	0.57				NA	NA	NA	NA
4.E - Other (please specify)	NA	NA	NA				NA	NA	NA	NA
5 - Other	NA	NA	NA				NA	NA	NA	NA

2.1.8 Overall emissions trend by sector and gas

Table 2. 13 Overall emissions by gas

Year	**1994**	**2000**	**2010**	**2017**	Percentage change between 1994 and 2017[d]
Gas ($GgCO_2eq$)					
CO_2	18231.28	-921.26	468.71	3271.65	-82.05%
CH_4	3945.9	17.25	2,644.47	3342.5	-15.29%
N_2O	2405.6	16.26	500.35	428.58	-82.18%
HFCs					
PFCs					
SF_6					
Total	24582.78	-887.75	3,613.53	7042.72	-71.35%

Table 2. 14 GHG Emissions and removals by year and sector

Year	1994	2000	2010	2017	Percentage change between 1994 and 2017[d]
Sectors (CO_2eq)					
Energy	3717.87	1683.82	1,364.44	1740.37	-53.19%
Industrial Processes and Product Use	**50.12**	55.23	40.1	80.58	60.77%
Agriculture, forestry and other land use	20716.44	-2626.8	1205.02	4546.7	-78.05%
Waste			1,004.06	675.07	
Total	24582.78	-887.75	3,613.53	7,042.72	

2.2 Energy sector

2.2.1 Introduction

Malawi has undertaken two GHG inventories of emissions by sources in the Energy sector. Both inventories used Reference Approach (top-down) method, following the revised 1996 IPCC Guidelines for conducting GHG inventory, due to unavailability of key activity data. The two inventories covered CO_2, CH_4, N_2O, nitrogen oxide (NO_X) and CO. Emissions from fuel combustion in the sub-categories of mobile (using petroleum) and stationary (using coal) were estimated. The 2006 IPCC Guidelines were used in the BUR.

The Inventory for the Energy sector of Malawi covers the period from 2001 to 2017. The gases covered are direct GHGs in the sector, namely: CO_2, CH_4 and N_2O. Table 2.8 shows the GHGs emitted in the Energy sector in 2010.

Table 2. 15 GHGs (Gg) emitted from the Energy sector in 2010

Categories	CO_2	CH_4	N_2O
1 - Energy	939.02	20.79	0.37
1.A - Fuel Combustion Activities	936.58	20.01	0.37
1.A.1 - Energy Industries	3.12	0.76	0.10
1.A.1.a - Main Activity Electricity and Heat Production	3.12	0.00	0.00
1.A.1.a.i - Electricity Generation	3.12	0.00	0.00
1.A.1.a.ii - Combined Heat and Power Generation (CHP)			
1.A.1.a.iii - Heat Plants			
1.A.1.b - Petroleum Refining			
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries		0.76	0.10
1.A.1.c.i - Manufacture of Solid Fuels		0.76	0.10
1.A.1.c.ii - Other Energy Industries			
1.A.2 - Manufacturing Industries and Construction	258.50	0.01	0.00
1.A.3 - Transport	647.47	0.13	0.03
1.A.3.a - Civil Aviation	29.88	0.00	0.00
1.A.3.a.i - International Aviation (International Bunkers) (1)			
1.A.3.a.ii - Domestic Aviation	29.88	0.00	0.00
1.A.3.b - Road Transportation	616.96	0.13	0.03
1.A.3.b.i - Cars			
1.A.3.b.i.1 - Passenger cars with 3-way catalysts			
1.A.3.b.i.2 - Passenger cars without 3-way catalysts			
1.A.3.b.ii - Light-duty trucks			
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts			
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts			
1.A.3.b.iii - Heavy-duty trucks and buses			
1.A.3.b.iv - Motorcycles			
1.A.3.b.v - Evaporative emissions from vehicles			
1.A.3.b.vi - Urea-based catalysts	0.00		
1.A.3.c - Railways	0.00	0.00	0.00
1.A.3.d - Water-borne Navigation	0.64	0.00	0.00
1.A.3.d.i - International water-borne navigation (International bunkers) (1)			
1.A.3.d.ii - Domestic Water-borne Navigation	0.64	0.00	0.00
1.A.3.e - Other Transportation			

Categories	CO_2	CH_4	N_2O
1.A.3.e.i - Pipeline Transport			
1.A.3.e.ii - Off-road			
1.A.4 - Other Sectors	27.49	19.11	0.23
1.A.4.a - Commercial/Institutional			
1.A.4.b - Residential	27.49	19.11	0.23
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	0.00	0.00	0.00
1.A.4.c.i - Stationary	0.00	0.00	0.00
1.A.4.c.ii - Off-road Vehicles and Other Machinery			
1.A.4.c.iii - Fishing (mobile combustion)			
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	2.44	0.78	
1.B.1 - Solid Fuels	2.44	0.78	
1.B.1.a - Coal mining and handling	2.44	0.78	
1.B.1.a.i - Underground mines	2.44	0.78	
1.B.1.a.i.1 - Mining	2.14	0.78	
1.B.1.a.i.2 - Post-mining seam gas emissions	0.30	0.00	
1.B.1.a.i.3 - Abandoned underground mines			
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2	0.00	0.00	
1.B.1.a.ii - Surface mines	0.00	0.00	
1.B.1.a.ii.1 - Mining	0.00	0.00	
1.B.1.a.ii.2 - Post-mining seam gas emissions	0.00	0.00	
1.B.1.b - Uncontrolled combustion and burning coal dumps			
1.B.1.c - Solid fuel transformation			
1.B.2 - Oil and Natural Gas	NO		
1.B.3 - Other emissions from Energy Production			
1.C - Carbon dioxide Transport and Storage	NO		
1.C.3 - Other	0.00		
Memo Items (3)			
International Bunkers			
1.A.3.a.i - International Aviation (International Bunkers) (1)			
1.A.3.d.i - International water-borne navigation (International bunkers) (1)			
1.A.5.c - Multilateral Operations (1)(2)			
Information Items			
CO_2 from Biomass Combustion for Energy Production	10518.339		

In terms of share of energy emissions by type of GHG, CO_2 dominates the energy emissions, contributing a total of 939.02Gg in 2010 with 647.47Gg coming from Transport -1A3. The largest amount of CH_4 emissions were from Other Sectors-1A4, accounting for 19.11Gg. Other Sectors-1A4 also contributed the largest amount of N_2O amounting to 0.23Gg.

The GHGs emitted from the Energy sector in units of CO_2eq in 2010 are presented in Table 2.9. The total emissions were 1,489.65GgCO_2eq, with Road Transport 1A3b contributing 42.24%, followed by 1.A.4.b - Residential with 33.59% and the Manufacturing Industry and Construction (1.A.2) with 17.43%. The bulk of the emissions (98.73%) in 2010 from the sector came from 1.A - Fuel Combustion Activities.

Table 2. 16 GHG (CO_2eq) emissions from Energy in 2010

	Emissions (Gg)				% contribution
Categories	**CO_2**	**CH_4**	**N_2O**	**Total (CO_2eq)**	
1 - Energy	939.02	436.63	113.99	1,489.65	100.00%
1.A - Fuel Combustion Activities	936.58	420.17	113.99	1,470.74	98.73%
1.A.1 - Energy Industries	3.12	16.02	31.53	50.67	3.40%
1.A.1.a - Main Activity Electricity and Heat Production	3.12	0.00	0.01	3.13	0.21%
1.A.1.a.i - Electricity Generation	3.12	0.00	0.01	3.13	0.21%
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	0.00	16.01	31.52	47.53	3.19%
1.A.1.c.i - Manufacture of Solid Fuels	0.00	16.01	31.52	47.53	3.19%
1.A.2 - Manufacturing Industries and Construction	258.50	0.12	1.00	259.62	17.43%
1.A.3 - Transport	647.47	2.72	9.87	660.07	44.31%
1.A.3.a - Civil Aviation	29.88	0.00	0.26	30.14	2.02%
1.A.3.a.ii - Domestic Aviation	29.88	0.00	0.26	30.14	2.02%
1.A.3.b - Road Transportation	616.96	2.72	9.61	629.28	42.24%
1.A.3.c - Railways	0.00	0.00	0.00	0.00	0.00%
1.A.3.d - Water-borne Navigation	0.64	0.00	0.01	0.64	0.04%
1.A.3.d.ii - Domestic Water-borne Navigation	0.64	0.00	0.01	0.64	0.04%
1.A.4 - Other Sectors	27.49	401.31	71.59	500.39	33.59%
1.A.4.b - Residential	27.49	401.31	71.59	500.39	33.59%
1.A.5 - Non-Specified	0.00	0.00	0.00	0.00	0.00%
1.B - Fugitive emissions from fuels	2.44	16.46	0.00	18.90	1.27%
1.B.1 - Solid Fuels	2.44	16.46	0.00	18.90	1.27%
1.B.1.a - Coal mining and handling	2.44	16.46	0.00	18.90	1.27%
1.B.1.a.i - Underground mines	2.44	16.46	0.00	18.90	1.27%
1.B.1.a.i.1 - Mining	2.14	16.46	0.00	18.60	1.25%
1.B.1.a.i.2 - Post-mining seam gas emissions	0.30	0.00	0.00	0.30	0.02%
1.B.2 - Oil and Natural Gas	NO				
1.B.3 - Other emissions from Energy Production					
1.C - Carbon dioxide Transport and Storage	NO				
1.C.1 - Transport of CO_2	NO				
1.C.2 - Injection and Storage	NO				
1.C.3 - Other					

The residential (subcategory 1.A.4.b) contributed a significant 92% of the 20.79Gg of CH_4 emitted in 2010. This was followed by the Manufacture of Solid Fuels (1.A.1.c.i) with 3.67% (Table 2.2). Even though the manufacturing industry and construction has relatively high consumption of diesel and coal, the CH_4 emissions are lower than the residential category. This is so because, according to the 2006 IPCC Inventory Guidelines, the residential category is associated with high emission factors: paraffin in the residential category has a higher emission factor of 10 kg CH_4/TJ compared to 3 and 1 kg CH_4/TJ for diesel and sub-bituminous coal, respectively, in the manufacturing industry and construction category.

The total GHG emissions in the Energy sector is dominated by CO_2 (63.04%), the rest being CH_4 and N_2O. This is because; most of the sources of GHG are from fossil fuel combustion, whose main gaseous product is CO_2. Total GHG from the Energy sector from 2001 to 2017 are presented in figure 2.1.

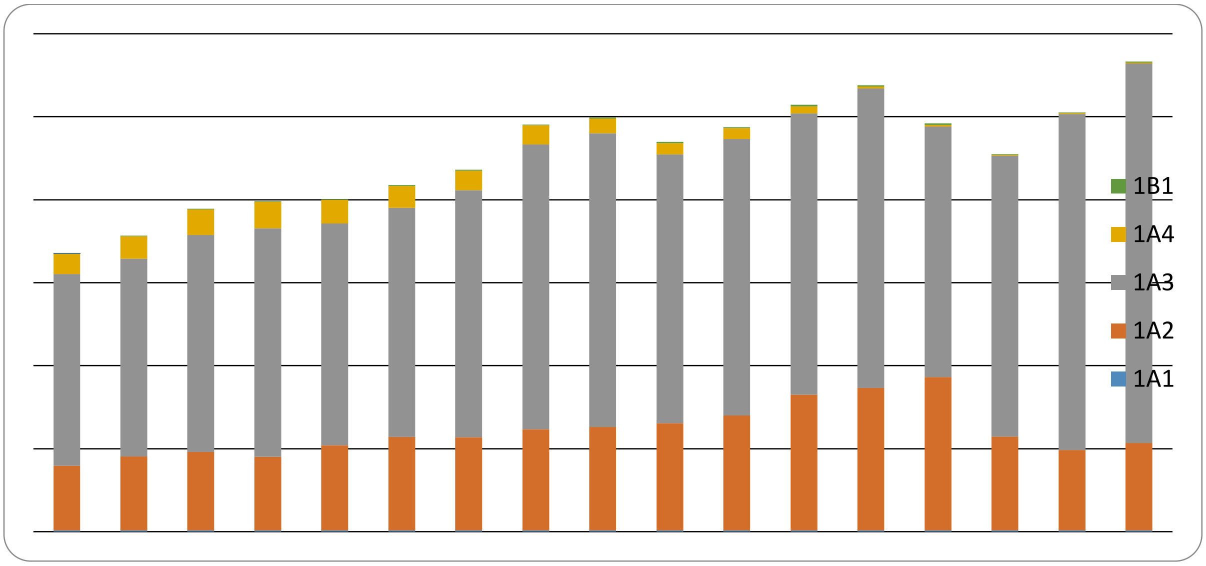


Figure 2. 1 Trends of CO_2 emissions from Energy Sector from year 2001 to 2017

The trend shows a general increase in the GHGs from the Energy sector over the period 2001 to 2017. The total emissions increased from 669.61 to 1,130.77 Gg of CO_2, from the year 2001 to 2017, respectively. From SNC, the total emission in 2000 was 726 Gg of CO_2eq. The SNC reported for biomass emissions in the Energy sector. However, to avoid double counting, emissions from biomass are reported in the AFOLU in the TNC, as dictated by the IPCC Guidelines for conducting national GHG inventory (IPCC, 2006).

2.2.1.1 Key Category Analysis

Key category analysis was done using the IPCC Inventory Software version 2.54. Tables 2.17 and 2.18 show the results based on level assessment and trend assessment, respectively.

Table 2. 17 Energy sector Key Category Analysis results based on level assessment

IPCC Category code	IPCC Category	GHG	"|Ex,t| (Gg CO_2 eq)"	Lx,t (%)	Cumulative (%)
1.A.3.b	**Road Transportation**	**CO_2**	**616.96**	**41.42**	**41.42**
1.A.4	**Other Sectors - Biomass**	**CH_4**	**401.23**	**26.93**	**68.35**
1.A.2	**Manufacturing Industries and Construction - Solid**	**CO_2**	**154.05**	**10.34**	**78.69**
1.A.2	**Manufacturing Industries and Construction - Liquid**	**CO_2**	**104.45**	**7.01**	**85.70**
1.A.4	**Other Sectors - Biomass**	**N_2O**	**71.52**	**4.80**	**90.50**
1.A.1	**Energy Industries - Biomass**	**N_2O**	**31.52**	**2.12**	**92.62**
1.A.3.a	**Civil Aviation**	**CO_2**	**29.88**	**2.01**	**94.63**
1.A.4	**Other Sectors - Liquid Fuels**	**CO_2**	**27.49**	**1.85**	**96.47**
1.B.1	Solid Fuels	CH_4	16.46	1.11	97.58
1.A.1	Energy Industries - Biomass	CH_4	16.01	1.08	98.65
1.A.3.b	Road Transportation	N_2O	9.61	0.64	99.30

IPCC Category code	IPCC Category	GHG	"|Ex,t| (Gg CO_2 eq)"	Lx,t (%)	Cumulative (%)
1.A.1	Energy Industries - Liquid Fuels	CO_2	3.12	0.21	99.51
1.A.3.b	Road Transportation	CH_4	2.72	0.18	99.69
1.B.1	Solid Fuels	CO_2	2.44	0.16	99.85
1.A.2	Manufacturing Industries and Construction - Solid Fuels	N_2O	0.75	0.05	99.90
1.A.3.d	Water-borne Navigation - Liquid Fuels	CO_2	0.64	0.04	99.95
1.A.3.a	Civil Aviation	N_2O	0.26	0.02	99.96
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.26	0.02%	99.98%
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.09	0.01%	99.99%
1.A.4	Other Sectors - Liquid Fuels	CH_4	0.08	0.01%	99.99%
1.A.4	Other Sectors - Liquid Fuels	N_2O	0.07	0.00	100.00
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CH_4	0.03	0.00	100.00
1.A.1	Energy Industries - Liquid Fuels	N_2O	0.01	0.00	100.00
1.A.3.d	Water-borne Navigation - Liquid Fuels	N_2O	0.01	0.00	100.00
1.A.3.a	Civil Aviation	CH_4	0.00	0.00	100.00
1.A.1	Energy Industries - Liquid Fuels	CH_4	0.00	0.00	100.00
1.A.3.d	Water-borne Navigation - Liquid Fuels	CH_4	0.00	0.00	100.00

The identified key categories are:

i. 1.A.3.b Road Transportation
ii. 1.A.4 Other Sectors - Biomass
iii. 1.A.2 Manufacturing Industries and Construction - Solid Fuels
iv. 1.A.2 Manufacturing Industries and Construction - Liquid Fuels
v. 1.A.4 Other Sectors - Biomass
vi. 1.A.1 Energy Industries - Biomass
vii. 1.A.3.a Civil Aviation
viii. 1.A.4 Other Sectors - Liquid Fuels

Table 2. 18 Energy sector Key Category Analysis results based on trend assessment

IPCC Category code	IPCC Category	Greenhouse gas	1990 Year Estimate Ex0 (Gg CO_2 eq)	2010 Year Estimate Ext (Gg CO_2 eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
1.A.1	Energy Industries - Liquid Fuels	CO_2	0	3.12	0	0	0
1.A.1	Energy Industries - Liquid Fuels	CH_4	0	0.00	0	0	0
1.A.1	Energy Industries - Liquid Fuels	N_2O	0	0.01	0	0	0
1.A.1	Energy Industries – Biomass	CH_4	0	16.01	0	0	0
1.A.1	Energy Industries – Biomass	N_2O	0	31.52	0	0	0
1.A.2	Manufacturing Industries and Construction - Liquid	CO_2	0	104.45	0	0	0
1.A.2	Manufacturing Industries and Construction - Liquid	CH_4	0	0.09	0	0	0
1.A.2	Manufacturing Industries and Construction - Liquid	N_2O	0	0.26	0	0	0
1.A.2	Manufacturing Industries and Construction - Solid	CO_2	0	154.05	0	0	0
1.A.2	Manufacturing Industries and Construction - Solid	CH_4	0	0.03	0	0	0
1.A.2	Manufacturing Industries and Construction - Solid Fuels	N_2O	0	0.75	0	0	0
1.A.3.a	Civil Aviation	CO_2	0	29.88	0	0	0
1.A.3.a	Civil Aviation	CH_4	0	0.00	0	0	0
1.A.3.a	Civil Aviation	N_2O	0	0.26	0	0	0
1.A.3.b	Road Transportation	CO_2	0	616.96	0	0	0
1.A.3.b	Road Transportation	CH_4	0	2.72	0	0	0
1.A.3.b	Road Transportation	N_2O	0	9.61	0	0	0
1.A.3.d	Water-borne Navigation - Liquid Fuels	CO_2	0	0.64	0	0	0
1.A.3.d	Water-borne Navigation - Liquid Fuels	CH_4	0	0.00	0	0	0
1.A.3.d	Water-borne Navigation - Liquid Fuels	N_2O	0	0.01	0	0	0
1.A.4	Other Sectors - Liquid Fuels	CO_2	0	27.49	0	0	0
1.A.4	Other Sectors - Liquid Fuels	CH_4	0	0.08	0	0	0
1.A.4	Other Sectors - Liquid Fuels	N_2O	0	0.07	0	0	0
1.A.4	Other Sectors – Biomass	CH_4	0	401.23	0	0	0
1.A.4	Other Sectors – Biomass	N_2O	0	71.52	0	0	0
1.B.1	Solid Fuels	CO_2	0	2.44	0	0	0
1.B.1	Solid Fuels	CH_4	0	16.46	0	0	0

2.2.2 Energy sector GHG methodology

In this NIR, the development of GHG inventory in the Energy sector has involved several steps. The first step involved stakeholder consultations, where among others, previous national experts for the INC and SCN projects, officials from EAD and Department of Energy Affairs (DEA) were consulted. The second step involved reviewing relevant literature including INC, SNC, the 2006 IPCC GHG guidelines and other related reports and publications.

A questionnaire was used as a tool to collect the activity data. The process of developing the questionnaire was informed from the review of the 2006 IPCC GHG Inventory Software under the Energy Sector and the 2006 IPCC GHG Guidelines, as well as expert judgment of the sectoral experts. In order to make sure that the questionnaire was efficient, it underwent a review by experts, which were identified by the EAD. The respondents were purposefully selected from organizations engaged in activities that emit GHG from the Energy sector in Malawi. These organizations were identified through desk study, consultations and Energy sector inventory compilers' knowledge on the Malawi's energy sector. The activity data from the organisations was then arranged according to the societal and economic activity in the Energy sector.

The GHG inventory in the Energy sector employed the sectoral approach, using the Tier 1 IPCC methodology. Tier 1 methodology was chosen due to absence of country specific emission factors. The availability of information on how energy is used at sector level of the Malawian economy informed the choice of using the sectoral approach. Under the Tier 1 approach, emissions are estimated based on amount of fuel combusted and the average emission factors.

2.2.2.1 Emission factors used in the Energy Sector GHG Inventory -

The emission factors that were used to estimate GHG emissions from stationary and mobile combustion activities are presented in Table 2.5. The emission factor for coal from the category of fugitive emissions under the sub-category of surface mines was 1.2 m^3/tonne for mining and 0.1m^3/tonne for post-mining (IPCC, 2007).

Table 2. 19: Emission factors used in estimations of GHG emissions in the Energy sector

Category	Subcategory	Fuel	Emission factor (kg CO_2 eq/TJ)		
			CO_2	CH_4	NO_2
Energy Industry	Electricity generation	Diesel	74,100	3	0.6
Manufacturing Industries and Construction		Diesel	74,100	3	0.6
		Sub-bituminous coal	96,100	1	1.5
		Natural gas (LPG)	56,100	1	0.1
Transport	Civil aviation	Jet kerosene (Jet a1)	71,500	0.5	2
		Aviation gas (Avgas)	70,000	0.5	2
	Road transport	Motor gasoline (Petrol)	69,300	33	3.2
		Gas/Diesel oil	74,100	3.9	3.9
	Water-borne navigation	Gas/Diesel oil	74,100	7	2
Other Sector	Residential	Other kerosene	71900	10	0.6

Source: Default emission factors from (IPCC, 2007)

2.2.2.2 Processing of data to be used in the 2006 IPCC GHG Inventory Software

Raw data from characterisation of emission sources, for the 2001 to 2017 reporting period, was processed manually to make it compatible with the 2006 IPCC GHG Inventory Software version 2.54.

2.2.2.3 Malawi energy mix

The Malawi Energy sector is dominated by biomass, which is sourced unsustainably from forest and used as fuel in form of charcoal and firewood (GoM, 2016). The energy mix for Malawi in 2015 is compared with that of the sub-Saharan Africa (SSA) region in 2012 in Table 2.2. The table shows that Malawi depended more (86%) on biomass in 2015 than the region (61%) in 2012. The country's supply of commercial forms of energy (coal, oil and gas) is below the SSA average, which indirectly indicates lower levels of development compared to average development level for SSA. Unsustainable biomass energy supply reduces forest cover, thus reducing the amount of CO_2 removal (carbon sink). Apart from lowering the capacity for carbon sink, reduction of forest cover exposes the land to degradation from floods and accelerated soil erosion. This reduces the climate change adaptive capacity for Malawi.

Table 2. 20 Comparison between energy mixes for Malawi and sub-Saharan Africa

	Oil	Gas	Coal	Biomass	Hydro	Nuclear	Other	Total demand
SSA	15%	4%	18%	61%	1%			750MToE
Malawi	9.7%	0.01%	0.18%	85.6%	2.3%	-	2.2%	4170 kToE

Sources: GoM, 2016, OECD/IEA, 2014).

The energy demand for Malawi and its projection for industry, transportation, household and service sectors are given in Table 2.21, whilst Figure 2.5 shows the projected electricity demand for period of 2015 to 2030. From Table 2.21, the household sector dominates energy demands, which is mostly for provision of cooking and heating.

Table 2. 21 Energy demand and its projection for Malawi

Sector	Energy Demand Mix (kTOE)					
	2008	**2015**	**2020**	**2025**	**2030**	**2035**
Industry	343.94	386.93	601.89	859.85	1,289.77	1,526.23
Transportation	214.96	343.94	429.92	601.89	773.86	902.84
Household	3,439.38	3,353.40	3,181.43	3,095.44	2,837.49	2,708.51
Service	128.98	85.98	128.98	171.97	257.95	300.95
Total	**4,127.26**	**4,170.25**	**4,342.22**	**4,729.15**	**5,159.07**	**5,438.52**

Source: GoM, 2016

The electricity installed capacity for Malawi is at 351 MW between 2001 and 2009. Not all installed capacity is available, yet demand is over 450MW, as in the year 2016 (GoM, 2016). Almost all the installed electricity capacity comes from hydroelectric power stations. However, the power sector is being affected by impacts of Climate Change, in terms of reduction in flow and destruction of structures and equipment due to floods and siltation. As presented in Figure 2.5, the projected electricity demand is expected to increase steadily from nearly 450 MW in 2015 to nearly 1.6 GW by the year 2030 (GoM, 2010).

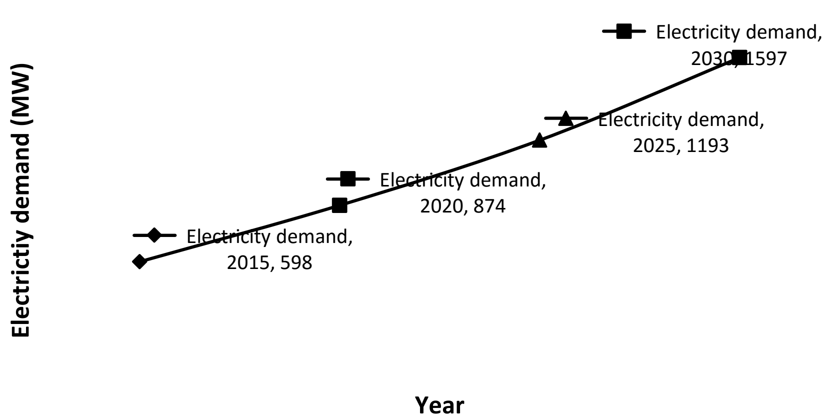


Figure 2. 2 Projection of electricity demand for Malawi (GoM, 2010)

The Government identified economic growth opportunities that would increase demand for energy and power as shown in Table 2.19 (Lapukeni, 2013).

Table 2. 22 Current electricity demand driver

Identified growth opportunity	Estimated power demand (MW)
Mining	800
Green Belt Irrigation Initiative	130
Service (ICT, Tourism, Banks, Hospital, Offices and Education)	500
Manufacturing	700
Domestic	700
Total	2830

Source: Status of energy demand in Malawi (Lapukeni, 2013)

Most of the sources of GHG emissions are from combustion activities that occur in energy generation, manufacturing industry and construction, transportation as well as in service categories. The other source categories include coal mining and handling.

2.2.3 GHG emissions by category

This section presents GHGs from the Energy sector by category

2.2.3.1 1.A.1 - Energy Industries

Table 2.23 presents the GHGs from Energy Industries. The emissions are dominated by CH_4 and N_2O from the manufacture of solid fuels.

Table 2. 23 GHGs from 1.A.1 - Energy Industries

Categories	CO_2	CH_4	N_2O	Total (CO_2eq)
1.A.1 - Energy Industries	**3.12**	**16.02**	**31.53**	**50.67**
1.A.1.a - Main Activity Electricity and Heat Production	3.12	0.00	0.01	3.13
1.A.1.a.i - Electricity Generation	3.12	0.00	0.01	3.13
1.A.1.a.ii - Combined Heat and Power Generation (CHP)	0.00	0.00	0.00	0.00
1.A.1.a.iii - Heat Plants	0.00	0.00	0.00	0.00
1.A.1.b - Petroleum Refining	0.00	0.00	0.00	0.00
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	0.00	16.01	31.52	47.53
1.A.1.c.i - Manufacture of Solid Fuels	0.00	16.01	31.52	47.53
1.A.1.c.ii - Other Energy Industries	0.00	0.00	0.00	0.00

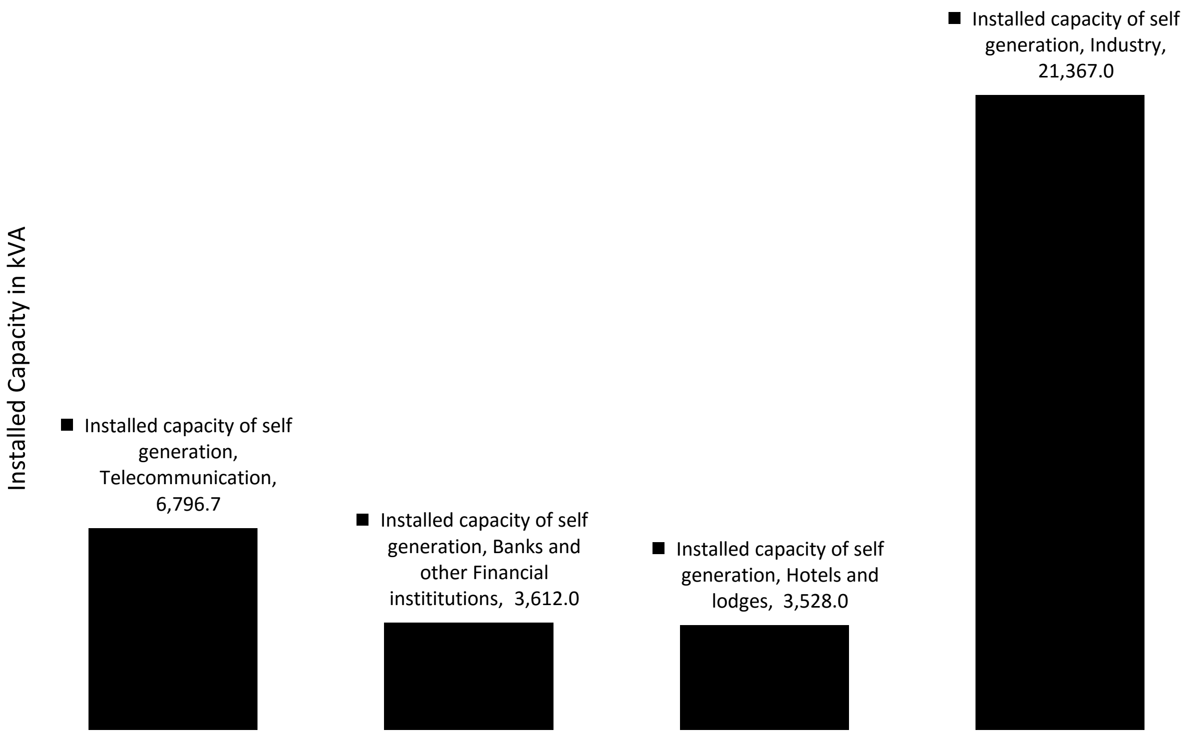


Figure 2. 3 Installed self-generation in Malawi from various sectors
Source: (MERA, 2017)

2.2.3.2 1.A.2 - Manufacturing Industries and Construction

The amount of energy used for generation of electricity for self-consumption, is accounted for in the category of Manufacturing, Industries and Construction. The amount of diesel, coal and LPG used in the generation of electricity for own consumption and for other energy consuming activities in the manufacturing, industry category (as used in the calculation of GHG emission in this category) is presented in Table 2.14. The amount of diesel used is obtained from that used to generate electricity for self-consumption and from that consumed in the manufacturing, industry and construction. Conversion of diesel consumed, from litre to TJ was done. It is assumed that all of coal and LPG are consumed in the Manufacturing, Industries and Construction category.

The 2006 IPCC Inventory Software does not have worksheets for the aggregated values of fuels for different sub-categories, under the Manufacturing, Industries and Construction. Thus, the software estimates the GHG emission from this category using a reference approach.

Table 2. 24: Fuel (TJ) used in the Manufacturing Industries and Construction category for self-generation of electricity and other energy uses

	Diesel Oil (TJ)	LPG (TJ)	Coal (TJ)
2001	22.94	0.47	848.54
2002	23.11	0.48	1069.54
2003	23.88	0.49	1159.91
2004	24.83	0.51	1008.36
2005	25.23	0.52	1279.09

2006	25.28	0.53	1489.64
2007	26.43	0.55	1443.82
2008	33.29	0.56	1417.36
2009	33.63	0.57	1459.87
2010	32.23	0.59	1603.02
2011	32.52	0.60	1782.89
2012	33.79	0.58	2266.46
2013	34.39	0.50	2416.64
2014	26.10	0.57	2959.15
2015	26.65	0.66	1449.34
2016	28.64	0.83	1039.28
2017	29.65	0.88	1176.66

Source: MERA, 2017

In terms of sectoral emissions, second to Transport sub-category is the Manufacturing Industry and Construction category. The emissions in the latter increased steadily from 163.6 Gg in 2001 to 261.3 Gg in 2009. However, there was a drop in 2004 (186 Gg from 197 Gg in 2003). This is due to closing of Changalume plant that manufactured clinker, which greatly reduced coal consumption. There was also a general decline in national economic activities during the year 2003 and 2004, which affected coal consumption in the manufacturing industry and construction category.

2.2.3.3 1.A.3 - Transport

The Malawi's transport system, carrying cargo and passengers within and outside of the country, comprises the following modes of transport: road, water, rail and air. The transport sub-category is the main consumer of petroleum in Malawi, and therefore, its significance in GHG emissions is recognised. GHG emissions from transport in 2010 are shown in Table 2.25.

Table 2. 25 GHG emissions from transport

Categories	CO_2	CH_4	N_2O	Total (CO_2eq)
1.A.3 - Transport	647.47	2.72	9.87	660.07
1.A.3.a - Civil Aviation	29.88	0.00	0.26	30.14
1.A.3.a.i - International Aviation (International Bunkers) (1)	0.00	0.00	0.00	0.00
1.A.3.a.ii - Domestic Aviation	29.88	0.00	0.26	30.14
1.A.3.b - Road Transportation	616.96	2.72	9.61	629.28
1.A.3.b.i - Cars	0.00	0.00	0.00	0.00
1.A.3.b.i.1 - Passenger cars with 3-way catalysts	0.00	0.00	0.00	0.00
1.A.3.b.i.2 - Passenger cars without 3-way catalysts	0.00	0.00	0.00	0.00
1.A.3.b.ii - Light-duty trucks	0.00	0.00	0.00	0.00
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts	0.00	0.00	0.00	0.00
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts	0.00	0.00	0.00	0.00
1.A.3.b.iii - Heavy-duty trucks and buses	0.00	0.00	0.00	0.00
1.A.3.b.iv - Motorcycles	0.00	0.00	0.00	0.00
1.A.3.b.v - Evaporative emissions from vehicles	0.00	0.00	0.00	0.00
1.A.3.b.vi - Urea-based catalysts	0.00	0.00	0.00	0.00
1.A.3.c - Railways	0.00	0.00	0.00	0.00
1.A.3.d - Water-borne Navigation	0.64	0.00	0.01	0.64
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	0.00	0.00	0.00	0.00
1.A.3.d.ii - Domestic Water-borne Navigation	0.64	0.00	0.01	0.64
1.A.3.e - Other Transportation	0.00	0.00	0.00	0.00
1.A.3.e.i - Pipeline Transport	0.00	0.00	0.00	0.00
1.A.3.e.ii - Off-road	0.00	0.00	0.00	0.00

2.2.3.3.1 . Civil Aviation -1 A 3 a

The air transport in Malawi is relatively small, with only two international airports: Kamuzu International Airport in the capital Lilongwe and Chileka International Airport in Blantyre city. Club Makokola Airport in Mangochi district, Mzuzu Airport and Karonga Airports rarely service small commercial flights. The rest of domestic airports,13 of them, are based at district level and sugar factories (Dwangwa and Nchalo) and are rarely used as well. Passenger air transport in the country mainly involves regional aircraft, namely Kenya Airways, Ethiopia Airlines, South Africa Airlines. The national carrier, Air Malawi is operating as Malawian Airlines. The following airlines are involved in freight transportation in Malawi: South African Airlines, Kenya Airlines, Emirates Airlines as well as specialised cargo carriers like DHL.

