ETHIOPIA'S

Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC)

The Federal Democratic Republic Of Ethiopia
Ministry of Environment and Forest
2015

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SUBMITTED TO:
UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

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FOREWORD

On behalf of the government of the Federal Democratic Republic of Ethiopia, it is an honour and privilege to present Ethiopia's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). Ethiopia is currently faced with serious challenges arising from climate change which include erratic rainfall, severe droughts and floods. Ethiopia ratified the UNFCCC on 31 May 1994 and the Kyoto Protocol on 21 February 2005 as a Non-Annex I party, thereby signifying its commitment to joining the international community in combating climate change. Ethiopia is therefore obliged to submit national communications in accordance with the requirements of the UNFCCC. Ethiopia's Initial National Communication (INC) was presented to the UNFCCC on 16 October 2001. The INC reported that the Ethiopian economy is dependent on agriculture and natural resources that are extremely sensitive to the effects of climate change. The Second National Communication (SNC) is a follow-up to the INC and is built on the continued work under the convention. Since the submission of the initial communication, the Government of the Federal Democratic Republic of Ethiopia has developed the Climate Resilient Green Economy (CRGE) Strategy that utilizes a sectoral approach in identifying and prioritizing more than 60 initiatives. GoE has also developed policies, strategies and action plans, including Ethiopia's Growth and Transformation Plan (GTP), the National Adaptation Programme of Action (NAPA), the Nationally Appropriate Mitigation Actions (NAMAs), Ethiopia's Programme of Adaptation to Climate Change (EPACC), Energy Policy, Water Policy, Agricultural and Rural Development Policy Strategies (ARDPS), among others. These provide a legal basis for resource mobilization to address climate change adaptation and mitigation, including mainstreaming and integrating climate change issues into relevant government organs. They also promote the enhancement of synergies among different sectors. Every sector has been requested to prepare and implement a sector strategy to address the effects of climate change by identifying and implementing appropriate mitigation and adaptation measures. Ethiopia's SNC recognizes that climate change is a cross-cutting issue which affects all sectors of our economy. The country's primary focus is to build a climate resilient green economy and secure long-term sustainable resources for adaptation to the effects of climate change. The country is overwhelmingly embracing low carbon development and the exploitation of sustainable energy resources. This SNC has been prepared taking into account the country's reliance on natural resources. The promotion of environmental and ecological sustainability has become one of the key national strategies in the present communication. The SNC document has pointed out that the fragile environment places a limit on the economic development of our country. Therefore, there is a need to safeguard natural resources since they form a fundamental basis for livelihood generation and the accumulation of national assets that are of significant value to the people of Ethiopia. The preparation of this SNC draws on input from relevant stakeholders such as the Federal Government, academic and research institutions, and non-governmental organization. Their involvement has greatly contributed to the comprehensive information contained in this document.

H.E. Belete Tafere

Minister for Environment and Forest

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This SNC publication was compiled and reviewed by the National GHG Inventory team. The team comprises of designated sector experts representing various government institutions from all the four IPCC GHG Inventory Sectors which include; Agriculture, Forestry, and Land Use sector (AFOLU); Energy sector; Industrial Processes and Product Use sector (IPPU); and the Waste sector. The national stakeholders drawn from the Regions, Lead Agencies, NGOs, CSOs, Universities and the private sector conducted rigorous review of this report. GEOENVI Solutions International provided the required capacity-building services that resulted in the production of this SNC for Ethiopia.

ACKNOWLEDGEMENTS

The Global Environment Facility (GEF) through the United Nations Development Programme (UNDP) supported the development of Ethiopia's Second National Communication (SNC) to the UNFCCC. This national communication is required in order to meet the country's obligations under the Convention. The Ministry of Environment and Forest, as the body responsible for overseeing and coordinating climate change issues in the country, coordinated the preparation of this SNC, which was built on work done under the Initial National Communication (INC) of Ethiopia, presented to the UNFCCC on16 October 2001, and the Climate Resilient Green Economy (CRGE) Strategy launched in 2011. This report was prepared with technical support from the National GHG Inventory Team, and was managed and coordinated by the State of Environment Reporting Directorate within the Ministry of Environment and Forest, while UNDP under the leadership of Samual Bwalya; the UNDP Country Director, provided technical, financial, and logistical guidance. We believe that the exercise of preparing this National Communication, besides meeting commitments under the convention, has provided us with experience that can be used to undertake similar work in the future. We would like to take this opportunity to express our gratitude to the GEF and to UNDP for their financial and technical support. We acknowledge the role of the staff of the Ministry of Environment and Forestry, the GEF and UNDP in organizing workshops and meetings, and providing and distributing technical materials, information, and analytical tools to the stakeholders involved in the preparation of this National Communication. To this end, 10 GHG Inventory Team members drawn from stakeholder institutions came together as a team to contribute and review the technical information and data used in its preparation. This multi-disciplinary approach was used to ensure that a holistic understanding of climate change issues in the country was achieved. Thus, this report represents the culmination of collaboration between experts from Government, non-governmental organizations, educational and research institutions, and professional associations.

ABBREVIATIONS AND ACRONYMS

AAGR	Average Annual Growth Rate
ACMAD	African Centre for Meteorological Applications and Development
AFD	Agence Française de Développement
AFOLU	Agriculture, Forestry and Land Use
AMJ	AprilMay-June (Northern Hemispheric Spring season)
AQUASTAT	FAO's global water information system, developed by the Land and Water Division
ARDPS	Agricultural and Rural Development Policy Strategies
AR4	Fourth Assessment Report (IPCC, 2007)
AR5	Fifth Assessment Report (IPCC 2013/2014)
AWD	Acute Water-Borne Diarrhea
BAU	Business as Usual
BOD	Biochemical Oxygen Demand
Br	Birr (Ethiopian currency)
CBD	Convention on Bio-diversity
CCAP TWG	Climate Change Adaptation Programme Technical Working Group
CCM	Canadian Climate Model
CCD	Convention to Combat Desertification
CCI	Complimentary Community Investment (Ethiopia's Food Security Programme)
CDM	Clean Development Mechanism
CEEPA	Centre for Environmental Economics and Policy in Africa
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CNG	Compressed Natural Gas
COP	Conference of the Parties
CPWD	Community Participatory Watershed Development
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
CSO	Civil Society Organization
DFID	Department for International Development (UK)
DRASTIC	GIS-based software for modelling groundwater
EAEDPC	Ethiopian Alternative Energy Development and Promotion Centre
ECIC	Ethiopia Climate Innovation Centre
ECPC	Ethiopian Cleaner Production Centre
EEA	Ethiopian Economics Association

ABBREVIATIONS AND ACRONYMS

EEPCO	Ethiopian Electric Power Corporation
EfD	Environment for Development
EIB-	Ethiopian Institute of Biodiversity Conservation
EIGS	Ethiopian Institute of Geological Surveys
EJ	Exa-joules
ENSO	El Niño Southern Oscillation
EPACC	Ethiopia's Programme of Adaptation to Climate Change
ERA-	The Ethiopian Road Authority
EREPC	Ethiopian Rural Energy Promotion Centre
EWCA	Ethiopia Wildlife Conservation Authority
FDRE	Federal Democratic Republic of Ethiopia
FAO	Food and Agricultural Organization of the United Nations
FEWS NET	Famine Early Warning Systems Network
FOD	First Order Decay
FSP	Food Security Programme (of the Federal Democratic Republic of Ethiopia)
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDL	Geophysical Fluid Dynamics Laboratory's model
GHC	Greenhouse Gas
GIS	Geographical Information System
GJ	Gigajoule = 109 Joules
GPG2000	Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000)
GPG-LU-LUCF	Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003)
GTP	Growth and Transformation Plan
GTZ	Gesellschaft für Internationale Zusammenarbeit
GWh	Gigawatt hour
GWP	Global Warming Potential
HABP	Household Asset Building Programme (of Ethiopia's Food Security Programme)
HSS	Health Systems Strengthening
ICPAC	IGAD Climate Prediction and Application Centre

ABBREVIATIONS AND ACRONYMS

IE/BCC	Information and Education/ Behavioral Changes and Communications
IFPRI	International Food Policy Research Institute
IFRC	International Federation of Red Cross and Red Crescent Societies
IGAD	Intergovernmental Authority on Development
INCFC	Intergovernmental Negotiating Committee for Framework Convention on Climate Change
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPCC, 1996	Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories
IPCC, 2006	2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006)
IPPU	Industrial Processes and Product Use
ITCZ	Inter-tropical Convergence Zone
IUCN	International Union for Conservation of Nature
JAS	July-August-September (Northern Hemispheric Summer season)
JFM	January-February-March (Northern Hemispheric Winter season)
JICA	Japan International Cooperation Agency
JJAS	June-July-August-September (season)
JRC	Joint Research Centre, European Commission Institute for Environment and Sustainability
LEAP	Long-range Energy Alternatives Planning System
LEDS	Low Emission Development Strategy
LPG	Liquefied Petroleum Gas
LUCF	Land-Use Change and Forestry
LULUCF	Land Use, Land-Use Change and Forestry
MCF	Methane Correction Factor
MEF	Ministry of Environment and Forest
MME	Ministry of Mines and Energy
MMS	Manure Management System
MoA	Ministry of Agriculture
MoCB	Ministry of Capacity Building
MoE	Ministry of Education
MoFED	Ministry of Finance and Economic Development
MoID	Ministry of Infrastructure Development

ABBREVIATIONS AND ACRONYMS

MoWIE	Ministry of Water, Irrigation and Energy
MRV	Measuring, Reporting and Verification
MSW	Municipal Solid Waste
NAMAs	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programme of Action
NMA	National Meteorology Agency
NMSA	National Meteorological Services Agency
NOAA	National Oceanic and Atmospheric Administration
OND	October, November, December (Northern Hemispheric Autumn season)
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PJ	Peta-Joule = 1015 Joules
ppb	Parts per billion
PSNP	Productive Safety Net Programme (of Ethiopia's Food Security Programme)
R & D	Research and Development
RFE	Rainfall estimates (for Africa, produced by NOAA Climate Prediction Center)
RVF	Rift Valley Fever
SAR	Second Assessment Report (IPCC, 1995)
SBN	Standard Book Numbering or Standard Book Number
SEI	Stockholm Environment Institute
SNC	Second National Communication
SNNP	Southern Nations, Nationalities and Peoples
SOC	Soil Organic Carbon
SSA	Sub-Saharan Africa
SWC	Soil and water conservation
SWDS	Solid Waste Disposal Site
TAR	Third Assessment Report (IPCC, 2001)
TOE	Tons of oil equivalent
UKMO	United Kingdom Meteorological Office
UKMO-89	United Kingdom Meteorological Office-1989 model
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNU-WIDER	United Nations University World Institute for Development Economics Research

ABBREVIATIONS AND ACRONYMS

WBISPP	Woody Biomass Inventory and Strategic Planning Project
WCED	World Commission on Environment and Development
WMO	World Meteorological Organization
WSSD	World Summit on Sustainable Development

LIST OF STANDARD EQUIVALENTS, UNITS AND CONVERSION FACTORS

1 mega joule (MJ)	= 10^6 joules
1 gigajoule (GJ)	= 10^9 oules
1 terajoule (TJ)	= 10^{12} joules
1 pet joule (PJ)	= 10^{15} joules
1 exajoule (EJ)	= 10^{18} joules
1 toe	= 41.868 *10^9 Joules
1 ton	= 1,000 kilogram
1 cubic metre	= 1,000 litres
1 gallon	= 3.785 litres
1 ton	= 1 megagram
1 kiloton	= 1 gigagram
1 megaton	= 1 teragram
1 gigaton	= 1 petagram
1 kilogram	= 2.2046 lbs
1 hectare	= 10,000 m
1 calorie	= 4.1868 joules
1 atmosphere	= 01.325 kPa
Bt	= billion tons
cc	=cubic centimetre
Dm	= dry matter
g	= gram
Gg	= gigagrams
GW	= gigawatts
GWh	= gigawatt-hours
Ha	= hectare

LIST OF STANDARD EQUIVALENTS, UNITS AND CONVERSION FACTORS

J	= joule
L	= litre
l/s	= litres per second
mm	= millimetres
m^3	= cubic metre
mamsl	= metres above mean sea level
mbmsl	= metres below mean sea level
m/s	= metres per second
Mt	= million tons
MW	= megawatt
MWe	=megawatt electrical
MWh	= megawatt-hour
^oC	= degree Celsius
t	= ton
tC	=tons of carbon
Wh/m^2	= watt hours per square metre

GLOBAL WARMING POTENTIALS[1] -AR4 (100-YEAR TIME HORIZON)

Gas	GWP
CO_2	1
CH_4	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
HFC-4310mee	1,640
CF4	7,390
C_2F_6	12,200
C_4F_{10}	8,860
C_6F_{14}	9,300
SF_6	22,800
NF_3	17,200

1 Source: IPCC, 2007 The CH_4 GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapour. The indirect effect due to production of CO_2 is not included.

EXECUTIVE SUMMARY

ES-1.1. Background

It is evident that the increase in concentrations of greenhouse gases in the atmosphere continues to cause global warming, leading to adverse climatic changes. The proliferation of these gases is mainly due to increased anthropogenic activities[2], including use of fossil fuels in transport and energy generation, land use changes and deforestation due to expansion of agriculture and settlements. Climate change caused by the effects of greenhouse gases emitted as a result of anthropogenic activities has widespread negative implications for the economy, people, and the natural and built environment. Due to concerns arising from the risk of global climate change, the UN General Assembly established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INCFCCC) in 1990. These efforts succeeded, and the United Nations Framework Convention on Climate Change (UNFCCC) came into force on 21 March 1994. The Kyoto Protocol entered into force in February, 2005. The UNFCCC sets an overall framework for intergovernmental efforts to tackle the challenge posed by global climate change. Ethiopia ratified the UNFCCC on 31 May1994 and the Kyoto Protocol on 21[t]February 2005 as a Non-Annex I party, thereby signifying its commitment to join the international community in combating the problem of climate change. The ultimate objective of this convention and any related legal instruments that the Conference of Parties may adopt is to achieve, in accordance with the relevant provisions of the convention, stabilization of greenhouse gas concentrations globally.

This Second National Communication (SNC) has been compiled to meet Ethiopia's obligations under the UNFCCC. It describes national progress made to implement the Convention since 1994, after the First National Communication since FNC or since 1994.

In accordance with the guidelines for preparing national communications, this report contains the results of the National Inventory of Greenhouse Gas (GHG) sources and sinks, the precursor and non-GHG emissions. The main progress made in addressing the country's vulnerability and adaptation to climate change, mitigation measures, and other information relevant for the implementation of the Convention, taking into account Ethiopia's national circumstances and development goals, objectives and priorities. Ethiopia's barriers, gaps, and national capacity and technical support needs are also documented in this SNC.

ES-1.2. The National Communication Process

The Directorate of the State of Environment and Reporting within the Ministry of Environment and Forest (MEF) coordinated the preparation of this Second National Communication. MEF is the National Climate Change Focal Point for the UNFCCC. To support its preparation, six Technical Working Groups (TWGs) based on the IPCC GHG Inventory sectors were established to source and interpret information on the impacts of climate change and the activity data used in estimating GHG emissions. Contributions were made by the TWGs in the following thematic areas: Energy, Transport, Land Use Change and Forestry, Industrial Processes and Product Use, Agriculture, Waste, and Meteorology Reviews. The Thematic Working Groups worked under the guidance of the present GHG Inventory coordinator at the Directorate of the State of Environment and Reporting. These Thematic Working Groups form the National GHG Inventory team, a multisectoral National Climate Change Committee which comprises representatives from various government ministries

2 **The term "anthropogenic," in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities**

and departments. The team is responsible for developing and coordinating programmes, and projects aimed at addressing climate change in line with the country's development priorities and its constituent working groups are focal points for climate change at their respective institutions. Stakeholder participation in the national communication process is expected to strengthen the capacity of the relevant stakeholders to fulfill the country's obligations under the Convention in the preparation of future communications. It will also permit the mobilization of physical, financial, and technical resources to support the regular compilation of the information required for updating national strategies and the UNFCCC.

In following the UNFCCC requirement under Article 4, to develop and submit national greenhouse gas emissions estimations, the emissions and sinks presented in this report are organized by source and sink categories, and calculated using internationally-accepted methods developed by the IPCC. In addition, annual emissions and sinks have been calculated and presented in line with the UNFCCC reporting guidelines under the international agreement. The use of consistent methods to calculate emissions and sinks by all parties to the UNFCCC ensures the comparability of the estimates.

ES-1.3. National Circumstances

ES-1.3.1. Country Profile

The Federal Democratic Republic of Ethiopia comprises nine regions (Tigray, Afar, Amhara, Oromia, Somalia, Benshangul/Gumuz, Southern Nations, Nationalities and Peoples (SNNP), Gambela, Harari Peoples) and two City Administrations, Addis Ababa (the capital city) and Dire Dawa. The overall responsibility to fulfill the obligations under the United Nations Framework Convention on Climate rests with the Federal Government, while the regional governments participate in achieving them through the relevant policies for which they have responsibility.

Ethiopia is implementing the Climate Resilient Green Economy (CRGE) Strategy to achieve the vision of becoming a low carbon; middle income economy by 2025. This strategy will also enable the country to strengthen its capacity to adapt to the effects of climate change. Over the past few years, Ethiopia has registered unprecedented and continuous growth as a result of policies and strategies carefully tailored to respond efficiently to the existing socio-economic context. The CRGE strategy is considered to be an additional positive step to resist the adverse effects of climate change and build an economy that will provide sustainable development. The Government has identified four major economic pillars to underpin the CRGE, namely: improving crop and livestock production practices to allow better food security and to increase farmers' incomes while reducing greenhouse emissions; protecting and re-establishing forests for their value to the economy and the ecosystem, specifically by increasing carbon stocks. The other two goals include expanding electricity generation from renewable sources of energy for domestic and regional markets; and leapfrogging to modern and energy-efficient technologies in the transport, industrial and construction sectors.

ES-1.3.2. Geographic Profile

The country is located in the North East Africa region, the Horn of Africa, between approximately E 32°58'00" to E 48°00'00" and 14°55'00" N to 3°25'00" N. It is bordered by Eritrea to the north, Djibouti and Somalia to the east, Sudan and South Sudan to the west, and Kenya to the south. It occupies an area of 1,104,300 km^2 (426,372 square miles), a significant portion of the Horn of

Africa, and is landlocked. Ethiopia has a tremendous diversity of climatic and biophysical settings, ranging from equatorial rainforest in the south and southwest, which is characterized by high rainfall and humidity, to Afro-Alpine on the summits of the Semen and Bale mountains and desert-like conditions in the north-east, east and south-east lowlands. Altitudinal gradient ranges from 126 mbmsl at the Kobar sink in the Dallol Depression to about 4,620 masl at Ras Dajen in the Semien Mountains whre temperatures are below freezing for most of the year. The resulting annual rainfall varies from about 3,000 mm at Masha in the Baro-Akobo Basin to barely 200 mm along the Ethiopia-Djibouti and Ethiopia-Somali border in the Ogaden and Aysha Basins. The variation in the biophysical characteristics of Ethiopia ranging from hot arid desert to mountain ranges accounts for the variation in climate, soil type and cultural practices across the country.

ES-1.3.3. Climatic Characteristics of Ethiopia

The climate of Ethiopia is controlled by the complex topography of the country and its geographical location lying within the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and its associated atmospheric circulations. The Inter-Tropical Convergence Zone (ITCZ) migration drives mainly the seasonal rainfall in Ethiopia. The ITCZ changes its precise position over the course of the year, while oscillating across the equator from its northernmost position over northern Ethiopia in July and August, to its southernmost position over southern Kenya in January and February. The movements of the ITCZ are sensitive to variations in the Indian Ocean's sea surface temperatures and vary from year to year; hence the onset and duration of the rainy seasons vary considerably inter-annually, causing frequent drought. The best documented cause of this variability is the El Niño Southern Oscillation (ENSO). Warm phases of ENSO have not only been associated with reduced rainfall in the main wet season, causing severe drought and famine in north and central Ethiopia, but also with enhanced rainfalls in the earlier February-April rainy season, which mainly affects southern Ethiopia.

ES-1.3.4. Population

The population of Ethiopia has increased steadily over the last three decades, from 42.6 million in the 1984 census to 53.5 million in the 1994 census and 73.8 million in the 2007 census, and to a projected 91 million in 2013. There were slight declines in population growth rates between censuses, from 3.1 per cent per annum in 1984 to 2.9 per cent in 1994 and 2.6 per cent in 2007. The majority of Ethiopia's population lives in the rural areas with about 16 per cent of the population living in urban areas. The main occupation of the rural population in the uplands is mixed crop and animal farming, while a pastoral people who depend mainly on livestock production and practise traditional nomadism in search of grass and water mostly inhabits the lowland areas. It is worth noting that more than 80 per cent of the country's total population lives in the regional states of Amhara, Oromiya, and SNNP.

ES-1.3.5. Biodiversity

Ethiopia has a very rich biodiversity resulting from the extraordinary number of ecological zones that it encompasses owing to its large longitudinal and latitudinal ranges. These ecological zones host rare, endangered species and high rates of endemism. Because of its importance as a centre of genetic and agricultural diversity, the conservation of Ethiopia's biodiversity is an issue of global importance. Most parts of the country fall within two biodiversity hotspots, Eastern Afromontane and the Horn of Africa, which are among the 34 globally important biodiversity conservation regions.

ES-1.3.6 Water Resources

The geographical location of Ethiopia and its favorable climate provides it with relatively high rainfall, making the country a critical catchment in the region. Preliminary studies and professional estimates indicate that the country has an annual surface runoff of close to 122 billion m^3 of water excluding ground water. The hydrology of Ethiopia forms a critical foothold for the water resources of the Horn of Africa region, including Sudan and Egypt. Much of the water flows across Ethiopia's borders, being carried away by the transboundary rivers to neighboring countries in northern and eastern Africa. The water resources in Ethiopia are unevenly distributed, both spatially and temporally. Between 80 and 90 per cent of Ethiopia's water resources are found in the four river basins in the west and south-western part of the country, where no more than 30-40 per cent live. The water resources available in the east and central river basins represent only 10-20 per cent of the total, whereas over 60 per cent of the country's population live in these basins.

ES-1.3.7. Agriculture and Forestry

Agriculture plays a central role in the economic and social life of the people of Ethiopia. It is considered to be the backbone of Ethiopia's economy and it employs about 80-85 per cent of working population. This sector contributes about 40-50 per cent of total GDP with livestock and livestock products accounting for about 20 per cent of agricultural GDP (27 per cent of total GDP) with livestock and forestry producing 20 per cent and 7 per cent, respectively. In the country, smallholders who are engaged in subsistence agriculture that is rain-fed and with low yields cultivate about 95 per cent of the cropped area. Ethiopia's agriculture is heavily dependent on natural rainfall, with irrigated land accounting for less than 1 per cent of the total cultivated land.

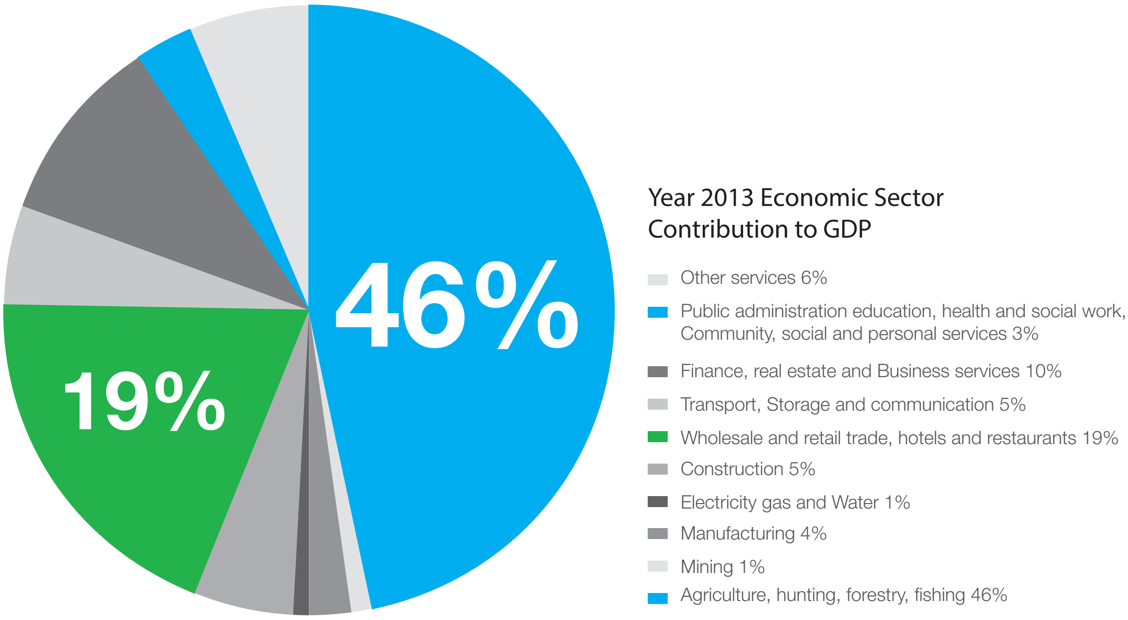
ES-1.3.8. Energy

The energy sector is identified as a key part of the economy's infrastructure in the country's development plans. The GTP envisages a reliable supply of energy to the different economic and social sectors. Ethiopia plans to earn foreign exchange by developing the country's full potential for electricity generation. The country plans to construct the Grand Renaissance Dam on the Nile. This is multi-billion dollar project to develop electricity for domestic consumption and export. The total hydropower potential of Ethiopia is estimated at 40 GW of which less than 10 per cent has been developed (Awulachew, and others 2007). Considering solar energy in Ethiopia, the national annual average daily irradiance is estimated to be 5.2 $kWhm^{-2}day^{-1}$ with seasonal variations that range between a minimum of 4.5 $kWhm^{-2}day^{-1}$ in July to a maximum of 5.6 $kWhm^{-2}day^{-1}$ in February and March (ENEC-CESEN, 1986). The country has exploitable potential for geothermal energy of 5,000 MW (700MWe). Total energy consumption in Ethiopia is estimated to be about 1,250 PJ, of which the traditional biomass fuels, which are the main sources of energy, translate to 16 GJ of energy (1,000 kg of wood equivalent) per capita.

ES-1.3.9. Economic Development

The vision of Ethiopia is to become a middle-income country by 2025. The Ethiopian economy has recently experienced pronounced growth, averaging 10.9 per cent per year in 2004/05-2012/13, which is way above the regional average of 5.3 per cent. This growth rate is double the Sub-Saharan African rate and triples the world average, making Ethiopia one of the fastest growing economies in the world. Agriculture is largest economic sector while the growth rate in the mining sector has been very rapid, reaching 55.7 per cent in the year 2011.

Figure ES 1-1: Contribution to GDP by Economic Sector, 2013



The services sector has been a major driver of economic growth, contributing up to half of total growth during the last decade. The industry sector's performance has been boosted by the construction boom and expansion in the mining and manufacturing subsectors. Growth in the industry sector was very strong in the three years to 2012/13 and was the strongest sectoral performer in 2012/13, registering 18.5 per cent growth. The Government continues to foster political good will, develop ambitious development plans such as the CRGE and the GTP, and keep the country resilient enough to maintain double-digit economic growth and to achieve most of the Millennium Development Goals (MDGs). Figure ES 1-1 and Figure 1 8 (see Chapter one) show the economic sectors' contributions to GDP for 2013 and 2008 respectively.

The main challenge for Ethiopia is to address the living standards of its population, keep up with, and accelerate building on the progress made in recent years. The Government is already devoting a very high share of its budget to pro-poor programmes and investments. Over the past two decades, there has been significant progress in key human development indicators: primary school enrolment has quadrupled, child mortality has been cut by half, and the number of people with access to clean water has more than doubled. These gains, together with recent moves to intensify the fight against malaria and HIV/AIDS, demonstrate the Government's determination to improve the well-being of its population.

The Government of Ethiopia's recently completed five-year development plan (2010/11-2014/15), the Growth and Transformation Plan (GTP I), was geared towards fostering broad-based development in a sustainable manner. The GTP envisaged a major leap in not only economic structure and income levels, but also in the social indicators. Key goals included the following.

i. Rapid economic growth, targeted at 11 per cent per year at worst, and at best at a rate fast enough to double the size of the economy and to bring GDP per capita to $698 by 2015.

ii. Doubling agricultural production, to ensure food security in Ethiopia for the first time.

- **iii.** An increased contribution from the industrial sector particularly focused on raising production in sugar, textiles, leather products and cement.
- **iv.** An increase in foreign exchange reserves and the annual appreciation of the Birr by 5 per cent against the dollar.
- **v.** An increase in the road network from 49,000 km to 64,500 km by 2015.
- **vi.** An increase in power generation capacity from 2,000 MW to 8,000 MW, and in the number of customers from 2 million to 4 million by 2015.
- **vii.** Construction of 2,395 km of railway line.
- **viii.** Achievement of all the Millennium Development Goals (MDGs).

ES-1.4. National Greenhouse Gas Inventory

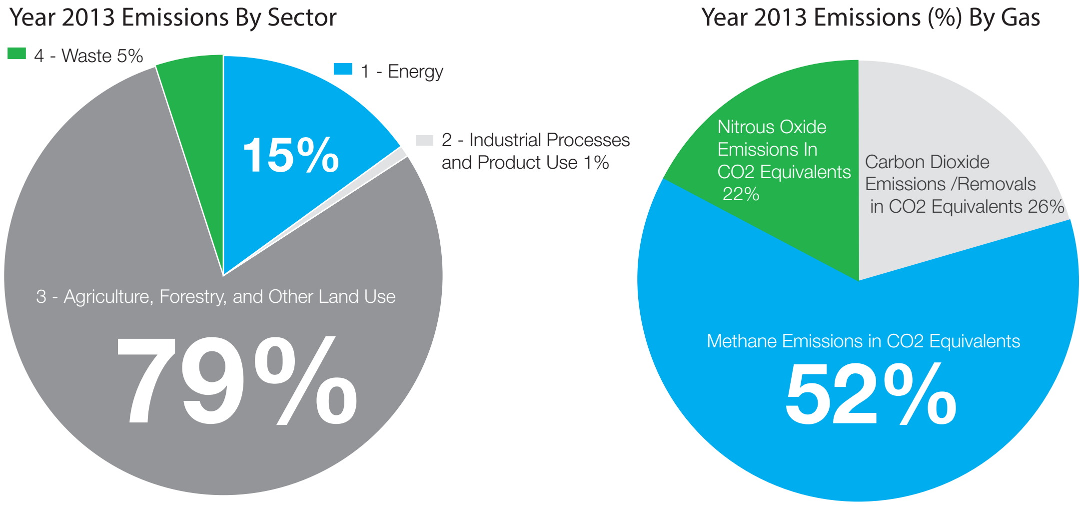
In following the UNFCCC requirement to develop and submit data on national greenhouse gas emissions estimates, the emissions and sinks presented in this report were calculated using internationally-accepted methods originating with the IPCC. The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories were used to estimate the country's greenhouse gas emissions for the years 1994-2013 by sources and removals by sinks. Emissions/removals of seven gases, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_X), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulfur dioxide (SO_2), were addressed. In year 2013, the total emissions were estimated to be 146,160.43 Gg of carbon equivalent. The quantity by GHG was carbon dioxide, 40,357.15 Gg; methane, 72,793.82 Gg and Nitrous Oxide, 30418.03 Gg. In year 2013, there was a decrease of 24.11 per cent in total estimated emissions compared with 2010.

The results for CO_2-equivalent emissions and removals clearly indicate that the agriculture and energy sectors are the most important sources of emissions, while the land-use change and forestry sector (LUCF) is the most important with respect to removals. Methane and carbon dioxide are the primary greenhouse gases emitted through human activities in Ethiopia. In 2013, methane and carbon dioxide accounted respectively for about 52 and 26 per cent of all greenhouse gas emissions from human activities in the country. The pie charts in Figure 1-2 show emissions by sector and by gas in 2013. Figure 1-2 indicates that 79 per cent of all emissions were from the AFOLU sector while the energy and industrial processes and product use (IPPU) sectors contributed 15 per cent and 1 per cent respectively and the waste sector only 5 per cent.

The largest sources of CO_2 were cropland and grassland at 59 per cent and 33 per cent while the transport sector contributed only 3 per cent. CH_4 emissions were mainly from enteric fermentation associated with domestic livestock, at 26 per cent, other energy sector which is primarily from the use of fuel wood and wood waste in the residential and commercial institutions at 26 per cent, and solid waste disposal and decomposition at 25 per cent. The other sources of methane included wastewater treatment and discharge at 6 per cent, manure management and biomass burning at 5 per cent each, rice cultivation 3 per cent, transport 2 per cent, solid fuels (coal) and energy industries at 1 per cent each.

The largest contribution of nitrous oxide was from manure management at 44 per cent with direct and indirect N_2O emissions from manure management accounting for 38 and 6 per cent respectively. This was followed by direct and indirect N_2O emissions from managed soils, at 24 per cent and 16 per cent respectively. The fuel combustion activities, other energy sectors (residential and commercial), and wastewater treatment and discharge contributed 5 per cent, 5 per cent and 4 per cent respectively. This indicates that manure management, agricultural soil management, energy generation and waste management were the major sources of N_2O emissions.

Figure ES 1-2: Emissions by Sector and by Gas, by 2013.



ES-1.4.1. Aggregated Emissions and Trends

There has been a rising trend in aggregated national GHG emissions in Ethiopia. Estimated emissions in 2013 were about 447 per cent higher than in 1994 but 34.5 per cent and 24.6 per cent lower than in 2000 and 2010 respectively. Comparing GHG emissions in 1994, 2000 and 2010 with those in 2013 shows that total (gross) CO_2 emissions increased by an estimated 237.6 per cent between 1994 and 2013, but by 2013 had decreased by 66.1 per cent and 58.3 per cent from the 2000 and 2010 estimates respectively. The 2013 methane emission estimates show significant increases from 1994, 2000, and 2010, by 96.6 per cent, 24.4 per cent and 6 per cent respectively, while the nitrous oxide emissions increased by 113.5 per cent, 61.5 per cent and 3.2 per cent between the comparator inventory years and 2013. The trend of carbon stocks of Ethiopia in the LUCF sub-sector which was decreasing rapidly in the period 1990-2000 is now stabilizing following the intensive afforestation and re-afforestation campaigns by the Government. This has seen the forest cover increase from 7 per cent the late 1990s to 14 per cent in 2013. Aggregation of the 2013 CO_2, CH_4 and N_2O emissions for all the national GHG inventory sectors using the AR4 IPCC Global Warming Potential (GWP) factors over a 100 years' time horizon yields a total of about 146,160.43 Gg CO_2-equivalents, excluding emissions/removals from the categories classified as memo items. Assuming a population of 91 million for the year 2013, the estimated per capita emission was 1.5776 tons of CO_2-equivalents in that year. The Figures ES 1- 3, ES 1- 4 and ES 1- 5 shows Percentage of Emissions Change between the years 2010, 2000 and 1994, and 2013. The Table-ES 1-1 below shows aggregated emissions for the years 1994-2013.

Figure ES 1-3: Change in Emissions Change between 2010 and 2013 (%)

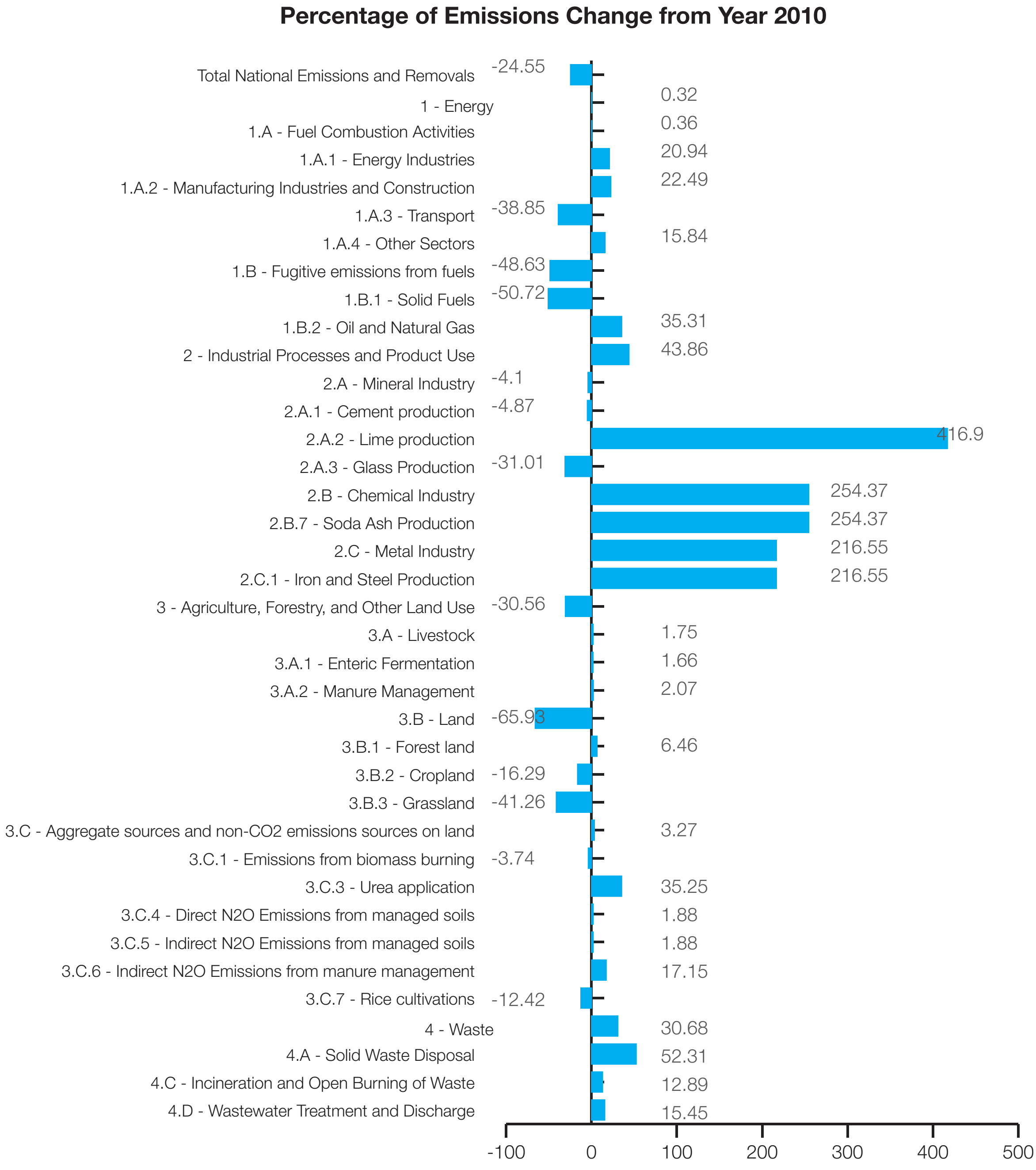


Figure ES 1-4: Change in Emissions between 2000 and 2013 (%)

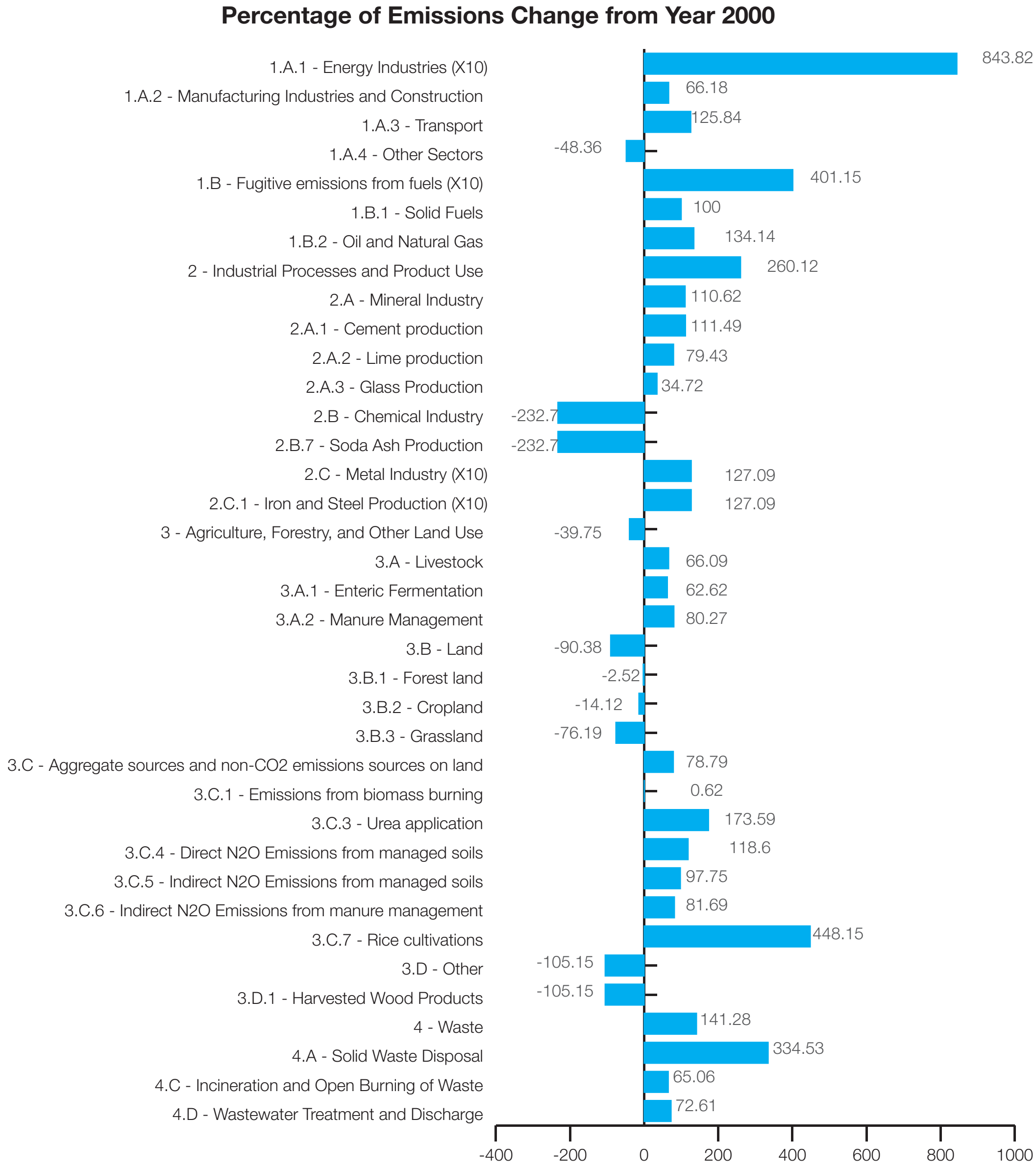
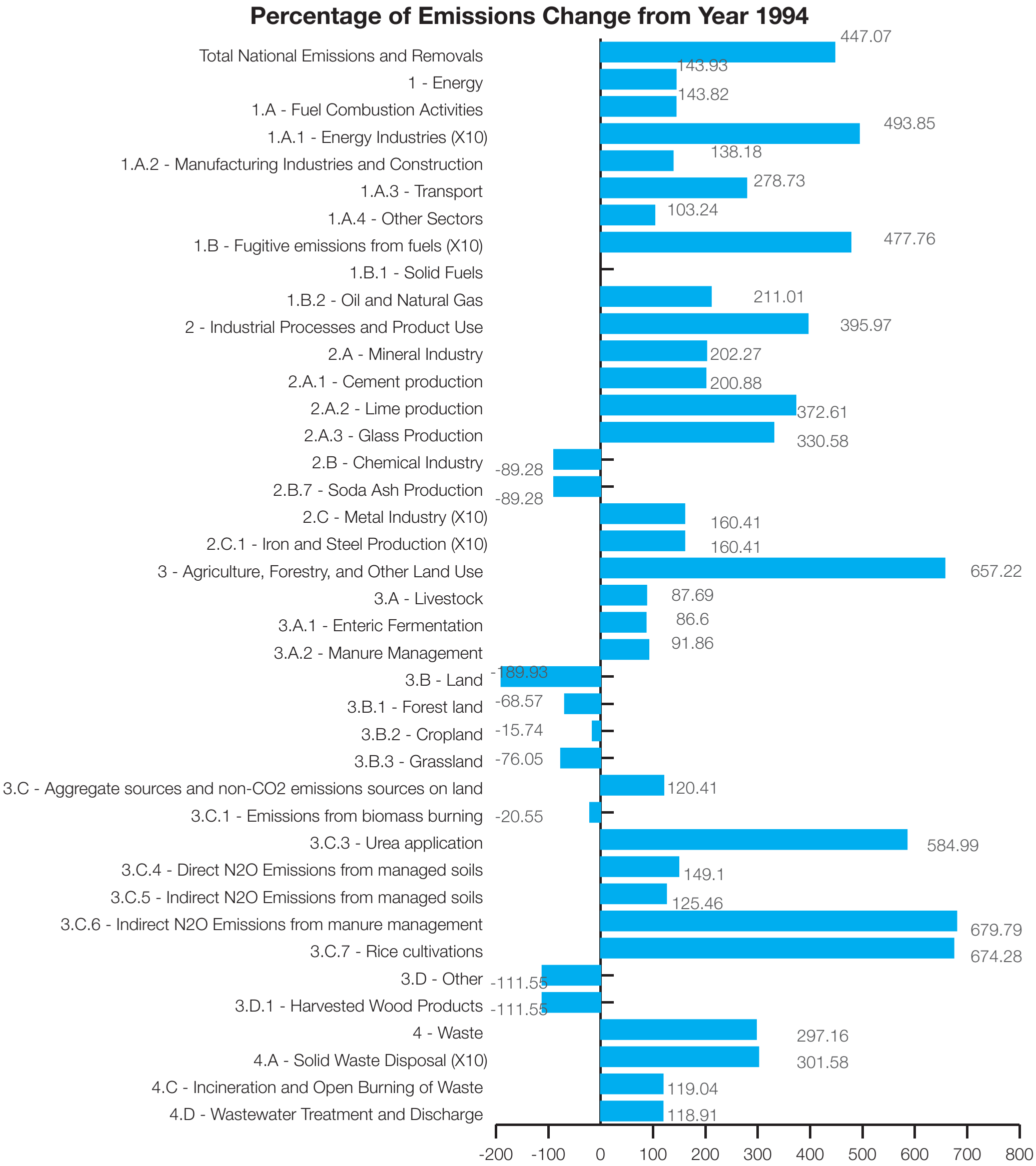


Figure ES 1-5: Change in Emissions between 1994 and 2013 (%)



Community Participation in Conservation Activities

Table ES 1-1: Aggregated Emissions, 1994-2013 (Gg)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total National CO2 Equivalent Emissions and Removals	25,433.179	124,159.49	104,606.97	130,230.52	133,209.21	134,092.33	183,422.00	202,697.74	201,828.80	204,306.18
Carbon Dioxide Emissions/ Removals in CO2 Equivalents	-26,050.54	72,340.089	50,511.81	51,561.39	53,760.92	54,478.54	105,663.2	122,681.3	113,253.8	116,779.5
Methane Emissions in CO2 Equivalents	37,033.398	38,068.558	39,454.12	59,160.622	59,680.902	59,910.412	58,499.454	60,432.116	66,519.072	65,935.504
Nitrous Oxide Emissions in CO2 Equivalents	14,303.658	13,492.568	14,658.637	19,299.657	19,558.628	19,721.684	18,911.616	19,260.924	22,077.237	21,614.561

Table ES 1-2: Aggregated Emissions, 1994-2013 (Continued)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total National CO2 Equivalent Emissions and Removals	157,626.65	144,358.07	148,884.24	160,211.53	176,075.07	173,651.75	186,361.60	208,884.77	142,590.49	146,160.43
Carbon Dioxide Emissions/ Removals in CO2 Equivalents	66,810.55	68,019.98	68,512.75	71,372.27	85,187.04	80,912.06	88,095.24	111,818.2	40,266.83	35,856.73
Methane Emissions in CO2 Equivalents	67,051.694	53,905.573	55,932.864	62,142.798	63,410.744	65,551.894	68,699.37	71,341.652	71,825.46454	72,793.82214
Nitrous Oxide Emissions in CO2 Equivalents	23,790.877	22,462.551	23,769.002	26,733.978	27,514.442	27,224.805	29,603.401	25,759.662	30,500.73633	30,418.03479

ES-1.4.2 Recalculation of Emission Estimates

The development of the national GHG inventory used in the compilation of the Second National Communication involved recalculation of emissions estimates for 1994 and 1995, which were reported in the INC, and of the estimates for 2010, which were used in the development of the CRGE Strategy. In the INC the total emissions were estimated to be 39,885 Gg and 44,886 Gg for 1994 and 1995 respectively, while the revised estimates for the SNC are 25,433.179 Gg for 1994 and 124,159.49 Gg for 1995. Although there was a great disparity in the two estimates for 1995, the estimates for 1994 were close and the estimated removals from the forests are very close.

In the CRGE Strategy, the estimated emissions for 2010 were about 150 Mt, while in the second national communication the emission level for that year is estimated approximately 186 Mt. In addition, the projected trend of emissions for 2030 is shown as 400 Mt in the CRGE Strategy while the SNC estimates indicate fairly close value of 367 Mt. It should be noted that the estimates in the SNC are in the same range as presented in the CRGE Strategy estimates. For instance the livestock emissions for 2010 in the SNC are identical to the CRGE Strategy estimate, at 65 Mt, while the estimates for transport in the SNC are 0.8 Mt short of the CRGE estimates.

ES-1.5. Mitigation Options for Ethiopia

Ethiopia is not obliged under the Climate Change Convention to reduce its greenhouse gas (GHG) emissions. The country has, however, voluntarily and informed by national development objectives, goals and priorities, designed a Climate-Resilient Green Economy (CRGE) Strategy, which it is now implementing. This strategy will go a long way in ensuring that the country's development follows a climate resilient and green (low emissions) pathway. In addition the aim of the CRGE is to help the country achieve middle-income status before 2025. Further, Ethiopia has been implementing phased five-year Growth and Transformation Plans (GTP 2010-2015 and GTP 2015-2020) which lay out the basis for transforming the economy. The population of Ethiopia is expected to increase from 91 million in 2013 to 100 million by 2020, 120 million by 2030 and 145 million by 2050. The projected population increase, urbanization and income changes are predicted to alter profoundly the prospects for sustained economic development, exert pressure on natural resources and contribute to increases in greenhouse gas (GHG) emissions.

Ethiopia's contribution (146 Mt CO_2e in 2013) to total global GHG emissions is marginal, representing less than 0.3 per cent of total global emissions (34.5 Bt CO_2) in 2012. Of the 146 Mt CO_2e of GHG emissions in 2013, about 79 per cent came from the AFOLU, of which agriculture accounted for 55 per cent (cropland 26 per cent, livestock 23 per cent, direct and indirect emissions from managed soils and manicure managements aggregated 6 per cent), while grassland produced 14 per cent and forestry removed 30 per cent. The energy and waste sectors contributed 15 per cent and 5 per cent respectively and the IPPU sector only 1 per cent.

Ethiopia has put in place several initiatives with the potential to contribute to climate change mitigation. As indicated in the 1994 Environmental Policy, Ethiopia is committed to work with the international community to combat anthropogenic climate change. The country's Initial National Communication (INC) to the UNFCCC, identified several mitigation options in the energy sector; the land use, land use change and forestry (LULUCF) sector; agriculture; and the waste sector. Some of these measures have been implemented and are contributing not only to GHG mitigation, but also to the country's sustainable economic development objectives.

Under Article 4, paragraph 1(b) of the UNFCCC. Ethiopia is expected to formulate, implement, publish and regularly update national programmes containing measures to mitigate climate change. Within the framework of the preparation of the Second National Communication, Ethiopia has undertaken mitigation analysis and assessment of options to reduce the emission of GHGs and/or enhance their sinks. Detailed information is presented in Chapter Four, which includes inputs from the available data and information, new facts provided by the key stakeholders and information generated using activity data collected to update the list of potential mitigation options. In addition, the mitigation analysis and implementation strategy are also informed by the GHG emissions projections. The analyses carried out recognize the role of Nationally Appropriate Mitigation Actions (NAMAs)[3] as a pathway for not only delivering on GHG emissions abatement, but also contributing to Ethiopia's sustainable development programmes and poverty reduction. Chapter Four also takes into account adaptation actions/programmes with mitigation co-benefits. The potential initiatives, programmes, activities and investments with the potential to contribute to the two-fold objectives of sustainable economic development and GHG mitigation are identified in the energy and transport, land use change and forestry, agriculture and waste sectors.

Some of the mitigation options in the energy sector include: fuel switching to less emitting types, and the use of efficient improved stoves by households to reduce charcoal consumption and conserve forests by reducing deforestation. The country is also implementing an Intra-urban Electric Rail NAMA with the overall objective of replacing 50 per cent of the transport of cargo with electric rail under the CRGE strategy. The other options include the use of efficient vehicles, alternative fuels, bio-diesel, practising enhanced ethanol-gasoline (gasohol) blending, improving rural and urban transport infrastructure, promoting mass transportation and the use of non-motorized transport, such as cycles and other types of intermediate transport.

Some of the mitigation options identified in the AFOLU sector include soil mitigation options using lower-emitting techniques, such as conservation agriculture, watershed management, and nutrient and crop management, as well as agricultural intensification and capture of new agricultural land in arid areas through irrigation, to increase the abatement potential from saved forests. The livestock mitigation options identified include potential increases in the efficiency of the cattle value chain through shifting to higher productivity cattle (for both meat and milk) and an increased off-take rate (decreasing the age at which livestock are sold), and a partial shift towards lower-emitting sources of protein raising more poultry, for example, could reduce emissions. Other options include: the treatment of forage to improve digestibility; mixed crop/livestock farming to decrease pressure on land and single systems; improving livestock's genetic characteristics; using methane recovery technologies in manure management systems; afforestation and the conservation of forests..

Other mitigation options include composting, incineration, construction, and the operation of sanitary landfill in the waste sector. The IPPU sector mitigation options include; improving energy efficiency in industrial processes;, materials substitution (e.g. blended cement); switching to low carbon and other energy sources; and carbon dioxide sink enhancement among others.

3 According to Decision 1/CP.16 of 2010 (the Cancun Agreements), "developing country parties will take nationally appropriate mitigation actions in the context of sustainable development, supported and enabled by technology, financing and capacity-building, aimed at achieving a deviation in emissions relative to 'business as usual' emissions in 2020". This builds on previous decisions of the Conference of the Parties, namely 1/CP.13 of 2007 and the Copenhagen Accord of 2009.

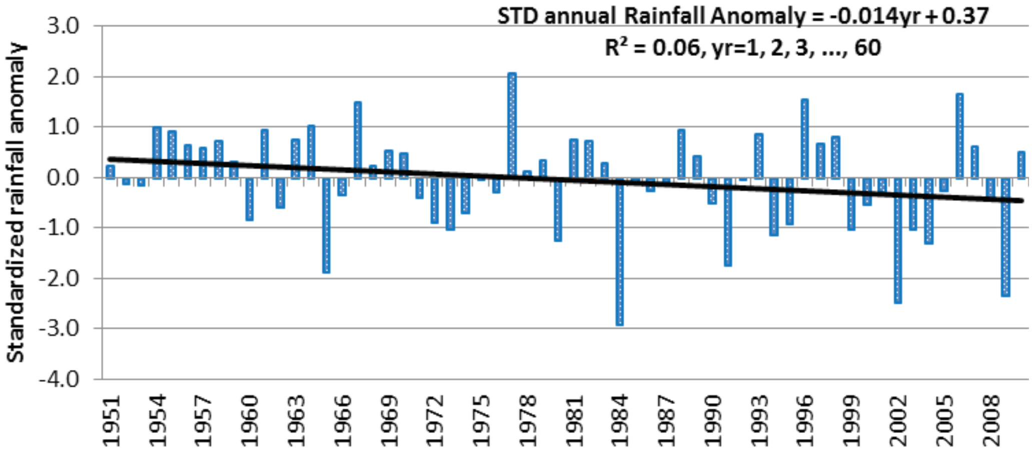
ES-1.6. Climate Change Impacts, Vulnerability and Adaptation Options

Ethiopia is one of the most vulnerable countries to climate changes due to its dependence on rain-fed agriculture and natural resources. This is aggravated by its under-developed water resources; low health service coverage; a high population growth rate; its low level of economic development; low adaptive capacity; inadequate road infrastructure in drought-prone areas; weak institutional structures; and low levels of awareness on climate change. Rising temperatures and increased rainfall variability are the most evident signals of climate change in Ethiopia, the impact of which is manifested through extreme events of droughts and floods with increasing frequency and intensity.

The methodology used to analyse the impacts of and vulnerability of the country to climate change and variability involved five steps, namely; (i) generation of current and historic climate data. (ii) assessment of current vulnerability to climate variability; (iii) projection of the future climate using climate model outputs to outline a range of scenarios for future rainfall, temperature and other climate variables; (iv) assessment of future impacts and costs of climate change; and (v) review of on-going adaptation measures and the identification of new options.

Analysis of the inter-annual variation of rainfall for the period 1951-2010 (ES 16) indicates that some years experienced above normal rainfall, others below normal, and still others around the average value. Mean annual rainfall shows a slightly declining trend, indicative of a decrease in total annual rainfall over the years.

Figure ES 1-6: Year-to-Year Variation in Ethiopia's Rainfall (1951-2010)[4]



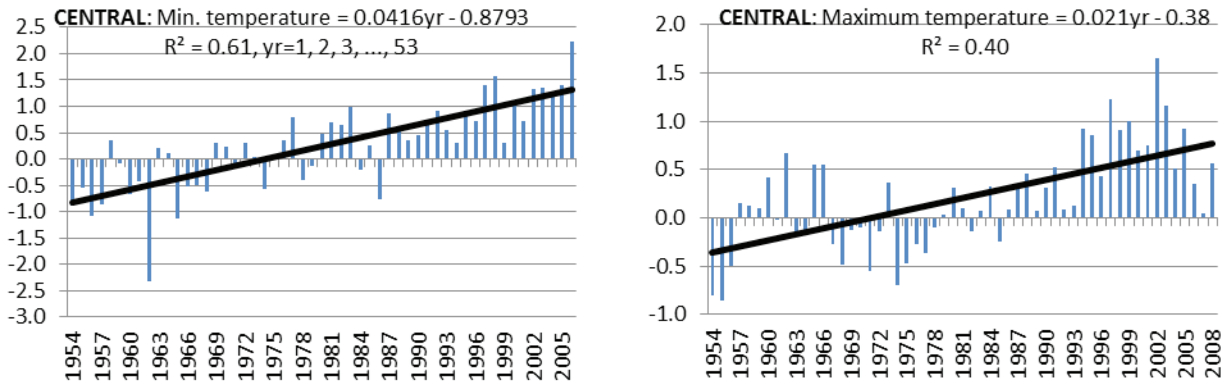
Further analysis showed that the trend in total annual rainfall varies from one region to another, with the drier southern parts of the country showing the highest variability and the wetter north western parts the lowest. Some heavily populated areas in south central Ethiopia recorded declines of as much as 20 per cent in the spring and summer rains. There was also a pronounced increase in the projections of the total rainfall occurring in "heavy" rainfall events, indicative of an increase in potential floods. These results are probably an indication of a potential increase in the frequency of extreme climate events in the coming years.

Figure ES 17 shows the inter-annual variation of temperature in Central Ethiopia over a 50-year period, which reveals a rising trend, indicative of warming over the whole country. There were,

4 Relative to the 1961-1990 norm.

however, variations in the degree of warming from one part of the country to another. These results are consistent with the CRGE analysis that indicates a temperature increase 0.1-0.4°C per decade, resulting in an average temperature increase of around 1°C (0.25°C per decade) since the 1960s. The observed temperature increase is commensurate with corresponding increases in the minimum and maximum temperature, an increased frequency of hot days and nights, and decreases in the frequency of cold days and nights.

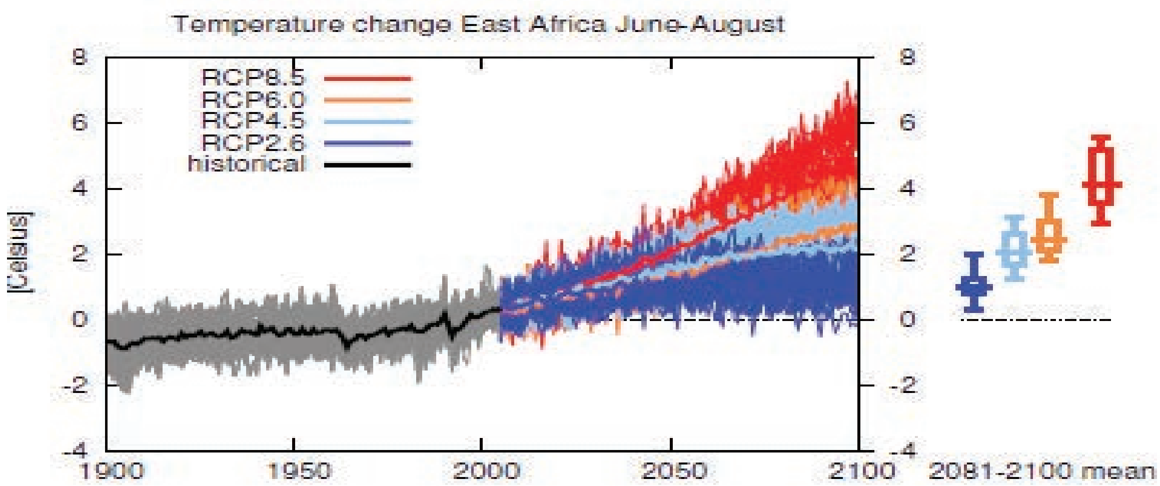
Figure ES 1-7: Inter-Annual Variation of the Mean Minimum and Maximum Temperatures for Central Ethiopia



The observed temperature increases are expected to lead to increased evapotranspiration, and reduced soil moisture content and atmospheric humidity, with serious socio-economic consequences for the country.