Amount of fuel (Jet a1 and Avgas) consumed in the civil aviation is presented in Table 2. 26 in litres and Gg and in Table 2.16 in TJ. These were converted from litres to Gg (1 litre of Jet a1 = 0.79 kg and (1 litre of Avgas = 0.72 kg).

Table 2. 26 Jet kerosene (Jet a1) and aviation gas (Av gas) used in civil aviation

	Jet kerosene (Jet a1)		aviation gas (Av gas)	
Year	Litres	Gg	Litres	Gg
2001	8,800,186	6.95	356,926	0.2570
2002	6,417,316	5.07	201,917	0.1454
2003	11,911,286	9.41	213,898	0.1540
2004	10,862,036	8.58	284,286	0.2047
2005	9,267,805	7.32	235,537	0.1696
2006	11,764,101	9.29	224,682	0.1618
2007	13,001,437	10.27	259,393	0.1868
2008	13,261,288	10.48	268,978	0.1937
2009	9,758,855	7.71	254,470	0.1832
2010	11,710,626	9.25	318,088	0.2290
2011	12,838,968	10.14	126,422	0.0910
2012	7,525,000	5.94	261,700	0.1884
2013	9,896,951	7.82	223,686	0.1611
2014	7,785,520	6.15	133,067	0.0958
2015	8,766,307	6.93	176,058	0.1268
2016	8,841,768	6.98	176,206	0.1269
2017	9,653,413	7.63	176,714	0.1272

Source: MERA, 2017

The air traffic (sum of landings and take-offs) is an important contributor to the emissions from civil aviation.. The fuel consumed during the landings and take-offs includes those consumed for all activities near the airport that take place below the 3000 feet (1000 m) (Rypdal, n.d.). In the case of IPCC default emission factors for Tier 1 methodology, the emission factors have been averaged over all flying phases based on an assumption that 10 %t of the fuel is used in the landing and takeoff phase of the flight (Rypdal, n.d.). Amount of fuel (Jet a1 and Avgas) consumed in the civil aviation is presented in Table 2.17. These were converted from litres to Gg (1 litre of Jet a1 = 0.79 kg and (1 litre of Avgas = 0.72 kg).

Table 2. 27: Aviation Gasoline and Jet kerosene used in civil aviation (TJ)

Fuel	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Aviation Gasoline	0.257	0.1454	0.154	0.2047	0.1696	0.1618	0.1868	0.1937	0.1832	0.229	0.091	0.1884	0.1611	0.0958	0.1268	0.1268	0.1272
Jet Kerosene	6.95	5.07	9.41	8.58	7.32	9.29	10.27	10.48	7.71	9.25	10.14	5.94	7.82	6.15	6.93	6.98	7.63

Source: MERA, 2017

The civil aviation and water-born navigation contributed small amounts of CO_2 emissions compared to the road transport. In the year 2010, civil aviation contributed 30.14 Gg of CO_2eq (representing 2.02% in the total GHG from energy sector)., These emissions were 4.57% of emissions from the Energy sector in 2010. Generally, during this period the country was undergoing some economic challenges, which affected the aviation industry, causing reduction in civil aviation fuel consumption. The other reason is that, during this period, Air Malawi was underperforming and that some international airlines preferred to fuel outside the country because the local fuel pump price was relatively high.

2.2.3.3.2 Road and Rail Transport -1 A 3 b and 1 A 3 c

Road transport dominates emission from the transport category. This is probably due to road mode of transport being the largest share of both transporting cargo and passengers in Malawi, coupled with data that transport consumes significant share of petroleum imports in Malawi. According to Lall, et al. (2009), road routes account for approximately 70% of internal freight transport and over 90% of international freight traffic and 99% of passenger traffic. Since the rail transport is insignificantly small, the amount of diesel used in rail transport was analysed together with diesel used in road transport.

Road transport is the major source of GHG emissions in the country arising from mobile combustion processes. Only about 26% of Malawian roads are paved, of which 70% are main roads and 19% urban roads (Millenium Challenge Account-Malawi Country Office, 2011). The rest of the roads are unpaved and in poor condition, especially during the rainy season. Poor and rough roads increase fuel consumption per unit distance compared to paved and smooth roads. Thus, increased vehicular emissions of NO_2 and CH_4 is expected for Malawi. Furthermore, Lilongwe and Blantyre (two major cities in Malawi) experience localised traffic congestion, which increases fuel consumption per unit distance because the vehicles take longer time to reach their destinations, and thus consume more fuel (due to idling) than without congestion. During traffic congestion low gears are mostly used, which are not efficient in fuel consumption. The increase in fuel consumption in traffic congestion correspondingly, generates GHG emissions per unit distance. The emissions resulting from traffic congestion is expected to increase due to corresponding increase in vehicle population and limited interventions to decongest the urban roads.

2.2.3.3.3 Water-borne navigation -1 A 3 d

Fuel data used in the estimation of GHG emissions in the water borne navigation is presented in Table 2.26.

Table 2. 28: Diesel used in water-borne navigation

Year	Litres	Gg
2001	202065	59.73
2002	258982	65.10
2003	192805	68.52
2004	109108	69.42
2005	211990	61.93
2006	239837	65.10
2007	206636	67.28
2008	231986	75.91
2009	221087	82.72
2010	238412	74.56

2011	257337	77.26
2012	243627	73.40
2013	214,274	0.18
2014	86,928	0.07
2015	238,195	0.20
2016	259,445	0.22
2017	277,613	0.23

Source: (Malawi Shipping Company, 2017)

Biomass

The wood fuel and wood charcoal are assumed to be used in the institutional and residential subcategories. This assumption is in order because a lot of wood fuel and charcoal is used in households and institutions. The appliances technologies (stoves) for combustion differ between those of households and institution as well as those used in curing tobacco and tea curing processes. However, in the absence of country specific emission factors, this inventory used the default emission factors for combustion of biomass which are the same for residential and institutional categories.

Table 2. 29: GHG emissions from Residential (1A4)

Year	CH_4 (Gg of CO_2 eq)	N2O (CO_2eq)
2001	364.59	65.76
2002	367.79	66.26
2003	371.18	66.81
2004	374.44	67.33
2005	378.21	67.91
2006	382.49	68.59
2007	386.98	69.3
2008	391.56	70.04
2009	396.43	70.81
2010	401.31	71.59
2011	406.62	72.45
2012	412.01	73.31
Totals	4633.61	830.16

2.2.3.3.4 Fuel Combustion Activities - Non-Specified -1A5

2.2.3.3.5 Fugitive emissions from fuels – 1B

2.2.3.3.6 Fugitive emissions from fuels – Solid Fuels 1B1

In this category, only coal mined from surface mines were considered. Almost all of coal mined in Malawi is mined using surface mines. The coal data used for mining is the same as for post-mining operations. The data is presented in the Table 2.31.

Table 2. 30: Coal production data used in Fugitive emissions from fuels

Year	Metric tonnes	Gg
2001	34,410	34.41
2002	43,372	43.372
2003	47,037	47.037
2004	40,891	40.891
2005	51,870	51.87
2006	60,408	60.408
2007	58,550	58.55
2008	57,477	57.477
2009	59,201	59.201
2010	65,006	65.006
2011	72,300	72.3
2012	91,910	91.91
2013	98,000	98
2014	120,000	120
2015	58,774.00	58.774
2016	42,144.00	42.144
2017	47,716.00	47.716

Sources of data:

2001 to 2009 obtained from Malawi State of Environment and Outlook Report (GoM, 2010)

2010 to 2012 obtained from US Department of Geological Survey, US Department of Interior (Yager, 2017)

Carbon dioxide from fugitive emissions as a result of coal mining and handling processes was also calculated. As presented in Figure 2.8, the results of fugitive CO_2 emissions are insignificant compared to other categories in the Energy sector. In the year 2010 2017, the emissions were only 18.90GgCO_2eq.. The fugitive emissions did not increase steadily, because they depend on quantities of coal mined, assuming the mining conditions and handling processes were constant during the period of inventory.

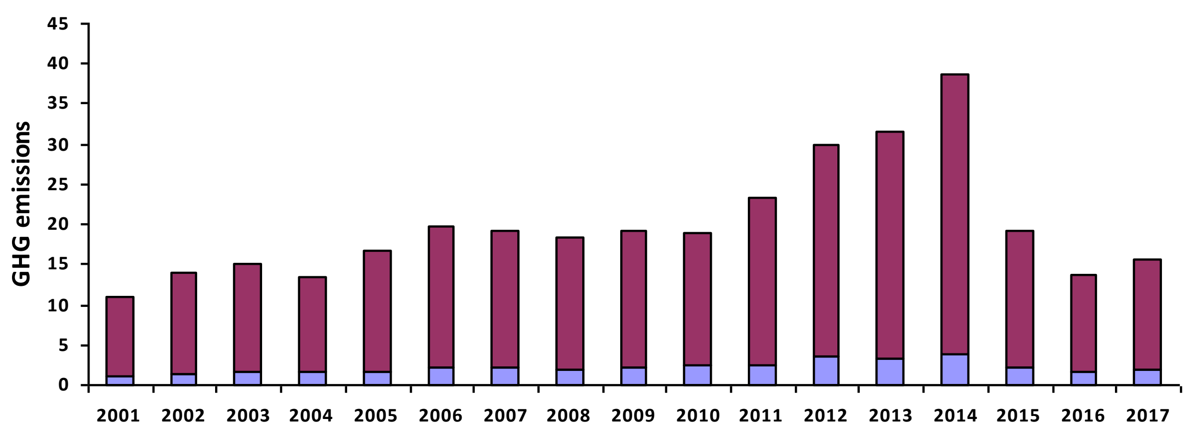


Figure 2. 4 Annual total CO_2 emissions in the fugitive emissions from 2001 to 2017

The following energy activities were not occurring in Malawi:

- 1B2- Fugitive Emissions from Oil and Natural Gas -
- 1C-Carbon Dioxide Transport and Storage

2.2.3.4 Reference Approach Data

This inventory has used the sectoral approach to estimate the GHG emissions in the Energy sector, using the 2006 IPCC GHG Inventory Software. Another set of estimations, using the same software, was conducted using the reference approach. The aim was to compare the variance and thus, validate the sectoral approach estimations. The data used in the reference approach is presented in the Table 2.31.

Table 2. 31: Fuel data used in GHG emissions calculations using the Reference Approach

	Diesel	Petrol	Paraffin	Jet a1	Avgas	LPG	Wood fuel	Wood charcoal	Coal
Inventory year	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)	(Gg)
2001	104.09	59.73	15.52	6.95	0.2570	0.465	3204	400	34.41
2002	105.80	65.10	17.19	5.07	0.1454	0.479	3225	409	43.372
2003	113.49	68.52	19.40	9.41	0.1540	0.492	3248	418	47.037
2004	123.07	69.42	20.31	8.58	0.2047	0.506	3271	426	40.891
2005	127.02	61.93	17.91	7.32	0.1696	0.519	3297	436	51.87
2006	127.49	65.10	16.66	9.29	0.1618	0.533	3328	446	60.408
2007	139.04	67.28	14.95	10.27	0.1868	0.546	3360	457	58.55
2008	165.78	75.91	14.73	10.48	0.1937	0.560	3394	467	57.477
2009	169.15	82.72	11.41	7.71	0.1832	0.573	3430	478	59.201
2010	155.20	74.56	8.73	9.25	0.2290	0.587	3466	489	65.006
2011	158.07	77.26	8.41	10.14	0.0910	0.600	3505	501	72.3
2012	170.74	73.40	5.38	5.94	0.1884	0.577	3545	513	91.91
2013	176.77	80.25	1.43	7.82	0.1611	0.496	3587	526	98
2014	132.95	80.25	1.26	6.15	0.0958	0.568	3630	540	120
2015	138.45	98.10	0.42	6.93	0.1268	0.659	3675	553	58.774
2016	158.38	122.88	0.70	6.98	0.1269	0.834	3712	565	42.144
2017	168.45	147.04	0.78	7.63	0.1272	0.884	3751	578	47.716

Source: MERA, 2017

2.2.3.4.1 Comparison between Sectoral Approach and Reference Approach

This inventory employed sectoral approach of the Tier 1 IPCC Methodology. It was indicated in the methodology, another set of calculations, was conducted using the reference approach using the same 2006 IPCC GHG Inventory software. The aim was to compare the variance and thus, validate the sectoral approach. The difference between the two approaches, in terms of percentage, was the largest for aviation gasoline (4.76%) followed by kerosene (-4.64%) and gas/diesel oil (-4.50%). This validates the sectoral approach, according to IPCC (IPCC, 2006). Table 2.33 presents the results of comparison between SA and RA.

Table 2. 32: Comparison between RA and SA

	Reference Approach				Sectoral Approach		Difference	
Fuel	**Apparent Consumption (TJ)**	**Excluded consumption (TJ)**	**Apparent Consumption (excluding non-energy use and feedstocks) (TJ)**	**CO_2 Emissions (Gg)**	**Energy Consumptio n (TJ)**	**CO_2 Emissions (Gg)**	**Energy Consumption (%)**	**CO_2 Emissions (%)**
Motor Gasoline	3303.01		3303.01	228.90	3568.81	228.90	-7.45	0.00
Aviation Gasoline	10.14		10.14	0.71	10.14	0.71	0.00	0.05
Jet Kerosene	407.93		407.93	29.17	407.93	29.17	0.00	0.00
Other Kerosene	382.37	0.00	382.37	27.48	426.17	27.49	-10.28	-0.05
Shale Oil	0.00		0.00	0.00			0.00	0.00
Gas/Diesel Oil	6673.60	0.00	6673.60	494.29	9210.60	494.51	-27.54	-0.04
Residual Fuel Oil	0.00		0.00	0.00			0.00	0.00
Liquefied Petroleum Gases	27.77	0.00	27.77	0.00	27.77	1.75	0.00	-100.00
Other Bituminous Coal	0.00		0.00	0.00	10216.80	0.00	-100.00	0.00
Sub-Bituminous Coal	1603.02		1603.02	154.00	1603.02	154.05	0.00	-0.03

The memo items recorded were CO_2 emissions from biomass (Table 2.34)

Table 2. 33: Memo items

	Emissions(Gg)						
Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
International Bunkers				0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers) (1)				0	0	0	0
1.A.3.d.i - International water-borne navigation (International				0	0	0	0
1.A.5.c - Multilateral Operations (1)(2)				0	0	0	0
Information Items							
CO_2 from Biomass Combustion for Energy Production	10518.339						

2.2.4 Planned improvements

1. Recommendations on the improvement of the quality of the inventory in the next national communication are suggested as follows:
   - (i). There should be a deliberate policy to compel government department, companies and other stakeholders to provide information for such a national cause
   - (ii). Getting the data in the organised and in form required for the analysis was not easy from most of public and private organisations. It is recommended to have a data management plan for all government departments and enrage private sector to also have it.
   - (iii). The project to generate emission factors for Malawi in the Energy sector should be finalised before the next inventory

2.3 Industrial Processes and Product Use

2.3.1 Introduction

The IPPU sub-sectors that are relevant to Malawi are: 2A-Mineral industry, 2A1-Cement production and 2A2- Lime production. The mining industry in Malawi continues to grow and remains an important sector to propel the country's economy. In 2014, the cement and lime industries alone employed 1,694 direct employees and generated MK238.14 million in revenue in the same year (GoM, 2014). In the construction industry, lime and cement companies, contribute greatly to saving of the country's foreign exchange earnings by availing their products locally, thus cutting on imports. In 2012, property worth MK5,053.7 million was completed using locally produced cement (NSO, 2015). The GHGs emitted from IPPU sector in 2010 are presented in Table 2.34.

Table 2. 34: GHGs emitted from IPPU in 2010

Categories	(Gg)			CO_2 eq (Gg)		
	CO_2	CH_4	N_2O	HFCs	PFCs	SF6
2 - Industrial Processes and Product Use	40.01					
2.A - Mineral Industry	40.01					
2.A.1 - Cement production	16.07					
2.A.2 - Lime production	23.84					
2.A.3 - Glass Production						
2.A.4 - Other Process Uses of Carbonates						
2.A.4.a - Ceramics						
2.A.4.b - Other Uses of Soda Ash						
2.A.4.c - Non-Metallurgical Magnesia Production						
2.A.4.d - Other (please specify) (3)						
2.A.5 - Other (please specify) (3)						
2.B - Chemical Industry						
2.B.1 - Ammonia Production						
2.B.2 - Nitric Acid Production						
2.B.3 - Adipic Acid Production						
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production						
2.B.5 - Carbide Production						
2.B.6 - Titanium Dioxide Production						
2.B.7 - Soda Ash Production						
2.B.8 - Petrochemical and Carbon Black Production						
2.B.9 - Fluorochemical Production						
2.B.10 - Other (Please specify)(3)						
2.C - Metal Industry						
2.D - Non-Energy Products from Fuels and Solvent Use(6)						
2.E - Electronics Industry						
2.F - Product Uses as Substitutes for Ozone Depleting Substances						
2.G - Other Product Manufacture and Use						
2.H - Other						

Malawi's IPPU contribution to the national totals remains low owing to low levels of industrialization and an economy that is largely agro-based. The IPPU sector contributed only 0.78% of the total country GHG emissions in 2010. The cement industry continues to be a major contributor of CO_2 emissions in Malawi for in the IPPU sector followed by lime production as indicated in Figure 2.8.

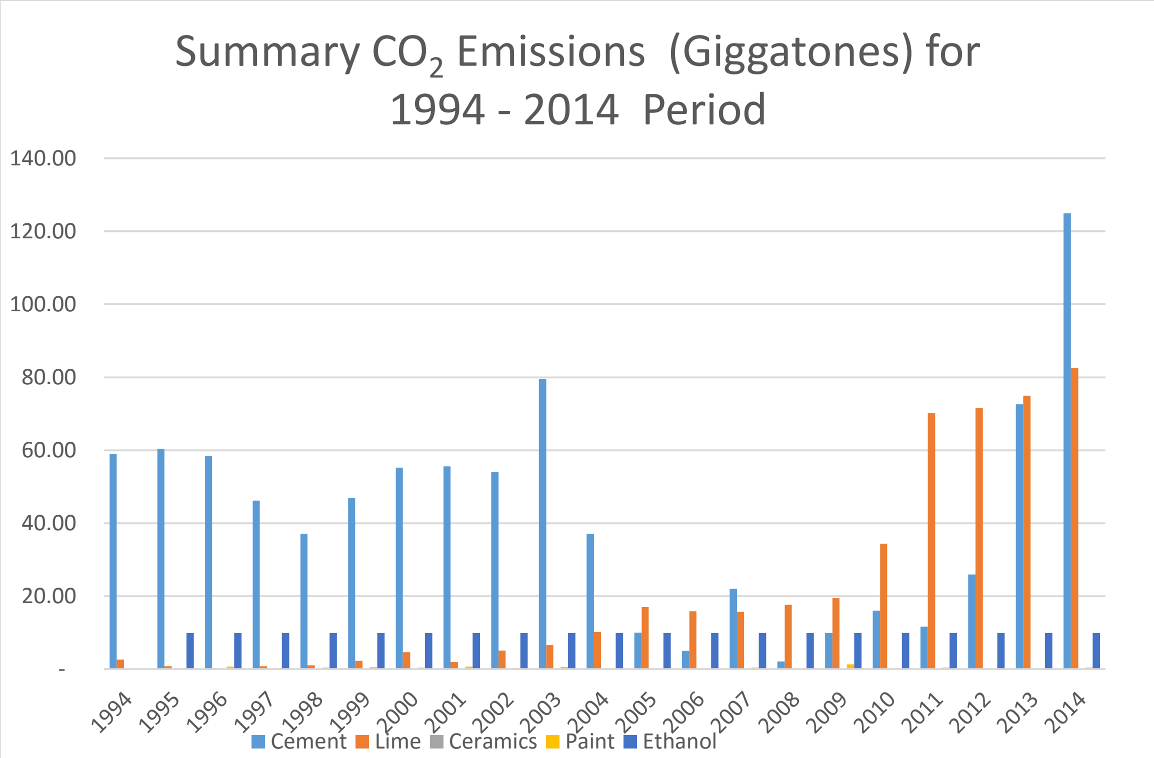


Figure 2. 5 Summary CO_2 Emission for IPPU Sector

2.3.2 Methodology

Several approaches were employed so as to get the requisite data. These include;

- Literature review of the Initial and Second National Communications was undertaken to determine the adequacy of the GHG inventories compiled. The 2006 IPCC Guidelines were also examined alongside data from the National Statistical Office (NSO), Department of Mines, Department of Economic Planning and Development, Ministry of Commerce, Trade and Industry and the United States Geological Survey (USGS);
- Visits were made to product producer such as Shayona Cement Limited, Department of Mines and the Malawi Revenue Authority to fill gaps observed in the literature secured.

Activity data was obtained from the following institutions:

i. Data Provider
ii. Lafarge
iii. Shayona
iv. Changalume
v. United States Geological Survey
vi. Nkhotakota
vii. Dedza

2.3.3 GHG Emissions from IPPU by category

2.3.3.1 Cement Production-2A1

Malawi has three cement producing plants, namely: Portland Cement Company in Blantyre, Shayona Cement Limited plant in Kasungu and Cement Products in Mangochi. Although the production of cement has risen, Malawi continues to import the product to meet the ever-increasing demand. Figure 3.2 shows GHG emissions from cement for the period 1994 to 2014.

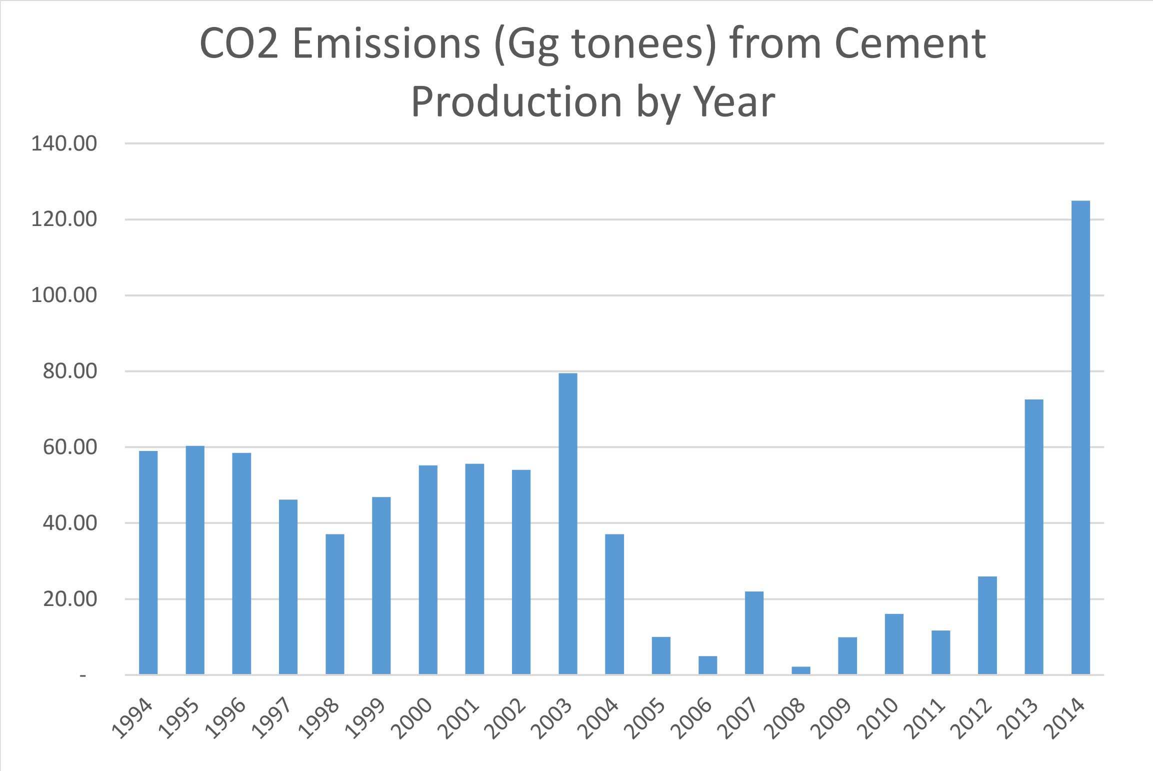


Figure 2. 6 Carbon Dioxide Emissions from Cement Production (2001-2014)

Estimations of GHG emissions in the BUR inventory covered the period from 2001 to 2014. A major deviation from the previous communications where calculations were based on lime production and figures from Lafarge only is that, carbon dioxide emissions from cement production have incorporated clinker imports and exports and production figures from Shayona.

The country experienced a major decrease in limestone production from Changalume from 2004 to 2008 (SOER, 2010) and an influx of imported cement from Zambia, Zimbabwe and Tanzania (SNC, 2011) in the years between 2005 to 2009 to cover the deficit. This resulted in decrease in CO_2 emissions resulting from reduced calcination.

In general, there has been an increase in GHG emissions in both cement and lime production from the year 2001 to 2003 and thereafter a decline up to the year 2009 although there were variations during the period as explained above.

- In 1994, during the INC, the total CO_2 emissions amounted to 61.69 Gg as recalculated in the BUR;
- In 2009, the total net CO_2 emissions amounted to 30.80 Gg ŧ owing to declining production at Changaluume due to reduced calcination, scarcity of wood and influx of imports;
- The revision of default emission factors has had an upward effect on emissions from cement production.

Greenhouse gas emissions from IPPU were estimated from the following sources categories: CO_2 emissions from cement and lime production using methodologies outlined in the 2006 IPCC Guidelines based on the following chemical equation (3.1).

$$CaCO_3 + heat \longrightarrow CaO + CO_2$$

Equation 2.1: CO_2 formation from limestone

Equations 3.2 and 2.3 from the IPCC Guidelines for the estimation of carbon dioxide emission based on cement production data using global emission factors was adopted for the study as follows:

CO_2 Emissions $=\sum(M_{ci}*C_{cli})-I_m+E_x*EF_{cli}$

Equation 2.2: CO_2 emissions from cement

Where:

CO_2 Emissions = emissions of CO_2 from cement production in tonnes
M_{ci} = weight (mass) of cement produced of type i in tonnes
C_{cli} = clinker fraction of cement of type i, fraction = 0.95
I_m = imports for consumption of clinker in tonnes
E_x = exports of clinker in tonnes
EF_{clc} = emission factor for clinker in the particular cement in tonnes CO_2/tonne clinker = 0.52
The default clinker emission factor (EFclc) is corrected for cement kiln dust (CKD).

For lime production: Tier 1 Equation, 2.8 was used to estimate carbon dioxide emissions based on tonnage of lime produced, thus (IPCC, 2006):

$EF_{lime} = 0.85*EF_{high\ calcium\ lime} + 0.15*EF_{dolomite\ lime}$
$= 0.85*0.75 + 0.15*0.77$
$= 0.6375 + 0.1155$
$= 0.75$ tonne CO_2 / tonne lime produced

For carbon dioxide emissions emanating from ethanol production, the following equations were used:

i. Ethanol production for the period 2001-2009 (t) = (volume in litre x specific gravity) /1000

ii. Mass of CO_2 emitted (t) = (molar weight of CO_2}/ (molar weight of CH3CH2OH) x volume of ethanol (t)

In the case of ceramics production, carbon dioxide emissions were arrived at using equation

CO_2 Emissions (tonnes) = $M_c * (0.85EF_{ls} + 0.15\ EF_d)$

Where: CO_2 Emissions = emissions of CO_2 from other process uses of carbonates, tonnes
Mc = mass of carbonate consumed, tonnes
EFls or EFd = emission factor for limestone or dolomite calcination, tonnes CO_2/tonne carbonate

A review was conducted of the GHG emissions from the inventory figures arrived at during the INC of 1994 and SNC and the figures were compared with those arrived at during the TNC compilation as shown in Table 2.35 below.

Table 2. 35: Comparative Analysis of INC and SNC Inventories with BUR figures

Year	INC and SNC Inventory		Recalculation in BUR	
	CO_2 Emission from Lime	CO_2 Emission from Cement	CO_2 Emission (Gg) from Lime	CO_2 Emission from Cement
1994	1.7551	56.62	2.7	59.03
1995	0.507	59.022	0.8	60.37
1996	0.128	46.46	0.2	58.49
1997	0.538	37.388	0.8	46.19
1998	0.733	47.308	1.1	37.05
1999	1.572	55.732	2.3	46.88
2000	3.132	56.081	4.6	55.23

It is clear from the table that:

- Lime emission figure for the INC (1994) is lower than that for BUR. This can be attributed to variation of the global emission factor of 0.5071 tonne CO_2 / tonne of lime produced used in 1994 to 0.75 tonne CO_2 / tonne of lime produced used in the BUR based on the 2006 IPCC Guidelines;
- Carbon emissions from cement production have risen from 56.62 Gg in 1994 to 59.03 in the . In the INC, the figure was based on lime used using a default factor of 0.4985 CO_2 / tonne of cement produced that has been revised upwards to 0.52 CO_2 / tonne of clinker produced.
- The trend, however remains the same in that from 1995 there was a decrease in carbon dioxide emissions from both cement and lime production due to, among others, an economy that took a downward turn (SOER, 2010), reduced production of lime as fuelwood became scarce (USGS, 2010) and closure of production plant at Changalume Factory owned by Lafarge in 2002; and
- From 1998, there was an increase in the emission levels due to increased activity emanating from opening of Malawi's second cement factory in Kasungu owned by Shayona.

2.3.3.2 Lime Production-2A2

The data on cement production for the period 2001-20 that were used to compute CO_2 emissions were obtained from the Department of Mines, Department of Economic Planning and Development (EP&D), National Economic Reports, National State of Environment and Outlook Report (2010), Portland Cement Company (which is now called Lafarge Cement Company Limited) and the United States Geological Survey (https://minerals.usgs.gov/minerals/pubs/country/1995/9257095.pdf).

Figure 2.10 below shows that there was an upward trend in lime production from 2001 that is attributed to the following factors:

- Increase in demand for agriculture lime during the period especially in the tobacco estimates;
- The One Village One Product (OVOP) program had positive impact in increasing production capacities of smallholder lime producers (EP&D, 2011);
- Demand from poultry and paint industries remained robust during the period;
- Shayona Cement Company had become operational and increased its lime output hence carbon dioxide emissions; and
- Data on imports of clinker, which is now available, could not be found between 2001 and 2003.

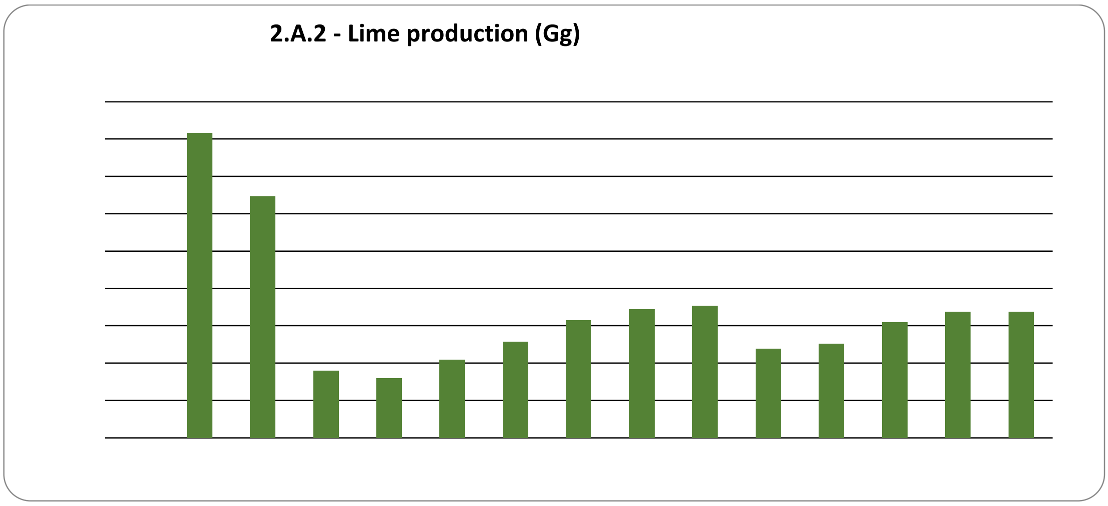


Figure 2. 7 Carbon Dioxide Emissions in Gg from Lime Production (2001-2014)

The coming into operation of Shayona Cement Company that led to higher emissions of CO_2 especially after commissioning the clinker production in 2013. The other developments that led to increased lime production as stated above did not necessarily lead to higher emissions as they do not involve calcination. Shayona's GHG contribution has already been factored in the CO_2 emissions from cement.