The projections also show substantial increases in the frequency of days considered “hot” in current climate conditions, and are consistent with other temperature projections for the country (Figure ES 1-8). The trend explains a very high proportion of the total variance ($R^2 = 0.910 \approx 91\%$).

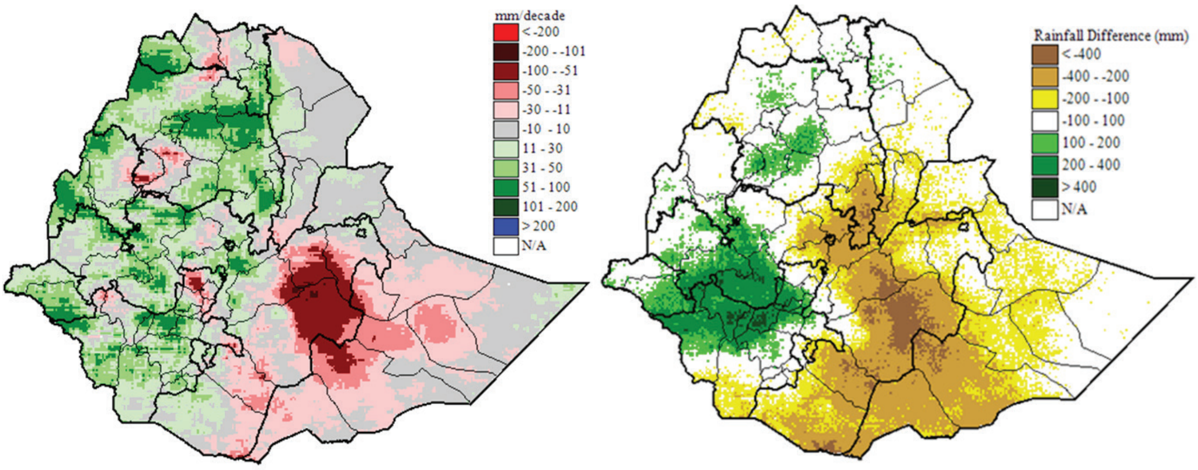
Figure ES 1-8: Time Series of Temperature Averaged over Land Grid Points in East Africaa, June-August



Rainfall projections indicate a significant decline in the Belg (short rainy season in March-April rainfall across the south-central and eastern parts of the country. This may have far-reaching adverse implications for pastoralists and agro-pastoralists in the southern regions of the country, who rely on the meager Belg rains for their livelihoods. Projection for the Kiremt rains (the long rainy season in June-August) indicated large rainfall declines across the western and southern parts of Ethiopia

(Figure ES 1-9). This has serious socio-economic implications as the western regions include the densely populated long cycle crop growing area of the country.

Figure ES 1-9: Annual Climate Changes and Average Differences in Rainfall, 1981-2013



The major adverse impacts of climate variability and change in Ethiopia include:

i. food insecurity arising from occurrences of droughts and floods;

ii. outbreak of diseases such as malaria, dengue fever, waterborne diseases (such as cholera and dysentery) associated with floods and respiratory diseases associated with droughts;

iii. land degradation due to heavy rainfall;

iv. damage to infrastructure by floods; and

v. loss of life and property.

It is estimated that climate change may reduce Ethiopia's GDP by 2-6 per cent by 2015 and by up to 10 per cent by 2045, compared with a baseline scenario (2011). Past assessments have shown agriculture, water and human health as the most vulnerable sectors. From a livelihood approach, smallholder farmers who depend heavily on rain-fed operations and pastoralists are found to be the most vulnerable. The arid, semi-arid and the dry sub-humid parts of the country are most affected by drought. Vulnerability therefore varies from one region to another, according to socio-economic, institutional and environmental conditions, among other things. The projected warming across the entire country is likely to exacerbate the observed declining rainfall trends, leading to increased water stress.

The Government of Ethiopia recognizes that adaptation is neither a one-off intervention nor a stand-alone activity, but rather an iterative process that needs to be mainstreamed in development planning, including the design and implementation of projects and programmes across the relevant sectors. The Government has demonstrated its determination to address climate change through the mainstreaming of response measures in national and sectoral development plans. Several regional administrations also have regional climate change adaptation programmes.

Some of the major barriers to adaptation include:

i. the inadequacy of current impact assessments for some sectors;

ii. the absence of an effective overall coordination mechanism at both the federal and regional levels;

iii. the inadequacy of guidelines for the mainstreaming of climate change adaptation into the relevant policies and programmes;

iv. the inadequacy of cross-sectoral links between ministries, departments and agencies;

v. the inadequacy of linking elements such as cross-sectoral federal committees;

vi. inadequate capacity at different levels, including the absence of an institution for research and development (R & D) on climate change adaptation;

vii. the inadequacy of an environmental mechanism providing outreach to local communities;

viii. lack of awareness of the long-term environmental impacts of activities with short-term economic benefits;

ix. limited finance available for environment and climate change;

x. the low level of awareness and public literacy;

xi. the high level of poverty.

For the country to fully realize the gains of climate change adaptation and related initiatives, these barriers, among others, need to be addressed. The Government of Ethiopia has put in place national policies and legislation, strategies and guidelines with the potential to bring about integrated rural development and enhance community resilience against both natural and man-made risks. These include the National Policy on Disaster Prevention and Preparedness. For any meaningful benefits to accrue from these different initiatives, however, there is a need to enhance the institutional coordination structures at both cross-ministerial level and between national and sub-national authorities.

Chapter Five identifies the impacts of climate change and the vulnerabilities of selected sectors in Ethiopia, the potential adaptation options, and presents measures the country has put in place to facilitate adequate adaptation to climate change, in accordance with Article 12, paragraph 1 (b) and (c) of the Convention

ES-1.7. Technology Development and Transfer

The UNFCCC recognizes the importance of technology transfer as a key means to combat man-made climate change. This is clearly stated in Article 4 paragraphs 3, 7 and 8 of the Convention. In 1998, the Fourth Conference of Parties (COP-4) by its Decision 4/CP.4 also urged Non-Annex I Parties to submit their priority technology needs for mitigation and adaptation. Ethiopia, like most developing countries, is characterized by a low level of technological development. However, there is great potential for adopting technologies available in the developed and some developing countries to facilitate mitigation options for greenhouse gases and adaptation to climate change. The cost of the research and innovation component of technology development is high and there is no effective mechanism in place to address issues related to technology development and transfer. New and clean energy technologies need to be developed to reduce greenhouse gas emissions and to address climate change adaptation issues.

ES-1.8. Research and Systematic Observation

The responsibility for climate and hydrological monitoring in Ethiopia lies with the National Meteorological Agency (NMA). Currently Ethiopia has a network of about 1,153 meteorological and climatological stations run by NMA. NMA also maintains an upper air sounding station and primary data receiver systems for METEOSAT and NOAA satellites at Addis Ababa. NMA provides routine information on current climate conditions in the country, including monthly and seasonal climate outlooks. Ethiopia actively participates in the World Weather Watch (WWW) programme of the World Meteorological Organization (WMO) by providing daily weather observations from 17 synoptic stations, which are disseminated worldwide for use in climate and weather prediction. Ethiopia also cooperates with regional organizations, such as the African Centre for Meteorological Applications and Development (ACMAD) and the IGAD Climate Prediction and Application Centre (ICPAC) in the field of climate and meteorology.

Hydrological monitoring in Ethiopia is carried out by the Hydrology Department of the Ministry of Water, Irrigation and Energy. Currently there are about 338 operational stream gauging stations distributed over the major river basins. Data base on energy use and energy balance is maintained by the Ethiopian Rural Energy Promotion Center (EREPC) of the Ministry of Water, Irrigation and Energy. The Central Statistical Authority (CSA), the main Government organ collecting data and developing databases in Ethiopia, has introduced a national data archiving system to support research and policy formulation. It should be noted that the existing climatological and hydrological observation network in the country is far from being adequate. The management of the climatological, hydrological and other databases relevant to climate change also needs strengthening and financial support.

ES-1.9. Climate Research

NMA carries out research, studies in the field of meteorology, and implements this task through its Meteorological Research and Studies Department. Other institutions also carry out research related to climate change. So far significant progress has been made in understanding the weather and climate of the country. Topics such as Assessment of Drought and its Impact in Ethiopia, Climate Change and the Ethiopian Economy, Recent Drought and Precipitation Tendencies in Ethiopia, Temperature and Rainfall Trends, Climatic and Agro Climatic Resources of Ethiopia, Rainfall Variability and its Relation to El Niño Phenomena and Application of Satellite Data in Rainfall and Vegetation Monitoring have been covered. Although meteorology and climatology research has been incorporated in graduate and undergraduate courses/programmes, climate change curricula in higher institutes of education need to be enhanced.

ES-1.10. Education, Training and Public Awareness

Reporting of information on activities relating to climate change education, training and public awareness can serve as a basis for the periodic review of the progress made in implementing Article 6 of the Convention (on Education, Training and Public Awareness). The people of the Federal Democratic Republic of Ethiopia need to be made well aware of the country's commitments under the Convention, the impacts of climate change, and adaptation and mitigation options, as well as measures that can be taken at the individual level to combat climate change.

Access to information is very important for improved environmental protection and management and the promotion of an environmentally sustainable development programme. Additional activities are being undertaken to promote public awareness, for example, publication of a monthly newsletter (*CRGE Highlights*) by the Ministry of Environment and Forest (MEF), radio broadcasts on environmental issues, and promoting the establishment of environment clubs at schools. However, still more needs to be done to enhance environmental and climate change education and awareness in Ethiopia. Graduate and undergraduate courses/programmes should be designed to include climate change related courses, and awareness among policymakers, professionals and the public enhanced. The effort to raise awareness, to create educated and skilled experts to handle climate change issues should continue through various means such as:

i. Enhancing climate change information sharing platforms;

ii. Preparing and disseminating information and teaching materials as well as fact sheets on climate change; and

iii. Producing articles and interviews, through the mass media, including translations into the numerous local languages and dialects.

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CHAPTER ONE:

NATIONAL CIRCUMSTANCES

1.1. Introduction

This section is devoted to Ethiopia's national circumstances in relation to climate change and the country's obligations as a party to the UNFCCC. Special attention has been given to information pertaining to the national development priorities, objectives and circumstances that serve as the basis for addressing climate change, namely existing legal, policy and institutional frameworks established by the Government to implement the Convention and address climate change within the broader context of sustainable development. Ethiopia ratified the UNFCCC on 31 May 1994 and the Kyoto protocol on 21 February 2005 as a Non-Annex I Party. As such, Ethiopia became legally obligated to communicate to the Conference of Parties information related to implementation of the Convention, in accordance with Article 12. Ethiopia conformed to this obligation by submitting the Initial National Communication in 2001. The submission of this Second National Communication (SNC) is yet another milestone, as Ethiopia continues to meet its obligation under the Convention in accordance with Article 4, paragraph j of the Convention. The Ministry of Environment and Forest is responsible for overseeing the coordination of climate change issues and as such coordinated the preparation of the SNC. The SNC project built on and continued the work done under the Initial National Communication (INC).

Ethiopia is on an economic growth trajectory informed by its core policy instruments, the Climate Resilient Green Economy (CRGE) and the Growth and Transformation Plan (GTP). The fundamental objectives of the country are to accelerate economic growth while at the same time utilizing natural resources sustainably to ensure human development and an enhanced quality of life for its population. Against this background, the following sections summarize the country's current biophysical, economic and social circumstances, which will influence the impact that climate change will have on Ethiopia, as well as the plans in place to address climate change and meet its obligations under the Convention.

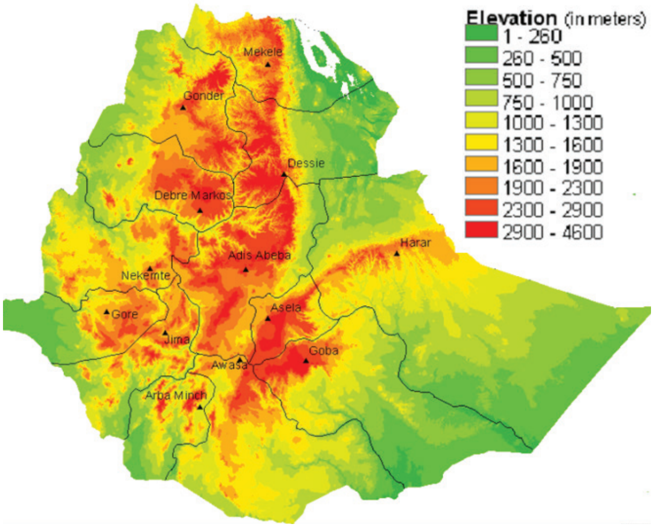
1.2. Geography

Ethiopia is a landlocked country located in the North East Africa region, the Horn of Africa, between approximately 32°58'00" E to 48°00'00" E and 14°55'00" N to 3°25'00" N. It is bordered by Eritrea to the north, Djibouti and Somalia to the east, Sudan and South Sudan to the west, and Kenya to the south. The country covers an area of 1,104,300 km^2 (426,372 square miles), a significant portion of the Horn of Africa.

Ethiopia is the most elevated part of north-eastern Africa and has great geographical diversity with prominent topographic features, which include high and rugged mountains; extensive highlands, with undulating plateaus, deep river gorges, and the Great Rift Valley, which separates the country's central/western and southern/eastern highlands. Ethiopia has a high central plateau that varies from 1,290 m to 3,000 m (4,232 ft to 9,843 ft) above mean sea level (amsl), with the highest mountain reaching 4,533 m. The plateau undulates gradually to the lowlands of Sudan on the west, and the Somali-inhabited plains to the east. A number of rivers, including the Blue Nile, arising from Lake Tana, cross the plateau. The region between the valley of the Upper Nile and Ethiopia's border with Sudan and South Sudan has elevated plateaus from which rise various tablelands and mountains that constitute the Ethiopian Highlands. The Western Ethiopia Highlands are separated into the Abyssinian Highlands, i.e. the area north of the capital Addis Ababa, and the southern region of the Kaffa Highlands. Ethiopia's altitudes range from 126 m below mean sea level in the northern parts of the Ethiopian Rift Valley to more than 4,533 m amsl in the Semien Mountains. The Ethiopian Rift Valley separates the Somali Plateau that is located in the east and south-east of

Ethiopia, from the Western Highlands. The highlands (higher than1500m amsl constitute around 45 per cent of the total area of the country. In Ethiopia, the entire land area below 1500 meters in altitude is classified as lowlands, while the land lying above 1500 meters is classified as highlands. This is illustrated in figure 1-1.

Figure 1-1: Elevation map of the Federal Republic of Ethiopia



The rock types found in the country include Igneous (covering most of the Ethiopian Highlands), sedimentary in the Abbay, Southern Rift and Mekele basins and metamorphic rocks in Chelga, Adigrat and along the Blue Nile. The present land forms of Ethiopia, its mountains, plateaus, the Rift Valley, gorges, and plains, formed during the Tertiary period of the Cenozoic era and are a result of a series of orogeny, volcanism, denudation, pen-plantation, faulting, and deposition over the years.

1.3. History and Culture

Originally referred to as Abyssinia, Ethiopia is sub-Saharan Africa's oldest and second-most populous state. The current nation was created through the consolidation of smaller kingdoms that owed feudal allegiance to the Ethiopian emperor Menelik II. Emperor Menelik II ensured the country's independence by repelling a colonial invasion in 1896. Ethiopia's rich natural and cultural heritage permeates every facet of daily life, which acts as a major attraction to tourists and has been an important element in the development of a tourism industry.

The history of Ethiopia can be traced back to the Axumite Empire (fourth century B.C.). There is evidence that the city of Axum was an ancient commercial hub with its own currency, where trade with Egypt, Arabia, Persia and India was conducted. Ethiopia's rich history and cultural treasure is epitomized by the seventeenth^{h} century castles at Gonder (the then capital of Ethiopia), the rock hewn churches at Lalibella (a UNESCO World Heritage site) and the Sof Omar caves in Bale. Further, Ethiopia has yielded some of humanity's oldest traces, making the country the cradle of mankind. Recent studies claim that the vicinity of the present-day capital, Addis Ababa, was the point from which human beings migrated around the world. Addis Ababa, meaning "New Flower" in Amharic, is located almost at the heart of the country and was founded by the Emperor Menelik II and Empress Taitu in the late nineteenth century.

1.4. Population, Health and Education

Ethiopia's first population and household census was conducted in 1984. The second census was done in 1994, and the third in 2007. The results from the census show that the population has increased steadily over the last three decades, from 42.6 million in 1984 to 53.5 million in 1994 and 73.8 million in 2007, and was estimated to be about 91 million in 2013. The population is projected to increase to 129.1 million by the year 2030. However, there were slight declines in the population growth rates over these periods, from 3.1 per cent per annum in 1984 to 2.9 per cent in 1994 and 2.6 per cent in 2007. Ethiopia has 16 per cent of the population living in urban areas (CSA, 2007), while the majority of the population lives in the highland areas in rural settings. The main occupation of the rural population in the uplands is farming (mixed crop and animal production), while the lowland areas are mostly inhabited by pastoral peoples, who practice traditional nomadism in search of grass and water. More than 80 per cent of the country's total population lives in the regions of Amhara, Oromiya, and Southern Nation Nationalities and Peoples (SNNP).

The structure of the population of Ethiopia is typical for a high fertility household population with children below 15 years accounting for about 47 per cent and people older than 65 years accounting for 4 per cent of the population. Women head about 26 per cent of Ethiopian households, a slight increase from 23 per cent in 2005. The average household size is 4.6 persons, a decrease from the 2005 average of 5 persons per household. Urban households have fewer members than rural households, at 3.7 and 4.9 persons respectively. The structure of the population reflects a high dependency ratio of about 45.4 per cent of the total population under the age of 15 years and 3.2 per cent aged 65 and above.

In any society the key determinant of individual opportunities, attitudes, and economic and social status is knowledge gained through education. Educational attainment has a strong effect on reproductive behaviour, fertility, infant and child mortality and morbidity, attitudes and awareness related to family health, use of family planning, and sanitation. In 2013, Ethiopia had a three-tier system of formal education comprising eight years of primary education, four years of secondary education, and four to seven years of tertiary education, depending on the area of study. The majority of Ethiopians have little or no formal education. About 52 per cent of females and 38 per cent of males have had no formal education. This is a substantial decrease from the findings of the 2005 Ethiopia Demographic and Household Survey (EDHS), when 67 per cent of females and 52 per cent of males had had no formal education. In 1994, only 23 per cent of both genders were found to be literate out of the total population of those aged 10 years old and above. The literacy rates for urban and rural areas were found to be 69 per cent and 15 per cent respectively in that year. Several demographic studies indicate that there is increasing urbanization of the population. The 2011 EDHS results showed a remarkable decline in childhood mortality. Infant mortality has declined by 42 per cent from 101 deaths per 1,000 live births to 59 deaths per 1,000 live births over a 15-year period. According to the 2011 EDHS findings, the adult mortality rate has also declined sharply: only 16 per cent of women and 18 per cent of men were likely to die in the 15-50 age range by 2011 compared with 28 per cent of men and 22 per cent of women in 2000. Further, the survey showed a sharp increase in life expectancy, In 2013, at 65 years.

1.4.1. Water, Sanitation and Health

Ethiopia has made much progress in extending the provision of Water, Sanitation and Hygiene (WASH) services from the 1990 very low base of 19 per cent for water supply and 3 per cent for sanitation coverage, to 52 per cent and 63 per cent access to WASH in rural and urban areas respectively by 2010. Notwithstanding, these significant improvements, there are considerable disparities in WASH provision which mean that Ethiopia is still far from meeting its MDG targets for water and sanitation. However, the Government is committed to extending WASH services to underserved households and populations, as articulated in the Growth and Transformation Plan (2010–2015), in spite of the significant challenges that still exist to meeting the GTP goals.

Women, children, older people, people living with disabilities and HIV/AIDS, and communities in remote rural areas and in urban informal settlements are some of the groups known to experience the greatest challenges in accessing WASH services..

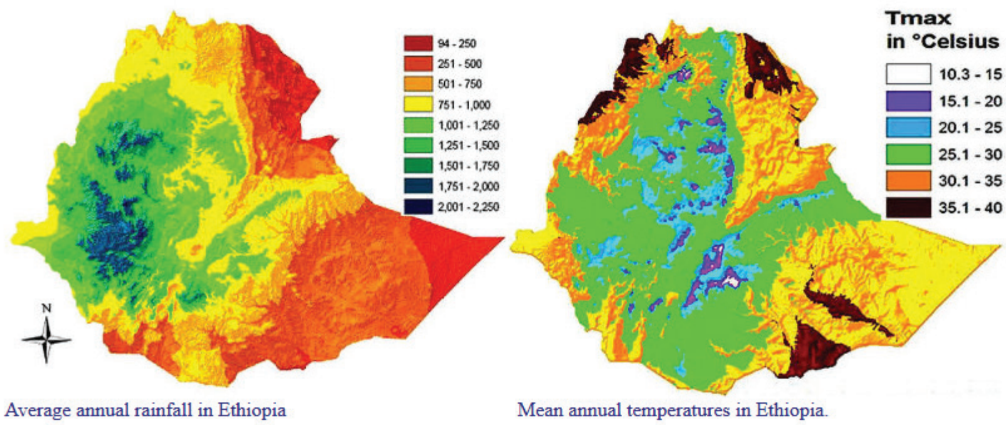
1.5. Climatic Characteristics

Ethiopia displays tremendous diversity of climatic and biophysical settings, ranging from equatorial rainforests in the south and south-west, which is characterized by high rainfall and humidity, to Afro-Alpine on the summits of the Semien and Bale mountains and desert-like conditions in the north-east, east and south-east lowlands. Altitude ranges from 126 m below mean sea level (bmsl) at the Kobar sink in the Dallol Depression to about 4,600 m amsl at Ras Dajen in the Semien Mountains with freezing temperatures most of the year. The resulting average annual rainfall varies from about 3,000 mm at Masha in the Baro-Akobo Basin to barely 200 mm in the Ogaden and Aysha Basins and along the border with Djibouti and Somali.

In spite of Ethiopia's proximity to the equator, the highlands experience a wide range of climatic features suitable for different agricultural production systems. Thus climatic heterogeneity is a hallmark of the country. Altitude determines the distribution of climatic factors (temperature and rainfall) and land suitability; and influences the crops grown, the rate of crop growth, and the natural vegetation types and their species diversity.

Middle and higher altitudes (above 1,500 m) receive substantially greater rainfall than the lowlands, except for the lowlands in the west where relief rainfall is high (FAO, 1984a). Generally the average annual rainfall in areas above 1,500 m exceeds 900 mm. In the lowlands (below 1,500 m), annual rainfall is erratic and averages below 600 mm. There is strong inter-annual variability of rainfall all over the country. Despite variable rainfall which makes agricultural planning difficult, a substantial proportion of the country gets enough rain for rain-fed crop production (FAO, 1984b). Figure 1-2 below shows the rainfall and temperature characteristics of Ethiopia.

Figure 1-2: Rainfall and Temperature Characteristics of Ethiopia



Source: Worldclim.org, 2009.

The climate of Ethiopia is influenced by the complex topography of the country and the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and associated atmospheric circulations. It has a diversified climate ranging from semi-arid desert type in the lowlands to humid and warm (temperate) type in the south-west. Mean annual rainfall distribution has maxima (>2,000 mm) over the south-western highlands and minima (<300 mm) over the south-eastern and north-eastern lowlands. Mean annual temperatures range from below 15 ºC over the highlands to above 25 ºC in the lowlands.

The ITCZ oscillates across the equator from its northernmost position over northern Ethiopia in July and August, to its southernmost position over southern Africa in December-January. There are three rainfall seasons, namely, Bega, Belg and Kiremt. The main rainfall season (Kiremt) from mid-June to mid-September, coincides with the time the ITCZ is at its northernmost position. Parts of northern and central Ethiopia also have a secondary wet season of sporadic and considerably less rainfall from February to May (Belg). The southern regions of Ethiopia experience two distinct wet seasons which occur as the ITCZ passes over the region. The February to May Belg season is the main rainfall season in the southern regions, yielding 100-200 mm per month, while a season with less rainfall (around 100 mm per month) called Bega occurs in October-December. The easternmost corner of Ethiopia receives very little rainfall throughout the year. The movements of the ITCZ are sensitive to variations in Indian Ocean sea-surface temperatures and hence the onset and duration of the rainfall seasons vary considerably inter-annually, causing frequent droughts. The best documented cause of this variability is the El Niño Southern Oscillation (ENSO). Warm phases of the ENSO have been associated with reduced rainfall in the main wet season, causing severe droughts and famine in north and central Ethiopia, but it has also been associated with enhanced rains in the earlier February-April rainfall season, which mainly affects southern Ethiopia.

1.5.1. Agro-ecological Zones

According to Koppen's climate classification system, Ethiopia has 10 climate types. These are the Hot Arid Climate (Bwh), the Hot Semi-Arid Climate (Bsh), Tropical Climate (Aw) with distinct dry winter, Tropical Monsoon Rainy Climate (Am) with short dry winter, Warm Temperate Rainy Climate (Cwb) with dry winter and Warm Temperate Rainy Climate (Cfb) without distinct dry season[5]. Ethiopia's agro-ecological zones (AEZs), on the other hand, are classified into five categories, and three sub-categories based on altitude and temperature, each with a traditional name. These are Bereha, Kola, Weinadega, Dega (temperate-like climate -in highlands of 2,500-3,500 m and Wurch (cold climate at more than 35,000 m altitude as shown in Table 1-1). The amount of rainfall and its distribution are also important factors in classifying the common agro-ecological zones.

Table 1-1: Traditional Agro-Ecological Zones[a]

Zone	Altitude(m)	Mean Rainfall (mm)	Temperature (oC)
Bereha (dry-hot)	500-1,500	<900	>22
Weinadega (dry-warm)	1,500-2,500	<900	18-20
Erteb Kola (sub-moist warm)	500-1,500	900-1,000	18-24
Weinadega (sub-moist cool)	1,500-2,500	900-1,000	18-20

5 Koppen's climate classification system divides climate into five main groups, A (Tropical), B (Dry), C (Temperate), D (Continental) and E (Polar and Alpine) each with several types and sub-types.

Zone	Altitude(m)	Mean Rainfall (mm)	Temperature (oC)
Erteb Weinadega (moist-cool)	1,500-2,500	>1,000	18-20
Dega (cold)	2,500-3,500	900-1,000	14-18
Erteb Dega (moist-cold)	2,500-3,500	>1,000	10-14
Wurch (very cold or Alpine)	>3,500	>1,000	<10

[a]The extreme desert (between 500 m and -126 m) is not traditionally classified. Source: FDRE, 2000.

1.6. Natural Resources and Biodiversity

1.6.1. Water Resources

The geographical location of Ethiopia and its endowment with favourable climate provides it with a relatively higher amount of rainfall. Preliminary studies and professional estimates indicate that the country has an annual surface run-off of close to 122 billion m^3 of water excluding ground water. The hydrology of Ethiopia forms a foothold for the water resources in the Horn of Africa, including Sudan and Egypt. Much of the water flows across the borders, being carried away by the transboundary rivers to the neighbouring countries in northern and eastern Africa, where 11 of the 12 major river/drainage basins originating in Ethiopia are transboundary. Table 1-2 summarizes the characteristics of Ethiopia's main basins.

Table 1-2: Characteristics of the Basins in Ethiopia[a]

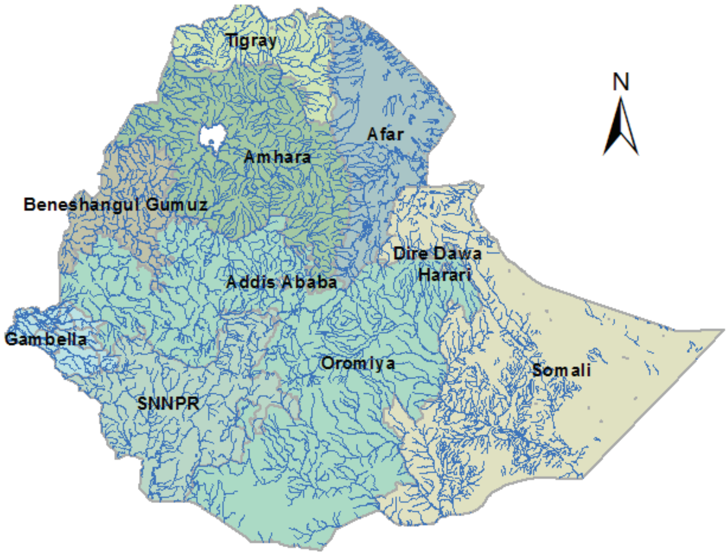
R.No.	Basin Name	Type	Source	Area (km2)	Direction of Flow	Terminal
1	Wabishebelle	R	Bale Highland	202,220	East	Indian Ocean
2	Abbay	R	West, Southwest HL	199,912	West (Nile)	Mediterranean Sea
3	Genale Dawa	R	Bale Highland	172,259	East	Indian Ocean
4	Awash	R	Central highland	110,000	North-east	Terminal Lakes (Internal)
5	Tekeze	R	North Wollo Highland	82,350	West(Nile)	Mediterranean Sea
6	Denakil	D	North Wollo Highland	64,380	NF	Internal
7	Ogaden	D	No flow	77,120	NF	Internal
8	Omo-Ghibe	R	Central, Western HL	79,000	South	Rudolph Lake Internal)
9	Baro-Akobo	R	Western Highland	75,912	West (Nile)	Mediterranean Sea
10	Rift Valley Lakes	L	Arsi and Central HL	52,000	South	Chew Bahir
11	Mereb	R	Adigirat HL	5,900	West (Nile)	Swamp in Sudan
12	Aysha	D	No flow	2,223	NF	Internal

[a] Abbreviations: HL=Highland; D=Dry; R=River; L=Lake; NF=No flow.

Source: Basin Master Plan Studies.

The water resources in Ethiopia are unevenly distributed, both spatially and temporally. Between 80 per cent and 90 per cent of Ethiopia's water resources are found in four river basins, Abay (Blue Nile), Tekeze, Baro-Akobo, and Omo-Gibe, in the west and south-western part of Ethiopia where no more than 30-40 per cent of the country's populations live. On the other hand, the water resources available in the east and central river basins account for only 10-20 per cent of the total, whereas over 60 per cent of the country's population live in these basins. The temporal distribution of Ethiopia's water resources poses no less a challenge. In spite of Ethiopia getting plenty of annual rainfall in aggregate, it falls either ahead of time, comes too late, or even stops short in mid-season. Figure 1-3 below shows the rivers and other water bodies found in Ethiopia

Figure 1-3: Rivers and Water Bodies of Ethiopia

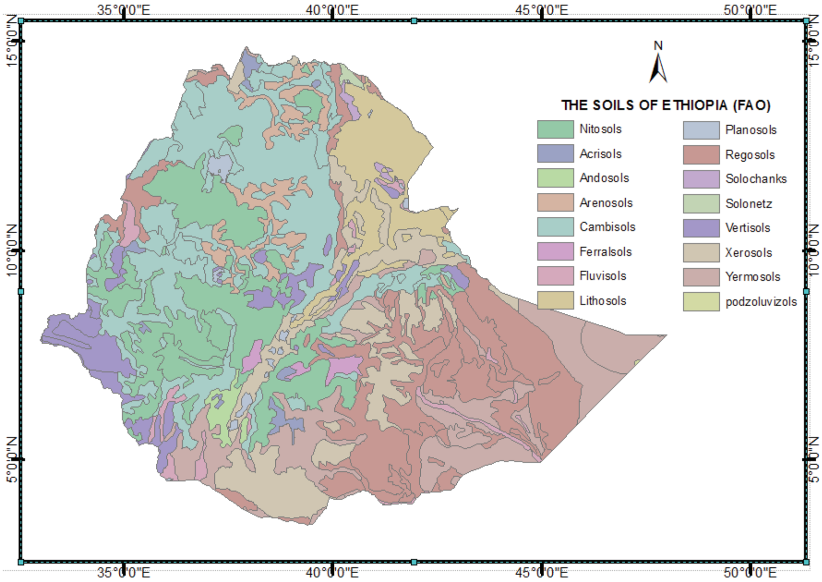


1.6.2 The Soils

The FAO Soil Map of Ethiopia (1998) lists 18 soil classes. Estimates show that about 80 per cent of the country is covered by nine major soil types. Some of these soil types and their percentage area coverage are Cambisols (21 per cent), Regosols (20 per cent), Nitosols (16 per cent), Yermosols (13 per cent), Xerosols (11 per cent), Vertisols (5 per cent), and Lithosols (7 per cent), together accounting for 93 per cent of the area covered by soil (FAO, 1998). Various general clusters of similar soil types can be distinguished, such as Nitisols in the southern part of the Western Ethiopian Highlands; and Luvisols and Leptosols, with isolated occurrences of Cambisols, in the northern part of the western Ethiopian Highlands.

The extreme variability of the spatial extent of Ethiopian soils is caused by the wide range of topographic and climatic factors, the diversity of parent material, and the variability of the uses to which has been put (FAO, 1984c). The complexes of soil forming factors have primarily influenced the distribution of the soil types. It is worth noting that the information on soil fertility status is inadequate. However, research has shown that the potassium, nitrogen, cation exchange capacity (CEC) and organic matter content of most mountain soils is high (EARO, 1998), while there is a general deficiency in phosphorous content. Figure 1-4 below shows the soils of Ethiopia, using the FAO classification system.

Figure: 1-4: The Soils of Ethiopia



1.6.3. Biodiversity

Ethiopia encompasses an extraordinary number of ecological zones due to its wide longitudinal and latitudinal ranges. These ecological zones in turn host rare and endangered species and high rates of endemism. As an important centre of genetic and agricultural diversity, the conservation of Ethiopia's biodiversity is an issue of global importance. The country is a signatory to the Convention on Biological Diversity (CBD), articulating the intention of the country to join the global community to protect habitats, species, genes and sustainable modes of resource use. Ethiopia is one of the top 25 biodiversity rich countries in the world and centres of origin and diversity for several cultivated crops including the domestication of arabica coffee. It is the only country to have standing populations of wild aribica coffee in the montane rainforest of Ethiopia. Most parts of the country fall within two biodiversity hotspots, Eastern Afromontane and Horn of Africa, which are among the 34 globally important biodiversity conservation regions.

Ethiopia is endowed with great diversity of species including 320 mammals[6] 861 birds, 201 reptiles, and more than 6,000 plants with high rates of endemism, having about 36 endemic species (Wilson and Reeder, 2005). These resources are spread throughout the national parks, wildlife sanctuaries, wildlife reserves and controlled-hunting areas that have been established to protect and conserve the treasured biodiversity as shown in Figure 1-5. According to the "red list" of these species produced by the International Union for the Conservation of Nature (IUCN) in 2007, Ethiopia had six species that were critically endangered, 23 endangered, and 70 vulnerable.

Ethiopia has developed a National Biodiversity Strategy and Action Plan (NBSAP)[7] to conserve biodiversity through the sustainable use and management of the components of biodiversity and the equitable sharing of benefits derived from the utilization of genetic resources. This is meant enhance food security, wealth creation (poverty reduction), health and livelihood improvement of the Ethiopian population with special regard to rural communities (farmers and pastoralists), whose

6 Vreugdenhil, D. and others, 2012.

7 Available from www.ibc.gov.et/?page_id=2395.

survival depends on the use of natural resources. The country has also submitted a Fifth National Report under the Convention on Biological Diversity. Table 1-3 below shows the species groups recorded in Ethiopia.

Table 1-3: Species and Endemics in Ethiopia by Group

Group	Number of Species	Number of Endemics	% of Endemics
Mammals	320	31	11
Birds	861	28	3
Reptiles	201	9	4
Amphibians	63	24	38
Freshwater fish	168-183	37-57	22-31
Butterflies	324	7	2
Plants	6,044	~1,150	~19

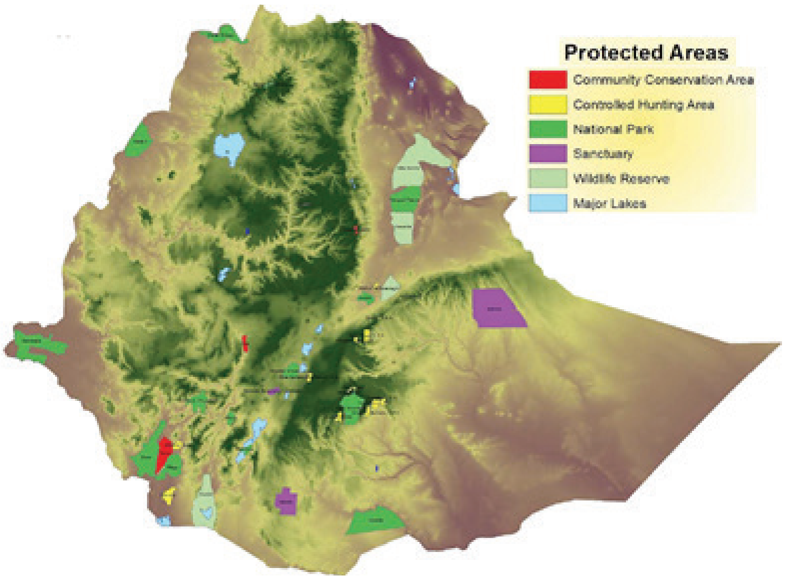
Sources: USAID, 2008a; USAID, 2008b; Vreugdenhil and others, 2012.

1.6.4. Vegetation and Wildlife

The natural vegetation of Ethiopia is influenced by five main biomes namely: Savannah, Montane, Tropical Thickets, Wooded Steppe and Desert biomes. The vegetation can be assigned to eight major types that range from Afro-alpine formations through dense high canopy montane forest to savannah, scrubland and desert. The dominant trees and shrubs growing in plains and the rift valley areas include: *Prosopis juliflora*, *Tamarix aphylla*, *Calotropis procera*, *Parkinsonia aculeata*, *Balanites aegypitiaca, Dodonaea angustifolia, Rumex nervosus*, Acacia *spp*., *Combretum molle, Azadirachta indica, Salix subserrata, Carissa edulis, Tamarindus indica,* and *Euclea schimepri*. The wildlife existing in this area includes wild ass, zebra, duiker, lion, leopard and ostrich. The semi-arid zone (400–2,200 m) has mean annual rainfall of 300–800 mm; and potential evapotranspiration (PET) ranging from 1,900 mm to 2,100 mm. The trees growing in these areas include: *Boswellia papyrifera, Acacia seyal, Acacia Senegal, Acacia nilotica,* Ziziphus *spp., Diospyros mespiliformis,* and *Balanites aegyptiaca*. The common wildlife in the semi-arid zone is: reticulated giraffe, Grant's gazelle, Oryx, Burchell's zebra, waterbuck, elephant, lion, duiker, greater kudu, lesser kudu and buffalo. The Ethiopian Rift system is in the arid/semi-arid zone. Originally the vegetation in the Rift floor and escarpments was wooded grassland with Balanites, Combretum and various species of acacia. Broad-leaved woodland, dominated by *Combretum, Olea* spp., Celtis, *Dodonaea viscosa* and Euclea, occupy the mid altitudes of the escarpments. Lake margins and swamps of the Rift valley are covered by swampy genera of Typha, Phragmites, Cyperus, with *Suaeda monoica* on alkaline soils.

Examples of Water Resource Management and Irrigation Applications[8]

Figure 1-5: Ethiopia National Reserves/Parks for Wildlife Conservation



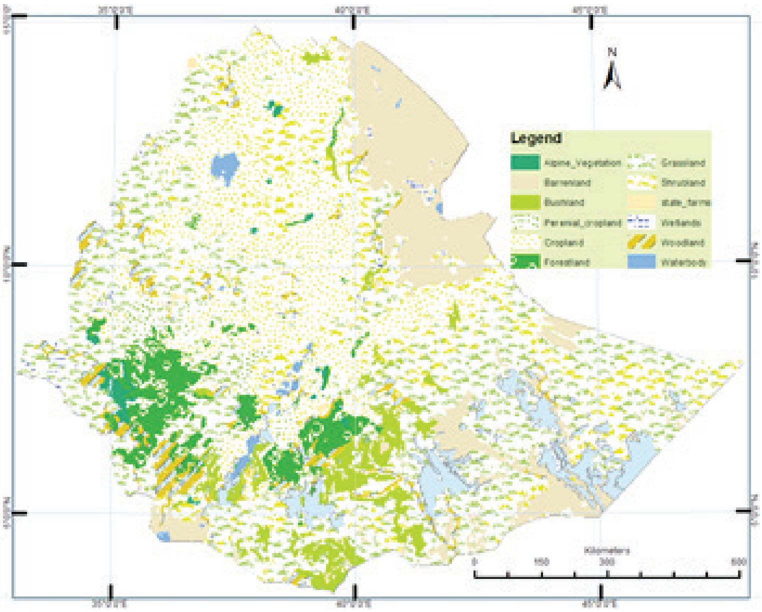
Source: Vreugdenhil and others, 2012.

1.6.5 Land Use

Simplifying the complex topography of Ethiopia, the country can be categorized into lowland areas (< 1,500m amsl) and highland areas (>1,500m amsl). Further, the country has diverse agro ecological conditions owing to its spatial heterogeneity in land resources and climate variations over space. There are 12 major geomorphologic units and 70 sub-units, 19 soil associations, six climatic and edaphic vegetation associations, six rainfall patterns, 10 thermal zones, 14 length of growing period zones and 14 production regions (Bekele, 1987), which indicate Ethiopia's diverse land uses. The country can be divided into 15 land use patterns, 48 cropping patterns, 19 livestock patterns and at least six farming systems. In Ethiopia, grazing, browsing, cultivation, forests, and woodlands form the dominant land use patterns.

8 **Pictures showing water resource management and irrigation application (Source: Eyob Alemu and Andualem Gebere, Min. of Agriculture (2014))**

Figure 1-6: Land Use Map of Ethiopia



Source: Ethiopia Mapping Agency (EMA).

Figure 1-6 shows Ethiopia's land use map. The arid, semi-arid and sub-humid zones of Ethiopia, covering around 61-65 per cent, provide grazing lands. This land mass has a number of agro-ecological sub-zones with diverse types of crop and animal production systems. The arid zone altitude range is from 126 m bmsl to 1,200 m amsl, with mean annual rainfall ranging from 100 to 600 mm and the potential evapotranspiration (PET) is estimated at 1,700-3,000 mm.

The plains and the Rift Valley areas are covered by bushed grassland with patches of woodland and wooded grasslands respectively. Crop production in these areas takes place only along rivers and irrigated state farms. The seasonal crops commonly grown in these areas include cotton, maize and sorghum, while the perennials include citrus, banana and mango. Livestock rearing (goats, sheep, camels and cattle) is the major land use. Nomadic and semi-nomadic pastoralism is the most common livestock production system in the arid zones. The main Rift Valley is a zone of intensive agricultural activity; increasing and progressive settlement has led to grazing lands being replaced with small to medium farms, some of which are mechanized. The semi-arid zone, at altitudes ranging from 400 to 2,200 m, has mean annual rainfall of 300-800 mm, and PET ranging from 1,900 to 2,100 mm. Most hilly and stony terrains in these areas are under wooded grassland or bush grassland, while the flat land is under rain-fed crops (often mechanized). Extensive grazing is the major land use where cattle, goats, sheep and donkeys form the majority of the livestock.

1.7. Agriculture and Forestry

Agriculture plays a central role in the economic and social life of the people and is considered the backbone of Ethiopia's economy, employing about 80-85 per cent of the working population. The agriculture sector will continue to be the major source of economic growth and is expected to grow on average by 8.6 per cent per annum. To realize this plan, the Government of Ethiopia has developed strategies that are designed to increase agricultural production and productivity, improve natural resource management and utilization, build disaster prevention and preparedness capacity, improve agricultural marketing, promote the participation of the private sector in the agriculture sector, and ensure food security in rural households. In the 2011/12 fiscal year, the agriculture sector (value added) grew by 4.9 per cent. The photograph below shows soil and water conservation being carried out on agricultural land with community participation.

Practising Soil and Water Conservation

This sector contributes about 40-50 per cent of total GDP with livestock and their products accounting for about 20 per cent of agricultural GDP. About 95 per cent of the cropped area is cultivated by smallholders, producing 95 per cent of cereals, pulses and oilseeds for subsistence agriculture that is almost entirely rain-fed and with low yields. Ethiopia's agriculture is heavily dependent on natural rainfall, with irrigated agriculture accounting for less than 1 per cent of the total cultivated land. This means that temperature, the amount and temporal distribution of rainfall, and other climatic factors during the growing season are key determinants of crop yields and, in turn, food security/shortages, malnutrition and famine. This indicates the critical importance climate has for the survival of the Ethiopian population.

Access to water is extremely important to maintain agricultural production and will become even more pressing in some areas of Sub-Saharan Africa, including Ethiopia, due to the impacts of climate change already being felt.

Agricultural production in Ethiopia is beset by periodic drought, soil degradation caused by overgrazing, deforestation, high population density and poor infrastructure hindering access to markets. The country has great potential for self-reliance in grains and for export development in livestock, grains, vegetables and fruits.

Tea Farming

Most economic activities in the country depend on agriculture, i.e. marketing services, processing, and export of agricultural products. The nature of agricultural production is overwhelmingly of a subsistence nature, and a large part of commodity exports are provided by the small agricultural cash-crop sector. Principal crops include coffee, pulses (e.g., beans), oilseeds, cereals, potatoes, sugarcane and vegetables. Exports are almost entirely agricultural commodities, with coffee the largest foreign exchange earner, and its flower industry becoming a new source of revenue. In 2005/2006, Ethiopia's coffee exports represented 0.9 per cent of the world total, and oilseeds and flowers each represented 0.5 per cent. Ethiopia is Africa's second biggest maize producer while Ethiopia's livestock contribute significantly to GDP.

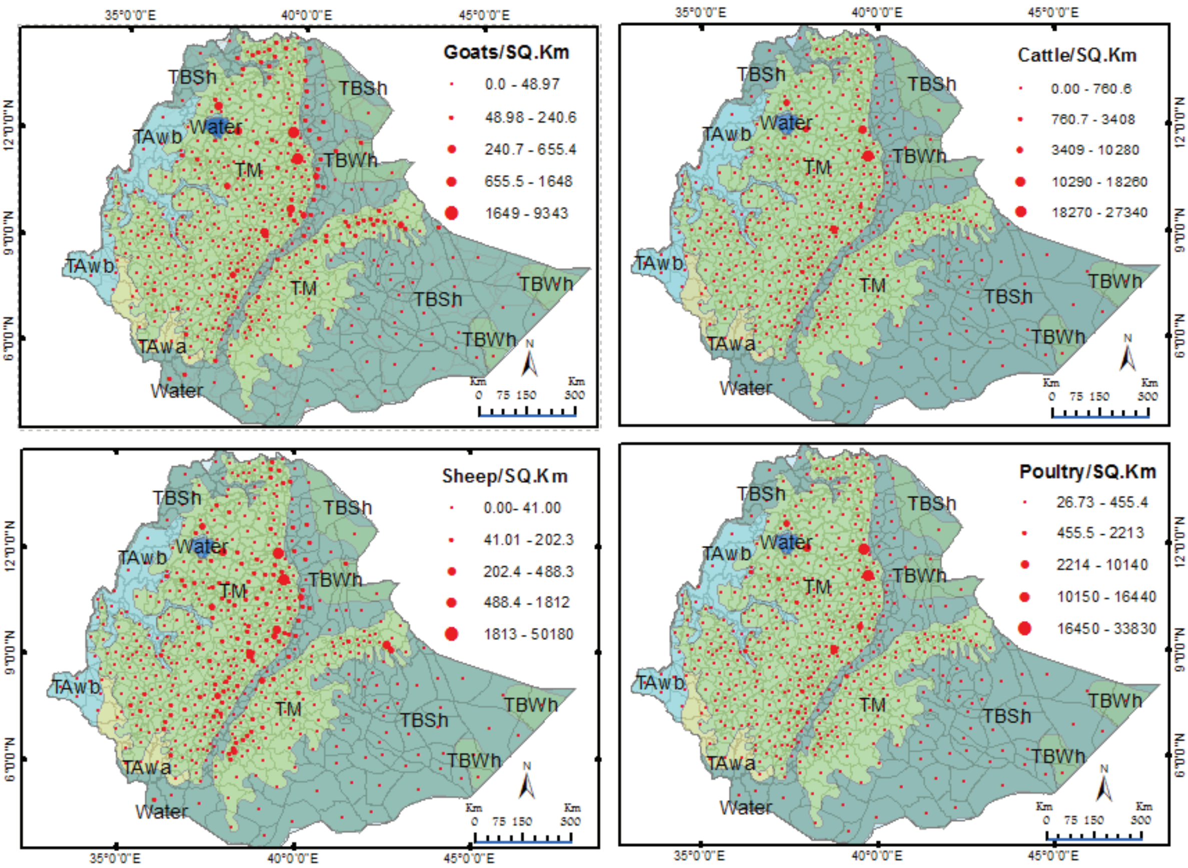
1.7.1. Agricultural Crop Production

Agricultural crops in 2013, made up 67 per cent of agricultural GDP (27 per cent of total GDP) with livestock and forestry accounting for 26 per cent and 7 per cent respectively. The main crops are cereals, pulses, coffee, oilseeds, spices, herbs, vegetables, fruits, sugarcane, and fiber principal crops include coffee, pulses (e.g., beans), oilseeds, cereals, potatoes, sugarcane and vegetables. Small-scale subsistence farming based on rain-fed agriculture and traditional farming techniques predominates. Within crop production, the edible cereals predominate covering up to 84.6 per cent of production followed by pulses at 11.1 per cent and others 4.3 per cen. Five crops account for almost all cereal production: maize 34 per cent, teff (*Eragrostis tef*) 23 per cent, sorghum 20 per cent and wheat 19 per cent (FAOSTAT, 2014). However, crops such as pulses (e.g. chick peas, beans), peas; oil crops (e.g. sunflower), safflower, rape, neug (*Guizotia abyssinica*), groundnuts; and root and plantation crops, such as potatoes, sweet potatoes, yams, cassava, `enset` (*Ensete ventricosum*) and sugarcane have great food and industrial value. Small-scale traditional irrigation has been practiced for decades in the highlands, where small streams are diverted seasonally for limited dry season cropping. Medium and large-scale schemes are of more recent origin, particularly in the Rift Valley.

1.7.2. Livestock

This sector contributes 26 per cent of agricultural GDP (around 10 per cent of total GDP). Ethiopia has the largest livestock population in Africa. Like agricultural cropping, livestock cultivation is mainly based on either mixed farming or pastoralism. Ethiopia's livestock population (2013) is the largest in Africa, with 54 million cattle, 25.5 million sheep, 24.1 million goats, 915,000 camels (downward trend) and 50. 4 million poultry. About 70 per cent of the cattle and sheep and 30 per cent of the goats are in the highlands above 1,500 m. All camels are in the lowlands. Most cattle breeds (99 per cent) are indigenous and just 1 per cent are hybrids. The cattle population is expected to increase by almost 30 per cent by 2030 under business as usual assumptions, resulting in increased emissions. To combat this rise in emissions, a possible abatement option has been identified, which includes improvement of the efficiency of livestock production systems. Figure 1-7 below shows livestock distribution in Ethiopia.

Figure 1-7 Livestock Distribution (head/km2)



1.7.3 Forestry

Forestry makes up 7 per cent of agricultural GDP (3 per cent of total GDP). Forests and woodlands contribute to the national economy and to livelihoods. This is through the provision of timber, fuelwood and non-timber forest products. Forests also provide benefits in the form of food security, health and employment, and support wider ecosystem services (such as water filtration, flood control, and soil retention), which in turn provide economic benefits. For example, 42,000 tons of honey production (much of which occurs in forests) was harvested in 2010/11. Although nationally it provides a low proportion of agricultural GDP (<1 per cent) and exports, it is a valuable source of additional income for rural households in some regions. The main driver of deforestation is pressure for agricultural land and energy demand. However, a number of policies to tackle this, such as reforestation programmes and programmes to reduce demand for fuelwood (for example, through efficient cook stoves) are being considered.

1.7.4 Fisheries

Ethiopia, having an estimated inland water body covering about 7,400 km^2 of lake area and a total of 7,000 km river length, has a huge potential for fish production. However, due to rising population, urbanization, agricultural development, industrialization and other water resource development activities, there has been a decrease in the species diversity of freshwater fish species (Dereje, 2014). Ethiopia's climatic conditions and agro-ecology are conducive to the availability of commercially popular species such as tilapia, catfish and carp.

The country's fisheries are entirely dependent on fresh water. Fishing is an economic activity carried out in the country's many lakes, rivers and reservoirs. The fishing sector is hampered by some significant challenges that hamper the realization and development of a commercial fishing industry in Ethiopia. These include low technical capacity, limited knowledge about the sector, the dietary culture, the absence of infrastructure and equipment, the unavailability of feeds and low quality seeds. The Ministry of Agriculture plans to promote Ethiopia's fisheries industry on the international market through focused research and development, and increased partnerships between hatcheries, feed suppliers, producers and researchers, as well as more significant investment by the private sector. It plans to establish seed production centres to develop commercial aquaculture.

Although the Second Five-Year Agricultural Development Plan (2001-2005) set several targets to improve the yield of Ethiopia's fisheries, a number of problems remain to be overcome. Federal and state laws regarding commercial fishing did not exist until 2002/2003, leading to localized overfishing. Some of the commercially important species that are suffering from overexploitation include the Nile perch in Lake Chamo and tilapia in Lake Awassa.

1.8. Industry

1.8.1. Manufacturing

In 2013, the manufacturing sector contributed 3.9 per cent of GDP and 34.8 per cent to the total value of industrial production (AEO, 2014b). The main manufacturing activities are production of food and beverages, tobacco, textiles and garments, leather goods, paper, metallic and non-metallic mineral products, cement and chemicals.

There are manufactures activities that are meant for the export market, as indicated in the industrial development strategy. They include textiles and garments, leather products and agro-processing. The largest manufacturing industry is textiles and garments, which includes both state-owned and private factories.

Cotton Production for the Textile Industry

The main textile products are cotton and nylon fabrics, acrylic yarn, wool and waste cotton blankets, and sewing thread. Other manufacturing industries include: paper and paper products manufacturing, including small-scale paper, corrugated paper boxes, sanitary napkins, particle boards, labels and badges. The metallic industry produces adjustable hospital beds, stretchers and trolleys, rivets, metal fittings for leather goods and garment, steel pipes, nails, electric water heaters and aluminium frames, while the non-metallic industries produce marble, refractory ceramics, grinding stones, gemstones, cement tiles, roof tiles, cement, cut granite, bricks and lime. The other two main industries are the leather and leather products industry, which produces leather garment, crust leather, leather goods, finished leather and leather shoes; and the chemical and pharmaceutical industry, which produces laundry soap, fertilizer from crushed bone, polyester products, pharmaceuticals formulations, calcium chloride, bleaching powder, acetylene products, boric acid and calcium silicate. The country's cement industry has been growing steadily since 1997 with a cumulative annual growth rate of around 10 per cent per annum (up to 2007), accelerating to around16 per cent in recent years as a result of the booming construction industry.

Agro-processing related manufacturing industry has tremendous potential in Ethiopia. It is worth noting that most agricultural products are exported without being processed, while agriculturally based imports are processed at source countries. The Government aims to export processed products to stimulate the growth of the agro-processing sector. The major products of the agro-processing industry include coffee, sugarcane, oilseeds, cotton, and essential oils. The country also has plans to upgrade the sugar and rubber production industries.

1.8.2. Energy

The energy sector is identified as a key economic infrastructural component in the country's development plans. The GTP envisages a reliable supply of energy to the different economic and social sectors as well as the generation of foreign currency earnings by developing the country's potential. Developing renewable energy sources and strengthening the capacity to administer the energy infrastructure are the key focus areas in the sector. The country intends to expand the bio-fuel development, getting fuel from different renewable energy sources as set out in the Green Economy Strategy. From this perspective, a number of measures are being taken to strengthen the institutional capacity and power generating and transmission capacity in 2011/12.

The vast renewable energy resources that Ethiopia has range from biomass, solar, wind, geothermal to hydropower, of which only a tiny proportion has been harnessed. Construction continues on the Grand Renaissance Dam on the Nile, a multi-billion dollar project to develop electricity for domestic consumption and export. Currently existing and operational hydropower plants have a total installed capacity of 1,953.5 MW, while hydropower plants having a potential of 8,124 MW are under construction.

The national annual average daily irradiance in Ethiopia is estimated to be 5.2 $kWh/m^2/day$ with seasonal variations that range between the minimum of $4.5 kWhm^{-2}day^{-1}$ in July and a maximum of $5.6 kWhm^{-2}day^{-1}$ in February and March (ENEC-CESEN, 1986). The Rift Valley region and the eastern and western lowlands of the Ethiopia receive a higher level of irradiance, well above $6 kWhm^{-2}day^{-1}$, while the densely populated central, western and northern highlands receive relatively low irradiance. The country has exploitable potential for geothermal energy of 5,000 MW (700 MWe), which can be broken down as follows: Rift Valley (170 MWe), Southern Afar (120 MWe), Central Afar (260 MWe) and Denakil Depression (150 MWe).

The waste and by-products from agriculture and agro-based industries (coffee, cotton, oilseeds and sugarcane processing are potentially untapped energy sources. Annual production of coffee is between 250,000 and 300,000 tons and that of lint cotton is between 20,000 and 30,000 tons per year. Bagasse from sugar estates is expected to increase from the 2013 figure of 0.4 million tons to 2.7 million tons per annum. The annually available solid biomass waste from these sources is estimated to be 4 million tons of which only a small part is currently utilized. Urban solid and liquid waste is available from the major cities in Ethiopia but there are currently no projects converting it into energy.

Further to this renewable resource, Ethiopia has great potential to derive bioenergy from forest resources (*Prosopis juliflora),* agricultural and agro-industrial waste and liquid biofuels. It is true that the utilization of forest resources at its 2013 national level is not sustainable; nonetheless, there are areas where biomass resources are underutilized. For instance, the bamboo forests in the western periphery and southern parts of Ethiopia estimated to be spread over an area of 0.5-1.0 million ha, and the huge tracts of shrubs in the lowland areas to the east can be considered an inexhaustible biomass resource. The other area where the Ethiopian Government sees great promise is in the liquid biofuels sector. The Government is now producing ethanol from two of its four sugar factories. It plans to start production from the other existing and new sugar factories of up to 195 million litres by 2015 and to export US$1 billion worth of biofuels by the same year.

1.8.2.1. Energy supplies

Total energy consumption in Ethiopia is estimated to be about 1,250 PJ. Traditional biomass fuels are the main source of energy. Biomass sources translate to 16 GJ of energy (1,000 kg of wood equivalent) per capita. The biomass fuels, including firewood, charcoal and agro-residue, contribute about 92 per cent of the total energy supply. Petroleum and electricity contribute about 7 per cent and 1 per cent to the total. There has been a decline in the share of biomass in the national energy supply over the years. The contribution of biomass fuels to the energy supply declined by about 2.3 per cent between 1996 and 2009, while the relative contributions of petroleum and electricity increased by 2 and 0.3 percentage points respectively (Mulugeta and Tadesse, 2010).

1.8.3 Tourism

Almost all types of prime tourism attractions exist in Ethiopia including historical attractions, national parks with endemic wild life and cultural and religious festivals. There are eight UNESCO recognized world heritage sites namely, the ruins of the city of Axum, the monolithic churches of Lalibela, Gondar's castles, the Omo Valley, Hadar (where the skeleton of the hominid "Lucy" was discovered), Tia's carved standing stones, the Semien National Park, and the walled city of Harar. The gross domestic product (GDP) contribution from tourism for Ethiopia is about 5.5 per cent and is steadily growing. As a measure to combat poverty and encourage economic development, the government is proving its commitment and willingness to develop tourism through a number of initiatives as in the Ethiopia's Poverty Reduction Strategy Paper (PRSP).