2.3.3.3 Ceramics Production-2A4a

The ceramics industry has, in terms of production, remained unchanged at both the Nkhotakota and Dedza plants growing only slightly from the year 2000 to 2007. This is attributed to the growing imports of ceramics from China, South Africa and East Africa. In the case of ceramics production, carbon dioxide emissions were arrived at using Equation 3.3.

$$CO_2 \text{ Emissions (tonnes)} = M_c * (0.85EF_{ls} + 0.15\ EF_d)$$

Equation 2.3: CO_2 emissions from ceramics

Where: CO_2 Emissions = emissions of CO_2 from other process uses of carbonates, tonnes

Mc = mass of carbonate consumed, tonnes

EFls or EFd = emission factor for limestone or dolomite

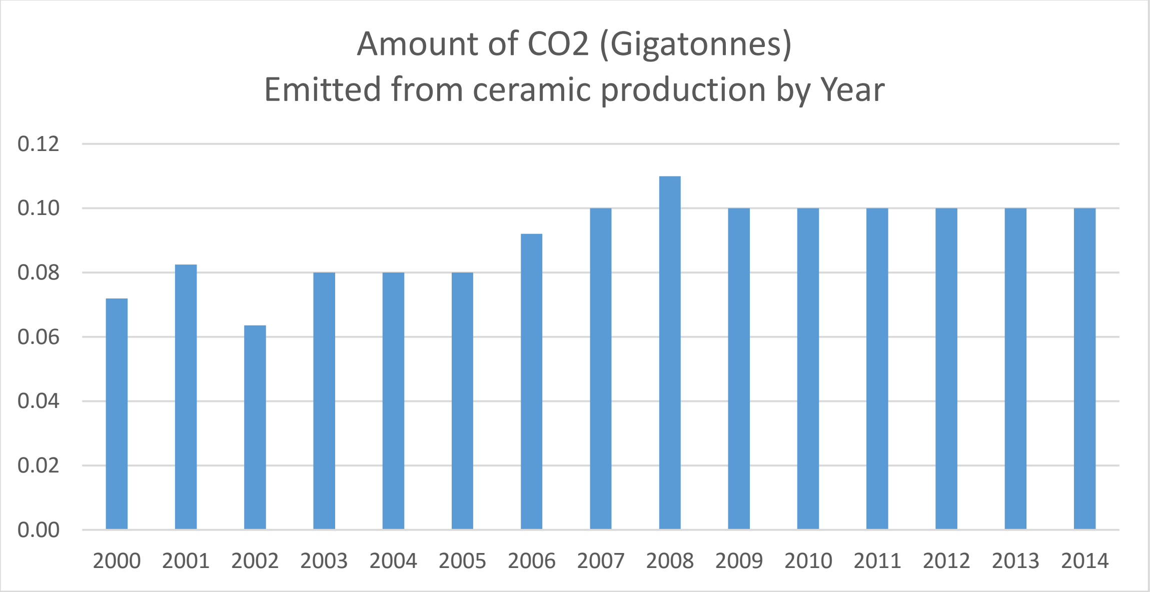


Figure 2. 8 CO_2 Emissions from Ceramics Industry (2000 – 2014)

2.3.3.4 Product Uses as Substitutes for Ozone Depleting Substances – Other Applications-2F6

2.3.3.4.1 Greenhouse Gas Emissions from Paint Industry

Overall, there is an increase in the production and resultant CO_2 emissions from paint industry from 0.5 Gg tonne in 2000 to 1.35 Gg in 2009 (Figure 3.5).

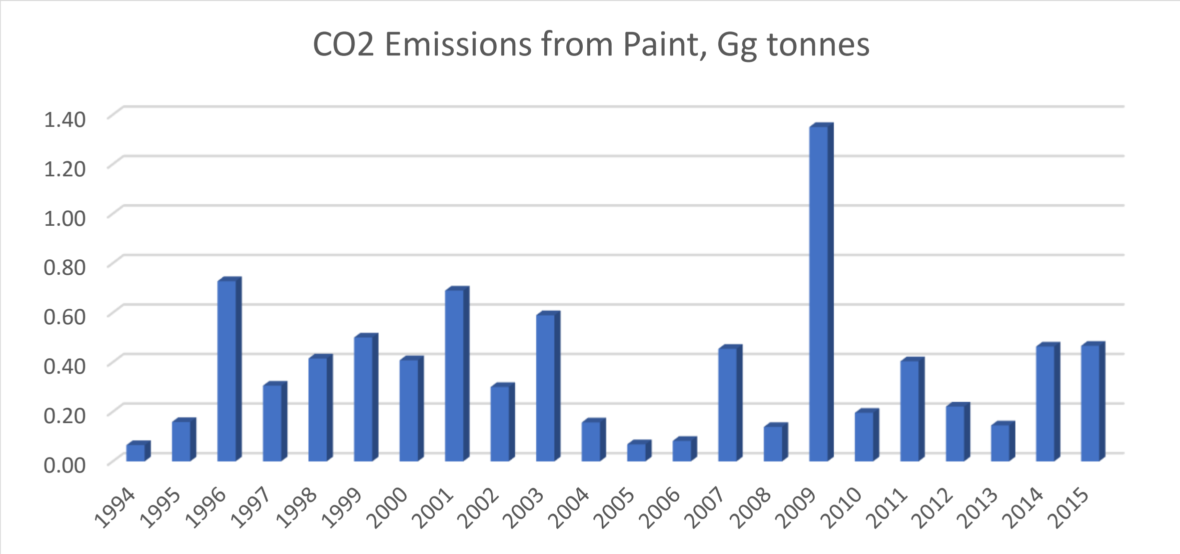


Figure 2. 9 CO_2 Emissions from Paint Production (1994 - 2015)

This trend is attributed to the rise in construction industry and improvements in economic performance from 2009. The decline between 2004 and 2006 reflects the economic decline that also resulted in poor industrial output coupled with imports from Malawi's major trading and neighbouring countries such as South Africa and Tanzania.

2.3.3.5 Greenhouse Gas Emissions from Ethanol Production-2H2

Malawi has two industrial ethanol production plants based at Dwangwa in Nkhotakota and Chikhwawa. Three types of ethanol are produced, namely, potable and rectified blends. There has been a steady increase from 2001 to 2009 owing to commissioning of new plant in Chikhwawa, increased blending and the country's need to reduce forex losses. It was assumed that CO_2 releases from ethanol production are reabsorbed in the production of sugarcane and as such does not contribute to the net country's emissions.

For carbon dioxide emissions emanating from ethanol production, the following equations were used:

i. Ethanol production for the period 2001-2009 (t) = (volume in litre x specific gravity) /1000

ii. Mass of CO_2 emitted (t) = (molar weight of CO_2}/ (molar weight of CH3CH2OH) x volume of ethanol (t)

Malawi has two industrial ethanol production plants based at Dwangwa in Nkhotakota and Prescane in Chikhwawa. Two types of ethanol are produced, namely,potable and rectified blends. Based on the available data as presented in Annex3, the following results were observed:.

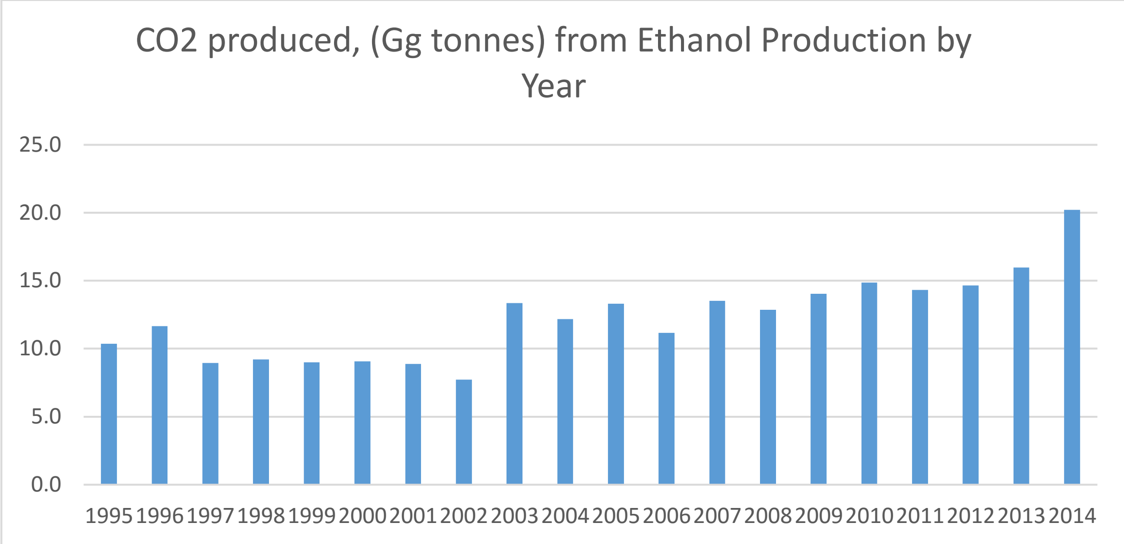


Figure 2. 10 GHG Emissions from Ethanol Production (1994 - 2014)

Generally, the results show a steady increase of carbon dioxide emissions from 2001 to 2014 owing to Prescane Company which was commissioned in 2001. However, for the plant-based raw materials, it is assumed that CO_2 is re-absorbed during plant growth so that net emission is practically assumed to be zero (Malawi SNC, 2002).

However, for the plant-based raw materials, it is assumed that CO_2 is re-absorbed during plant growth so that net emission is practically assumed to be zero (Malawi SNC). This inventory does not cover the following sub-categories that were not occurring in Malawi:

i. 2A3-Glass Production 2A4 Mineral Other Process Uses of Carbonates-
ii. 2B1 Ammonia Production
iii. 2B2 Nitric Acid Production
iv. 2B3 Adipic Acid Production
v. 2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production
vi. 2B5 Carbide Production,
vii. 2B6 Titanium Dioxide Production
viii. 2B7 Soda Ash Production
ix. 2B8 Petrochemical and Carbon Black Production
x. 2B9 Fluorochemical Production
xi. 2C1 Iron and Steel Production
xii. 2C2 Ferroalloys Production
xiii. 2C3 Aluminium Production PFCs
xiv. 2C4 Magnesium Production
xv. 2C5 Lead Production 2
xvi. 2C6 Zinc Production
xvii. 2D Non-Energy Products from Fuels and Solvent Use
xviii. 2E Electronics Industry
xix. 2F1 Product Uses as Substitutes for Ozone Depleting Substances-NE
xx. 2G Other Product Manufacture and Use

2.3.4 Discussion

There were limitations encountered in the course of conducting the study, the most notable of which were:

- Reluctance to release data from companies. Some companies treated data as confidential and were unwilling to provide such data to the study team;
- Completeness of data availability for the reporting periods. While data was required for the period from the year 1992 to 2014, it was difficult to get data for some years for certain sector such as ceramics and ethanol.

2.3.5 Planned improvements

- Data collection for the remaining years if data not available extrapolation will be done in the Fourth National Communication
- General public awareness to the data providers on the importance of providing data for inventory purposes

2.4 Agriculture, Forest and Other Land-Uses

2.4.1 Introduction

Malawi has an agro-based economy with the agriculture sector accounting for over 35.5 % of GDP, employing about 84.5 % of labour force and accounting for 82.5 % of foreign exchange earnings. The main agricultural export crop is tobacco, followed by tea, sugar and coffee. Agricultural expansion and biomass energy demand have been some of the major issues driving forest loss in Malawi. Biomass accounts for over 95% of the total primary energy supply in the country (GoM, 2010) with forest reserves as the main sources of fuelwood and contribute nearly 75% of the total biomass supply besides being the highly encroached areas (Jumbe and Angelsen, 2011).

In the BUR the overall net emission position from AFOLU was 1,205.02Gg CO_2eq in 2010, largely driven by forest land (3B1). The largest amount of CO_2 emissions was from Cropland (3B2) amounting to 1,589.39Gg, while Livestock (3A1) contributed the highest quantity of CH_4 at 1355.61GgCO_2eq. The largest amount of N_2O was 205.29GgCO_2eq from manure management (3A2). The summary of emission from AFOLU in 2010 is shown in Table 2.36.

Table 2. 36: GHG emissions from AFOLU

Categories	Net CO_2 emissions / removals (Gg)	CH_4 Emissions((GgCO_2eq)	N_2O Emissions (GgCO_2eq)
3 - Agriculture, Forestry, and Other Land Use	-519.45	1509.29	215.18
3.A - Livestock	0.00	1355.61	205.29
3.A.1 - Enteric Fermentation	0.00	1246.56	0.00
3.A.1.a - Cattle	0.00	756.12	0.00
3.A.1.a.i - Dairy Cows		87.28	0.00
3.A.1.a.ii - Other Cattle		668.84	0.00
3.A.1.b - Buffalo		0.00	0.00
3.A.1.c - Sheep		31.72	0.00
3.A.1.d - Goats		408.86	0.00
3.A.1.e - Camels		0.00	0.00
3.A.1.f - Horses		0.00	0.00
3.A.1.g - Mules and Asses		0.00	0.00
3.A.1.h - Swine		49.86	0.00
3.A.1.j - Other (please specify)		0.00	0.00
3.A.2 - Manure Management(1)	0.00	109.05	205.29
3.A.2.a - Cattle	0.00	22.47	204.27
3.A.2.a.i - Dairy cows		0.89	5.17
3.A.2.a.ii - Other cattle		21.58	199.10
3.A.2.b - Buffalo		0.00	0.00
3.A.2.c - Sheep		1.27	0.09
3.A.2.d - Goats		35.45	0.00
3.A.2.e - Camels		0.00	0.00
3.A.2.f - Horses		0.00	0.00
3.A.2.g - Mules and Asses		0.00	0.00

Categories	Net CO_2 emissions / removals (Gg)	CH_4 Emissions(($GgCO_2eq$)	N_2O Emissions ($GgCO_2eq$)
3.A.2.h - Swine		49.86	0.93
3.A.2.i - Poultry		0.00	0.00
3.A.2.j - Other (please specify)		0.00	0.00
3.B - Land	-562.58	0.00	0.00
3.B.1 - Forest land	-2626.93	0.00	0.00
3.B.1.a - Forest land Remaining Forest land	-2498.48	0.00	0.00
3.B.1.b - Land Converted to Forest land	-128.45	0.00	0.00
3.B.1.b.i - Cropland converted to Forest Land	-106.45	0.00	0.00
3.B.1.b.ii - Grassland converted to Forest Land	-9.30	0.00	0.00
3.B.1.b.iii - Wetlands converted to Forest Land	-12.70	0.00	0.00
3.B.1.b.iv - Settlements converted to Forest Land	0.00	0.00	0.00
3.B.1.b.v - Other Land converted to Forest Land	0.00	0.00	0.00
3.B.2 - Cropland	1589.39	0.00	0.00
3.B.2.a - Cropland Remaining Cropland	0.00	0.00	0.00
3.B.2.b - Land Converted to Cropland	1589.39	0.00	0.00
3.B.2.b.i - Forest Land converted to Cropland	1589.38	0.00	0.00
3.B.2.b.ii - Grassland converted to Cropland	0.00	0.00	0.00
3.B.2.b.iii - Wetlands converted to Cropland	0.01	0.00	0.00
3.B.2.b.iv - Settlements converted to Cropland	0.00	0.00	0.00
3.B.2.b.v - Other Land converted to Cropland	0.00	0.00	0.00
3.B.3 - Grassland	261.89	0.00	0.00
3.B.3.a - Grassland Remaining Grassland	0.00	0.00	0.00
3.B.3.b - Land Converted to Grassland	261.89	0.00	0.00
3.B.3.b.i - Forest Land converted to Grassland	261.89	0.00	0.00
3.B.3.b.ii - Cropland converted to Grassland	0.00	0.00	0.00
3.B.3.b.iii - Wetlands converted to Grassland	0.00	0.00	0.00
3.B.3.b.iv - Settlements converted to Grassland	0.00	0.00	0.00
3.B.3.b.v - Other Land converted to Grassland	0.00	0.00	0.00
3.B.4 - Wetlands	0.00	0.00	0.00
3.B.4.a - Wetlands Remaining Wetlands	0.00	0.00	0.00
3.B.4.a.i - Peatlands remaining peatlands	0.00	0.00	0.00
3.B.4.a.ii - Flooded land remaining flooded land		0.00	0.00
3.B.4.b - Land Converted to Wetlands	0.00	0.00	0.00
3.B.4.b.i - Land converted for peat extraction		0.00	0.00
3.B.4.b.ii - Land converted to flooded land	0.00	0.00	0.00
3.B.4.b.iii - Land converted to other wetlands		0.00	0.00
3.B.5 - Settlements	24.78	0.00	0.00
3.B.5.a - Settlements Remaining Settlements	0.00	0.00	0.00
3.B.5.b - Land Converted to Settlements	24.78	0.00	0.00
3.B.5.b.i - Forest Land converted to Settlements	24.78	0.00	0.00
3.B.5.b.ii - Cropland converted to Settlements	0.00	0.00	0.00
3.B.5.b.iii - Grassland converted to Settlements	0.00	0.00	0.00
3.B.5.b.iv - Wetlands converted to Settlements	0.00	0.00	0.00
3.B.5.b.v - Other Land converted to Settlements	0.00	0.00	0.00
3.B.6 - Other Land	188.29	0.00	0.00
3.B.6.a - Other land Remaining Other land		0.00	0.00
3.B.6.b - Land Converted to Other land	188.29	0.00	0.00
3.B.6.b.i - Forest Land converted to Other Land	188.29	0.00	0.00
3.B.6.b.ii - Cropland converted to Other Land	0.00	0.00	0.00
3.B.6.b.iii - Grassland converted to Other Land	0.00	0.00	0.00
3.B.6.b.iv - Wetlands converted to Other Land	0.00	0.00	0.00
3.B.6.b.v - Settlements converted to Other Land	0.00	0.00	0.00
3.C - Aggregate sources and non-CO2 emissions sources on	88.71	153.68	9.90
3.C.1 - Emissions from biomass burning	0.00	31.28	0.00
3.C.1.a - Biomass burning in forest lands		27.15	0.00
3.C.1.b - Biomass burning in croplands		0.18	0.00
3.C.1.c - Biomass burning in grasslands		3.95	0.00
3.C.1.d - Biomass burning in all other land		0.00	0.00
3.C.2 - Liming	0.00	0.00	0.00
3.C.3 - Urea application	88.71	0.00	0.00
3.C.4 - Direct N2O Emissions from managed soils(3)		0.00	0.00
3.C.5 - Indirect N2O Emissions from managed soils		0.00	0.20
3.C.6 - Indirect N2O Emissions from manure management		0.00	9.69
3.C.7 - Rice cultivations		122.40	0.00
3.C.8 - Other (please specify)		0.00	0.00
3.D - Other	-45.58	0.00	0.00
3.D.1 - Harvested Wood Products	-45.58	0.00	0.00
3.D.2 - Other (please specify)		0.00	0.00

Eight categories were the main contributors to GHG emissions or sinks in 2010. These key categories in terms of level are presented in Table 2.38. The categories cumulatively contributed 96.03% and these were:

- 3.B.1.a-Forest land Remaining Forest land
- 3.A.1-Enteric Fermentation
- 3.B.2.b-Land Converted to Cropland
- 3.B.3.b-Land Converted to Grassland
- 3.A.2-Manure Management
- 3.B.6.b-Land Converted to Other land
- 3.B.1.b-Land Converted to Forest land
- 3C7-Rice Cultivations

Table 2. 37 AFOLU sector key category for 2010 by level

IPCC Category code	IPCC Category	GHG	2010 Ex,t (Gg CO_2 Eq)	|Ex,t| (Gg CO_2 Eq)	Lx,t (%)	Cumulative Total of Column F (%)
3.B.1.a	Forest land Remaining Forest land	CO_2	-2,498.48	2,498.48	38.14	38.14
3.B.2.b	Land Converted to Cropland	CO_2	1,589.39	1,589.39	24.27	62.41
3.A.1	Enteric Fermentation	CH_4	1,246.56	1,246.56	19.03	81.44
3.B.3.b	Land Converted to Grassland	CO_2	261.89	261.89	4.00	85.44
3.A.2	Manure Management	N_2O	205.29	205.29	3.13	88.57
3.B.6.b	Land Converted to Other land	CO_2	188.29	188.29	2.87	91.45
3.B.1.b	Land Converted to Forest land	CO_2	-128.45	128.45	1.96	93.41
3.C.7	Rice cultivations	CH_4	122.40	122.40	1.87	95.28
3.A.2	Manure Management	CH_4	109.05	109.05	1.66	96.94
3.C.3	Urea application	CO_2	88.71	88.71	1.35	98.30
3.D.1	Harvested Wood Products	CO_2	-45.58	45.58	0.70	98.99
3.C.1	Emissions from biomass burning	CH_4	31.28	31.28	0.48	99.47
3.B.5.b	Land Converted to Settlements	CO_2	24.78	24.78	0.38	99.85
3.C.6	Indirect N2O Emissions from manure management	N_2O	9.69	9.69	0.15	100.00
3.C.5	Indirect N2O Emissions from managed soils	N_2O	0.20	0.20	0.00	100.00
3.C.4	Direct N2O Emissions from managed soils	N_2O	0	0	0.00	100.00
3.C.2	Liming	CO_2	0	0	0.00	100.00
3.C.1	Emissions from biomass burning	N_2O	0	0	0.00	100.00
3.B.5.a	Settlements Remaining Settlements	CO_2	0	0	0.00	100.00
3.B.4.b	Land Converted to Wetlands	N_2O	0.00	0.00	0.00	100.00
3.B.4.b	Land Converted to Wetlands	CO_2	0.00	0.00	0.00	100.00
3.B.4.a.i	Peatlands remaining peatlands	CO_2	0.00	0.00	0.00	100.00
3.B.4.a.i	Peatlands remaining peatlands	N_2O	0.00	0.00	0.00	100.00
3.B.3.a	Grassland Remaining Grassland	CO_2	0.00	0.00	0.00	100.00
3.B.2.a	Cropland Remaining Cropland	CO_2	0.00	0.00	0.00	100.00

2.4.2 GHG Emissions from Agriculture

2.4.2.1 Methodology for the Agricultural sector

The quantities of GHGs emitted from the different source categories were estimated using the 2006 IPCC Guidelines. No national emission factors are available in Malawi. Hence, default emission factors sourced from the IPCC Guidelines were used in the calculations. The total amount of CH_4 emitted through enteric fermentation was calculated as the product of the selected emission factors for each animal species with the associated livestock population, and then summed up to estimate the total amount of CH_4 emissions. The CH_4 emissions from livestock manure management were estimated as the product of the livestock category emission factor and the sub-category population figure, which were then summed up across all the categories. The total CH_4 emissions were obtained by adding the GHG emissions, in CO_2eq units, from enteric fermentation and manure management from livestock. Equation 10.25 from the 2006 IPCC Guidelines was employed to calculate direct N_2O emissions from livestock manure for each species and subcategory of each species. N_2O emissions from each species were summed up to derive total N_2O emissions. The Tier 1 approach was also used to calculate CH_4 emissions from rice cultivation.

2.4.3 -GHG Emissions from livestock – 3A

The main ruminant animals in Malawi are cattle, goats and sheep (Table 2.39), with cattle and goats being more dominant. Cattle are the most important source of CH_4 because of their large numbers, large sizes and large ruminant digestive systems. The increases in population are attributed to increase in adoption of animal husbandry practices and injections from Government livestock programmes, especially on goats and injections from Non-Governmental Organization in dairy, goats and chicken species. Most of the livestock are indigenous breeds and are generally raised by smallholder farmers under extensive management systems.

Table 2. 38: Types and total numbers of livestock in Malawi, 2001-2017

Year	Dairy Cattle	Non-Dairy	Indigenous Sheep	Indigenous Goats	Indigenous Swine	Poultry	Rabbits
2001	9034	739995	115247	1669669	205056.8	7,348,450	157,093
2002	10728	742347	1659966	1659966	204136	7,348,450	160,058
2003	12422	769325	108179	1716822	204571	8,871,625	168,423
2004	14116	749945	227363	1922264	224596	9,947,612	182,718
2005	14116	763730	156714	1961080	273873	9,946,591	260,380
2006	20248	778769	175394	2301349	299386	8,800,960	416,120
2007	20248	778769	175394	2301349	299386	10,802,810	513,467
2008	30274	917224	188520	3106271	577852	15,044,516	609,319
2009	35934	946428	199649	3480473	677333	16,843,753	609,319
2010	42457	1027397	214230	3893922	62945	18,813,710	857,380
2011	43987	1066573	228649	4442907	1015515	44,672,086	1,022,864
2012	44643	1119795	240269	4929808	1171791	58,629,593	1,229,193
2013	49435	1192314	255928	5356545	1294575	61,370,456	1,332,938
2014	50334	1326524	269830	5882106	1470442	68,177,602	1,330,252
2015	52753	1345623	275537	6545306	1713444	78,121,449	1,408,506
2016	80439	1390456	286974	7348361	1978308	81,621,972	1,518,638.
2017	90355	1449552	302090	7672737	2374381	93,086,952	1,735,875

Source: DAHLD and ADD annual reports

In Malawi, domestic livestock waste is from livestock kraals, pasture fields and rangelands, kept mostly as solid storage in dry-lots. In most cases this manure is then applied to agricultural soils. N_2O is also emitted from manure management, but this varies significantly between different types of manure management systems. The dominant manure management systems in Malawi are Default emission factors for developing countries obtained from the 2006 IPCC Guidelines were used (Table 4.4). The quantities of GHGs emitted from the different source categories were estimated using the IPCC 2006 software Version 2691.

Table 2. 39: Selected CH_4 default Emission Factors:

CH_4 from enteric fermentation		
Species	Emission factors	Source: 2006 IPCC Guidelines
Non Dairy	31	Table 10.11
Dairy	46	Table 10.11
Goats	5	Table 10.10
Sheep	5	Table 10.10
Pigs	1	Table 10.10
CH_4 manure management		
Species	Emission factors	
Non Dairy	1	Table 10.14
Dairy	1	Table 10.14
Goats	0.22	Table 10.15
Sheep	0.2	Table 10.15
Pigs	1	Table 10.15
Poultry	0.02	Table 10.15
Rabbits	0.08	Table 10.16

.Sources: IPCC, 2006

A total of 64.55Gg CH_4 and 0.66Gg N_2O were emitted from domestic livestock in 2010 (Table 2.41). Increases in methane production were attributed to ever increasing livestock populations from 2006 to 2017.

Table 2. 40: GHG emissions from livestock - 3A

Categories		CH_4	N_2O
3 - Agriculture, Forestry, and Other Land Use	**-**	**71.87**	**0.69**
3.A - Livestock	0.00	64.55	0.66
3.A.1 - Enteric Fermentation	0.00	59.36	0.00
3.A.1.a - Cattle	0.00	36.01	0.00
3.A.1.a.i - Dairy Cows		4.16	
3.A.1.a.ii - Other Cattle		31.85	
3.A.1.b - Buffalo		0.00	
3.A.1.c - Sheep		1.51	
3.A.1.d - Goats		19.47	
3.A.1.e - Camels		0.00	
3.A.1.f - Horses		0.00	
3.A.1.g - Mules and Asses		0.00	
3.A.1.h - Swine		2.37	
3.A.1.j - Other (please specify)		0.00	
3.A.2 - Manure Management (1)	0.00	5.19	0.66
3.A.2.a - Cattle	0.00	1.07	0.66
3.A.2.a.i - Dairy cows		0.04	0.02
3.A.2.a.ii - Other cattle		1.03	0.64
3.A.2.b - Buffalo		0.00	0.00
3.A.2.c - Sheep		0.06	0.00
3.A.2.d - Goats		1.69	0.00
3.A.2.e - Camels		0.00	0.00
3.A.2.f - Horses		0.00	0.00
3.A.2.g - Mules and Asses		0.00	0.00
3.A.2.h - Swine		2.37	0.00
3.A.2.i - Poultry		0.00	0.00
3.A.2.j - Other (please specify)		0.00	0.00

The major sources of methane from enteric fermentation were cattle, goats and sheep. There was a 104.20% increase in CH_4 from enteric fermentation from the 29.07Gg emitted in 2000 as reported in the SNC to the 59.36Gg emitted in 2010.

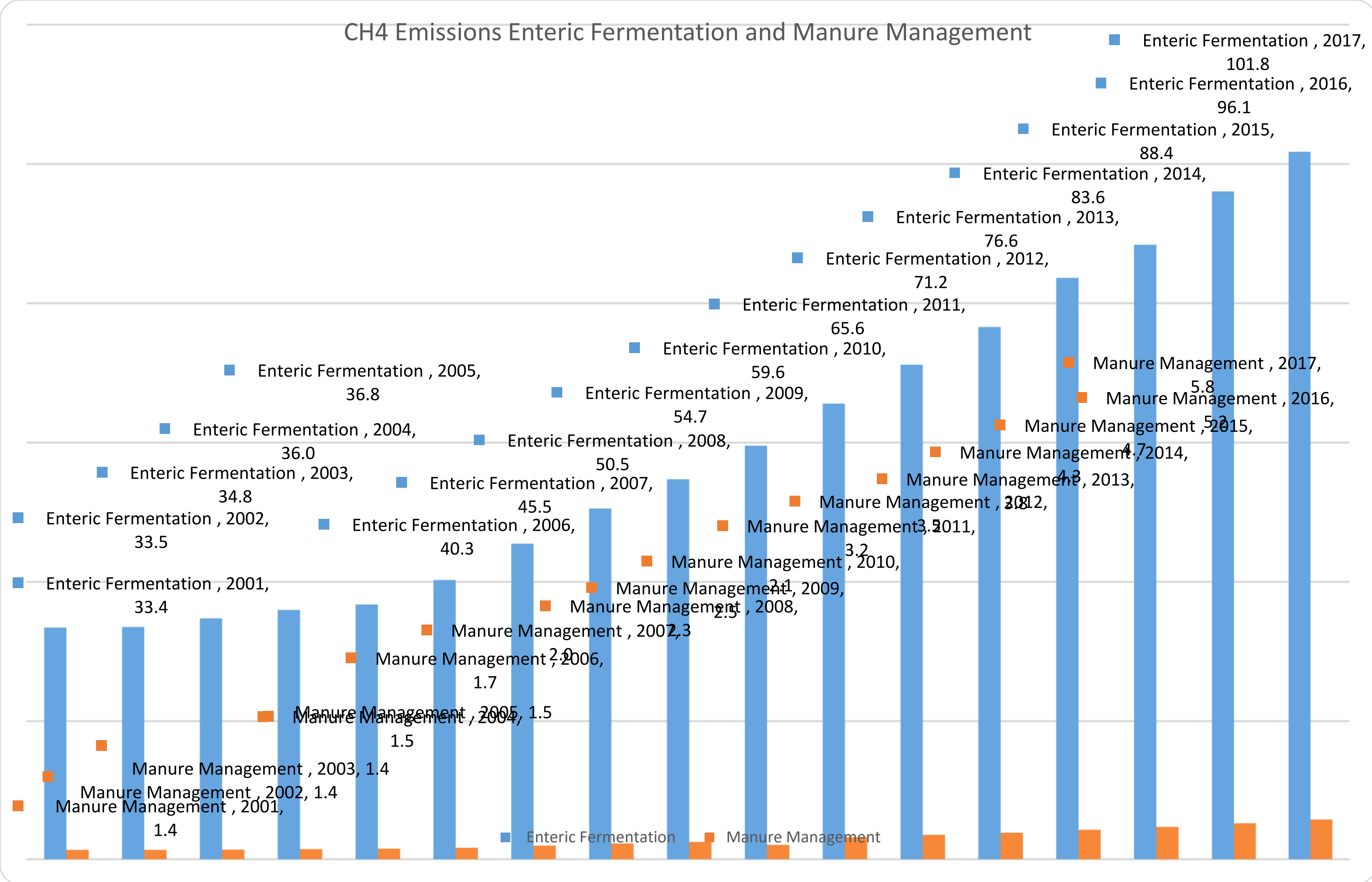

CH4 Emissions Enteric Fermentation and Manure Management
Enteric Fermentation , 2001, 33.4
Enteric Fermentation , 2002, 33.5
Enteric Fermentation , 2003, 34.8
Enteric Fermentation , 2004, 36.0
Enteric Fermentation , 2005, 36.8
Enteric Fermentation , 2006, 40.3
Enteric Fermentation , 2007, 45.5
Enteric Fermentation , 2008, 50.5
Enteric Fermentation , 2009, 54.7
Enteric Fermentation , 2010, 59.6
Enteric Fermentation , 2011, 65.6
Enteric Fermentation , 2012, 71.2
Enteric Fermentation , 2013, 76.6
Enteric Fermentation , 2014, 83.6
Enteric Fermentation , 2015, 88.4
Enteric Fermentation , 2016, 96.1
Enteric Fermentation , 2017, 101.8
Manure Management , 2001, 1.4
Manure Management , 2002, 1.4
Manure Management , 2003, 1.4
Manure Management , 2004, 1.5
Manure Management , 2005, 1.5
Manure Management , 2006, 1.7
Manure Management , 2007, 2.0
Manure Management , 2008, 2.3
Manure Management , 2009, 2.5
Manure Management , 2010, 2.1
Manure Management , 2011, 3.2
Manure Management , 2012, 3.5
Manure Management , 2013, 3.8
Manure Management , 2014, 4.3
Manure Management , 2015, 4.7
Manure Management , 2016, 5.2
Manure Management , 2017, 5.8
Enteric Fermentation
Manure Management

Figure 2. 11 CH_4 emissions from livestock-3A (Gg/year), 2001-2017.

2.4.3.1 Emissions from managed soils

Table 2.41 presents the GHG emissions from managed soils in 2010

Table 2. 41: GHG emissions from managed soils

Category	Net CO_2	CH_4	N_2O
3.C.2 - Liming	NE		
3.C.3 - Urea application	88.71		
3.C.4 - Direct N_2O Emissions from managed soils(3)	NE		0.00
3.C.5 - Indirect N_2O Emissions from managed soils			0.20
3.C.6 - Indirect N_2O Emissions from manure management			0.03
3.C.7 - Rice cultivations		5.83	
3.C.8 - Other (please specify)			

2.4.3.2 GHG Emissions from Liming - 3.C.2

Not estimated (NE)

2.4.3.3 GHG Emissions from Urea Application - 3.C.3

Figure 4.2 presents the amount of inorganic fertiliser applied for the period 2001 to 2017. The general increase in quantities of fertiliser applied is attributed to increased fertilizer usage as a result of implementation of Government Farm Subsidy Programme in Malawi.