1.8.4 Mining

According to geological surveys, Ethiopia is endowed with a variety of mineral resources. The Federal Democratic Republic of Ethiopia has placed mining at the top of its development agenda, which sees the mining sector as the catalyst for the export-orientated development strategy. It is worth noting that the mining sector is undergoing huge transformation as new opportunities for investment have opened up. The available metallic minerals include gold**,** which has huge potential for exploration, reserves of natural gas (12.6 trillion cc), deposits of platinum (and other platinum group elements PGEs), tantalite, iron, copper, lead, zinc, nickel and other base metals. There are substantial industrial and construction minerals such as quartz, feldspar, mica, kyanite, kaolin, talc chromites, graphite, magnetite, industrial olivine, marble, granite, potash, rock salt, soda ash, sulfur, silica sand, diatomite and bentonite. The mining proclamation recognizes the significant role of private investment in capital formation, technology acquisition and the marketing of minerals. The gold mines in Ethiopia include Legedembi (the largest) and eight mines in the Gambella, Somali, Tigray, Amhara, Benishangul/Gumuz and Southern Nation Nationalities and Peoples (SNNP) regions. Gold exports provided more than US$360 million in 2010 and revenue from this source is expected to increase.

1.9. Governance and Economic Development

1.9.1. Governance

The current system of governance devolves powers and mandates to regional states below which are *Woredas* (districts) and *Kebeles* (villages). The introduction of this devolved system has transformed Ethiopia from a highly centralized system to a federal and increasingly decentralized one. The following are the Regional States and City Administrations of The Federal Democratic Republic of Ethiopia: Tigray, Afar, Amhara, Oromia, Somali, Benshangul/Gumuz, Southern Nations, Nationalities and Peoples (SNNP), Gambela, and Harari (Regional States), and, Addis Ababa and Dire Dawa (City Administrations).

1.9.2. Infrastructure development

Investment in infrastructure continues to drive Ethiopia's economic growth. The improvement of infrastructure is critical in sustaining high growth rates. There are currently large investments being made to expand the road and railway network, power infrastructure, house construction, and industry in urban areas. For instance, development of power infrastructure alone will require almost US$38 billion over the next two years and development of water supply and sanitation infrastructure will require US$1.2 billion by 2020. Ethiopia faces a huge challenge in developing infrastructure in accordance with the CRGE initiative and its objectives of reducing GHG emissions and integrating green growth strategies. The gains from implementing the planned infrastructure improvement will nonetheless make the population of the country more adaptable to the extreme weather conditions which are expected to increase due to climate change. The country has shown a commitment to developing low carbon, high resilience infrastructure and to moving towards greener growth as envisaged in the many policies developed. Since green infrastructure tends to have high direct costs and long pay-back periods, the country requires massive investment to achieve the required green infrastructure 10 per cent annual growth rates, which require, among other things, 14 per cent annual additions to hydroelectric power.

1.9.3. Development Challenges

The main challenge for Ethiopia is to address and improve the living standards of its population and keep up with and accelerate the economic growth rates of recent years. The government is already devoting a very high share of its budget to pro-poor programmes and investment. Over the past two decades, there has been significant progress in key human development indicators: primary school enrolments have quadrupled, child mortality has been cut in half, and the number of people with access to clean water has more than doubled. These gains, together with more recent moves to strengthen the fight against malaria and HIV/AIDS, illustrate the government's determination to ensure the improved well-being of Ethiopians.

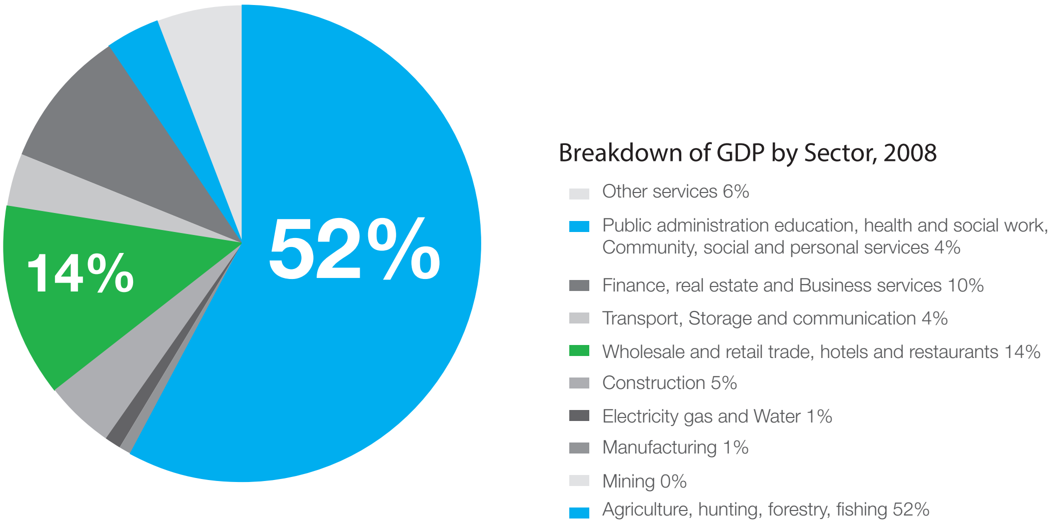
The Government of Ethiopia's current five-year development plan (2010/11-2014/15), the Growth and Transformation Plan (GTP), is geared towards fostering broad-based development in a sustainable manner to achieve the MDGs. The GTP envisages a major leap in terms of not only economic structure and income levels, but also in terms of social indicators. The key goals of the GTP included the following.

- **i.** Rapid economic growth, targeted at 11 per cent per year at worst and at best at a rate fast enough to double the size of the economy and to bring GDP per capita to US$698 by 2015.
- **ii.** Doubling agricultural production, to ensure food security in Ethiopia.
- **iii.** An increased contribution from the industrial sector particularly focused on raising sugar production of sugar, textiles, leather products and cement.
- **iv.** An increase in foreign exchange reserves, the annual appreciation of the Birr by 5 per cent against the dollar.
- **v.** An expansion in the roads network from 49,000 km to 64,500 km by 2015.
- **vi.** An increase in power generation capacity from 2,000 MW to 8,000 MW, and in the number of customers from 2 million to 4 million by 2015.
- **vii.** Construction of 2,395 km of railway line.
- **viii.** Achievement of all the Millennium Development Goals (MDGs).

1.9.4. Economic Development

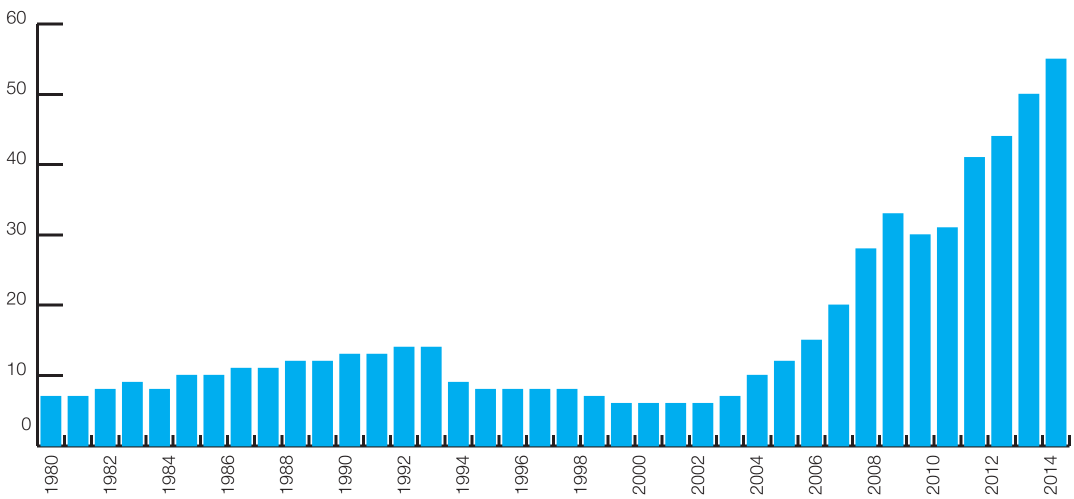
The vision of Ethiopia is to become a middle-income country by 2025. The Ethiopian economy has recently experienced rapid growth, averaging 10.9 per cent per year in 2004/05-2012/13, which is way above the regional average of 5.3 per cent. This growth rate is double the Sub-Sahara African rate and triple the world average, making Ethiopia one of the fastest growing economies in the world. Agriculture is the largest economic sector, while the growth rate in the mining sector has been very rapid, reaching 55.7 per cent in the year 2011. Figure 1 8 shows a breakdown of GDP by Sector, for year 2008.

Figure 1-8: Breakdown of GDP by Sector, 2008



The services sector has also been a major driver of growth, contributing up to half of total growth during the last decade. The industry sector's performance is boosted by the construction boom and expansion in the mining and manufacturing subsectors. Figure 1-9 shows that the Ethiopia's GDP growth has been very strong in the past three years (2011-2014). The Government continues to provide political good will, develop ambitious development plans such as the CRGE and the GTP, and keep the country resilient enough to maintain double- digit economic growth and achieve most of the MDGs.

Figure 1-9: Trend in GDP, 1980-2014 (US$ billion)



The trend in real GDP growth and in sectoral shares is shown in Tables 1-4 and 1-5. The rate of growth of the sectors indicates that growth is trending upward from the financial year 2011/12 to 2012/13 in all the sectors except the services sector, which is showing some recovery. One of the major causes for the fluctuation in real GDP growth rate is climate variability, which directly affects agriculture. As indicated in Figure 1-11 below, the trend in overall real GDP growth follows the same pattern as the trend in agricultural growth rate. Table 1-4 shows sectoral growth rates for the period 2006/07 to 2012/13.

Table 1-4: Growth Rate by Sector (% unless otherwise stated)

YEAR	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
Real GDP Growth	11.8	11.2	10.0	10.4	11.4	8.8	9.7
Sub-Saharan Africa average	6.7	5.5	2.8	5.3	5.2	4.9	5.0
Agriculture	9.4	7.5	6.4	7.6	9.0	4.9	7.1
Industry	9.5	10.1	9.7	10.6	15	17.1	18.5
Services	15.3	16.0	14.0	13.0	12.5	10.6	9.9
Mid-year Population (million)	72.4	74.9	76.8	78.8	80.9	83.0	84.8

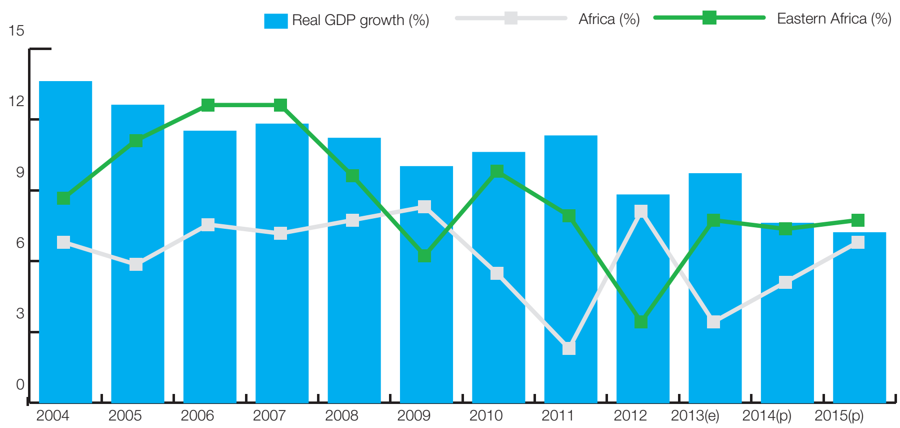
Table 1-5: GDP by Sector (%)

	2008	2013
Agriculture, hunting, forestry, fishing	52.0	45.8
of which fishing	*0.0*	*0.1*
Mining	0.4	1.3
of which oil	*0.0*	*0.0*
Manufacturing	4.1	3.9
Electricity, gas and water	1.5	1.0
Construction	5.3	5.0
Wholesale and retail trade, hotels and restaurants	13.5	18.8
of which hotels and restaurants	*2.9*	*2.9*
Transport, storage and communication	4.1	5.3
Finance, real estate and business services	9.7	9.8
Public administration, education, health and social work, community, social and personal services	3.7	3.4
Other services	5.5	5.7
Gross domestic product at basic prices / factor cost	100.0	100.0

Source: AEO, 2014b.

Figure 1-10 shows that the real GDP growth rate has been much higher than that of the East African region and of Africa as a whole.

Figure 1-10: Real GDP Growth Rates: Ethiopia, Eastern Africa and Africaa (%)



[a] (e)=Estimate; (p)=Projections. Sources: AEO, 2014a: AEO, 2014b.

In the financial year 2012/13, the respective shares of agriculture, industry and services sectors in GDP stood at 43 per cent, 11.2 per cent and 43 per cent. The share of the services sector in GDP increased from 36.5 per cent to 43 per cent in the five years from 2007/08 to 2012/13, while the share of agricultural declined from 52 per cent to 45.8 per cent in the same period. Agriculture still remains the backbone of the economy of Ethiopia, however. There is a dire need for measures to raise productivity in smallholder agriculture as well as to boost private investment in commercial agriculture. They are essential for the growth and transformation of the whole economy through diversification, achieving linkages with other sectors, improving the quality of employment and reducing rural poverty.

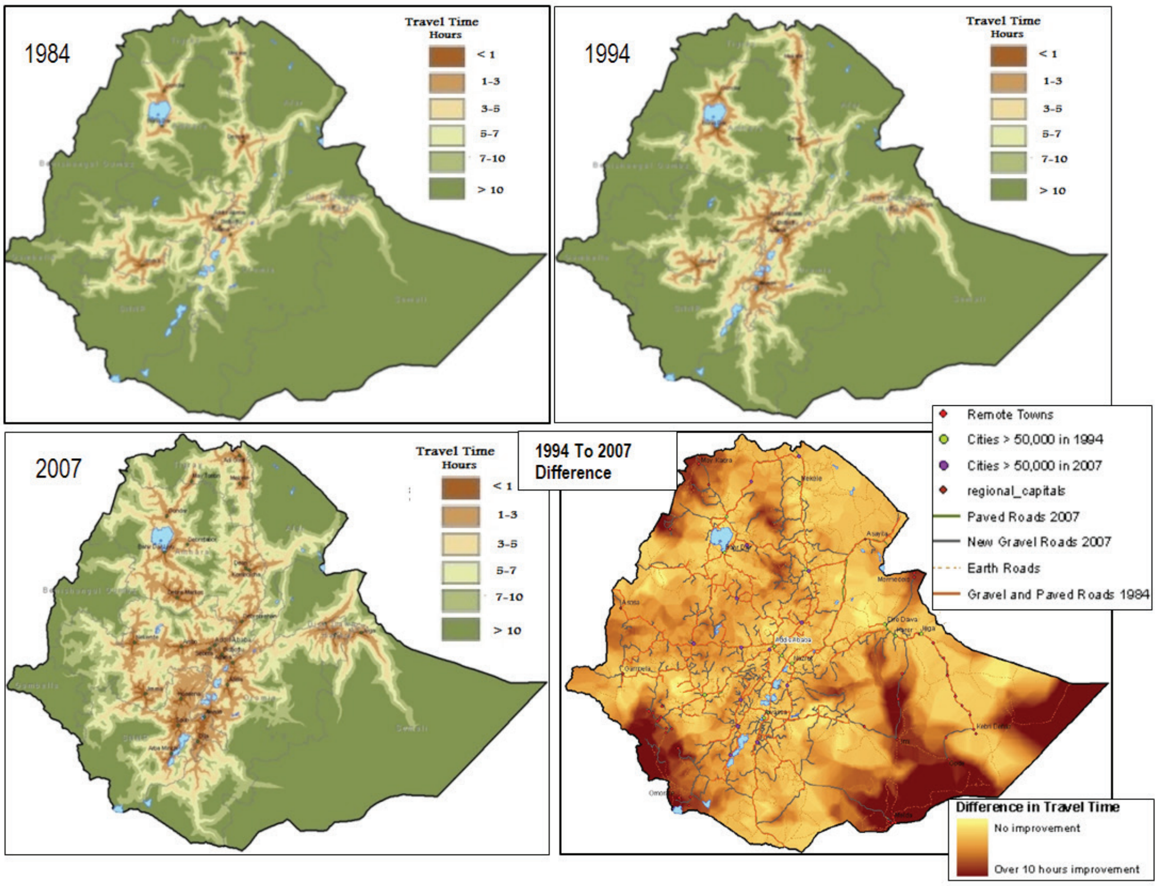
Figure 1-11: Trends in Sectoral Growth Rates, 2006/07-2012/13 (%)

1.10 Transport and Trade

1. 10.1 Transport

The contribution of the transport sector to total GDP may be small at about 6 per cent, but it plays a fundamental role in supporting the other sectors, especially agricultural development and the adoption of an outward-oriented trade strategy, which helps to improve domestic competitiveness. The transportation types available in Ethiopia are road transport, air transport, rail transport, and water transport. The most significant of the four is road transport, which handles about 90 per cent of transportation in the import and export sectors and 95 per cent of public transportation services. Figure 1-12 below shows the improvement in the road network as reflected in reduced travel times to major cities in the period 1984-2007.

Figure 1-12: The Changing Road Network and Travel Times, 1984-2007



Source: ERA, 2008.

The strategic goals of the GTP for the road transport sector include expansion of the country's road network, developing the organizational capacity of the Ethiopia Road Authority and the Regional Road Agencies to manage the road sector programmes effectively, and improving the quality of the overall road network. The Ethiopian Government through its robust development and transformation programme increased the federal and regional total road length from 53,143km in 2010/11 to 56,190km in 2011/12. This indicates the commitment by the Government to get the country networked through its road infrastructure.. The Road Sector Development Program developed for 10 years between 1997 and 2006 began a persistent effort to improve the roads infrastructure. As a result, as of 2002 Ethiopia had a total (federal and regional) of 33,297 km of roads, both paved and gravel.

The share of federally managed roads in good quality improved from 14 per cent in 1995 to 31 per cent in 2002 through the program, and to 89 per cent in 2009. Road density increased from 21 km per 1,000 km^2 (in 1995) to 889 km per 1,000 km^2 (in 2009), which is higher than the average of 50 km per 1,000 km^2 for Africa as a whole. The transport sector accounts for over 50 per cent of total fuel consumption, making it a major user of fossil fuel in the country.

The greatest challenges in the development of surface transport in Ethiopia include wide topographical variations, extremely rugged terrain, severe climatic conditions and a widely dispersed population. These factors make construction of transport infrastructure not only physically difficult but also extremely costly.

Section of Highway to Hawzen
Developed under the RSDP

The rehabilitation of roads as outlined in the RSDP has improved travel time within the country considerably (ERA, 2008). In 1984, 40 per cent of the population was over 10 hours away from a city of at least 50,000 and 42 per cent were over five hours away from a large city. By 1994, 31 per cent of the population was more than 10 hours travel time away from a major city and five of the nine administrative units had populations that could reach a city within an hour. Since 1994, the Ethiopian government has continued to invest in key road infrastructure reducing the percentage of the population who are more than 10 hours from a major city to 3.2 per cent in Amhara and 4.5 per cent in SNNP. In Tigray and Oromia, 21 per cent of the population improved market access from over 10 hours to between 3 and 10 hours travel time to a major city. At the time of the 2007 population census, every region except Gambela has a city of at least 50,000 people (FDRE, 2008) and many of these cities have built networking transportation infrastructure in order to harness the potential of economic corridors between cities.

Railway transport is a cost effective and time efficient means of carrying bulk inputs and produce. Construction of a national railway network has, therefore, become an important task in the Growth and Transformation Plan. Under the plan, a total of 2,395 km railway line is planned to be constructed in three corridors and five lines. The construction of a railway linking Addis Ababa to Djibouti is under way.

1.10.2. Foreign Trade

In 2012, the value of Ethiopia's exports of increased by 10.6 per cent to reach US$2.9 billion, while there was an even more substantial increase in imports of 33.9 per cent, to reach US$11.9 billion (as shown in Figure 1-13). In 2012, the value of Ethiopia's exports of services decreased slightly by 2.6 per cent, reaching US$2.7 billion, while its imports of services increased slightly by 4.4 per cent to reach US$3.5 billion (as shown in Figure 1-14).

Figure 1-10: Total Merchandise Trade, 2000-2013 (US$ billion)

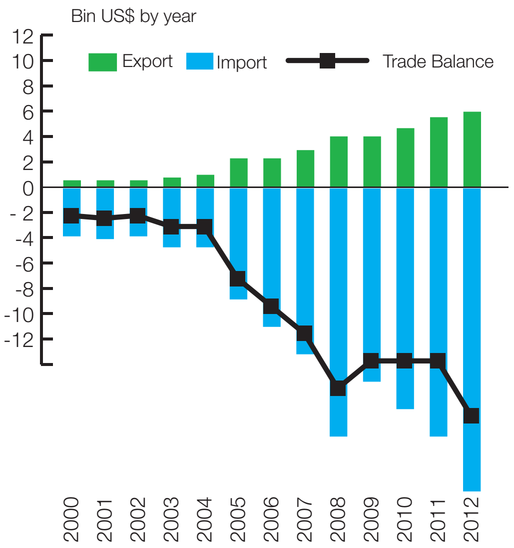
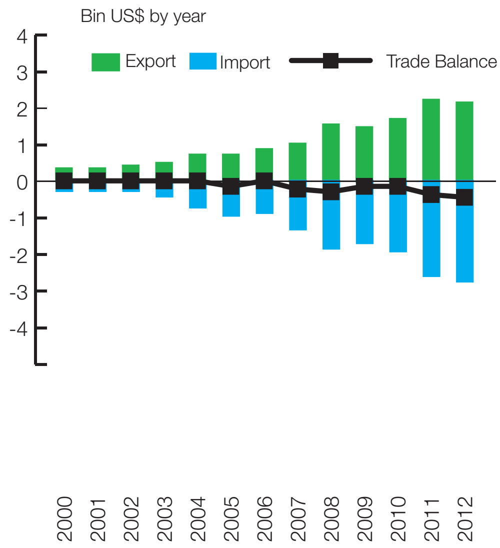


Figure 1-11: Total Services Trade, 2000-2013 (US$ billion)



1.11. Waste

Waste management is a huge challenge for municipalities and governments in the developing world, mainly owing to inadequate infrastructure and limited institutional capacity at the local level. Solid waste collection and landfill management throughout Ethiopia is the responsibility of the municipalities. According to the Environmental Protection Authority, the per capita amount of waste generated in Ethiopia is 0.17-0.48 kg/person/day in urban areas and 0.11-0.35 kg/person/ day of waste in rural areas. However, the amount of waste generated also depends on other factors such as income and season. Municipal solid waste generated in Ethiopia was estimated to be 2.8-8.8 million tons in 2003, divided between 0.6-1.8 million tons in urban areas and 2.2-7 million tons in rural areas.

Most Ethiopian municipality administrations are responsible for waste collection. However, this is a daunting task for the municipalities as up to 43 per cent of the waste is collected for disposal in unmanaged landfills, while the rest remains in the streets or is dumped in open spaces. The country is running a waste to energy project based in Addis Ababa's 36 hectare municipal landfill that has been operating for nearly 50 years, since 1968. The landfill that is currently 85 per cent full, was recently closed and transformed into the Repi project. The project is meant to capture and flare methane, which is produced by decomposing organic matter in the landfill site. It is expected to capture 96,884 tCO2e annually (UNFCCC, 2013). The first stage of a methane capture and flaring system has already been installed

The waste-to-energy facility under construction will generate 50 MW of clean energy through a controlled combustion process consuming 350,000 tons of waste annually. This will reduce municipal solid waste, beautifying the city and providing a meaningful source of income for young people as well as being an additional power source that will be connected to the grid.

CHAPTER TWO:

DESCRIPTION OF STEPS TAKEN OR ENVISAGED TO IMPLEMENT THE CONVENTION

2.1. Introduction

This chapter provides information on the steps taken or envisaged by Ethiopia to implement the UN Framework Convention on Climate Change. The information provided covers institutional coordination of climate change and other major UNFCCC activities, policies and programmes related to climate change.

2.2. The Second National Communication Process

The Directorate of the State of Environment and Reporting within the Ministry of Environment and Forest coordinated the preparation of the Second National Communication. To support the preparation of the National Communication, six Technical Working Groups (TWGs) based on the IPCC GHG Inventory, seven sectors were established to source and interpret information and data about the impact of climate change. The TWGs, drawn from the thematic areas of Energy, Transport, Land Use Change and Forestry, Industrial Processes and Product Use, Agriculture, Waste and Meteorology, formed a multi-sectoral National GHG Inventory team. The team comprised representatives from various Government ministries and departments, most of whom were responsible for developing and coordinating programmes and projects aimed at addressing climate change in line with the country's development priorities and were focal points for climate change at their respective institutions. The participation of the stakeholders in the national communication was conducted to create awareness, review the content of the report and strengthen capacity among relevant stakeholders.

2.3. Coordination of Climate Change and UNFCCC Activities

2.3.1. Institutional Arrangement to Climate Change

The Ministry of Environment and Forest (MEF) is the National Focal Point to the Kyoto Protocol and to the United Nations Framework Convention to Climate Change (UNFCCC). MEF is mandated by the Government of Ethiopia to spearhead and coordinate environment, forest and climate change issues in the country. The ministry prepares regulatory instruments and plays a regulatory role, ensures the mainstreaming and implementation of environment, forest and climate change issues in sectoral programmes and plans, coordinates implementation of the Climate Resilient Green Economy (CRGE) strategy across the national sectors, and carries out capacity-building activities for sectoral and regional bodies.

2.3.2. Ministry of Environment and Forest

As part of the Government's efforts to realize its CRGE strategy, the former Environment Protection Authority was combined with the Ministry of Environmental Protection and Forestry to create the Ministry of Environment and Forest. The ministry is the focal point and coordinator of the international conventions and agreements regarding climate change, the environment, and biodiversity. The Government has made progress in implementing the international conventions and agreements by establishing and strengthening institutions, enacting biological and environmental laws, and developing policies, strategies and other actions.

MEF is responsible for spearheading reforestation and other wide-ranging environmental protection initiatives. The task of environment protection requires undertaking multi-pronged activities that could play a significant role in the improvement of the lives of the citizens. The ministry coordinates and provides policy and technical support for environmental protection and reforestation campaigns at the national level. It is also mandated to collect vital data, tailor better strategies and coordinate activities undertaken by other bodies and stakeholders to ensure that all matters pertaining to the country's social and economic development. MEF is required to ensure that the activities are carried out in a manner that will protect the welfare of human beings as well as sustainably protect, develop and utilize the resource bases on which they depend for survival. The ministry's mission is to put in place an environmental management system that could support the nation's development objectives by avoiding duplication of efforts among stakeholders, promoting sustainable utilization of environmental resources, and strengthening coordinated but differentiated responsibilities through:

i. preparing the State of Environment Report;
ii. development of an environmental strategic plan;
iii. formulation of environmental laws and standards;
iv. provision of support for environmental regulatory bodies and implementers; and
v. undertaking monitoring and effectiveness evaluation of the environmental system in place.

2.3.3. National Meteorological Agency (NMA)

The NMA has the mandate to collect meteorological data, study the atmosphere and provide weather forecasts and early warnings on the adverse effects of weather and climate in Ethiopia. The agency is committed to exchanging and disseminating information in accordance with the international agreements, and disseminating advice and educational information through the mass media.

2.4. Integrating Climate Change into National Development Policies and Planning

Ethiopia has put in place a number of environmentally oriented policies, strategies and action plans that can directly or indirectly contribute to the objectives of the Climate Convention. Support for the implementation of these policies, strategies and action plans in the form of funding, technical assistance, training and technology transfer through the Convention mechanisms is essential. In this section the relevant policies, strategies and action plans are briefly highlighted.

2.4.1. The Environment Policy of Ethiopia

The Government of Ethiopia (GoE) delivered the country's Environmental Policy in the year 1997 with the aim of rectifying the economic and social costs of environmental damage from widespread mismanagement of natural resources. This is also meant to provide general guidance on the conservation and sustainable utilization of resources. The areas that were covered in the policy include: soil, forest, woodlands, biodiversity, water, energy, minerals, the urban environment, environmental health, industrial pollution, atmospheric pollution, and the cultural and natural heritage. The policy also included other cross-sectoral issues such as population and the environment, community participation and the environment, and tenure and access rights to land.

The overarching goal of the policy, is to improve and enhance the health and quality of life for all Ethiopians, and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources, and the environment as a whole. This should meet the needs of the present generation without compromising the ability of future generations to meet their needs. Most of the aspects of policy still hold up today. The environmental policy has the following objectives.

i. Ensure that essential ecological processes and life support systems are sustained, biological diversity is preserved and renewable natural resources are used in such a way that their regenerative and productive capabilities are maintained and where possible enhanced so that the satisfaction of the needs of future generations is not compromised. Where this capability is already impaired it will seek through appropriate interventions to restore it.

ii. Ensure that the benefits from the exploitation of non-renewable resources are extended as far into the future as they can be managed, and minimize the negative impacts of their exploitation on the use and management of other natural resources and the environment.

iii. Identify and develop natural resources that are currently underutilized by finding new technologies, and/or intensifying existing uses which are not widely applied.

iv. Incorporate the full economic, social, and environmental costs and benefits of natural resource development into the planning, implementation and accounting processes through a comprehensive valuation of the environment and the services it provides, and by considering the social and environmental costs and benefits which cannot currently be measured in monetary terms.

v. Improve the environment of human settlements to satisfy the physical, social, economic, cultural and other needs of their inhabitants on a sustainable basis.

vi. Prevent the pollution of land, air and water in the most cost-effective way so that the cost of effective preventive intervention would not exceed the benefits.

vii. Conserve, develop, sustainably manage, and support Ethiopia's rich and diverse cultural heritage.

viii. Ensure the empowerment and participation of the people and their organizations at all levels in environmental management activities; and raise public awareness and promote understanding of the essential linkages between the environment and development.

Most countries, have either a developed climate change policy or have updated their environment policy. Since the Ethiopian Government has moved a long way towards following a low carbon development path, it would be advisable either to update the policy or to develop a climate change policy,

2.4.2. Ethiopia's Growth and Transformation Plan (GTP)

This is a medium-term strategic development framework covering three consecutive five-year periods (beginning with GTP I, 2011-2015), whose aim is to achieve rapid economic development, by aggressively promoting agricultural investment, boosting industrial growth, expanding access to social service provision, while ensuring equity as well as quality and meeting the MDGs. The GTP I aimed to double domestic agricultural production to enhance food security at the family, regional and national levels. It presents an opportunity to build a climate-resilient green economy through unleashing the potential for agriculture, harnessing the multiple benefits of water resources, massively expanding access to modern energy and combining climate change adaptation and parallel approaches. It also focuses on Ethiopia`s green growth path and on continued efforts to stabilize greenhouse gases through appropriate mitigation actions in all major sectors of the economy, while lobbying for international solidarity for a fair and ambitious outcome in the international climate change negotiations.

The GTP sees climate change as a threat and an opportunity for Ethiopia, requiring both adaptation and mitigation measures and sound environmental management for sustainable development. The GTP further articulates the government's commitment to building a green economy and to continued implementation of country's environmental policies and laws. The GTP recognizes the importance of appropriate climate change adaptation and mitigation measures in propelling the country to a climate-resilient and carbon-neutral economy. It is recognized in the GTP that 6 per cent of Ethiopia's annual production is lost to climate change, mainly through lost agricultural production, inundation, and drying up of water resources, and the loss of biodiversity. In addition to adaptation measures, the plan recommends the preparation of action plans, laws, and standards; raising and enhancing public awareness; scaling-up of best practices; certification, and standardization. It also recommends accreditation of experts and organizations working on environmental issues and climate change mitigation; embarking on aggressive economic expansion and development measures in the areas of renewable energy resources; building climate change mitigation capacity; and implementation of environmental management practices.

2.4.3. National Adaptation Programme of Action (NAPA)

Pursuant to the articles of the UNFCCC requiring parties to address climate change through the preparation of a national adaptation document and the integration of climate change into its sectoral development policies and plans, Ethiopia prepared its NAPA in 2007. The NAPA represented the first step in coordinating adaptation activities across government sectors, but was not intended to be a long-term strategy in itself.

2.4.4. Nationally Appropriate Mitigation Action (NAMA)

NAMAs are voluntary emission reduction measures undertaken by developing country parties and reported to the UNFCCC. In accordance with the requirements of the Copenhagen Accord, Ethiopia prepared and submitted its NAMA in January 2010. The Ethiopian NAMA comprises various sectors and concrete projects (in the energy, transport, forestry, agriculture and urban waste management sectors) and has been registered by the Secretariat of the UNFCCC in line with the Copenhagen Accord.

2.4.5. Ethiopia's Programme of Adaptation to Climate Change (EPACC)

This programme links climate change adaptation strongly with the economic and physical survival of the country and identifies key climate change adaptation measures, strategic priorities, and intervention areas to address the adverse effects of climate change. The main objective of EPACC is to create the foundation for a carbon-neutral and climate-resilient path towards sustainable development in the country. The programme states that the residents and farmers at the local and district levels will implement most of the solutions to climate change, thus the role of the federal institutions will be to initiate, facilitate, and monitor activities with the exception of some cases that need the intervention of the concerned federal organs.

The programme identifies 20 climate change risks and the institutions responsible for countering and mitigating each of them. The climate risks identified are broadly in the areas of human, animal and crop diseases, land degradation, loss of biodiversity, decline in agricultural production, dwindling water supply, social inequality, urban waste accumulation, and displacement due to environmental stress and insecurity. It identifies adaptation strategies and options in the various socioeconomic sectors, including cloud seeding, crop and livestock insurance mechanisms, grain storage, societal reorganization, renewable energy, gender equality, factoring disability, climate change adaptation education, capacity-building, research and development, enhancing institutional capacity, and building political momentum.

The work programme adequately captures the growing threat of climate change in Ethiopia, and clearly spells out the need to mainstream climate change in all spheres of development policymaking and planning at all phases and stages in the implementation process. The programme clearly states the urgency of taking practical adaptaton and mitigation actions in the various social and economic sectors.

2.4.5.1. Climate Change Adaptation Strategies and Programmes

Ethiopia needs to adapt to climate change since its mainstay economic sector, agriculture, is highly susceptible to climate shocks. In addition, the limited infrastructure and people's way of living adds to their vulnerability to climate extremes. Understanding this, the Government of Ethiopia has prepared and is implementing the following adaptation strategies and programmes.

- **a.** Ethiopia's Programme of Adaptation to Climate Change (EPACC) (under implementation since 2011). EPACC has identified 20 critical adaptation issues and has assigned responsibility for them to specific bodies and identified implementation mechanisms for them.
- **b.** Agriculture Sector Adaptation Strategies;
- **c.** Water and Irrigation Adaptation Strategies;
- **d.** Health Sector Adaptation Strategies; and
- **e.** A Sectoral Reduction Mechanism (SRM).

2.4.6. Climate Resilient Green Economy (CRGE)

The Climate Resilient Green Economy (CRGE) strategy has taken a sectoral approach to identify and prioritize more than 60 initiatives, which will help the country to achieve its development goals while reducing 2030 GHG emissions to around 150 tCO_2e from 400 tCO_2e in the 2030 business as usual (BAU) scenario. The green economy plan has four pillars.

- **i.** Improving crop and livestock production practices for higher food security and farmer income while reducing emissions.
- **ii.** Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks.
- **iii.** Expanding electricity generation from renewable sources of energy for domestic and regional markets.
- **iv.** Leapfrogging to modern and energy-efficient technologies in transport, industry and construction.

By developing a green economy, the country could exchange GHG emissions abatement for climate finance to fund some of the required investment. As part of the strategy, the Government has selected four initiatives for fast-track implementation: exploiting the country's vast hydropower potential; large-scale promotion of advanced rural cooking technologies; efficiency improvements to the livestock value chain, and Reducing Emissions from Deforestation and Forest Degradation (REDD). These initiatives have been selected as having the best chance of promoting growth immediately, capturing large abatement potentials and attracting climate finance for their implementation. To ensure a comprehensive programme, initiatives from all other sectors will also be developed into concrete proposals.

The CRGE initiative also outlines the structure of a permanent institutional set-up to drive implementation, and to promote the participation of a broad set of stakeholders. The government is dedicating significant resources to building the green economy. To capture the full potential of the plan, it will take advantage of emerging climate finance schemes, which will compensate developing countries for the provision of environmental services to the world. Bi- and multilateral development partners as well as the private sector can help in achieving these goals.

2.4.7. Energy Policy

The renewable energy potential of Ethiopia is rich in the form of hydropower and plentiful solar and wind resources. Ethiopia has developed a comprehensive energy policy that will ensure that the demand for energy from the productive sectors of the economy is met in the future, while giving due attention to environment and climate change. Energy is the driving force for economic development. Therefore energy is critical for economic development. Its importance stems from the fact that energy is a basic input in all productive activities, including in the household sector. Once the cost of energy increases all other costs increase. This implies that favourable policies will reduce the cost of energy and improve the environment.

The Government of Ethiopia's energy sector policy priorities are: the development of hydropower sources; a gradual transition from traditional to modern fuels; publicizing standards and codes which will ensure that energy is used efficiently and properly; developing human resources and establishing competent energy institutions. The Government also aims to provide the private sector with the necessary support and incentives to participate in the development of the country's energy resources, and to pay due attention to ecological and environmental issues during the development of energy projects.

The Government's energy policy addresses supply-side options in household, transport, agriculture and industrial energy. The Government is committed to putting in place measures to address supply and demand, energy and conservation and make energy more affordable. Apart from the cost of implementation, it is important to create an institution which is entrusted with policy formulation, priority setting and the coordination of all development activities in the energy sector in order to coordinate and ensure consistency in energy resource development, and to avoid wasting resources and duplicating efforts.

2.4.8. Water Policy

The geographical location of Ethiopia and its favourable climate provide it with a relatively high amount of rainfall. Much of the water, however, flows across the borders, being carried away by the trans-boundary rivers to neighbouring countries. The major water resources problem facing Ethiopia is the uneven spatial and temporal occurrence and distribution of rainfall. In order to alleviate the problems this causes for agricultural and other water users, sustainable and reliable development and proper use of the water resources of Ethiopia are imperative. Obviously, this requires a judicious water resources management policy, in which priorities are carefully set, and the associated finance to back it up. Such a policy has been formulated in the belief that an appropriate water resources management policy for the sector is one that enhances the development of the country's water resources to make the optimum contribution to accelerated socio-economic growth. This water resources management policy is based on the Constitution of the FDRE's provisions on macroeconomic and social policy and development strategies as well as objectives and principles formulated by the Government in this area with a view to enhancing socio-economic development in Ethiopia.

The overall goal of water resources policy is to enhance and promote national efforts towards the efficient, equitable and optimum utilization of the water resources of Ethiopia for significant socioeconomic development on sustainable basis.

The main objectives of the water resources policy are the following.

i. Development of the water resources of the country for the economic and social benefit of the people on an equitable and sustainable basis.

ii. The allocation and apportionment of water based on comprehensive and integrated plans and optimum allocation principles that incorporate efficiency of use, equity of access and sustainability of the resource.

iii. Managing and combating drought as well as other associated slow onset disasters through, inter alia, efficient allocation, redistribution, transfer, storage and use of water resources.

iv. Combating and regulating floods through sustainable mitigation, prevention, rehabilitation and other practical measures.

v. Conserving, protecting and enhancing water resources and the overall aquatic environment on a sustainable basis.

The fundamental policy principles that guide the equitable, sustainable and efficient development, utilization, conservation and protection of water resources in Ethiopia include the following.

i. Water is a natural endowment commonly owned by all the people of Ethiopia.

ii. Ethiopian citizens shall have access to sufficient water of acceptable quality and to satisfy basic human needs.

iii. In order to significantly contribute to development, water shall be recognized both as an economic and a social good, and he participation of all stakeholders and user communities, with particular emphasis on women, shall be promoted.

2.4.9. Agricultural and Rural Development Policy Strategies (RDPS)

The RDPS Strategies include the following.

i. The Sustainable Land Management Program (SLMP) as a tool to reduce rural vulnerabilities and building ecosystem resilience.

ii. Environmental rehabilitation.

iii. Watershed development for environmental adaptation.

iv. Harnessing the multiple benefits of water resources.

v. Integrated disaster risk monitoring and early warning.

vi. The use of improved agricultural inputs and modern technologies.

2.5. Ethiopia`s Contribution to International Climate Change Processes

Climate change represents a significant threat to Ethiopia with drought-induced food, water and energy insecurity already being felt as recurrent problems. These events affect above all the worst-off and most vulnerable and can pose a serious threat to the alleviation of poverty and the attainment of the five-year Growth and Transformation Plan (2011-2015) and the MDGs. In terms of policy, unlike in the case of developed countries which are obliged to mitigate their greenhouse gas emissions, the practical responses expected from Ethiopia are to adapt and mitigate the impacts of climate change through the development of nationally appropriate policies and practical adaptation and mitigation measures, while lobbying for international solidarity, equity and climate justice. Accordingly, Ethiopia has ratified the UNFCCC (1994) and its related instrument, the Kyoto Protocol (2005), and submitted its initial national communication (in 2001) and National Adaptation Programme of Action (NAPA) (in 2007) to the UNFCCC. The country also submitted its Nationally Appropriate Mitigation Action (NAMA) plan to the UNFCCC in January 2010. The country has completed the preparation of a new work programme, Ethiopia's Program of Adaptation to Climate Change (EPACC) and had by 2011 launched an overarching framework and national strategy called Climate Resilient Green Economy (CRGE) in addition to more detailed sectoral adaptation strategies produced as a result of the implementation of the CRGE.

The Government of Ethiopia (GoE) also promulgated a five year (2011-2015) development plan, the Growth and Transformation Plan (GTP I). GTP I sets out the country's ambition to build a climate resilient green economy by 2030. Other than the GTP, various national policies, initiatives and sectoral programmes now in place also address climate change, albeit indirectly. Such policy and programme initiatives include, the Environmental Policy, the Energy Policy and the Biofuels Strategy, the Agriculture and Rural Development Strategy, the Water Resources Management Policy, Strategy and Programme, the Health Policy, the National Policy on Disaster Prevention and Preparedness, the National Policy on Biodiversity Conservation, the Pastoral Policy, and the recently introduced National Development Plan for Ethiopian Women, Children and Youth. These policies are meant to expedite Ethiopia's joining the international community in integrating climate change low emission development strategies (LEDS) into economic growth.

2.6. Status of the Implementation of Ethiopia's obligations under the UNFCCC

NMSA established Climate Change and Air Pollution Studies Team in 1994 under the Meteorological Research Studies Department to implement the UNFCCC in Ethiopia. The following major activities have been undertaken in this regard.

2.6.1. US-Ethiopia Climate Change Country Study Project

One of the outcomes of the Rio Conference for Ethiopia was the opportunity to conduct a Climate Change Country Study Project with US Government financial and technical assistance. The project covered the period from June 1993 to August 1995. Activities undertaken and outputs of that project include the following:

i. Institutional Support & Capacity-Building

Technical documents, hands-on training on some of the analytical tools and backstopping services were provided by the funding agency, the US Country Studies Program. Hardware and equipment were also acquired through the project.

ii. Greenhouse Gases (GHGs) Inventory: Phase I

Sectors included in the GHGs inventory exercise were: energy, agriculture, land use change and forestry, waste management, and industrial processes (cement factories only).

iii. Vulnerability, Impact, Adaptation and Mitigation Assessments: Phase II

During Phase II of the project, vulnerability, impact, adaptation and mitigation assessments were conducted in the following sectors: agriculture (crops – wheat + grassland/livestock), forestry and water resources (Awash Basin). Climate change mitigation assessments were carried out for the grassland/livestock and energy sectors. The outputs of the project were a GHGs inventory report; as well as sectoral reports on vulnerability, impact, adaptation and mitigation assessments. Though not published, the final report on the project was handed over to the Government of Ethiopia and the funding agency.

2.6.2. GEF-Ethiopia Climate Change Enabling Activities Project

The US-supported, first project on climate change in Ethiopia created the momentum for continued activities in the sphere of climate change. So as a party to the UNFCCC and at the request of the Government of Ethiopia in February 1997, the Global Environment Facility (GEF) approved financial support of US$218,000 to be channeled through the UNDP to allow Ethiopia to participate in the GEF's Climate Change Enabling Activities programme. The same funding institution, GEF, has since provided top-up of funds worth about US$100,000 for the second phase of this project.

2.6.3. Greenhouse Gases (GHGs) Inventory and Mitigation Assessment

This is another activity that has been built on the previous activities carried out under the US-Ethiopia Climate Change Study Project. A national inventory of GHGs for the years 1990-1995 was carried out covering seven gases; namely: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOC) and sulfur dioxide (SO_2). The sectors covered were: energy, agriculture, land-use change and forestry (LUCF) and waste. GHG mitigation options have also been identified in these four sectors. The Technical Working Group on Greenhouse Gas Inventory and Mitigation carried out both the inventory of GHGs and the mitigation assessments.

2.6.4. Vulnerability, Impact and Adaptation Assessments

Vulnerability, impact and adaptation studies and assessments have been undertaken focusing on six socioeconomic sectors: crops (sorghum), grassland/rangelands and livestock (pastoral areas of Ethiopia), water resources (Abay or Blue Nile Basin), forestry, wildlife, and human health (malaria).

2.6.5. Developing Framework National Climate Change Action Plan

Ethiopia has developed a draft Framework National Climate Change Action Plan (FNCCAP). However, the action plan is just a framework that needs further improvement before implementation.

2.6.6. Major Outcomes of the National Climate Change Projects

Prominent among the climate change projects carried out in Ethiopia was the Initial National Communication of Ethiopia to the UNFCCC, published in June 2001 and submitted to the Conference of Parties (COP) through the Convention Secretariat on 16 October 2001. Copies of the document were distributed to various stakeholders. Other activities include the following.

i. Preparation of the Draft Framework National Climate Change Action Plan.

ii. Compilation of National Greenhouse Gases Inventory data for the years 1990-1995.

iii. Production of six technical reports on Vulnerability and Stage I Adaptation Assessments.

iv. Production of four technical reports on mitigation studies (energy, land use change and forestry, agriculture and waste).

v. Intensification of public awareness activities about climate change.

vi. National Report to the World Summit on Sustainable Development (WSSD).

vii. Short-term training courses.

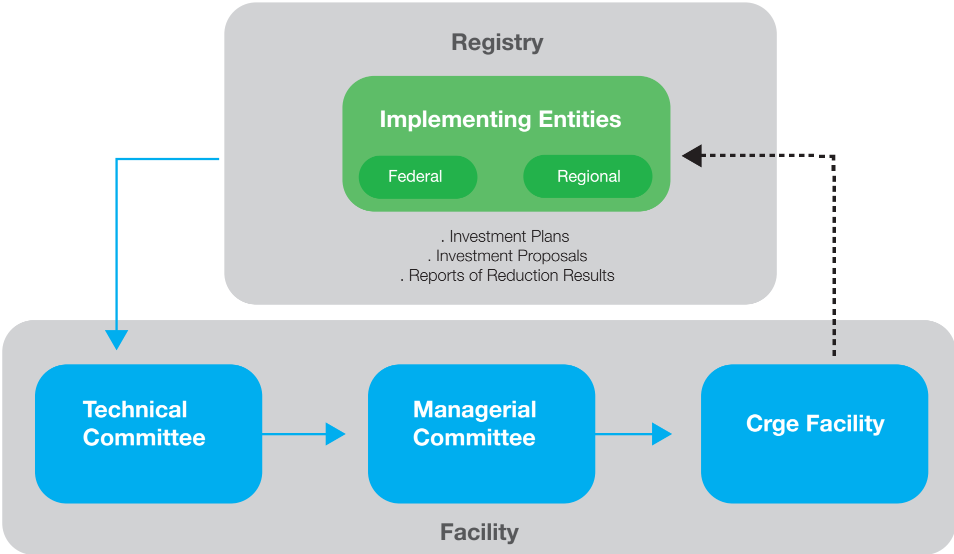
2.7 CRGE Strategy Implementation

2.7.1 Coordination of the CRGE Strategy Implementation

The institutions involved in the CRGE Strategy development and implementation include; The Prime Minister's Office; Ethiopian Development Research Institute; Ministry of Environment & Forest (MEF); Ministry of Finance and Economic Development (MoFED); Ministry of Agriculture; Ministry of Water; Ministry Irrigation & Energy; Ministry of Trade and Industry; Ministry of Transport; Ministry of Science & Technology; Ministry of Urban Development and Construction; Regional States. The collaborating partners include United Nations Development Programme (UNDP); UK Department for International Development (DFID); Government of Norway; and Government of Austria. The Ministry of Environment and Forest (MEF) and the Ministry of Finance and Economic Development (MoFED) are the main entities coordinating the CRGE implementation. MEF's role includes putting in place the overall technical approach and system for coordination for CRGE implementation and the monitoring of progress. MEF is also responsible for managing the technical aspects of the CRGE Facility; a national financing mechanism for CRGE implementation. MOFED's responsibility is to establish the CRGE Facility in collaboration with MEF. The Facility is functional fully equipped with an operational manual developed in consultation with the national stakeholders and, multilateral and bilateral partners.

The CRGE implementing entities include priority sectors; agriculture, energy, transport, industry and urban development and all regions. The sectors which immensely contributed to the development of the CRGE have also established CRGE units with the focus of ensuring effective mainstreaming the strategy at sector level. The sectors are also preparing their sector specific climate resilience strategies and are developing specific subsector CRGE investment and action plans. The figure 2-1 below shows the CRGE Implementation operations structure

Figure 2-1: CRGE Implementation Operations Structure



2.7.2. Resource needed for Green Economy Building

The resource needed to implement the CRGE Strategy for building green economy by the year 2025 is estimated to be USD200 billion. This resource is intended to be obtained from three major sources: Domestic public and private, international climate funds and bilateral and multilateral partners. The country has made great strides in implementing the CRGE Strategy with limited resources. The following sections describe different sectoral efforts which have been undertaken and the results obtained in the implementation of the CRGE Strategy since 2011.

2.7.3. Renewable and Green Energy Development

Ethiopia has been making great progress in exploiting its immense potential for hydropower, wind, geothermal, bio-fuels and other renewable energy resources. National demand for power is increasing at an annual average rate of 25 per cent. Table 2-1 shows production to date and potential reserves of Ethiopia's major power resources (renewable and non-renewable).

Table 2-1: Power Resource Potential in Ethiopia

Resource	Units	Exploitable reserve	Percentage Exploited
Hydropower	MW	45,000	<5
Solar	KWh/m^2/day	5.5	<1
Wind power Speed	GW m/s	1,350 > 6.5	<1
Geothermal	MW	10,000	<1
Wood	Million tons	1.120	50
Agriculture remnants	Million tons	15-20	30
Natural gas accumulation	Billion m^3	133	0
Coal	Million tons	320	0
Oil shale	Million tons	253	0

Source: Adapted from MME, 2011g.

2.7.3.1 Hydropower

The electricity in Ethiopia's grid is now derived entirely from renewable energy. Hydropower accounts for most of it with some wind power added. But at present the gird reaches mainly the urban population, which accounts for less than 20 per cent of the total population. Ethiopia's long-term plan is for the gird to reach all rural homesteads as well in about 20 years. In the meantime, the Government is promoting fuelwood efficient stoves and biogas, with solar panels to power telecommunication technologies and public service centres in the rural areas.

The Great Renaissance Dam on the Blue Nile is planned to have a total capacity of generating 6,000 MW when it is fully operational. The construction will be finalized in 2018. The Ethiopian Government is funding the entire project from domestic sources, including through selling bonds to the public. Gibe III hydropower plant project is currently under construction, some 250 km south-west of Addis Ababa. The construction of two power generating plants downstream, Gibe IV and Gibe V, have now been planned. Tables 2-2-2-4 show hydropower projects which are either operational, under construction and or planned.

a. Currently existing (operational) hydropower plant projects:

- Total installed capacity = **1,953.5 MW**
- Total average energy production = **9,630 GWh/yr**

Table 2-2: Operational Hydropower Plans and their Production

No	Plant	Installed capacity (MW)	Average energy production (GWh/yr)
1	Koka	43.2	134
2	Awash II	32	185
3	AwashIII	32	185
4	Fincha	134	797
5	Melka Wakena	153	557
6	Tis Abbay I	11.3	85
7	Tis Abbay II	73	359
8	Gilgel Gibe I	192	885
9	Tekeze	300	1,404
10	Gilgel Gibe II	420	2,037
11	Beles	460	2,756
12	Fincha-Amerti Neshe	98	246
13	Sor	5	0
	Total	**1953.5**	**9,630**

b. Hydro power plants under construction:

- Total installed capacity = **8,124 MW**
- Total Average energy production = **22,617 GWh/yr**
- Total installed capacity = **2,280 MW**

Table 2-3: Hydropower under Construction

No	Hydro plants	Installed capacity (MW)	Average energy production (GWh/yr)	Regional location
1	Genale Dawa III	254	1,200	Oromia
2	Gilegel Gibe III	1,870	6,240	SNNPR
3	Grand Renaissance	6,000	15,177	Benishangul-Gumuz
	Total	**8,124**	**22,617**	

The Great Renaissance Dam under Construction

Table 2-4: Candidate Power Plants for Investment

No	Power plants	Installed capacity MW	Study level	Location
1	Geba I and II	372	Feasibility study completed	Oromia
2	Halele Werabesa	436	Feasibility study completed	
3	Gilgel Gibe IV	1,472	Feasibility study completed	SNNPR
	Total	**2,280**		
1	Genale VI	246	Under feasibility study	
2	Upper Dabus	326	Reconnaissance	
3	Tekeze II	450	Under feasibility study	
4	Genale V	100	Reconnaissance	
5	Wabeshebele 18	87	Reconnaissance	
6	Karadobi	1,600	Under feasibility study	
7	Tams	1,700	Reconnaissance	

8	**Beko Abo**	935	Under feasibility study
9	**Upper Mendeya (Blue Nile)**	1,700	Under feasibility study
10	**Birbir R**	467	Reconnaissance
11	**Baro I & II and Genji**	859	Feasibility study completed
12	**Genale V**	100	Reconnaissance
13	**Gojeb**	153	Feasibility study completed
14	**Gibe V**	660	Under feasibility study
15	**Lower Dedessa**	613	Reconnaissance
16	**Derbu I**	250	Feasibility study completed
17	**Derbu II**	325	Feasibility study completed
	Total	**10,571**	

2.7.3.2 Wind Energy

Ethiopia has extensive wind resources with velocities ranging from 7 to 9 m/s. Its wind energy potential is estimated to be 10,000 MW. The Ethiopian National Meteorological Services Agency (NMSA) began work on wind data collection in 1971 using some 39 recording stations located in selected locations. On the basis of data obtained from existing wind measurement stations two important conclusions can be drawn.

i. First and foremost, Ethiopia's wind energy potential is considerable.

ii. Secondly, wind energy is highly variable over the terrain, mainly as a function of topography of the country.

Pockets with high wind velocities of up to 10 m/s are distributed throughout the eastern half of the country, and the western escarpment of the Rift Valley.

Africa's biggest wind farm, Ashegoda, started producing energy in October 2013, aiding efforts to diversify electricity generation from hydropower plants and help the country become a major regional exporter of energy. The €210 million Ashegoda Wind Farm was built in collaboration with French firm Vergnet SA with concessional loans from BNP Paribas and the French Development Agency (AFD). As an initial token of its commitment, the Ethiopian Government covered 9 per cent of the cost.

Ashegoda Wind Farm

The 120 MW Ashegoda wind farm, about 700 km north of Addis Ababa, has started generating electricity. It improves diversification of electricity generation, to reduce dependence on hydropower generation that is susceptible to extreme weather events. The Adama Wind Farm, which is also now operational, is about 80 km south of Addis Ababa. It produces 51 MW of electricity per year. The 153 MW Adama II wind farm project is under construction. Tables 2-5-2-7 show wind power projects which are either operational, under construction and or planned.

a. Operational wind power plant projects

- Total Installed capacity = **171 MW**
- Study level = **612 MW**

b. Wind farm plants under construction

- Total Installed capacity (MW) = **153 MW**
- Study level = **479 MW**

Table 2-5: Operational and Under Construction Wind Power Plant Projects

No	Power plants	Installed capacity MW	Study level MW
	a) Operational wind power plant projects		
1	**Ashegoda**	120	450
2	**Adama I**	51	162
	Total	171	612
	b) Wind farm plants under construction		
1	**Adama II**	153	479

c. Wind power projects under preparation for construction

- Total installed capacity (MW) = **780 MW**

Table 2-6: Wind Power Projects under Preparation for Construction

No	Power plants	Installed capacity MW	Study level MW
3	Chemoga yeda I and II	280	Feasibility study completed
4	Aysha	300	Feasibility study completed
5	Assella and Debre birhan	200	Feasibility study completed
	Total	780	

d. Wind farm sites selected

- Total capacity (MW) = **5,400 MW**

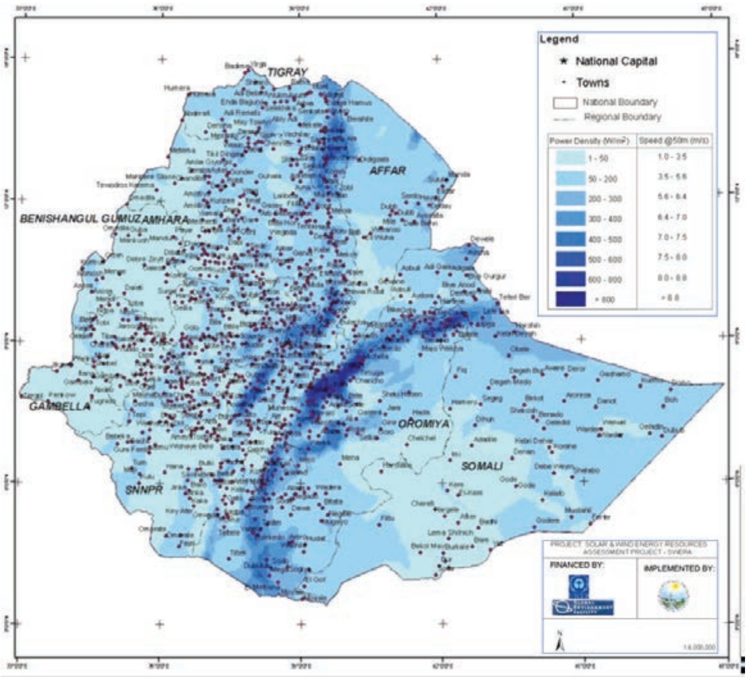
Table 2-7: Wind Farm sites Selected in Ethiopia

	Name of site	Capacity (MW)	Area (km2)	Grading preliminary selection <explain?>	Location
F1	Nazret wind farm	300	254	100	Oromiya
F2	Mek'ele South wind farm	100	77	85	Tigray
F3	Sheno wind farm	100	56	88	Oromiya
F4	Ch'ach'a wind farm	100	56	86	Amhara
F5	Phase I wind farm inlteya	100	66	95	Oromiya
F6	Sulalta wind farm	100	60	92	Oromiya
F7	Gondar West wind farm	50	49	82	Amhara
F8	Imdibir wind farm	50	47	90	SNNP
F9	Dire Dawa wind farm	50	40	91	Dire Dawa
F10	Dilla East wind farm	300	268	96	SNNP
F11	Mek'ele North wind farm	200	185	85	Tigray
F12	Debre Markos East wind farm	200	143	87	Amhara
F13	Soddo wind farm	200	160	84	SNNP
F14	Sendafa North wind farm	100	70	88	Oromiya
F15	Sendafa South wind farm	100	70	88	Oromiya
F16	Gondar North wind farm	100	65	80	Amhara
F17	Phase II wind farm inlteya	100	70	95	Oromiya
F18	Bu'i East wind farm	100	80	83	SNNP
F19	Aysha wind farm	100	60	83	Somali
F20	Phase I wind farm in Bolo	100	60	90	Oromiya
F21	Diche Oto wind farm	50	100	78	Afar
F22	Bahir Dar wind farm	50	80	82	Amhara
F23	Assela wind farm	50	71	93	Oromiya
F24	Jacho wind farm	600	330	73	SNNP
F25	Phase II wind farm in Bolo	500	300	90	Oromiya
F26	Hula wind farm	300	220	64	Oromiya
F27	Dilla West wind farm	300	230	96	SNNP
F28	Dangla wind farm	200	170	67	Amhara
F29	Debre Markos West wind farm	200	150	87	Oromiya
F30	Ambo wind farm	200	130	72	Oromiya
F31	Babile wind farm	200	130	56	Oromiya
F32	Dabat wind farm	100	61	56	Amhara
F33	Phase I wind farm in Weldiya	100	43	70	Amhara
	Total	5,400			

2.7.3.3. Wind Power Resource Assessment

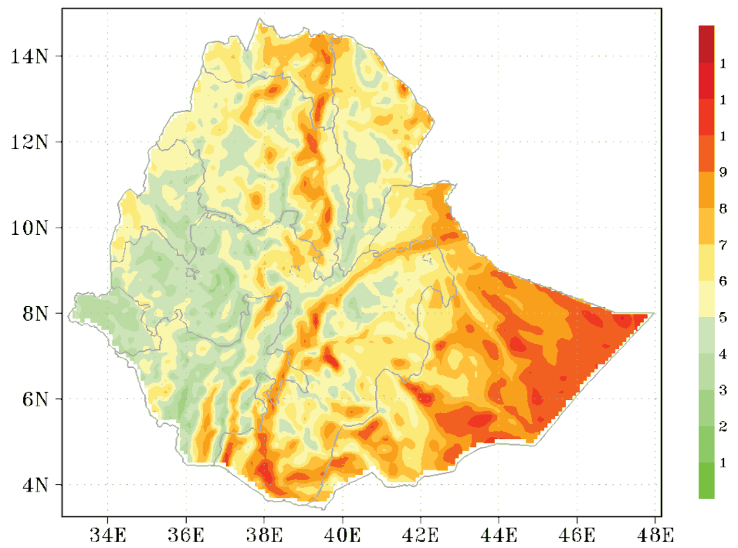
The Government of Ethiopia with the collaboration of Chinese Government has prepared a solar and wind master plan for the whole country. Figure 2-1 below shows the geographic distribution of wind resources in Ethiopia.