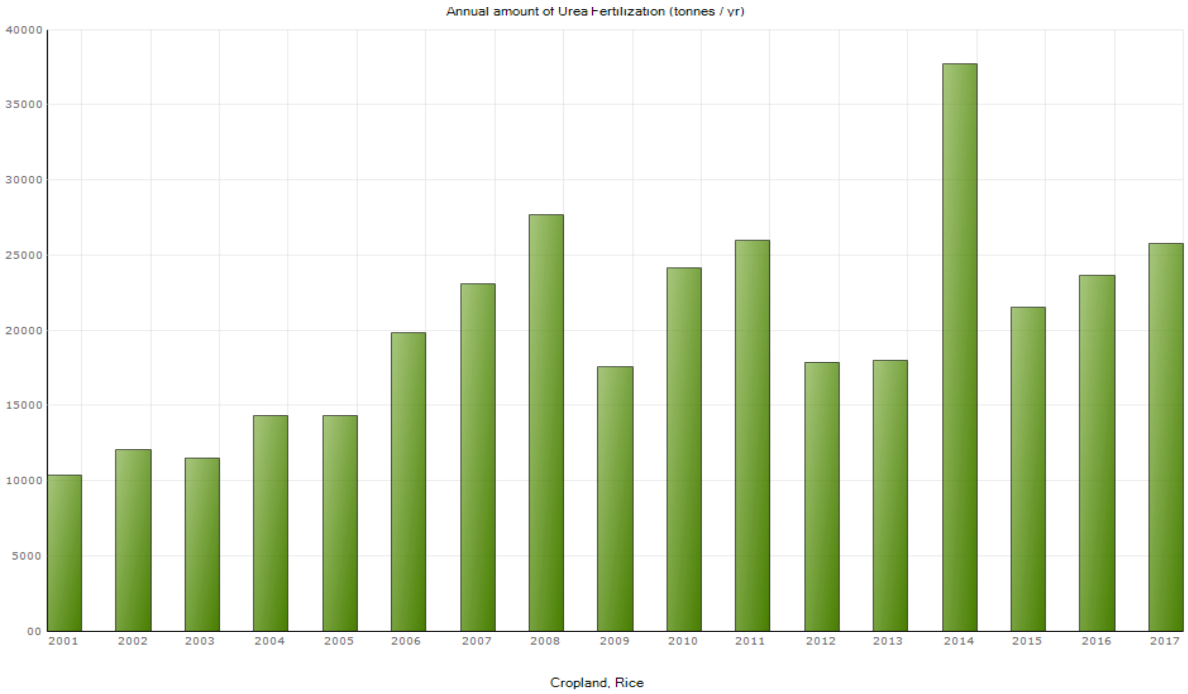


Figure 2. 12 Inorganic fertilizer use in Malawi, 2001-2017

In 2010, 88.71Gg of CO_2 were emitted from urea application (Figure 4.3). Total non-CO_2 for the period under review is 1,192.93Gg. This is five times higher than that reported in the GHG SNC inventory of 1996-2000(225Gg).

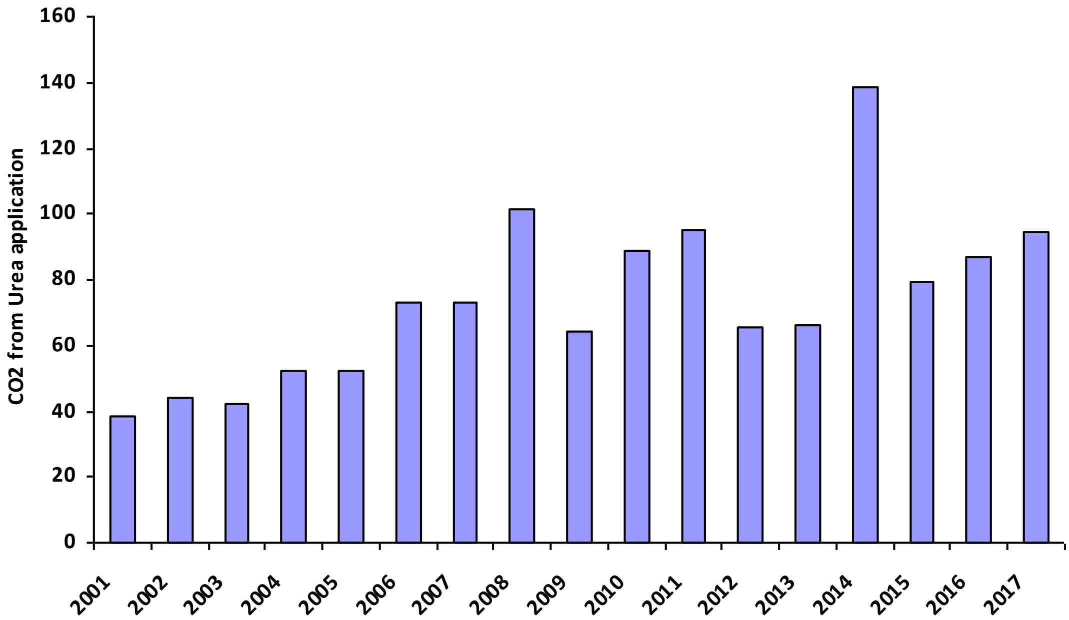


Figure 2. 13 CO_2 emissions from urea application

2.4.3.4 Direct N_2O Emissions from Managed soils - 3C4

Direct N_2O emissions from managed soils were not estimated

2.4.3.5 Indirect N_2O Emissions from Managed soils - 3C5

Figure 2.18 shows the annual quantities of indirect N_2O emitted from managed soils.

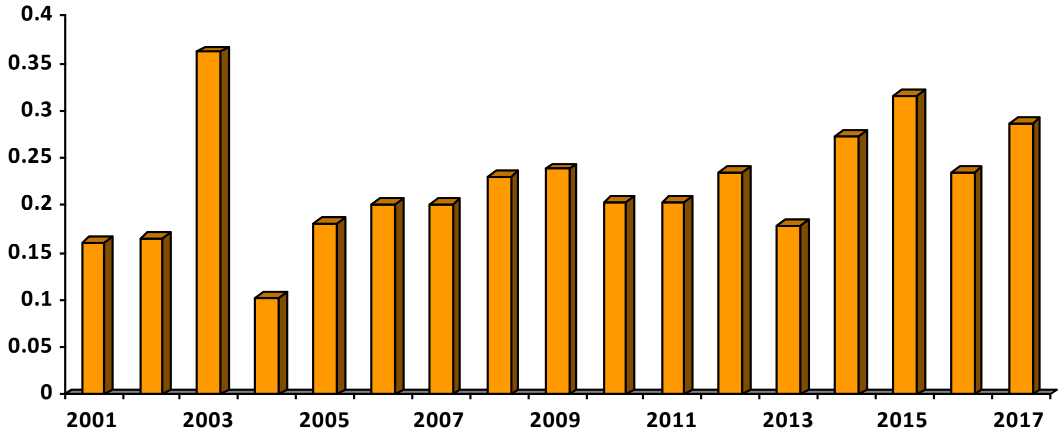


Figure 2. 14 Indirect N_2O from manure

2.4.3.6 Indirect Nitrous emissions from Livestock – 3.C.6

Despite the emissions coming from only one source category livestock, it is on the higher side. GHG inventory 1996-2000 established that 9.57 Gg from manure management. In the TNC, big contribution of nitrous emissions 63.4% came from poultry possible because of the concentrate diets that these species consume that have a relative higher crude protein percentage compared to diets of ruminants. In Malawi, 65% of the poultry population are commercial chickens and within this category, broilers are the predominant species. In the reporting period, there was a relative jump in poultry population from 2001 -2017 (Table 2.42) due to an increased number of entrepreneurs venturing into commercial poultry production. Due to high global warming potential of N_2O of 310 relative to 1 for CO_2, higher emissions from poultry should be a concern to the nation.

In the BUR, it was established that a total of 826.5 Gg of N_2O (Figure 2.18). A bigger contribution of N_2O came from goats, cattle and swine. Due to high global warming potential of N_2O of 310, high emissions of N_2O from these species should be a concern to the nation. There has been big jump due to increases of these species in the reporting period and also increases in fertilizer usage as a result implementation of Government Input Subsidy Programme starting from year 2004.

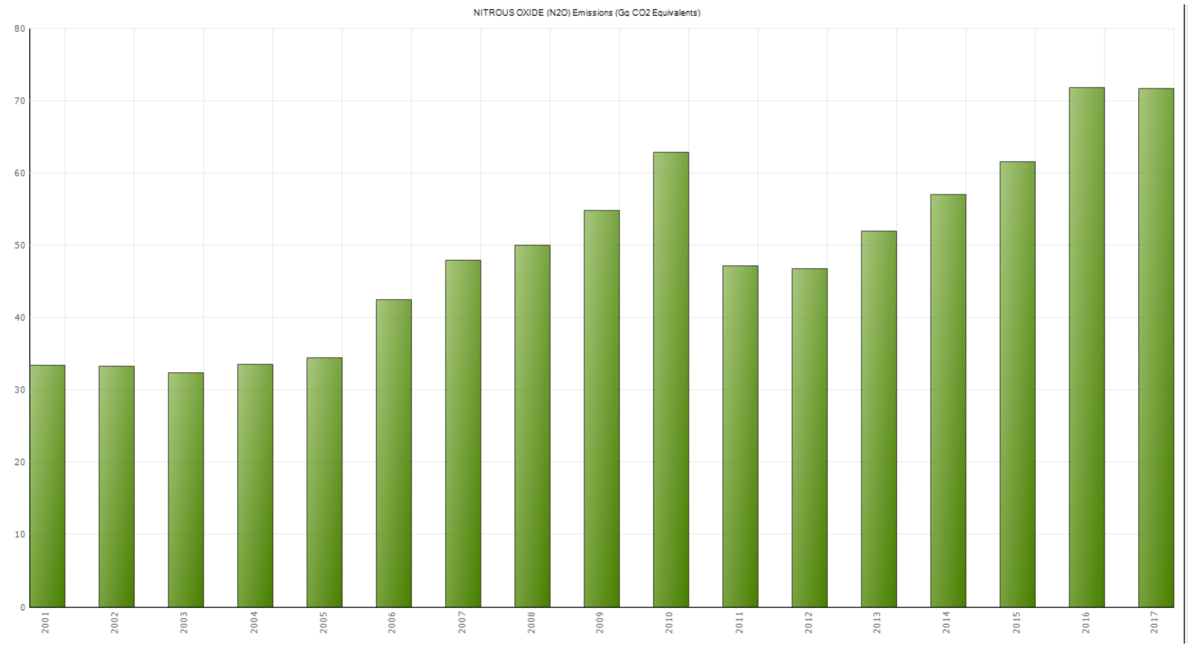


Figure 2. 15 Indirect N_2O Emissions (Gg/year), 2001-2017.

2.4.3.7 Rice Cultivations – 3.C.7

In Malawi, rice is mainly produced in areas along the lakeshore plain and river valleys, under two water production regimes: (i) rain-fed with intermittent irrigation during the wet months of December to May, and (ii) flood irrigation during the dry months of May to October. Figure 4.6 shows the total harvested land area for rice by year. The annual amount of CH_4 emitted was calculated based the area, number and duration of the crops grown, water regimes before and during the cultivation period, and organic and inorganic soil amendments according to Neue and Sass (1994) and Minami (1995). Soil type, temperature and rice cultivar also affect CH_4 emissions.

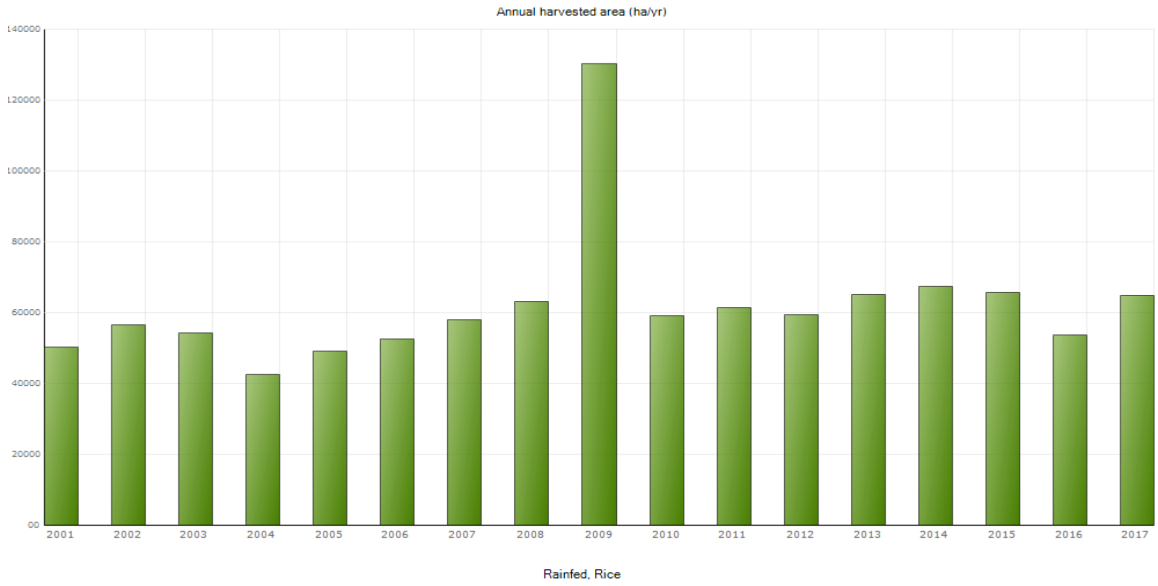


Figure 2. 16 Total harvested land area (Ha) for rice by year 2001-2017

A total of 103.9 Gg of CH_4 was emitted from rice cultivation in the period under review (2001-2017) as shown in Figure 4.7. This is relatively higher compared to the 5.13 Gg reported in the SNC,. The increase is attributed to establishment of new rice schemes by Government and development partners and also extension of existing rice schemes. In 2009, there was more rice cultivation because there was Government subsidy fertilizers for rice.

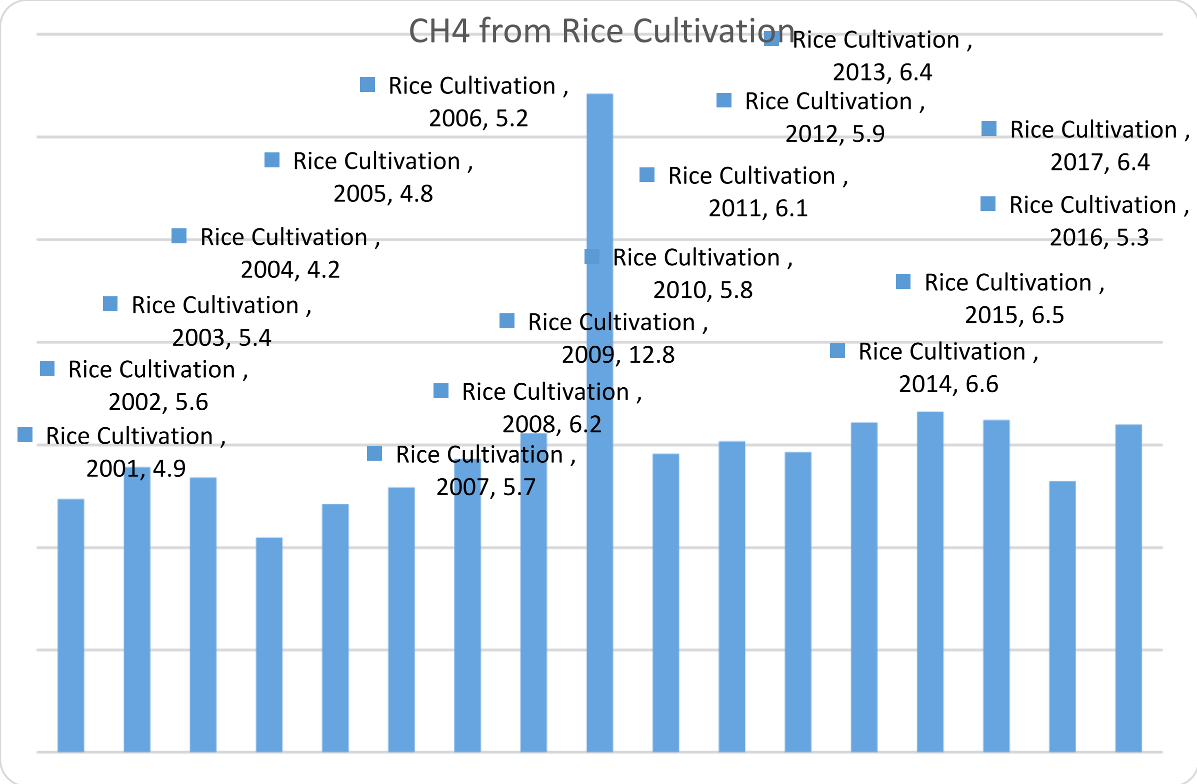


Figure 2. 17 CH_4 emissions (Gg) from rice cultivation, 2001-2017

A total of 24.05 Gg of CH_4 were emitted from rice cultivation as shown in Figure 4.7 over a nine-year period (2001-2017). About 99.5% of this was emitted from the intermittent flooded rice source category, whereas the continuously flooded rice source category contributed 0.5%. The CH_4 emissions from continuously flooded rice were generally lower because of the low hecterage grown to rice under this system of cultivation. The CH_4 emissions for the 1996-2000 GHG Inventory of 5.13 Gg is almost 5 times lower the present emission value of 24.05 Gg. This large increase in the present value can be attributed to expansion of old rice schemes and creation of new ones by Government projects as well as by Non-Governmental Projects.

2.4.4 GHG emissions and sinks from land - 3B

This section only covers emissions and removals in land uses other than agriculture. Besides agriculture, it does not include aggregate sources and non-CO_2 emission sources thus, liming, urea application, direct and indirect N_2O emissions from managed soils and manure management, and rice cultivation – all considered under the Agriculture section. Biomass burning in croplands is, however, included. Table 2.43 presents the emissions from land (3B) in 2010.

Table 2. 42: GHG emissions from land in 2010

Category	CO_2 emissions/ removals (Gg)	CH_4 emissions	N_2O emissions
3.B – Land	**-562.58**	**0.00**	**0.00**
3.B.1 - Forest land	-2626.93	0.00	0.00
3.B.1.a - Forest land Remaining Forest land	-2498.48		
3.B.1.b - Land Converted to Forest land	-128.45	0.00	0.00
3.B.1.b.i - Cropland converted to Forest Land	-106.45		
3.B.1.b.ii - Grassland converted to Forest Land	-9.30		
3.B.1.b.iii - Wetlands converted to Forest Land	-12.70		
3.B.1.b.iv - Settlements converted to Forest Land	0.00		
3.B.1.b.v - Other Land converted to Forest Land	0.00		
3.B.2 - Cropland	1589.39	0.00	0.00

Category	CO_2 emissions/ removals (Gg)	CH_4 emissions	N_2O emissions
3.B – Land	**-562.58**	**0.00**	**0.00**
3.B.2.a - Cropland Remaining Cropland	0.00		
3.B.2.b - Land Converted to Cropland	1589.39	0.00	0.00
3.B.2.b.i - Forest Land converted to Cropland	1589.38		
3.B.2.b.ii - Grassland converted to Cropland	0.00		
3.B.2.b.iii - Wetlands converted to Cropland	0.01		
3.B.2.b.iv - Settlements converted to Cropland	0.00		
3.B.2.b.v - Other Land converted to Cropland	0.00		
3.B.3 - Grassland	261.89	0.00	0.00
3.B.3.a - Grassland Remaining Grassland	0.00		
3.B.3.b - Land Converted to Grassland	261.89	0.00	0.00
3.B.3.b.i - Forest Land converted to Grassland	261.89		
3.B.3.b.ii - Cropland converted to Grassland	0.00		
3.B.3.b.iii - Wetlands converted to Grassland	0.00		
3.B.3.b.iv - Settlements converted to Grassland	0.00		
3.B.3.b.v - Other Land converted to Grassland	0.00		
3.B.4 - Wetlands	0.00	0.00	0.00
3.B.4.a - Wetlands Remaining Wetlands	0.00	0.00	0.00
3.B.4.a.i - Peatlands remaining peatlands	0.00		0.00
3.B.4.a.ii - Flooded land remaining flooded land			
3.B.4.b - Land Converted to Wetlands	0.00	0.00	0.00
3.B.4.b.i - Land converted for peat extraction			0.00
3.B.4.b.ii - Land converted to flooded land	0.00		
3.B.4.b.iii - Land converted to other wetlands			
3.B.5 - Settlements	24.78	0.00	0.00
3.B.5.a - Settlements Remaining Settlements	0.00		
3.B.5.b - Land Converted to Settlements	24.78	0.00	0.00
3.B.5.b.i - Forest Land converted to Settlements	24.78		
3.B.5.b.ii - Cropland converted to Settlements	0.00		
3.B.5.b.iii - Grassland converted to Settlements	0.00		
3.B.5.b.iv - Wetlands converted to Settlements	0.00		
3.B.5.b.v - Other Land converted to Settlements	0.00		
3.B.6 - Other Land	188.29	0.00	0.00
3.B.6.a - Other land Remaining Other land			
3.B.6.b - Land Converted to Other land	188.29	0.00	0.00
3.B.6.b.i - Forest Land converted to Other Land	188.29		
3.B.6.b.ii - Cropland converted to Other Land	0.00		
3.B.6.b.iii - Grassland converted to Other Land	0.00		
3.B.6.b.iv - Wetlands converted to Other Land	0.00		
3.B.6.b.v - Settlements converted to Other Land	0.00		

2.4.4.1 Methodology for the FOLU Sector

The FOLU inventory adopted the 2006 IPCC Guidelines for the estimation of the emissions and removals while employing both tier 1 and 2 estimation levels. As more refined activity data and new emission factors were developed, especially for the Miombo woodlands, recalculations were made for the period outside the reporting period, 2001 to 2017, further down to the year 1990. Activity data from the JICA-Malawi Government mapping initiative covered epochs 1990, 2000 and 2010. Data between the three epochs was linearly interpolated while extrapolation was conducted for the period 2011 to 2017. Due to paucity of data in literature for uncertainty tests, unlike in other sectors like energy, uncertainty tests were not conducted for the FOLU sector.

The GHGs were estimated using Approach 1 (reporting total land-use area without conversions between land uses) and partly approach 2, where land use conversions and data between land cover classes is available. The classes are Forestland, Cropland, Grasslands, Wetlands, Settlements, and Other Land. Except for wetlands, all the other five classes are considered as managed in the country's context. The six land classes are nationally defined as indicated in Table 2.44, and their distribution in Malawi are presented in Figure 2.22.

Table 2. 43: Malawi's land use classes and their definitions

Land Use Class	Definition
Forestland	Land with woody vegetation consistent with thresholds used to define forest land. These thresholds are minimum mapping area or unit (MMU), minimum crown closure at maturity, minimum height, and minimum width of linear features. Recommended definition thresholds for the GoM are a minimum mapping area of 0.5 hectare, a minimum 10% crown closure, a minimum height of 5 meters, and a minimum linear feature width of 20 meters.
Cropland	Arable and tillage land, and agroforestry systems where vegetation falls below the thresholds used to define forest land. The FAO Land Cover Classification System (LCCS) calls these Agriculture Lands.
Grassland	Rangelands and pastureland that is not considered cropland.
Wetlands	Land that is covered or saturated by water for all or part of the year and that does not fall into the previous categories or settlements.
Settlements	developed land, including transportation infrastructure and human settlements of any size unless they are already included under other categories.
Other Land	Bare ground, rock, and all unmanaged land not in the previous categories.

Source of Definitions: McGann, 2015

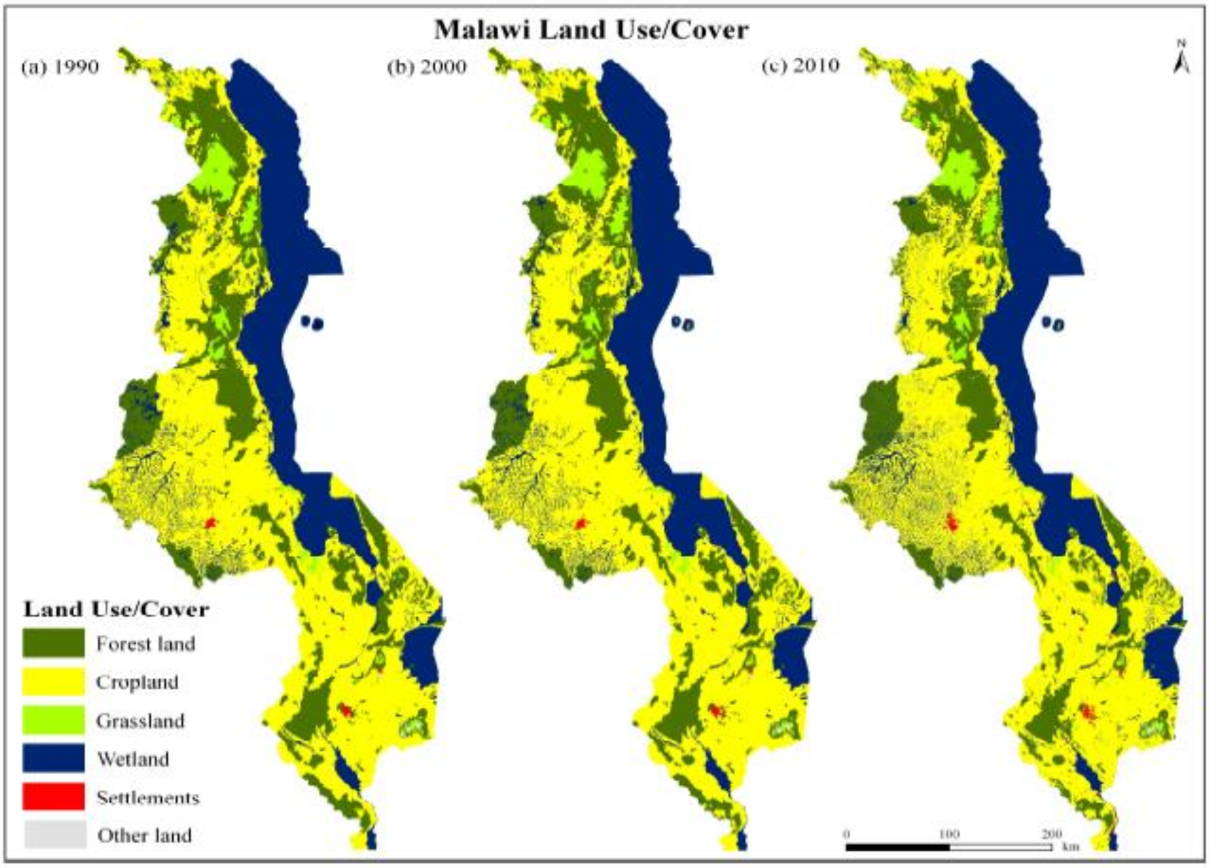


Figure 2. 18 Land cover distribution in Malawi (GoM, 2012)

A. Forest Land

i) Deforestation, forest gains and total forest area

Forest land remains key in GHG estimations for Malawi as both a source and sink of GHGs. For improved estimation of the GHG emissions and removals, forest land from the Malawi Government-Japan mapping initiative was stratified into three main forest sub-classes in Malawi, i.e. the indigenous *Miombo* that are predominantly *Brachystegia* and *Julbernardia*;

and Forest Plantations that are predominantly *Eucalyptus* and Pine. Despite that the Malawi Government – Japan mapping initiative did not have these sub-classes, data on proportions of forest land from other sources (GoM, 2010) were used to further subdivide the total land mass for forest into these three sub-classes in proportions of 89, 9, and 3% for the *Miombo*, *Eucalyptus* and pines respectively.

Out of a total country area of 11,832,040ha utilized in the land classification, Malawi's total forest area as at the reporting time was 2,338,859ha. Segregated distribution of area by land class and forest sub-class is presented in Table 2.45. The forest area has steadily declined from 2,577,396 ha in 2001 (Figure 2.21). Over the sixteen-year reporting period, from 2001 to 2017, Malawi has lost about 238,537ha, thus a deforestation rate of 14, 909 ha per annum. This deforestation continually stems from massive pressure from human activities related to agricultural expansion and unsustainable harvesting of fuelwood and timber (GoM, 2010; Ministry of Natural Resources, Energy and Mines, 2019).

Table 2. 44: Area distribution by land classes and forest sub-classes (in ha)

Year	*Miombo*	Pine	*Eucalyptus*	Cropland	Grassland	Wetlands	Settlements	Other Lands
1990	2,352,234	79,289	211,437	5,773,900	351,620	3,022,870	22,430	18,260
1991	2,347,978	79,145	211,054	5,781,798	350,044	3,021,554	22,588	17,878
1992	2,343,722	79,002	210,672	5,789,696	348,468	3,020,238	22,746	17,496
1993	2,339,466	78,858	210,289	5,797,594	346,892	3,018,922	22,904	17,114
1994	2,335,210	78,715	209,907	5,805,492	345,316	3,017,606	23,062	16,732
1995	2,330,955	78,572	209,524	5,813,390	343,740	3,016,290	23,220	16,350
1996	2,326,699	78,428	209,141	5,821,288	342,164	3,014,974	23,378	15,968
1997	2,322,443	78,285	208,759	5,829,186	340,588	3,013,658	23,536	15,586
1998	2,318,187	78,141	208,376	5,837,084	339,012	3,012,342	23,694	15,204
1999	2,313,931	77,998	207,994	5,844,982	337,436	3,011,026	23,852	14,822
2000	2,309,675	77,854	207,611	5,852,880	335,860	3,009,710	24,010	14,440
2001	2,293,882	77,322	206,192	5,861,746	334,078	3,017,760	26,741	14,319
2002	2,278,090	76,790	204,772	5,870,612	332,296	3,025,810	29,472	14,198
2003	2,262,298	76,257	203,353	5,879,478	330,514	3,033,860	32,203	14,077
2004	2,246,506	75,725	201,933	5,888,344	328,732	3,041,910	34,934	13,956
2005	2,230,714	75,193	200,514	5,897,210	326,950	3,049,960	37,665	13,835
2006	2,214,922	74,660	199,094	5,906,076	325,168	3,058,010	40,396	13,714
2007	2,199,129	74,128	197,675	5,914,942	323,386	3,066,060	43,127	13,593
2008	2,183,337	73,596	196,255	5,923,808	321,604	3,074,110	45,858	13,472
2009	2,167,545	73,063	194,836	5,932,674	319,822	3,082,160	48,589	13,351
2010	2,151,753	72,531	193,416	5,941,540	318,040	3,090,210	51,320	13,230
2011	2,141,729	72,193	192,515	5,949,922	316,361	3,093,577	52,765	12,979
2012	2,131,705	71,855	191,614	5,958,304	314,682	3,096,944	54,210	12,727
2013	2,121,681	71,517	190,713	5,966,686	313,003	3,100,311	55,655	12,476
2014	2,111,657	71,179	189,812	5,975,068	311,324	3,103,678	57,100	12,224
2015	2,101,633	70,842	188,911	5,983,450	309,645	3,107,045	58,545	11,973
2016	2,091,609	70,504	188,010	5,991,832	307,966	3,110,412	59,990	11,721
2017	2,081,585	70,166	187,109	6,000,214	306,287	3,113,779	61,435	11,470

The land conversions that occurred from 1990 to 2017 are shown in Figure 2.23

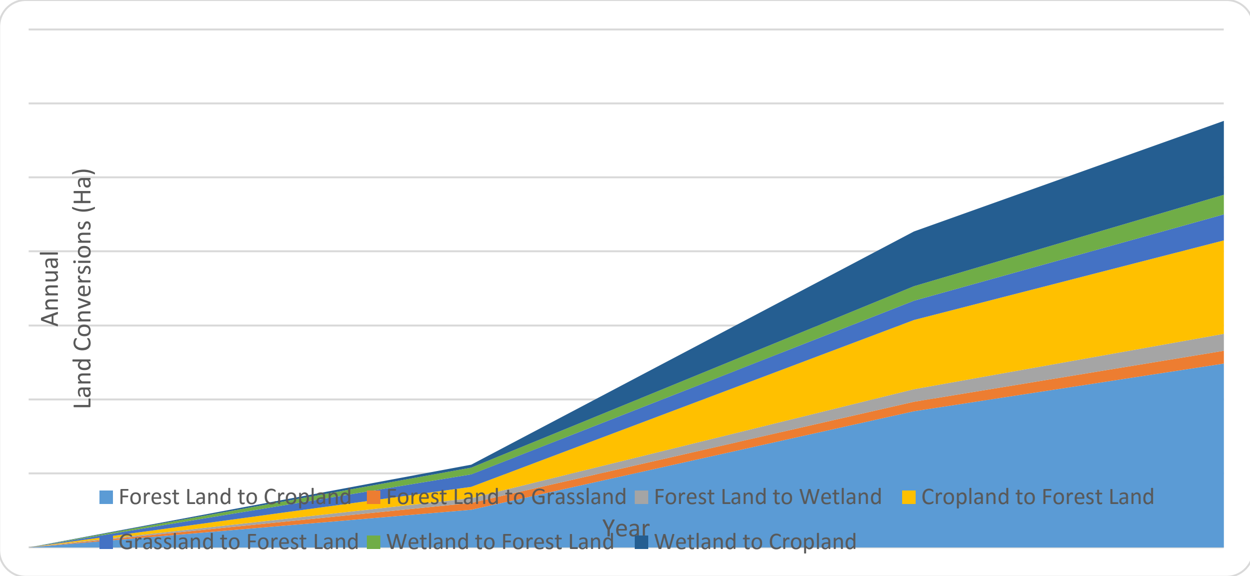


Figure 2. 19 Land conversions between the land classes from 1990 to 2017

Reforestation, which includes natural regeneration, afforestation and reforestation (A/R), occurs across Malawi. This is the total land area transitioning annually from other land uses (non-forest classes) to forests during the period between 2001 and 2017. Reforestation is reportedly around 9,354ha per annum. hence representing a net deforestation rate of around 5,556ha per annum.

There are a number of published sources from the miombo woodland ecoregion reporting on annual biomass gains of miombo woodlands and Malawi's plantation species following afforestation/regeneration. Walker et al. (2015), summarized these annual biomass gains from different sources (Table 4.10). These values were used in this study to estimate sequestration resulting from afforestation and natural regeneration.

Table 2. 45: Growth rates for the various forest types planted or naturally regenerating

Forest type	*Growth rate (t C ha^{-1} yr^{-1}*				*Source*
	Up to 20 years		After 20 years		
	AG	BG	AG	BG	
Miombo woodlands	0.7	0.39	0.7	0.39	Williams et al., 2008
Eucalyptus	10	2.1	12.5	2.63	Mercer et al., 2011; Kuyah et al., 2015
Pinus	8.2	1.7	8.2	1.7	GoM National Forest Inventory 2004

Source: Walker et al. (2015)

Emission factors for the miombo were developed during an NFI initiative by Malawi Government – USAID, thus 91.8 t.d.mha $^{-1}$for above-ground and below-ground BGB (Ministry of Natural Resources, Energy, Mines; 2019). Default IPCC values were used for the other forest types - *Eucalyptus* and Pine plantations both for above ground and below ground carbon. The dead wood pool was assumed to have a zero emission, following a Tier 1 assumption that the carbon stocks in dead wood do not significantly change over time if the land remains within the same land-use category. Furthermore, Malawi's populace is highly dependent on fuel wood and less wood is left lying for longer periods in the forestlands unlike in other highly significant areas like peatlands. Annual wood removals (Table 4.11) were obtained from FAO.

Table 2. 46: Wood removals

Year	Total wood removals (m^3)	Fuelwood (m^3)
1990	6 044 443	5164443
1991	6 002 063	5122063
1992	6 132 139	5207139
1993	5 918 708	4988708
1994	6 031 330	5101330
1995	6 296 283	4896283
1996	6 201 751	4801751
1997	6 227 059	4827059
1998	6 281 301	4881301
1999	6 321 718	4921718
2000	6 364 075	4964075
2001	6 395 659	4995659
2002	6 429 117	5029117
2003	6 464 449	5064449
2004	6 501 655	5101655
2005	6 540 741	5140741
2006	6 589 348	5189348
2007	6 640 100	5240100
2008	6 693 000	5293000
2009	6 748 068	5348068
2010	6 805 340	5405340
2011	6865603	5465603
2012	7 023 097	5528235
2013	7 105 715	5593238
2014	7 191 419	5660730
2015	7 280 252	5730655
2016	7 354 319	5788956
2017	7 431 273	5849531
2018	7 023 097	5912397

Sources: FAO,2015; FAO, 2020;

Expert judgement was used to split wood removals in the following proportions: 85% Miombo; 10% Pine and 5% Eucalyptus

For wood density, the mean value of 0.63 (g cm^{-3}) for *Miombo* species(Abbot et al., 1999) was used to convert the volume values to biomass with default IPCC values such as biomass expansion factors and root to shoot ratios adopted. The default carbon fraction of 0.47 was used in the calculations. Default IPCC emission factors and related values were used for non-forest lands.

B) Non-forest Lands

Forest land has been observed to be the major land cover being converted into other land use types in Malawi. No further stratification for land other than forest was considered due to time limitations and need to collate additional data. As Malawi is predominantly annual cropland, Cropland was conservatively assumed to be all annual cropland other than perennial. However, this has been considered for the improvement plan for the next inventory cycle.

C) Soils and Climate

Default Tropical Dry Climate for Malawi in combination with the predominant HAC.

2.4.4.2 Emissions from land use

Figures 4.10 presents the FOLU sector net Gg emission by source and their trends. Malawi's forest sink drastically declining from 10,952.2 Gg CO_2 in 2001 to 9,032.5 Gg CO_2in 2017. 'Forest land remaining forest Land' and conversion of forest land to cropland (1,589.4 Gg CO_2per annum) were the key sink and emission sources within this sector in this reporting period. Grassland, Settlements and Other Land accounted for average net CO_2eq missions of 261.9, 24.8 and 188.3Gg CO_2per annum.

Forest conversion in the SNC was reported to be accounting for 2,088.3 Gg CO_2per annum while the current inventory estimates it between 2,064.3 and 2,084.4Gg CO_2per annum. This has resulted in net emissions between 6,968.2 and 9,358.3Gg CO_2per annum. Previous communications reported emissions between 17,512 and 21,200.3, and removals between 889.4 and 1,320 Gg CO_2per annum. The discrepancies may be due to different activity data and emission factors used in the estimations. Despite the inconsistencies in some of the figures, charcoal and firewood production are some of the other factors further fuelling rapid decline in forest cover in Malawi. Reports indicate that fuelwood and charcoal are the main sources of CO_2 emissions in Malawi, accounting for 97% of energy use in Malawi (Kambewa and Chiwaula, 2010).

Figure 2.24 presents the GHG emissions and removals from land from 1990 to 2017.

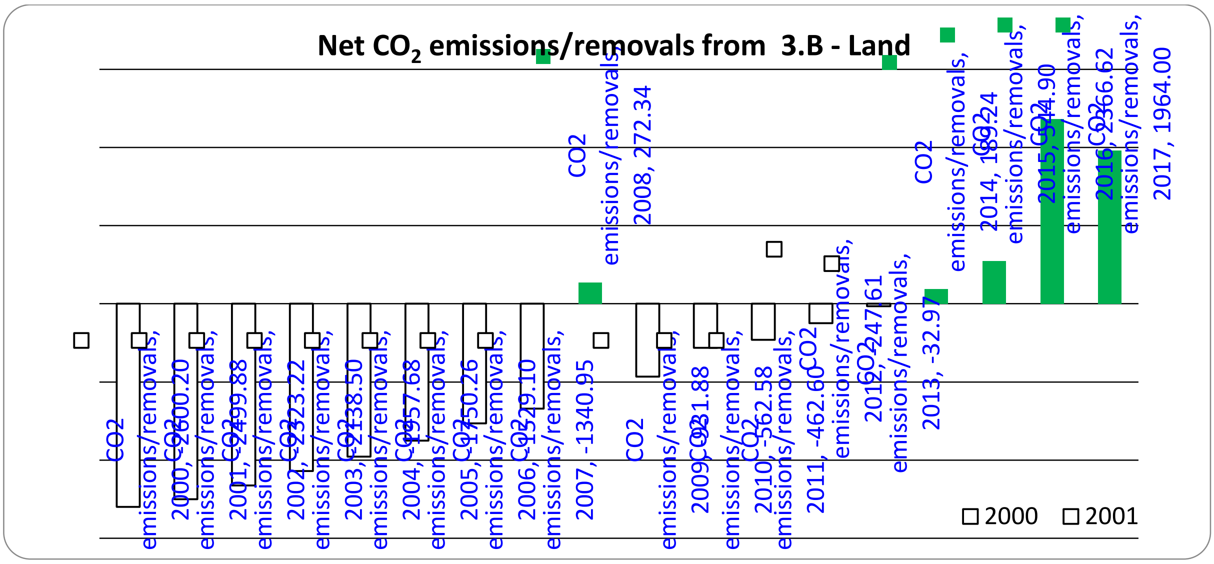


Figure 2. 20 FOLU sector emissions by source and trends

2.4.4.3 Aggregate sources and non-CO_2 emissions sources on land - 3.C

The non-CO_2 emissions from land In 2010 are shown in Table 2.47.

Table 2. 47: Non-CO_2 emissions sources on land - 3.C

	Net CO_2	CH_4	N_2O
3.C - Aggregate sources and non-CO_2 emissions sources on land(2)	88.71	7.32	0.03
3.C.1 - Emissions from biomass burning	0.00	1.49	0.00
3.C.1.a - Biomass burning in forest lands		1.29	0.00
3.C.1.b - Biomass burning in croplands		0.01	0.00
3.C.1.c - Biomass burning in grasslands		0.19	0.00
3.C.1.d - Biomass burning in all other land		0.00	0.00

2.4.4.4 Emissions from biomass burning – 3.C.1

Only losses of carbon stocks due to fires were considered in this inventory. Other disturbances such as wind, and pest and disease outbreaks were considered insignificant. The statistics of the burnt areas were acquired from Global Forest Resource (FRA) assessment and distributed proportionately to forest sub-types and other land classes. Biomass burning utilized combustion values and fuel loads from regionally existing studies (Hoffa et al., 1999).

The FOLU sector contributes N_2O, Carbon dioxide (CO_2) and CH_4 and Carbon monoxide (CO) gases to the national emissions. In the reporting period, CO_2 was clearly the most significant for the FOLU sector. However, with regard to biomass burning, over the reporting period, CO_2 was the most significant gas (35,093.9 1Gg of CO_2eq) as compared to the other gases (Figure 4.11) with the amounts varying from year to year (Table 4.12). The second most significant gas was CO at 315.6 1Gg of CO_2 eq. The least significant gas was N_2O with less than 1Gg of CO_2eq for the whole reporting period. Malawi's initial communication also showed similar trends with relatively high CO for LUCF.

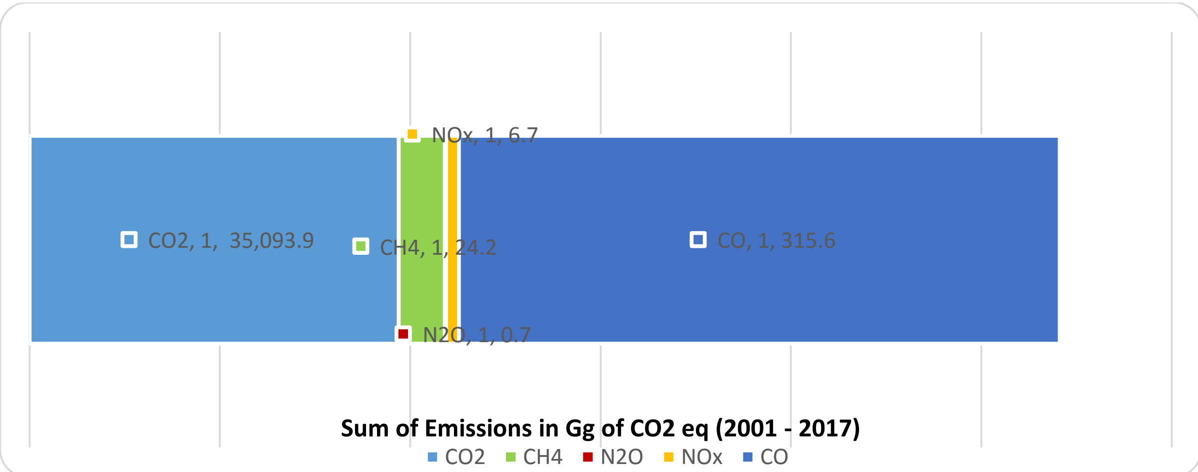


Figure 2. 21 Emissions from biomass burning (2001 – 2017)

The trend of non-CO_2 emissions from biomass burning is shown in Table 2.48. The emissions were fluctuating over the whole time series.

Table 2. 48: Trends in gases for biomass burning (1990 – 2017)

Year	Source	CH_4 (Gg)	N_2O (Gg)	NOx (Gg)	CO (Gg)
1990	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	1.164
1991	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	0.000
1992	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	1.164
1993	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	0.000
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.000	0.000
1994	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	1.164
1995	3.C.1.a - Biomass burning in forest lands	0.837	0.025	0.197	12.804
	3.C.1.b - Biomass burning in croplands	0.005	0.000	0.005	0.169
	3.C.1.c - Biomass burning in grasslands	0.122	0.004	0.070	0.000
1996	3.C.1.a - Biomass burning in forest lands	0.475	0.014	0.112	7.258
	3.C.1.b - Biomass burning in croplands	0.013	0.000	0.012	0.450
	3.C.1.c - Biomass burning in grasslands	0.069	0.002	0.040	0.000
1997	3.C.1.a - Biomass burning in forest lands	0.289	0.008	0.068	4.420
	3.C.1.b - Biomass burning in croplands	0.013	0.000	0.012	0.454
	3.C.1.c - Biomass burning in grasslands	0.042	0.001	0.024	0.402
1998	3.C.1.a - Biomass burning in forest lands	0.381	0.011	0.090	5.825
	3.C.1.b - Biomass burning in croplands	0.013	0.000	0.012	0.456
	3.C.1.c - Biomass burning in grasslands	0.055	0.002	0.032	0.000
1999	3.C.1.a - Biomass burning in forest lands	0.351	0.010	0.083	5.367
	3.C.1.b - Biomass burning in croplands	0.010	0.000	0.009	0.342
	3.C.1.c - Biomass burning in grasslands	0.051	0.002	0.029	0.488
2000	3.C.1.a - Biomass burning in forest lands	0.097	0.003	0.023	1.479
	3.C.1.b - Biomass burning in croplands	0.018	0.000	0.017	0.699
	3.C.1.c - Biomass burning in grasslands	0.014	0.000	0.008	0.134
2001	3.C.1.a - Biomass burning in forest lands	0.690	0.020	0.162	10.549
	3.C.1.b - Biomass burning in croplands	0.022	0.001	0.020	0.735
	3.C.1.c - Biomass burning in grasslands	0.100	0.003	0.058	0.000
2002	3.C.1.a - Biomass burning in forest lands	0.435	0.013	0.102	6.658
	3.C.1.b - Biomass burning in croplands	0.006	0.000	0.005	0.189
	3.C.1.c - Biomass burning in grasslands	0.063	0.002	0.036	0.605
2003	3.C.1.a - Biomass burning in forest lands	0.959	0.028	0.226	14.665
	3.C.1.b - Biomass burning in croplands	0.006	0.000	0.006	0.219
	3.C.1.c - Biomass burning in grasslands	0.140	0.004	0.080	1.334
2004	3.C.1.a - Biomass burning in forest lands	0.283	0.008	0.067	4.328
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.094
	3.C.1.c - Biomass burning in grasslands	0.041	0.001	0.024	0.394
2005	3.C.1.a - Biomass burning in forest lands	1.255	0.037	0.295	19.191
	3.C.1.b - Biomass burning in croplands	0.004	0.000	0.004	0.140
	3.C.1.c - Biomass burning in grasslands	0.183	0.006	0.105	1.745
2006	3.C.1.a - Biomass burning in forest lands	0.245	0.007	0.058	3.744
	3.C.1.b - Biomass burning in croplands	0.001	0.000	0.001	0.028
	3.C.1.c - Biomass burning in grasslands	0.036	0.001	0.020	0.000
2007	3.C.1.a - Biomass burning in forest lands	0.259	0.008	0.061	0.000
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.019
	3.C.1.c - Biomass burning in grasslands	0.038	0.001	0.022	0.360
2008	3.C.1.a - Biomass burning in forest lands	0.755	0.022	0.178	11.549
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.099
	3.C.1.c - Biomass burning in grasslands	0.110	0.003	0.063	1.050
2009	3.C.1.a - Biomass burning in forest lands	0.291	0.009	0.069	4.455
	3.C.1.b - Biomass burning in croplands	0.007	0.000	0.006	0.227
	3.C.1.c - Biomass burning in grasslands	0.042	0.001	0.000	0.000
2010	3.C.1.a - Biomass burning in forest lands	1.293	0.038	0.304	19.775
	3.C.1.b - Biomass burning in croplands	0.009	0.000	0.008	0.294
	3.C.1.c - Biomass burning in grasslands	0.188	0.006	0.108	1.798
2011	3.C.1.a - Biomass burning in forest lands	0.639	0.019	0.150	9.775
	3.C.1.b - Biomass burning in croplands	0.002	0.000	0.002	0.000
	3.C.1.c - Biomass burning in grasslands	0.031	0.003	0.053	0.889
2012	3.C.1.a - Biomass burning in forest lands	1.272	0.037	0.299	19.458
	3.C.1.b - Biomass burning in croplands	0.002	0.000	0.002	0.068
	3.C.1.c - Biomass burning in grasslands	0.185	0.006	0.106	1.769
2013	3.C.1.a - Biomass burning in forest lands	0.938	0.028	0.221	0.000
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.099
	3.C.1.c - Biomass burning in grasslands	0.136	0.004	0.078	1.305
2014	3.C.1.a - Biomass burning in forest lands	1.618	0.048	0.381	24.751
	3.C.1.b - Biomass burning in croplands	0.001	0.000	0.001	0.039
	3.C.1.c - Biomass burning in grasslands	0.080	0.007	0.135	0.000
2015	3.C.1.a - Biomass burning in forest lands	1.448	0.043	0.341	22.153
	3.C.1.b - Biomass burning in croplands	0.004	0.000	0.004	0.147
	3.C.1.c - Biomass burning in grasslands	0.211	0.007	0.121	2.014
2016	3.C.1.a - Biomass burning in forest lands	1.618	0.048	0.381	24.751
	3.C.1.b - Biomass burning in croplands	0.001	0.000	0.001	0.039
	3.C.1.c - Biomass burning in grasslands	0.235	0.007	0.135	2.251
2017	3.C.1.a - Biomass burning in forest lands	0.741	0.022	0.174	11.334
	3.C.1.b - Biomass burning in croplands	0.003	0.000	0.003	0.114

	3.C.1.c - Biomass burning in grasslands	0.108	0.003	0.062	0.000

2.4.4.5 Harvested Wood Products (HWP) - 3D

GHG emissions from HWP were estimated for the period 1990 to 2000 (Table 4.13). Emissions and removals from HWP had not been estimated in previous communications.

Table 2. 49: GHG emissions from HWP

3.D - Other	-152.7	0.00	0.00	0.00	0.00	0.00
3.D.1 - Harvested Wood Products	-152.7			0.00	0.00	0.00
3.D.2 - Other (please specify)				0.00	0.00	0.00

Statistics for timber harvests in the form of round wood, sawn wood, wood-based panels and industrial round wood were obtained from FAOSTAT. The FAO data was consolidated into harvested wood products/types as indicated in Table 2.50. Simple decay approach was the methodology used in the estimation of the emissions.

Table 2. 50: Categorization of wood types for HWP for Malawi

Wood Type	Sub-categories
Round wood	Wood fuel, coniferous; Wood fuel, non-coniferous; and Wood fuel, all species.
Sawnwood	Sawnwood, coniferous; and Sawnwood, non-coniferous.
Wood-based Panels	Veneer sheets; Plywood; Particle board and OSB; Particle board; OSB; Hardboard; MDF/HDF; Other fibreboard; and Fibreboard, compressed.
Wood Pulp and Recovered Paper	Mechanical wood pulp; Semi-chemical wood pulp; Chemical wood pulp; Chemical wood pulp, sulphate, bleached and unbleached; Dissolving wood pulp; Pulp from fibres other than wood; Recovered fibre pulp; Recovered paper; Newsprint; Printing and writing papers; Printing and writing papers, uncoated, mechanical; Printing and writing papers, uncoated, wood free; and Printing and writing papers, coated.
Paper and Paperboard	Other paper and paperboard; Household and sanitary papers; Wrapping and packaging paper and paperboard; Case materials; Carton board; Wrapping papers; Other papers mainly for packaging; and Other paper and paperboard not elsewhere specified.
Industrial Roundwood	Industrial roundwood, coniferous; Industrial roundwood, non-coniferous; Sawlogs and veneer logs, coniferous; Sawlogs and veneer logs, non-coniferous; Other industrial roundwood, coniferous; Other industrial roundwood, non-coniferous; and Other industrial roundwood, all species.
Chips and Particles	Wood chips and particles
Wood Charcoal	Wood charcoal
Wood Residues	Wood residues

HWPs accounted for net removals between 68.2 and 157.4 1 Gg of CO_2 per annum (Figure 4.12). While this total GHG removal is on a decline between 92.9 and 68.2 1Gg of CO_2 per annum between 1990 and 2007, there is contrasting general increase 85.4 and 157 1Gg of CO_2 between 2008 and 2017.

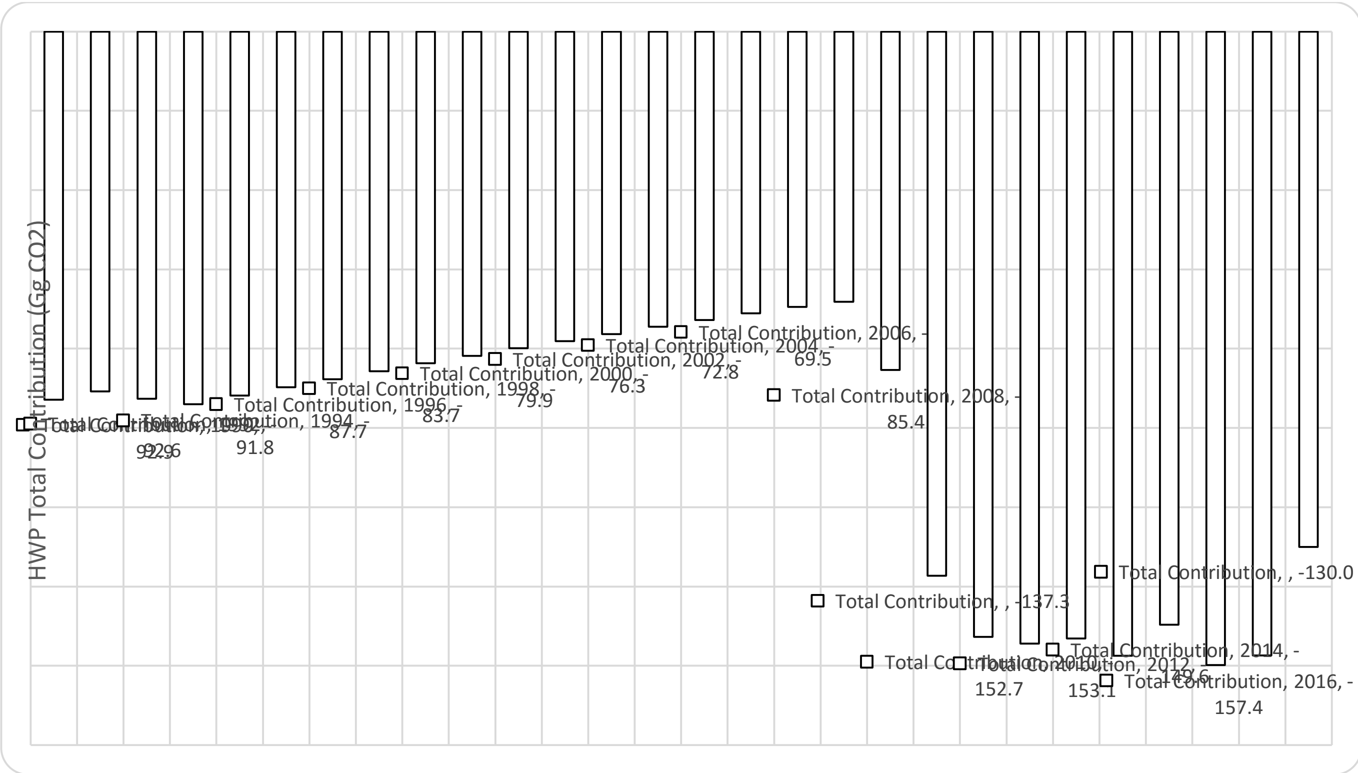


Figure 2. 22 GHG emissions from harvested wood from 1990 to 2017

2.5 Planned improvements

While there is need to improve the monitoring system through sustained capacity building and improvement of its core elements such as data archiving, specific to the inventory, in the next inventory cycle, there is need to:

- Classify crop types into perennial and annual cropland and determine their distribution extent within the country.
- Further classify forest land and cropland into two key soil types (HAC and LAC) and determine their distribution by Malawi's climate – tropical dry climate**.**
- Properly document the sector's uncertainties of the estimates as well as overall uncertainties of the whole inventory.
- Extend calculations of HWP data to year 1911 other than the existing year of 1961 as in the current inventory.

2.6 Waste

2.6.1 Waste Sector GHG emissions in Malawi

In 2010, the Waste sector in Malawi contributed 1004.06Gg CO_2eq with 47.37% coming from Wastewater Treatment and Discharge (4D), 42.17% from Solid waste disposal (4A), and 10.46% from Incineration and Open burning of waste (4.C). The GHG emission are presented in Table 2.51.

Table 2. 51: Waste sector GHG emissions by mass (Gg)-2010

Source category	CO_2	CH_4	N_2O	Total	%
4 - Waste	9.13	803.17	191.77	1004.06	100.00%
4.A - Solid Waste Disposal		423.42		423.42	42.17%
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					
4.C - Incineration and Open Burning of Waste	9.13	80.28	15.59	104.99	10.46%
4.C.1 - Waste Incineration					
4.C.2 - Open Burning of Waste	9.13	80.28	15.59	104.99	10.46%
4.D - Wastewater Treatment and Discharge		299.47	176.18	475.65	47.37%
4.D.1 - Domestic Wastewater Treatment and Discharge		299.47	176.18	475.65	47.37%
4.D.2 - Industrial Wastewater Treatment and Discharge					
4.E - Other (please specify)					

2.6.2 Waste management in Malawi

Waste management in Malawi is practiced with limited capacity in urban Councils (Cities and towns) and almost insignificant in the rural areas. In Lilongwe (the Capital City of Malawi), its Council only manages to collect 10-20 % of the total solid waste generated within the City per day. This is because, often, waste collection is not a main priority in most of the councils due to limited budget. This was even evident during the time of data collection, as waste management data was not readily available in various Councils during data collection, which would simply indicate that it is not systematically recorded. The main challenges were the lack of resources and/or responsible personnel for waste management data collection.

The main data providers for the Waste sector were:Balaka, Blantyre City Council, Dedza town Council, Karonga town Council, Kasungu town Council, Lilongwe City Council, Machinga town Council, Mangochi town Council, Mulanje town Council, Mzuzu City Council, Salima town/district Council, Zomba City Council,

2.6.3 Developing activity data and Calculation values

Waste activity data was obtained from twelve selected Councils, based on the previous study by Chipofya (2003). This was done with an aim of establishing a trend, at the same time appreciating the changes in the Waste sector in Malawi. The targeted data sources were councils owing to their delegated responsibility to manage waste. In Malawi, Councils are also responsible for waste collection and disposal, as well as compiling waste management data.

The twelve selected councils were chosen on the basis that, they are among councils known to generate a relative significant amount of waste compared to others. The selection also aimed to cover almost all geographical parts of Malawi e.g. North, Central, South and Eastern region, in order to ensure adequate representativeness of the data. The study was initially done in 2014 after receiving initial funding, and later repeated in 2017 in those councils, whose data was not convincingly representative due to some limiting factors, when the second funding was received.

The total selected Councils are as follows:

- *Northern Region:* Karonga town Council, Mzuzu City Council
- *Central Region:* Kasungu town Council, Lilongwe City Council, Salima town/district Council, Dedza town Council.
- *Southern Region:* Blantyre City Council, Zomba City Council, and Mulanje town Council
- *Eastern Region:* Mangochi town Council, Balaka and Machinga town Council.
- Out of these areas, the Councils where samples were retaken were; Deza, Mangochi, Salima, Kasungu, Balaka and Machinga

2.6.4 Methods of Data Collection and Analysis

2.6.4.1.1 Data Collection

The data collection procedure was in two fold;
1. Sample collection and Laboratory analysis
2. Structured questionnaire interview

Sample collection and Laboratory analysis

Waste samples were collected in all councils in two forms, solid waste from the SWDS and liquid waste from the liquid waste treatment plant/sewerage, where available. The collected samples were then taken to the laboratory for chemical analysis on the following parameters; *Dry matter, Fraction of Carbon, Carbon Content, Fraction of Carbon in dry matter, total Nitrogen, Protein Content* etc. The outcome values to this were the ones which were used to calculate the required data for GHG emissions.

Structured questionnaire interview

The Questionnaire was developed with an aim of capturing some information which could not be established through laboratory analysis but may still be useful during the calculation. Such data included population of the particular town, district or city, amount of waste generated in that particular area, composition of waste in percentage in the area, and any other parameters which were required according to the formula and method of calculation. The captured values were used together with the lab values for the actual calculations.

Apart from the above-mentioned tools of data collection, the team also relied on the literature review to establish the existing data and at the same time validate the sampled data. The literature review benefited from many sources in line and relevant to the subject of GHG and emissions, but among them the most used were;

- Waste Management World Bank Report, 2012
- 2006 IPCC Guidelines
- Malawi Second National Communication, 2011
- NSO Website for Populations Census
- Solid Waste GHG Emissions baseline study for Lilongwe City
- PERFOM, 2017.

2.6.5 Findings

It was observed that most Councils have no stable site for Solid waste disposal. As such, most of them simply secured temporary land to utilize. The land used had no proper security to develop permanent structures, assuming there are intentions to develop such sites**.** Examples are cases of Mangochi, Dedza, Karonga, and Luchenza and even Zomba; where solid waste was simply dumped in a forest or bush and sometimes some trenches which were excavated during road construction projects, this had effects of having multiple micro disposal sites which were being used interchangeably based on the willingness of the of the Land owner. Such practices had a negative bearing on efforts to establish the historical data on waste management practices and composition.

Even in cases where the site was considered stable, most Councils had no proper documentation for proof of ownership of the land, a situation which indicated questions on land ownership. Much as there were officers (EDO) assigned with a responsibility on waste management issues among other Environmental issues, it appeared that the area of waste management was not prioritised. This was evidenced by the way in which most of the officers could struggle to produce data on waste management when responding to the structured questionnaire. Despite some Urban Councils having the formal sites for disposal, it was noted that the method of disposal in all the Councils (sites) visited was open or crude dumping with no further treatment.

Most Councils to fail implement proper waste management practices due to numerous challenges, such as;

- Inadequate waste collection vehicles, inadequate fuel allocation for waste collection vehicles and high frequency rate of vehicle downtime.
- Indiscriminate disposal of waste at all levels of the society (burning, dumping in open space);
- Limited waste collection services to households (waste is collected mainly from low and medium density areas), institutions and other commercial entities
- Weak enforcement of the laws and by-laws governing solid waste management in the cities;
- Inadequate communal bins in residential areas, irregular collection schedules and non-collection of waste resulting in waste over spilling onto the surrounding areas causing nuisance and posing health risks;
  (Munthali et al., 2016)

Waste Composition
In Malawi, solid waste, on average, constitutes: (i) Organic matter (70 - 90%),
(ii) Plastic and rubber (4-10%), (iii) paper (4-7%), (iv) Metal (1.0 %), (v) Textile (0.5%), and (vi) Glass (0.5%) (Chinyama and Mandhlopa, 1999).

2.6.6 4A Solid Waste Disposal

2.6.7 Waste Management and GHG emissions

The treatment and disposal of municipal, industrial and other solid waste releases large amounts of methane (IPCC, 2006). Methane produced at solid waste disposal sites (SWDS) contributes about 3 to 5% of the annual global anthropogenic GHG emissions (IPCC, 2001; *World Bank, 2012*). Further, degradable organic carbon methane production starts one or two years after waste is deposited in landfills (Chipofya, 2003). In Malawi, there was steady increase of CH_4 emissions from solid waste from 2001 to 2017.

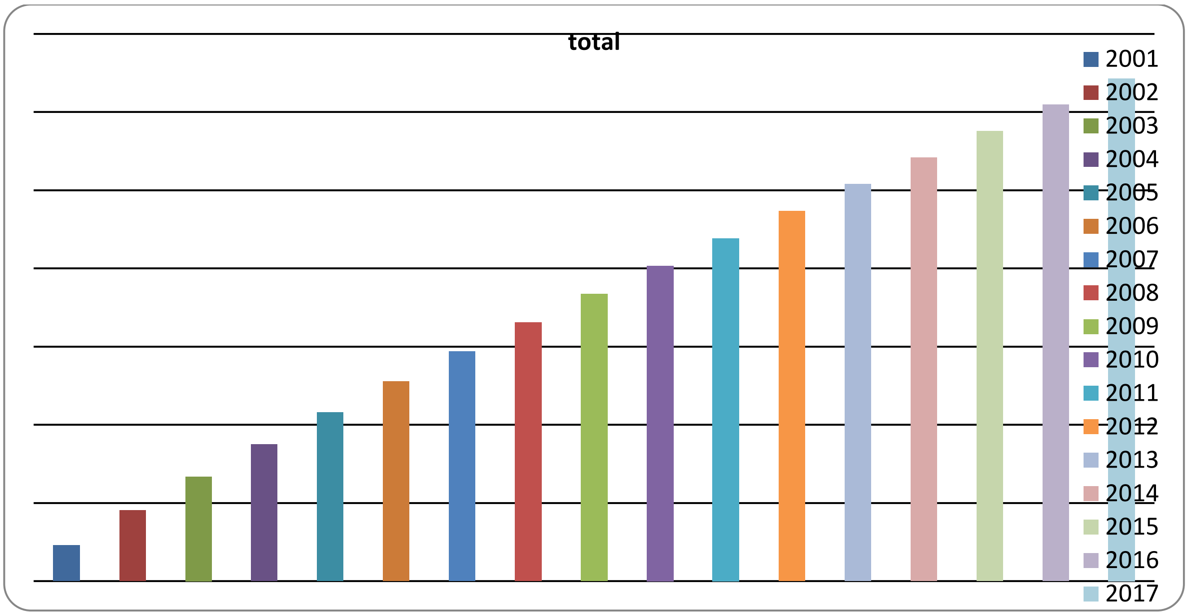


Figure 2. 23 Methane emissions from Solid Waste (2001-2017)

2.6.8 Wastewater Treatment and Discharge- 4D

It was observed that most Councils had no wastewater treatment facility, let alone formal disposal area for their public. However, few councils had such a facility, namely; Blantyre, Lilongwe, Mzuzu, Zomba, and Balaka/Liwonde, despite the fact that the facilities from the mentioned Councils had also challenges when it comes to functionality.

Greenhouse gas emissions were estimated from domestic wastewater treatment. The IPCC default parameters used to estimate emissions from water treatment are presented in Table 2.52 and the emissions are shown in Table 2.53.

Table 2. 52: Parameters used to calculate GHG emissions from waste water treatment

Type of treatment or discharge	Maximum methane producing capacity (BO-kg CH_4/kh Biological Oxygen Demand (BOD)	Methane correction factor (MCF)	Emission factor (kgCH_4/kgBOD)
Centralized aerobic treatment	0.6	0	0
Aerobic deep lagoon	0.6	0.8	0.48
Septic system	0.6	0.5	0.3
Latrine	0.6	0.1	0.06

Table 2. 53: Methane and nitrous oxide emissions from wastewater treatment

Year	2010	2011	2012	2013	2014	2015	2016
CH_4 (CO_2eq)	299.47	-	-	836.53	--	885.76	911.44
N_2O (CO_2eq)	176.18	--	--	105.90	--	106.00	105.90

Emissions from biological treatment of solid waste (4B),as well as those from Incineration and Open Burning of waste (4C) and were not reported in this inventory because of lack of data.

2.6.9 Waste sector QA/QC

Since the study had a number of limitations which could compromise the results, the team resorted to using both the calculated values for activity data the default values, of which according to the IPCC guidelines the eastern African values were very much relevant to the Malawi data, due to similarity in climate, at the same time economic status and other social and environmental factors that have a bearing on waste type and methods of management.

2.6.10 Constraints and gaps

A number of limitations negatively affected the quality of the waste sector GHG inventory compilation process. These include;

- Since waste was not segregated from source of generation, it is hard to collect samples in waste categories at the disposal site, which had also an effect in analyzing waste by category hence the laboratory analysis was done on crude sample.
- The data collected from various councils was done in one type of season (dry), it was not repeated during other seasons, which could have a bearing on other factors such as Dry matter, fraction of Carbon in dry matter etc.
- The samples collected at the time of study could not include the other forms of waste which are seasonal in nature, i.e. Garden waste is usually abundant during and soon after rain season and may have a significant effect on factors like Carbon content. This was evident, for example, in Salima where Malawi Mangoes is one of the major waste generators, and during the first data collection the site was full of Banana peels, which was not the case during the second collection.
- The unavailability of ready data forced the respondents to give estimates based on calculation of expected situations; this meant that the data may somehow reflect the anticipated situation and not necessarily the real practical time situation on ground.
- It is because of this situation that the calculation was done mainly based on the default values (for the sake of validity of the data) as a requirement in tier one.

2.6.11 Recommendations for improvement

- There is a need to frequently carry on laboratory tests on the various required parameters for GHG emission calculation even at Council level, so that we can easily develop our estimate Country Specific EF values in near future for easy calculation without major discrepancies.