Figure 2-2 Geographic Distribution of Wind Resources of Ethiopia



This is very useful in identifying the gross amount and distribution of wind and solar energy resources, the construction conditions, cost and other limiting factors of wind and solar power generation projects. Based on the analysis of this master plan, it is indicated that Ethiopia has a capacity of 1,350 GW of energy from wind. Figure 2 2 below indicates the distribution of Average Wind Speed, m/s (height: 50m, 1980-2009)

Figure 2-3: Distribution of Average Wind Speed, m/s (height: 50m, 1980-2009)



2.7.3.4. Solar Power and Off-grid Electrification

Ethiopia receives solar irradiation of 5,000-7,000 Wh/m² varying between regions and seasons. This indicates great potential for the use of solar energy. According to the solar and wind master plan for the whole country conducted with the collaboration of Chinese Government, Ethiopia has an annual total solar energy reserve of 2.199 million TWh/yr. The average solar radiation is more or less uniform, the yearly average daily radiation reaching the ground is 5.26 kWh/m²/day. The values vary seasonally, from 4.55 to 5.55 kWh/m²/day and with location from 4.25 kWh/m²/day in the extreme western lowlands to 6.25 kWh/m²/day in the Adigrat area of northern Ethiopia.

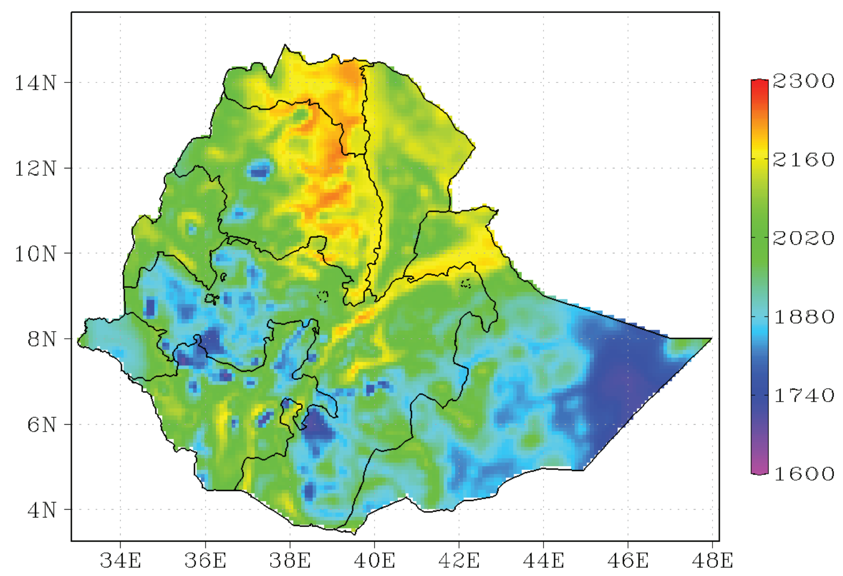
Drake and Mulugetta (1996) estimated that most parts of Ethiopia have over 3,000 hours of sunshine annually receiving solar energy of some 5.0 kWh/m²/day with the northern part of the country having an estimated annual solar energy of over 6.0kWh/m²/ day. "13 Months of Sunshine" is the slogan of the Ethiopian Tourist Commission, encapsulating the country's year-long sunny weather and the 13 months of the Ethiopian calendar.

In 2014 Ethiopian Electric Power (EEPCO) signed a memorandum of understanding with the US-based company Green Technology Africa (GTA) to generate 300 MW of solar energy, which will be linked to the national grid. GTA has agreed to deliver solar generated photovoltaic systems with total capacity of 300 MW as a turnkey project in three selected sites. This project is planned as part of GTP2 by Ministry of Water, Irrigation and Energy. Figure 2-3 below shows the distribution of average annual total solar radiation in kWh/m2/yr (1980-2009). Table 2-8 shows the solar power technologies implemented in Ethiopia.

Table 2-8: Solar Power Technologies Implemented

No	Projects	Quantity planted/ distributed	
1	**PV solar home systems**	131,976	ħ2003 – 2014
2	**Soar systems for schools, Health posts**	3,500	ħ2003 – 2014
3	**Solar coking panels and boilers distributed**	888,990	ħ2003 – 2014
4	**Solar Lanterns**	1,896,405	ħ2003 – 2014

Figure 2-4: Distribution of Average Annual Total Solar Radiation in kWh/m2/yr, (1980-2009)



The direct environmental benefits from the solar technologies disseminated include:

i. reduced GHG emissions due to the use of kerosene for lighting; and

ii. avoidance of indoor air pollution.

2.7.3.5. Geothermal Energy

According to EEPCO, geothermal energy development is second in priority to hydropower. Feasibility studies have been carried out since 1969 and Ethiopia's total geothermal energy capacity is estimated to be 7,000-10,000 MW. However, the initial investment for a geothermal energy plant is huge and also the risk is relatively high (the excavation of expensive wells frequently fails). Therefore, no big plant has been built since the first pilot plant at Alto Langano was established in 1998. The identified potential areas for geothermal energy plants are:

a. lakeside areas, such as Alto-Langano, Corbetti and Abaya;

b. areas in South Afar, such as Tulu-Moye, Gedemsa, and Dofan, and

c. areas in North Afar, such as Tendaho and Dallol.

The pilot plant at Alto-Langano is located at 200 km south of Addis Ababa. Two generation units have a capacity of 7.28 MW in total, about 3.5 MW for each. After a period of malfunction caused by lack of maintenance skills, a feasibility study for the expansion of the Aluto Langano plantl power was completed in 2010 with the assistance from the Japan International Cooperation Agency (JICA). The Government is now working on expansion of the Aluto-Langano geothermal field to 70 MWe. The World Bank, African Development Bank and JICA are involved in financing expansion of this geothermal field. Tables 2-9 and 2-10 show the geothermal projects that are under different stages of development, either operational, under construction and or planned

a. Existing geothermal power plant projects

- Total installed capacity = **75 MW**
- Study level = **591 MW**

Table 2-9: Existing Geothermal Power Plant Projects

No	Power plants	Installed capacity MW	Study level
1	Aluto Langano	75	591

b. Candidate Geothermal power plants for investment

- Total installed capacity = **440 MW**

Table 2-10: Candidate Geothermal Power Plants for Investment

No	Power plants	Installed capacity MW	Study level
1	Aluto Langano	75	Under feasibility study
2	Tendaho	100	Under feasibility study
3	Corbit	75	Under feasibility study
4	Abaya	100	Under feasibility study
5	Tulu Moye	40	Under feasibility study
6	Dofan	50	Under feasibility study
	Total	**440**	

Future Plans for Geothermal

As part of its plans to mix renewable energy sources in generating electricity and thus attain resilience against extreme weather events, Ethiopia has started constructing a geothermal electric power generating capacity of 1,000 MW in the Rift Valley. The first phase will be completed in 2018. The second phase will be completed in 2021. In addition, a private firm has entered into the business for development of 1000 W from geothermal resources.

2.7.3.6. Thermal Energy power plants

a. Bamza thermal power project

The project is targeted to generate 120.5 MW of electric power by utilizing wood cleared from the ground as inputs. This project is financed by the Government of Ethiopia and constructed by Ethiopia Metal and Engineering Corporation (METEC). Currently geological investigation and site clearing work are being carried out.

b. Awash Melka Sedi thermal power project

This project is found in Oromia regional state in Amibara *wereda* near Awash Arba, about 200km from Addis Ababa. In order to begin the main construction activities of the project, site clearing activities are being carried out, including clearing of the *Prosopis juliflora,* an exotic weed plant found around Afar and Oromia regions. Upon the completion of work on the project, it could generate 137.5 MW of electric power.

2.7.3.7. Bio energy (Waste to energy)

The Repi waste to energy project is designed to generate 50 MW of electric power by utilizing waste materials collected from Addis Ababa. Besides its contribution to environmental protection and development through emissions reduction and enhancing environmental sanitation, the project will create many jobs. It is also understood that 65 per cent of the waste that has hitherto been polluting the environment will be used to produce energy. An agreement on the supply of 1,000 tons of dry waste that can be used to generate electricity has been reached between the electric power company and the Addis Ababa city administration council. Cambridge Industrial, a British company, has carried out the project while Ranball, a Danish company, is conducting consultancy services. The project's construction started in 2013 and was completed in 2015. The direct environmental benefits will include the following.

i. The Repi Land Fill project is expected to flare nearly 46,494 tCO_2e of methane a year over a 10-year period.

ii. Support to the concept of green building is being integrated in urban sector planning.

iii. Increasing the electricity made available to the urban population for household use.

iv. Mainstreaming of waste management strategies.

2.7.3.8. Bio-ethanol

Bio-ethanol is blended with benzene and used for motor vehicles and other engines working with benzene. The national production of ethanol has reached 20,500m^3 per annum, with two new factories to add to production soon. It is expected that by the end of 2015 national ethanol production capacity will reach 181.6 million litres/yr. The blending started at 5 per cent, is currently at 10 per cent, and is targeted to reach 20-25 per cent. Moreover, without blending, ethanol can be used for cooking and house lighting as well. Table 2-11 shows the status of ethanol blending in the country.

Table 2-11: Status of Bio-Ethanol Blending in Ethiopia

No.	Year	Ethanol Production (litres)	Blended Ethanol (litres)	Saved Foreign Currency (US$ million)
1.	2009	5,878,578	6,790,000	5.5
2.	2010	7,116,585	3,400,000	1.6
3.	2011	7, 131,509	9,800,000	7.0
4.	2012	13,811,953	10, 650,000	9.23
5.	2013	6,535,396	8,630,000	7.6
6.	2014	9,850,000	7,550,683	7.6
	Total	**50,324,021**	**46,820,683**	**38.53**

Source: FDRE, 2014.

2.7.3.9. Biogas

In the first four years of the Growth and Transformation Plan period, 9,139 biogas plants were constructed, 35 per cent of the 26,000 biogas plants targeted for the full five years of the plan. It produces 75,387 MWh/yr and net power installation of 21,000 kW. In the second phase of the biogas programme, to be implemented from January 2014 to January 2017, it is planned that 20,000 biogas plants will be built with an outlay of €25.5 million secured from international donors and government sources. The direct environmental benefits include the following.

i. It is estimated that a total of 5,336 ha of forest land will be saved from deforestation.

ii. There will savings of 7,277 tons of agricultural residues, 5,822 tons of charcoal, 27,162 tons of fuelwood and 485 tons of imported fossil fuels, 40,315 people will be protected from indoor air pollution, the workload of women and children will be reduced.

2.7.3.10. Energy Saving Technologies

Table 2-12 shows the distribution of improved wood saving stoves over the first four years of the GTP with the following direct environmental benefits.

- It is estimated that 97,000 ha of forest land was saved.
- GHG emissions were reduced by a sizeable 7 Mt CO_2e. (N.B: This figure doesn't include the 9.41 Mt CO_2e disseminated before the GTP period).

Table 2-12: Distribution of Improved Wood Saving Stoves

		Distribution of Improved Wood Saving Stoves	
	Years	Planned	Achieved
1	2011	1,500,000	1,420,515
2	2012	1,785,000	1,488,071
3	2013	1,850,000	2,004,751
4	2014	1,850,000	2,004,751
	Total	**7,185,000**	**6,601,899**

Source: FDRE, 2014.

2.7.4 Greening the transport sector

The Addis Ababa light railway, which runs for 37 km and has 41stations, was completed in January 2015 and began trial operations on 1 Feb 2015. Waiting times at stations will not exceed 15 minutes and it is expected to transport 60,000 people per hour. In addition, the construction of the 5,000 km regional electric rail is under way. Also a project for piloting 12 battery charged electric cars in four major towns and private sector cars is under way, and applications for private investment in the assembly of electric cars are being processed.

The light rail project's direct environmental benefit include the avoidance of 1.8 Mt CO_2e of GHG emissions by 2030, while the first phase of the regional train network, involving three routes, will lead to the avoidance of 5.3 Mt CO_2e of emissions by 2030. In general, the total avoided emissions by 2030 would amount to 54 Mt CO_2

Addis Ababa's Electric Light Railway

2.7.5. Agriculture Sector Resilience to Climate Change

The main focuses for promoting climate resilient agriculture are:

i. Actions involving community participation;

ii. The expansion of irrigated agriculture; and

iii. Increasing agricultural productivity.

Increasing agricultural productivity in agricultural is to be achieved through the rehabilitation of degraded land, watershed management; and enhancing soil fertility. The expansion of irrigated agriculture is designed to ensure water availability in times of drought; and to enable food to be produced two or three times a year. Irrigated agriculture was to increase from less than 300,000 ha at the beginning of the GTP to more than 2.5 million ha under small farmer management at the end of the plan period. As a result productivity is expected to double, to meet its requirement of forming the base for industrialization. The following actions are among those been carried out during the GTP I period.

i. 19,807 community-based watersheds have been identified and a management plan prepared (101 per cent of the target).

ii. A 8,519,000 ha area has been enclosed (85 per cent of the target).

iii. 16,285,000 ha of soil and water conservation works have been constructed (465 per cent of the target).

iv. Activities that increase soil fertility have been undertaken on 1,926,000 ha, an increase of 115 on the 894,000 ha on which such activities were undertaken in the initial period.

v. An additional 1,129,060 ha have been brought under small-scale irrigation compared with 853,100 ha at the beginning of the plan period.

vi. Forest cover has increased by 12,296,000 ha from 13,000,000 ha at the beginning of the plan period, bringing the percentage of the land area covered by forest from 5 per cent in 2010 to 13-15 per cent in 2013.

2.7.5.1. Community participation actions

On average, 26 million people have participated annually in watershed rehabilitation, water, and soil conservation activities for an average of 30 days/yr. During period of the GTP I a total of 1,390,915,860 people participated in these activities. This can be expressed in monetary terms by assuming the wage for daily labour which brings the total cost to Br27.8 billion (about US$1.4 billion). The photograph below shows community participation in watershed rehabilitation.

2.7.5.2. Major initiatives in the agriculture sector

The following initiatives are being implemented under the CRGE with a focus on improving climate change resilience and natural resource management.

i. *Ethiopia's Agriculture Sector Policy and Investment Framework (PIF)* focuses on supporting resilience work at farm level by enhancing Natural Resource Management and Disaster Risk Management.

ii. *The Agricultural Growth Project* provides clear resilience benefits through addressing nutrient, pest/diseases and land management; provision of improved seed, breed and planting material; community level soil and water conservation measures (bunding, gully protection, check dams, water harvesting and watershed management).

iii. *Disaster Risk Management Strategic Programme and Investment Framework (DRM-SPIF),* gives emphasis to risk management, prevention and mitigation, and early warning and planning elements of preparedness. The SPIF also promotes the scale up of classic adaptation options, including community early warning systems, contingency and response planning.

iv. *Productive Safety Net Programme* sets out a range of activities that support improved resilience. Subsequent phases of the programme also incorporate a systematic disaster risk management and climate adaptability agenda into the social safety net programme of Ethiopia.

v. *The Strategic Investment Framework for Sustainable Land Management (SLM),* has a number of components with resilient benefits including promoting locally appropriate SLM activities, such as soil management practices, harvesting and storage of water, and increasing carbon sequestration. The framework also has components relating to the provision of capacity building and micro-finance support to improve resilience.

2.7.6. State Industry Initiatives

In the industry sector, there are several resource use efficiency and cleaner production initiatives that aim to reduce pollution and at the same time increase productivity.

2.8. Challenges Encountered in the Implementation of CRGE and the Way Forward

Community Participation in Watershed Rehabilitation

Capacity limitations of finance, technology and technical know-how; limited awareness of the CRGE, particularly at the grassroots level, limited communications infrastructure at lower administrative levels hampering the exchange of information, and weak information management and infrastructure generally are identified as major challenges in the implementation of the CRGE.

As a result, strengthening institutional coordination mechanisms at all levels, soliciting support from domestic, bilateral and international climate change funding sources for CRGE implementation, capacity-building at all levels, conducting continuous awareness creation at different levels and improving information management capacity and infrastructure are preconditions for the effective implementation of the CRGE.

2.9. Ethiopia's Intended Nationally Determined Contributions (INDCs)

Intended Nationally Determined Contributions (INDCs) to the UNFCCC are a purely country driven process (bottom-up process). Ethiopia is committed to meet its information communication requirements as per paragraph 14 of the Lima Declaration of 2014, i.e. in a manner that facilitates clarity, transparency, and understanding.

The Ethiopia's approach to its INDCs has had six milestones.

- **Step 1:** The general concept note on Ethiopia's INDC before the Lima COP.
- **Step 2:** Information/data collection based on:
  - i. Information from the sectors on their GTP I performance
  - ii. Information from the sectors on their CRGE performance

   iii. Intended climate actions (CRGE) mainstreamed, i.e. the proposed engagement of sectors during GTP II.

- **Step 3:** Generating options on what Ethiopia's INDC should look like, taking into account a number of aspects:
   i. Option 1 (short-period)
   ii. Option 2 (long-period).
- **Step 4:** Initial meetings of sectors, the MEF and the technical team were conducted through workshops.
- **Step 5:** Identifying types of contributions. In this case Ethiopia was able to present different initiatives for future action as set out in the CRGE, which has 60 umbrella initiatives. Ethiopia also showed its commitment by applying domestically policy instruments that promote GHG emission reduction, such as the removal of the fuel subsidy.
- **Step 6:** Drafting the Ethiopian INDC–a preliminary draft has already been submitted, whose main components cover both mitigation and adaptation activities that incorporate high levels of fairness, equity and transparency.

CHAPTER THREE:

NATIONAL INVENTORY OF GREENHOUSE GASES

3.1. Introduction

This chapter highlights the country's GHG emissions by sources and removals by sinks, which will help Ethiopia in the formulation of strategies for green growth. The methodology and procedures used in preparing this inventory were drawn from the IPCC's 1996 Guidelines for National Greenhouse Gas Inventories, its Good Practice Guidance (GPG) for 2000 and 2003, and its 2006 guidelines. The base year for this inventory process was 1994 and activity data for all the years up to 2013 were collected and applied in the development of the inventory.

The sectors covered are energy, industrial processes and product use (IPPU), agriculture, forestry and land use (AFOLU) and waste. Also included in this reporting are the emissions associated with the memo Items set forth in the Convention. The chapter also contains a preliminary overview of the uncertainties associated with the results and identifies gaps that need to be addressed in order to improve the accuracy of Ethiopia's National GHG Inventory.

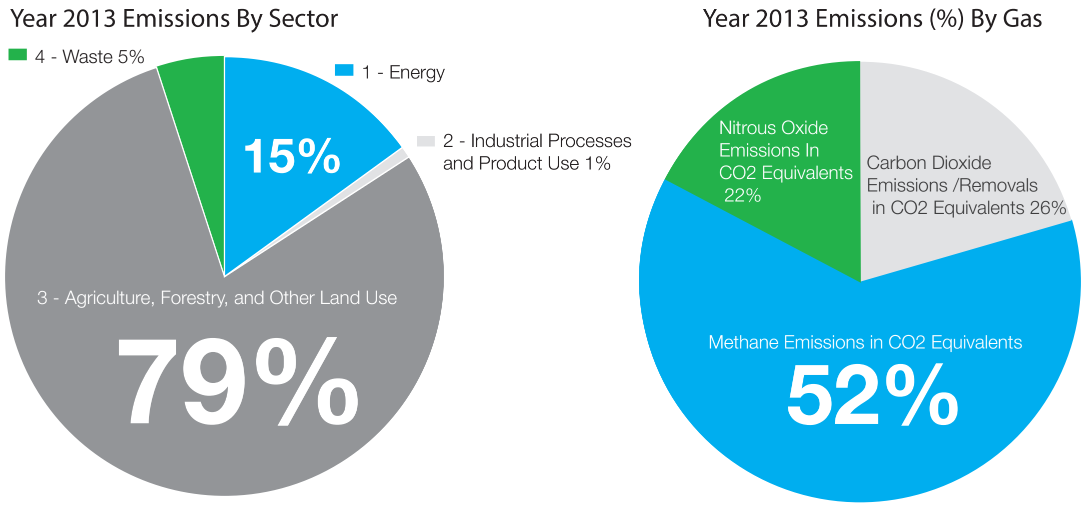
This GHG Inventory is meant to help Ethiopia to place its own emissions within the larger picture of global emissions; and to provide a baseline with which the country's future emissions can be compared. It also provides a basis for the formulation of national greenhouse gas mitigation policies and strategies. The compilation of the GHG inventory has the additional benefit of improving national statistics and increasing awareness about climate change among stakeholders as well as spreading knowledge of the carbon trajectory.

The objective of developing the GHG inventory was to identify the principal sources/sinks, to establish quantitative estimates of GHG emissions from different sectors, and to enhance decision-making by focusing on emissions/removals within the larger context of the global contribution to the accumulation GHG emissions. Emissions and removals of seven gases in the sectors under discussion were addressed: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_X), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulfur dioxide (SO_2).

3.1.2. GHG Inventory Overview

Carbon dioxide is naturally present in the atmosphere as part of the earth's carbon cycle (the natural circulation of carbon between the atmosphere, soil, plants and animals). Human activities are altering the carbon cycle both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase of GHG concentrations that has occurred in the atmosphere since the industrial revolution. Carbon dioxide (CO_2) and methane (CH_4) are the main greenhouse gas emitted through human activities in Ethiopia. In 2013, CH_4 and CO_2 accounted for about 26 per cent of all greenhouse gas emissions from human activities in the country. The pie charts in Figure 3-1 show the emissions by sector and by gas emitted in 2013. By sector, 79 per cent of all emissions were from the AFOLU sector while energy and IPPU contributed 15 per cent and 1 per cent respectively and the waste sector 5 per cent.

Figure 3-1: Emissions by Sector and by Type of Gas, 2013 (%)



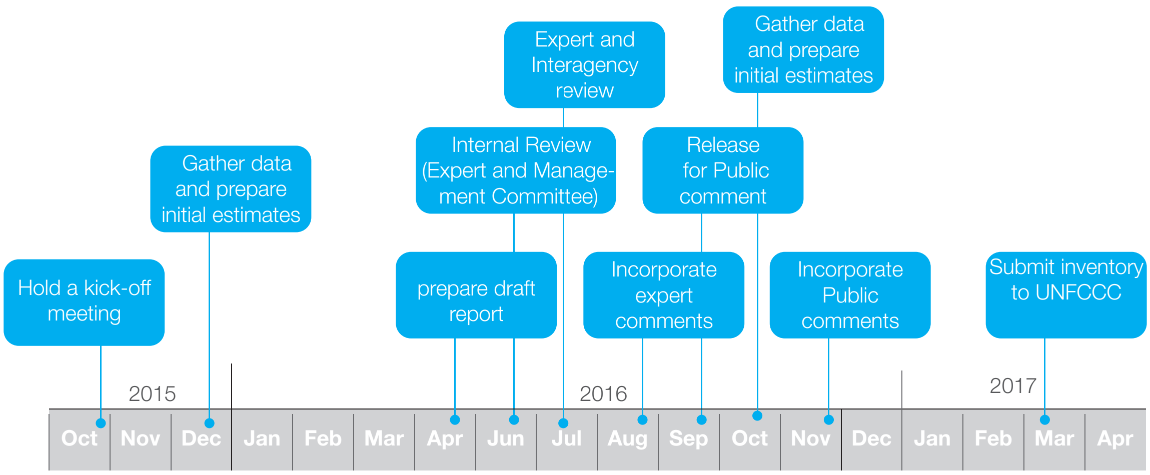
3.2. Data Collection and Institutional Arrangements

Ethiopia has made great progress in building the capacity of the National GHG Inventory sector teams on data requirements, collection, archiving and general procedures for operating a national GHG Inventory management system. It is envisaged that the country will continue to improve and update its institutional arrangements to include strategic data providing organizations, government lead agencies, NGOs and private entities. The country has also put in place the basic infrastructure for online data collection, entry and access by the GHG Inventory sector teams. This is aimed at improving the preparation of the country's future National Communications and Biennial Update Reports to the UNFCCC.

The Ministry of Environment and Forest (MEF) is the designated institution for coordinating the country's reporting to the UNFCCC, including the National Communications, the National GHG Inventories and Biennial Update Reports. The Ministry, therefore, supports, oversees and coordinates the collection, analysis and archiving of information and data for the estimates on GHG emissions and removals. The Director of the State of the Environment and Reporting Directorate in the MEF is the national coordinator of the GHG Inventory development process and provides the necessary administrative and logistical support to ensure efficient and sustainable GHG Inventory management system and National Communication processes. The national coordinator is responsible for initiating and coordinating the processes of data collection, developing a national schedule of activities, and communicating with sector leads, individual stakeholders and organizations during the collection and compilation of activity data. Further, the task of analysing the technical and scientific issues relating to the different thematic areas of the National Communication, including the compilation of the GHG Inventory, are vested in the National Coordinator and the Assistant Technical Coordinator. Figure 3-2 shows the proposed schedule for tracking annual inventory development, updates and National Communications to the UNFCCC, while the institutional set-up for Ethiopia's National GHG Inventory Management System is shown in Figure 3-3.

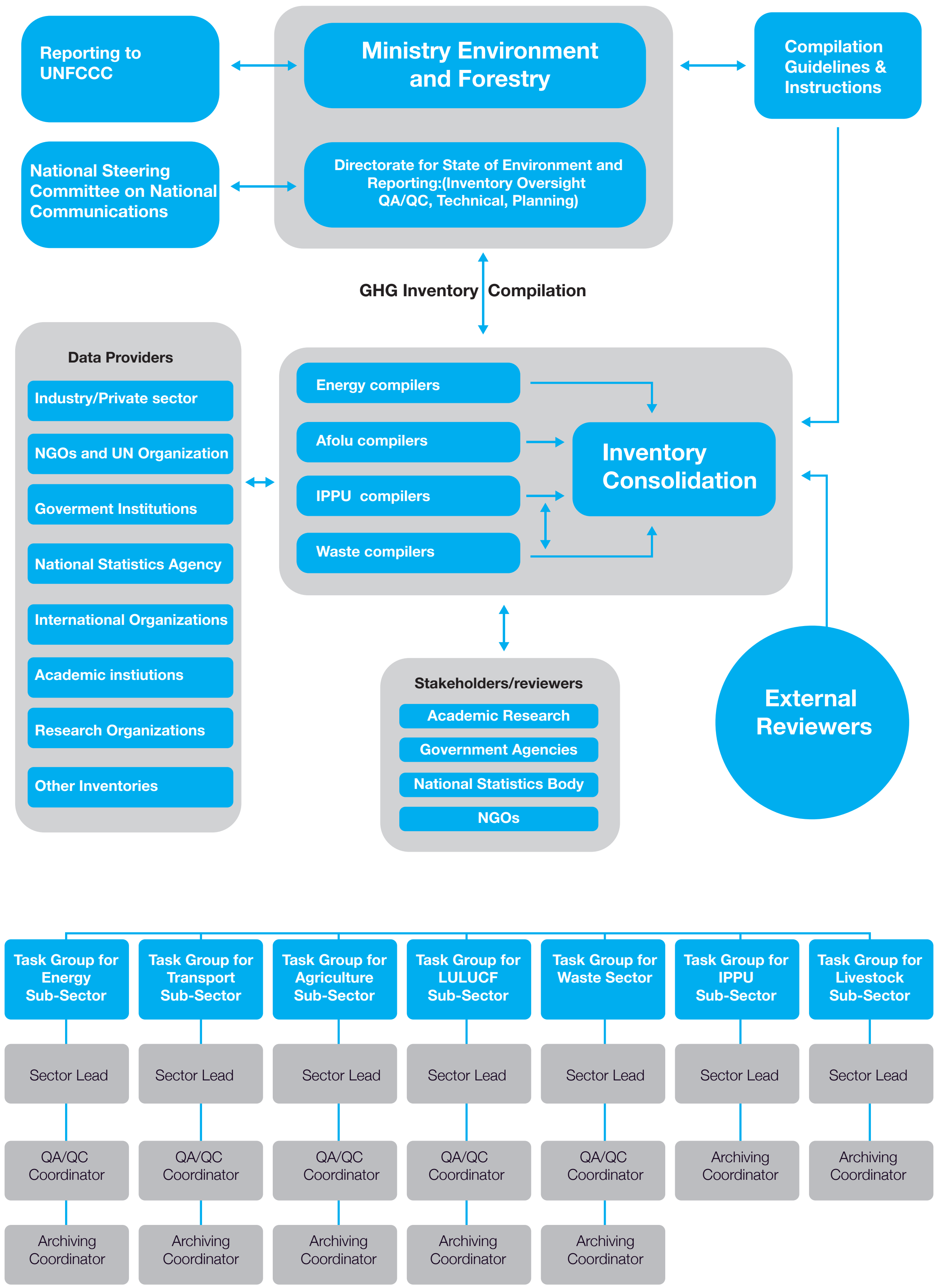
The GHG inventory team comprises designated representatives from institutions and government lead agencies covering all the four IPCC GHG Inventory sectors; namely, agriculture, forestry, and land use (AFOLU); energy; industrial processes and product use (IPPU); and waste. The institutional arrangements can be improved significantly if the arrangements for data collection are formalized and mainstreamed within the key sectoral institutions. Further, the process for data collection needs to be integrated into annual statistical data collection and updates. Capacity-building needs to be addressed so as to harmonize and/or standardize formats and units of measurement and to reduce the time taken for data processing and improve quality. Frequent updates of the National Inventory will enable the country to obtain information on short-term changes and medium-term trends for each inventory sector and emission or removal category.

Figure 3-2: Proposed Schedule for Tracking Annual Inventory Development, Updates and NCs to the UNFCCC



Improved Livestock Production Practices

Figure 3-3: Institutional Arrangements for GHG Inventory Management and National Communications



3.3. General Methodology and Data Sources

Box 3.1 GWPs

Global Warming Potentials (AR4 GWPs)

The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas.

Greenhouse gases in the atmosphere can contribute to climate change both directly and indirectly. Direct effects occur when the gas itself absorb radiations. Indirect forcing occurs when chemical transformations of the substance produce other greenhouse gases, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the earth (e.g. affect cloud formation or albedo).

The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas (CO2) (IPCC, 2013).

GWP values from the IPCC Fourth Assessment Report (AR4) (IPCC, 2007) are used in this report.

Box 3.2 Definitions

Completeness

This requires that the inventory be complete in terms of gases, categories and territorial coverage

Accuracy

This requires the inventory to be constructed with as much detail as possible to ensure results are accurate and prevent over- or underestimations of emissions and/or removals.

Transparency

This requires the inventory to be based on publicly available activity data and to make assumptions explicit.

Comparability

This requires that internationally accepted methodologies should be followed.

Consistency

This requires the application of the same methodological approach, including the same emission factors and activity data over the years indicated.

As agreed by the Parties to the Convention (Decision 17/CP.8 of January 2003), Non-Annex I country parties are required to draw up annual inventories using the IPCC methodology and the 2000 and 2003 Good Practice Guidance (GPG) and the revised guidelines of 2006. Within this framework, GHG sources and sinks are reported for each sector, category and subcategory. The six sectors considered are; energy; industrial processes; solvents and other product use; agriculture; land use, land use change and forestry (LULUCF); and waste. These categories are consolidated into four sectors, namely; energy, industrial processes and product use (IPPU), agriculture, forestry and land use (AFOLU) and waste. The gases considered for the compilation of the inventory are, first, the direct GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6); and secondly, the indirect GHGs carbon monoxide (CO), nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOCs), and sulfur oxides (SO_X) The calculations of GHG emissions were carried out using activity data for each sector as provided by the line ministries, CSA, FAO, the Ethiopia Revenue and Customs Authority and from literature reviews. The activity data and emission factors were assessed for completeness, accuracy, transparency, consistency and comparability, in accordance with the IPCC guidelines on basic quality principles.

The default values listed in the IPCC documents were selected to accord with national circumstances and used to quantify emissions and or removals. The country's emissions and removals were quantified using the methods provided by the IPCC for the preparation of national inventories. The following documents and guidelines were used to build the National GHG Inventory for Ethiopia:

i. the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997);

ii. the IPCC's Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000);

iii. the IPCC's Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003); and

iv. the IPCC's 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

3.3.1. Important Greenhouse Gases and Precursor Emissions

3.3.1.1. Methane (CH_4)

CH_4 is primarily produced through anaerobic decomposition of organic matter in biological systems. Agricultural processes such as wetland rice cultivation, enteric fermentation in animals and the decomposition of animal wastes emit CH4, as does the decomposition of municipal solid wastes. CH_4 is also emitted during the distribution of natural gas and petroleum, and is released as a by-product of coal mining and incomplete fossil fuel combustion. Atmospheric concentrations of CH_4 have increased by about 152 per cent since 1750, from a pre-industrial value of about 700 ppb to 1,762–1,893 ppb in 2012.[9] Although the rate of increase decreased to near zero in the early 2000s, it has recently increased again to about 5 ppb/year. The IPCC has estimated that slightly more than half of the current CH_4 flux to the atmosphere is anthropogenic, from human activities such as agriculture, fossil fuel use, and waste disposal (IPCC, 2007).

CH_4 is primarily removed from the atmosphere through a reaction with the hydroxyl radical (OH) and is ultimately converted to CO_2. Minor removal processes also include reaction with chlorine in the marine boundary layer, a soil sink, and stratospheric reactions. Increasing emissions of CH_4 reduce the concentration of OH, a feedback that increases the atmospheric lifetime of CH_4 (IPCC, 2013). Incomplete combustion of hydrocarbons in fuels results in methane emissions. The amount of CH_4 emitted is also a function of the methane content of the fuel, the amount of hydrocarbons unburnt in the engine, the engine type, and any post-combustion controls (IPCC, 1997). CH_4 emissions from fuel combustion are relatively small on a national scale and the uncertainty is high.

3.3.1.2. Nitrous Oxides (N_2O)

Anthropogenic sources of N_2O emissions include agricultural soils, especially production of nitrogen-fixing crops and forages, the use of synthetic and manure fertilizers, and manure deposition by livestock; fossil fuel combustion, especially from mobile combustion; adipic (nylon) and nitric acid production; wastewater treatment and waste incineration; and biomass burning. The atmospheric concentration of N_2O has increased by 20 per cent since 1750, from a pre-industrial value of about 270 ppb to 324-326 ppb in 2012,[10] a concentration that has not been exceeded during the last thousand years. N_2O is primarily removed from the atmosphere by the photolytic action of sunlight in the stratosphere (IPCC 2007).

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9 The range is the annual arithmetic averages from a mid-latitude Northern Hemisphere site and a mid-latitude Southern Hemisphere site for October 2012-September 2013 (Blasing, 2014).

10 The range is the annual arithmetic averages from a mid-latitude Northern-Hemisphere site and a mid-latitude Southern-Hemisphere site for October 2012 through September 2013 (Blasing, 2014).

3.3.1.3. Nitrogen Oxides (NOx)

Most of the emissions of NO_x from fuel combustion activities are from mobile sources. Even though it is not a GHG, NO_x plays a role in the formation of tropospheric ozone, O_3, as well as in the formation of acid rain.

3.3.1.4. Carbon Monoxide (CO)

Carbon monoxide is created when carbon-containing fuels are burned incompletely. Carbon monoxide has an indirect radiative forcing effect by elevating concentrations of CH_4 and tropospheric ozone[11] through chemical reactions with other atmospheric constituents (e.g. the hydroxyl radical, OH) that would otherwise assist in destroying CH_4 and tropospheric ozone. Through natural processes in the atmosphere, it is eventually oxidized to CO_2. Carbon monoxide concentrations are both short-lived in the atmosphere and spatially variable. The release of CO from the energy sector comes from the incomplete combustion of fuel in motor vehicles.

3.3.1.5. Non-Methane Volatile Organic Compounds (NMVOCs)

Non-CH_4 volatile organic compounds include substances such as propane, butane and ethane. These compounds participate, along with NOx, in the formation of tropospheric ozone and other photochemical oxidants. NMVOCs are emitted primarily from transportation and industrial processes, as well as biomass burning and non-industrial consumption of organic solvents. Concentrations of NMVOCs tend to be both short-lived in the atmosphere and spatially variable. NMVOCs are generated from transportation and residential combustion of biomass fuels. Estimation of the non-CO_2 emissions is done by multiplying the fuel consumption data (TJ) by the respective emission factors for each fuel (kg/TJ). The emission factors required for computation of emissions of various GHGs are extracted from the IPCC Guidelines as default factors and the EMEP/CORINAIR Emission Inventory Guidebook, 2007.

3.4. The Energy Sector Methodology

This section describes the methods, activity data, emission factors and conversion factors that were used to develop the national inventory for the energy sector. The Revised 1996 IPCC Guidelines were used principally as the source for the methods and default values applied. Additional methods or emission factors from IPCC good practice guidance and the 2006 guidelines were also used to improve the GHG estimates.

Energy sector activities in Ethiopia are largely driven by the combustion of fossil fuels used to produce mechanical energy for generating electricity and energy for transportation. Emissions arise from these activities by combustion and as fugitive emissions, or escape without combustion. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the GHGs released in the combustion of fuels. Also released in the process are the GHG pre-cursors carbon monoxide (CO), nitrogen oxides (NOx), and non-methane volatile organic compounds (NMVOCs). There are two ways to estimate CO_2 emissions from fuel combustion: the top-down or reference approach, and the bottom-up or sectoral approach. Both top-down and bottom-up analyses were carried out for

11 The ozone layer is the part of the stratosphere from 19 km up to 48 km where the concentration of ozone reaches up to 10 parts per million. The stratosphere is the layer from the troposphere up to roughly 50 km. In the lower regions the temperature is nearly constant but in the upper layer the temperature increases rapidly because of sunlight absorption by the ozone layer.

comparison and ideally there was not much of a difference in the emission calculations using the two methods.

3.4.1 Reference or Top-Down Approach

This approach considers the primary level of energy supply and distribution. This approach enables calculations of CO_2 emissions by considering the overall national inventory of fuel supply. The basic data requirement is an overall inventory of the national fuel supply which includes information on fuel quantities for each fuel type utilized in the following activities:

i. production;

ii. imports;

iii. exports;

iv. international bunkers, or the amount of fuel used for international aviation and marine transport; and

v. stock change or the variations in the quantity of fuel in stock.

Fuels that are exported and or fuels used for international bunkers (i.e. aviation) are subtracted from the overall apparent consumption and hence are not included in the national GHG emissions inventory. CO_2 emissions from international bunkers, nonetheless, are still computed as a separate memo item as recommended by the IPCC guidelines.

a. Calculating the Apparent Fuel Composition

The fuel type data on fuel production, import, export, transport through international bunkers and stock change are used (in kilotons of oil equivalent or gigagrames (Gg)). The data were provided by the Ministry of Water, Irrigation and Energy, and the Ministry of Transport and Communication.

Apparent Consumption = Production + Imports – Exports – International bunkers – Stock Change

3.4.2. The Sectoral or Bottom-up Approach

This approach involves looking at the actual consumption of the specific subsectors. The subsectors are the energy industries (power generation or energy production); transportation; manufacturing industries and construction; residential; commercial/institutional, and agriculture/forestry; and other non-specified stationary or mobile. This methodology is basically the same as in the reference approach but it is more detailed in the sense that it is applied for each specific end-user category.

This approach identifies the specific sectoral consumers of fuel, including major emitters of energy-related GHGs, and thus provides a more detailed inventory of the CO_2 emissions from fuel combustion. Compared with the reference approach, however, it requires more detailed data and is more computation-intensive. Also, the estimated CO_2 emissions may be underestimated since this approach relies heavily on data reported by fuel end-users, which may not always be complete. This approach faces perennial problems of incompleteness of data submitted by end- users due to recording errors and biases in addition to data collection challenges.

a. Calculating Apparent Fuel Consumption for Each Fuel Type

In order to calculate the emissions from fuel consumption, the following are the parameters required:

i. the fuel type;

ii. its consumption figures for every sub-category; and

iii. the carbon emission factors and conversion factors extracted for the fuel type are subdivided into CO2 and non-CO2 categories. The Tier 1 approach was used to compute GHG emissions for this inventory where default emission factors were used to estimate emissions since there are no country specific emissions data. The inventory compiler has to state the activity data very clearly as it is advisable to align it with the IPCC inventory software to facilitate data entry in the system.

The GHG emissions from the stationary combustion are calculated using equation 2.1, from volume 2 of the 2006 IPCC guidelines.

Emissions GHG,Fuel =Fuel Consumption Fuel*Emissions GHG,Fuel

Where

- Emissions $_{GHG,\ fuel}$ = emissions of a given GHG by type of fuel (kg GHG)
- Fuel Consumption $_{fuel}$ = amount of fuel combusted (TJ)
- Emission Factor $_{GHG,\ fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ).

The CO_2 emission factors mainly depend on the carbon content of the fuel. Emission factors for CO_2 are in units of kg CO_2/TJ on a net calorific value basis and reflect the carbon content of the fuel and the assumption that the carbon oxidation factor is 1. Emission factors for CH_4 and N_2O for different source categories differ due to differences in combustion technologies applied in the different source categories. The default factors presented for Tier 1 apply to technologies without emission controls.

Apart from CO_2. non- CO_2 emissions are emitted during fuel combustion. When coal, gasoline, diesel, wood/wood-waste, charcoal and other biomass fuels are burnt, the following non-CO_2 gases are emitted: methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC).

3.4.3. Emission and Conversion Factors

Table 3-1 shows a summary of carbon emission factors and conversions factors used in the estimation of emissions from the energy sector.

Table 3-1: Calorific Conversions and Carbon Emission Factors by Fuel

Fuel	Calorific Value (TJ/1,000 tons)	Carbon Emission Factor (tC/TJ)
Crude Oil	42.08a	20.15
Gasoline	44.8	18.9
Jet Kerosene	44.59	19.5
Kerosene	44.75	19.6
Diesel Oil	43.33	20.2
Residual Fuel Oil	40.19	21.1
LPG	47.31	17.2
Bitumen	40.19	22
Lubricants	40.19	20
Refinery Feedstocks	44.8	20
Other Oil	40.19	20
Sub-bituminous Coal	25.75	26.2
Solid Biomass	22.46b	29.9
Fuelwood	19.2	29.9
Charcoal	21.1	29.9
Agricultural Residues	15.4	29.9

[a] Source: IPCC, 2000, Table 2.4. [b] Source: IPCC, 1996, Energy Reference Manual, Tables 1.1 and 1.3.

The conversion coefficients for the fraction of carbon oxidized when different fuels are combusted are presented in Table 12.

Table 3-2: Emission Coefficients Fraction of Carbon Oxidized[a]

Fuel	Fraction of Carbon Oxidised
Coal	0.98
Oil and Oil Products	0.99
Gas (including LPG)	0.995
Biomass	0.98

[a] Source: IPCC, 1996, Energy Reference Manual, Table 1.6.

The emission coefficients for non-CO_2 greenhouse gases are presented in Tables 3-3 - 3-7. The emission coefficients are found in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Energy Reference Manual.

Table 3-3: Methane Emission Factors for Selected Energy Sectors (Kg/TJ)

Sector		Coal	Diesel / Kerosene	Gasoline	Wood	Charcoal	Other Biomass
Energy Industries		1	3	3	30	200	30
Manufacturing Industries and Construction		10	2	2	30	200	30
Transport	Aviation		0.5	0.5			
	Road		5	20			
	Railways		5				
	Navigation		5				
Commercial / Institutional		10	10	10	300	200	300

Residential		300	10	10	300	200	300
Agriculture / Forestry / Fishing	Stationary		5	5			
	Mobile		5	5			

Source: IPCC, 1997.

Table 3-4: Nitrous Oxide Emission Factors for Selected Energy Sectors (Kg/TJ)

Sector		Coal	Diesel / Kerosene	Gasoline	Wood	Charcoal	Other Biomass
Energy Industries		1.4	0.6	0.6	4	4	4
Manufacturing Industries and Construction		1.4	0.6	0.6	4	4	4
Transport	Aviation		0.6	0.6			
	Road		0.6	0.6			
	Railways		0.6				
	Navigation		0.6				
Commercial / Institutional		1.4	0.6	0.6	4	1	4
Residential		1.4	0.6	0.6	4	1	4
Agriculture / Forestry / Fishing	Stationary		0.6	0.6	4	1	4
	Mobile		0.6	0.6			

Source: IPCC, 1997.

Table 3-5: Nitrogen Oxides Emission Factors for Selected Energy Sectors (Kg/TJ)

Sector		Coal	Diesel / Kerosene	Gasoline	Wood	Charcoal	Other Biomass
Energy Industries		300	200	200	100	100	100
Manufacturing Industries and Construction		300	200	200	100	100	100
Transport	Aviation		300	300			
	Road		800	600			
	Railways		1200				
	Navigation		1500				
Commercial / Institutional		100	100	100	100	100	100
Residential		100	100	100	100	100	100
Agriculture / Forestry / Fishing	Stationary		100	100	100	100	100
	Mobile		1200				

Source: IPCC, 1997.

Table 3-6: Carbon Monoxide Emission Factors for Selected Energy Sectors (Kg/TJ)

Sector	Coal	Diesel / Kerosene	Gasoline	Wood	Charcoal	Other Biomass
Energy Industries	20	15	15	1,000	1,000	1,000
Manufacturing Industries and Construction	150	10	10	1,000	4,000	1,000

Transport	**Aviation**		**100**	**100**			
	Road		1,000	8,000			
	Railways		1,000				
	Navigation		1,000				
Commercial / Institutional		2000	20	20	5,000	7,000	5,000
Residential		2000	20	20	5,000	7,000	5,000
Agriculture / Forestry / Fishing	Stationary		20	20	5,000	7,000	5,000
	Mobile		1,000				

Source: IPCC, 1997.

Table 3-7: Non-Methane Volatile Organic Compounds Emission Factors for Selected Energy Sectors (Kg/TJ)

Sector		Coal	Diesel / Kerosene	Gasoline	Wood	Charcoal	Other Biomass
Energy Industries		5	5	5	50	100	50
Manufacturing Industries and Construction		20	5	5	50	100	50
Transport	**Aviation**		59	50			
	Road		200	1500			
	Railways		200				
	Navigation		200				
Commercial / Institutional		200	5	5	600	100	600
Residential		200	5	5	600	100	600
Agriculture / Forestry / Fishing	**Stationary**		5	5	600	100	600
	Mobile		200				

Source: IPCC, 1997.

The assumptions that were made regarding the sulfur content of different fuels are presented in Table 18.

Table 3-8: Sulfur Dioxide Content for Various Fuels

Fuel	Sulfur Content (%S)
Gasoline	0.1
Jet Kerosene	0.05
Kerosene	0.05
Diesel Oil	0.05
Residual Fuel Oil	0.5
Sub-bituminous coal	0.5
Solid Biomass	0.2

Source: IPCC, 2000.

The sulfur retention in coal ash is assumed to be 5 per cent and negligible for all other fuels.

3.5. Industrial Processes and Product Use Methodology

This section provides a description of the methods, activity data, emission factors and coefficients that were used to develop the national inventory for the industrial processes and product use sector. Methods and default values are primarily from the Revised 1996 IPCC Guidelines but with the addition of some alternative methods or emission factors from IPCC good practice guidance or 2006 guidance to improve the GHG estimates. There are complete data sets for activity data between 1994 and 2013 covering cement, lime, glass, and soda ash production. The data are adjusted to develop an emissions trend for the years 1994-2013. In some cases, adjustments in emission factors or coefficients for this period are also identified.

Data collection needs to be improved to reduce uncertainties, address data gaps and improve the overall quality of the inventory, particularly with regard to potential emissions of NMVOCs from road paving and hydrofluorocarbon (HFC) releases. Road paving emissions may be estimated fairly easily if bitumen consumption by asphalt plants can be determined or if it is possible to identify the total length of roadways that are paved in a given period. HFC data must be collected through import statistics and the chemical formula for all the alternative ozone depleting substances clearly provided. Collection of new activity data for these emission sources through surveys or other means could significantly improve the quality of the inventory. There is also a need to develop agreements on the confidentiality and level of data sharing with the industrial and manufacturing associations in Ethiopia, since data on industrial processes and product use are usually held with some confidentiality.

3.5.1 Mineral Production (Cement, Lime and Soda Ash)

The main sources of emission are production processes and product use which chemically or physically transform materials. This section considers greenhouse gas emissions produced from the production of a variety of minerals which are not related to energy. The different greenhouse gases considered include CO_2, CH_4, N_2O, and PFCs. The general methodology employed to estimate emissions associated with mineral production involves the product of activity level data, e.g. the amount of material produced or consumed, and an associated emission factor per unit of consumption/production according to the following method:

$$TOTAL_{ij} = \Sigma Aj \times EF_{ij}$$

Where:

$TOTAL_{ij}$ = process emission (tons) of gas i from industrial sector j

A_j = amount of activity or production of process material in industrial sector j (tons/yr)

EF_{ij} = emission factor associated with gas i per unit of activity in industrial sector j (ton/ton)

3.5.1.1 Emission Factors

Default emission factors were drawn from the sections of Chapter 2, Volume 2 and the Reference Manual (Volume 3) of the 1996 Revised IPCC Guidelines and the updated 2006 guidelines that cover industrial processes. Table 3-9 shows the emission factors and coefficients for mineral production.

Table 3-9: Emission Factors and Coefficients for Mineral Production

Mineral	Description of Emission Factor / Coefficient	Value
Cement	Fraction of clinker in cement	0.95
	CO2 emission factor per ton of clinker produced	0.52 tCO2 /t clinker
	SO2 emission factor per ton of cement produced	0.3 kg SO2 /t cement
Lime	Stoichiometric ratio (CO2 / CaO)	0.79
	CaO content	0.85
	MgO content	0.85
Soda Ash	CO2 emission factor per ton of trona used	0.097 tCO2 /t trona
	CO2 emission factor per ton of soda ash used	138 kg CO2 /t soda ash used
Glass Production	CO2 emission factor per ton of glass (flint)	210Kg of CO2/t of glass

Sources: IPCC 1997; IPCC 2006.

3.5.1.2. Temporal Effects

Temporal effects such as changes to emission factors over time are not considered in the analysis.

3.5.1.3. Data Gaps and Potential Improvements to Inventory

It is a considered best practice to estimate CO_2 emissions using data for clinker production, but most of the available data give only tons of cement produced. Clinker production data would need to be collected from cement producers and/or their associations. In this way it would be possible to account for imports and exports of clinker and the average CaO content of the clinker. The IPCC 2006 Inventory software was applied to compile the volume of imports and exports of clinker using data from CSA. In addition, the data used on cement production were mainly obtained from CSA. It is likely that data quality would be improved if these data were collected annually by the national agency subject to strict quality control. Further, there were no records on the non-energy use of lubricants, bitumen or asphalt. Efforts should be made to collect these data.

3.5.1.4. Uncertainty

Cement emission factors estimated using Tier 1 methods are unlikely to be known more accurately than within a range of plus or minus a certain percentage (IPCC, 2000). Cement production data are likely to be accurate within ±10 per cent. Uncertainty estimates related to emission factors for lime are ±10 per cent. Expert judgement is that uncertainty in lime and soda ash production data is ±20 per cent, as reported production may only account for a portion of actual production since non-marketed intermediate lime production is generally not well accounted for or reported. The default uncertainties for glass production emission factors are 30-60 per cent

3.5.2. Use of HFCs

Partially and fully fluorinated hydrocarbons (HFCs) are not controlled by the Montreal Protocol, and as a result anthropogenic releases must be reported in the GHG inventory. Applications of HFC include:

i. refrigeration and air conditioning;

ii. fire suppression and explosion protection;

iii. aerosols;

iv. solvent cleaning;

v. foam blowing; and

vi. applications such as sterilization equipment and solvents in the manufacture of adhesives, coating and inks.

Imports of HFCs occur as bulk imports of the gas that are mainly used to recharge refrigeration and air conditioning products, and or they are imported in products themselves. It is very difficult to determine the amount of HFCs imported in the products since the data are over-aggregated due to particular sizes and brands not being specified. When the quantity of HFCs in the products is not known, emissions of HFCs can be estimated in two ways: as potential emissions using Tier 1 methodology; and as actual emissions, using Tier 2 methodologies. The potential emissions of a certain chemical are equal to the amount of virgin chemical consumed in the country minus the amount of chemical recovered for destruction or reported in the year under consideration. Actual emission estimates take into account the time lag between consumption and emission, which may be considerable in some applications, e.g. closed cell foams, refrigeration, and fire extinguishing equipment. A time lag results from the fact that a chemical is placed in a new product and then slowly leaks out over time.

Potential Emissions = Production + Imports - Exports – Destruction

The activity data used were obtained from bulk imports and exports of the HFCs or use in refrigeration and air conditioning.

3.5.2.1 Data Gaps and Potential Improvements to Inventory

The release of HFCs presents a potentially significant emission source that is inadequately accounted for in the emissions recorded in the current inventory. Data needs to be collected on imports of HFCs into Ethiopia in either bulk or product form.

3.6. Agriculture, Forestry and Land Use (AFOLU) Sector Methodology

3.6.1. Agriculture

The methods, activity data, emission factors and conversion factors for the national inventory for the agriculture sector covered in this section are primarily drawn from the Revised 1996 IPCC Guidelines with the addition of some more default/national/regional specific methods, activity data or emission factors to improve the GHG emission estimates.

The primary areas where future work could be done to reduce uncertainties, address data gaps and improve the overall quality of the inventory are related to nitrogen management in animal waste management systems, the prescribed burning of crop residues and the burning of savannah. Estimates related to the areas of savannah burned annually, and the crops and area where it is the practice to burn crop residues, have a very high level of uncertainty. In addition, crop production and fertilizer application are based on data from the FAO, and these data should be compared to national statistics to judge their reliability and completeness. Collection of new activity data for these emission sources through surveys or other means could significantly improve the quality of the inventory.

3.6.1.1. Enteric Fermentation

Methane is produced by herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The calculation of methane emissions from enteric fermentation was completed using the Tier 1 methodology from the 1996 Revised IPCC Guidelines. This method relies on default emission factors drawn from previous studies and the only country specific data required are the populations of different livestock types.

Methane Emissions (kg/yr) = ∑Population of Livestock (head) x Emission Factor (kg CH_4 per head per year)

The application of Tier 2 methods would require detailed country specific data on nutrient requirements. feed intake and CH_4 conversion rates for specific feed types, to develop country specific emission factors for individual livestock categories. While enteric fermentation is a significant emission source category, resources are not currently available to develop Tier 2 methods.

3.6.1.1.1. Emission Factors

Default emission factors were drawn from Tables 4-2 and 4-3 in Module 4 (Agriculture) in Volume 2 of the 1996 Revised IPCC Guidelines. Total emissions are dominated by cattle and because of the significance of enteric fermentation emissions the 2006 IPCC Guidelines were reviewed to determine if improved estimates were available. Table 110 summarizes the enteric fermentation emission factors that were used.

Table 3-10: Enteric Fermentation Emission Factors by Type of livestock

Type of Livestock	Emission Factor Enteric Fermentation (CH4/head/yr)
Dairy Cattlea	40
Cattleb	31
Sheep	5
Goats	5
Pigs	1
Rabbits	0
Asses	10
Camels	46
Chickens	0

a No statistics available.

b Includes all cattle classified under "other cattle" category

Sources: IPCC, 1997; IPCC, 2006.

3.6.1.1.2. Temporal Effects

No temporal effects such as changes to enteric fermentation emission factors over time are considered in the analysis. If significant changes in the diet or management of livestock are occurring over time, emission factors should be reviewed.

3.6.1.1.3. Data Gaps and Potential Improvements to Inventory

Enteric fermentation emissions are a significant source of overall national greenhouse gas emissions. Tier 1 emission factors are used in the analysis. The adoption of a Tier 2 methodology for emission factors would significantly improve the quality of the estimates. However, the Tier 2 methodology would require the development of country specific emission factors based on enhanced livestock characteristics such as weight, average weight gain per day, feed characteristics and milk production.

3.6.1.1.4. Uncertainty

The uncertainty in livestock population data is larger than typically recognized. There may be systematic biases in the reporting of the livestock population to national census takers (positive and negative). Additionally, seasonal changes in populations may not be adequately reflected in annual census data. The population data should be examined in collaboration with the national statistical agencies with these factors in mind. Emission factors estimated using the Tier 1 method are unlikely to be more than ±30% accurate (IPCC, 2000). Livestock population sizes have a lower degree of uncertainty; expert judgment is that uncertainty in these activity data is ±10%. This results in a combined uncertainty of ±32 per cent.

3.6.1.2. Methane Emission from Manure Management

When manure is managed under anaerobic conditions, methane is produced from the decomposition process. This is common in dairy farms, beef feedlots, and swine and poultry farms, when large numbers of animals are managed in a confined area. This can also happen when manure is typically stored in large piles or disposed of in lagoons (this is not common in Ethiopia). The calculation of methane emissions from manure management was done using the Tier 1 methodology from the 1996 Revised IPCC Guidelines. This method relies on default emission factors drawn from previous studies and the only country specific data required are the populations of different livestock. The IPCC default emission factors for manure management were used for different categories of livestock based on the climate region (warm, about 26^{0}C annual average) (IPCC, 1997, Volume 3, Chapter 4, Table 4-4). Table 3-11 below shows the manure management emission factors for different types of livestock.

Methane Emissions (kg/yr) = ∑Population of Livestock (head) x Emission Factor (kg CH4 per head per year)

3.6.1.2.1. Emission Factors and Coefficients

Table 3-11: Manure Management Emission Factors Type of Livestock

Type of Livestock	Emission Factor Manure Management CH4/head/y
Dairy Cattle	1
Cattle	1
Sheep	0.189
Goats	0.204
Pigs	1.02
Rabbits	0
Asses	1.09
Camels	2.56
Chickens	0.022

Source: IPCC, 1997.

3.6.1.2.2. Temporal Effects

No temporal effects such as changes to animal waste management systems over time are considered in the analysis.

3.6.1.2.3. Data Gaps and Potential Improvements to Inventory

Manure management emissions especially nitrous oxide is a key source category and it is recommended that Tier 2 country specific emission factors be developed where possible considering that developing country specific methane conversion factors and volatile solids data would require significant effort..

3.6.1.2.4. Uncertainty

The Tier 1 default emission factor values employed may have a large uncertainty for Ethiopia, because the African values used may not reflect conditions within the country. It is estimated that the level of uncertainty is in the ±20 per cent range (IPCC, 1997, Volume 3, Chapter 4, Table 4.5). Livestock populations have a lower degree of uncertainty; expert judgement is that uncertainty in this activity data is ±10 per cent. This results in a combined uncertainty of ±22 per cent.

3.6.1.3. Nitrous Oxide Emissions from Manure Management

During storage of manure, some manure nitrogen is converted to nitrous oxide (N_2O). Emissions of N_2O related to manure handling before the manure is added to soils are included in this source category. The IPCC guidelines consider five main manure management systems. The amount of nitrogen excreted and managed by each of the animal waste management systems (AWMS) can be estimated using the following Tier 1 equation.

$$Nex = \Sigma(T)[N(T) \times Nex(T) \times AWMS(T)]$$

Where:

$\mathbf{N_{ex}}$ **(AWMS)** = N excretion per Animal Waste Management System (kg/yr);

$\mathbf{N_{(T)}}$ = number of animals of type T in the country;

$\mathbf{N_{ex\,(T)}}$ = N excretion of animals of type T in the country (kgN/animal /yr);

$\mathbf{AWMS_{(T)}}$ = fraction of $N_{ex(T)}$ that is managed in one of the animal waste management systems for animals of type T in the country;

T = type of animal category.

Using the expert guidance and judgement available within the Department of Livestock in the Ministry of Agriculture, the fraction of animals that are managed in each of the management systems were determined. The IPCC default values are taken from the Revised 1996 Guidelines for the whole region of Africa and are presented in Table 3.12

Table 3-12: Fraction of Manure per Manure Management System

Type of Livestock	Pasture /Range / Paddock		Burned as Fuel	Solid Storage / Dry lot	Other
	Manure from pasture and range grazing animals is allowed to lie as is and is not managed.		Manure is collected in solid form and is burnt as fuel.	Manure is collected but is stored in bulk for a long time (months) before disposal.	Anaerobic digesters and using manure as fuel.
Other Cattle	0.35		0.15	0.45	0.05
Dairy Cattle	0		0	0	0
Poultry	Without Litter	With Litter			0
	0.93	0.07			
Sheep/Goats	0.8		0	0.2	0
Swine	1		0	0	0
Camels	1		0	0	0
Horses/Mules/ Donkeys/Asses	0.7		0	0.3	0

Sources: Department of Livestock, Ministry of Agriculture; IPCC, 1997, Volume 3, Chapter 4, Table 4.7.

3.6.1.3.1 Emission Factors

The default nitrogen excretion factors were drawn from the 1996 Revised IPCC Guidelines and are presented in Table 3.13 below.

Table 3-13: Nitrogen Excretion Emission Factors by Type of Livestock

Type of Livestock	IPCC 1996 Guidelines Nitrogen Excretion Nex (kg/head/yr)	Computed Values Using IPCC Software Nitrogen Excretion Nex (kg/head/yr)
Other Cattle	40	39.7814
Dairy Cattle	60	Not considered
Poultry	0.6	0.2694
Sheep	12	11.9574
Goat		15.0015
Swine	16	16.0454
Others	40	
Mules/Asses		21.827
Horses		39.9602
Camels		36.4343

Source: IPCCC, 1997, Volume 3, Chapter 4, Table 4-6.

3.6.1.3.2. Temporal Effects

No temporal effects, such as changes to animal waste management systems over time, are considered in the analysis.

3.6.1.3.3. Data Gaps and Potential Improvements to Inventory

Manure management emissions are a significant source of overall national greenhouse gas emissions. Default activity data for Africa on the fraction of livestock managed under different manure management systems (MMS) are employed. Country specific estimates for the livestock fractions managed under different systems could greatly improve the inventory's quality. It is recommended that surveys be conducted to estimate reliably the fraction of livestock managed under each of the MMSs in the revised 1996 IPCC Guidelines (IPCC, 1997, Volume 3, Chapter 4, Table 4.8) and recalculate estimated changes in these fractions over the 1994 to 2013 period. In addition, estimates could be improved if there were an age profiling for the livestock. Younger animals have lower nitrogen excretion rates and lower emission factors could be applied.

3.6.1.3.4 Uncertainty

Substantial uncertainty in the estimates of the fraction of livestock managed under each of the MMS is confirmed. Relying on default fractions from the revised 1996 Guidelines introduces significant uncertainty because they are unlikely to represent conditions in Ethiopia today. The overall combined uncertainty of emission factors and allocation to MMSs is estimated to be ±50 per cent.

3.6.1.4. Rice Cultivation

Upland rice cultivation is the main practice the main form of rice cultivation in Ethiopia. Upland rice fields which are not flooded do not produce significant methane emissions, since the anaerobic decomposition of organic material in flooded rice fields that produces methane is not occurring. However, upland rice also requires some short periods of flooding, which are covered here. Emissions of methane from rice fields can be represented by the following Tier 1 equation.

$$Fc = EF \times A \times 10\text{-}6$$

Where:

Fc = estimated annual emission of methane from a particular rice water regime and for a given organic amendment (t/yr);

EF = methane emission factor integrated over cropping season (g/m2);

A = annual harvested area cultivated under flooding conditions for at least part of the year. (It is given by the cultivated area times the number of cropping seasons per year (m2/yr) and the excretion of animals of type T in the country (kgN/animal /yr.)

3.6.1.4.1 Activity Data

Data on annual harvested areas of rice are available from the Ministry of Agriculture as shown in Table 3-14. Unfortunately, these data are not disaggregated between different rice water regimes, which are associated with different levels of methane emissions.

Table 3-14: Harvested Area of Rain-fed Rice, 1994-2013

Rice ecosystem	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Rain-fed Rice (ha)	5,400	7,210	5,900	6,989	6,500	7,000	7,500	8,200	8,364	7,700	7,200

Rice ecosystem	2005	2006	2007	2008	2009	2010	2011	2012	2013
Rain-fed Rice (ha)	6,500	6,241	6,421	24,434	35,088	47,738	29,866	47,739	41,811

Source: Crop Production Department, Ministry of Agriculture.

3.6.1.4.2. Emission Factors

Default scaling factors for methane emissions, correction factors for organic amendments and seasonally integrated emission factors were drawn from the 1996 Revised IPCC Guidelines (Volume 3, Chapter 4, Tables 4-10 and 4-11) and are presented in Table 3 15.

Table 3-15: Rice Water Management Regime Emission Factors and Coefficients

Water Management Regime	Baseline emission factor for continuously flooded fields without organic amendment	Fraction/Scaling Factor to account for difference in water regimes during cultivation	Fraction/Scaling Factor to account for difference in water regimes during preseason before cultivation	Conversion factors for organic amendment	Seasonally integrated emission factor for continuously flooded rice (g/m2)
Irrigated Continuously Flooded		1.3	1.3	2	20
Rain fed – Drought Prone		0.4	0.4	2	20
Regularly rain fed[a]	1.3	0.28	1.9	0.14	

[a] *The main rice ecosystem category for the national inventory.*

Sources: IPCC, 1997, Volume 3, Chapter 4, Tables 4-10 and 4-11; IPCC, 2006, Volume 4, Chapter 5, Tables 5.11- 5.14.

3.6.1.4.3. Temporal Effects

No temporal effects other than changes in activity data are considered in the analysis. Any other significant changes in water management regimes over time should be considered if these are expected.

3.6.1.4.4. Data Gaps and Potential Improvements to Inventory

The quality of activity data for flooding of rice fields in Ethiopia is relatively low and improved surveys could help to identify the crop areas that are continuously flooded and rain-fed. However, the magnitude of emissions relative to other sources is low enough that this work is not a priority.

3.6.1.4.5. Uncertainty

Substantial uncertainty exists in the crop areas as well as in the default emission factors used. Uncertainty is estimated to be ±10 per cent in the activity data and ±40 per cent in the emission factors for a combined overall uncertainty of ±41 per cent.

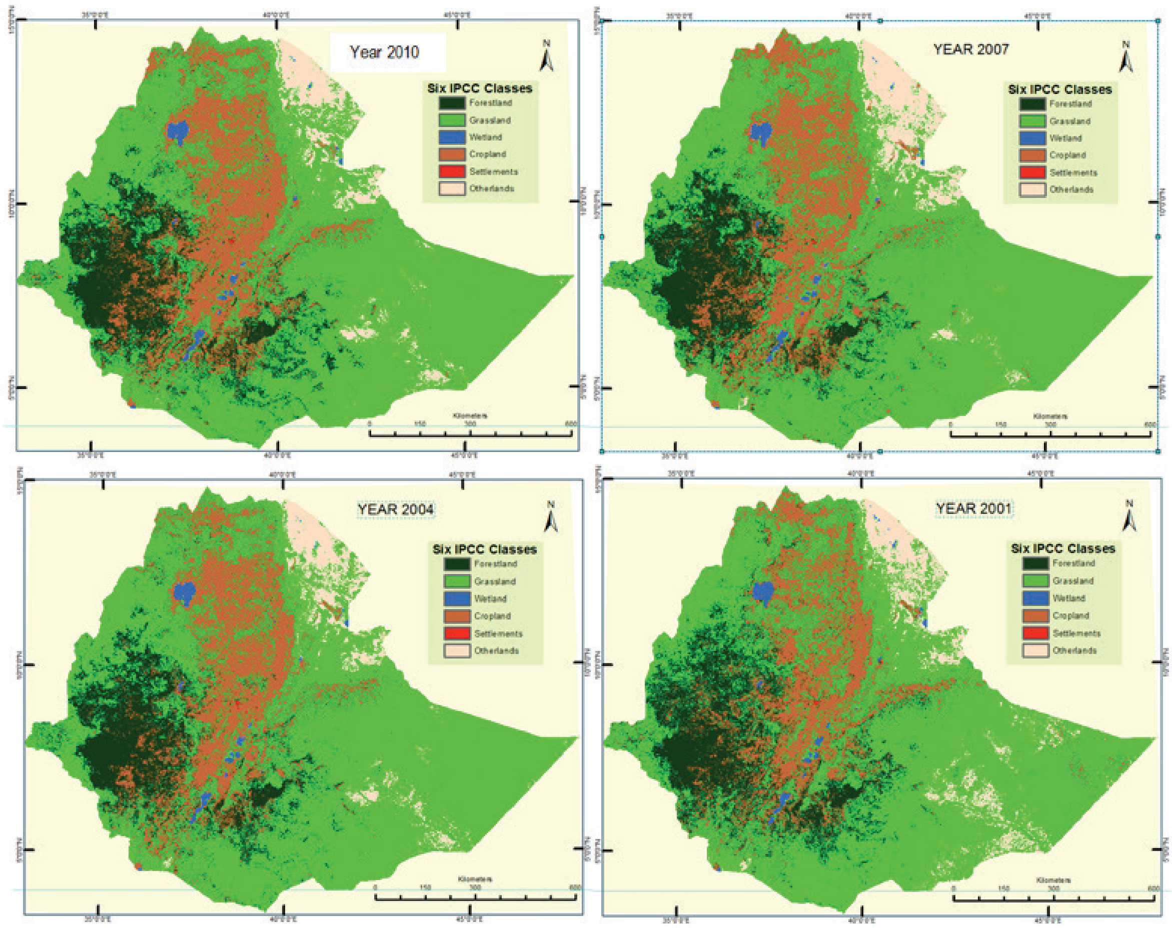
3.6.2. Land Use Change and Forestry (LUCF)

The primary objective of using the land cover parameter "land unit" is to facilitate the inference of biophysical information from land cover for use in estimation of emissions resulting from changes and/or conversions from one cover or use category to the other. There are no consistent land cover data for the country over a sufficiently long time series to carry out change detection and calculate percentage land cover for the IPCC's six land use categories. MODIS Land Cover (IGBP) Type I was thus selected and acquired from the USGS site to fill the land use data gap. Annual land cover maps for the years 2001-2010 were generated using the MODIS dataset and the 17 classes aggregated to the IPCC's six sectors using a decision tree classification algorithm which was applied to all the datasets for 2001–2010 (Table 3-16). Figure 3-4 below shows the land cover maps for the years 2001, 2004, 2007 and 2010.

Table 3-16: Description of the MODIS Land Cover Classes and the Aggregated Six IPCC Land Categories

Code No.	MODIS Land Cover Category	Description	IPCC Land Category Aggregate
1	Evergreen Needleleaf Forests	Lands dominated by woody vegetation with percentage cover >60 per cent and height exceeding 2 metres. Almost all trees remain green all year. Canopy is never without green foliage.	Forestland
2	Evergreen Broadleaf Forests	Lands dominated by woody vegetation with percentage cover >60 per cent and height exceeding 2 metres. Almost all trees and shrubs remain green year round. Canopy is never without green foliage	Forestland
3	Deciduous Needleleaf Forests	Lands dominated by woody vegetation with percentage cover >60 per cent and height exceeding 2 metres. Consists of seasonal needleleaf tree communities with an annual cycle of leaf-on and leaf-off periods.	Forestland
4	Deciduous Broadleaf Forests	Lands dominated by woody vegetation with percentage cover >60 per cent and height exceeding 2 metres. Consists of broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.	Forestland
5	Mixed Forests	Lands dominated by trees with percentage cover >60 per cent and height exceeding 2 metres. Consists of three communities with interspersed mixtures or mosaics of the other four forest types. None of the forest types exceeds 60 per cent of landscape.	Forestland
6	Closed Shrublands	Lands with woody vegetation less than 2 metres tall and with shrub canopy cover >60 per cent. The shrub foliage can be either evergreen or deciduous.	Grasslands
7	Open Shrublands	Lands with woody vegetation less than 2 metres tall and with shrub canopy cover between 10 and 60 per cent. The shrub foliage can be either evergreen or deciduous.	Grasslands
8	Woody Savannahs	Lands with herbaceous and other understory systems and with forest canopy cover between 30 and 60 per cent. The forest cover height exceeds 2 metres.	Forestland
9	Savannahs	Lands with herbaceous and other understory systems and with forest canopy cover between 10 and 30 per cent. The forest cover height exceeds 2 metres.	Grasslands
10	Grasslands	Lands with herbaceous types of cover. Tree and shrub cover is less than 10 per cent.	Grasslands
11	Permanent Wetlands	Lands with a permanent mixture of water and herbaceous or woody vegetation. This can be salt, brackish, or fresh water.	Wetlands
12	Croplands	Lands covered with temporary crops followed by harvest and a bare soil period (e.g. single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.	Croplands
13	Built-Up Lands	Land covered by buildings and other man-made structures	Settlements
14	Cropland/ Natural Vegetation Mosaics	Lands with a mosaic of croplands, forests, shrublands and grasslands, in which no one component comprises more than 60 per cent of the landscape.	Croplands
15	Snow and Ice	Lands under snow/ice cover throughout the year.	Wetlands
16	Barren	Lands with exposed soil, sand, rocks or snow which never has more than 10 per cent vegetated cover during any time of the year	Other lands
17	Water Bodies	Lakes, reservoirs and rivers. Can be either fresh or salt-water bodies.	Wetlands

Figure 3-4: Ethiopia Maps Showing Aggregated Categories of MODIS Land Cover Type I, 2010, 2007, 2004 and 2001



It was not possible to obtain data on the area covered by plantation forests, unmanaged grassland, and perennial cropland because available ancillary data was insufficient to delineate the classes satisfactorily.

The section on Land Use, Land-Use Change and Forestry (LULUCF) accounts for emissions and removals resulting from managed forestland (that displays some human intervention), cropland, wetland, settlements and other lands. Unmanaged woodland in areas set aside for national parks for wildlife conservation were excluded from the National Inventory. This section mainly records pathways for carbon and nitrogen through CO_2 emissions and capture by processes of forest biomass expansion

3.6.2.1. Combination of Soils and Ecological zones

The following eco-zones and FAO soil classes as shown in Figure 3.5 were combined using GIS applications to create the IPCC soil classes and climatic zones as required by the IPCC's Good Practice Guidance

Figure 3-5: The Eco-zones and FAO Soil Classes of Ethiopia

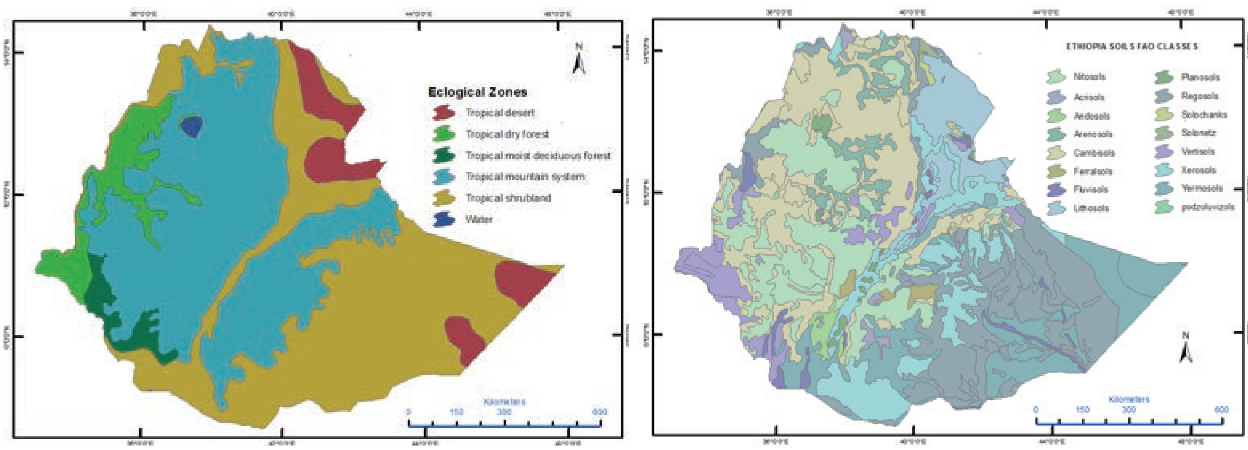
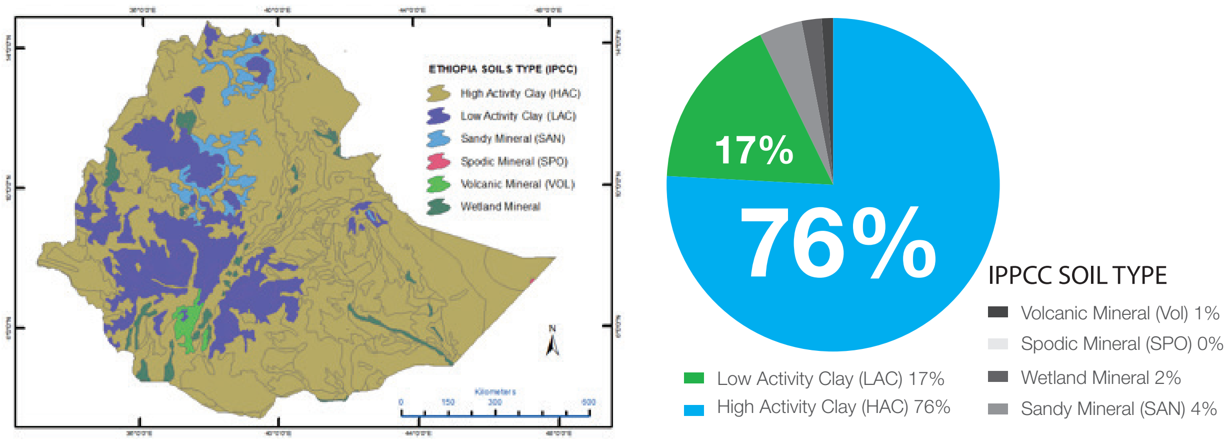


Figure 3.6 shows the IPCC soil types and percentage coverage in Ethiopia. The soil classes were further combined with land cover land use maps using GIS applications to establish the area of land use categories remaining in the same category for a particular year. The masks of land use changes derived from land use change detection carried out using remote sensing applications were also combined with the soil-climate data. This was done to estimate the land area for land conversions from one land use category to the other

Figure 3-6: Distribution of IPCC Soil Types



3.7. Waste Sector Methodology

The methods, activity data, emission factors and coefficients that were used to develop the national inventory for the waste sector are described in this section. The methods and default values are primarily drawn from the Revised 1996 IPCC Guidelines with additional alternative methods or emission factors taken from the IPCC's publications on Good Practice Guidance or the 2006 guidelines so as to improve the GHG estimates. Complete data sets, mainly population data for the period 1994-2013 are provided in this document. The activity data set can be used to adjust the baseline to develop emission trends for the years 1994-2013. In some cases adjustments in emission factors or coefficients for this time period are also identified. The primary areas where future work can be done to complete and reduce uncertainties, address data gaps and improve the overall quality of the inventory are related to estimating domestic and industrial solid waste and wastewater generation. Collection of this information through national surveys that determine amounts generated but also the type of disposal or treatment could significantly improve the quality of the inventory.

3.7.1. Methane Emissions from Solid Waste Disposal Sites

Organic waste decomposes at a diminishing rate and takes many years to decompose completely. In the process methane (CH_4) is emitted during anaerobic decomposition of the organic waste disposed of in solid waste disposal sites (SWDSs). The calculation of methane emissions from SWDSs was done using the Tier 1 First Order Decay (FOD) model methodology from the 2006 IPCC Guidelines. The FOD method produces a time-dependent emission profile that better reflects the true pattern of the degradation process over time, whereas the default method is based on the assumption that all potential CH_4 is released in the year the waste is disposed. The default method will give a reasonable annual estimate of actual emissions if the amount and composition of deposited waste have been constant or varying slowly over a period of several decades. To assist countries implement the FOD method, the IPCC has developed a spreadsheet which provides step-by-step guidance and thus enables countries to estimate these emissions.

In the IPCC FOD spreadsheet model, methane formation is calculated for each year of disposal. This is done in the spreadsheet by adding the mass of degradable organic carbon available for anaerobic decomposition (DDOCm) removed to the disposal site in one year to the DDOCm left over from the previous years. Methane emissions for the following year is then calculated from this "running total" of the DDOCm remaining in the site. A detailed description of the FOD model is available in the 2006 IPCC Guidelines, Volume 5, Chapter 3. The inputs required include the total solid waste generated over time, the distribution of wastes in different solid waste disposal sites, and the composition of waste going to landfill. A copy of the waste model employed is available with this report and at www.ipcc-nggip.iges.or.jp/public/2006gl/.../IPCC_Waste_Model.xls.

The FOD method can be expressed by the equations below.

$$\text{Methane Emissions in year t (Gg/yr)} = \Sigma_X [(A \bullet k \bullet MSWT_{(X)} \bullet MSWF_{(x)} \cdot L0_{(x)}) \bullet e^{-k(t-x)}] \text{ for x = initial year to t}$$

Where:

t = year of inventory;

x = years for which input data should be added;

A = (1 –e-k)/k = normalization factor which corrects the summation;

K = Methane generation rate constant (1/yr);

$MSWT_{(x)}$ = Total municipal solid waste (MSW) generated in year x (Gg/yr);

$MSWV_{(x)}$ = Fraction of MSW disposed at SWDSs in year x;

$L0_{(x)}$ = Methane generation potential [($MCF_{(x)}$ • $DOC_{(x)}$ • DOC_F • F • 16/12 (Gg CH_4/Gg waste)];

$MCF_{(X)}$ = Methane correction factor in year x (fraction);

DOC $_{(x)}$ = Degradable organic carbon (DOC) in year x (fraction) (Gg C/Gg waste);

DOC_F = Fraction of DOC dissimilated;

F = Fraction by volume of CH_4 in landfill gas;

16 /12 = Conversion from C to $CH_{4.}$

Then sum individual results for all years (x).

Methane emitted in year t (Gg/yr) = [(CH4 generated in year t – R(t)] (1 – OX)

Where:

R(t) = Recovered CH4 in inventory year t (Gg/yr);

OX = Oxidation factor (fraction).

Data on municipal waste generation and disposal are not available in properly documented records for use in the GHG inventory process. For this reason the urban population statistics were applied in accordance with the IPCC guidelines. Table 3-17 shows the types of SWDSs considered for urban populations in Ethiopia.

Table 3-17: Types of SWDSs for Urban Populations in Ethiopia

Type of site	Description	Percentage of Urban Waste Deposited
Managed anaerobic	Have controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) leveling of the waste.	0
Managed semi-aerobic	Have controlled placement of waste and will include all of the following structures for introducing air to waste layer: (i) permeable cover material; (ii) leachate drainage system; (iii) regulating pondage; and (iv) gas ventilation system.	0
Unmanaged – deep (>5 m waste) and/ or high water table	All SWDSs not meeting the criteria of managed SWDSs and which have depths of greater than or equal to 5 metres and/or a high water table at near ground level. Latter situation corresponds to filling inland water, such as ponds, rivers or wetlands, by waste.	
Unmanaged – shallow (<5 m waste)	All SWDSs not meeting the criteria of managed SWDSs and which have depths of less than 5 metres.	10 (corresponds to dumpsite / landfills in cities)
Uncategorised SWDSs	If countries cannot categorize their SWDSs into above four categories of managed and unmanaged SWDSs, the Methane Correction Factor (MCF) for this category can be used.	90

The analysis assumes that there are currently no waste disposal sites in Ethiopia that are capturing methane for flaring or utilization, and that none will be installed in the baseline. However, the Clean Development Mechanism (CDM) project on the old dumpsite in Addis Ababa will be captured in the future inventory once it becomes operational. The composition of waste has an impact on the amount of organic material that is available for anaerobic decay and therefore the projected methane emissions released. The waste composition used in the modeling is presented in Table 3 18.

Table 3-18: Composition of Wastes Generated

Type	Municipal Waste Composition (%)
Food Waste	53.9
Garden waste	4.5
Textiles	4.0
Nappies	0.7
Wood	7.0
Paper	7.7
Plastic + rubber + glass + metal + ceramics and other inert	22.3
TOTAL	100.0

Source: IPCC 2006, Volume 5, Chapter 2, Table 2.3.

These data are then extrapolated to represent the historic and projected urban population and waste generation rates between 1950 and 2013. The data were then entered into the IPCC software for calculation of emission.

3.7.1.1. Emission Factors

Default emission factors were drawn from the 2006 IPCC Guidelines as selected from the drop down list of software integrated factors. The Table 3-19 shows the waste sector IPCC default emission factors and coefficients applied.

Table 3-19: Waste Model IPCC Default Emission Factors and Coefficients

Default IPCC parameter	Default values used in model
Methane Correction Factor (MCF)	0.4 (unmanaged shallow)
	0.6 (uncategorized SWDSs)
Methane Recovery Factor	0
Fraction of DOC dissimilated	0.5
Methane Generation Rate Constants (yr-1) Default for Eastern Africa and Dry Tropical climate zone	0.085 (food waste, sewage sludge)
	0.065 (gardens, disposable nappies)
	0.025 (wood and straw)
Delay time (months)	6
Fraction of methane (F) in developed gas	0.5

Source: IPCC 2006, Volume 5, Chapter 3, Tables 3.1 and 3.3

The default DOC contents of specific waste streams identified are provided in Table 3 20 below.

Table 3-20: Default DOC Content of Different MSW components

Type	DOC Content of wet waste (%)	Methane Generation Rate Constant
Food Waste	15	0.085
Textiles	24	0.045
Leather	39	0.04
Garden	20	0.065
Grass/Wood	43	0.025
Paper	40	0.045
Disposable Nappies	24	0.05
Sewage Sludge	5	0.085
Industrial Waste	15	0.065

Source: IPCC 2006, Volume 5, Chapter 2, Table 2.4.

3.7.1.2 Temporal Effects

Temporal effects can be related to changes in the amounts of waste disposed, the management and fractions disposed for different types of management and the composition of wastes that may change overtime. In this case, we vary only the production of waste based on per capita waste generation rates. These rates are also likely to have changed over time.

3.7.1.3 Data Gaps and Potential Improvements to Inventory

Estimates of the municipal solid waste (MSW) sent to solid waste disposal sites is based on a very limited data set extrapolated for urban areas. Estimates of MSW and industrial solid waste are simply based on regional default values from the IPCC 2006 Guidelines related to GDP and population. A national survey to characterize formal and informal waste sites in the country would be useful for the development of an emissions inventory. Survey data should include the amount of wastes deposited, the average depth of waste at sites and a description of management practices.

3.7.1.4. Uncertainty

The uncertainty in waste generation rates that are sent to solid waste disposal sites is very high. It is estimated that uncertainty related to these activity data is ±100 per cent. The combined uncertainty of emission factors and coefficients is estimated to be ±50 per cent. These uncertainties are primarily driven by the default organic carbon content (DOC) values as well as the methane correction factors, oxidation factors and methane generation rate constant. Combined activity data and emission factor uncertainty is estimated to be ±112 per cent.

3.7.2. Wastewater Treatment Emissions

Wastewater handling under anaerobic conditions can produce CH_4 (methane). Anaerobic methods are particularly prevalent in developing countries when handling wastewater from municipal sewage, food processing and other industrial facilities. Aerobic municipal wastewater treatment, recovery and utilization of methane are more capital intensive. CH_4 emissions from wastewater handling are calculated for two different types of wastewater and their resulting sludge types, domestic wastewater and sludge, and industrial wastewater and sludge.

The method for estimating CH_4 emissions from domestic or industrial wastewater handling can be expressed by the equation below and involves the following three steps.

Wastewater Emissions = Bo • MCF • P • Ddom

Where:

Bo = Maximum methane producing capacity (kg- CH_4/kgBOD)

MCF = Methane Conversion Factor (fraction)

P = Human population

$\mathbf{D_{dom}}$ = Degradable organic component (kgBOD/1000 persons/yr)

K = Methane generation rate constant (1/yr)

3.7.2.1. Procedure Wastewater Treatment emission Estimation

i. Step 1: Determine the total amount of organic material in the wastewater produced for each wastewater handling system.

ii. Step 2: Estimate emissions factors for each wastewater handling system in kgCH_4 per kg of degradable organic content.

iii. Step 3: Multiply the emissions factors for each wastewater handling system by the total amount of organic material in the wastewater produced for each system, and sum across the wastewater systems to estimate total CH_4 emissions.

The activity data required to estimate Tier 1 emissions from municipal wastewater systems includes the degradable organic component (DOC), country population data and the fraction of biochemical oxygen demand. (BOD) removed as sludge. Both the urban and rural populations are considered but specific characteristics, such as the waste management system and the degree of utilization, are varied. The types of wastewater treatment systems and the fraction of total sewage that they hande systems were estimated and are presented Tables 3-21 and 3-22.

Table 3-21: Wastewater Treatment Systems

Wastewater Treatment Systems	Fraction of Total Sewage (%)	Methane Conversion Factor
Sea, lake discharge	10	0.1
Stagnant sewer	20	0.5
Centralized aerobic treatment plant (50% well managed)	10	0.15
Anaerobic shallow lagoon	30	0.2
Anaerobic deep lagoon	25	0.8
Septic system	5	0.5
Average based on total	100	0.41

Sources: IPCC, 1997, Volume 3, Chapter 6, Table 6-7; IPCC, 2006, Volume 5, Chapter 6, Table 6.3.

Table 3-22: Wastewater Treatment Parameters

Wastewater Parameter	Value
Degradable organic component (default for Africa region)	13,505 kg BOD/1,000 persons/yr
Fraction of BOD to sludge (%)	0

Source: IPCC, 1997, Volume 3, Chapter 6, Table 6-5.

3.7.2.2. Temporal Effects

Temporal effects can be related to changes in the amount of wastewater generated and the type of wastewater management employed. In this case temporal effects are solely based on changes in population. To capture changes in wastewater management over time would require estimates of treatment systems operating over different periods.

3.7.2.3. Data Gaps and Potential Improvements to Inventory

Estimates of the wastewater treatment systems and the population serviced are based on regional values from the Revised 1996 IPCC Guidelines. However, the type of wastewater treatment systems in place and the methane conversion factors assumed for the wastewater treatment systems are values that should be reviewed by experts in Ethiopia and revised based on local expert opinion.

Estimates for industrial wastewater are based on the production of a number of commodities that are known to generate significant wastewater. Production data to estimate industrial wastewater has been collected for the years 1994-2013.

3.7.2.4. Uncertainty

The total wastewater generation for domestic wastewater treatment systems is estimated to have an uncertainty of ±50 per cent. Estimates of total industrial wastewater generation are more uncertain, specifically because there may be gaps in the activity that is included. It is estimated that uncertainty related to industrial wastewater activity is ±100 per cent. The uncertainty in the methane generating capacity of domestic and industrial wastewater is estimated to be ±30 per cent. The combined uncertainty of emission factors and coefficients is estimated to be ±58 per cent for domestic wastewater and ±104 per cent for industrial wastewater.

3.7.3. Nitrous Oxide Emissions from Sewage

Consumption of foods by humans results in the production of sewage. During the treatment of human sludge, nitrous oxide can be produced due to the nitrification and denitrification of sewage nitrogen. The emissions of N_2O from human sewage are calculated as follows.

$$N_2O(s) = Protein \times FRAC_{NPR} \times NR_{PEOPLE} \times EF_6$$

Where:

$N_2O(s)$ = N_2O emissions from human sewage (kg N_2O-N/yr)

Protein = annual per capita protein intake (kg/person/yr)

NR_{PEOPLE} = number of people in country

EF6 = emissions factor (default 0.01 (0.002-0.12) kg N_2O-N/kg sewage-N produced)

$Frac_{NPR}$ = fraction of nitrogen in protein (default = 0.16 kg N/kg protein)

The activity data required to estimate nitrous oxide emissions from human sludge are the annual per capita protein intake and total population and this is available in the FAOSTAT Database of the Food and Agriculture Organization of the United Nations.

3.7.3.1 Emission Factors

The Table 3-23 shows the IPCC default emission factors for nitrous oxide emissions from sewage.

Table 3-23: IPCC Default Emission Factors for Nitrous Oxide Emissions from Sewage

Default IPCC parameter	Default values used in model
Emission Factor (EF6)	0.01 kg N2O-N/kg sewage-N produced
Fraction of Nitrogen in Protein	0.16 kg N/kg protein

Source: IPCC 1997, Volume 3, Chapter 6, p.6-28.

3.7.3.2. Temporal Effects

Temporal effects can be related to changes in the amount of human sewage generated and how it is treated. In this case temporal effects are solely based on changes in population and the methodology does not provide for more detailed analysis.

3.7.3.3. Data Gaps and Potential Improvements to Inventory

An improvement would allow consideration of the types of treatment in place for human sewage. Nitrous oxide emissions may vary depending on whether the human sewage is treated at a facility, applied to land, buried or incinerated.

3.7.3.4. Uncertainty

Total protein consumption is estimated to have an uncertainty of ±20 per cent. The uncertainty in the nitrous oxide emission factors are estimated to be ±30 per cent. The combined uncertainty of emission factors and coefficients is estimated to be ±36 per cent.

3.8. Key Categories Analysis

The IPCC sets out a three-tier method for the estimation of GHGs, namely Tier I, Tier II, and Tier III. The application of any of these tiers depends on the level of disaggregation, availability of data, availability of country-specific activity data and/or emission factors, and depends on the specific category's importance to total national emissions.

Tier I is the default method and the simplest methodology, and is applied when country-specific emission factors or activity data are not available. However, this method carries the risk of failing to reflect adequately national circumstances. Tier II uses the same methodological procedure as Tier I, but employs activity data and/or emission factors that are specific to the country or to a region of the country, thus achieving more accurate estimates of greenhouse gas emissions/removals. It should be applied in key categories to reduce the cost involved in the inventory. Tier III relies more on country-specific methodologies models, censuses and other procedures developed for the country. However, the application of these methods is recommended with due validation and, in the case of models, if published in peer-reviewed journals. The National GHG Inventory for Ethiopia was compiled at Tier I level.

The assessment of key categories for Ethiopia was carried out using expert judgement, Approach 1 Level Assessment of the Inventory, Approach 1 Trend Assessment of the Inventory and on review of the national circumstances, Ethiopia's Initial National Communication (INC), and national action plans and strategies. The categories with the greatest contribution to the overall level of national emissions, high uncertainty levels, and largest influence on the trends of emissions were considered key. Given their relative importance, these categories were given due attention to improve emissions estimates.

The categories making the greatest contributions to overall emissions, trend influences and uncertainties were identified to help prioritize resources for improving national greenhouse gas inventories. These categories were listed as the most important national inventory categories. The results from this analysis were used in laying down an inventory improvement plan. Documentation on the process of key category identification to support the transparency and completeness requirements of the inventory compilation process was developed. The first step in a key category analysis is to define the level of detail at which the analysis will be done. To perform the key category analysis at the level at which the IPCC methods are described and to enable the use of emission estimates in CO_2-equivalent units for sources emitting more than one gas, each GHG was treated separately. The steps followed to identify the key categories are discussed in the following section.

3.8.1. Tier 1 Current Year Level Assessment and Trend Analysis

The identified key categories for GHG inventory were first enlisted with their GHG type, emission estimates and cumulative percentages. The categories were ordered in decreasing magnitude and those categories contributing up to about 95 per cent of emissions were selected as shown in Table 3-24 and 3-25.

Employing the IPCC software, trend assessments using both the base year estimates and current year estimates were carried out and categories contributing more to the trend and cumulative percentage were picked as the key categories. The following are the key categories identified using the trend and level assessments.

Table 3-24: Key Categories Assessment Based on Trend Assessment

IPCC Category code	IPCC Category	Green-house gas	2000 Year Estimate Ex0 (Gg CO2 Eq)	2013 Year Estimate Ext (Gg CO2 Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
3.B.3.b	Land Converted to Grassland	CO2	108122.3793	41403.88429	0.098280704	0.280693668	0.280693668
3.A.1	Enteric Fermentation	CH4	30693.975	52088.325	0.069271096	0.197841054	0.478534722
3.B.1.a	Forest land Remaining Forest Land	CO2	-84887.37633	-76253.5206	0.064878887	0.185296727	0.663831449
3.A.2	Manure Management	N2O	6365.599364	12037.16233	0.017461422	0.049870528	0.713701976
1.A.4	Other Sectors - Biomass	CH4	23080.7535	11639.77862	0.01692941	0.048351079	0.762053056
3.B.2.b	Land Converted to Cropland	CO2	88066.10539	75893.34521	0.014332441	0.040934033	0.802987088
3.C.4	Direct N2O Emissions from Managed soils	N2O	3340.236514	7553.491397	0.012264427	0.035027701	0.838014789
3.C.5	Indirect N2O Emissions from Managed soils	N2O	2544.638402	5212.17824	0.007983893	0.022802321	0.86081711
4.A	Solid Waste Disposal	CH4	802.591908	3582.069327	0.007377326	0.021069942	0.881887053
1.A.3.b	Road Transportation	CO2	1533.81003	3847.788447	0.006582653	0.018800325	0.900687377
1.A.1	Energy Industries - Liquid Fuels	CO2	19.264518	1620.781038	0.004025057	0.011495725	0.912183102
4.D	Wastewater Treatment and Discharge	CH4	1368.339242	2608.985559	0.003807374	0.010874013	0.923057115
3.B.4.b	Land Converted to Wetlands	CO2	197.6919637	1437.08911	0.00320804	0.009162292	0.932219407
1.A.4	Other Sectors - Biomass	N2O	3608.192404	1635.105115	0.003109205	0.008880014	0.941099422
3.C.6	Indirect N2O Emissions from Manure Management	N2O	1062.426132	2013.249318	0.002924944	0.008353758	0.94945318
3.A.2	Manure Management	CH4	1139.089833	2035.375	0.002827253	0.008074749	0.957527928
3.B.5.b	Land Converted to Settlements	CO2	164.7495147	1155.058874	0.002576634	0.007358972	0.9648869
1.A.4	Other Sectors - Liquid Fuels	CO2	608.2050612	1395.231425	0.002282949	0.006520195	0.971407095
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO2	795.889356	1459.999451	0.002070365	0.005913047	0.977320142

IPCC Category code	IPCC Category	Green-house gas	2000 Year Estimate Ex0 (Gg CO2 Eq)	2013 Year Estimate Ext (Gg CO2 Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
2.C.1	Iron and Steel Production	CO2	61.29405	840.6396	0.001985154	0.005669681	0.982989823
2.A.1	Cement production	CO2	404.609218	905.1741194	0.001461057	0.004172837	0.98716266
4.D	Wastewater Treatment and Discharge	N2O	822.4238324	1125.887315	0.001179683	0.003369223	0.990531884
3.C.1	Emissions from Biomass Burning	CH4	1352.163774	700.9004996	0.000944169	0.002696586	0.993228469
3.B.2.a	Cropland Remaining Cropland	CO2	-55.4125	-308.913605	0.000607345	0.001734601	0.99496307
3.D.1	Harvested Wood Products	CO2	-134.757918	9.0904469	0.000429281	0.001226044	0.996189114
3.C.3	Urea Application	CO2	73.74546667	199.925	0.000353909	0.001010779	0.997199893
3.C.1	Emissions from Biomass Burning	N2O	1119.014208	757.4099606	0.000336691	0.000961604	0.998161497
3.B.1.b	Land Converted to Forest land	CO2	-8957.641967	-10727.89468	0.000123767	0.000353483	0.99851498
4.C	Incineration and Open Burning of Waste	CH4	47.62141313	80.62170188	0.00010699	0.000305568	0.998820547
1.A.3.b	Road Transportation	N2O	23.2124865	59.39989703	0.000102549	0.000292885	0.999113432
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CO2	0	27.27	6.837E-05	0.000195268	0.9993087
3.C.7	Rice Cultivation	CH4	5.167153819	28.80584911	6.18974E-05	0.000176781	0.999485481
1.A.1	Energy Industries - Solid Fuels	CO2	0	24.038	6.02669E-05	0.000172125	0.999657606
1.B.1	Solid Fuels	CH4	0	9.96625	2.49869E-05	7.13636E-05	0.99972897
4.C	Incineration and Open Burning of Waste	N2O	7.728735559	13.08453011	1.7364E-05	4.95922E-05	0.999778562
4.C	Incineration and Open Burning of Waste	CO2	5.883291021	9.960244848	1.32179E-05	3.77507E-05	0.999816313
1.A.3.b	Road Transportation	CH4	6.66445785	10.28995214	1.24838E-05	3.56543E-05	0.999851967
2.A.2	Lime Production	CO2	6.6965	9.923816472	1.15018E-05	3.28497E-05	0.999884817
1.A.1	Energy Industries - Liquid Fuels	N2O	0.046484424	3.901373142	9.68847E-06	2.76707E-05	0.999912487
1.A.4	Other Sectors - Liquid Fuels	CH4	2.0986375	4.859779845	7.99142E-06	2.28238E-05	0.999935311
1.A.4	Other Sectors - Liquid Fuels	N2O	1.498450207	3.455789174	5.6705E-06	1.61952E-05	0.999951506
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N2O	1.882846248	3.482444114	4.96935E-06	1.41927E-05	0.999965699
1.A.1	Energy Industries - Liquid Fuels	CH4	0.0194985	1.636482023	4.06395E-06	1.16068E-05	0.999977306
2.F.5	Solvents	HFCs, PFCs	0	0.855614435	2.14516E-06	6.12665E-06	0.999983432

IPCC Category code	IPCC Category	Green-house gas	2000 Year Estimate Ex0 (Gg CO2 Eq)	2013 Year Estimate Ext (Gg CO2 Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CH4	0.7897845	1.460756759	2.08446E-06	5.9533E-06	0.999989386
2.A.3	Glass Production	CO2	1.8749115	2.078788152	1.46603E-06	4.18704E-06	0.999993573
1.B.2.a	Oil	CH4	0.2559875	0.67391375	1.17818E-06	3.36492E-06	0.999996938
1.A.2	Manufacturing Industries and Construction - Solid Fuels	N2O	0	0.12069	3.02588E-07	8.64204E-07	0.999997802
2.B.7	Soda Ash Production	CO2	0.369085	0.182091511	2.80849E-07	8.02116E-07	0.999998604
1.A.1	Energy Industries - Solid Fuels	N2O	0	0.106386	2.66726E-07	7.6178E-07	0.999999366
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CH4	0	0.0675	1.69233E-07	4.83336E-07	0.999999849
1.B.1	Solid Fuels	CO2	0	0.010614	2.66109E-08	7.60018E-08	0.999999925
1.A.1	Energy Industries - Solid Fuels	CH4	0	0.00595	1.49176E-08	4.26051E-08	0.999999968
1.B.2.a	Oil	CO2	0.001326034	0.005556265	1.12812E-08	3.22195E-08	1
1.B.2.a	Oil	N2O	6.556E-07	5.25208E-06	1.1858E-11	3.38668E-11	1
	Total		**183,423.81**	**146,163.85**	**0.3501**	**1**	

Table 3-25: Key Categories Assessment Based on Level Assessment

IPCC Category code	IPCC Category	Greenhouse gas	2013 Ex,t (Gg CO2 Eq)	|Ex,t| (Gg CO2 Eq)	Lx,t	Cumulative Total of Column F
3.B.1.a	Forest land Remaining Forest Land	CO2	-76253.5206	76253.5206	0.219541659	0.219541659
3.B.2.b	Land Converted to Cropland	CO2	75893.34521	75893.34521	0.218504677	0.438046336
3.B.3.b	Land Converted to Grassland	CO2	41403.88429	67929.62054	0.195576302	0.633622638
3.A.1	Enteric Fermentation	CH4	52088.325	52088.325	0.149967597	0.783590235
3.A.2	Manure Management	N2O	12037.16233	12037.16233	0.034656217	0.818246453
1.A.4	Other Sectors - Biomass	CH4	11639.77862	11639.77862	0.033512109	0.851758562
3.B.1.b	Land Converted to Forest Land	CO2)	-10727.89468	10727.89468	0.030886702	0.882645264
3.C.4	Direct N2O Emissions from Managed Soils	N2O	7553.491397	7553.491397	0.021747272	0.904392536
3.C.5	Indirect N2O Emissions from Managed Soils	N2O	5212.17824	5212.17824	0.015006392	0.919398928
1.A.3.b	Road Transportation	CO2	3847.788447	3847.788447	0.011078175	0.930477103
4.A	Solid Waste Disposal	CH4	3582.069327	3582.069327	0.010313143	0.940790246
4.D	Wastewater Treatment and Discharge	CH4	2608.985559	2608.985559	0.007511535	0.948301781
3.A.2	Manure Management	CH4	2035.375	2035.375	0.005860052	0.954161834

IPCC Category code	IPCC Category	Greenhouse gas	2013 Ex,t (Gg CO2 Eq)	|Ex,t| (Gg CO2 Eq)	Lx,t	Cumulative Total of Column F
3.C.6	Indirect N2O Emissions from Manure Management	N2O	2013.249318	2013.249318	0.00579635	0.959958184
1.A.4	Other Sectors - Biomass	N2O	1635.105115	1635.105115	0.004707634	0.964665818
1.A.1	Energy Industries - Liquid Fuels	CO2	1620.781038	1620.781038	0.004666394	0.969332212
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CO2	1459.999451	1459.999451	0.004203487	0.973535699
3.B.4.b	Land Converted to Wetlands	CO2	1437.08911	1437.08911	0.004137526	0.977673225
1.A.4	Other Sectors - Liquid Fuels	CO2	1395.231425	1395.231425	0.004017013	0.981690238
3.B.5.b	Land Converted to Settlements	CO2	1155.058874	1215.334656	0.003499072	0.985189311
4.D	Wastewater Treatment and Discharge	N2O	1125.887315	1125.887315	0.003241544	0.988430855
2.A.1	Cement Production	CO2	905.1741194	905.1741194	0.002606089	0.991036944
2.C.1	Iron and Steel Production	CO2	840.6396	840.6396	0.002420287	0.993457231
3.C.1	Emissions from Biomass Burning	N2O	757.4099606	757.4099606	0.00218066	0.995637891
3.C.1	Emissions from Biomass Burning	CH4	700.9004996	700.9004996	0.002017964	0.997655855
3.B.2.a	Cropland Remaining Cropland	CO2	-308.913605	308.913605	0.000889394	0.998545249
3.C.3	Urea Application	CO2	199.925	199.925	0.000575604	0.999120853
4.C	Incineration and Open Burning of Waste	CH4	80.62170188	80.62170188	0.000232118	0.999352972
1.A.3.b	Road Transportation	N2O	59.39989703	59.39989703	0.000171018	0.99952399
3.C.7	Rice Cultivation	CH4	28.80584911	28.80584911	8.2935E-05	0.999606925
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CO2	27.27	27.27	7.85131E-05	0.999685438
1.A.1	Energy Industries - Solid Fuels	CO2	24.038	24.038	6.92079E-05	0.999754646
4.C	Incineration and Open Burning of Waste	N2O	13.08453011	13.08453011	3.76717E-05	0.999792318
1.A.3.b	Road Transportation	CH4	10.28995214	10.28995214	2.96258E-05	0.999821943
1.B.1	Solid Fuels	CH4	9.96625	9.96625	2.86938E-05	0.999850637
4.C	Incineration and Open Burning of Waste	CO2	9.960244848	9.960244848	2.86766E-05	0.999879314
2.A.2	Lime Production	CO2	9.923816472	9.923816472	2.85717E-05	0.999907885
3.D.1	Harvested Wood Products	CO2	9.0904469	9.0904469	2.61723E-05	0.999934058
1.A.4	Other Sectors - Liquid Fuels	CH4	4.859779845	4.859779845	1.39918E-05	0.99994805
1.A.1	Energy Industries - Liquid Fuels	N2O	3.901373142	3.901373142	1.12325E-05	0.999959282
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	N2O	3.482444114	3.482444114	1.00263E-05	0.999969308
1.A.4	Other Sectors - Liquid Fuels	N2O	3.455789174	3.455789174	9.94957E-06	0.999979258
2.A.3	Glass Production	CO2)	2.078788152	2.078788152	5.98504E-06	0.999985243

IPCC Category code	IPCC Category	Greenhouse gas	2013 Ex,t (Gg CO2 Eq)	|Ex,t| (Gg CO2 Eq)	Lx,t	Cumulative Total of Column F
1.A.1	**Energy Industries - Liquid Fuels**	CH4	1.636482023	1.636482023	4.7116E-06	0.999989955
1.A.2	**Manufacturing Industries and Construction - Liquid Fuels**	CH4	1.460756759	1.460756759	4.20567E-06	0.99999416
2.F.5	**Solvents**	HFCs, PFCs	0.855614435	0.855614435	2.4634E-06	0.999996624
1.B.2.a	**Oil**	CH4	0.67391375	0.67391375	1.94027E-06	0.999998564
2.B.7	**Soda Ash Production**	CO2	0.182091511	0.182091511	5.2426E-07	0.999999088
1.A.2	**Manufacturing Industries and Construction - Solid Fuels**	N2O	0.12069	0.12069	3.47479E-07	0.999999436
1.A.1	**Energy Industries - Solid Fuels**	N2O	0.106386	0.106386	3.06296E-07	0.999999742
1.A.2	**Manufacturing Industries and Construction - Solid Fuels**	CH4	0.0675	0.0675	1.94339E-07	0.999999936
1.B.1	**Solid Fuels**	CO2	0.010614	0.010614	3.05588E-08	0.999999967
1.A.1	**Energy Industries - Solid Fuels**	CH4	0.00595	0.00595	1.71307E-08	0.999999984
1.B.2.a	**Oil**	CO2	0.005556265	0.005556265	1.59971E-08	1
1.B.2.a	**Oil**	N2O	5.25208E-06	5.25208E-06	1.51213E-11	1
	Total		**146,163.8598**	**347,330.5296**	**1**	

3.3.2. Description and Interpretation of Trends for Individual GHGs

The Revised 1996 IPCC methodology stipulates that national communications should include GHG emissions separated for each type of gas emissions and removals covering mainly the three main GHGs, carbon dioxide (CO_2), Methane (CH_4) and nitrous oxide (N_2O). Table 3-26 and Table 3-27 show a summary of the results for the years 2013 and 1994, for three greenhouse gases (CO_2, CH_4 and N_2O) and other non-GHG gases subject to complementary reporting under the Convention (CO, NOX, NMVOC and SO_X) in the format agreed to under the Convention (Table 1 of Decision 17/CP.8 of the UNFCCC).

Table 3-26: Total Emissions, 2013

Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CH4 (Gg)	N2O (Gg)	CO Gg	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
Total National Emissions and Removals	42,951.1472	2,892.1514	102.47229	785.397	52.4421	240.73066	8.7385
1 - Energy	8,375.1245	466.74956	5.7233949	0	0	0	0
1A - Fuel Combustion Activities	8,375.10836	466.32396	5.7233949	0	0	0	0
1A1 - Energy Industries	1,644.8190	0.0656972	0.0134488	0.00561	0.02253	0.0002773	0.016
1A2 - Manufacturing Industries and Construction	1,487.26945	0.061130	0.0120910	0.12911	0.85233	0.0127580	2.2251
1A3 - Transport	3,847.78844	0.4115980	0.1993285	0.75474	2.07147	0.0852321	6.0332
1A4 - Other Sectors	1,395.23142	465.78553	5.4985265	0.32364	0.29127	0.0262867	0.0388
1A5 - Other	0	0	0	0	0	0	0

Greenhouse gas source and sink categories	**CO2 Emissions (Gg)**	**CH4 (Gg)**	**N2O (Gg)**	**CO Gg**	**NOx (Gg)**	**NMVOCs (Gg)**	**SOx (Gg)**
1B - Fugitive Emissions from Fuels	0.01617026	0.4256065	1.762E-08	0	0	0	0
1B1 - Solid Fuels	0.010614	0.39865	0	0	0	0	0
1B2 - Oil and Natural Gas	0.00555626	0.0269565	1.762E-08	0	0	0	0
2 - Industrial Processes	1,757.99841	0	0	0	0	0	0
2A - Mineral Products	917.176724	0	0	0	0.42021	0	0.4252
2B - Chemical Industry	0.18209151	0	0	0.15754	0	0	0
2C - Metal Production	840.6396	0	0	0	0	0.0054813	0
3 - Solvent and Other Product Use	0	0	0	0	0	0	0
4 - Agriculture		2,164.948	40.393162	0	0	0	0
4A - Enteric Fermentation		2,083.533		0	0	0	0
4B - Manure Management		81.415	40.393162	0	1.7426	240.5675	0
4C - Rice Cultivation		1.1522339		0	0	0	0
4D - Agricultural Soils			25.347286	0	0	0	0
4E - Prescribed Burning of Savannas		27.742505	2.5330113	784.0273	47.04164	0	0
4G - Other	9.11340332	0	0	0	0	0	0
5 - Land-Use Change & Forestry	32,599.0486		0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-76253.5206			0	0	0	0
5B - Forest and Grassland Conversion	30,675.9896			0	0	0	0
5E - Other	0			0	0	0	0
6 - Waste	9.96024484	231.26560	3.8220531	0	0	0	0
6A - Solid Waste Disposal on Land		143.27371		0	0	0	0
6B - Wastewater Handling		84.767025	3.7781453	0	0	0.03312199	0
6C - Waste Incineration	9.96024484	3.22486807	0.0439078	0	0	0	0
Memo Items							
International Bunkers	1075.70863	0.00752243	0.03008975	0	0	0	0
1A3a1 - International Aviation	1075.70863	0.00752243	0.03008975	0	0	0	0
1A3d1 - International Marine (Bunkers)	0	0	0	0	0	0	0
CO2 emissions from biomass	188,485.506						

Table 3-27: Total Emissions, 1994

Greenhouse gas source and sink categories	**CO2 Emissions (Gg)**	**CH4 (Gg)**	**N2O (Gg)**	**CO (Gg)**	**NOx (Gg)**	**NMVOCs (Gg)**	**SOx (Gg)**
Total National Emissions and Removals	-26050.54	1481.336	48.44820	982.6534	58.97675	240.6554	2.70529
1 - Energy	2000.133	239.2829	3.134244	0	0	0	0
1A - Fuel Combustion Activities	2000.130	239.2742	3.134244			0	0
1A1 - Energy Industries	25.68602	0.108919	0.014591	0.005615	0.022531	0.000277	0.01611
1A2 - Manufacturing Industries and Construction	624.79106	0.012428	0.004949	0.129115	0.852338	0.012758	2.22511
1A3 - Transport	1,014.4960	0.234044	0.047034	0.12412	0.03028	0.015546	0
1A4 - Other Sectors	335.15773	238.9188	3.067668	0.32364	0.291276	0.026286	0.03883
1A5 - Other	0	0	0	0	0	0	0
1B - Fugitive Emissions from Fuels	0.0028670	0.008624	1.18E-08	0	0	0	0
1B1 - Solid Fuels	0	0	0	0	0	0	0
1B2 - Oil and Natural Gas	0.0028670	0.008624	1.18E-08	0	0	0	0
2 - Industrial Processes	354.45822	0	0	0	0	0	0
2A - Mineral Products	303.42858	0	0	0	0.42021	0	0.425226
2B - Chemical Industry	1.6979498	0	0	0.1575417	0	0	0
2C - Metal Production	49.3317	0	0	0	0.0054813	0	0
2D - Other Production	0	0	0	0	0	0	0
2E - Production of Halocarbons and Sulfur Hexafluoride				0	0	0	0
2F - Consumption of Halocarbons and Sulfur Hexafluoride				0	0	0	0
2G - Other (please specify)	0	0	0	0	0	0	0
3 - Solvent and Other Product Use	0	0	0	0	0	0	0
4 - Agriculture		1,158.6481	21.085346	0	0	0	0
4A - Enteric Fermentation		1,116.59		0	0	0	0
4B - Manure Management		42.0581	21.085346	0	1.742695	240.56750	0
4C - Rice Cultivation		0.1488140		0	0	0	0
4D - Agricultural Soils			10.175503	0	0	0	0
4E - Prescribed Burning of Savannas		32.796778	2.9944885	926.86549	55.611929	0	0
4F - Field Burning of Agricultural Residues		0	0	0	0	0	0

Greenhouse gas source and sink categories	CO2 Emissions (Gg)	CH4 (Gg)	N2O (Gg)	CO (Gg)	NOx (Gg)	NMVOCs (Gg)	SOx (Gg)
4G - Other	-78.713501	0	0	0	0	0	0
5 - Land-Use Change & Forestry	-28,360.159		0	0	0	0	0
5A - Changes in Forest and Other Woody Biomass Stocks	-282,774.57			0	0	0	0
5B - Forest and Grassland Conversion	164,525.28			0	0	0	0
5E - Other (please specify)	0			0	0	0	0
6 - Waste	4.5472785	46.812079	2.3274038	0	0	0	0
6A - Solid Waste Disposal on Land		4.5986413		0	0	0	0
6B - Wastewater Handling		40.741148	2.3073580	0	0	0.033122	0
6C - Waste Incineration	4.5472785	1.4722904	0.0200458	0	0	0	0
6D - Other	0	0	0	0	0	0	0
7 - Other	0	0	0	0	0	0	0
Memo Items							
International Bunkers	432.9325	0.0030275	0.01211	0.0914305	0.85981	0.0139265	2.99722
1A3a1 - International Aviation	432.9325	0.0030275	0.01211	0.0914305	0.85981	0.0139265	2.99722
1A3d1 - International Marine (Bunkers)	0	0	0	0	0	0	0
CO2 emissions from biomass	92,226.816						

Table 3-28 shows the change in Ethiopia's sinks and sources between 1994 and 2013. Ethiopia's net emissions contribution increased by a sizeable 450 per cent. However, at sector level, there are significant increases and reductions in emissions at various sub-category levels. Energy sector emissions increased by 144 per cent, IPPU sector emissions by 396 per cent and waste sector by 297 per cent while there was a particularly large increase in emissions from AFOLU, by 657 per cent. Substantial decreases in emissions were recorded in the soda ash production and grassland sub-categories, of 89 per cent and 76 per cent respectively.

Table 3-28: Change in Ethiopia's Sinks and Sources in 1994 and 2013

Categories	CO2e (Gg) 2013	CO2e (Gg) 1994	Difference	Percentage Difference
Total National Emissions and Removals	146,163.00	25,420.425	120,728.51	474.66466
1 - Energy	21,749.435	8,916.2112	12,833.224	143.93136
1.A - Fuel Combustion Activities	21,738.779	8,915.9927	12,822.786	143.81782
1.A.1 - Energy Industries	1,650.4692	32.757433	1,617.7118	4,938.4571
1.A.2 - Manufacturing Industries and Construction	1,492.4008	626.57668	865.82416	138.18327
1.A.3 - Transport	3,917.4783	1,034.3635	2,883.1148	278.73324
1.A.4 - Other Sectors	14,678.431	7,222.2952	7,456.1356	103.23776
1.B - Fugitive Emissions from Fuels	10.656339	0.2184768	10.437862	4777.5606

Categories	CO2e (Gg) 2013	CO2e (Gg) 1994	Difference	Percentage Difference
1.B.2 - Oil and Natural Gas	0.6794753	0.2184768	0.4609984	211.00565
2 - Industrial Processes and Product Use	1,757.9984	354.45823	1,403.5402	395.96772
2.A - Mineral Industry	917.17672	303.42858	613.74814	202.27104
2.A.1 - Cement Production	905.17412	300.846	604.32812	200.87624
2.A.2 - Lime Production	9.9238165	2.09979	7.8240265	372.60995
2.A.3 - Glass Production	2.0787882	0.48279	1.5959982	330.57813
2.B - Chemical Industry	0.1820915	1.6979498	-1.5158583	-89.275801
2.B.7 - Soda Ash Production	0.1820915	1.6979498	-1.5158583	-89.275801
2.C - Metal Industry	840.6396	49.3317	791.3079	1,604.0556
2.C.1 - Iron and Steel Production	840.6396	49.3317	791.3079	1,604.0556
3 - Agriculture, Forestry, and Other Land Use	108,140.53	1,4281.34	93,859.186	657.21553
3.A - Livestock	66,160.862	35,249.636	30,911.226	87.692329
3.A.1 - Enteric Fermentation	52,088.325	27,914.75	24,173.575	86.597856
3.A.2 - Manure Management	14,072.537	7,334.8858	6,737.6515	91.857619
3.B - Land	32,599.0486	-28,346.09899	53,864.773	-189.93114
3.B.1 - Forestland	-91,481.848	-29,1090.27	19,9608.42	-68.572687
3.B.2 - Cropland	75,582.577	89,703.881	-14,121.304	-15.742133
3.B.3 - Grassland	41.403.884	172,840.98	-131,437.09	-76.045099
3.B.4 - Wetlands	1,437.089	54.556757	1,382.5322	2,534.1173
3.B.5 - Settlements	1,155.058	143.45375	1,011.6043	705.17798
3.C - Aggregate sources and non-CO2 emissions sources on land	16,465.96	7,470.5776	8,995.3827	120.41081
3.C.1 - Emissions from Biomass Burning	1,458.3105	1,835.4396	-377.12918	-20.547076
3.C.3 - Urea Application	199.925	29.186667	170.73833	584.98744
3.C.4 - Direct N2O Emissions from managed soils	7,553.4914	3,032.3	4,521.1914	149.10106
3.C.5 - Indirect N2O Emissions from managed soils	5,212.1782	2,311.753	2,900.4252	125.46432
3.C.6 - Indirect N2O Emissions from manure management	2,013.2493	258.17796	1,755.0714	679.79133
3.C.7 - Rice Cultivation	28.805849	3.7203507	25.085498	674.27778
3.D - Other	9.0904469	-78.713502	87.803949	-111.54878
3.D.1 - Harvested Wood Products	9.0904469	-78.713502	87.803949	-111.54878
4 - Waste	7,420.6087	1,868.4156	5,552.1931	297.16049
4.A - Solid Waste Disposal	3,582.0693	114.96603	3,467.1033	3,015.7632
4.C - Incineration and Open Burning of Waste	103.66648	47.328189	56.338288	119.03749
4.D - Wastewater Treatment and Discharge	3,734.8729	1,706.1214	2,028.7515	118.91015
International Bunkers	1,084.8634	436.61697	648.24647	148.47029
1.A.3.a.i - International Aviation (International Bunkers)	1,084.8634	436.61697	648.24647	148.47029

Table 3-29 shows the emissions results for all the inventory years expressed in terms of individual GHGs and CO_2 equivalent for the various IPCC categories, while Table 3-30 presents the emissions results in carbon dioxide equivalents for all the inventory years.