  There is also a need to promote the arrangement of mainstreaming the calculation exercise into day to day work for ownership and consistency of data from various points of data collection. General Comments

  i. Need to link properly waste and climate
  ii. Show trends in emission from waste over the specified period and provide reasons for such trend

- Institutions responsible for waste management should keep data on waste management, just as they do with other Environmental sectors like Forestry. This can be in form of developing a template which can be used to capture basic activity data which may be readily available for use when needed.
- Frequently carry on laboratory tests on the various required parameters for GHG emission calculation even at Council level, so that we can easily develop our estimate Country Specific EF values in near future for easy calculation without major discrepancies.
- Investigate reasons why some areas generate more waste than others and what should be done to manage the waste properly to minimize emissions of GHGs.

APPENDIXES

Appendix 1. 1 Waste Analysis Data

Description:	fraction of municipal solid waste comprised of type	dry mass fraction of waste type	carbon mass fraction of dry mass	fossil carbon mass fraction of carbon mass	fossil carbon mass fraction of waste (wet basis)
UNITS:	fraction	fraction	fraction	fraction	fraction
municipal waste	WF	dm_WF	CF_dm	FCF_CF	FCF_WF
paper/cardboard	7.7%	90.0%	46.0%	1.0%	0.032%
textiles	1.7%	80.0%	50.0%	20.0%	0.136%
food waste	53.9%	40.0%	38.0%	0.0%	0.000%
wood	7.0%	85.0%	50.0%	0.0%	0.000%
garden (yard) and	0.0%	40.0%	49.0%	0.0%	0.000%
disposable nappie	0.0%	40.0%	70.0%	10.0%	0.000%
rubber and leathe	1.1%	84.0%	67.0%	20.0%	0.124%
plastics	5.5%	100.0%	75.0%	100.0%	4.125%
metal	1.8%	100.0%	0.0%	0.0%	0.000%
glass	2.3%	100.0%	0.0%	0.0%	0.000%
other inert waste	11.6%	90.0%	3.0%	100.0%	0.313%
unknown	7.4%				0.000%

Appendix 1. 2 Laboratory Test Findings (First analysis)

ID	DRY MATER %	F. CARBON %	PROTEIN %	NITROGEN %	POTASSIUM (g/kg)	PHOSPHORUS (mg/g)
Soche Dry Sludge(A)	56.85	43.16	9.62	1.54		
Soche Wet Sludge(I)	16.08	16.93	4.97	0.8		
Soche Dry Sludge 2(G)	9627	39.5	1.73	0.28		
Blantyre Municipal Waste(B)	59.29	25.48	5.38	0.86		
LL Mtandire Solid Waste(C)	94.97	8.37	1.73	0.38	22.53	8.72
LL Dumpside Area 38(U)	98.03	21.99	2.38	0.52	18.32	7.8
LL Composite Solid Waste(Q)	73.54	20.36	3.25	0.63	18.32	14.75
Kauma Sludge (liquid)(Z1)	29.89	42.24	3.93	0.2	4.31	12.8
Kauma Dry Sludge(Z2)	4.47	60.53	1.27	1.15	1.92	2.28
Kanengo Sludge(Y2)	5.15	56.21	0.91	2.42	1.66	1.14
Mzuzu Dry Sludge(E)	76.36	54.86	15.12	0.14		
Mzuzu Municipal Waste(F)	78.73	16.22	0.86	0.82		
Mzuzu Wet Sludge(P)	32.42	24.48	5.13	0.33		
Balaka Wet Sludge(H)	68.18	5.89	2.09	1.52		
Balaka Dry Sludge(T)	97.2	29	9.47	0.31		
Balaka Municipal Waste(S)	99.01	7.79	1.95	0.83		
Zomba Wet Sludge(N)	18.98	62.16	5.18	1		
Zomba Dry Sludge(O)	97.53	20.93	6.25	0.93		
Zomba Dry Sludge 2(W)	63.92	44.82	5.8	0.49		
Zomba Municipal WasteX	93.09	12.67	3.11	0.22		
Liwonde Municipal Waste(V)	96.28	7.76	1.4	0.32		
Luchenza Municipal Waste(J)	86.17	6.03	2.04	0.98		
Dedza Municipal Waste(Y)	95.38	29.47	6.15	0.9		
Kasungu Municipal Waste(D)	92.95	12.74	1.14	0.18		
Kalonga Municipal Waste(R)	98.51	11.21	3.25	0.52		
Kalonga Dry Sludge(M)	89.16	28.8	8.43	1.35		
Mangochi Municipal Waste(L)	98.96	6.76	1.59	0.25		
Salima Municipal Waste(K)	99.15	11.07	0.87	0.14		

Appendix 1. 3 Laboratory Test Findings (Second Analysis)

SAMPLE ID	PROTEIN(%)	TOTAL NITROGEN(%)	CARBON CONTENT (%)	DRY MATTER(%)	Fr. Of C. IN DRY MATTER	P (mg/100g)
B a1	3.171	0.507	7.691	83.949	0.092	84.99
B a2	2.843	0.455	8.093	82.935	0.098	86.81
B b1	2.844	0.455	9.509	77.593	0.123	102.91
B b2	2.625	0.42	7.567	77.024	0.098	102.64
S a1	2.298	0.368	7.138	75.539	0.095	79.456
S a2	2.845	0.455	6.037	75.517	0.08	81.074
S b1	2.4	0.384	6.719	75.781	0.089	179.709
S b2	2.618	0.419	6.976	73.706	0.095	180.346
D a1	1.309	2.209	14.28	59.238	0.241	114.832
D a2	1.2	0.191	19.835	63.447	0.312	114.195
D b1	2.4	0.384	9.369	60.705	0.154	94.086
D b2	2.732	0.437	8.81	61.144	0.144	94.99
M a1	2.156	0.415	4.725	85.43	0.055	95.086
M a2	2.298	0.367	3.236	88.368	0.037	94.722
M b1	2.297	0.368	5.21	84.206	0.062	94.177
M b2	3.282	0.425	10.028	76.495	0.131	94.359
K a1	1.3	0.21	10.753	93.551	0.115	74.431
K a2	1.29	0.22	10.847	94.706	0.215	74.704
K b1	3	0.48	20.296	99.035	0.109	88.808
K b2	3.001	0.478	25.989	98.923	0.262	87.898

Key:
B = Balaka, S= Salima, D = Dedza, M = Mangochi, K = Kasungu, Fr. of C = Fraction of Carbon, P = Phosphorus

3 Mitigation Actions and Their Effects

3.1. Introduction

Malawi, being a signatory of the UNFCCC, participates in implementation of measures to mitigate climate change. In line with the Bali Action Plan of 2007, in 2012, the country prepared and submitted the Nationally Appropriate Mitigation Actions (NAMAs), which covers five key sectors namely: Energy; Transport; Industrial Products and other Products Use (IPPU); Agriculture, Forestry, and Land Use (AFOLU), and Waste. The production of the NAMAs was informed from the important national documents on mitigation. These are the Initial and Second National Communication Reports that were published in 2002 and 2011 respectively; national development frameworks such as the Malawi 2020 Vision, the Malawi Growth and Development Strategy II (MGDS II). Also information from stakeholders in the five mentioned sectors provided useful information in production of NAMAs. The country's NAMAs provide a platform from which the government and other stakeholders could work together to promote low carbon national development through the reduction of greenhouse gas emissions and enhancement of carbon sink capacity. Implementation of the NAMAs will assist in achieving the mitigation goals as outlined in the National Climate Change Management Policy which is "*to promote the reduction of greenhouse gas emissions; and enhance the capacity of carbon sinks while ensuring sustainable development*".

In 2015, Malawi, through a national consultative process produced its NAMAs (GoM, 2015). The stakeholder identified NAMAs were prioritized basing on potential to reduce emissions (mitigation), synergy with government policies and plans, and potential to secure funding and the co-benefits. The co benefits include the impact on improvement of the environment, economic opportunities, and social well being. The final list of NAMAs included the mitigation options:

(i). Energy: solar water heaters, biomass gasification, fuel blend with ethanol, efficient biomass stoves, household biogas digesters, energy efficiency and hydro-electric power generation.

(ii). Industrial Processes: Soil-cement stabilized blocks, cement blends (rice or coal ash) and Solvay process for lime making.

(iii). AFOLU: Efficient use of fertilizers and manure management, conservation agriculture, improved livestock feeding systems, improved rice cultivation, sustainable land management, afforestation and forest regeneration.

(iv). Waste: Municipal solid waste management, composting, waste to energy (biogas/ incineration) and landfills.

To make sure that the transparency in implementation and its effect is enhanced, the NAMAs used the Measurement, Reporting and Verification (MRV) Framework (which is presented in Figure 3.1). This framework is also adopted from the Malawi Climate Change Institutional Coordination Framework.

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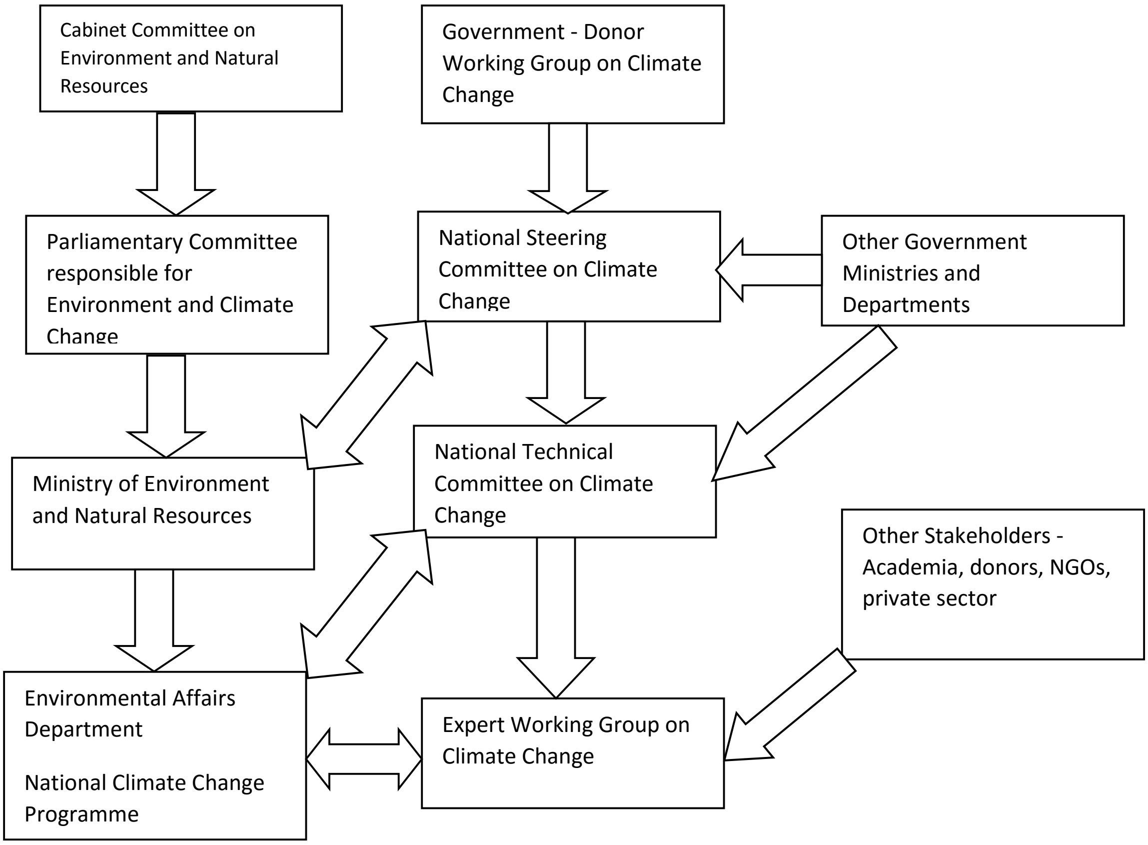


Figure 3. 1 Climate Change Institutional Coordinator Framework in Malawi (Source NAMA)

The country has also come up with a number of initiatives and processes to mitigate climate change through while pursuing a path of sustainable development. These include the development of the Intended Nationally Determined Contributions (INDC) within the framework of the Paris climate Agreement 2016, setting out the country's adaptation and mitigation goals to 2040. Despite its low level of GHG emissions, both on an absolute and per capita basis, the INDC also highlighted Malawi’s commitment to moving its development pathway towards a green economy based on its national circumstances and capabilities. In terms of mitigation, the NDC covers a wide range of policy-based mitigation measures are identified within all key emitting sectors. These include low carbon grid-based electricity generation from hydropower and other renewable sources to meet growing demand, small-scale generation, solar water heating and small-scale PV supply (energy); promotion of mass public transport and low carbon fuels such as biodiesel and ethanol (transport); increased use of blended cements and alternative low carbon production processes (industry); implementation of landfill gas recovery, energy to waste and composting (waste); sustainable livestock and crop management practises (agriculture) and afforestation, reforestation, forest conservation and sustainable fuel wood production (forestry).

The other initiative developed by the Government of Malawi is the National Climate Change Response Framework (NCCRF). Through NCCRF, the country aims to strengthen and focus nationwide actions towards climate change adaptation and GHG emission mitigation. At Governmental level, Malawi has prioritised climate change management, environment and natural resources management among the priorities of the Malawi Growth and Development Strategy (MGDS) in all its versions. The MGDS, a five-year medium term overarching development strategy for Malawi, at the time of writing this report, Malawi was implementing the MGDS III) and integrated climate considerations within a wide range of sectoral policies and strategies. Most recently, climate change mitigation is embedded within Malawi 2063, which sets out the country's vision to become an inclusively wealthy and self-reliant industrialised upper-middle-income country by 2063 (GoM, 2021).

In 2016, the country developed overarching policy that guides stakeholders including reference document for policy makers in Government, the private sector, civil society, and donors, on climate change management actions such as mitigation (GoM, 2016). The Policy provides climate change mitigation strategic direction in all the sectors, namely: agriculture, energy, industrial processes, waste management, forestry, water resources, and wildlife. Other interventions being spearheaded for implementation in the policy include the following priority areas:

(i). Climate change adaptation;
(ii). Capacity building, education, training and awareness;
(iii). Research, technology development and transfer and systematic observation;
(iv). Climate financing (such as clean development mechanism); and
(v). Cross-cutting issues (includes gender considerations, population dynamics and HIV and AIDS).

Recently, in 2021, Malawi submitted the revised NDC to UNFCCC (GoM, 2021). The revised NDC presented a more detailed and robust assessment of mitigation and adaptation measures for Malawi (up to 2040), including emissions reductions and estimated funding requirements, informed by in-depth analysis, improved information and data, and an extensive national stakeholder-driven consultation process. The country's mitigation contribution takes the form of a reduction in GHG emissions relative to a business-as-usual (BAU) emissions scenario over the period to 2040. The mitigation options that were identified (in each of the sectors) for the NDC measures NDC are presented in Table 3.1 below:

Table 3. 1 Unconditional and conditional NDC mitigation measures

	Mitigation measure	Conditional	Unconditional
ENERGY	Grid hydropower	100%	-
	Grid solar	100%	-
	Small scale solar PV/SHS	100%	-
	Grid wind power	100%	-
	High efficiency coal plant	100%	-

	Efficient charcoal production	-	100%
	Carbon capture and storage	100%	-
	Power factor correction	100%	-
	Modal shift: passenger	70%	30%
	Modal shift: freight	50%	50%
	Ethanol blending	50%	50%
	Biodiesel blending	90%	10%
	Efficient charcoal stoves	-	100%
	Efficient wood stoves	-	100%
	Efficient tobacco curing	-	100%
	Conservation tillage	-	100%
IPPU	Cement blended with RHA	100%	-
	Earth stabilised blocks	100%	-
	Low carbon clinker	100%	-
AGRICULTURE	Fertiliser and manure management	40%	60%
	Crop residue and rotation	50%	50%
	Improved rice management	70%	30%
	Improved livestock husbandry	40%	60%
	Improved farm management	10%	90%
	Conservation tillage	50%	50%
	Improved livestock and breed management	70%	30%
FOLU	Forestry measures (average)	57%	43%
WASTE	Landfill gas utilisation	100%	-
	Waste-to-energy (WtE) plants	100%	-
	Waste-water treatment and re-use	100%	-

3.2 Overall Mitigation effects as reported in the Revised NDC of 2021

As presented in the GHG Inventory Chapter, the latest national inventory data estimate total greenhouse (GHG) emissions excluding forestry and other land use (FOLU) at 9.33 million tonnes of carbon dioxide equivalent (tCO_2e) for 2017. Agriculture Sector accounted for by far the largest share of the total (5.07 million tCO_2e, 54% of total), followed by Energy (2.34 million tCO_2e, 25% of total) and waste (1.67 million tCO_2e, 18% of total). Emissions from industrial processes represented just 0.24 million tCO_2e, equivalent to around 3% of total emissions in 2017 (mainly associated with calcination CO_2 emissions from minerals production). Emissions from livestock represented the largest emissions source category, followed by emissions from managed soils in crop production. Following these agriculture sources, major sources included CO_2 emissions from fossil fuel use in transport, which accounted for 11% of the total, and methane emissions from unmanaged waste disposal site (dumps), which accounted for 13% of the total.

In the revised NDC, under a BAU emissions scenario, total emissions excluding FOLU are forecast to increase by more than three times by 2040, rising from 9.3 million tCO_2e in 2017 to 34.6 million tCO_2e in 2040. This outlook was based on assumptions around the growing contribution from fossil fuels to national emissions, arising from increasing demand for thermal power generation and transport services. At the same time, despite potential for increased productivity, agricultural output was expected to be more limited, growing broadly in line with trends over the past decade.

A detailed assessment of identified GHG mitigation options for Malawi estimates a total emissions reduction potential of around 17.7 million tCO_2e in 2040 against the BAU scenario emissions in the same year of 34.6 million tCO_2e, equivalent to a reduction of 51 per cent. Based on the analysis, mitigation measures have been grouped according to two different contributions:

(i). Unconditional contribution: A reduction of 6 per cent relative to BAU in the year 2040; equivalent to an estimated mitigation level of 2.1 million tonnes of carbon dioxide equivalent (tCO_2e) in that year. This is an unconditional target that was based on domestically supported and implemented mitigation measures and policies.

(ii). Conditional contribution: An additional reduction of 45 per cent relative to BAU in the year 2040; equivalent to an estimated mitigation level of 15.6 million tCO_2e in that year. This represented an additional targeted contribution, based on the provision of international support and funding.

The combined unconditional and conditional contribution resulted into a 51% reduction in GHG emissions compared to BAU in 2040, expressed as a single year target. The coverage of the contribution included the three main greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The sectoral scope of this contribution covered all emissions sources described in the IPCC 2006 Reporting Guidelines, including emissions from the categories of energy; industrial processes and product use (IPPU); waste; and agriculture, forestry and other land use (AFOLU) but excluding sources from forestry and other land use (FOLU). These latter sources could be included within future contributions, subject to improved data availability and ongoing development in the accuracy of their quantification within the national GHG inventory. For the revised NDC, an indicative emissions reduction contribution was estimated at 59.8 million tCO_2e of reductions through a range of FOLU interventions covering an area of up to 2 million hectares (ha), of which 22% was unconditional and 78% conditional on international support.

3.3. Mitigation Actions in form of Policies and Strategies

The country has put in place instruments, in form of institutions, policies and regulations that create enabling environment for implementation of climate change mitigation actions in the five sectors, as described in Table 3.2.

Table 3. 2 Policies and strategies that create enabling environment for mitigation actions in Malawi

Sector	Instrument	Description of the Action	Outcomes (effects)

<table>
<tr>
<td>Energy</td>
<td>Energy Policy of 2003 and the revised version of 2018</td>
<td>The goal of the 2003 Energy Policy was to transform the country's energy economy from one that is overly dependent on biomass to one with a high modern energy component in the energy mix. The revised policy of 2018's goal is to increase access to affordable, reliable, sustainable, efficient and modern energy for every person in the country. The project energy supply mix up to 2035, according to the revised 2018 policy is given in the Table below
<table>
<tr><th>Energy Source</th><th>2008</th><th>2015</th><th>2020</th><th>2025</th><th>2030</th><th>2035</th></tr>
<tr><td>Biomass</td><td>88.2%</td><td>80.5%</td><td>70.3%</td><td>57.6%</td><td>44.8%</td><td>33.5%</td></tr>
<tr><td>Liquid Fuels and Biofuels</td><td>6.4%</td><td>9.9%</td><td>11.6%</td><td>13.0%</td><td>14.2%</td><td>14.8%</td></tr>
<tr><td>LPG, Biogas and Natural Gas</td><td>0.0%</td><td>0.1%</td><td>2.0%</td><td>3.7%</td><td>6.0%</td><td>9.0%</td></tr>
<tr><td>Electricity from Renewable Sources</td><td>2.6%</td><td>6.9%</td><td>10.7%</td><td>16.0%</td><td>23.0%</td><td>28.9%</td></tr>
<tr><td>Electricity from Non-Renewable Sources</td><td>0.0%</td><td>0.3%</td><td>1.8%</td><td>5.7%</td><td>7.5%</td><td>8.0%</td></tr>
<tr><td>Coal</td><td>2.8%</td><td>2.3%</td><td>3.6%</td><td>4.1%</td><td>4.5%</td><td>4.9%</td></tr>
<tr><td>Electricity from Nuclear Energy</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1%</td></tr>
<tr><td>Total</td><td>100%</td><td>100%</td><td>100%</td><td>100%</td><td>100%</td><td>100%</td></tr>
</table>
</td>
<td>1) The Energy Policy of 2003 liberalized the energy market. The energy sector is now liberalized, allowing independent power producers in the energy market. Most of the Independent power producers have submitted Power Purchase Agreements in solar PV, wind and hydropower all being climate change mitigation technologies.

2) It also enabled creation of energy laws in 2004, which provide legal framework for the liberalized energy market, which supports mitigation actions. These energy laws as follows:

(i). Energy Regulation Act, No 20 established an independent Energy Regulatory Authority to regulate the energy sector, define the functions and powers of the Energy Regulatory Authority, license energy projects and oversee energy-related matters. The Malawi Energy Regulator Authority (MERA) was established as a corporate body in 2004, to regulate by the energy sector.</td>
</tr>
</table>

			(ii). Rural Electrification Act, No 21 which enables the promotion, funding (through the Rural Electrification fund), management and regulation of rural electrification, and ensures site selection is objective, and based on economics, equity among districts and speed in rural electrification (iii). Electricity Act, No 22 which outlines Malawi's liberalization of the electricity supply industry, particularly the new legal framework for regulating generation, transmission, distribution, sales, and the import and export of electricity. The 2016 Electricity Amendment Bill included specific terms to drive IPPs participation in the market. (iv). Liquid Fuels and Gas (Production and Supply) Act, No 23 which outlines liberalization of the liquid fuels and gas supply industry, and

			mechanisms for governing competition in downstream operations and activities in petroleum, ethanol and gas imports, wholesaling, transportation, distribution and retailing 3) For the revised energy policy of 2018, two legislative changes are expected to follow the adoption of the revised NEP: (1) the launch of the Malawi Renewable Energy Strategy (MRES) and (2) the establishment of a Rural Electrification Agency (REA). REA is expected to be a legal entity responsible for rural electrification via grid extension and off-grid alternatives, utilizing the Malawi Rural Electrification Fund (MAREF), the fund would be used to promote private sector participation through fiscal incentives for renewable energy players in the market. These instruments, will create an enabling environment for increased participate of private sector in power supply business
	Biomass Strategy of 2009	The Biomass Strategy of 2009 was framed to develop a rational and implementable approach to the management of Malawi's biomass energy sector through a combination of measures designed to improve the sustainability of biomass energy supply, raise end-user efficiencies and promote appropriate alternatives.	This strategy has made available mechanisms (technologies and strategies) to reduce dependence on biomass energy (especially charcoal), such as National Charcoal Strategy and sustainable

			production of biomass energy. Also, the management of biomass energy resources is decentralised (local management) and becomes more efficient.
	National Charcoal Strategy of 2017	National Charcoal Strategy covering the period 2017 to 2027 aimed at providing guidance on sustainable use of charcoal while promoting alternative energy sources of cooking and heating to charcoal.	A National Cook stove Steering Committee was set to see to it that the country target of 2 million households have access to clean cook stoves by 2020. The new target on the clean and efficient cook stoves is 5 million by 2030.
	Renewable Energy Strategy of 2017	The Renewable Energy Strategy was developed in 2017. The objectives were to upgrade and restructure the market so as to encourage large scale (grid-based) renewable energy power projects. The other objective was to increase contribution of mini-grid and off-grid renewable energy systems in the energy supply mix of Malawi.	The strategy provides a path to increase share of renewable energy in the country's energy mix through creation of an enabling environment for meaningful private sector involvement in renewable energy development. Two important instruments have come out from this strategy. These are the Independent Power Producer Framework, the Standard Power Purchase Agreement for Electricity, and the Minigrid Regulatory Framework.
	Integrated Resource Plan (IRP) for Malawi (2017 to 2040)	The Integrated Resource Plan, developed in 2017, provides high-level policy direction in the investment in the energy sector upto 2040. The Plan is complemented with detailed technical and economic analysis and dispatch of different energy options, including renewable energy. For renewable energy, the recommended energy options for investment (least cost investment) include the following (i). The commissioning of the 308 MW Mpatamanga hydropower plant in 2023. (ii). The extension of the Kapichira hydropower plant (Kapichira III) which would add another 112 MW of capacity to the system by 2024 (iii). 40 MW from solar PV (iv). A programme of solar-water heaters to reduce peak demand by 14 MW	The IRP provides an important resource document for stakeholders (Government and private sector) to guide investments in the energy sector of Malawi. Guided b this Plan, the country has seen increase in Independent Power Producers applications (there were 10 approved applications in 2021).
	Minigrid Regulatory Framework	This regulatory framework was launched in 2020. It complements realisation of the objectives of the revised National Energy Policy (2018) promotes mini-grids as one way of accelerating electrification in locations where grid extension cannot be an economically viable electrification approach. The minigrids is planned to contribute signficanly to electricity access, reaching the Government of Malawi	The mini-grids regulatory framework provides structures for organised and regulated development and operation of mini-grids in Malawi in order to ensure sustainability and tangible socio-economic impact of

		target of 30% Malawi being on grid based electricity by 2030. Based on the Malawi Renewable Energy Strategy (2017), Malawi would have at least fifty (50) operational mini-grids by 2025.	mini-grids and electrification approaches.
	Sustainable Energy for All Action Agenda (2017)	This strategy provides a plan of action for Malawi to achieve SDG 7 by 2030. The Action Agenda (AA) outlines a strategy to increase efforts in increasing energy access to underserved population of Malawi. The AA targets the following by the year 2030. (i). Increase in the number of energy-efficient wood stoves from 500,000 in 2016 to 5 million by 2030. (ii). Increase power generation from renewables from 304 MW in 2016 to 2170 MW in 2030 (iii). Decrease overall energy intensity by more than 50% over the period 2015 to 2030 through actions such as solar water heater replacements, smart meters, replacement of incandescent bulbs with energy savings bulbs (e.g LED bulbs), reduction of electricity transmission losses, (iv). Increase production of bioethanol from 19 million litre production in 2016 to 40 million litre production in 2030 (v). Increase ethanol blend in the petrol from 10% in 2016 to 30% in 2030 (vi). Produce 55 million litres of biodiesel from estimated potential of 150,000 litres in 2016	The Action Agenda provides a plan for Malawi as the country participates in improving the energy that is affordable, clean and secure for all in 2030.
Forestry and Other Land Use	National Forestry Policy of 1996, revised in 2016	Formulation of the National Forest Policy (NFP) of 2016, which is a revised version of the 1996 policy aims to conserve, establish, protect and manage trees and forests for the sustainable development of Malawi in a holistic manner, in a Malawi's democratic era operating within the Decentralization in Forestry. The policy aspires to control deforestation and forest degradation through promotion of forest conservation technologies and practices, as well as through creation of an enabling framework for inclusive participation in forest conservation and management. Further, the policy promotes strategies that will contribute to increased forest cover by 2% from the current 28% to 30% by 2021 through sustainable management of existing forest resources. The revised policy has ten priority areas namely: Community Based Forest Management; Indigenous Forests, Forest reserves; ecosystem management; Industrial Forest Plantations and Estates Management; Forest Regulation and Quality Control; Forestry Knowledge Acquisition and Management; Capacity Development for the forest sector; Biomass Energy Development; Development of Forest Based Industries; Regional and International Cooperation; and Financing Mechanisms. The revised NFP is framed to support achievement of overarching policy of national growth and development, as stipulated in the Malawi Growth and Development Strategy III, while being aligned to other national policies. The other national relevant policies the revised NFP is aligned to are: the National Energy Policy of 2018, National Land Policy of 2002, National Environmental Policy of 2004, The Water Policy of 2005, National Parks and Wildlife Policy of 2000, and National Population Policy of 2013. Apart from being	The National Forest Policy provided strategic direction to the Government of Malawi and other stakeholders in managing Malawian trees and forest to control deforestation and forest degradation for the country's sustainable development. The outcome is in general to enhance efforts to enhance sink of carbon dioxide in Malawi. This is achieved through numerous projects and programmes in the forestry sector, guided by the policy. The projects include: (i). Wood Energy Plantations or Reforestation/Afforestation In the long-term, it is clear that in most situations an improvement in fuelwood supplies require the creation of additional wood resources. The Malawi Government launched the Wood

		in line with other national existing policies and strategies, the revised National Forestry Policy also aligns to bilateral and multilateral agreements and conventions such as the Rio Declaration, United Nations Framework Convention on Climate Change, the Montreal Protocol, United Nations Convention to Combat Desertification, United Nations Convention on Biological Diversity (UNCBD), United Nations Convention on International Trade in Endangered Species of wild fauna and flora.	Energy Project in 1980 that was financed by the World Bank. The Project entails planting of more wood resources, either to replace the ones which have been cut down or cover the previously unwooded areas. The objective of the project was to improve fuel wood and pole supplies to both rural and urban population for domestic and commercial purposes. The Project is being championed by government Ministries, Departments and Agencies (MDAs), non-governmental organizations (NGOs), individuals and/or in groups. (ii). Blantyre City Fuel wood Plantations Realizing the dwindling forest resources on customary land, the Malawi Government, with funding from the Norwegian Agency for Development Cooperation (NORAD) implemented the Blantyre City Fuelwood Project from 1987 to 2001. The objective was to contribute to fuel requirements of low-income groups living in Blantyre and Zomba. A total of 4,700 ha were established on customary land in Blantyre, Chikwawa and Zomba Districts. However, all the plantations were later handed over to 98 village local communities in 2001, as part of decentralization process and poverty reduction strategy. (iii). Improved Forest Management for Sustainable Livelihoods Programme

			The programme focused on improving the management of trees and forest resources, improving access to income generating opportunities and enhancing rural livelihoods through sustainable management of forest areas in the country. The programme was financed by the European Union. The first phase ended in August of 2009 and activities planned for the second phase are expected to resume immediately after the activation of the Forest Management and Development Fund. The Improved Forestry Management for Sustainable Programme (IFMSLP) operates in 12 of Malawi's 27 Districts, namely: Chikhwawa, Chitipa, Dedza, Karonga, Kasungu, Mchinji, Mzimba, Nsanje, Ntcheu, Ntchisi, Rumphi and Zomba. The Programme has developed interventions that aim at contributing towards increased household income and food security. The interventions range from tree planting and forest conservation to the promotion of forest based income-generating activities such as honey, mushroom and timber production and processing. The programme has facilitated development of management plans and co-management agreements between Government and local communities living around forestry reserves. During the lifespan of the programme over 8 management agreements were signed between

			Government and Village Natural Resource Management Committees through their Block Committees. The signing of the management agreements for example in Malosa, Zomba and Liwonde Forestry Reserves improved access to natural resources by communities. (iv). Forestry Replanting and Tree Nursery Project Forestry Replanting and Tree Nursery Project (FOREP) is a Government of Malawi supported project, which aims at rehabilitating the degraded industrial forest plantations to ensure sustainable supply of timber to both the wood processing and construction industries. The project encourages planting and management of trees in selected industrial timber plantations. During the year under review, the department with funding from the project planted 901.76 hectares in different industrial softwood plantations. In addition, the project funds assisted in the management and protection of the old stands from fire within the plantations. (v). National Tree Planting and Management for Carbon Sequestration and Other Ecosystems Services Through the Department of Forestry, The Malawi Government supported the Tree Planting and Management for Carbon Sequestration and Other Ecosystems Services

			(TPMCSOES) Project. The project, launched in 2007, promotes tree planting and management by giving financial support to farmers (Chiotha & Kayambazinthu, 2009). In this project, farmers were financially compensated for the land that they put aside for tree growing and subsequently paid for trees that survive. (vi). The Income Generating Public Works Programme The Income Generating Public Works Programme (IGPWP) was designed to promote income generating activities as well as productive activities for the rural and peri-urban poor. One of the objectives was to develop productive local forestry and agriculture activities. The target is to plant 42,500,000 trees and assist in the management of 2,250 ha of existing forest areas. By 2010, 37,500,000 trees had been planted and 1,800 ha of existing forest area had been managed. (vii). Sustainable Management of Indigenous Forests Project Community-based forest management is a strategy being adopted by many governments in developing countries. One objective is to enhance local control of, and benefits from, local forest resources. The Wildlife and Environmental Society of Malawi (WESM) has been implementing a community-based project called "Sustainable Management of Indigenous Forests" (SMIF) at Kam'mwamba

			in Neno District (formerly known as Mwanza East). The Sustainable Management of Indigenous Forests Project (SMIF) was implemented in 1996 with the objective of sustainably managing these forests through tree planting, encouraging natural regeneration, fire protection and engaging the communities in a number of income-generating activities (IGAs) such as bee keeping (honey production), fruit juice making and guinea fowl rearing. 242,021 trees of various species were planted for soil amelioration, firewood, timber and nutritional (fruits) purposes over the project period. This translates into 96.8 hectares of forest cover if planted at 2 m by 2 m spacing. Most of the trees were planted by individuals (181,144 trees). (viii). Bwanje Rural Environmental and Development Organization Bwanje Rural Environmental and Development Organization (BERDO) is based in Ntcheu District in the Bwanje Valley. BERDO, launched in 2009, is implementing livelihood security and watershed management projects amongst many other projects focusing on income generating activities. The two main goals of these projects were to improved sustainable livelihoods in Bwanje area particularly of female headed and HIV and AIDS affected households, and to promote participatory

			watershed management in the Bwanje valley. (ix). Protecting Ecosystems and Restoring Forests in Malawi In Malawi, due to deforestation, forest ecosystem losses are eroding access to vital community resources and contributing to environmental degradation that negatively impacts the future of local and regional economic potential. To address deforestation and land degradation problem in Malawi, the Protecting Ecosystems and Restoring Forests in Malawi (PERFORM) was a five-year project funded by the U.S. Agency for International Development (USAID) and implemented by Tetra Tech, in association with five subcontractors: Total LandCare, Centre for Environmental Policy and Advocacy, Michigan State University, Winrock International, and World Resources Institute (TertaTech, 2014). To improve quality of life across Malawi, PERFORM promotes forest conservation and green growth, while working to reduce greenhouse gas (GHG) emissions from forestry land use and strengthen climate resilience. The PERFORM also worked to increase low-emissions land use opportunities in rural Malawi. Further, PERFORM works to build Malawian capacity to systematically collect, analyze, and report on GHG emissions. The project started in September 2014 and completed in September