Table 3-29: Total Emissions by GHGs (Gg) and CO2 Equivalents

Inventory Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Total Emissions (Gg) (CO2 Equivalents)	25,433.179	124,159.49	104,606.97	130,230.52	133,209.21	134,092.33	183,422.00	202,697.74	201,828.80	204,306.18
Carbon Dioxide (CO2) Emissions										
Total National CO2 Emissions and Removals	-26,050.54	72,340.089	50,511.81	51,561.39	53,760.92	54,478.54	105,663.2	122,681.3	113,253.8	116,779.5
1 - Energy	2,000.1338	1,878.5741	2,232.039	2,601.922	2,707.940	2,690.320	2,957.170	3,722.034	3,888.116	4,211.647
1A - Fuel Combustion Activities	2,000.1309	1,878.5713	2,232.036	2,601.919	2,707.938	2,690.319	2,957.169	3,722.032	3,888.114	4,211.645
1A1 - Energy Industries	25.686024	22.475271	22.47527	28.89677	41.73978	16.05376	19.26451	19.26451	16.05376	12.84301
1A2 - Manufacturing Industries and Construction (ISIC)	624.79107	675.28777	700.6803	659.3317	723.0798	713.4454	795.8893	960.7109	1,008.262	944.5296
1A3 - Transport	1,014.4961	804.26836	1,068.948	1,446.489	1,354.592	1,392.452	1,533.81	1,912.515	2,006.635	2,092.909
1A4 - Other Sectors	335.15773	376.53988	439.9323	467.2011	588.5263	568.3670	608.2050	829.5415	857.1623	1,161.362
1A5 - Other	0	0	0	0	0	0	0	0	0	0
1B - Fugitive Emissions from Fuels	0.002867	0.0028067	0.002866	0.002896	0.002142	0.001253	0.001326	0.001608	0.001652	0.001959
1B1 - Solid Fuels	0	0	0	0	0	0	0	0	0	0
1B2 - Oil and Natural Gas	0.002867	0.0028067	0.002866	0.002896	0.002142	0.001253	0.001326	0.001608	0.001652	0.001959
2 - Industrial Processes	354.45823	355.02774	220.3275	288.8590	282.0750	468.8543	474.8437	522.8179	570.2437	809.2016
2A - Mineral Products	303.42858	304.24044	175.4872	252.2208	238.5331	408.9233	413.1806	460.0995	446.2690	710.2769
2B - Chemical Industry	1.6979498	1.4556049	1.94	1.069746	0.917063	0.786173	0.369085	1.040934	0.372771	0.424569
2C - Metal Production	49.3317	49.3317	42.9003	35.56845	42.6249	59.14485	61.29405	61.67745	123.6019	98.50005
2D - Other Production										
2E - Production of Halocarbons and Sulfur Hexafluoride										
2F - Consumption of Halocarbons and Sulfur Hexafluoride										
2G - Other (please specify)										
3 - Solvent and Other Product Use										
4 - Agriculture										
4A - Enteric Fermentation										
4B - Manure Management										
4C - Rice Cultivation										

Inventory Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
4D - Agricultural Soils										
4E - Prescribed Burning of Savannas										
4F - Field Burning of Agricultural Residues										
4G - Other	-78.702953	-76.442293	-59.34514	-140.6889	-120.1724	-130.0231	-134.7445	-132.5935	-42.0233	-72.2244
5 - Land-Use Change & Forestry	-28,360.16	70,145.595	48,082.09	48,768.12	50,821.16	51,374.15	102,650.5	118,491.0	108,775.1	111,746.2
5A - Changes in Forest and Other Woody Biomass Stocks	-282,774.6	-151,954.57	-145,074.3	-127,504.7	-112,951.2	-100,708.7	-84,887.37	-84887.37	-84887.37	-84887.37
5B - Forest and Grassland Conversion	164,525.28	136,046.8	109,883.2	99,728.46	89,652.32	80,323.05	99,164.73	114,824.7	104,933.9	107,719.4
5E - Other (please specify)										
6 - Waste	4.5472786	4.7667232	4.980122	5.195939	5.415988	5.644501	5.883291	6.132357	6.392305	6.662530
6A - Solid Waste Disposal on Land										
6B - Wastewater Handling										
6C - Waste Incineration	4.5472786	4.7667232	4.980122	5.195939	5.415988	5.644501	5.883291	6.132357	6.392305	6.662530
6D - Other (please specify)										
7 - Other (please specify)										
Methane (CH_4) Emissions										
Total National Emissions and Removals	1,481.3359	1,522.7423	1,578.165	2,366.424	2,387.236	2,396.416	2,339.978	2,417.284	2,660.762	2,637.420
1 - Energy	239.28291	266.461	266.5159	882.9748	892.4102	908.0292	923.6232	936.1675	948.8044	961.6198
1A - Fuel Combustion Activities	239.27428	266.4514	266.5056	882.9642	892.3995	908.0197	923.6130	936.1542	948.7906	961.6027
1A1 - Energy Industries	0.1089199	0.1477659	0.19579	0.196397	0.197613	0.26687	0.000779	0.000779	0.00065	0.00052
1A2 - Manufacturing Industries and Construction (ISIC)	0.0124286	0.0268568	0.027846	0.026243	0.028671	0.028319	0.031591	0.038160	0.040052	0.037653
1A3 - Transport	0.2340446	0.1870835	0.179073	0.223465	0.244239	0.247522	0.266578	0.332973	0.346961	0.342467
1A4 - Other Sectors	238.91889	266.0897	266.1029	882.5181	891.9289	907.4770	923.3140	935.7823	948.4029	961.2221
1A5 - Other	0	0	0	0	0	0	0	0	0	0
1B - Fugitive Emissions from Fuels	0.0086243	0.0095963	0.010251	0.010573	0.010728	0.009452	0.010239	0.013308	0.013784	0.017120
1B1 - Solid Fuels	0	0	0	0	0	0	0	0	0	0
1B2 - Oil and Natural Gas	0.0086243	0.0095963	0.010251	0.010573	0.010728	0.009452	0.010239	0.013308	0.013784	0.017120
2 - Industrial Processes										
2A - Mineral Products										
2B - Chemical Industry										

Inventory Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
2C - Metal Production										
2D - Other Production										
2E - Production of Halocarbons and Sulfur Hexafluoride										
2F - Consumption of Halocarbons and Sulfur Hexafluoride										
2G - Other (please specify)										
3 - Solvent and Other Product Use										
4 - Agriculture	1,158.6481	1,166.6407	1,221.297	1,378.823	1,378.823	1,354.512	1,273.322	1,363.423	1,574.122	1,539.392
4A - Enteric Fermentation	1,116.59	1,124.666	1,177.629	13,30.006	1,330.006	1,306.598	1,227.759	1,314.654	1,517.930	1,484.541
4B - Manure Management	42.0581	41.9747	43.6678	48.816569	48.816569	47.914257	45.563593	48.769166	56.192338	54.850733
4C - Rice Cultivation	0.148814	0.1986943	0.162593	0.192603	0.179128	0.192907	0.206686	0.225976	0.230496	0.212197
4D - Agricultural Soils										
4E - Prescribed Burning of Savannas	32.796779	32.796779	31.04078	29.81784	36.81645	37.46756	34.96865	27.53194	41.1777	34.29308
4F - Field Burning of Agricultural Residues										
4G - Other (please specify)										
5 - Land-Use Change & Forestry										
5A - Changes in Forest and Other Woody Biomass Stocks										
5B - Forest and Grassland Conversion										
5E - Other (please specify)										
6 - Waste	46.81163	52.99748	58.72911	64.86858	71.74839	78.09207	88.73907	89.77190	95.69948	101.0847
6A - Solid Waste Disposal on Land	4.5981915	8.9721188	13.34495	18.01374	23.06967	28.03472	32.10064	35.88370	39.85706	43.62984
6B - Wastewater Handling	40.741148	42.48202	43.77172	45.17253	46.92516	48.22980	54.73357	51.9027	53.77275	55.29775
6C - Waste Incineration	1.4722905	1.5433409	1.612434	1.682310	1.753556	1.827542	1.904856	1.985497	2.069662	2.157154
6D - Other (please specify)										
7 - Other (please specify)										
Nitrous Oxide (N_2O) Emissions										
Total National Emissions and Removals	47.998851	45.277074	49.19005	64.76394	65.63297	66.18014	63.46179	64.63397	74.08468	72.53208
1 - Energy	3.134244	3.4899443	3.511360	11.68752	11.80711	12.01956	12.19742	12.38043	12.54871	12.72028
1A - Fuel Combustion Activities	3.134244	3.4899443	3.511360	11.68752	11.80711	12.01956	12.19742	12.38043	12.54871	12.72028

Inventory Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
1A1 - Energy Industries	0.014592	0.0197628	0.026166	0.026264	0.026461	0.035626	0.000156	0.000156	0.00013	0.000104
1A2 - Manufacturing Industries and Construction (ISIC)	0.0049493	0.0053714	0.005569	0.005248	0.005734	0.005663	0.006318	0.007632	0.008010	0.007530
1A3 - Transport	0.0470345	0.0380851	0.05235	0.071846	0.068658	0.070631	0.077894	0.097118	0.101934	0.106612
1A4 - Other Sectors	3.0676682	3.426725	3.427275	11.58416	11.70625	11.90764	12.11305	12.27552	12.43863	12.60604
1A5 - Other										
1B - Fugitive Emissions from Fuels	1.188E-08	1.102E-08	1.102E-08	1.102E-08	6.622E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09
1B1 - Solid Fuels										
1B2 - Oil and Natural Gas	1.188E-08	1.102E-08	1.102E-08	1.102E-08	6.622E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09
2 - Industrial Processes										
2A - Mineral Products										
2B - Chemical Industry										
2C - Metal Production										
2D - Other Production										
2E - Production of Halocarbons and Sulfur Hexafluoride										
2F - Consumption of Halocarbons and Sulfur Hexafluoride										
2G - Other (please specify)										
3 - Solvent and Other Product Use										
4 - Agriculture	20.513448	19.543095	20.41759	22.37413	22.37413	22.71885	21.36107	22.27336	26.42895	25.68491
4A - Enteric Fermentation										
4B - Manure Management	20.513448	19.543095	20.41759	22.37413	22.37413	22.71885	21.36107	22.27336	26.42895	25.68491
4C - Rice Cultivation										
4D - Agricultural Soils	10.175503	7.1336886	8.985562	12.03889	12.11518	11.84971	11.20884	11.73093	13.88716	13.39496
4E - Prescribed Burning of Savannas	2.9944885	2.9944885	2.834158	2.722499	3.361502	3.420951	3.192790	2.513786	3.759703	3.131107
4F - Field Burning of Agricultural Residues										
4G - Other (please specify)										
5 - Land-Use Change & Forestry										
5A - Changes in Forest and Other Woody Biomass Stocks										

Inventory Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
5B - Forest and Grassland Conversion										
5E - Other (please specify)										
6 - Waste	2.3274038	2.4045963	2.480425	2.555327	2.630270	2.706724	2.785746	2.867630	2.325482	2.919755
6A - Solid Waste Disposal on Land										
6B - Wastewater Handling	2.307358	2.3835831	2.458471	2.532422	2.606394	2.681841	2.759811	2.840597	2.297303	2.890381
6C - Waste Incineration	0.0200458	0.0210132	0.021953	0.022905	0.023875	0.024882	0.025935	0.027033	0.028179	0.029370
6D - Other (please specify)										
7 - Other (please specify)										

Table 3-30: Total Emissions by GHGs(Gg) and CO2 Equivalents (Continued)

Inventory Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total Emissions (Gg) CO2 Equivalents	157,626.65	144,358.07	148,884.24	160,211.53	176,075.07	173,651.75	186,361.60	208,884.77	142,590.49	146,160.43
Carbon Dioxide (CO2) Emissions										
Total National CO2 Emissions and Removals	66,810.55	68,019.98	68,512.75	71,372.27	85,187.04	80,912.06	88,095.24	111,818.2	40,266.83	35,856.73
1 - Energy	4,442.00	5,061.94	5,370.96	6,352.12	6,843.50	7,022.19	9,903.487	7,635.680	7,892.952	8,375.124
1A - Fuel Combustion Activities	4,441.998	5,061.940	5,370.957	6,352.120	6,843.496	7,022.169	9,903.330	7,635.666	7,892.936	8,375.108
1A1 - Energy Industries	16.05376	54.0962	42.53413	296.1252	835.5813	900.5733	1,360.083	1,330.857	1,455.546	1,644.819
1A2 - Manufacturing Industries and Construction (ISIC)	1,143.078	946.7665	974.3341	1,279.107	1,084.681	1,072.816	1,214.248	1,325.963	1,402.28	1,487.269
1A3 - Transport	2,246.703	3,134.733	3,369.282	3,689.164	3,808.603	3,968.596	6,294.998	3,701.868	3,701.868	3847.788
1A4 - Other Sectors	1,036.162	926.3437	984.8068	1,087.724	1,114.630	1,080.184	1,034.000	1,276.977	1,333.241	1,395.231
1A5 - Other										
1B - Fugitive Emissions from Fuels	0.002335	0.002972	0.003122	0.004554	0.011174	0.021411	0.157457	0.013987	0.015783	0.016170
1B1 - Solid Fuels					0.006551	0.015994	0.151981	0.009369	0.010614	0.010614
1B2 - Oil and Natural Gas	0.002335	0.002972	0.003122	0.004554	0.004622	0.005417	0.005475	0.004618	0.005169	0.005556
2 - Industrial Processes	840.3470	1,520.340	973.5289	2,706.958	1,487.501	1,973.449	1,222.036	1,877.166	1,752.893	1,757.998
2A - Mineral Products	627.4996	627.5588	856.4426	821.7807	795.4604	1,039.869	956.4185	932.9251	820.7299	917.1767
2B - Chemical Industry	0.889272	1.132566	0.3977	0.097	0.154909	1.552	0.051384	0.130884	0.135385	0.182091
2C - Metal Production	211.9581	891.6493	116.6886	1885.080	691.8858	932.0278	265.5666	944.1103	932.0278	840.6396

Inventory Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2D - Other Production										
2E - Production of Halocarbons and Sulfur Hexafluoride										
2F - Consumption of Halocarbons and Sulfur Hexafluoride										
2G - Other (please specify)										
3 - Solvent and Other Product Use										
4 - Agriculture										
4A - Enteric Fermentation										
4B - Manure Management										
4C - Rice Cultivation										
4D - Agricultural Soils										
4E - Prescribed Burning of Savannas										
4F - Field Burning of Agricultural Residues										
4G - Other (please specify)	-75.37787	-86.13171	-93.26088	-98.72952	-69.93494	-84.03834	-94.6134	7.805127	6.039788	9.113403
5 - Land-Use Change & Forestry	61,514.45	61,427.34	62,162.67	62,309.42	76,815.91	71,883.15	76,907.70	102,141.4	30,434.15	25,504.61
5A - Changes in Forest and Other Woody Biomass Stocks	-71,867.47	-71,988.66	-71,867.47	-71,867.47	-75,071.15	-75,071.15	-75,075.19	-75,105.90	-78,325.26	-80,753.95
5B - Forest and Grassland Conversion	35656.39	35656.39	35656.39	35256.45	59851.65	54764.20	59632.63	84728.63	31203.74	30675.99
5E - Other (please specify)										
6 - Waste	6.941824	7.228976	7.524591	7.828065	8.145444	8.476727	8.823122	9.185236	9.564277	9.960244
6A - Solid Waste Disposal on Land										
6B - Wastewater Handling										
6C - Waste Incineration	6.941824	7.228976	7.524591	7.828065	8.145444	8.476727	8.823122	9.185236	9.564277	9.960244
6D - Other (please specify)										
7 - Other (please specify)										
Methane (CH4) Emissions										
Total National Emissions and Removals	2,682.067	2,156.222	2,237.314	2,485.711	2,536.429	2,622.075	2,747.974	2,853.666	2,873.01	2,911.743
1 - Energy	974.5536	348.1664	370.2791	370.6962	381.6352	392.6401	403.6902	542.6694	472.4955	466.7495
1A - Fuel Combustion Activities	974.5366	348.1508	370.2628	370.6760	381.4570	392.1272	402.8667	542.2949	472.0710	466.3239
1A1 - Energy Industries	0.00065	0.001762	0.001737	0.009013	0.419851	0.399048	0.054010	0.052883	0.057969	0.065697

Inventory Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1A2 - Manufacturing Industries and Construction (ISIC)	0.044305	0.037945	0.039049	0.063210	0.045310	0.046632	0.049517	0.053889	0.056976	0.061130
1A3 - Transport	0.32991	0.356	0.364472	0.378727	0.394048	0.417956	0.527492	0.403918	0.403918	0.411598
1A4 - Other Sectors	974.1617	347.7551	369.8576	370.2251	380.5978	391.2636	402.2357	541.7842	471.5522	465.7855
1A5 - Other										
1B - Fugitive Emissions from Fuels	0.0170333	0.0155745	0.016281	0.0202088	0.178149	0.5128658	0.8235318	0.3745328	0.4244601	0.4256066
1B1 - Solid Fuels					0.155909	0.490172	0.803665	0.351884	0.39865	0.39865
1B2 - Oil and Natural Gas	0.017033	0.015574	0.016281	0.020208	0.02224	0.022693	0.019866	0.022648	0.025810	0.026956
2 - Industrial Processes										
2A - Mineral Products										
2B - Chemical Industry										
2C - Metal Production										
2D - Other Production										
2E - Production of Halocarbons and Sulfur Hexafluoride										
2F - Consumption of Halocarbons and Sulfur Hexafluoride										
2G - Other (please specify)										
3 - Solvent and Other Product Use										
4 - Agriculture	1,565.706	1,653.594	1,709.156	1,941.511	1,968.381	2,026.691	2,129.205	2,076.489	2,149.359	2,164.948
4A - Enteric Fermentation	1,509.838	1,594.808	1,645.977	1,871.312	1,895.124	1,951.008	2,049.514	1,998.639	2,068.900	2,083.533
4B - Manure Management	55.86860	58.78611	63.17925	70.19922	73.25785	75.68286	79.69116	77.85041	80.45953	81.415
4C - Rice Cultivation	0.198418	0.179128	0.171990	0.176950	0.673357	0.966968	1.315595	0.823056	1.315595	1.152234
4D - Agricultural Soils										
4E - Prescribed Burning of Savannas	35.04737	41.41902	27.93532	35.04983	28.79725	30.94723	28.82500	27.74250	27.74250	27.74250
4F - Field Burning of Agricultural Residues										
4G - Other (please specify)										
5 - Land-Use Change & Forestry										
5A - Changes in Forest and Other Woody Biomass Stocks										
5B - Forest and Grassland Conversion										

Inventory Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
5E - Other (please specify)										
6 - Waste	106.0265	112.0039	129.3990	137.6828	155.7243	170.7646	184.6394	205.6476	221.8032	250.858
6A - Solid Waste Disposal on Land	46.95742	50.70938	55.27507	61.18725	68.81133	79.13815	94.06395	111.9864	127.3037	143.2737
6B - Wastewater Handling	56.82154	58.95397	71.68771	73.96105	84.27571	88.88193	87.71881	90.68725	91.402795	104.3594
6C - Waste Incineration	2.247581	2.340554	2.436266	2.534524	2.637282	2.744543	2.856697	2.973940	3.096664	3.224868
6D - Other (please specify)										
7 - Other (please specify)										
Nitrous Oxide (N2O) Emissions										
Total National Emissions and Removals	79.83515	75.37768	79.76175	89.71133	92.33034	91.35840	99.34027	86.44182	102.7346	102.4722
1 - Energy	12.89614	4.800781	5.107859	5.093020	5.287392	5.433106	5.655629	7.380613	6.465895	5.723395
1A - Fuel Combustion Activities	12.89614	4.800781	5.107859	5.093020	5.287392	5.433106	5.655629	7.380613	6.465895	5.723394
1A1 - Energy Industries	0.00013	0.000516	0.000347	0.003731	0.058255	0.055839	0.011111	0.010886	0.011903	0.013448
1A2 - Manufacturing Industries and Construction	0.008861	0.007589	0.007809	0.011577	0.008843	0.008956	0.009785	0.010643	0.011260	0.012091
1A3 - Transport	0.115025	0.162077	0.174474	0.191356	0.197502	0.205688	0.328327	0.191645	0.191645	0.199325
1A4 - Other Sectors	12.77213	4.630604	4.925226	4.886351	5.022796	5.162628	5.306401	7.167433	6.251086	5.498525
1A5 - Other										
1B - Fugitive Emissions from Fuels	4.4E-09	8.8E-09	9.3E-09	1.54E-08	1.47E-08	1.90E-08	2.09E-08	1.45E-08	1.60E-08	1.76E-08
1B1 - Solid Fuels										
1B2 - Oil and Natural Gas	4.4E-09	8.82E-09	9.30E-09	1.54E-08	1.47E-08	1.90E-08	2.09E-08	1.45E-08	1.60E-08	1.76E-08
2 - Industrial Processes										
2A - Mineral Products										
2B - Chemical Industry										
2C - Metal Production										
2D - Other Production										
2G - Other (please specify)										
3 - Solvent and Other Product Use										
4 - Agriculture	26.01015	27.35070	30.78382	35.52229	36.53178	37.56057	39.57935	38.69961	40.13637	40.39316
4A - Enteric Fermentation										
4B - Manure Management	26.01015	27.35070	30.78382	35.52229	36.53178	37.56057	39.57935	38.69961	40.13637	40.39316

Inventory Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
4C - Rice Cultivation										
4D - Agricultural Soils	17.99317	18.78024	19.57324	22.38074	23.01364	23.88283	24.87952	14.69993	25.33343	25.34728
4E - Prescribed Burning of Savannas	3.199977	3.781737	2.550616	3.200202	2.629314	2.825617	2.631848	2.533011	2.533011	2.533011
4F - Field Burning of Agricultural Residues										
4G - Other (please specify)										
5 - Land-Use Change & Forestry										
5A - Changes in Forest and Other Woody Biomass Stocks										
5B - Forest and Grassland Conversion										
5E - Other (please specify)										
6 - Waste	3.004357	3.089982	3.176540	2.572125	3.353148	3.443615	3.535770	3.629622	3.725075	3.822053
6A - Solid Waste Disposal on Land										
6B - Wastewater Handling	2.973755	3.058114	3.143369	2.537617	3.317240	3.406247	3.496875	3.589131	3.682913	3.778145
6C - Waste Incineration	0.030601	0.031867	0.0331707	0.034508	0.0359076	0.037368	0.038895	0.040491	0.042162	0.043907
6D - Other (please specify)										
7 - Other (please specify)										

Table 3-30 shows total annual emissions expressed in carbon dioxide equivalents for the period 1994-2013 by category and sub-category.

Table 3-30: Total Emissions in Carbon Dioxide Equivalents

Categories	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total National Emissions and Removals	25,433.179	124,159.49	104,606.97	130,230.52	133,209.21	134,092.33	183,422.00	202,697.74	201,828.80	204,306.18
1 - Energy	8,916.211	9,580.102	9,941.321	28,159.18	28,536.72	28,972.88	29,682.58	30,815.59	31,347.74	32,042.79
1.A - Fuel Combustion Activities	8,915.993	9,579.86	9,941.062	28,158.91	28,536.45	28,972.64	29,682.33	30,815.26	31,347.4	32,042.36
1.A.1 - Energy Industries	32.75743	32.05873	35.16748	41.63351	54.56557	33.34206	19.3305	19.3305	16.10875	12.887
1.A.2 - Manufacturing Industries and Construction	626.5767	677.5599	703.0362	661.5519	725.5054	715.8413	798.562	963.9393	1,011.651	947.7151
1.A.3 - Transport	1,034.363	820.2948	1,089.026	1,473.487	1,381.159	1,419.689	1,563.687	1,949.781	2,045.686	2,133.242
1.A.4 - Other Sectors	7,222.295	8,049.946	8,113.833	25,982.24	26,375.22	26,803.77	27,300.75	27,882.21	28,273.95	28,948.52
1.B - Fugitive emissions from fuels	0.218477	0.242716	0.259139	0.267225	0.270345	0.237573	0.257314	0.334309	0.346265	0.429966
1.B.1 - Solid Fuels	0	0	0	0	0	0	0	0	0	0
1.B.2 - Oil and Natural Gas	0.218477	0.242716	0.259139	0.267225	0.270345	0.237573	0.257314	0.334309	0.346265	0.429966
2 - Industrial Processes and Product Use	354.4582	355.0277	220.3275	288.8591	282.0751	468.8543	474.8438	522.8179	570.2437	809.2016
2.A - Mineral Industry	303.4286	304.2404	175.4872	252.2209	238.5331	408.9233	413.1806	460.0995	446.269	710.277
2.A.1 - Cement production	300.846	300.846	168.6062	245.6932	231.9559	402.9363	404.6092	454.0668	439.7494	699.1024
2.A.2 - Lime production	2.09979	2.91165	4.25508	4.33355	3.90521	4.13	6.6965	4.60495	6.21388	9.25061
2.A.3 - Glass Production	0.48279	0.48279	2.626008	2.194154	2.671977	1.857009	1.874912	1.427811	0.305729	1.923999
2.B - Chemical Industry	1.69795	1.455605	1.94	1.069746	0.917064	0.786173	0.369085	1.040934	0.372771	0.424569
2.B.7 - Soda Ash Production	1.69795	1.455605	1.94	1.069746	0.917064	0.786173	0.369085	1.040934	0.372771	0.424569
2.C - Metal Industry	49.3317	49.3317	42.9003	35.56845	42.6249	59.14485	61.29405	61.67745	123.602	98.50005
2.C.1 - Iron and Steel Production	49.3317	49.3317	42.9003	35.56845	42.6249	59.14485	61.29405	61.67745	123.602	98.50005
3 - Agriculture, Forestry, and Other Land Use	14,294.09	112,178.1	92,232.91	99,394.04	101,807.4	101,886	150,210	168,254.3	166,818.8	168,050.2
3.A - Livestock	35,249.64	34,989.86	36,616.86	41,348.61	41,348.61	40,633.03	38,198.66	40,915.2	47,228.9	46,138.91
3.A.1 - Enteric Fermentation	27,914.75	28,116.65	29,440.73	33,250.16	33,250.16	32,664.96	30,693.98	32,866.37	37,948.26	37,113.53
3.A.2 - Manure Management	7,334.886	6,873.21	7,176.139	8,098.445	8,098.445	7,968.074	7,504.689	8,048.837	9,280.636	9,025.373
3.B - Land	-28,347.41	70,418.51	48,080.52	48,766.39	50,819.33	51,372.22	102,648.7	118,489.1	108,773	111,744.2
3.B.1 - Forest land	-291,090.3	-161,562.1	-154,246.5	-135,690.7	-121,111.3	-108,879.1	-93,845.02	-93,845.02	-93,845.02	-93,845.02
3.B.2 - Cropland	89,703.88	86,053.37	82,931.26	76,107.68	73,569.23	71,071.34	88,008.97	88,008.97	88,002.59	88,007.49
3.B.3 - Grassland	172,841	145,654.4	119,055.3	107,914.4	97,812.45	88,493.4	108,122.4	123,782.4	113,891.6	116,677

Categories	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
3.B.4 - Wetlands	54.54826	87.76351	100.0616	119.5951	133.085	161.1665	197.5998	296.3996	395.1995	493.9994
3.B.5 - Settlements	143.4538	185.15	240.2981	315.422	415.9044	525.3934	164.7495	246.4158	328.5544	410.693
3.C - Aggregate sources and non-CO2 emissions sources on land	7,470.578	6,846.151	7,594.887	9,419.747	9,759.672	10,010.76	9,497.392	8,982.538	10,859.03	10,239.33
3.C.1 - Emissions from biomass burning	1835.44	1835.44	1634.768	1885.89	2167.232	2568.024	2471.178	1442.924	2174.412	1818.022
3.C.3 - Urea application	29.18667	32.56807	31.7306	37.99253	64.51573	69.60727	73.74547	71.90847	55.9746	78.02227
3.C.4 - Direct N2O Emissions from managed soils	3,032.3	2,125.839	2,677.698	3,587.59	3,610.324	3,531.216	3,340.237	3,591.89	4,138.375	3,991.7
3.C.5 - Indirect N2O Emissions from managed soils	2,311.753	1,937.483	2,238.332	2,760.572	2,770.234	2,706.229	2,544.638	2,724.829	3,157.617	3,082.696
3.C.6 - Indirect N2O Emissions from manure management	258.178	909.8536	1,008.294	1,142.889	1,142.889	1,130.866	1,062.426	1,145.338	1,326.89	1,263.585
3.C.7 - Rice cultivations	3.720351	4.967357	4.064828	4.815098	4.4782	4.822677	5.167154	5.649422	5.76241	5.304945
3.D - Other	-78.7135	-76.45372	-59.35661	-140.7009	-120.1848	-130.0361	-134.7579	-132.6079	-42.03812	-72.23923
3.D.1 - Harvested Wood Products	-78.7135	-76.45372	-59.35661	-140.7009	-120.1848	-130.0361	-134.7579	-132.6079	-42.03812	-72.23923
4 - Waste	1,868.416	2,046.295	2,212.407	2,388.442	2,583.001	2,764.615	3,054.588	3,105.07	3,091.971	3,403.977
4.A - Solid Waste Disposal	114.966	224.3249	333.6565	450.3873	576.7964	700.9333	802.5919	897.1792	996.5241	1,090.854
4.C - Incineration and Open Burning of Waste	47.32819	49.61217	51.83324	54.07947	56.36975	58.74811	61.23344	63.82573	66.53128	69.34379
4.D - Wastewater Treatment and Discharge	1,706.121	1,772.358	1,826.918	1,883.975	1,949.835	2,004.934	2,190.763	2,144.065	2,028.915	2,243.779
International Bunkers	436.617	377.3438	255.7688	184.0209	196.4957	221.4452	237.0206	290.0204	274.445	265.0708
1.A.3.a.i - International Aviation (International Bunkers)	436.617	377.3438	255.7688	184.0209	196.4957	221.4452	237.0206	290.0204	274.445	265.0708
1.A.3.d.i - International water-borne navigation (International bunkers)										
1.A.5.c - Multilateral Operations										

Table 3-30 Total Emissions in Carbon Dioxide Equivalents (Continued)

Categories	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total National Emissions and Removals	157,626.65	144,358.07	148,884.24	160,211.53	176,075.07	173,651.75	186,361.60	208,884.77	142,590.49	146,160.43
1 - Energy	32,648.89	1,5196.74	1,6150.08	1,7137.25	1,7960.03	1,8457.26	2,1681.12	2,3401.84	2,1632.18	21749.44
1.A - Fuel Combustion Activities	32,648.47	15,196.35	16,149.67	17,136.74	17,955.57	18,444.42	21,660.38	23,392.46	21,621.55	21,738.78
1.A.1 - Energy Industries	16.10875	54.29418	42.68111	297.4627	863.4377	927.1897	1,364.745	1,335.423	1,460.543	1,650.469

Categories	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1.A.2 - Manufacturing Industries and Construction	1,146.827	949.9767	977.6377	1,284.137	1,088.45	1,076.651	1,218.402	1,330.483	1,407.06	1,492.401
1.A.3 - Transport	2,289.228	3,191.932	3,430.389	3,755.656	3,877.31	4,040.34	6,406.027	3,769.078	3,769.078	3,917.478
1.A.4 - Other Sectors	29,196.3	11,000.14	11,698.96	11,799.49	12,126.37	12,400.24	12,671.2	16,957.48	14,984.87	14,678.43
1.B - Fugitive emissions from fuels	0.428168	0.392338	0.41015	0.509778	4.464904	12.84306	20.74576	9.377311	10.62729	10.65634
1.B.1 - Solid Fuels					3.904276	12.27029	20.24361	8.80647	9.976864	9.976864
1.B.2 - Oil and Natural Gas	0.428168	0.392338	0.41015	0.509778	0.560627	0.572767	0.502151	0.570841	0.650425	0.679475
2 - Industrial Processes and Product Use	840.347	1520.341	973.529	2706.958	1487.501	1973.449	1222.037	1877.166	1752.893	1757.998
2.A - Mineral Industry	627.4997	627.5588	856.4427	821.7808	795.4605	1039.869	956.4186	932.9252	820.73	917.1767
2.A.1 - Cement production	618.8125	618.813	849.4987	816.9781	790.844	1028.689	951.4854	919.3852	807.4542	905.1741
2.A.2 - Lime production	6.9915	4.80319	2.63199	2.40012	2.25911	10.7343	1.91986	10.7343	10.69046	9.923816
2.A.3 - Glass Production	1.695656	3.942593	4.311962	2.402516	2.357355	0.446118	3.01328	2.805643	2.585307	2.078788
2.B - Chemical Industry	0.889272	1.132566	0.3977	0.097	0.154909	1.552	0.051384	0.130885	0.135385	0.182092
2.B.7 - Soda Ash Production	0.889272	1.132566	0.3977	0.097	0.154909	1.552	0.051384	0.130885	0.135385	0.182092
2.C - Metal Industry	211.9581	891.6494	116.6886	1,885.081	691.8858	932.0279	265.5666	944.1104	932.0279	840.6396
2.C.1 - Iron and Steel Production	211.9581	891.6494	116.6886	1,885.081	691.8858	932.0279	265.5666	944.1104	932.0279	840.6396
3 - Agriculture, Forestry, and Other Land Use	120,584.4	123,912.7	127,571.4	136,150.8	1,51726.9	147,917.1	157,779.8	177,373.56	112,540.50	115,232.3847
3.A - Livestock	46,893.7	49,490.36	52,299.5	59,123.43	6,0096.02	61,860.34	65,024.8	63,444.73	65,694.63	66,160.86
3.A.1 - Enteric Fermentation	37,745.96	39,870.2	41,149.44	46,782.8	47,378.1	48,775.22	51,237.87	49,965.98	51,722.5	52,088.33
3.A.2 - Manure Management	9,147.74	9,620.163	11,150.06	12,340.63	12,717.92	13,085.12	13,786.93	13,478.75	13,972.13	14,072.54
3.B - Land	61,512.15	61,425.05	62,160.23	62,306.85	76,813.7	71,880.88	76,905.38	102,139.07	30,431.62	32,596.472
3.B.1 - Forest land	-8,0637.4	-80,758.59	-8,0637.4	-8,0637.4	-85,707.01	-90,794.46	-85,930.07	-85,859.99	-87,445.87	-8,6981.415
3.B.2 - Cropland	96,637.59	96,642.76	96,644.68	96,644.68	90,296.35	90,296.35	90,296.35	90,296.35	73,878.83	75,582.58
3.B.3 - Grassland	44,426.32	44,426.32	44,426.32	44,026.38	70,487.51	70,487.51	70,487.51	95,482.72	41,611.01	41,403.88
3.B.4 - Wetlands	592.7993	618.8067	780.6974	942.588	940.558	1,035.644	1,132.851	1,232.206	1,333.697	1,436.366
3.B.5 - Settlements	492.8316	495.7455	945.9358	1,330.601	796.2924	855.843	918.7491	987.7828	1,053.947	1,155.058
3.C - Aggregate sources and non-CO2 emissions sources on land	12,253.94	13,083.46	13,204.93	14,819.25	14,887.12	14,259.92	15,944.24	1,1781.98	16,408.23	16,465.96

Categories	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
3.C.1 - Emissions from biomass burning	1,847.835	2,191.479	1,471.036	1,849.987	1,544.582	1,617.92	1,514.996	1,458.314	1,458.31	1,458.31
3.C.3 - Urea application	82.21033	89.27233	91.34473	94.68873	101.9245	108.8538	147.8224	146.9197	171.2524	199.925
3.C.4 - Direct N2O Emissions from managed soils	5,361.965	5,596.513	6,031.325	6,669.461	6,858.066	7,117.084	7,414.099	4,380.579	7,549.364	7,553.491
3.C.5 - Indirect N2O Emissions from managed soils	3,696.734	3,893.419	4,208.275	4,649.983	4,769.747	4,930.361	5,115.916	4,071.507	5,190.889	5,212.178
3.C.6 - Indirect N2O Emissions from manure management	1,260.232	1,308.3	1,398.646	1,550.705	1,595.968	461.5256	1,718.512	1,704.081	2,005.525	2,013.249
3.C.7 - Rice cultivations	4.960468	4.4782	4.299761	4.423773	16.83395	24.17421	32.88988	20.57641	32.88988	28.80585
3.D - Other	-75.39349	-86.148	-93.27786	-98.74755	-69.95371	-84.05787	-94.63376	7.783961	6.017745	9.090447
3.D.1 - Harvested Wood Products	-75.39349	-86.148	-93.27786	-98.74755	-69.95371	-84.05787	-94.63376	7.783961	6.017745	9.090447
4 - Waste	3,553.024	3,728.272	4,189.251	4,216.545	4,900.656	5,303.966	5,678.657	6,232.203	6,664.931	7,420.609
4.A - Solid Waste Disposal	1,174.055	1,267.865	1,382.018	1,529.834	1,720.447	1,978.63	2,351.787	2,799.861	3,182.807	3,582.069
4.B - Biological Treatment of Solid Waste										
4.C - Incineration and Open Burning of Waste	72.25068	75.23936	78.31613	81.4747	84.77799	88.22599	91.83128	95.60017	99.54524	103.6665
4.D - Wastewater Treatment and Discharge	2,306.718	2,385.167	2,728.917	2,605.236	3,095.431	3,237.11	3,235.039	3,336.743	3,382.578	3,734.873
International Bunkers	361.7683	455.3652	551.9906	683.0117	667.4363	773.4358	997.9816	1,090.735	998.7575	1,084.863
1.A.3.a.i - International Aviation (International Bunkers)	361.7683	455.3652	551.9906	683.0117	667.4363	773.4358	997.9816	1,090.735	998.7575	1,084.863

3.9. GHG Emission Estimates

3.9.1. Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is one of the main GHG emissions, constituting over 26 per cent of emissions in carbon equivalents. The highest level of CO_2 emissions occurred in the year 2001, mainly resulting from land use and land use changes and the energy sector. Emissions have since been on a generally declining trend. This trend is the result of various government initiatives to reduce emissions in response to climate change challenges and to conserve natural resources, especially forests. Trends for the period 1994-2013 and the contribution of carbon dioxide emissions by source for the 2013 year are shown in Figures 3-7 and Figure 3-8.

It is indicated that that most of the carbon dioxide results from land use and land use changes in cropland and grassland and respective conversions, which together contribute 92 per cent (cropland 59 per cent and grassland 33 per cent) of all the CO_2 emitted in the country. Transport and the energy industries follow as the other main sources, accounting for 3 per cent and 1 per cent respectively.

Figure 3-7: Total Carbon Dioxide Emissions, 1994-2013 (Gg)

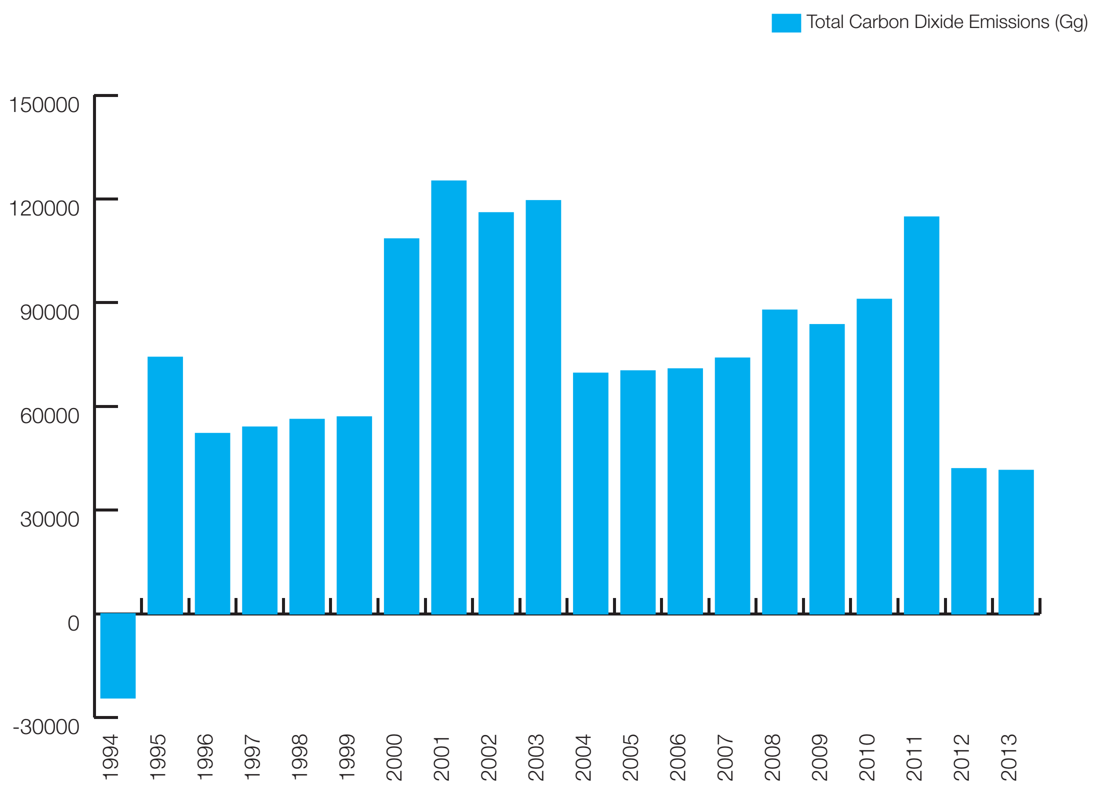
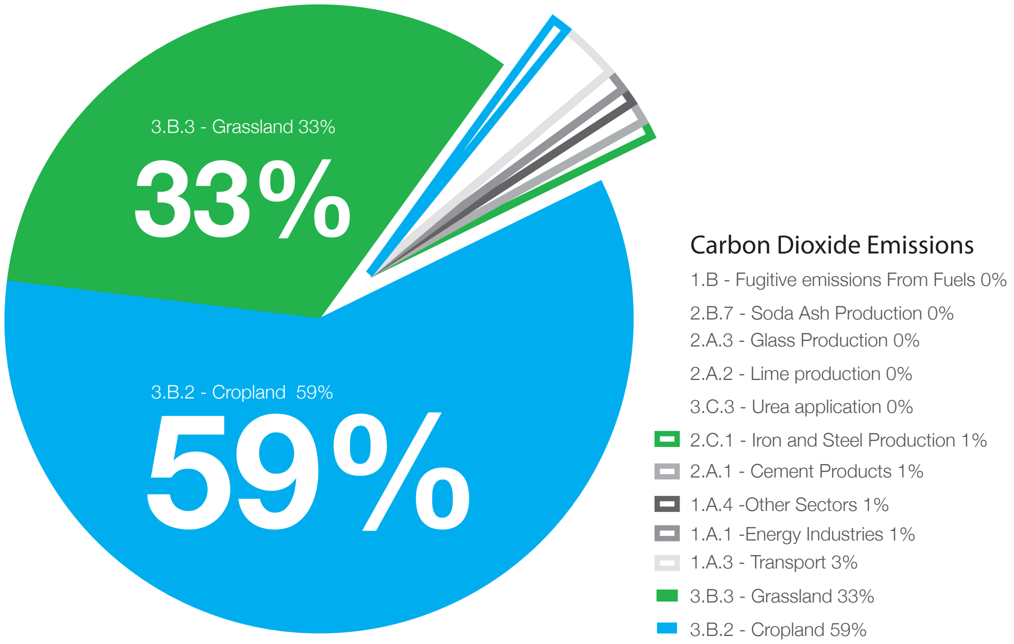


Figure 3-8: Contribution of CO2 by Source



3.9.2 Methane (CH_4)

The other most important gas is methane (CH_4), which is mainly generated from waste and livestock management. The annual variation of methane emissions is shown in Figure 3-9. The figure shows a rising trend in the methane gas CO_2 equivalent emissions. The peaks years for emissions in the period under consideration were in the years 2002-2004 and 2011-2013. This was a result of an increase in the livestock population and the gradual migration of people from rural to urban areas. It is expected that as the country continues to grow at rates that are among the highest in the world, methane emissions will continue to escalate.

The agriculture sector contributes the most methane emissions, accounting for 53 per cent of all national methane emissions in 2013, while the contribution from the "other energy sector" was 26 per cent, mainly biomass energy, whose CO_2 is included only as a memo item (Figure 3-10). The other high emissions are from the waste sector at 40 per cent (solid waste disposal 33 per cent and wastewater treatment and discharge 7 per cent), while energy contributes 8 per cent when "other energy" (residential and commercial/institutional), mainly covering biomass energy sources, but CO_2 from this category is excluded into the memo items. The increased visibility of the waste sector is attributed to population growth and rapid urbanization. Addis Ababa's population is, for example, estimated to have been growing at an annual rate of 3.8 per cent (CSA, 2007).

Figure 3-9: Methane Emissions, 1994-2013 (Gg)

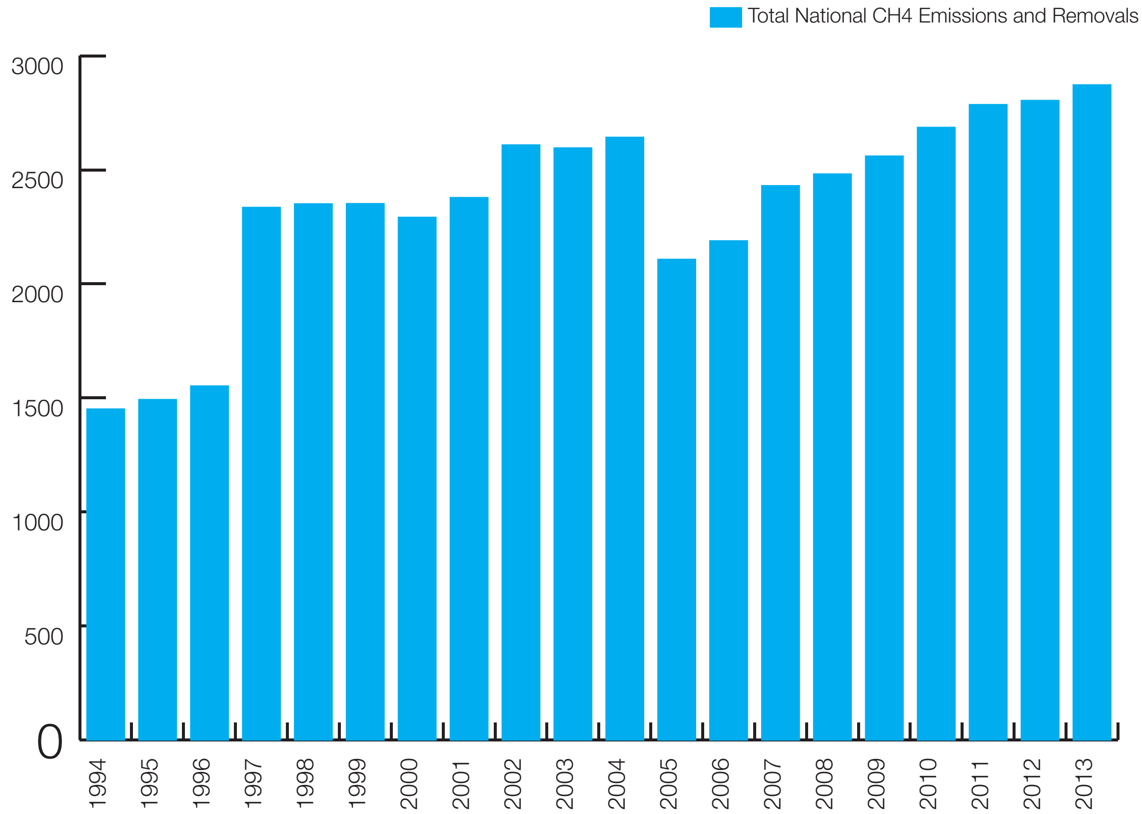
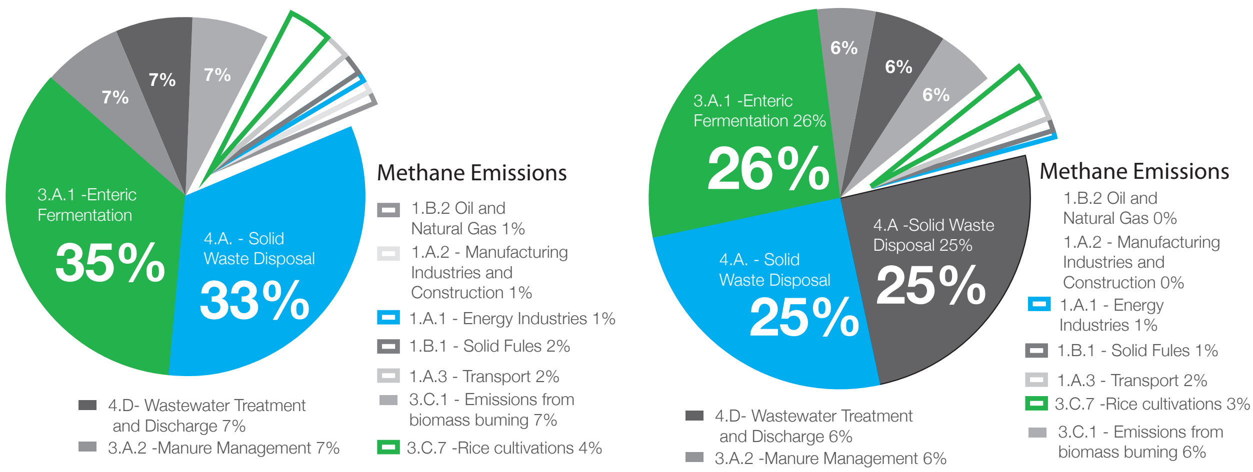


Figure 3-10: Methane Emissions by Sector, 1994 and 2013 (%)

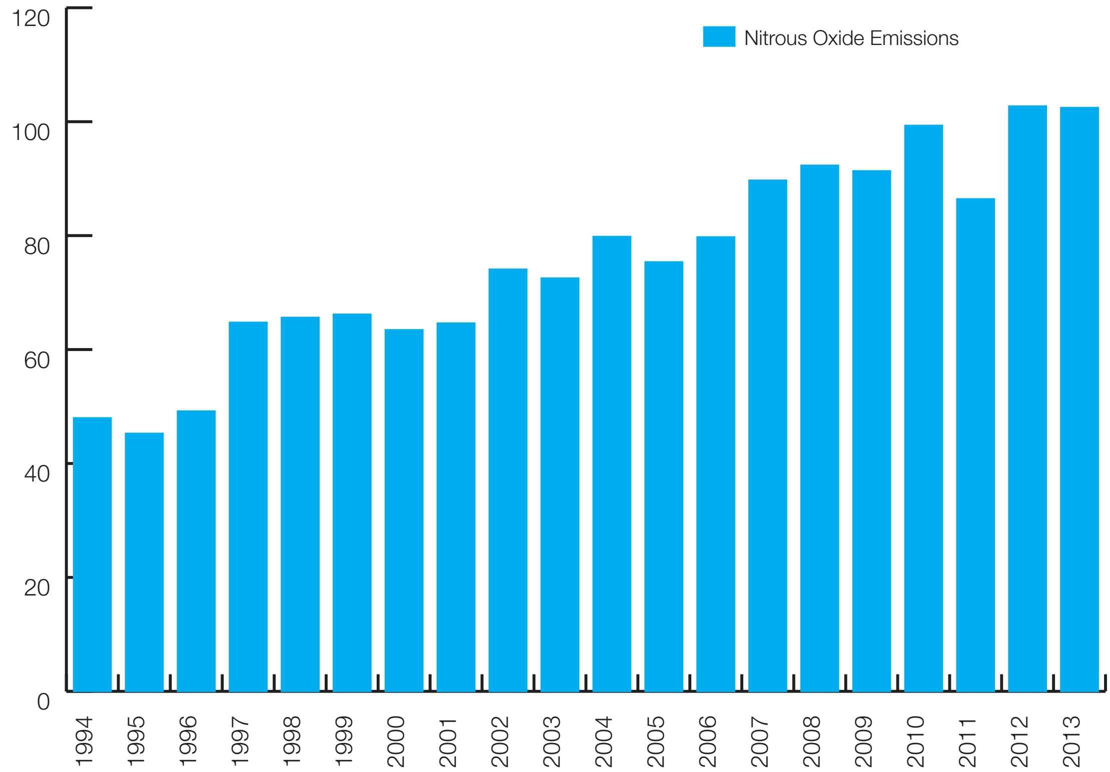


3.9.3. Nitrous Oxide (N_2O)

Nitrous Oxide is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy-related, industrial and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is approximately 298 times more powerful than CO_2 at trapping heat in the atmosphere (IPCC, 2007). Since 1750, the global atmospheric concentration of N_2O has risen by approximately 20 per cent (IPCC, 2007 and NOAA/ESRL, 2015. Figure 3 11 shows the Nitrous Oxide Emissions, 1994-2013 (Gg) while Figure

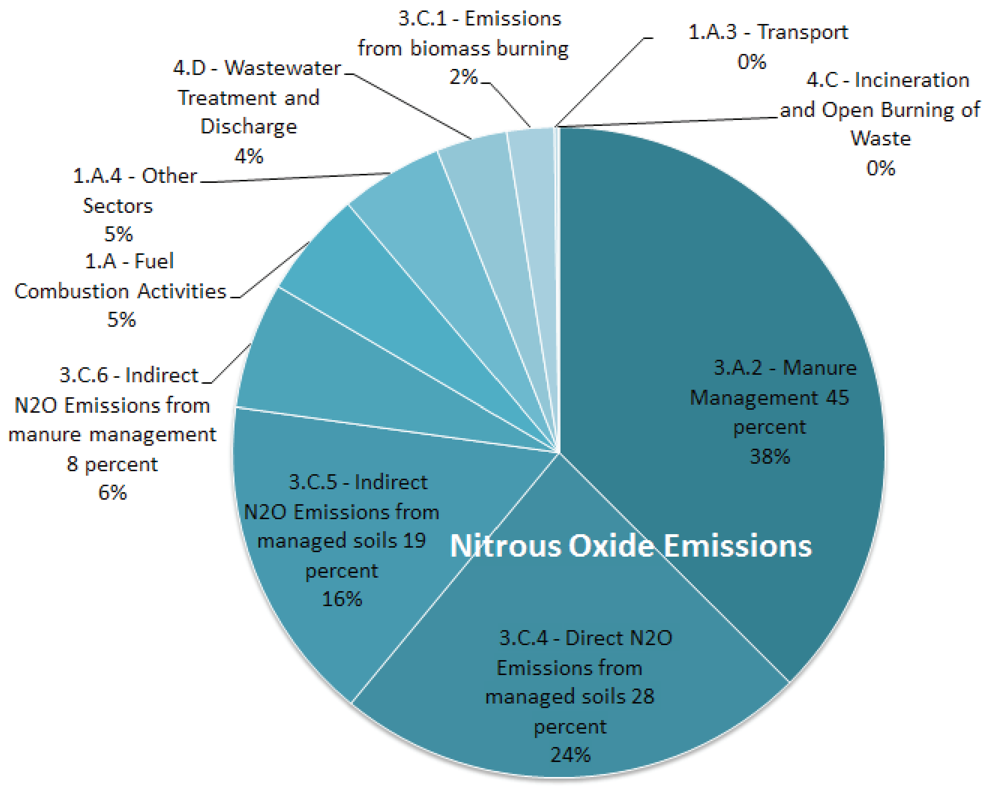
3-12 shows that the largest contributor to nitrous oxide emissions was manure management, at 45 per cent (direct and indirect N_2O emissions from manure management were 38 and 6 per cent respectively). This is followed by direct and indirect N_2O emissions from managed soils, at 24 per cent and 16 per cent respectively, while fuel combustion activities, other energy sectors (residential and commercial) and wastewater treatment and discharge contributed 5 per cent, 5 per cent and 4 per cent respectively.

Figure 3-11: Nitrous Oxide Emissions, 1994-2013 (Gg)



As shown in Figure 3.13 nitrous oxide emissions mainly originate from agriculture-related anthropogenic activities.

Figure 3-12: Nitrous Oxide Emissions by Sector, 2013 (%)



3.10. Estimation of Emissions and Trends by Sector

3.10.1. The Energy Sector

Energy sector activities in Ethiopia are largely driven by the combustion of fossil fuels. During combustion fossil fuels are converted mainly into carbon dioxide (CO_2) and water (H_2O), releasing the chemical energy in the fuel as heat which is used directly to produce mechanical energy and most often to generate electricity and energy for transportation. The energy sector is usually the most important sector in greenhouse gas emission inventories, with CO_2 accounting for the largest share of energy sector emissions and methane and nitrous oxide responsible for the balance. The energy sector mainly comprises of the following:

i. Exploration and exploitation of primary energy sources;

ii. Conversion of primary energy sources into more useable energy forms in refineries and power plants;.

iii. Transmission and distribution of fuels; and

iv. The use of fuels in stationary and mobile applications.

Emissions arise from these activities by combustion and as fugitive emissions, or escape without combustion. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the GHGs released in the combustion of fuels. Also released in the process are the GHG precursors carbon monoxide (CO), nitrogen oxides (NOx), and non-methane volatile organic compounds (NMVOCs). There are two ways to estimate CO_2 emissions from fuel combustion: the top-down or reference approach, and the bottom-up or sectoral approach.

3.10.1.1. The Reference or Top-Down Approach

This approach considers the primary level of energy supply and distribution. It allows calculation of emissions by analysing the overall national inventory of fuel supply. The basic data requirement is an overall inventory of the national fuel supply that includes information on fuel quantities for each fuel type broken down into the following categories:

- **i.** Production;
- **ii.** Imports;
- **iii.** Exports;
- **iv.** International bunkers (the amount of fuel used for international aviation and marine transport)
- **v.** Stock changes or variations in the quantity of fuel in stock.

Fuels that are exported and or fuels used for international bunkers (in the case of Ethiopia, aviation transport fuels are subtracted from overall apparent consumption and hence are not included in the national GHG emissions inventory). CO_2 emissions from international bunkers, nonetheless, are still computed as a separate memo item as recommended by the IPCC guidelines.

a. Calculating Apparent Fuel Consumption

The fuel type data (in kilotons oil equivalent or Gg) on fuel production, imports, exports, transport through international bunkers and stock change are used to arrive at apparent fuel consumption. The data were provided by the Ministry of Water, Irrigation and Energy, and the Ministry of Transport, and Communications. The conversion factor of 41.87 TJ/Gg is used for converting values to apparent fuel consumption figures in TJ.

Apparent Consumption = Production + Imports – Exports – International bunkers – Stock Change

b. Estimating the Carbon Content of the Fuel

The required inputs for the carbon emission factors (kg CO_2/TJ) are provided in Table 1.4 of the 2006 IPCC guidelines (IPCC, 2006, Volume 2, Chapter 1, Table 1.4) as default CO_2 emission factors for each fuel type. The carbon content is provided in Table 1.3 in the 2006 guidelines as default values of carbon content.

3.10.1.2 The Sectoral or Bottom-up Approach

This approach involves looking at the actual consumption of the specific subsectors. The subsectors are the energy industries (power generation or energy production); transportation; manufacturing industries and construction; residential, commercial, and agriculture/forestry and other non-specified stationery or mobile. This methodology is basically the same as in the reference approach but is more detailed in the sense that it is applied for each specific end-user category. This approach identifies the specific sectoral consumers of fuel which are major emitters of energy-related GHGs, and thus provides a more detailed inventory of the CO_2 emissions from fuel combustion. Compared with the reference approach, however, it requires more detailed data and is more computation-intensive. Also, CO_2 emissions may be underestimated since this approach relies heavily on data reported by fuel end-users, which may not always be complete. The approach thus faces perennial problem of incompleteness of data submitted by end users due to recording errors and biases in addition to data collection challenges.

Both top-down and bottom-up analyses were carried out for comparison and there was not much difference between the emission calculations using the two methods

i. Calculating Apparent Fuel Consumption for Each Fuel Type

For the energy industries, it is required to use the consumption figures for every fuel type and the carbon emission factors and conversion factors for each fuel type (as extracted from Tables 1.3 and 1.4 in the 2006 IPCC Guidelines-IPCC, 2007, Volume 2, Chapter 1).

3.10.1.3 Non- CO_2 Emissions from Fuel Combustion by Source Categories

In addition to $CO_{2,}$ non-CO_2 emissions are emitted during fuel combustion. When coal, gasoline, diesel, wood/wood-waste, charcoal, and other biomass fuels are burned, the following non-CO_2 gases are emitted: methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs).

ii. Methane (CH_4)

Incomplete combustion of hydrocarbons in fuels results into methane emissions. The amount of CH_4 emitted is also a function of the methane content of the fuel, the amount of hydrocarbons un-burnt in the engine, the engine type, and any post-combustion controls (IPCC, 1997, Volume 3, Chapter 1, p. 34). CH_4 emissions from fuel combustion are relatively small on at national scale and the uncertainty is high.

iii. Nitrogen Oxides (NOx)

Most of the emissions of NO_x from fuel combustion activities are from mobile sources. Though it is not a GHG, NO_x plays a role in the formation of tropospheric ozone, O_3, as well as in the formation of acid rain.

iv. Carbon Monoxide (CO)

The release of CO from the energy sector comes from the incomplete combustion of fuel in motor vehicles.

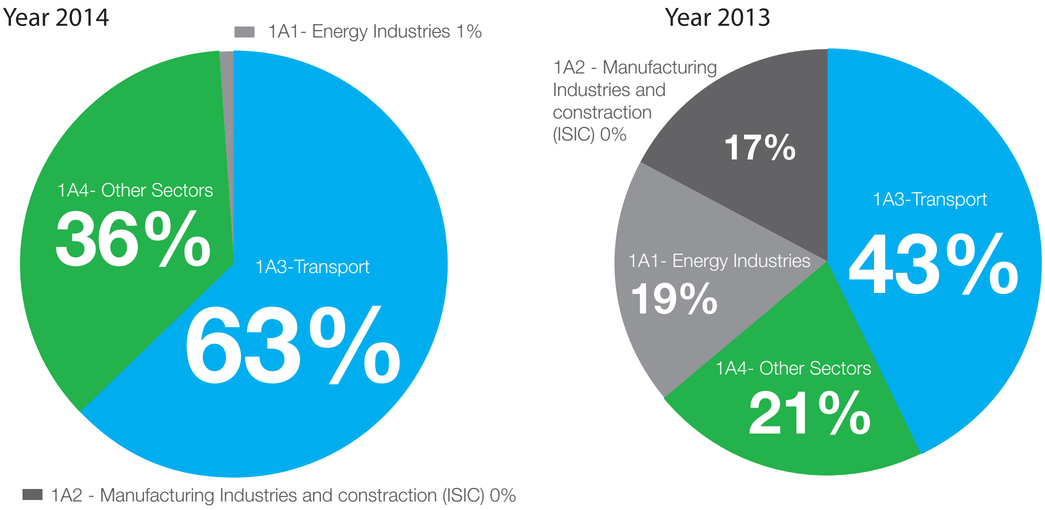
v. Non-methane Volatile Organic Compounds (NMVOCs)

NMVOCs are generated from transportation and residential combustion of biomass fuels. The estimation of the non- CO_2 emissions is done by multiplying the fuel consumption data (TJ) by the respective emission factors for each fuel (kg/TJ). The emission factors required for computation of emissions of the various GHGs are extracted as default factors from the IPCC 2006 Guidelines and the EMEP/CORINAIR Emission Inventory Guidebook, 2007.

3.10.1.4 Sectoral Approach Results

The Figures 3-13 and 3-14 show the changing composition and rising trend of emissions from the energy sector. Whereas, the transport subsector contributed 63 per cent of the energy sector's emissions (69 per cent of it, in the form of CO_2) in 1994, in the year 2013 the emission was 43 per cent (53 per cent as CO_2). The shares of the manufacturing and construction industry and the energy industries rose in this period from negligible levels in 1994 to 17 per cent and 18 per cent respectively in 2013. Figure 3 14: indicates emissions from the Energy Sector, 1994-2013 (Gg)

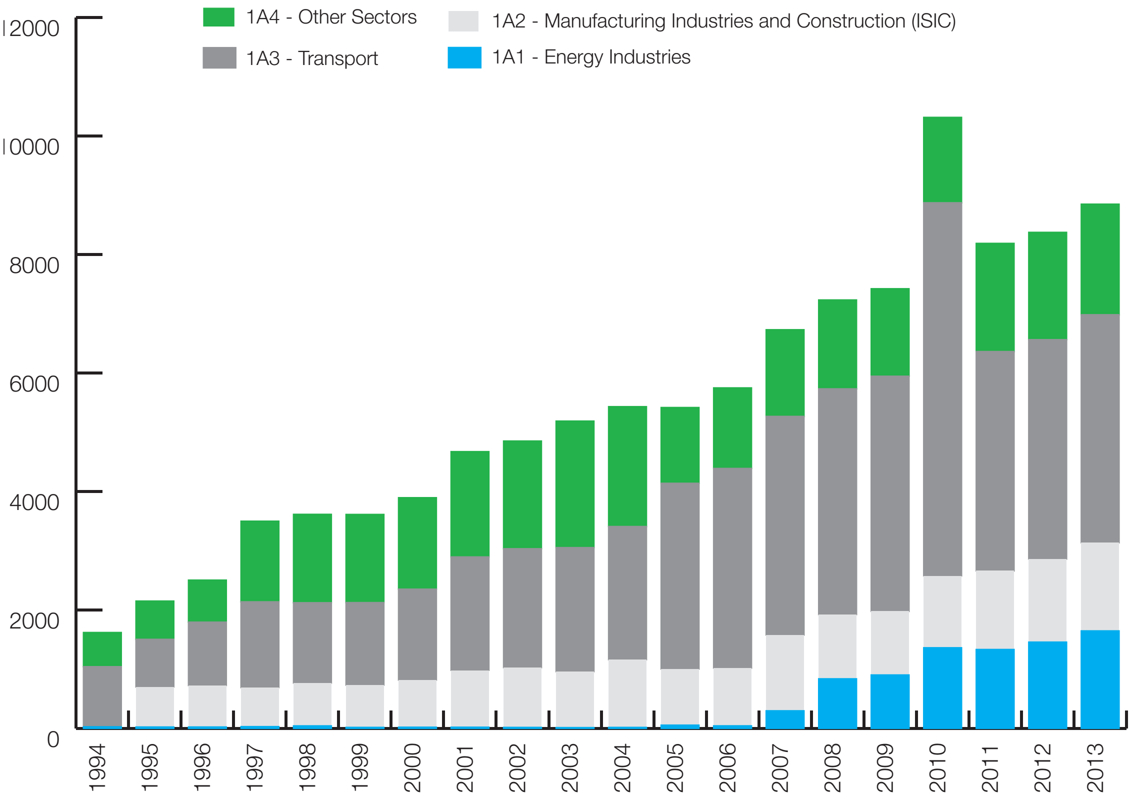
Figure 3-13 : Distribution of Emissions from the Energy Sector, 1994 and 2013



3.10.1.5 Comparison of the Reference Approach and the Sectoral Approach Results

The reference approach for the National Inventory involved a simple calculation of GHG emissions generated annually in the country on the basis of the apparent consumption of fuels, which is defined as the difference between fuel production and imports, on the one hand, and the sum of exports, international consumption, and variations in fuel stocks, on the other. These values are derived from the country's national energy balance. The sectoral approach was used to calculate emissions for 2013, which amounted to 21749.44 Gg CO_2e. For comparison, the reference approach yielded figures of 24424.62112 CO_2e. It is worth noting that the results using reference approach was higher than the sectoral approach values by 12.2 per cent. This is a result of low disaggregation in the country's national energy balance, making it difficult to distinguish between national and international consumption and the resulting emissions in air transport, and the fact that calculations associated with the reference approach may overestimate consumption and thus also overestimate greenhouse gas emissions.

Figure 3-14: Emissions from the Energy Sector, 1994-2013 (Gg)



3.10.2 Industrial Processes and Product Use

The industrial processes and product use category covers the processes that transform materials, chemically or physically, to make desired products. The energy inputs for process heating are covered under the energy sector section. The IPCC broadly classifies this sector into seven industrial processes, of which three are most relevant to Ethiopia: mineral products (cement and lime production), metal production (iron production/recycling), and other production, including textile, food and beverage production. The main industrial processes considered for estimation of emissions are the cement, lime, glass and iron manufacturing industries. Gases released include CO_2, NMVOC, SO_2, N_2O, and PFCs. The methodology for calculation of emissions involves multiplication of the activity data by the corresponding emission factors listed in the revised IPCC 1996 guidelines. Figure 3-15 shows the emissions from the IPPU sector in 1994-2013. The cement and metal production industries are growing fast due to the booming construction sector in the country.

Figure 3-15: Emissions from the IPPU Sector, 1994-2013 (Gg)

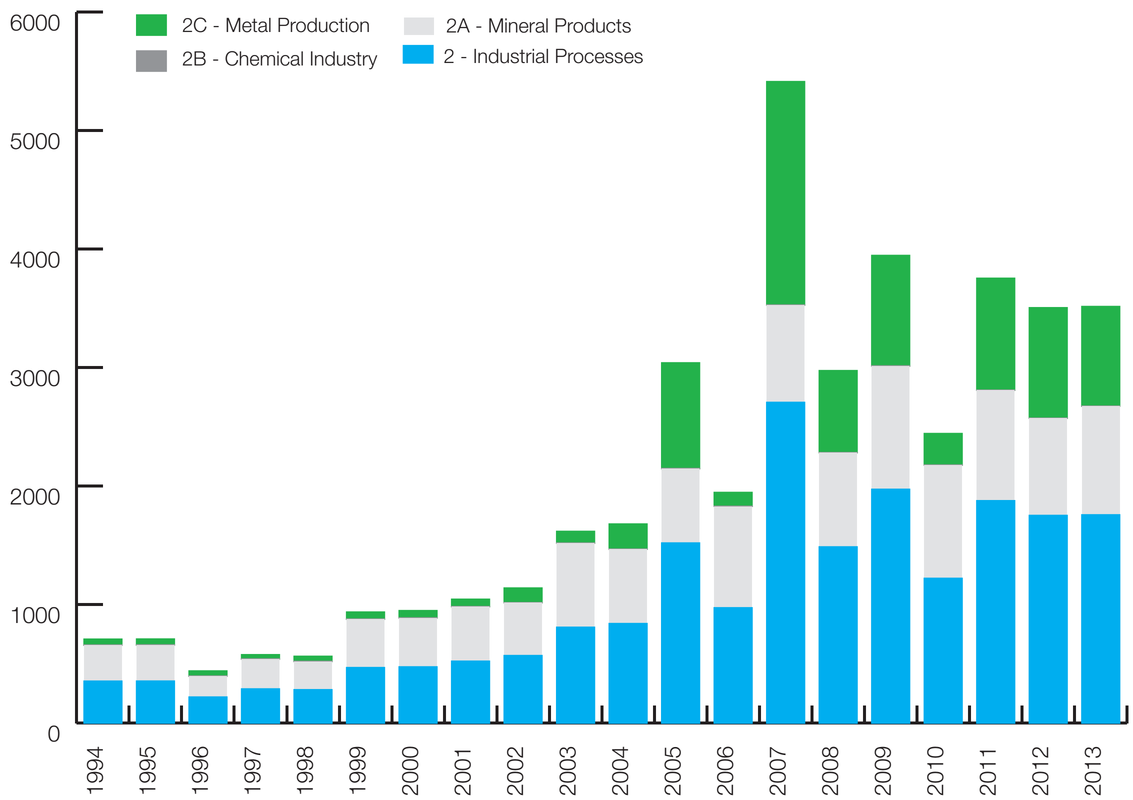
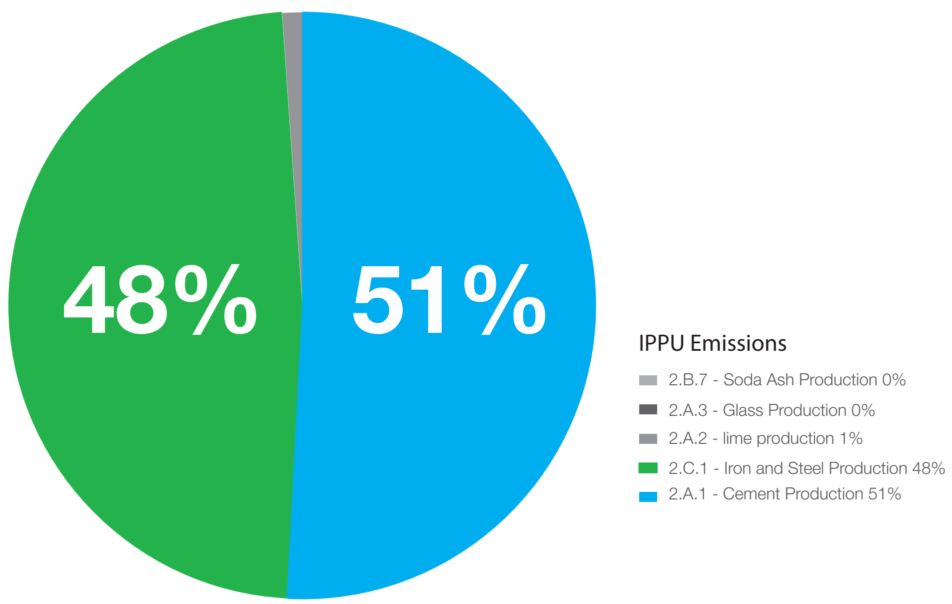


Figure 3-16 shows that 51 per cent of the emissions from the IPPU sector in 2013 resulted from cement production, while iron and steel production and lime production emitted 48 per cent and 1 per cent of the total respectively.

Figure 3-16: IPPU Sector Emissions by Source, 2013 (%)



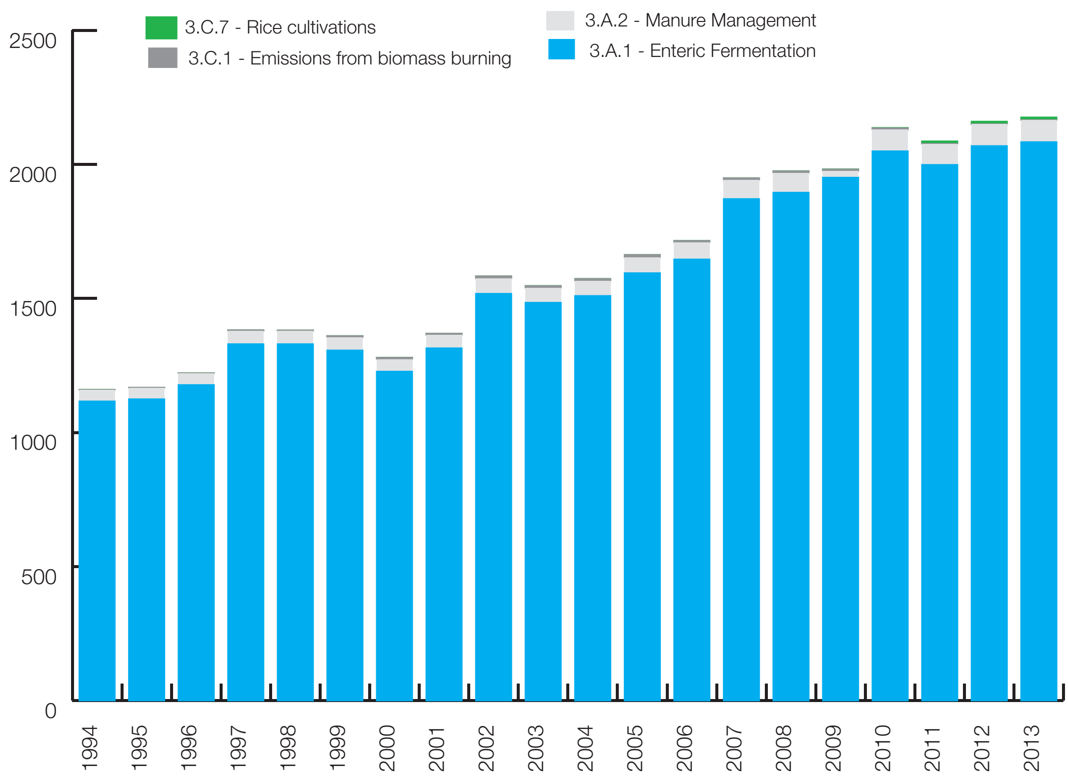
3.10.3 Agriculture, Forestry and Land Use (AFOLU)

In the agriculture sector, the main GHG emissions are of methane and nitrous oxide associated with agricultural production activities. Methane is produced through the processes of manure management, rice cultivation, and enteric fermentation. Nitrous oxide is produced from cultivated soil by direct and indirect mechanisms, while precursor gases are generated by the on-site burning of plant biomass, dead or live (burning of agricultural waste and periodic burning of savannahs). These gases are significant since over 50 per cent of Ethiopia's land area is covered by savannah grassland that is subject to frequent burning. Methane and nitrous oxide remain the most significant emissions resulting from the several types of activity:

i. Livestock rearing resulting in enteric fermentation and manure management;
ii. Biomass burning resulting from wildfires and the burning of savannah woodlands and grasslands in the dry season;
iii. Crop production resulting in carbon stock loss due to land conversion to cropland and the burning of crop residues;
iv. Direct N_2O emissions from managed soils; and
v. Indirect N_2O Emissions from managed soils.

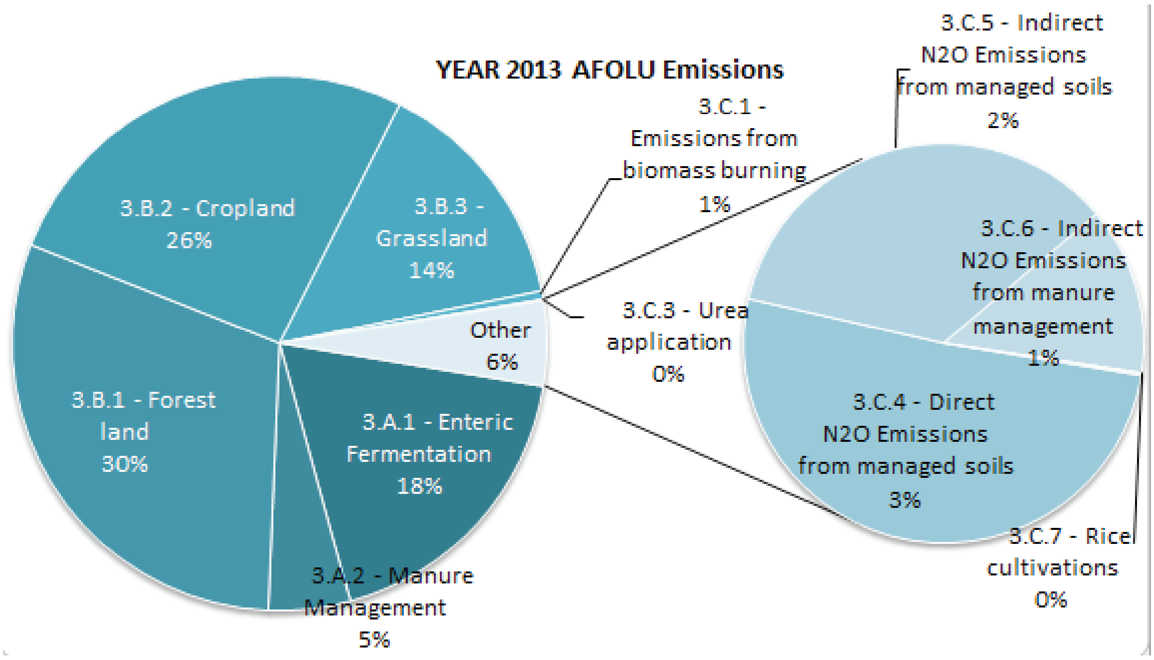
Methane emissions from agriculture broken down by main source category are shown in Figure 3-17. The figure shows that emissions from the sector have been continually increasing, mainly as a result of livestock related activities. The results further confirm that enteric fermentation is the main source of the methane emissions in the Agriculture sector.

Figure 3-17: Methane Emissions from Agriculture, 1994-2013 (Gg)



As indicated in Figure 3-18 the forestland sub-category forms the only sink for 30 per cent of carbon dioxide equivalent emissions from the AFOLU sector. The main sources in this sector include cropland 26 per cent, Enteric Fermentation 18%, Grassland 14% and manure management at 5%. About 6% of the AFOLU emissions result from direct and indirect emissions associated with manure and soil management.

Figure 3-18: AFOLU Sector Emissions by Source, 2013 (%)

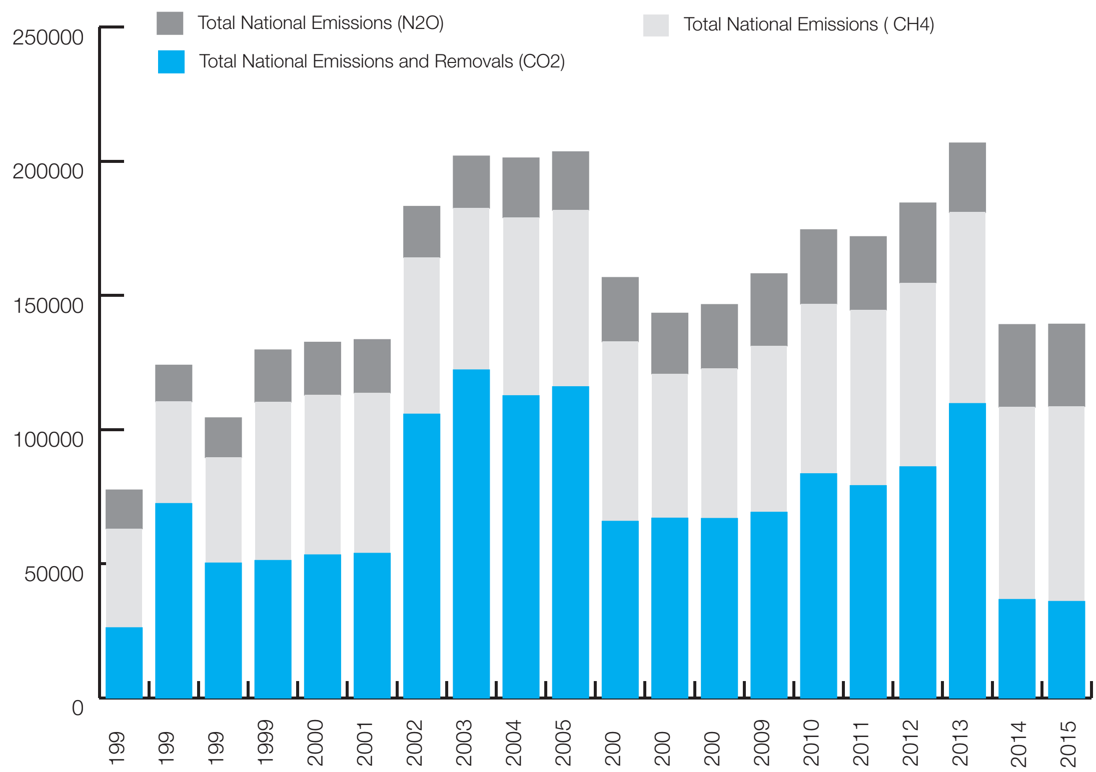


3.10.4 Waste

The waste sector is mainly a source of methane and nitrous oxide emissions resulting from the decay and treatment processes of organic matter under anaerobic and or aerobic management conditions at solid waste disposal sites. The nitrous oxide emissions result from the decomposition of human waste, and anaerobic treatment of domestic and industrial wastewater in liquid and solid phases (sludge). This sector depends heavily on the quality and availability of data to get satisfactory trends and emission estimates.

There is no systematic activity data collection for this sector in the country. The analysis and estimation of the emissions were carried out using the urban population and GDP. The emission trends from the waste sector are increasing exponentially and in tandem with the increase in urban population. The rate at which emissions from waste management has been growing in the country is shown in Figure 3-19.The rate of increase in waste sector emissions is dependent on the quantity of urban solid waste generated and wastewater treated/handled, which is directly related to urban development and rural-urban migration. It was not possible to quantify emissions arising from the incineration of hospital waste, other hazardous waste since the sector is not well developed. There are also inadequate activity data that could form the basis for estimations. Nitrous oxide emissions from the domestic wastewater category are proportional to variations in urban population.

Figure 3-19: Emissions from the Waste Sector, 1994-2013 (Gg)



In regard to solid waste management in the major cities and towns, there is at least one unmanaged landfill in every town. The waste that does not get to the landfill ends up in designated dumpsites. Urban solid municipal waste is managed mainly by dumping and opens burning, while most of the industrial wastewater generated is only superficially treated using lagoons. The semi-treated effluents are released into the aquatic system, that is, rivers and drainage ways.

3.11. Projection of Emission Scenarios

3.11.1. GHG Inventory Overview

Carbon dioxide (CO_2) and methane (CH_4) are the primary greenhouse gases emitted through human activities in Ethiopia. In 2013, CO_2 accounted for about 26 per cent of all greenhouse gas emissions from human activities in the country. Carbon dioxide is naturally present in the atmosphere as part of the earth's carbon cycle (the natural circulation of carbon among the atmosphere, soil, plants and animals) is 1 per cent.

Human activities are altering the carbon cycle—both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution. Figure 3-20, covering the years 1994-2013, shows that in 1994 there was net removal of CO_2, while in the rest of the years there was net emission of CO_2. However, the emissions have been decreasing since 2011. Carbon dioxide and methane have accounted for the largest proportion of emissions.

Figure 3-20 : Emission Trends for Key GHG Gases, 1994-2013 (Gg)

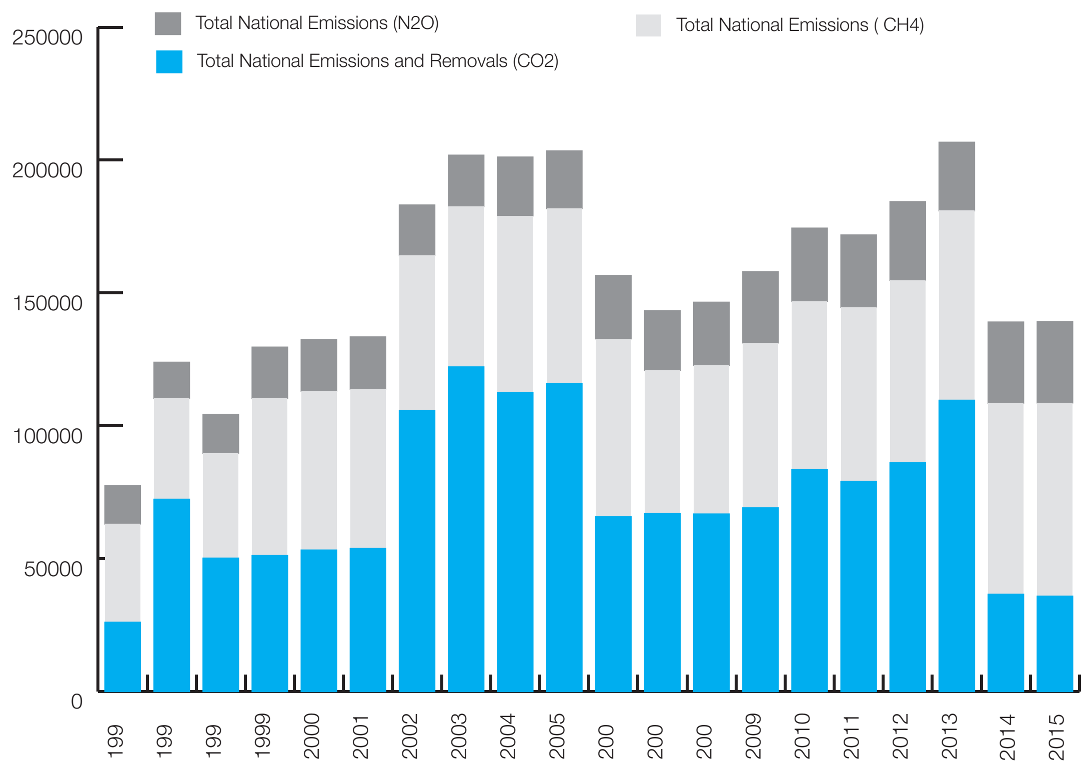


Figure 3-21 shows trends of emissions projected in the National GHG Inventory. It shows the carbon sinks drastically decreasing while the emissions from croplands persist and become the main driver of emissions. It also shows emissions from grasslands decreasing over the years while those from livestock and the management of soils are increasing drastically. It is projected that Ethiopia will emit 293,630.7 Gg CO_2e in 2025 and 362,735.7Gg CO_2e in 2030, as shown in Table 3-31 and Figure 3-21.

In Table 3-33, it is shown that in the BAU emissions scenario, the exponential growth of emissions will resume from 2018. This was the same trend experienced in 1994 to 2002. The interventions by the Government and other stakeholders to reduce the emissions specifically through re-afforestation and afforestation campaigns and the sectoral implementation of the CRGE strategy have yielded a marked change in the overall trend of emissions. This can be seen in the change of trends shown between 2002 and 2015.

This shows that the implementation of the CRGE strategy needs to be focused on the key areas that will achieve significant impacts on the emission trajectory of the country. Figure 3-22 shows the divergence of the low emission pathway from the projected trends under the BAU scenario required to achieve the CRGE strategic goal by year 2030. Figure 3 23 shows the projected emission trends by main sources and removals (Gg CO_2e)

Table 3-31: Projected Emissions (Gg CO_2e)

Year	2013	2015	2016	2017	2018	2019	2020	2021
Total Emissions	201,360	213,165.3	219,415.8	225,934.2	232,752.1	239,906	247,438.3	255,398.5
Year	2022	2024	2025	2026	2028	2029	2030	
Total Emissions	264,024	283,050.4	293,630.7	305,072.5	331,132.3	346,123.4	362,735.7	

Figure 3-21: Trend of Actual and Projected Emissions and Removals, 1994-2030 (Gg CO2e)

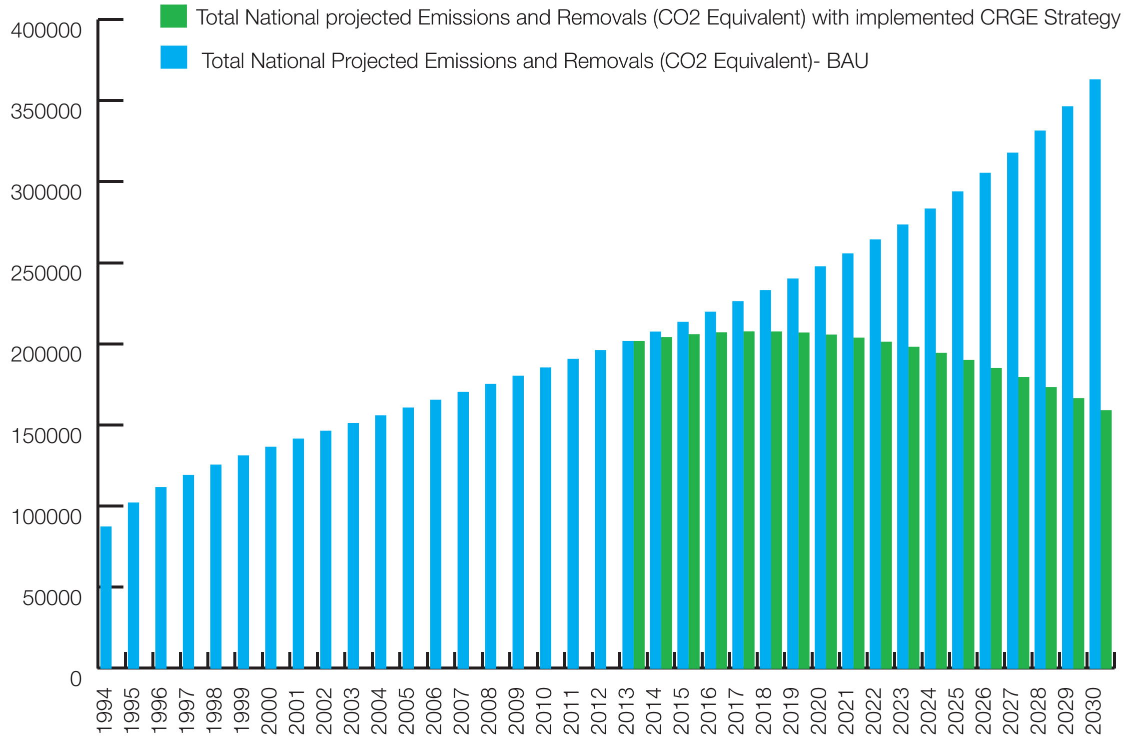


Table 3-32 shows actual and projected business as usual (BAU) emission for the main sources and sinks, while Table 3-33 shows estimated emission reductions by source and sink in Gg CO2e.

Figure 3- 22: Estimated Emissions Reductions Required to Achieve the CRGE Strategy by 2030 (Gg CO2e)

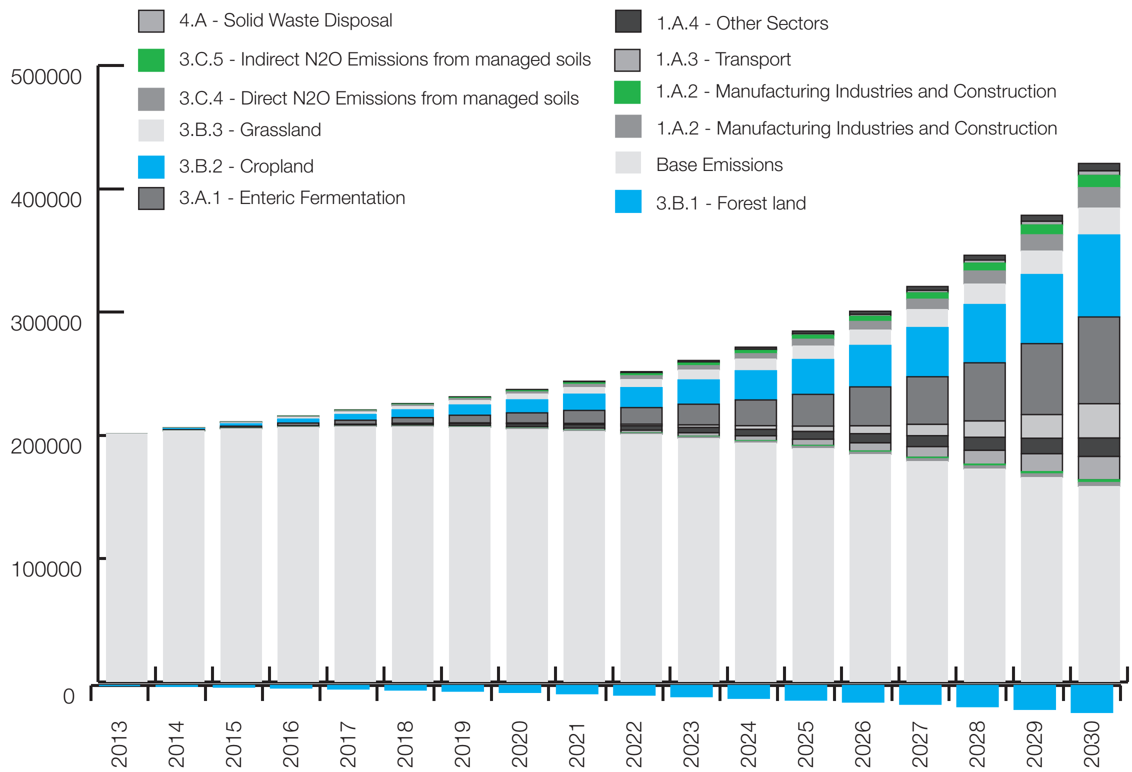


Figure 3-23: Projected Emission Trends by Main Sources and Removals (Gg CO2e)

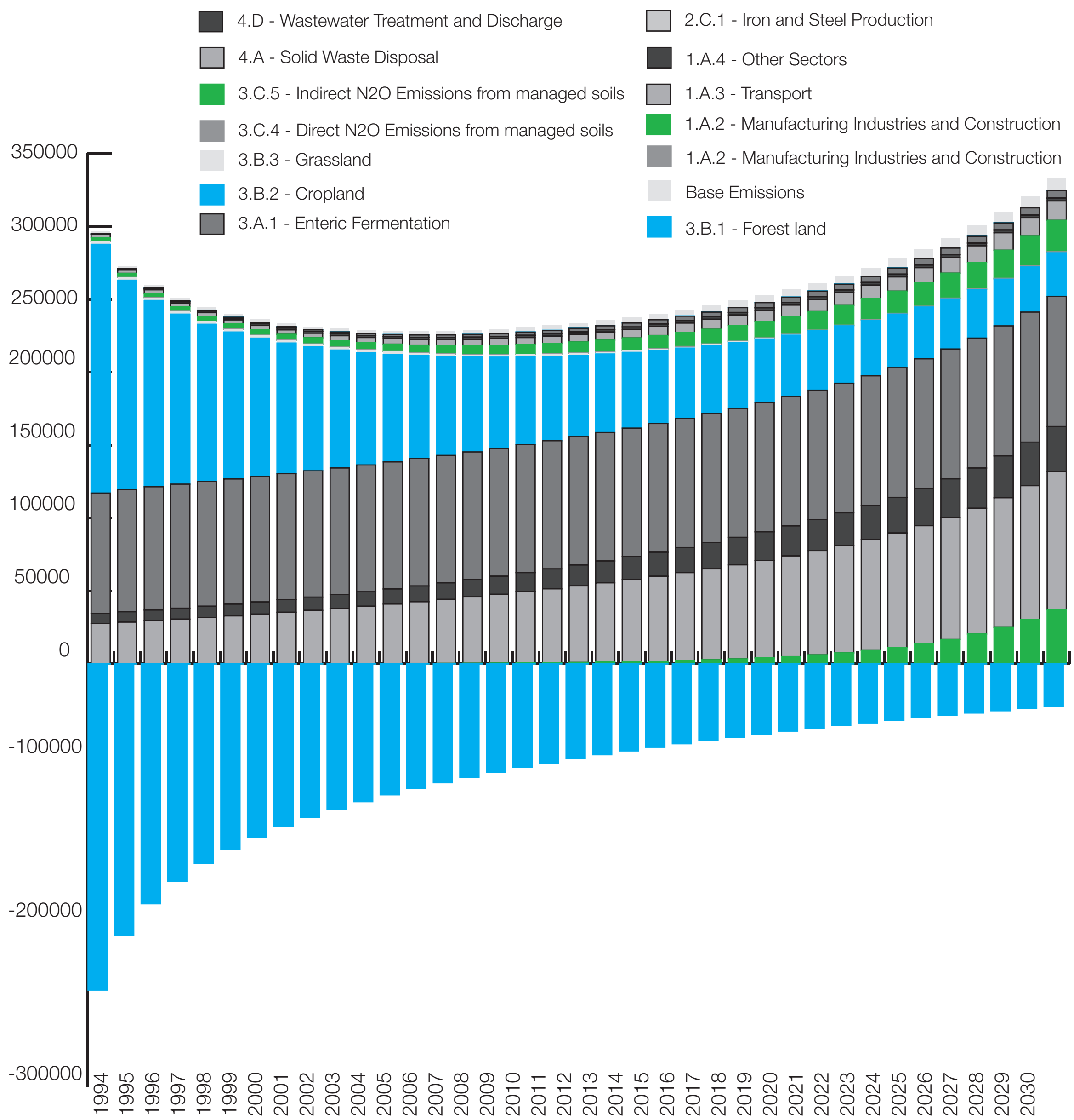


Table 3-32: Actual and Projected BAU Emission Trends for the Main Sources and Sinks (Gg CO2e)

Inventory Year	1994	2000	2010	2013	2020	2025	2026	2027	2029	2030
1.A - Fuel Combustion Activities										
1.A.1 - Energy Industries	182.0924	15.3516	1,046.144	1,767.46	4,137.4	6,418.958	6,934.144	7,468.954	8,597.45	9,191.136
1.A.2 - Manufacturing Industries and Construction	632.5569	821.6957	1,270.76	1,448.335	1,965.241	2,443.948	2,552.861	2,666.628	2,909.598	3,039.262
1.A.3 - Transport	979.0757	1,684.138	4,158.913	5,454.57	10,270.27	16,139.24	17,666.21	19,337.65	23,169.89	25,362.04
1.A.4 - Other Sectors	12,075	15,887.15	18,004.47	18,421.81	19,218.05	19,684	19,769.59	19,852.98	20,013.63	20,091.09
1.B - Fugitive Emissions from Fuels	0.9464	-0.3688	8.9752	14.5903	32.7392	50.0287	53.9192	57.9539	66.4559	70.9232
2 - Industrial Processes and Product Use										
2.A - Mineral Industry										
2.A.1 - Cement Production	154.5019	455.2591	877.3051	984.61	1200.331	1324.712	1346.617	1367.532	1406.392	1424.337
2.A.2 - Lime Production	0.7271	1.575871	2.24232	2.391958	2.695015	2.883309	2.918794	2.953636	3.021512	3.0546
2.A.3 - Glass Production	1.6248	0.9012	0.3192	0.2967	0.5172	0.9087	1.0104	1.1199	1.3623	1.4952
2.B - Chemical Industry										
2.B.7 - Soda Ash Production	1.6248	0.9012	0.3192	0.2967	0.5172	0.9087	1.0104	1.1199	1.3623	1.4952
2.C - Metal Industry										
2.C.1 - Iron and Steel Production	27.65565	91.93023	680.6375	1240.947	5039.338	13712.04	16751.28	20464.15	30541.14	37310.49
3 - Agriculture, Forestry, and Other Land Use										
3.A - Livestock										
3.A.1 - Enteric Fermentation	27,683.27	34,031.35	48,856.91	54,339.4	68,989.27	81,045.5	83,615.95	86,239.46	91,645.7	94,428.43
3.A.2 - Manure Management	6,919.454	8,350.046	13,031.01	14,995.1	20,582.77	25,435.2	26,491.81	27,577.12	29,833.88	31,005.33
3.B - Land										
3.B.1 - Forest Land	-22,3700	-11,8872	-71,072	-62,316.9	-46,150	-36,997.3	-35,339.6	-33,731.4	-30,652.3	-29,176.2
3.B.2 - Cropland	82,467.14	86,113.85	87,776.7	88,081.26	88,643.67	88,962.07	89,019.74	89,075.68	89,182.8	89,234.14
3.B.3 - Grassland	170,569	94,734.94	60,155.84	53,822.32	42,126.94	35,505.81	34,306.6	33,143.2	30,915.68	29,847.92
3.C - Aggregate Sources and Non-CO2 Emissions Sources on Land										
3.C.1 - Emissions from Biomass Burning	1,865.32	2,005.538	1,577.506	1,287.8	322.3138	151.3008	151.3008	151.3008	151.3008	151.3008
3.C.3 - Urea Application	38.8444	55.423	140.51	180.041	297.417	402.803	426.0348	449.9848	500.0394	526.144
3.C.4 - Direct N2O Emissions from Managed Soils	2,632.376	3,739.257	6,711.933	7,999.563	12,047.86	16,141.39	17,113.83	18,144.85	20,396.98	21,625.8

Inventory Year	1994	2000	2010	2013	2020	2025	2026	2027	2029	2030
3.C.5 - Indirect N2O Emissions From Managed Soils	2,115.695	2,873.077	4,784.509	5,575.508	7,967.601	10,281.88	10,819.86	11,385.99	12,608.65	13.268.38
3.C.6 - Indirect N2O Emissions from Manure management	433.04	1,202.803	1,553.803	1,618.092	1,736.807	1,804.016	1,816.188	1,827.998	1,850.608	1,861.447
3.C.7 - Rice Cultivation	6.6839	2.9441	21.7031	33.4226	71.7021	108.4166	116.6967	125.2892	143.4114	152.9411
4 - Waste										
4.A - Solid Waste Disposal	100.53	830.2847	2,174.367	2,593.661	3,591.909	4,319.002	4,465.636	4,612.648	4,907.767	5,055.854
4.C - Incineration and Open Burning of Waste	47.6811	61.1373	92.0123	103.334	133.4473	158.1248	163.3771	168.735	179.7676	185.4423
4.D - Wastewater Treatment and Discharge	1,753.974	2,039.706	3,198.166	3,712	5,209.426	6,534.856	6,825.526	7,124.724	7,748.704	8,073.486

Table 3-33: Estimated Emission Reductions by Source and Sink (Gg CO2e)

Inventory year	2013	2014	2015	2016	2017	2018	2019	2020	2021
Low Emissions Pathway	20,1360	20,3766	20,5558	20,6735	20,7298	20,7246	20,6580	20,5300	20,3405
1.A.1 - Energy Industries	7.8E-05	19.4244	48.5713	89.3462	143.717	213.695	301.326	408.667	537.772
1.A.2 - Manufacturing Industries and Construction	6.4E-05	14.5937	33.9226	58.7277	89.9104	128.567	176.037	233.957	304.348
1.A.3 - Transport	0.00024	57.5946	140.291	254.513	408.321	611.853	877.899	1222.65	1666.71
1.A.4 - Other Sectors	0.00081	178.929	400.791	668.435	985.591	1,357.01	1,788.63	2,287.87	2,863.88
1.B - Fugitive Emissions from Fuels	6.4E-07	0.16158	0.40903	0.76502	1.25644	1.91537	2.78024	3.89753	5.32376
2.A.1 - Cement Production	4.3E-05	9.82378	22.5649	38.5299	58.0784	81.6353	109.706	142.897	181.941
2.A.2 - Lime Production	1.1E-07	0.02353	0.05333	0.08996	0.1341	0.18658	0.24841	0.32084	0.40538
2.A.3 - Glass Production	1.3E-08	0.00294	0.00688	0.01225	0.0196	0.02964	0.04326	0.06157	0.08597
2.B.7 - Soda Ash Production	1.3E-08	0.00294	0.00688	0.01225	0.0196	0.02964	0.04326	0.06157	0.08597
2.C.1 - Iron and Steel Production	5.5E-05	14.6238	39.7552	80.4931	144.124	241.028	385.967	599.922	912.721
3.A.1 - Enteric Fermentation	0.0024	542.827	1,250.6	2,145.27	3,253.35	4,606.84	6,244.4	8,213.02	10,570
3.A.2 - Manure Management	0.00066	151.517	353.072	612.548	939.406	1,345.02	1,843.12	2,450.33	3,186.93
3.B.1 - Forest Land	-0.0027	-575.77	-1,227.5	-1,949.2	-2,737.3	-3,590.2	-4,508.3	-5,494	-6,551.7
3.B.2 - Cropland	0.00388	850.541	1,894.58	3,142.98	4,610.68	6,317.22	8,287.51	10,552.8	13,152.3
3.B.3 - Grassland	0.00237	500.845	1,075.61	1,721.06	2,435.99	3,221.17	4,079.31	5,015.12	6,035.54

Inventory year	2013	2014	2015	2016	2017	2018	2019	2020	2021
3.C.1 - Emissions from Biomass Burning	5.7E-05	11.3314	22.6101	32.8606	40.9703	45.6502	45.3852	38.3707	22.4316
3.C.3 - Urea Application	7.9E-06	1.8777	4.50754	8.04165	12.6606	18.5799	26.0579	35.4068	47.0064
3.C.4 - Direct N2O Emissions from Managed Soils	0.00035	81.8151	193.031	339.198	527.098	765.038	1,063.23	1,434.27	1,893.8
3.C.5 - Indirect N2O Emissions from Managed Soils	0.00025	56.5972	132.535	231.153	356.517	513.588	708.437	948.525	1,243.07
3.C.6 - Indirect N2O Emissions from Manure Management	7.1E-05	15.7948	35.5431	59.5336	88.1336	121.803	161.111	206.763	259.629
3.C.7 - Rice Cultivation	1.5E-06	0.36612	0.91869	1.70604	2.78562	4.22601	6.10959	8.53597	11.6264
4.A - Solid Waste Disposal	0.00011	26.3794	61.7409	107.384	164.826	235.856	322.6	427.609	553.963
4.C - Incineration and Open Burning of Waste	4.6E-06	1.03523	2.39151	4.11291	6.25242	8.87382	12.0541	15.8866	20.4851
4.D - Wastewater Treatment and Discharge	0.00016	37.6238	87.95	153.073	235.506	338.273	465.021	620.17	809.113

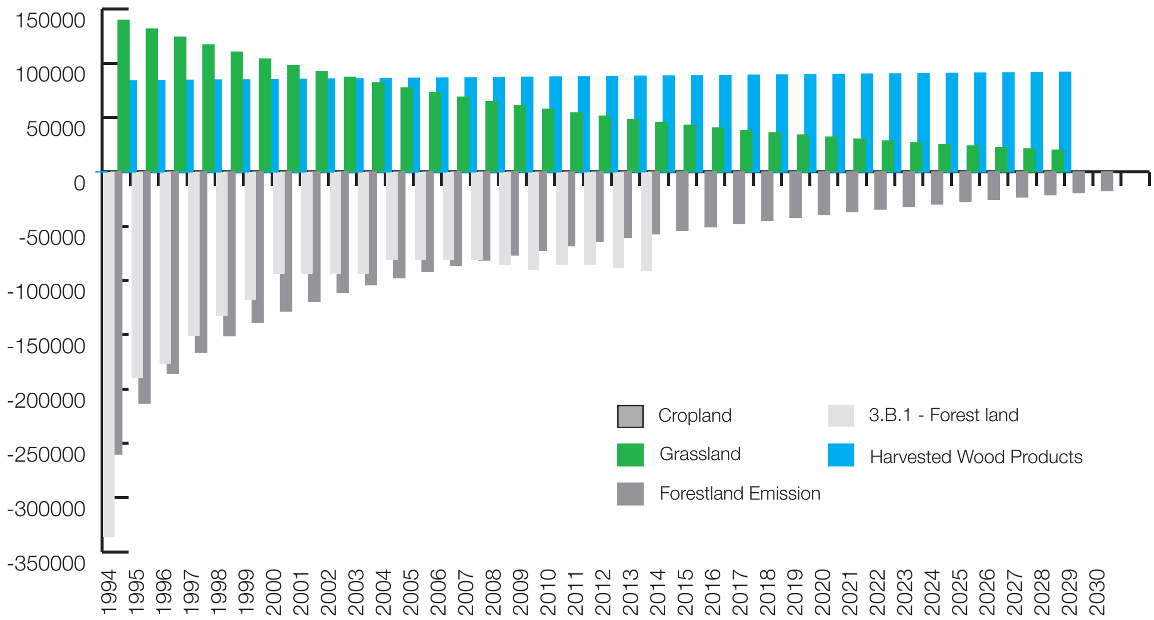
Table 3-34: (continued): Estimated Emission Reductions by Source or Sink (Gg CO2e)

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Low Emissions Pathway	20,0895	19,7772	19,4034	18,9681	18,4714	17,9133	17,2937	16,6127	15,8702
1.A.1 - Energy Industries	692.172	872.44	1.080.46	1318	1,586.7	1,888.02	2,223.2	2,593.17	2,998.53
1.A.2 Manufacturing Industries and Construction	390.817	495.567	622.558	776.818	964.788	1,194.82	1,477.86	1,828.46	2,266.29
1.A.4 - Other Sectors	3,538.12	4,315.61	5,214.26	6,256.63	7,471.4	8,895.38	10,576.3	12,577.1	14,981.4
1.B - Fugitive Emissions from Fuels	7.14861	9.44297	12.3151	15.9018	20.3774	25.967	32.9652	41.7625	52.8854
2.A.1 - Cement Production	228.38	282.741	346.396	421.064	508.919	612.74	736.129	883.812	1062.09
2.A.2 - Lime Production	0.50534	0.62177	0.75759	0.91647	1.10308	1.32341	1.58524	1.89879	2.27773
2.A.3 - Glass Production	0.11854	0.16122	0.21681	0.28883	0.38185	0.50179	0.65641	0.8561	1.11493
2.B.7 - Soda Ash Production	0.11854	0.16122	0.21681	0.28883	0.38185	0.50179	0.65641	0.8561	1.11493
2.C.1 - Iron and Steel Production	1,370.73	2,032.79	2,986.62	4,358.42	6,330.71	9,169.23	13,264	19,192.8	27,821.4
3.A.1 - Enteric Fermentation	13,423.8	16,829	20,895.3	25,760.6	31,600.5	38,640.7	47,175.3	57,592.5	70,412.6
3.A.2 - Manure Management	4,089.44	5,179.02	6,494.46	8,084.67	10,011.9	12,356.3	15,222.4	18,748.4	23,119.8
3.B.1 - Forest Land	-7,709.6	-8,954.8	-10,300	-11,760	-13,356	-15,114	-17,068	-19,263	-21,756
3.B.2 - Cropland	16,180.5	19,656	23,655.8	28,276.9	33,642.7	39,911.5	47,288.8	56,044.7	66,539.4
3.B.3 - Grassland	7,170.43	8,412.09	9,776.85	11,285.6	12,965.3	14,850.2	16,985.1	19,428.2	22,256.7
3.C.1 - Emissions from Biomass Burning	27.5758	33.4751	40.2592	48.0915	57.1802	67.7923	80.2741	95.0812	112.821
3.C.3 - Urea Application	61.4971	79.3164	101.19	128.032	161.009	201.621	251.832	314.237	392.331

3.C.4 - Direct N2O Emissions from Managed Soils	2,468.37	3,176.94	4,050.96	5,130.6	6,467.73	8,130.04	10,206.9	12,818	16,125.7
3.C.5 - Indirect N2O Emissions from Managed soils	1,608.1	2,054.26	2,599.84	3,268.13	4,089.09	5,101.64	6,357.03	7,923.59	9,893.85
3.C.6 - Indirect N2O Emissions from Manure Management	321.7	393.488	476.683	573.413	686.381	819.058	975.946	1,162.97	1,388.03
3.C.7 - Rice Cultivation	15.5741	20.5305	26.7281	34.4606	44.1025	56.1374	71.198	90.1233	114.044
4.A - Solid Waste Disposal	707.433	890.95	1,110.32	1,372.81	1,687.67	2,066.76	2,525.48	3,084.16	3,770.01
4.C - Incineration and Open Burning of Waste	26.0632	32.7309	40.7055	50.2605	61.7441	75.6039	92.4227	112.97	138.279
4.D - Wastewater Treatment and Discharge	1,041.43	1,322.87	1,663.76	2,077.13	2,579.53	3,192.32	3,943.36	4,869.48	6,020.17

Figure 3-22 indicates substantial mitigation interventions in the land-use change and forestry (LUCF) sector. There is an observable divergence of the trend in the forestland carbon stock/sinks from the projected trend, indicating emerging carbon stocks, starting from 2007. This will eventually alter the projected trend by improving the removals in the National GHG Inventory. The change is attributed to "concerted" afforestation and reforestation efforts by the GoE.

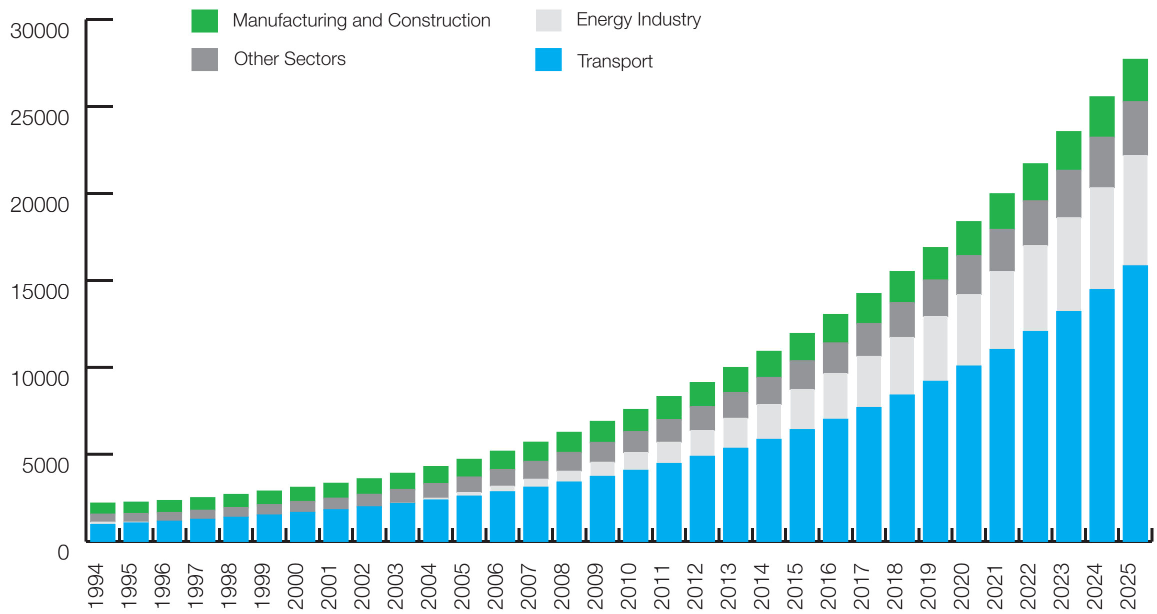
Figure 3-24: Interventions in the LUCF Sector (Gg)



3.11.2. Energy Sector Emission Projections

The main human activity that emits CO_2 in the energy sector is the combustion of fossil fuels (coal, natural gas and oil) for energy and transportation. The transport subsector contributes the largest share of emissions at 54 per cent, while energy generation contributes 18 per cent and manufacturing and construction, and the other sectors, including commercial and residential energy use, each contribute 14 per cent of emissions. Figure 3-23 shows the projected emissions from the energy sector. Electricity is a significant source of energy in the Ethiopia and is used to power homes, businesses and industry. The combustion of fossil fuels to generate electricity is the second largest single source of CO_2 emissions in the nation. Each type of fossil fuel used to generate electricity will emit different amounts of CO_2. To produce a given amount of electricity, burning coal, which began in 2008, will produce more CO_2 than oil or natural gas. The combustion of fossil fuels, such as gasoline and diesel, to transport people and goods is the largest source of CO_2 emissions. This category includes the use of fossil fuels for transportation services such as highway vehicles and aircraft. The country has adopted various measures to achieve the CRGE strategy, including use of electric powered vehicles and motor cycles, trams and the light rail transport system currently under construction (see section 2.7.3).

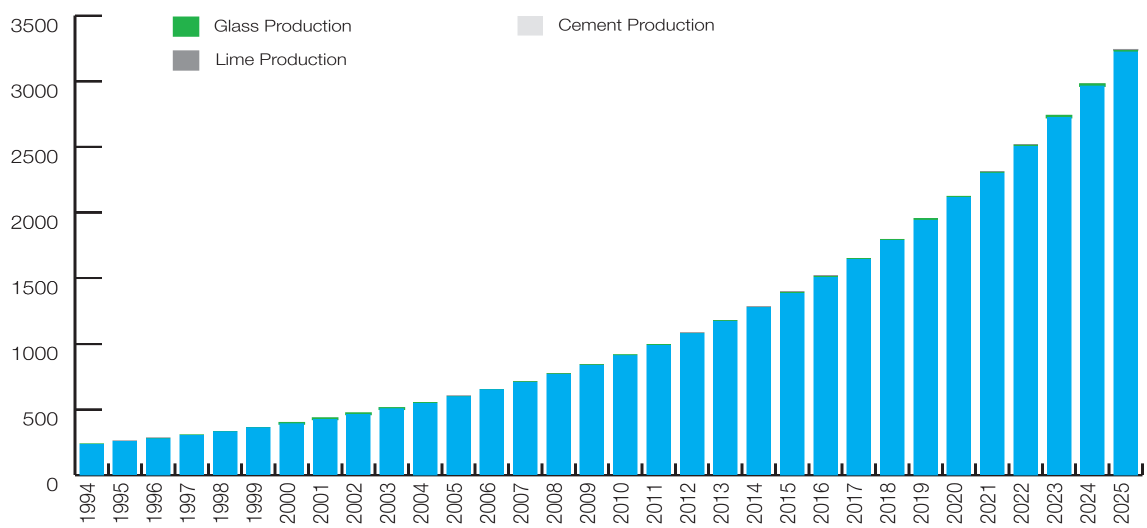
Figure 3-25: Projected Energy Sector Emissions (Gg



3.11.3. Projection of IPPU Sector Emissions

Total emissions from the industrial processes and product use (IPPU) sector are estimated to have been 1.76 million tons tCO_2 in 2013 and are expected to rise to 9.49 million tons CO_2 by 2025. The non-metallic mineral products subsector, comprising cement, lime production and the use of soda ash for glass production, is identified as the main sources of CO_2 emission in the IPPU sector. The production of cement is the principal source of CO_2 emissions contributing 99 per cent of the sector total. Figure 3.24 shows the trend and projections of emissions for the IPPU sector.