			2019. The Project has supported Government of Malawi and other local stakeholders to develop and implement a new approach to forest co-management, which capitalizes on sound forest inventories that inform planning and articulates the rights, roles, and responsibilities needed to promote the transparency and accountability of national, district, and local partners. (x). National Tree Planting Season The Malawi Government through Department of Forestry carries out a yearly national tree planting season, where citizens, schools and organisations are urged to plant trees. One of the activities during the planting season is the Dzalanyama Forest Tree planting exercise (JICA, 2019). Despite many forest projects and programmes the Malawi Government and its development partners have put in place to address issues of deforestation and environmental degradation in Malawi, challenges still persist. (xi). Malawi Youth Forest Restoration Programme In 2016, Malawi Government embarked on a programme, named: Malawi Youth Forest Restoration Programme (MYFRP), with the aim of restoring 4.5 million hectares of degraded land, or 38% of its total landmass (GOM, 2016). This programme is part of the African Forest Landscape Restoration Initiative (AFR100) and

			Bonn Challenge. The AFR100 is a country-led initiative that aims to bring 100 million hectares of land into restoration by 2030. The country notes that the restoration has many benefits, such as increasing agricultural productivity and water security, improving resilience to climate change and severe weather, limiting erosion, and spurring sustainable economic growth. The Programme will contribute to building a resilient nation, with livelihoods and local economies supported by healthy ecosystems. The Programme targets the youth because Malawi is a young country with an entrepreneurial and ambitious youth. Despite the potential, many of the 64% of Malawians that are under the age of 24 are unemployed. Therefore, apart from contributing towards building a resilient nation, this Programme tackles both youth unemployment and improving the productivity of the land.
	National Forests Landscape Strategy of 2017	The strategy is formulated to promote sustainable use of natural resources, and enhancement of the resilience of ecosystems. About 8 million hectares of degraded and deforested lands across the country can potentially be restored through a wide range of FLR interventions.	The Strategy outlines priority opportunities and interventions that translate the potential of restoration into multiple benefits such as improved food security, increased biodiversity, improved water supply, job creation, income, carbon sequestration and enhanced resilience to climate change. Under this initiative, the country has identified and mapped degraded sites in every district to address vulnerability to climate change, adapt, and mitigate through integrated landscape management approaches

			to forest landscape restoration. The Strategy has developed the following forest-based restoration interventions: (i) establishment and management of community forests and woodlots;(ii) forest management (forest reserves and plantations); and (iii) rehabilitation of stream and river banks.
	Republic of Malawi National Commitment (2017) to Achieve Land Degradation Neutrality	At national scale Malawi has set a target of achieving land degradation neutrality by 2030 as compared to the baseline of 2015 (no net loss) and an additional 2% of the land territory of 9.4 million hectares improvement. This translates to 188,000 hectares with net gain as compared to 2015. Specific targets for avoiding, minimizing and reversing land degradation Improve productivity of 754320 hectares cropland by 2030 (i). Improve Soil Organic Carbon (SOC) stocks on cropland to 55 ton/ha by 2025 as compared to 44.7 ton/ha estimated in 2015 (ii). Rehabilitate one million hectares of degraded land for crop production by 2030 (iii). Halt the conversion of forests and wetlands to other land cover classes by 2020 (iv). Improve forest (plantation & indigenous) cover by 33750 hectares by 2030 as compared to 2015 (v). Reduce the rate of top soil loss (soil erosion) to 20 tons per hectare per year by 2030 from the 2015 estimated rated of 29 tons/ha/year (vi). Increase forest cover by 2% from 2015 baseline by 2022 (vii). Restore 820,000 hectares of degraded indigenous forest by 2030 (viii). Sustainably manage 138,000 hectares of plantation forest by 2025 (ix). Restore 36000 hectares of degraded stream banks by 2030 (x). Protect 2.4 million hectares of natural forest by 20354	The actions on reducing levels of land and forest degradation are getting enjoy Government of Malawi commitment. This will increase amount of carbon sequestered by forest and soil while at the same time improving food security, increased biodiversity, improved water supply, job creation, income, and enhanced resilience to climate change.
	Malawi's National Forest Monitoring System	This is charged with the responsibility of tracking and regularly reporting greenhouse gas emissions and removal from REDD+ activities in Malawi.	The monitoring system ensures that accounting methods and procedures are compliant with the Intergovernmental Panel on Climate Change (IPCC) principles and guidelines of transparency, consistency, comparability, completeness, and accuracy. The actions for mitigating climate change

			in Forestry sector is therefore well informed to produce required results.
Agriculture	Agriculture Sector-wide Support Approach in Malawi	The development objective of the Agriculture Development Programme Support Project (ADP-SP), later renamed Agriculture Sector Wide Approach Support Project (ASWAp SP) was to improve the effectiveness of investments aimed at food security and sustainable agricultural growth. One of the key focus areas on sustainable agriculture land and water management focused on sustainable land and water utilization. Main focal areas of the component were conservation farming, afforestation, protection of fragile land and catchment areas, and rehabilitation of degraded agricultural land. This programme was implemented over 4 year period (2011-2015)	According to the Report from World Bank of 2017 on terminal evaluation of the programme, it stated that the there was increased organic matter observed from integration of conservation agriculture principles in Malawi. This increased capacity to sequester carbon in the agriculture sector
	Promotion of soil fertility initiatives and increased application of organic fertiliser in Malawi implemented by govt and nongovernmental organisations such as Plan Malawi	Malawi has been promoting agroforestry to enhance soil fertility for a long period of time. Agroforestry was introduced in Malawi in 1984 by the Department of Agricultural Research of the Ministry of Agriculture. In the study area, agroforestry technologies were predominantly introduced and promoted by World Forestry (ICRAF) since 1994. Agroforestry technologies for soil fertility improvement that are being promoted include, intercropping of Glicidia sepium and maize, improved fallow and annual relay cropping. Also, Malawi through Ministry of Agriculture and Other Non government organisation, have been promoting compost manure to replace inorganic fertiliser application. Compost manure is affordable and easy to make, using maize stalks and other biodegradable substances. Use of compost can help soils to retain both water and nutrients hence an alternative to inorganic fertilizers.	This has led to enhancement of soil fertility and thus reduction in inorganic fertiliser application which contribute towards nitrous oxide emissions in reduction Malawi. The impact of this mitigation measure is relatively small because soil fertility enhancement projects are not applied on a large scale and inorganic fertiliser dominate the agricultural sector, especially with promotion of inorganic fertiliser subsidy programme.
	Programmes by Government of Malawi and non-governmental organisations aimed at enhancing knowledge on manure management(including use of CH4 from manure for energy production)	The country is promoting animal husbandry with application of improved practices, for example on digestible feed and improved manure handling to improve aeration and thus reduce methane (CH4) emissions. The activities are promoted by the Ministry of Agriculture and other non-governmental organisations like International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).	This has increased productivity of animal production with associated reduction of methane emissions from enteric and manure handling management, as well as extra economic activities of feed production and energy from manure (biogas)
Waste	National Waste Management Strategy (2019 to 2023). The Malawian cities of Blantyre, Lilongwe, Mzuzu have individual waste	The National Waste Management Strategy provides information on the regulatory and institutional infrastructure, status of waste management in Malawi, and different types of wastes as well as tools to enable regulatory bodies, generators of hazardous waste, including the public, and recyclers and operators of facilities to minimize, recycle, treat and dispose of waste in an environmentally sound manner for the sustainable development of Malawi	The Strategy sets out the priorities to be pursued in Malawi to minimize the detrimental impact on human health and the environment arising from poor waste management (including minimising GHG emissions from waste) and to improve the management of waste.

	management strategies		Improved waste handling and disposal practices reduces emissions from the waste sector, with associated health benefits especially in the three cities of Malawi
	Environment Management Act of 2017	This is the law defines responsibilities of the stakeholders on waste management and sanitation, among others. The Environment Management Act of 2017, will lead to the establishment of the Malawi Environmental Protection Agency (MEPA), which will be an autonomous body under Ministry of Environment and Natural Resources.	The availability of legal framework in managing waste in Malawi helps in achieving objectives of Waste Management Strategy in Malawi.
Industrial Processes and Product Use	Manufacturing and industrial in Malawi is currently limited and thus the emissions from IPPU are correspondingly small. The significant emissions from IPPU are those from cement reduction process. This explains why there is no national strategy on reduction of emissions from IPPU. However, cement industry are investing in technologies that requires less clinker to produce a unit mass of cement, hence reducing emissions	The objective of investment in efficient cement production is triggered by economic objectives, which at the same time help to reduce GHG emissions	Investment in efficient cement producing machines helps reduce CO2 emissions from cement production in Malawi

3.4 Mitigation Actions in form of Projects

Mitigation actions for Malawi are also being presented in form of projects being conducted in the country that reduce GHG emissions. Refer to Table 3.3, most of the projects are implemented throughout the country. As it can be seen from the Table 3.3, the energy sector dominates (9 projects) in projects for mitigation climate change. The energy sector is seconded by Forest and Other Land Use Sector (FOLU), having 5 projects. This is so because most of the mitigation actions are achieved in the energy and FOLU sectors. The other sectors: Agriculture, Waste and Industrial Processes and Product Use (IPPU) have small numbers of mitigation projects. The outcomes of the actions (projects) are presented in general, due to limitations in activity data to quantify the specific effects for example in reducing GHG emissions. For the case of use of fuel grade ethanol the mitigation action and its effects are described in detail in the subsequent sector.

Table 3. 3 Description of mitigation actions as projects for each sector and their general effects

Sector	Project	Description of action including objectives and purpose	Outcome (effect) of the mitigation action
Energy sector	Use of biofuel in the transport sector	Malawi uses fuel grade ethanol to blend with petrol as transportation fuel. This fuel is sold out to consumers in all filling stations in the country. The fuel grade ethanol is produced locally by two companies: Presscane Malawi Limited and Ethanol Company (ETHCO) of Malawi. This mitigation action is well explained in the subsequent section.	Through fuel ethanol, petrol imports have been reduced resulting in significant reduction GHG emissions from the transport category of the energy Sector. The effects of this mitigation action are further explained in the subsequent section.
	Malawi Electricity Access Project 2020 to 2024	The project is framed to increase access to electricity services in Malawi, which among others supports the use of energy - efficient appliances including distribution of free energy-efficient light emitting diode (LED) bulbs to enhance the affordability and reduce household electricity consumption.	Increased usage of access to electricity, which reduces pressure on charcoal firewood, enhancing carbon sink
	Millennium Challenge Corporation through its implementing agency Millennium Challenge Account (MCA) Malawi	The MCC Compact, a grant from the USA Government, ran from 2013 to 2018, provided USD $350.7 million to support the reforms and to reinforce Malawi's energy infrastructure. The goal was to help fund power infrastructure projects, especially to increase transmission and distribution capacity of hydroelectric power, a renewable energy. With this project, rehabilitation of Nkula A station and increase of capacity from 24MW to 36MW.	This project has increased the installed power (renewable energy) b an addition of 12 MW. It has also created virtual renewable energy power through increasing the efficiency of hydroelectric power transmission and distribution. The country is currently relying less on diesel power generators, reducing emissions from the power sector.
	The 60 kW Mulanje Electricity Generation Authority (MEGA) - mini-grid	This is the only significant minigrid in Malawi, from renewable energy micro hydropower. The Project was financed by the European Union and the Scottish Government. The minigrid has an installed capacity of 60 kW, servicing a community of 570 households. It provides clean energy displaying kerosene for lighting and diesel for power maize mills. The authority of the minigrid, MEGA, is planning to expand the installed power to 208 kW.	The project has demonstrated use of renewable energy for rural economic growth, while reducing emissions from use of fossil fuels.
	Independent power producers projects in the country	Development of renewable energy power projects in Malawi through promotion of private sector involvement following formulation of liberated energy policy of 2003 revised in 2018. The country has registered several IPP applications. Four IPPs JCM Matswani Solar Corporation (Nanjoka and Golomoti in Mchinji), Phanes Renewable Energy Group (Nkhotakota) and Voltalia SA (Kanengo) were awarded contracts in June 2017 for the construction of solar photovoltaic (PV) plants across four sites at Nanjoka, Golomoti, Nkotakota and Kanengo, with a combined capacity of 70 MW and the option to increase capacity to 160 MW in the future. Some of the IPPs have secured PPAs with Government of Malawi as are now in construction phase. These includes the solar powered 60 MW JCM Power project in Mchinji started in 2018.	Installations of renewable energy power projects have increased access to renewable energy in Malawi, contributing to increase in share of renewable energy in the energy supply mix of Malawi. According to revised energy policy of 2018, the Government of Malawi projects to achieve 23% of total

			energy supply by 2030 coming from electricity from renewable energy sources.
	Development of a new Tedzani 4 Hydropower plant by JICA	The Government of Malawi with support from JICA developed a new hydroelectric power project at Tedzani (Tedzani 4), adding an extra 18MW renewable energy to the grid. This project commenced in 2018 and was commissioned in 2021	This project. a run-of river system, has increased the amount of electricity generated from renewable energy sources (hydropower) in Malawi. This is an important mitigation effect because the country reliance on diesel power stations is greatly reduced.
	Plan to develop a 350 MW hydropower project at Mpatamanga Gorge along the Shire River	This project, supported by the World Bank that financed its feasibility study is viable and is one the planned power generation projects from renewable energy (hydropower). The study prove that th project is feasible both technically and financially and the World Bank has committed to financing the project	This project once constructed will again contribute significant amount of renewable electricity to the grid. The feasibility study and the commitment from World Bank to finance it is a good indicator that the project will be materialised.
	Various installed of solar PV and wind turbine for generation of electricity by members Renewable Energy Industry of Malawi (REIAMA), NGOs and Government of Malawi	The Government of Malawi, through the Barrier Removal to Renewable Energ in Malawi (BARREM) Project installed six 21 kW wind-solar hybrid mini-grids in Mzimba, Nkhata-Bay, Nkhota-Kota, Ntcheu, Chiradzulu and Thyolo, each of which was serving a community of 150 households. Also, several solar mini-grids are installed, notably by Churches Action in Relief Development (CARD) and Environment Africa (both have made use of EU-donated funds to develop their mini-grids). CARD manages two mini-grids of 1 x 30 kW and 1 x 15 kW, with the intention of enabling and empowering rural communities to fund expansions themselves through productive use of energy. The mini-grids are complemented by several kiosks which promote use of portable solar lamps and rent these out. Environment Africa manages two mini-grids of 15 kW each. The renewable energy companies, registered with REIAMA have installed a number of large scale solar PV projects and several solar home systems in Malawi. One of the largest installations in the country is a 830 kW installation developed by JICA at Kamuzu International Airport in Lilongwe to supply electricity to the airport and the residential quarters on site. The Government of Malawi and its development partners are installing solar PV to rural public institutions (hospitals and schools) with no access to grid electricity. For example, the Ministry of Health has in 2020s embarked on a USD $3.7 million project to install PV solar installations in 85 health centers across the country, with assistance from the Global Fund. Also, USAID and DFID have been supporting GOM in procuring 230 modular, prefabricated solar PV pharmacy storage units rated between 3 to 5 kW for public health facilities. Other projects include 4 schools and 4 hospitals in Chikhwawa district funded under the Malawi Renewable Acceleration Program supported by the Scottish Government, and community day secondary schools in Mchinji and Dedza funded by Action Aid	Installations of renewable energy power projects have increased access to renewable energy in Malawi, contributing to increase in share of renewable energy in the energy supply mix of Malawi. According to revised energy policy of 2018, the Government of Malawi projects to achieve 23% of total energy supply by 2030 coming from electricity from renewable energy sources.

		The renewable energy installed capacity from local renewable energy companies is not yet documented. Stand-alone PV solar installations in Malawi have historically been used as back-up or alternative power systems for grid-connected affluent households and corporate institutions. It is estimated that approximately 27,000 SHS units are installed in Malawi and at least 118,000 pico products sold since 2009. The installed capacity could be significantly higher than this contributing to realisation of Malawi achieving of SDG 7 through its Action Agenda.	
	Cogeneration at Sugar Factories of Illovo at Dwangwa and Nchalo	Malawi produces electricity and heat from baggase using the same power plant through Illovo Sugar Factories based in Dwangwa and Nchalo, with installed capacity of 18 MW. The electricity for generation is used by the factories, which the companies would have used diesel generators to complements unreliable electricity from the grid. However, the two sugar mills have the potential to generate up to 62 MW_e of power (Seng, et al., 2017).	The action of producing electricity from baggage is a mitigation activity by the sugar companies which reduce amount of GHG emissions equivalent to that which would have been emitted by a diesel electric generator producing the amount of power (18 MW)
Agriculture	Promotion of conservation agriculture by Government and Non-governmental organisations	The Government of Malawi through the Ministry of Agriculture together with Non-governmental organisations are engaged in promoting conservation agriculture throughout the country. For example, the Global 2000 Sasakawa Initiative is promoting the adoption of minimum tillage amongst resource poor smallholders by providing input packages including fertilisers and hybrid maize seeds to farmers who agreed to shift to CA. This model of CA is successful and is replicated across Malawi. The other organisations that promote conservation agriculture are: Total Land Care, Care Malawi, Concern Worldwide, World Vision International and Concern Universal.	Conservation Agriculture is promoted throughout the country. This is helping improve soil fertility, which reduces amount of chemical fertiliser application such urea which is a source of N_2O. Also the Conservation Agriculture practice helps to improve the soil texture and its capacity to sequester carbon. This is also a recommended climate change adaptation measures in the country. However, the country needs to develop technical guidelines on Conservation Agriculture to properly guide the activities in Malawi to reap the maximum benefits associate with the practice.
	Promotion of improved practices of animal husbandry e.g on improved feed and improved manure	The country is registering increased number of domestic animals. Government through the Ministry of Agriculture is promoting good animal husbandry practices throughout the country such as on improved feed and improved manure management to increase aeration. These practices, among others lower methane emission from animal husbandry	Promotion of improved animal husbandry practices has enhanced action to reduce methane emission from the agriculture sector.

<table>
<tr><td></td><td>management</td><td></td><td></td></tr>
<tr><td>Forestry and Other Land Use Sector (FOLU)</td><td>Afforestation and Natural/Assisted Regeneration programme</td><td>The country through the Ministry of Environment and Natural Resources (Department of Forestry) and development partners implement the Afforestation and Natural/Assisted Regeneration programme as one the key interventions to enhance carbon sink in the FOLU sub-sector.</td><td>According to Malawi's Intended Nationally Determined Contributions (2015), the mitigation actions that enhance afforestation and natural/assisted regeneration result in the unconditional sequestration of approximately 1 million tCO2e annually through planned afforestation in plantations and on customary land. Since 2011, 50 plus million trees have been planted each year in Malawi, as presented in the following Table, with data obtained from the Report of Malawi REDD + Programme National Forest Reference Level, also presented in (Missanjo & Kadzuwa, 2021).
<table>
<tr><th>Year</th><th>Quantity planted</th><th>Area planted (Ha)</th></tr>
<tr><td>2011</td><td>53,941,221</td><td>21,576.0</td></tr>
<tr><td>2012</td><td>52,334,642</td><td>20,934.0</td></tr>
<tr><td>2013</td><td>57,507,938</td><td>23,003.0</td></tr>
<tr><td>2014</td><td>63,196,846</td><td>25,279.0</td></tr>
<tr><td>2015</td><td>52,395,006</td><td>20,958.0</td></tr>
<tr><td>2016</td><td>52,343,450</td><td>20,937.0</td></tr>
<tr><td>2017</td><td>63,912,740</td><td>25,565.1</td></tr>
<tr><td>2018</td><td>62,531,346</td><td>25,012.5</td></tr>
<tr><td>2019</td><td>63,876,257</td><td>25,550.5</td></tr>
</table>
Planting of different tree species has been done entailing all land tenure categories of Malawi that include state-owned forest plantations and reserves, customary</td></tr>
</table>

			lands, and private-owned lands and/or estates. As of date, a substantial 60% survival rate has been reported Department of Forestry in its biannual report of 2020-2021.
	Management and Conservation of Protected Areas Programme	As reported in (Missanjo & Kadzuwa, 2021), the Government of Malawi is implementing the Management and Conservation of Protected Areas Programme. The country has established a national framework/policy on REDD+ that ably guides, monitors, and informs future actions on GHG emissions emanating from forestlands and associated land uses. After her formal acceptance as an UN-REDD partner country in March 2014, Malawi continues to estimate carbon and other GHG emissions from other categories including FOLU. This forms part of the national GHG accounting and reporting system that, as a signatory to the Kyoto Convention, obliges the country to report to the United Nations Framework Convention on Climate Change (UNFCCC). In this respect, implementation of the REDD+ initiative has involved the Malawi Government to engage various partners in monitoring forests and the associated GHG emissions notably through a number of projects and studies, as put in the following Table sourced from (Missanjo & Kadzuwa, 2021).	This action is enhancing the efforts of mitigating climate change in the Forestry Sector through enhancing carbon sink in Malawi while at the same time creating sustainable livelihoods

Study/initiative	Period	Focus	
Avoiding unplanned mosaic deforestation and degradation in Malawi	2008-2009	Forest biomass and carbon assessments (REDD+ technology transfer)	Mkuwazi F
Tree planting and management for carbon sequestration and other ecosystem services	2006–2011	Forest biomass and carbon assessments	
Forest resource mapping under the Forest Preservation Programme (FPP)	2010–2012	Forest biomass assessments and promoting of technology transfer on REDD+	Central, so
Lake Chilwa Basin Climate Change Adaptation Programme	2010–2014	Secure livelihoods and enhance resilience natural resource base through REDD+	Lake Chilv
Integrated Assessment of Land-Use Options in Malawi (IALUO) of LTS land cover/change map	2012	Assessment of land-use options and land cover/change map	
Development of integrated monitoring systems for REDD+ in the Southern African development community project (SADC-GIZ MRV project)	2013-2014	Development of integrated MRV systems for REDD+ and/or forest ecosystems in the SADC region	Transbo Zambia-Ma Malawi (K Nkh
Liwonde, Ntchisi, and Perekezi forest reserves inventory	2016	Forest biomass and carbon assessments	Liwonde
Thuma and Dedza-Salima escarpment forest reserves inventory	2017	Forest biomass and carbon assessments	Thuma and
National Forest Inventory	2018	Forest biomass and carbon assessments	

	Establishment of Seed Banks for Raising Drought Tolerant Tree Species.	The Government of Malawi recognises the importance of tree seed banks for the development of the forest sector as far as the regeneration and sustainability of tree species is concerned. In response to the call on the need to develop drought-resistant species, The Forest Research Institute of Malawi (FRIM) in conjunction with the Mulanje Mountain Conservation Trust (MMCT) has within the period 2001 to 2017 established tree nurseries and seed research plots of *Widdringtonia whytei* (Mulanje cedar) in Mulanje, Dedza, and Viphya Plantations. Indigenous to Malawi, this particular *Widdringtonia whytei* serves to suit the dynamic climate that is becoming warmer and drier in Malawi (Missanjo & Kadzuwa, 2021).	This action is enhancing the efforts of mitigating climate change in the Forestry Sector through enhancing carbon sink in Malawi
	Breeding of Fast-Growing and Drought-Tolerant Tree	Malawi's Second National Communication for Malawi to UNFCCC recommended a coordinated research approach to tree breeding and indicated the need for developing suitable species for the predicted warmer and drier environments in the future. In response, reported in (Missanjo & Kadzuwa, 2021) the FRIM outsourced fast-growing hybrid pine seeds (*Pinus patula, Pinus kesiya, and Pinus oocarpa*). These were genotypically improved breeding material of the 4th and	This action enhancing efforts of mitigating climate change in the Forestry Sector through enhancing carbon sink in Malawi.

	Species.	5th generation which mature faster compared to the earlier generations. The germ plasm is high yielding, drought, and disease tolerant. It has been planted on a trial basis in Zomba, Dedza, and Viphya Forest Plantations as a response to the climate change phenomenon that Malawi continues to experience	
	Screening of Disease and Pest-Resistant Species and Promotion of Biological Control.	The Government of Malawi recognises that disease and pest infestation are threatening the forest carbon sink in Malawi has been. As reported in (Missanjo & Kadzuwa, 2021), of late, Eucalyptus species have been adversely infested by *Glycaspis brimblecombei* nymphs and adult pests that cause damage by sucking plant phloem sap. In spite of this, Eucalyptus species are highly preferred due to their robust growth and their multiple uses and nature, i.e., firewood, poles, medicine and being resistant to fire, and drought spells. Locally, these attributes render their management key to climate change mitigation and adaptation. Ongoing research by FRIM to establish the relative susceptibility of some of the Eucalyptus species to other pests, precisely *Leptocybe invasa*, indicates that there is less susceptibility of the pest for adoption in tree planting initiatives. As a mitigation measure, biological control research is also underway for *Leptocybe invasa* infestation, and FRIM procured *Selitrichodes neseri* as a biological controller of the pest. +e biological controller was released in October 2016, but the results on its effectiveness have not yet been documented. Another option recommended is the planting of higher-resistance tree species such as *Eucalyptus citriodora*.	This action enhancing efforts of mitigating climate change in the Forestry Sector through enhancing carbon sink in Malawi.
Waste	Promotion of waste benefitiaon in cities of Malawi	On a limited scale, the country implements waste benefiation projects such as harnessing of biogas from waste. The other beneficiation from waste is making of briquettes, which is mostly done by groups of women association and non-government organisations. These actions limit the amount of waste that could emit methane and other gases	Waste beneficiation activities are contributing towards efforts of waste is controlling towards limitation of methane from waste, as well as helping in creation of sustainable livelihoods and cleaning up the environment for a health city living
	Improvement in waste handling and disposal in cities	The 4 Malawian cities of Blantyre, Lilongwe, Mzuzu and Zomba have dedicated units that look at safe handling and disposal of waste. In conjunction with Environmental Affairs Department, by-laws are in place to collect, handle and dispose waste using improved practice that encourage aeration limiting methane emissions.	Improve waste management practices are contributing towards efforts of waste is controlling towards limitation of methane from waste, as well as helping in creation of sustainable livelihoods and cleaning up the environment for a health city living
Industrial processes and product use	Promotion of efficient cement production processes	The emissions from IPPU are limited. The mitigation actions in form of projects are being carried out in this sector. These are associated with producing cement with efficiency. The emission reduction is proportional to the amount of cement that would have been saved for the efficient process. For example, Lafarge Malawi Limited has invested clinker (Aether)which produces cement of less CO_2 compared with cement from other ordinary machines (clinkers) (Lafarge Malawi, 2020). The new clinker *Aether* uses less limestone compared to ordinary clinkers and is operated a lower temperatures. These conditions results into a 25 to 30% cut in CO_2 emissions during the cement	Promotion of efficient cement production process contributes to lowering of CO2 emissions form cement production in Malawi

		production process using Aether clinkers (Aether Cement, 2020). The low carbon cement still offers similar performances to Portland Cement in a wide range of concrete applications (Aether Cement, 2020).	
	Alternative building materials other than cement	Earth stabilised blocks are building materials that could replace cement stabilised blocks. These are made of soil/earth, compressed in a machine to the required pressure. In most of the cases, a binding material is used, such as a small amount of cement. It requires less energy to produce a block, compared to cement blocks. Cement Stabilized Soil Blocks (SSBs) were introduced into Malawi by DFID in 1998 primarily because of the deforestation caused by burning clay bricks. The Government of Malawi has banned use of burnt bricks in construction, which increase demand for CSSBs especially in commercial and institutional construction projects. This has correspondingly increased demand for cement, hence associated CO_2 emissions. Malawi uses Earth Stabilised Blocks (ESBs) especially in building of institutional building like rural schools. This is mainly championed by non-governmental organisations that promote environmental sustainability. However, the popularisation of ESBs is not widespread. Increasing the share of ESB in the construction sector would reduce demand for cement; hence mitigate CO_2 emissions related to cement production. Promotion of ESBs is in line with National Construction Industry Council of Malawi position of using environmentally sustainable construction materials (NCIC, 2018).	Use of stabilised earth blocks signficantly reduces the aount of cement required for construction in Malawi, and thus reducing demand for cements hence contributing to lowering of CO_2 from cement industry.

3.5 Analysis of Mitigation Measure: Use of fuel grade ethanol in the Malawian Transport Sector

As stated already, detailed analysis of mitigation measure on use of fuel grade ethanol in the Malawian transport sector was conducted to report on under this BUR for Malawi. Table 3.4 provides the analysis of the mitigation action and the effect on use of ethanol as transportation fuel in Malawi. The analysis includes the description of the mitigation action, methodology used to estimate the emissions reduced and the accompanying assumptions. It also includes objectives and steps to achieve them. Finally the analysis is also on progress of implementation of the mitigation action and whether the mitigation action is under an international market mechanism.

Table 3. 4 Mitigation action and its effect: Use of fuel grade ethanol in the Malawian Transport Sector

Name and description of mitigation action	**Methodologies and assumptions**	**Objectives and steps taken to achieve the action**	**Progress of implementation of the mitigation action**	**International market mechanisms**
The name of mitigation measure is use of fuel grade ethanol in the Malawian Transport Sector Fuel grade ethanol (99.5% v/v alcohol strength) can potentially replace petroleum: petrol and diesel,	The methodology for estimating GHG emissions reduced from the action of using ethanol as transportation fuel replacing petrol is the one stipulated in the 2006 IPCC Guidelines for National Greenhouse Gas	According to the revise energy policy of 2018, the goal of the Malawi Government	The Government of Malawi is in talks with the current ethanol fuel producing	These two companies have not yet participate d in internation

respectively, achieving significant amounts of GHG reductions. Research has shown that fuel grade ethanol can be used in place of petrol without affecting engine performance. The only limitation is the reduced energy in the ethanol compared to petrol per unit mass. However, this is compensated by ethanol fuel having a higher octane rating compared to petrol) which improves engine performance. Malawi has used ethanol fuel for some time, being blended with petrol, in the transport sector. The fuel grade ethanol is produced by two companies: Ethanol Company Limited and Presscane Limited. On a national average, the total fuel grade ethanol production is around 15 million litres per year. The official blending ratio is 20:80 (ethanol to petrol), but it is not met due to limitation in the supply of molasses to produce ethanol. A considerable share of molasses is imported from outside the country, which is at a considerable disadvantage to Malawi in terms of foreign exchange management. The analysis started from 2017 to 2020, and the estimated upto to 2040. This was to be in line with revised NDC for Malawi. The estimated was done using LEAP software. LEAP stands for Low Emissions Analysis Platform (formerly Long-range Energy Alternatives Planning System), developed by Stockholm Environment Institute. LEAP is one of the recommended software for mitigation analysis for countries conducting National Communication to UNFCCC. The results are presented in Figure xxx. As it can be seen, the country mitigated 9.7142 Gg of CO_2 equivalent in 2001 to 22.1558 Gg of CO_2 equivalent in 2017, and this rose to 31.0507 Gg in 2020. The potential to mitigate more CO_2 is higher (up to 2040) with planned investment by ethanol fuel producing companies and Government of Malawi creation of enabling environment on making biofuels a significant fuel in the transport sector as reflected in the revised energy policy of 2018 that seeks to increase the ethanol blend ratio and promote flexible-fuel vehicles. The country is thus projected to mitigate 49.5988 Gg of CO_2	Inventories. Since ethanol replaced petrol, the GHG emissions reduced are basically the emissions that would have been emitted by petrol in the mobile combustion. The emissions from mobile combustion of petrol that were estimated are only for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) despite being many GHG emissions arising from combustion of petrol in car engines such as carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrate (NOx), which cause or contribute to local or regional air pollution. This is because the default emission factors in the 2006 IPCC Guidelines for petrol mobile combustion are provide for the mentioned CO_2, CH_4 and N_2O gases only. The specific GHG emission was calculate as the product of the emission factor for that gas and the amount of petrol by energy units consumed in the mobile combustion. The total emissions were calculated as a sum of individual GHG emissions, using the following equation below. $Total\ Emission\ = \sum_i^N (EF)_i \times Q$ Where Q is the Energy content of petrol and EF is the emission factor for a particular GHG i. N is the number of GHGs to be estimated The ethanol fuel, in energy units was converted into petrol equivalent, and the emissions calculated using LEAP, using the described technology. The calorific value of ethanol is 23.4 MJ/litre and that for petrol is 33.7 MJ/litre, thus 1 litre of ethanol has 0.6943 energy units of 1 litre of petrol. The IPCC default emission factors used for petrol mobile combustion in the road category and the GHGs global warming potential values	is increase share of biofuels in the energy mix from 10% in 2015 to 15% in 2035. The purpose is to ensure energy security for Malawi through use of biofuels. Specifically, the Government of Malawi wants to increase production of fuel grade ethanol so that the blending ratio of 10:90 is increased to higher blending ratios of 30:70 by 2040. In order to of this, the government has planned the following steps, as manifested in the revised energy policy of 2018 and the Malawi's TNA Report of Barrier Analysis and Enabling Framework of 2021): 1. Increase the number of players in the biofuel productio n through incentives	companies (Presscane and ETHCO) to increase production capacity through investing in machinery and increase in production of raw material - molasses. These two companies have adequate machinery to double the current production and will invest in sugarcane growing to increase availability of molasses. The Malawi Government, through Malawi Bureau of Standards produced the standards on ethanol-petrol blends (10:90 and 20:80) as transport fuel. The review of these standards is underway. Also the Government of Malawi developed standards for biodiesel on 9:91 blend ratio The Government of Malawi is	al carbon trade on carbon dioxide mitigation through production and use of ethanol fuel in the transport sector.

<table>
<tr>
<td>equivalent in 2030 and 190.1131Gg CO_2 equivalent in 2040. In the period of TNC reporting (2001 to 2017) the country mitigated a total of 220.9734 Gg of CO_2 equivalent.

<table>
<tr><th>Year</th><th>Amount of CO_2 equivalent mitigated (Gg)</th></tr>
<tr><td>2001</td><td>9.7142</td></tr>
<tr><td>2005</td><td>10.0720</td></tr>
<tr><td>2010</td><td>12.1277</td></tr>
<tr><td>2015</td><td>15.9551</td></tr>
<tr><td>2020</td><td>31.0507</td></tr>
<tr><td>2025</td><td>39.2438</td></tr>
<tr><td>2030</td><td>49.5988</td></tr>
<tr><td>2035</td><td>150.4225</td></tr>
<tr><td>2040</td><td>190.1131</td></tr>
<tr><td>Total GHG reduced from 2001 to 2017 (TNC reporting period)</td><td>220.9734</td></tr>
</table>
</td>
<td>used (from the Fifth Assessment Report)

<table>
<tr><th>GHG</th><th>Emission factor (kg/TJ)</th><th>Global warming potential</th></tr>
<tr><td>CO_2</td><td>69300</td><td>1</td></tr>
<tr><td>CH_4</td><td>33</td><td>28</td></tr>
<tr><td>N_2O</td><td>3.2</td><td>265</td></tr>
</table>

The assumptions used in estimating the GHG emissions are given as follows:

The petrol blend (with ethanol) is consumed in the road transport category and it is assumed that it is used in private cars more than in passenger cars, in the same ratio as the petrol consumption, which was 80% and 20%, respectively. As for the year 2020, and in the past, average blending ratio for ethanol has been around 8 to 9%. This is far much lower than the Government of Malawi approved blending ratio of 80:20. During stakeholder consultations with the two companies, it was revealed that they have plans to increase fuel grade ethanol production, among others through increasing processing capacity and investing in alternative sources of molasses through having own sugarcane farms. Furthermore, feedstock for production of molasses could be obtained from sugarcane cultivated by local cooperatives surrounding the three sugar factories of Nchalo Illovo Sugar Factory, Dwangwa Illovo Sugar Factory and Salima Sugar Company Limited.

In estimating the consumption of ethanol fuel after ear 2021, he following assumptions were made, confirmed by experts in the industry:
i. The blend ratio of 10% would be achieved by 2023 and would remain constant up to 2030, and then</td>
<td>2. Develop an enabling environment for involvement of private sector in biofuel production and processing.

3. Develop and revise standards for bio fuel consumption

4. Provide prerequisite and adequate infrastructure to support marketing and consumption of other biofuels like biodiesel for use not only in vehicles but for other applications such as cooking and lighting

5. Promote the use of flex vehicles capable of running on 100% bioethanol and any</td>
<td>working together with oil service stations on having facilities to handle 100% bio fuels to service fuel flexible vehicle that could run on 100% biofuels</td>
<td></td>
</tr>
</table>

	gradually increase to 15% by 2035. Investment in fuel grade ethanol production by the two companies could see Malawi starting to achieve the 80:20 blend ratios by 2036, such that by the year 2040, the ratio would be fully achieved. This would be achieved through increased production capacity by the two companies and the entrance of new players in the fuel grade ethanol production market; and i. GHG emissions from petrol displaced by ethanol in the blend are equal to the emission mitigated. It is assumed that without ethanol, important of petrol would have increased accordingly.	other blending ratio through awareness campaign s and ensuring availabilit y of conversio n kits for existing petrol powered vehicles		

4 Domestic Measurement, Reporting and Verification (Monitoring, Reporting and Verification of Climate Change Mitigation Actions/Interventions)

4.1 Introduction

The current medium term national development plan, the Malawi Growth and Development Strategy (MGDS) III, guides all development interventions from the year 2017 to 2022. This strategy continues to operationalize the Vision 2020 in attempting to realise its aspirations. Development priorities articulated in the plan have been isolated based on the linkages and the impact they have on the social and economic development of the country. Being agriculture based economy agriculture and other environment and natural resource related sectors have been given much priority in order to realise the country development potential. However the impacts of climate change have affected many sectors' productivity including agriculture such that attention is also given to multi-sectoral approach in managing climate change.

Even though large proportion of the resources comes from development partners, government is committed to increase financial resources for the environment and natural resource management in order to avert the various challenges that faces the sector. Some of the challenges include increasing population, land degradation, deforestation, soil loss, air and water pollution, water body siltation, and many other impacts of climate change.

Attention to climate change and environmental management has been demonstrated by various efforts including the development of National Climate Change Policy, National climate change programme, and National climate change investment plan. In order to implement the national investment plan effectively, an M and E framework was developed so as to ensure close monitoring and provision of advisory to the process of implementing the plan. Among the major areas of interest in the management of climate change there are adaptation, mitigation interventions and financing. These have received much effort and support in order to reduce the severity of the impacts and also build resilience among majority of the affected rural Malawians.

4.2 National Monitoring and Evaluation Framework

Malawi as a country has a well laid out National Monitoring and Evaluation Master Plan (NM&EMP) that brings together a set of activities that are supposed to be carried out by central and line ministries in order to assess progress achieved in the implementation of the national development strategy. It presents a detailed and sequenced action plan that can be used for input, output, results, outcome and impact monitoring and evaluation. The mandate of monitoring and evaluating government programmes and projects is vested in the Ministry of Finance, Economic Planning and Development (MFEPD) in close collaboration with Semi-Autonomous National Planning Commission (NPC).

The country's National Development Strategy's (NDSs), which is currently the MGDS III, progress tracking system is based on the National M&E Mater Plan. The M&E framework is based on Results-Based Management (RBM) principles and a theory of change, with a clear results chain, indicators, targets, milestones, means of verification, frequency and responsible institution. The MGDSIII does not only track local interventions but also sustainable

Development Goals (SDGs) since the MGDS III domesticated the international Agenda. Each government Ministry, Department and Agency (MDA) submit quarterly progress reports from which the MFEPD produces concise reports, *Mid-year and Annual Reviews*, which analyses and gives a picture of the sectors' performance. The MDAs are expected to report, the financial implementation; physical implementation; and outcomes and impacts.

To ensure an enhanced coordination, various stakeholders developed the National Climate Change Investment Plan to guide planning, implementation, coordination and monitoring of climate change programmes. The National Climate Change Investment Plan (NCCIP) also strengthen the basis for effective national, regional, and global partnerships among government agencies, the donor community, the private sector, NGOs, CBOs, academia, and local communities. The NCCIP has an M&E framework which helps track progress in all climate change interventions in the country and feeds into the MGDS III M&E process. Since the NCCIP pools climate change interventions across many sectors, the M&E framework is expected to track progress of all the coordinated interventions in climate change and environment sector.

4.3 Conceptual Design of the M&E Framework

The design of the M&E Framework draws from the logical framework analysis. The conceptualization of the M&E Plan has been premised on the following:

i. Defining a list of key performance indicators that will enable tracking of progress in the implementation of tobacco related interventions;
ii. Specifying key data sources to enable data collectors gather necessary M&E data;
iii. Describing the M&E products and mechanisms for the dissemination of all critical information in accordance with the information needs of all stakeholders, implementing agencies, beneficiaries and the general public; and
iv. Defining a list of strategic M&E actions that will enable tracking of progress in the implementation of project and programmes.

Based on the programme interventions, the Framework seeks to reinforce the realization of intended results. The results chain describes the causality link in which program inputs lead to the production of outputs, to the generation of intermediate outcomes, and finally, to contributing towards final outcomes (impacts). Consequently indicators can be monitored at these four levels as depicted in the following Table 4.1.

Table 4. 1: **Levels of monitoring and Elements to be monitored**

Level of M&E Indicators	Definition	Main Elements Monitored	M&E Products	Use of Information
Input	These are Resources in form of money, persons, training, equipment and any other resources than can be used to undertake activities	Levels of Utilization of financial Resources; Effectiveness of Project strategies	Financial reports; Quarterly Reports; Field monitoring reports	Measure absorption capacity; Measure effectiveness of Project strategies

Level of M&E Indicators	Definition	Main Elements Monitored	M&E Products	Use of Information
Output	These are immediate deliverables (products) in form of tangible goods and services resulting from activities.	Infrastructure created(quantity and quality, accessibility); Persons reached with all forms of program outputs	Quarterly Reports; Annual Reports; Mid Term Review Reports	Measure whether or not outputs are being created according to expectation
Outcome	These include all desired changes in capabilities, increased usage and other behavioural changes of the citizenry following the use of outputs such as accessible infrastructure and other social services	Utilization of physical outputs/ behavioural changes/ Improvements in access to services	Annual Reports; MTR Reports; End of Project Evaluation	Measure effectiveness of outputs to generate outcomes
Impact	The ultimate result in changed well-being of the citizens income, literacy, freedom	Long term effects arising from the a well-regulated and functioning tobacco industry	Impact Evaluation Report	Measure of long term effects Learn lessons for future operations

4.4 Stakeholder Coordination and Reporting

The Monitoring, Reporting and Verification of climate change information will be done using the already set structures. Specific to climate change programmes and projects, the government has National Steering Committee on Climate Change[1] (NSCCC) which reviews policy related issues and National Technical Committee on Climate Change[2] (NTCCC) which monitors and evaluates government and other climate change programmes and projects in the country. The National Climate Change Programme (NCCP) has built capacity in the Government through Environmental Affairs Department (EAD), in the Ministry of Natural Resources, Energy and Mining. The EAD coordinates all the players including the development partners in the sector from both public and non-public institutions.

The figure 4.1 below shows how the information is reporting across stakeholders.

[1] NSCCC is made up of Principal Secretaries of relevant ministries and sectors
[2] NTCCC is made up directors from government agencies, and stakeholders from donors, NGOs/CSOs, academia, private sector who are active in climate change activities.

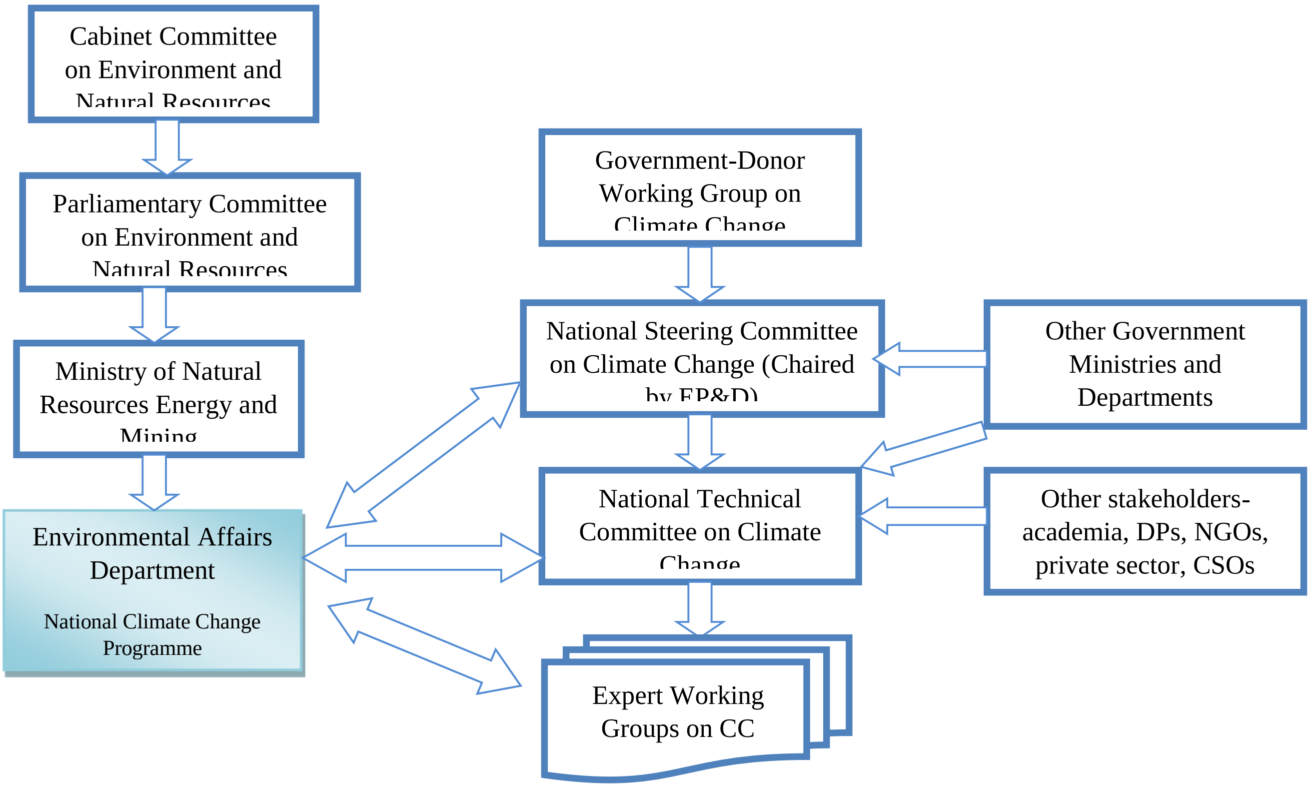


Figure 4. 1 ***Climate Change Institutional Coordination in Malawi Source: (GoM -NCCIP, 2013)***

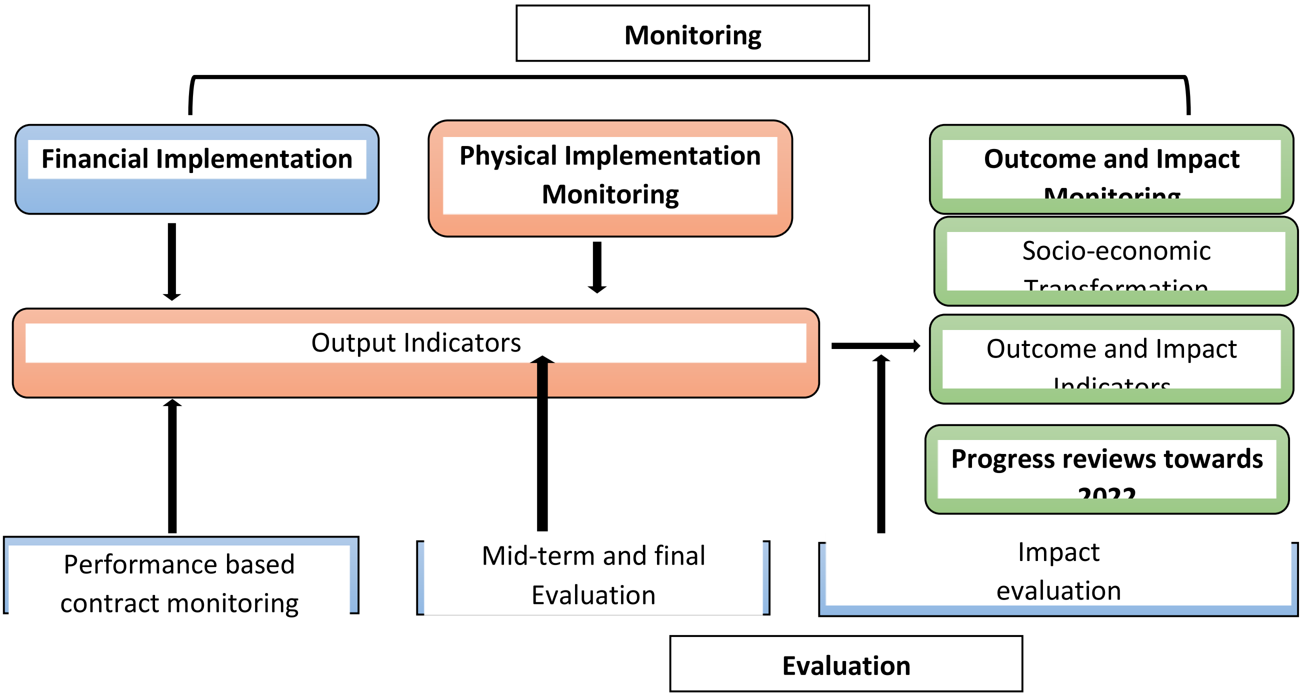
It is important to know that M&E activities will be undertaken at different levels to support effective implementation, ensure accountability, maintain strategic focus and direction, and provide information for addressing constraints and ensuring delivery of outputs. The figure 2 below shows the conceptual framework general Monitoring and Evaluation Framework. The areas to be monitored and evaluated include: Financial and Physical Implementation and Outcome and Impacts

4.5 Local Level Reporting

The information collected at local levels is aggregated at the central through the Ministry of Finance, Economic Planning and Development. In some cases depending on the level, the reporting at central level may disregard output level indicators. In order to improve data management at the local level the M&E Division in the Department of Economic Planning and Development (EP&D) have initiated the establishment of the data banks at every district council so that data is collected, cleaned and analysed to inform district development planning processes before. Some of the district councils of course have challenges to maintain their data banks due capacity challenges. It is expected that all other stakeholders which the CSOs, DPs, Private sector organisation should report at the district council for data aggregation and information sharing. The placement of the monitoring and evaluation officers and the establishment of the

District Environmental Sub-Committees (DESCs) play an important role in managing the ENRM information and policy coherence.

Figure 4. 2 Conceptual Framework Monitoring and Evaluation as articulated in the MGDS III



The M&E framework is based on the prevailing national M&E Master Plan (2007). The framework identifies main M&E components and sets the scope of the M&E processes, which follows a value-chain approach. The framework delineates clear roles for review, monitoring and evaluation. The roles and responsibilities of each node, as assigned to institutions, are explained in the section below.

4.6 Stakeholder Roles and Responsibilities on Monitoring, Reporting and Verification of Mitigation Actions

4.6.1 Various Key Stakeholders Roles

All key stakeholders will collaboratively pursue various mandates in fulfilling the specific roles regarding the management of climate change and environment. This stakeholders include the following: Ministry of natural resources, Energy and Mining, Environmental Affairs Department (EAD); National Planning Commission (NPC); Office of the President (OPC); National Statistics Office (NSO); Government ministries, Departments and Agencies, local councils, Civil Society Organisation (CSO); academia; and private sector organisations;

4.6.2 *The National M&E Coordination Committee*

The National M&E Coordination Committee reviews technical reports and recommendations from the sectors and will make recommendations to the Steering Committee. Membership in the M&E Coordination Committee will be interministerial and will include Directors of Planning.

4.6.3 *The National M&E Technical Working Groups*

The M&E Technical Working Groups will be based on the existing Sectoral Working Groups (SWGs). These comprises Ministries and Departments, Development Partners Cooperation (DPC), CSOs, media, academia, the private sector and parliament. This forum is actively involved in the review and oversight of the MGDS III implementation. It also acts as a national accountability forum for the implementers and facilitate information dissemination, discussion and policy recommendations.

4.6.4 Financial Reporting

The national planning, budgeting, and monitoring cycle is aligned to the national budget cycle and will run concurrently. Climate change targets, which are well articulated in the MGDS III, are disaggregated at sectoral and district levels, whenever possible. This allows sectors and districts to plan and budget their activities. Based on the approved plan and budget for the coming financial year, the various sectors and districts implement their activities. This ensures that there is a link between the annual plans and the monitoring reports. Reports are submitted quarterly. The second quarter report is the main input into the mid-year budget report and the fourth quarter report is the Annual MGDS III review report. The reports include physical progress of implementation, output indicators, targets, expenditure and qualitative assessments of progress by the implementing institutions.

4.6.5 Means of Verification for Evaluation

Verification of the progress made in activity implementation in the ENRM sector uses annual reports of sector ministries and surveys conducted by the NSO and some line ministries under the NSS. These include: the Malawi Demographic and Health Survey (DHS), the Integrated Household Survey (IHS), Multiple Indicators Cluster Survey (MICS) and the Agricultural Production Survey/Census including other institution specific exercises. Qualitative assessments of progress are validated through stakeholder consultations and feedback from implementing institutions and the beneficiaries.

4.6.6 Performance Indicators and Information Management

The M&E Framework is the main guide in determining the extent to which objectives have been attained. The M&E Framework has indicators that are selected to meet institutional, national as well as regional and global reporting requirements to which Malawi is a participating stakeholder. The choice of indicators for M&E is influenced by the following factors:

i. Inclusiveness and cost effectiveness: Only key and result focused indicators are considered to ensure manageability and to be cost effective in collecting, analyzing, storage and dissemination.
ii. Alignment; the need to achieve alignment with strategic documents such as the Investment Plan, MGDS III, National M&E Plan among others; and
iii. Collectability: the likelihood that data will be collected based on whether data is already being collected by departments and all stakeholders.

4.6.7 Data sources, management and reporting

The prior knowledge of the sources of data and data type is critical for ensuring consistency in the interpretation of the information. Equally of vital importance is the knowledge of data collection methodology, aggregation, storage, analysis and dissemination. Data is collected from various sources. Some of the sources include: administrative data, field monitoring, community based monitoring reports as well as national surveys. Data collection tools are designed to capture quantitative and qualitative information at implementation level.

4.6.8 Data collection, aggregation and storage

Data is collected from various sources using a range of methods including surveys and audits. The structured questionnaires are used in order to collect data on outcomes and impacts. The Climate Change M&E Framework is designed to respond to standardized reporting formats for routine administrative data, periodic field monitoring visits, and community feedback on organisation performance. All information are aggregated at central level and stored in an operational database.

4.6.9 Data Analysis and Reporting

The designated central level Office has the overall responsibility for data analysis. The information is ultimately used by the Department to generate M&E products. However other departments also complements the designated department in data analysis, reporting and follow-up actions. The M&E products informs tailor-made interventions for effective implementation of activities and ensure informed decision making. Furthermore, the products will inform MGDS Annual Reviews and Sustainable Development Goals (SDGs) reports. The frequency of reporting is part of the M&E Matrix. Some of the M&E products that are produced include Quarterly progress reports; Semi-Annual reports; Annual reports; Annual review reports; Baseline survey reports; Ad hoc reports; Field supervision monitoring reports; Periodic survey reports; Mid-term evaluation reports; End-line evaluation reports; and Technical audits reports.

4.6.10 Dissemination

The designated central level office ensures that the M&E system produces information that is user friendly by all departments and other stakeholders. A thorough stakeholder analysis is done to map up the demand of various stakeholders in terms of their information requirements. Reviews, conferences and coordination meetings will be the main fora where M&E products will be disseminated.

4.6.11 Utilization

To facilitate use of information for decision-making amongst the different stakeholders, the Climate Change M&E system promotes communication and feedback mechanisms through: Structured management meetings on Climate Change programmes performance with implementing; Distilling lessons and challenges to feed into the annual work programming; and ensure documentation of lessons learnt from impact and other evaluations to inform future designs of similar operations.

4.7 Climate Change Monitoring and Evaluation Action Plan

The Action Plan is based on the indicators and targets reflected in M&E Framework. This will be done through annual assessments. These assessments will create opportunities for redirection of efforts by allowing for the use of lessons learnt to addressing any challenges and gaps. The Major Climate Change/Mitigation M&E activities include field visits, review meetings, projects formulation and monitoring, surveys and evaluations.

Table 4. 2. Some Mitigation Indicators and their Verification Method

Indicators	B/line	Targets / year				MOV	Frequency	Data Collection Instruments/Strategy	Responsibility for Data Collection
1.0 IMPROVED CLIMATE CHANGE MITIGATION									
Outcomes									
1.1.1 Percent increase in the amount of carbon stock						Monitoring Report	Annual	Survey	Forestry
1.1.2 Percent increase in the amount of carbon sinks						Monitoring Report	Annual	Survey	Forestry
1.1.3 Percentage of land area covered by forest						Monitoring Report	Annual	Survey	Forestry
1.1.4 Contribution of forestry products to GDP						Monitoring Report	Annual	Survey	Forestry/NSO
Outputs/ Process									
1.1.5 Area planted with trees (ha)						Monitoring Report	Annual	Survey	Forestry
1.1.6 Area replanted with trees (ha)						Monitoring Report	Annual	Survey	Forestry
1.1.7 Percentage of household income generated from forest related products (i) Bee keeping, (ii) Charcoal, (iii) Timber, (iv) Edibles (mushroom and indigenous fruits)						Monitoring Report	Annual	Survey	Forestry
1.1.8 Number of seedlings planted per year						Monitoring Report	Annual	Administrative	Forestry
1.1.9 Survival rate of tree seedlings						Monitoring Report	Annual	Administrative	Forestry
1.1.10 Number of communities using agro-forestry technologies						Monitoring Report	Annual	Administrative	MoAFS, Forestry
1.1.11 Number of trees planted in national plantations						Monitoring Report	Annual	Administrative	Forestry
1.1.12 Number of carbon trading projects						Monitoring Report	Annual	Administrative	Forestry
1.1.13 Number of REDD+ projects developed						Monitoring Report	Annual	Administrative	Forestry
1.2 Improved Waste Management and Pollution Control									
Outcome									

Indicators	B/line	Targets / year				MOV	Frequency	Data Collection Instruments/Strategy	Responsibility for Data Collection
1.2.1 Proportion of population with access to improved sanitation (i) National (ii) Rural (iii) Urban						Monitoring Report	Annual	Survey	NSO/ MoH
1.2.2 Percentage reduction in carbon dioxide emission						Monitoring Report	Annual	Survey	EAD
1.2.4 Percentage of (-) with improved waste management system (i) Households – Rural/ Urban (ii) Communities (iii) Industrial						Monitoring Report	Annual	Survey	EAD
Output/ Process									
1.2.5 Number of private sector institutions participating in waste management						Monitoring Report	Annual	Administrative	EAD
1.2.6 Number of landfills constructed						Monitoring Report	Annual	Administrative	EAD
1.2.7 Number of incinerators constructed						Monitoring Report	Annual	Administrative	EAD
1.3 Improved access and utilization of alternative energy technology									
Outcome									
1.3.1 Land area under Payment of Ecosystem Services (PES)						Monitoring Report	Annual	Survey	NSO/EAD
1.3.2 Proportion of population using solid fuels						Monitoring Report	Annual	Survey	NSO/EAD
Output/Process									
1.3.3 Number of households benefitting from carbon credits						Monitoring Report	Annual	Administrative	EAD
1.3.4 Number of alternative energy technologies developed						Monitoring Report	Annual	Administrative	EAD
1.3.5 Number of trading centres electrified						Monitoring Report	Annual	Administrative	EAD
1.3.6 Number of CDM projects Developed						Monitoring Report	Annual	Administrative	EAD
2.0 CLIMATE CHANGE RESEARCH, TECHNOLOGY DEVELOPMENT AND TRANSFER									

Indicators	B/line	Targets / year				MOV	Frequency	Data Collection Instruments/Strategy	Responsibility for Data Collection
Outcomes									
2.1.2 % change in the number of climate change mitigation technologies						Monitoring report	Semi-annual	Survey	EAD
2.1.3 % change in the number of technology dissemination strategies						Monitoring report	Semi-annual	Survey	EAD
Outputs									
2.1.4 Number of mitigation technologies generated						Monitoring report	Annual	Administrative	EAD
2.1.5 Number of mitigation technologies promoted						Monitoring report	Annual	Administrative	EAD
2.1.6 Number of mitigation technologies promoted						Monitoring report	Annual	Administrative	EAD
2.1.7 Number of mitigation technologies adopted from other countries						Monitoring report	Annual	Administrative	EAD
2.1.8 Number of technology dissemination strategies						Communication strategy	Annual	Administrative	EAD
2.1.9 Number of stakeholders (public, private, CSO's) involved in dissemination of technologies						Monitoring report	Annual	Administrative	EAD

5 Constraints and gaps and Related Financial, Technical and Capacity Building Needs

5.1 Introduction

This section under constraints and gaps, and related financial, technical and capacity needs provides a brief overview of the identified constraints and challenges relating to capacity, technical, financial and research needs on climate change issues, in the following areas: Disaster Risk Reduction, Information sharing and networking, Biodiversity, Monitoring, Reporting and verification of climate change mitigation actions.

5.2 Technical and financial support needs for climate change activities in Malawi and areas of capacity gaps for support.

Table 5. 1 Technical and Financial support needs for climate change activities in Malawi

Technical Support	Financial Support
train scientists in conducting research, systems analysis, and computer simulation modelling	Development of local emission factors for livestock supported by USAID
Capacity building for local academic institutions in developing country-specific emission factors	
Development of historical data for hazard analysis leading to recurrence of disasters. There is need for a multi-hazard approach to disaster risk and climate change management	
comprehensive national wide risk assessments that would help to better address the root causes of disasters	

Table 5. 2 Areas of capacity gaps for support for Malawi

Technical Support	Financial Support
low uptake of modern information and communication and technologies due to poverty	There is a need for financial support to close gaps in capacity and training for bio safety regulatory framework enforcement
The financial resources in institutions mandated to implement information and networking initiatives are not adequate	
Inadequate human capacity to implement modern sophisticated but effective information and networking initiatives. For example, the Environmental Affairs Department does not have a trained Information, Communication and Technology (ICT) expert.	
There inadequate and old (outdated) ICT equipment and infrastructure. In the fast-	

paced ICT world, equipment needs to be upgraded regularly	
Absence of legally binding information sharing agreement between data/information producers or holders and users. Although efforts are being made under NEIN, the network is not yet formalized and sharing of data and information is purely voluntary	
Lack of a centralized coordination unit for the climate change research programs. Climate change issue as cross-cutting as it is requiring a central coordination unit to make sure that there is no duplication of efforts.	

The key challenges that Malawi faces in the preparation of BURs relates to the insufficient number of personnel responsible for compiling the NIR as well as the BUR. Malawi's Climate Change Monitoring and Evaluation System has not fully been operationalized so data relating to mitigation actions and support received is still collected to a large extent on manual basis. Institutional arrangements for data provision have not yet been fully formalized and data is provided based on informal arrangements between the Environmental Affairs Department and the data providers. This has resulted in some data gaps and often causes delays in the finalization of the reports.

6 Level of Support Received for Preparation and Submission of Malawi's First Biennial Update Report

6.1 Financial Support Received

The Global Environment Facility (GEF) through United Nations Environment (UNE) which is the Implementing Agency for Malawi's BUR 1, has provided funds to a total of USD 352 000 to support Malawi prepare its BUR 1 for the fulfilment of its obligations under the United Nations Framework Convention on Climate Change (UNFCCC). The Environmental Affairs Department under the Ministry of Environment, Wildlife and Tourism which is the Executing Agency provided in kind support, US $ 50,000, office space, government counterparts, and services of support personnel.

6.2 Capacity Building and Technical Support Received

Table 6. 1 Technical and financial support for preparing National Communications and Biennial Update Reports

Technical Support	Financial Support
East and Southern Africa workshop on climate change reports project management and regional Measurement, Reporting and Verification Network development, 28th to 30th May, 2018, Dar-es Salam, Tanzania.	GEF Contribution: US$ 352,000 Government in Kind contribution: US$ 50,000 Total Budget: US$ 402,000
Southern Africa Regional MRV first peer review and training workshop, 3rd to 6th September. 2019, Ezulwini, Swaziland	
Global Stocktake workshop on Quality Assurance of GHG Inventory Systems and Full Lands Integration Tool (FLINT), 14TH TO 17TH October, 2019	
In-Country training on Quality Assurance and Quality Control (QA/QC) by UNFCCC, 12th to 16th August, 2019, Lilongwe, Malawi	
Malawi IPCC Methodology virtual training dry run, 12th August, 2020	
Malawi's review of NCs and BURs/GHG Inventory reports by GSP as a quality assurance exercise, November, 2020.	

6.3 Transfer of Technologies

Pursuant to decision 4/CP.7, its annex, and the implementation of Article 4, paragraph 5, of the Convention, Malawi as a non-Annex I Party is encouraged, to provide information on activities relating to the transfer of, and access to, environmentally sound technologies and know-how, the development and enhancement of endogenous capacities, technologies and know-how, and measures relating to enhancing the enabling environment for development and transfer of technologies.

In 2003, Malawi developed the Technology Transfer and Needs Assessment (TTNA) Report with technical guidance from the Climate Technology Initiative (CTI) of the United States of America (USA). The report aimed to prioritizes climate technologies using the following three criteria: (i) development benefits, (ii) implementation potential, and (iii) contribution to climate change response measures and goals.

Building and learning on the TTNA process and report, Malawi through the Environmental Affairs is implementing the Technology Needs Assessment (TNA) project. The project is funded by Global Environment Facility and supported by United Nations Environmental Programme (UNEP) and Denmark Technical University. The project aims at identifying, prioritizing and developing an enabling framework for climate technologies.

The TNA is also aligned with National Climate Change Management Policy under priority area 3.4: Research, Technology Development and Transfer, and Systematic Observation. Under this priority area, the Policy highlights the role and contribution of technology and its transfer in the management of climate change. The TNA therefore provides a link between National Climate Change Management Policy and other policies and strategies to achieve Malawi's overarching development plan presented in the Malawi Growth and Development Strategy III. Due to the crossing cutting nature of climate change and its related impacts on national developmental sectors, the TNA also provides a framework for implementation of national sectoral priorities, strategies and plans which are related to climate change.

Four sectors with the greatest contribution to resilient building and mitigation efforts for Malawi were selected. These include agriculture and water sectors for adaptation, and energy and forestry sectors for mitigation theme respectively. The process of developing Technology Needs Assessment Report for Malawi in the adaptation and mitigation sectors involved stakeholder participation, ensuring gender inclusion at very stage.

A Multi-Criteria Analysis (MCA) methodology was used to priorities climate change technologies. The MCA process involved stakeholder expert working group establishing the evaluation criteria, weighting of the criteria and scoring the technologies against the criteria set. The criteria were grouped into costs and benefits of the climate technology for both adaptation and mitigation. The costs included the sub criteria of capital costs, and operating and maintenance of the technology hardware. The benefits included economic, social, and environmental and climate related (potential for greenhouse gas reduction and resilience building) benefits.

A minimum of ten climate technologies for each of the prioritized adaptation and mitigation sectors were identified and taken through the prioritization process using a participatory MCA. Through the MCA process, the ten climate technologies for each sector were ranked by stakeholders from the highest to the least priority technologies. In each sector, the top three climate technologies were selected to become the priority climate change technologies in Malawi. These technologies prioritized by Malawi's stakeholders are presented in the tables below, per sector.

Table 6. 2 Results of MCA process for Agriculture and Water Sectors, Adaptation Technologies

Sector	Priority (rank)	Adaptation Technology
	1	*Landscape restoration for improved land productivity*

Agriculture	2	*Integrated crop-livestock-aquaculture-forest production systems*
	3	*Community-based agricultural extension*
Water	1	*Rainwater harvesting*
	2	*Integrated river basin management*
	3	*Integrated flood management*

Malawi recently completed the first step of the TNA process. Please note that the TNA Reports provide a shop list of technologies and their attributes described in the related Technology Fact Sheets (TFS) appended to the TNA reports. Currently, the country is in the second step of TNA process, of identifying barriers for the prioritized climate technologies in table 8.0. Once the technology barriers have been identified and analyzed, and enabling framework developed, Technology Action Plans (TAPs) will be developed to guide the implementation and transfer of such technologies.

6.4 Research and Systematic Observation

Non-Annex I Parties are encouraged to provide information on climate change research and systematic observation, including their participation in and contribution to activities and programmes, as appropriate, of national, regional and global research networks and observing systems. Additionally, Non-Annex I Parties are encouraged to provide information on research relating to programmes containing measures to mitigate climate change; programmes containing measures to facilitate adequate adaptation to climate change; and the development of emission factors and activity data.

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