Figure 3-26: Projected IPPU Sector Emissions (Gg)



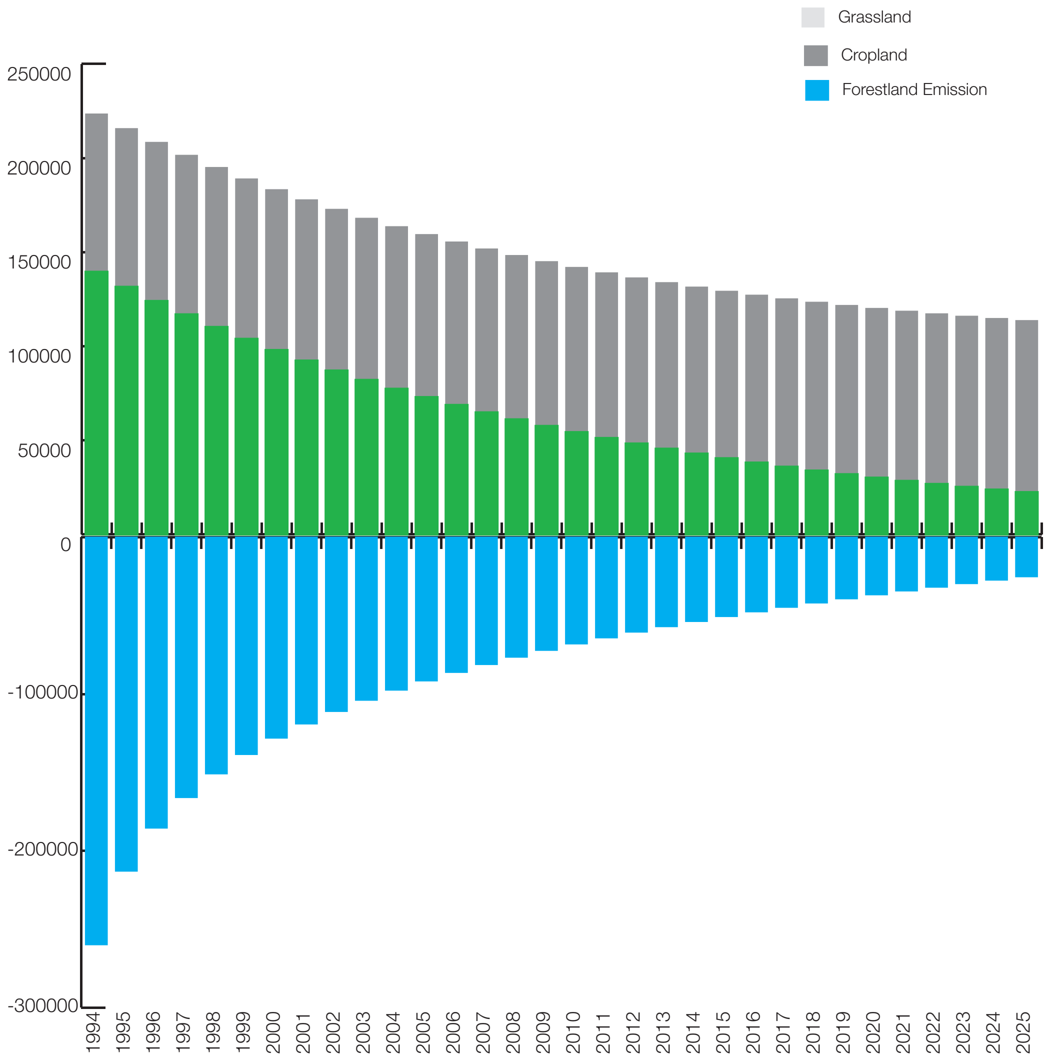
3.11.4 .AFOLU Emission Projections

In AFOLU emissions are expected from land use, land-use change resulting from deforestation, land clearing for agriculture, forest fires and biomass burning in grasslands. Conversion of grasslands to cropland is also a source of significant emission. This estimate does not include the CO_2 that ecosystems remove from the atmosphere.

Figure 3-25 shows the percentage distribution of emissions from land. Emissions from cropland form the largest proportion at 46 per cent. Grassland follows closely, at 24 per cent, while forests remove 30 per cent of the emissions from land. In aggregate these sources produce an insignificant share of total emissions but they are increasing rapidly and for this reason should be regarded as important.

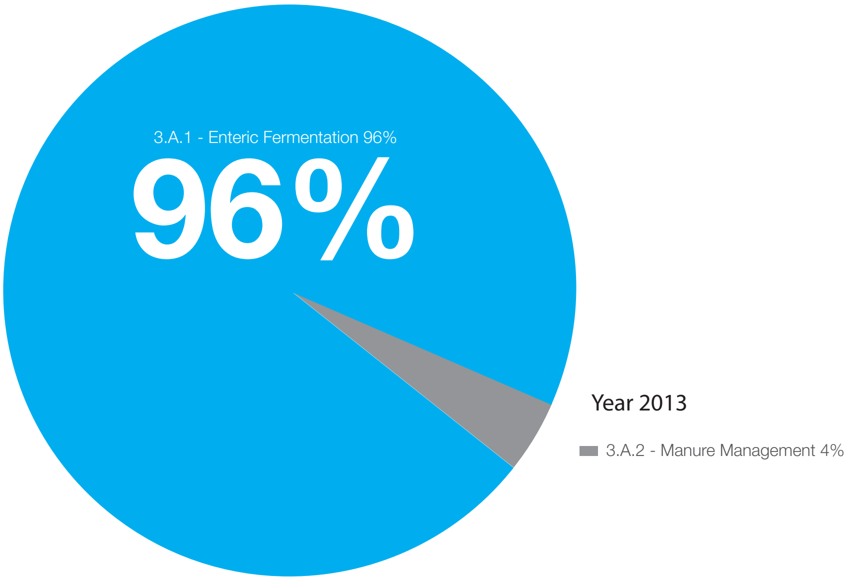
The amount of CO_2 that is removed in this sector is subject to great uncertainty, although recent estimates indicate that on a global scale, ecosystems on land remove about twice as much CO_2 as is lost by deforestation (IPPC, 2007; NRC, 2010; and Houghton, 2008). In agriculture, greenhouse gas emissions are mostly from the management of agricultural soils, livestock, rice production, and biomass burning. Figure 3-25 shows diminishing carbon stocks in the forestland of Ethiopia and a significant reduction of emissions from the grasslands. It can also be deduced that the emissions from cropland continues to increase steadily.

Figure 3-27: Projections of Emissions from Land (Gg)



Crop Production for Commercial Purposes

Figure 3-28: Livestock Emissions, 2013

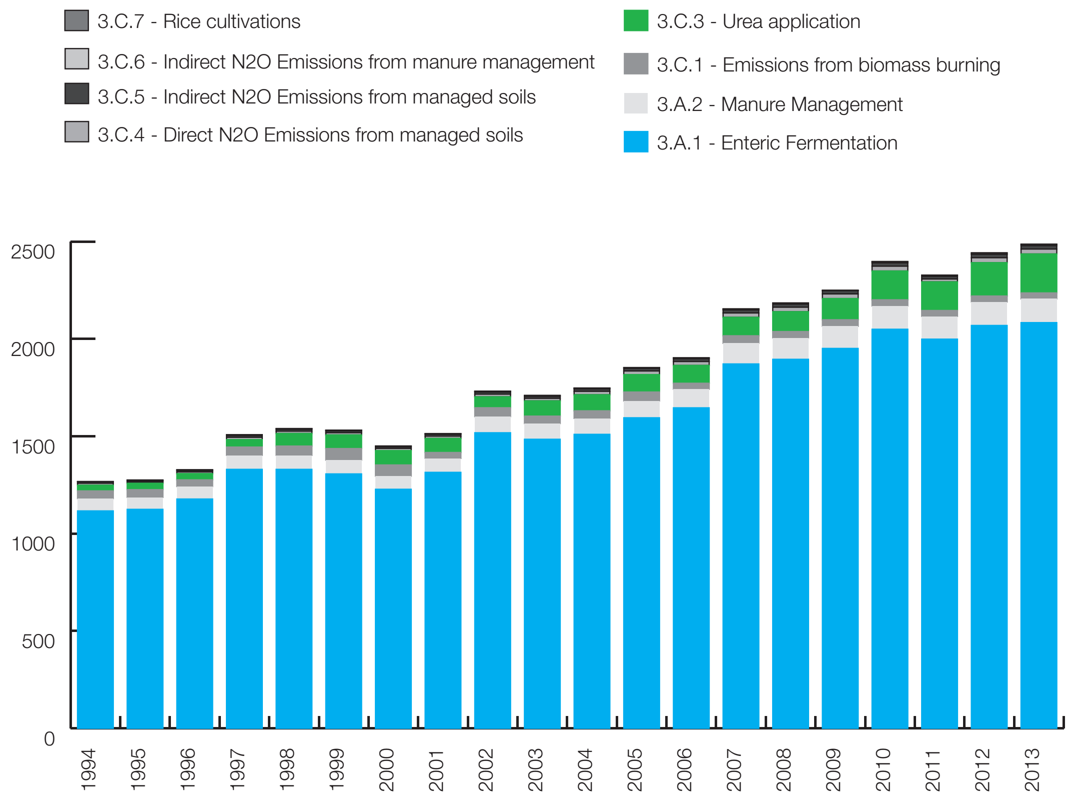


The livestock subsector produces significant methane and nitrous oxide emissions from the processes of enteric fermentation and manure management. Figure 3.26 shows that in 2013 only 4 per cent of the methane emissions from livestock production resulted from manure management while the bulk of it resulted from enteric fermentation.

Most of the methane emissions results from cattle farming.

Figure 3-27 shows that methane emissions from livestock through enteric fermentation and manure management are the dominating sources in agriculture sector. The types of livestock included: other (non-dairy) cattle, sheep, goats, swine, poultry, mules and asses, horses and camels. The methane emissions from livestock are projected to be 3.5 million tons of CO_2e by 2025.

Figure 3-29: Projection of Livestock and other Agricultural Emissions (Gg)

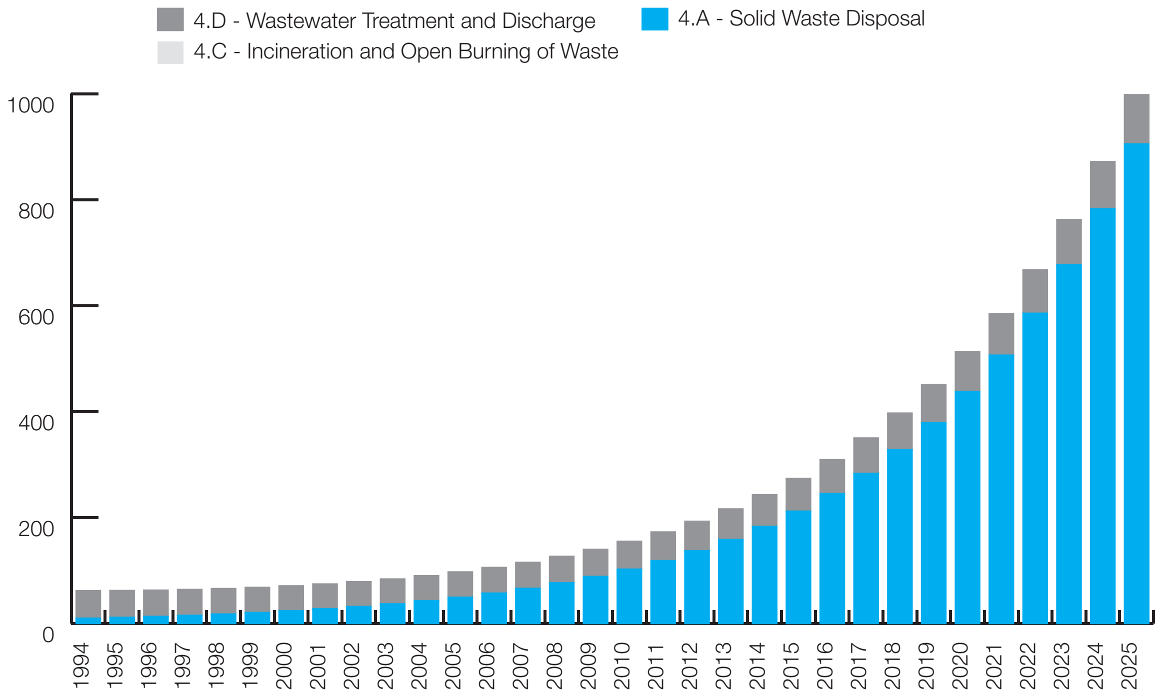


3.11.5. Projection of Waste Sector Emissions

As organic waste decomposes, it produces emissions at a diminishing rate and takes many years to decompose completely. This occurs during anaerobic decomposition of organic waste disposed of in solid waste disposal sites (SWDSs). Wastewater handling under anaerobic conditions also produces methane (CH_4). Anaerobic methods are particularly prevalent in developing countries when handling wastewater from municipal sewage, and food processing and other industrial facilities. CH_4 emissions from wastewater handling are calculated for two different types of wastewater and their resulting sludge types, namely domestic wastewater and sludge, and industrial wastewater and sludge.

Figure 3-28 shows the trend and projections for emissions from the waste sector.

Figure 3-30: Projected Emissions in the Waste Sector (Gg)

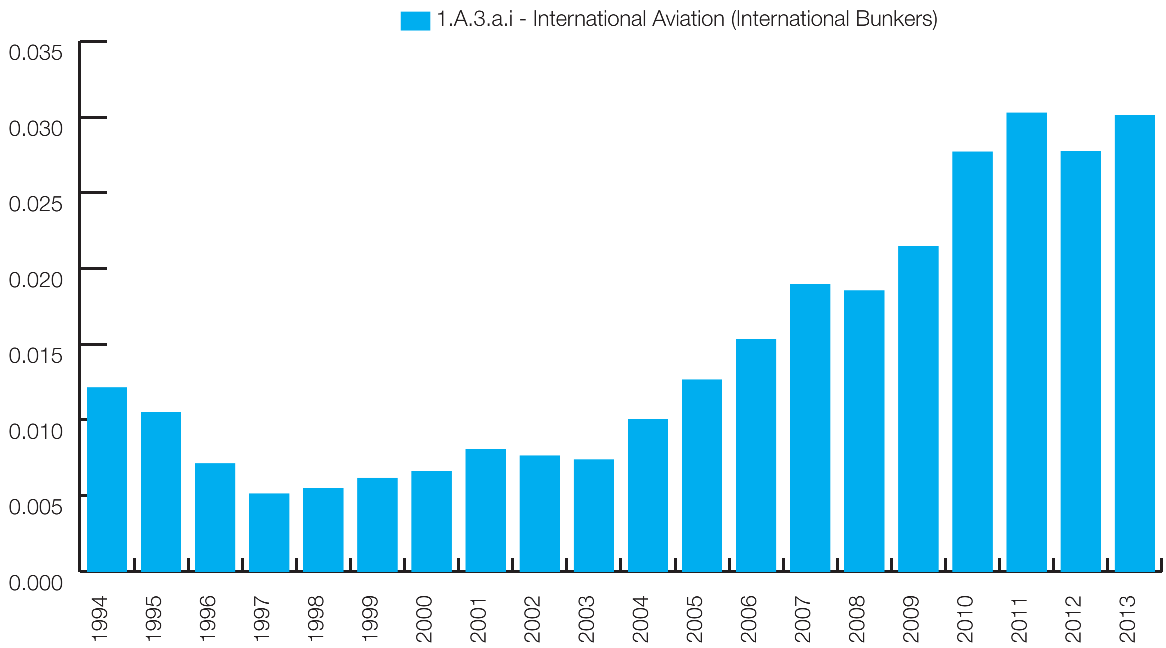


3.12. GHG Emissions Memo Items

In accordance with the GHG reporting methodology established by the UNFCCC, greenhouse gas emissions generated through the consumption of fuel used in international transport (bunker fuels) and CO_2 emissions generated from the use of wood and biogas as energy sources are not included in national total emissions. These emissions are reported as memo items separately from the rest of the country's emissions. The consumption of fuel in international transport occurs in air transport (mainly jet fuel and aviation gasoline) and maritime transport (diesel and petroleum fuels which are not significant in Ethiopia). The current arrangement for compiling information on fuel consumption, undertaken in the context of the national energy balance, makes it difficult to assign emissions from these fuels between domestic and international air transport, as the statistics for fuel consumption do not separate domestic and international transport. Nitrous oxide emissions fell between 1994 and 1998, but have been on an upward trend since then, with the steepest increase being from 2004 to 2013 (see Figure 3-29). This could be due to an increase in the number of flights connecting through Addis Ababa in recent years.

The other memo item is the emissions from consumption of woodfuel and bio-gas for energy use included. It is only CO_2 emissions from these activities which are presented as memo items. Emissions of greenhouse gases other than CO_2 are reported under the energy sector.

Figure 3-31: Nitrous Oxide Emissions from International Aviation (Memo Item) (Gg)



The information used in the compilation of the National Inventory is derived from the National Energy Balance, in which consumption of woodfuel is classified as consumption in the energy sector. Woodfuel consumption is significant in Ethiopia, notably at the residential and to a lesser extent in the industrial and commercial sectors. In 2013 CO_2 emissions from biomass combustion for energy generation produced 149,986.3 Gg of CO_2e of emissions.

3.13. Uncertainty assessment

The main activity data used to build the National Inventory were obtained from the official annual reports produced by government institutions. However, the data do not include metadata showing the uncertainty levels nor do they provide the statistics needed to gauge the uncertainty of the activity data they generate. Since these institutions do not calculate the uncertainties associated with the data that they submit, it is impossible to determine comprehensively the uncertainty associated with emission calculations in the National Inventory. However, some approximate uncertainties have been assigned to some activity data based on the felt general data collection constraints. Because of the incomplete nature of this information, activity data based on estimates will have higher degrees of uncertainty. Nevertheless, as official data on uncertainties associated with activity data are not available, uncertainty is taken to be zero, due to the lack of information. Nonetheless the uncertainty levels resulting from the use of default factors has been computed. The uncertainty assessment of the total inventory was evaluated and the results show a total inventory uncertainty of 4.2 per cent and trend uncertainty of 27.9 per cent. A comprehensive uncertainty result by category is shown in the Tables 3-34 and 3-35.

Table 3-34: Assessment of Uncertainty in Trend

A	B	C	D	H	I	J	K	L	M
2006 IPCC Categories	**Gas**	**Base Year emissions or removals (Gg CO2 equivalent)**	**Year T emissions or removals (Gg CO2 equivalent)**	**Contribution to Variance by Category in Year T**	**Type Sensitivity (%)**	**Type B Sensitivity (%)**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)**	**Uncertainty in trend in national emissions introduced by activity data uncertainty (%)**	**Uncertainty introduced into the trend in total national emissions (%)**
1.A - Fuel Combustion Activities									
1.A.1.a.i - Electricity Generation - Liquid Fuels	CO_2	25.686024	1620.781038	0.001332593	0.022882177	0.024764983	0.114410887	0.175114876	0.043755071
1.A.1.a.i - Electricity Generation - Liquid Fuels	CH_4	0.025998	1.636482023	1.35854E-09	2.30993E-05	2.50049E-05	0.000115497	0.000176811	4.46017E-08
1.A.1.a.i - Electricity Generation - Liquid Fuels	N_2O	0.061979232	3.901373142	7.72118E-09	5.50687E-05	5.96117E-05	0.000275344	0.000421518	2.53492E-07
1.A.1.a.i - Electricity Generation - Solid Fuels	CO_2	0	24.038	2.9312E-07	0.000367292	0.000367292	0.001836462	0.00259715	1.01178E-05
1.A.1.a.i - Electricity Generation - Solid Fuels	CH_4	0	0.00595	1.7959E-14	9.0914E-08	9.0914E-08	4.5457E-07	6.42859E-07	6.19901E-13
1.A.1.a.i - Electricity Generation - Solid Fuels	N_2O	0	0.106386	5.7414E-12	1.62554E-06	1.62554E-06	8.12771E-06	1.14943E-05	1.98179E-10
1.A.1.c.ii - Other Energy Industries - Biomass	CO_2	359.6	0	0	0.02635626	0	0.131781301	0	0.017366311
1.A.1.c.ii - Other Energy Industries - Biomass	CH_4	2.697	0	0	0.000197683	0	0.000988414	0	9.76962E-07
1.A.1.c.ii - Other Energy Industries - Biomass	N_2O	4.286432	0	0	0.000314184	0	0.001570918	0	2.46778E-06
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CO_2	624.791067	1459.999451	0.00108132	0.02348496	0.022308295	0.117424798	0.157743469	0.038671585
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.31071525	1.460756759	1.08244E-09	4.54722E-07	2.23199E-05	2.27361E-06	0.000157825	2.4914E-08
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	N_2O	1.474897956	3.482444114	6.15201E-09	5.48955E-05	5.32106E-05	0.000274477	0.000376255	2.16906E-07
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CO_2	0	27.27	3.77241E-07	0.000416676	0.000416676	0.002083382	0.002946347	1.30214E-05

A	B	C	D	H	I	J	K	L	M
2006 IPCC Categories	**Gas**	**Base Year emissions or removals (Gg CO2 equivalent)**	**Year T emissions or removals (Gg CO2 equivalent)**	**Contribution to Variance by Category in Year T**	**Type Sensitivity (%)**	**Type B Sensitivity (%)**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)**	**Uncertainty in trend in national emissions introduced by activity data uncertainty (%)**	**Uncertainty introduced into the trend in total national emissions (%)**
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CH_4	0	0.0675	2.3113E-12	1.03138E-06	1.03138E-06	5.15689E-06	7.29294E-06	7.97804E-11
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	N_2O	0	0.12069	7.3891E-12	1.8441E-06	1.8441E-06	9.22051E-06	1.30398E-05	2.55053E-10
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	CO_2	432.9325	1075.708634	0.000587	0.015295308	0.016436462	0.076476542	0.116223339	0.019356526
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	CH_4	0.0756875	0.18806095	1.7941E-11	2.67418E-06	2.87351E-06	1.33709E-05	2.03188E-05	5.91633E-10
1.A.3.a.i - International Aviation (International Bunkers) - Liquid Fuels	N_2O	3.60878	8.966746096	4.07867E-08	0.000127505	0.000137009	0.000637525	0.000968799	1.34501E-06
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CO_2	142.24925	0	0	0.010426259	0	0.052131295	0	0.002717672
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	CH_4	0.02486875	0	0	1.82281E-06	0	9.11406E-06	0	8.30661E-11
1.A.3.a.ii - Domestic Aviation - Liquid Fuels	N_2O	1.185742	0	0	8.69117E-05	0	0.000434558	0	1.88841E-07
1.A.3.b - Road Transportation - Liquid Fuels	CO_2	0	3354.154845	0.005707094	0.051250346	0.051250346	0.256251729	0.362394671	0.196994846
1.A.3.b - Road Transportation - Liquid Fuels	CH_4	0	4.413361638	9.8807E-09	6.74347E-05	6.74347E-05	0.000337173	0.000476835	3.41058E-07
1.A.3.b - Road Transportation - Liquid Fuels	N_2O	0	52.60727072	1.40391E-06	0.000803821	0.000803821	0.004019106	0.005683874	4.84596E-05
1.A.3.b.i - Cars - Liquid Fuels	CO_2	441.832545	493.633602	0.000123611	0.024840901	0.007542554	0.124204505	0.053333908	0.018271265
1.A.3.b.i - Cars - Liquid Fuels	CH_4	5.25991125	5.8765905	1.75186E-08	0.000295745	8.97923E-05	0.001478724	0.000634927	2.58976E-06
1.A.3.b.i - Cars - Liquid Fuels	N_2O	6.07981984	6.792626304	2.34058E-08	0.000341845	0.000103789	0.001709225	0.000733899	3.46006E-06

A	B	C	D	H	I	J	K	L	M
2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Year T emissions or removals (Gg CO2 equivalent)	Contribution to Variance by Category in Year T	Type Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
1.A.3.b.ii - Light-duty trucks - Liquid Fuels	CO_2	430.414296	0	0	0.03154613	0	0.157730651	0	0.024878958
1.A.3.b.ii - Light-duty trucks - Liquid Fuels	CH_4	0.5663346	0	0	4.15108E-05	0	0.000207554	0	4.30786E-08
1.A.3.b.ii - Light-duty trucks - Liquid Fuels	N_2O	6.750708432	0	0	0.000494808	0	0.002474041	0	6.12088E-06
1.A.4.a - Commercial/ Institutional - Biomass	CO_2	161.28	1044.31327	0.000553236	0.004135262	0.015956752	0.020676308	0.112831274	0.013158406
1.A.4.a - Commercial/ Institutional - Biomass	CH_4	7.2	69.93169217	2.48083E-06	0.000540791	0.001068532	0.002703957	0.007555666	6.43995E-05
1.A.4.a - Commercial/ Institutional - Biomass	N_2O	0.42912	11.11447694	6.26653E-08	0.000138372	0.000169825	0.00069186	0.001200847	1.9207E-06
1.A.4.b - Residential - Liquid Fuels	CO_2	245.94133	1088.232425	0.000600748	0.001398961	0.016627822	0.006994804	0.117576454	0.01387315
1.A.4.b - Residential - Liquid Fuels	CH_4	0.8337875	3.752279845	7.14232E-09	3.78081E-06	5.73336E-05	1.8904E-05	0.000405409	1.64714E-07
1.A.4.b - Residential - Liquid Fuels	N_2O	0.58283734	2.663705174	3.59933E-09	2.01989E-06	4.07005E-05	1.00995E-05	0.000287796	8.29286E-08
1.A.4.b - Residential - Biomass	CO_2	91705.936	187441.1931	17.82292283	3.80445028	2.864037715	19.0222514	20.2518049	771.9816499
1.A.4.b - Residential - Biomass	CH_4	5964.6375	11569.84693	0.067905363	0.260171369	0.176783328	1.300856845	1.250046902	3.254845788
1.A.4.b - Residential - Biomass	N_2O	912.9379	1623.990638	0.001337876	0.042095984	0.024814025	0.210479921	0.175461653	0.075088589
1.A.4.c.ii - Off-road Vehicles and Other Machinery - Liquid Fuels	CO_2	89.2164	0	0	0.006539232	0	0.032696159	0	0.001069039
1.A.4.c.ii - Off-road Vehicles and Other Machinery - Liquid Fuels	CH_4	0.301	0	0	2.20625E-05	0	0.000110312	0	1.21688E-08
1.A.4.c.ii - Off-road Vehicles and Other Machinery - Liquid Fuels	N_2O	0.2152752	0	0	1.57791E-05	0	7.88954E-05	0	6.22449E-09
1.B.1 - Fugitive Emissions from Fuels - Solid Fuels									
1.B.1.a.i.1 - Mining	CH_4	0	3.35	0	5.11869E-05	5.11869E-05	0	0	0

A	B	C	D	H	I	J	K	L	M
2006 IPCC Categories	**Gas**	**Base Year emissions or removals (Gg CO2 equivalent)**	**Year T emissions or removals (Gg CO2 equivalent)**	**Contribution to Variance by Category in Year T**	**Type Sensitivity (%)**	**Type B Sensitivity (%)**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)**	**Uncertainty in trend in national emissions introduced by activity data uncertainty (%)**	**Uncertainty introduced into the trend in total national emissions (%)**
1.B.1.a.i.2 - Post-mining seam gas emissions	CH_4	0	0.3015	0	4.60682E-06	4.60682E-06	0	0	0
2.A - Mineral Industry									
2.A.1 - Cement production	CO_2	300.846	905.1741194	0.010183081	0.008220068	0.013830753	0	0.684587339	0.468659825
2.A.2 - Lime production	CO_2	2.09979	9.923816472	2.24812E-07	2.27639E-06	0.000151633	0	0.003216612	1.03466E-05
2.A.3 - Glass Production	CO_2	0.48279	2.078788152	1.09607E-09	3.62403E-06	3.17632E-05	0	0.0002246	5.0445E-08
2.B - Chemical Industry									
2.B.7 - Soda Ash Production	CO_2	1.697949828	0.182091511	8.41004E-12	0.000121673	2.7823E-06	0	1.96738E-05	3.87059E-10
2.C - Metal Industry									
2.C.1 - Iron and Steel Production	CO_2	49.3317	840.6396	0.000716966	0.009228737	0.012844687	0	0.18165131	0.032997199
2.F - Product Uses as Substitutes for Ozone Depleting Substances									
2.F.5 - Solvents	CF_3CHFC $HFCF_2CF_3$	0	0.855614435	1.93112E-08	1.30735E-05	1.30735E-05	0.000653675	0.000184887	4.61474E-07
2.H - Other									
3.A - Livestock									
3.A.1.a.i - Dairy Cows	CH_4	0	0	0	0	0	0	0	0
3.A.1.a.ii - Other Cattle	CH_4	22823.75	41850	0	1.029873854	0.639453774	0	0	0
3.A.1.b - Buffalo	CH_4	0	0	0	0	0	0	0	0
3.A.1.c - Sheep	CH_4	2174	3312.5	0	0.108698344	0.050613874	0	0	0
3.A.1.d - Goats	CH_4	1043.75	3125	0	0.028750532	0.047748938	0	0	0
3.A.1.e - Camels	CH_4	385.25	1063.75	0	0.01198334	0.016253738	0	0	0
3.A.1.f - Horses	CH_4	517.5	900	0	0.024177746	0.013751694	0	0	0
3.A.1.g - Mules and Asses	CH_4	970	1836.25	0	0.043034725	0.028057276	0	0	0

A	B	C	D	H	I	J	K	L	M
2006 IPCC Categories	**Gas**	**Base Year emissions or removals (Gg CO2 equivalent)**	**Year T emissions or removals (Gg CO2 equivalent)**	**Contribution to Variance by Category in Year T**	**Type Sensitivity (%)**	**Type B Sensitivity (%)**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)**	**Uncertainty in trend in national emissions introduced by activity data uncertainty (%)**	**Uncertainty introduced into the trend in total national emissions (%)**
3.A.1.h - Swine	CH_4	0.5	0.825	0	2.40429E-05	1.26057E-05	0	0	0
3.A.1.j - Other (please specify)	CH_4	0	0	0	0	0	0	0	0
3.A.2.a.i - Dairy cows	N_2O	0	0	0	0	0	0	0	0
3.A.2.a.ii - Other cattle	N_2O	658.3501994	1911.339289	0	0.01904876	0.029204615	0	0	0
3.A.2.b - Buffalo	N_2O	0	0	0	0	0	0	0	0
3.A.2.c - Sheep	N_2O	109.5594179	415.4813863	0	0.001681967	0.006348414	0	0	0
3.A.2.d - Goats	N_2O	105.5855718	333.6869368	0	0.002640472	0.005098623	0	0	0
3.A.2.e - Camels	N_2O	0	0	0	0	0	0	0	0
3.A.2.f - Horses	N_2O	0	33.68302344	0	0.000514665	0.000514665	0	0	0
3.A.2.g - Mules and Asses	N_2O	0	67.56772044	0	0.001032412	0.001032412	0	0	0
3.A.2.h - Swine	N_2O	0	0	0	0	0	0	0	0
3.A.2.i - Poultry	N_2O	6.874745696	6.433248266	0	0.000405602	9.82978E-05	0	0	0
3.A.2.j - Other (please specify)	N_2O	0	0	0	0	0	0	0	0
3.A.2.a.i - Dairy cows	CH_4	0	0	0	0	0	0	0	0
3.A.2.a.ii - Other cattle	CH_4	736.25	1350	0	0.033333844	0.020627541	0	0	0
3.A.2.b - Buffalo	CH_4	0	0	0	0	0	0	0	0
3.A.2.c - Sheep	CH_4	54.35	132.5	0	0.001959137	0.002024555	0	0	0
3.A.2.d - Goats	CH_4	45.925	137.5	0	0.001265216	0.002100953	0	0	0
3.A.2.e - Camels	CH_4	21.44	59.2	0	0.000666936	0.000904556	0	0	0
3.A.2.f - Horses	CH_4	62.9625	109.5	0	0.00294183	0.001673123	0	0	0
3.A.2.g - Mules and Asses	CH_4	116.4	220.35	0	0.005164841	0.003366873	0	0	0
3.A.2.h - Swine	CH_4	0.5	0.825	0	2.40429E-05	1.26057E-05	0	0	0
3.A.2.i - Poultry	CH_4	13.625	25.5	0	0.000609043	0.000389631	0	0	0
3.B - Land									

A	B	C	D	H	I	J	K	L	M
2006 IPCC Categories	**Gas**	**Base Year emissions or removals (Gg CO2 equivalent)**	**Year T emissions or removals (Gg CO2 equivalent)**	**Contribution to Variance by Category in Year T**	**Type Sensitivity (%)**	**Type B Sensitivity (%)**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)**	**Uncertainty in trend in national emissions introduced by activity data uncertainty (%)**	**Uncertainty introduced into the trend in total national emissions (%)**
3.B.1.a - Forest land Remaining Forest land	CO_2	-327882.7644	-80753.95328	0	24.00148711	1.233892956	0	0	0
3.B.1.b.i - Cropland converted to Forest Land	CO_2	-5770.094646	-4481.828439	0	0.354764309	0.068480815	0	0	0
3.B.1.b.ii - Grassland converted to Forest Land	CO_2	-2545.598391	-6246.066241	0	0.091183181	0.095437769	0	0	0
3.B.2.a - Cropland Remaining Cropland	CO_2	-39.897	-308.913605	0	0.001795764	0.004720095	0	0	0
3.B.2.b.i - Forest Land converted to Cropland	CO_2	59081.9665	49300.88585	0	3.545242953	0.753300777	0	0	0
3.B.2.b.ii - Grassland converted to Cropland	CO_2	30661.81178	26590.60517	0	1.832547021	0.406295408	0	0	0
3.B.3.b.i - Forest Land converted to Grassland	CO_2	183123.3007	54666.75241	0	12.24454382	0.835289394	0	0	0
3.B.3.b.ii - Cropland converted to Grassland	CO_2	-10282.32379	-13262.86812	0	0.551881496	0.202652117	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land									
3.C.1.a - Biomass burning in forest lands	CH_4	29.1813796	0	0	0.002138907	0	0	0	0
3.C.3 - Urea application	CO_2	29.18666667	199.925	0	0.000915478	0.003054786	0	0	0
3.C.4 - Direct N2O Emissions from managed soils	N2O	2035.730574	4589.415332	0	0.079064251	0.070124706	0	0	0
3.C.5 - Indirect N2O Emissions from managed soils	N2O	2678.422734	5385.759243	0	0.113981931	0.08229257	0	0	0
3.C.6 - Indirect N2O Emissions from manure management	N2O	459.7915375	1436.972598	0	0.011744199	0.021956453	0	0	0
3.C.7 - Rice cultivations	CH_4	3.720350749	28.80584911	0	0.000167452	0.000440144	0	0	0
3.D - Other									

A	B	C	D	H	I	J	K	L	M
2006 IPCC Categories	**Gas**	**Base Year emissions or removals (Gg CO2 equivalent)**	**Year T emissions or removals (Gg CO2 equivalent)**	**Contribution to Variance by Category in Year T**	**Type Sensitivity (%)**	**Type B Sensitivity (%)**	**Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)**	**Uncertainty in trend in national emissions introduced by activity data uncertainty (%)**	**Uncertainty introduced into the trend in total national emissions (%)**
3.D.1 - Harvested Wood Products	CO_2	-76.65058504	25.50145869	0	0.006008005	0.000389654	0	0	0
4.A - Solid Waste Disposal									
4.A - Solid Waste Disposal	CH_4	114.9547886	3581.842847	0	0.046302652	0.054729341	0	0	0
4.B - Biological Treatment of Solid Waste									
4.C.2 - Open Burning of Waste	CO_2	0.022047411	0.048292096	0	8.78129E-07	7.37887E-07	0	0	0
4.C.2 - Open Burning of Waste	CH_4	0.17845945	0.3908931	0	7.10788E-06	5.97271E-06	0	0	0
4.C.2 - Open Burning of Waste	N2O	0.028963145	0.063440146	0	1.15358E-06	9.69344E-07	0	0	0
4.D - Wastewater Treatment and Discharge									
4.D.1 - Domestic Wastewater Treatment and Discharge	CH_4	1149.155382	2249.370356	0	0.049851617	0.034369614	0	0	0
4.D.1 - Domestic Wastewater Treatment and Discharge	N2O	687.5926945	1125.887315	0	0.033192024	0.017203175	0	0	0
4.D.2 - Industrial Wastewater Treatment and Discharge	CH_4	23.06158264	166.8222414	0	0.000858632	0.002548987	0	0	0
4.E - Other (please specify)									
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3									
5.B - Other (please specify)									
		Sum(C): 65,446.48211		Sum(H): 17.91306			Sum(M): 776.20352		
				Uncertainty in total inventory: 4.23238			Trend uncertainty: 27.86043		

a Base year=1994; T year=2013.

CHAPTER FOUR:

ANALYSIS OF MITIGATION OPTIONS FOR ETHIOPIA

4.1. Preamble

Ethiopia is not obliged under the UN Framework Climate Change Convention to reduce its greenhouse gas (GHG) emissions. Ethiopia's contribution (estimated at 146 million tons of CO_2e per annum to total global GHG emissions is marginal, representing less than 0.3 per cent of total global emissions (34.5 billion tons CO_2) in 2012. Out of the 146 million tons of CO_2e emitted in 2013, about 79 per cent of GHG emissions came from the AFOLU sector. The AFOLU emissions constituted 55 per cent produced from agriculture (cropland 26 per cent) while livestock produced 45 per cent. The direct and indirect emissions from managed soils and manure management aggregated to 10 per cent, grassland produced 14 per cent while forestry removed about 28 per cent. The energy and waste sectors contributed 15 per cent and 5 per cent respectively, and the IPPU sector only 1 per cent.

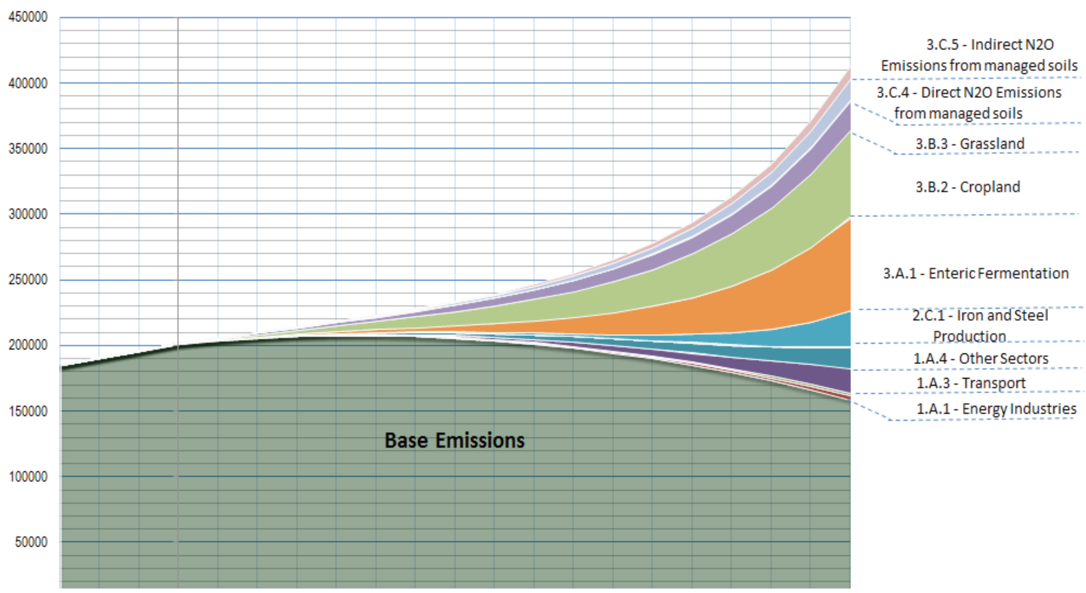
Under Article 12, paragraph 1(b) of the Convention, however, Ethiopia is expected to formulate, implement, publish, and regularly update national programmes containing measures to mitigate climate change. The mitigation actions should be informed by the country's national circumstances and the principles of the Convention as guided by Article 4, paragraph 1 (b). Ethiopia has indeed, voluntarily, and as informed by national development objectives, goals and priorities, designed and is already implementing a Climate Resilient Green Economy (CRGE) strategy that will go a long way in ensuring the country's development follows a climate resilient and green (low emissions) pathway (FDRE, 2011a). The objective of the CRGE is that the country should become a low carbon middle-income economy before 2025. The country`s five-year Growth and Transformation Plans (GTP 2010-2015 and GTP 2015-2020) lay out the basis for transforming the economy. The population of Ethiopia is expected to increase from the current 91 million to 100 million by 2020, 120 million by 2030 and 145 million by 2050, though population growth rates are expected to fall in later years (CSA, 2007). The projected population increase, urbanization and income change will profoundly alter the prospects for sustained economic development, exert pressure on natural resources and contribute to increases in greenhouse gas (GHG) emissions.

In the 2001 Initial National Communication (INC) to the UNFCCC, several mitigation options were identified in the energy; land Use, land-use change and forestry (LULUCF); agriculture; and waste sectors (NMSA, 2001). Some of these measures have been implemented and are contributing not only to GHG mitigation, but also to the country's sustainable economic development objectives. Ethiopia has put in place several initiatives with the potential to contribute to climate change mitigation as summarized in the following paragraphs. As indicated in the 1994 Environmental Policy, Ethiopia is committed to work with the international community to combat anthropogenic climate change.

Within the framework of the preparation of the Second National Communication, Ethiopia has undertaken mitigation analysis and assessment of options to reduce the emission of GHGs and/or enhance their sinks. The information presented in this chapter is built on information made available by the key stakeholders and on information generated using activity data to update the list of potential options for the country to reduce GHG emissions and/or increase sinks to mitigate against climate change in line with national development goals, objectives and priorities. Potential initiatives, programmes, activities and investments which could contribute to GHG emissions reduction and removals in the different socio-economic sectors have also been identified. Further, information on the mitigation analysis guiding implementation of the country's framework for sustainable and low carbon development is provided. The mitigation analysis and implementation strategy are informed by the GHG emissions projections.

The analyses carried out recognize the role of Nationally Appropriate Mitigation Actions (NAMAs) as a pathway for not only delivering on GHG emissions abatement, but also contributing to Ethiopia's sustainable development programmes and poverty reduction. According to Decision 1/CP.16 of 2010 (the Cancun Agreements), "developing country parties will take nationally appropriate mitigation actions in the context of sustainable development, supported and enabled by technology, financing and capacity-building, aimed at achieving a deviation in emissions relative to 'business as usual' emissions in 2020". This builds on previous decisions of the Conferences of the Parties (COPs), namely 1/CP.13 of the Bali COP of 2007 and the Copenhagen Accord of 2009. The chapter also takes into account adaptation actions/programmes with mitigation co-benefits. Figure 4-1 shows the emission reduction targets required to achieve a carbon neutral economy by year 2030 as enshrined in the country's CRGE Strategy.

Figure 4-1: Emission Reductions (Gg) Required to Meet the CRGE Strategy Targets by 2030 (Gg)



The following sections describe some of the methods, baselines, projections and mitigation options in the GHG categories of energy, agriculture, forestry, and land use (AFOLU), industrial processes, and product use (IPPU) and waste.

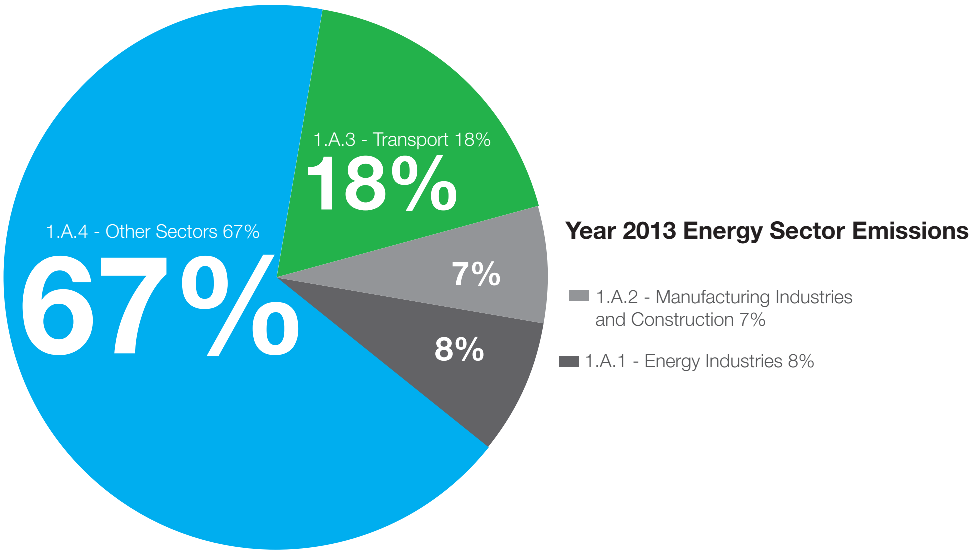
4.2. Energy Analysis, Assessment and Mitigation Options

4.2.1. The Energy Supply and Consumption Pattern

The pattern of energy supply and consumption in Ethiopia is characterized by a heavy reliance on biomass fuels. Traditional biomass fuels are the main sources of energy, with firewood, charcoal, and agro-residues contributing about 92 per cent of the total energy supply. Petroleum and electricity contribute about 7 per cent and 1 per cent to the total national energy supply respectively. In 2011, total energy consumption in Ethiopia was estimated to be about $1.25x10^9$ GJ. There has been a decline in the share of biomass fuels in the national energy supply over the years; their share of the energy supply declined by about 2.3 percentage points between 1996 and 2009, while the relative contributions of petroleum and electricity increased by 2 percentage points and 0.3 of a percentage point respectively (Gaia/PHE, 2011). The dependence of the majority of households on biomass resources has adverse effects on the country's ecology, while also contributing to the overall increase in GHG emissions.

Ethiopia is endowed with vast energy resources. According to the National Energy Policy document, they comprise: 45,000 MW of hydropower resources, 1,387 million tons of oil equivalent (TOE), biomass resources, including 17.5 million TOE of agricultural residues, 7000 MW of geothermal energy, 40.3 million tons of coal and vast resources of solar and wind energy. The country also has natural gas reserves estimated at 112 billion cubic metres. There is about four trillion cubic feet (tcf) of natural gas deposits in the eastern part of the county. Oil shale deposits are estimated at 112 million tons. However, the country has not been able to develop, transform, and utilize these resources for optimal economic development (FDRE, 2014).

Figure 4-2: Energy Sector Emissions, 2013



The energy sector contributes about 21,749.44 GgCO_2e, mainly from the "other sectors" component, which accounts for 67 per cent of total energy sector emissions, including prominently residential and commercial institutions, followed by transport 18 per cent, energy industries 8 per cent and manufacturing industries and construction 7 per cent (see Figure 12). Since biomass energy is accounted for as a memo item and thus does not contribute to the overall national GHG emissions, the other energy sector category is not significant since most of the energy used is biomass based. Discounting the other energy sector category makes the transport subsector the major source of emissions at 56 per cent while the energy industries and manufacturing industries and construction contribute 23 per cent and 21 per cent respectively. Emissions from inland water transport are minimal. Emissions from transport are projected to grow from around 5,454.57 GgCO_2e in 2013 to 16,139.24 GgCO_2e by 2025.

Box 4.1

ACHIEVEMENTS IN THE ENERGY SECTOR DURING THE PASDEP PERIOD

Expansion of Hydro-power Generation: The construction of new hydropower plants, including Tekee, Gilgel Gibe II and Tana Belese plants, enhanced Ethiopia`s hydropower generating capacity. In 2004/05 the total hydropower generation capacity country wide was 714 MW. The Plan for Accelerated and Sustained Development to End Poverty (PASDEP) target was to increase power generation capacity to 3,270MW by the end of 2009/10. The power generation capacity actually achieved was 2000MW at the end of 2009/10 amounting to 62% of the target.

Rural electrification: During the period the rural electrification program aimed to increase the number of towns and rural villages with electric power from 648 to 6000. Accordingly 5163 towns and rural villages had gained access to electricity by 2009/10 amounting to 78% realization of the PASDEP target. The total number of registered customers of electricity increased from 952,000 in 2004/05 to 2 million in 2009/10, 77% of the planned target.

Energy Saving Biomass Ovens and Solar Systems: The plan also so the distribution of 3 million improved energy saving biomass ovens. As a result, it was estimated that about 26, 176 ha of forest were conserved from deforestation, mitigating/avoiding carbon emissions of about 36 575 tons. About 10,081 rural families benefited from distribution of home solar systems and 238 rural health stations and first cycle schools were provided with solar electric power

The electric power subsector accounts for low emissions as it is largely based on renewable energy, with hydropower accounting for more than 90 per cent of the total power generation capacity, supplemented by the use of on and off-grid diesel generators administered by the Ethiopian Electric Power (EEPCO). Current emissions from the electricity sub-sector amount to 2 million tons CO_2e or 1 per cent of the country's total emissions.[12]

In the buildings subsector, an increasing urban population drives increasing waste generation and (off-grid) energy consumption. Total buildings-related emissions are expected to increase from 1.7575 to 6.386 million tons CO_2e by 2025, with around 25 per cent of the emissions attributable to off-grid energy consumption and 75 per cent to waste.

Development of alternative energy from renewable sources such as wind, geothermal, solar and biomass, as well as energy efficiency measures, will be a key part of Ethiopia's energy mix. This is already integrated in the country's Climate Resilient Green Economy (CRGE) strategy, the blueprint for the country's development up to 2025. The Growth and Transformation Plan (GTP), the CRGE and other national development policy documents are explicit in addressing issues of energy access, quality of supply and productive energy use in the context of new energy policies and planning (FDRE, 2012a).

With regard to the National Energy Policy, the following observations can be made.

i. About 92 per cent of households use biomass for cooking, 7 per cent use gas/paraffin and 1 per cent use electricity.

ii. The Government's household energy policy is to achieve a balance between supply and demand for household fuels. The Government will, with this in mind, seek to stabilize prices by increasing the supply of alternative fuels and relieving the pressure on wood resources.

12 The global average for electric power generation's share of a country's GHG emissions is more than 25 per cent.

iii. About 90 per cent of households do not have access to grid electricity more than 90 per cent, particularly those living in rural areas; rely heavily on biomass fuels for domestic energy end-uses.

The above information together with the set of collected data and GHG inventory reports was used to define the baseline and construct a reference scenario from which forecasts and mitigation scenarios were developed. The Long-range Energy Alternatives Planning System (LEAP) software was used to construct scenarios and assess the impact of selected mitigation options on the GHG emissions projections.

4.2.2. Reference scenarios

The reference or business as usual scenario is illustrated in Table 11. The overall energy demand is projected based on the most likely scenarios for the different subsectors, the BAU for biomass energy and electricity and the GTP, base-case scenario for petroleum fuels. Under these assumptions, the overall energy demand is expected to grow by approximately 5 per cent per year and will reach over 2 million TJ by 2030 (Table 11). The relative shares of petroleum fuels and electricity will increase to 23 per cent and 6 per cent, respectively, with a projected corresponding drop in biomass fuels to 72 per cent by 2030.

Table 4-1: Actual and Projected Energy Demand (BAU)

	('000 TJ)							AAGRa
Energy sources/ year	2008	2009	2010	2015	2020	2025	2030	%
Biomass	766.8	788.8	811.4	936.1	1083	1257.1	1465.1	3.1
Petroleum	68.6	74.8	81.4	124.8	192.3	297.5	462.5	9.3
Electricity	10.8	12	13.4	23.1	39.8	68.8	119.2	11.6
Total	846.2	875.6	906.2	1084	1,315.1	1,623.4	2,046.8	4.9
Share %	**2008**	**2009**	**2010**	**2015**	**2020**	**2025**	**2030**	
Biomass	90.6	90.1	89.5	86.4	82.4	77.4	71.6	
Petroleum	8.1	8.5	9.0	11.5	14.6	18.3	22.6	
Electricity	1.3	1.4	1.5	2.1	3.0	4.3	5.8	
Total	100	100	100	100	100	100	100	

a Annual average growth rate. (Source: EEA, 2009).

4.2.3. Mitigation scenarios for the Household Subsector

Using the LEAP model, two alternative household energy scenarios were designed and investigated based on two scenarios, namely, moderate shift and high shift towards efficient biomass use.

4.2.3.1. Bioenergy shift scenarios

In order to investigate future pathways for bioenergy use in Ethiopia, modelling and analysis of long-term shifts in bioenergy scenarios were formulated for 2013–2030. The baseline scenario assumes that current energy practices and policies continue without significant change. The two alternative scenarios–moderate shift and high shift–consider future shifts to more modern and efficient household energy use. The moderate shift scenario assumes parameters/targets that are viewed as being achievable through efforts to promote improved cook stoves, especially in rural areas, along with fuel-switching away from wood and charcoal in urban areas. The high shift scenario considers more optimistic parameters/targets design and implementation.

The market penetration of improved stoves and related assumptions for the two scenarios were based on discussions with stakeholders, as well as on Ethiopia's Green Economy Strategy and expert opinion. Population and GDP projections for the moderate and high shift scenarios were based on the Ethiopian Green Economy Strategy, whereas the baseline scenario is equivalent to the business-as-usual case. In the baseline scenario, the population increases from 87 million in 2011 to 133 million in 2030, whereas in the alternative scenarios, the population reaches 120 million in 2030. The baseline scenario assumes an annual GDP growth rate of 8.4 per cent, whereas it is assumed 10 per cent and 11 per cent in the moderate and high shift scenarios. The average useful energy per household per year for cooking was estimated at 5.6 GJ and was assumed to be constant.

4.2.3.2. Results of the Scenario Analyses

The moderate and high shift scenarios were investigated using SEI's Long-range Energy Alternatives Planning (LEAP) system, with gradual penetration of improved wood and charcoal cook stoves from 2013 to 2030, along with the fuel-switching options. The resulting shares of different cook stove options in 2030 are shown in Table 12, along with the assumed parameters for the different types of stoves.

Improved wood and charcoal stoves were assumed to have zero market shares at present, since their availability is currently constrained. Improved charcoal stoves are more cost-effective and have short payback times, so traditional charcoal stoves are assumed to disappear in urban areas. Furthermore, urban households that have the opportunity to switch to cooking with electricity do so. Traditional wood stoves have nearly disappeared in rural areas in the high shift scenario. Biogas and bioethanol play a small role in rural and urban areas, respectively.

Table: 4-2: Energy parameters for Cook Stove Options and Projected Market Shares in 2030

	Annual Energy Use		Market Share in 2030			
			Urban		Rural	
		Gj/HH		High Shift	Moderate Shift	
Efficiency	Energy Out/ In %	%	Moderate Shift %	%	%	High Shift %
Traditional Wood Stoves	7.5	74.7	26.6	16	31.1	8.4
Improved Wood Stoves	21.5	26.1	3.8	5	60	80
Traditional Charcoal Stoves	10	56.1	0	0	0.1	0.1
Improved Charcoal Stoves	25	22.4	25	20	0.4	0.6
Electric Stoves	75	7.5	39.7	53	3.8	5
Kerosene Stoves	35	15.9	0	0	0	0
LPG Stoves	65	8.5	0	0	0	0
Biogas Stoves	55	10.2	0	0	0	5
Bioethanol Stoves	55	10.2	3	4	4	0
Other Stoves/Fuels	7.5	74.7	2	2	2	0.9

The shift to improved stoves, along with fuel-switching, would significantly reduce wood consumption. The annual wood savings in the scenarios for 2015 and 2030 are shown in Table

13. The high shift scenario results in savings of more than 50 per cent of all wood consumption by 2030, relative to the reference or baseline case.

Table 4-3: Estimated Annual Wood Savings for the Scenarios (million tons)

	Savings in 2015			Savings in 2030		
Measure/scenario	**Baseline**	**Moderate Shift**	**High Shift**	**Baseline**	**Moderate Shift**	**High Shift**
Savings from Improved Cook Stoves	0	4.9	6.5	0	24.3	32.3
Savings from Fuel-switching	0.7	1.5	2.1	1.8	8.6	11.5
Total	0.7	6.4	8.6	1.8	32.9	43.8

Figure 43 shows wood demand over time, as households adopt improved stoves or switch fuels; the figure shows the total wood input requirement needed for fuelwood and charcoal use in the household sector. In the baseline case, wood demand reaches 2.1 EJ (135 million tons) by 2030, whereas demand in the moderate and high shift scenarios is 0.98 EJ (63 million tons) and 0.7 Exa-joules (45 million tons) respectively. As shown in Table 4.3, improved stoves account for about 64 per cent of the savings, while fuel-switching accounts for 36 per cent of the savings in the two scenarios.

Figure 4-3: Wood Energy Demand for Cooking under Three Scenarios

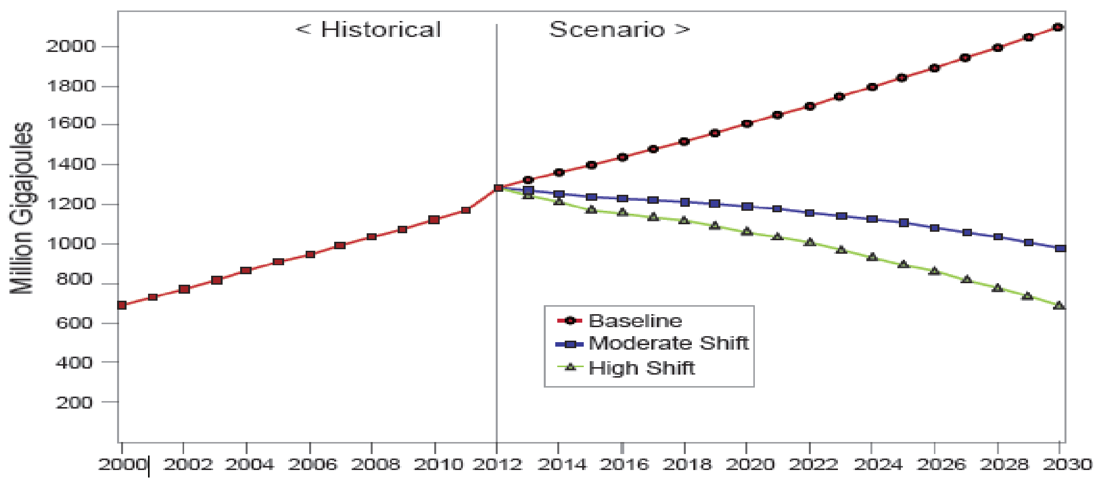


Figure 1: Wood energy demand for cooking under the three scenarios in Ethiopia

The moderate and high shift scenarios offer savings in GHG emissions through improved energy efficiency and reduced land use change. The estimated potential savings in 2015 and 2030 for each type of measure (improved stoves and fuel-switching) are shown in Table 4-4.

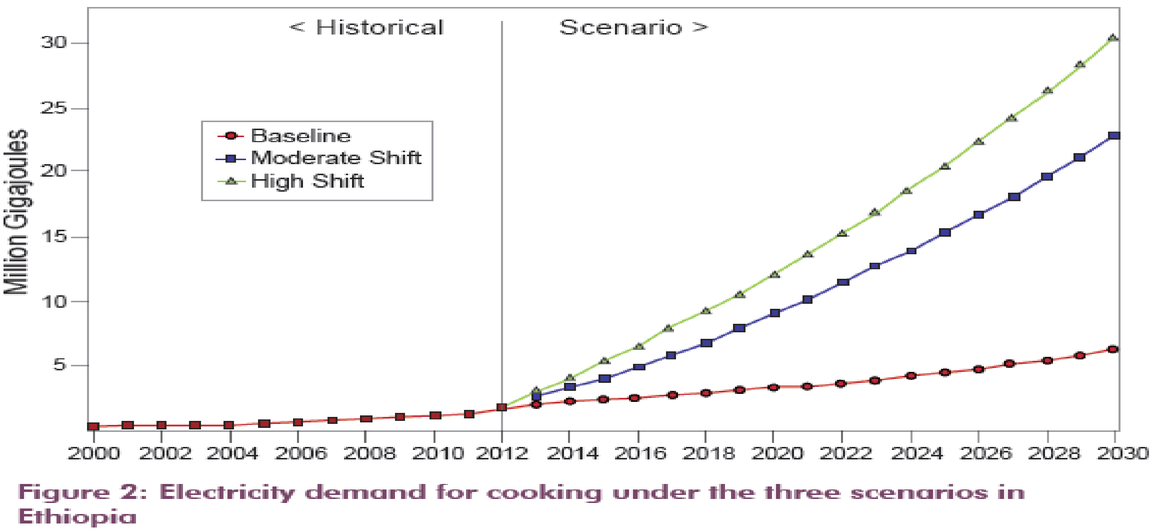
Table 4-4: Estimated Annual GHG Savings under the Three Scenarios (million Tons CO2e)

	Savings in 2015			Savings in 2030		
Measure/scenario	**Baseline**	**Moderate Shift**	**High Shift**	**Baseline**	**Moderate Shift**	**High Shift**
Improved cook stoves	0	6.67	8.89	0	33.08	44.10
Fuel-switching	1.54	3.35	4.48	3.95	18.78	25.06
Total	1.54	10.02	13.37	3.95	51.86	69.16

The GHG savings amount to more than 10 per cent of the projected baseline GHG emissions in 2030. Ethiopia's climate policy targets a reduction of 250 million tons in annual GHG emissions by 2030; thus, the savings estimated here from the moderate and high shift scenarios would account for 21 per cent and 18 per cent <28 per cent, of which 18 per cent is from cook stoves alone of the national target respectively. Consequently, improved stoves and household fuel switching support climate mitigation and offer higher quality energy services. Urban households will save on fuel expenditures, while rural households can avoid the drudgery and drain on productivity associated with fuel wood collection.

Figure 4-4 shows the rapid increase in urban electricity use under the two shift scenarios: whereas rural households adopt improved stoves, urban households switch from charcoal and other fuels to electricity. Since households tend to prioritize electricity for lighting, a shift to electricity for cooking requires additional disposable income, and thus the expected GDP growth in the coming years, which will be overwhelmingly concentrated in urban areas, will accelerate the shift. Electricity demand in the high shift scenario increases to roughly 7,500 GWh, which is nearly twice the 2010 level of total electricity use in Ethiopia (as of 2010). However, there are ambitious power expansion plans under way in Ethiopia that will considerably expand production and widen access.

Figure 4-4: Electricity Demand for Cooking under the Three Scenarios

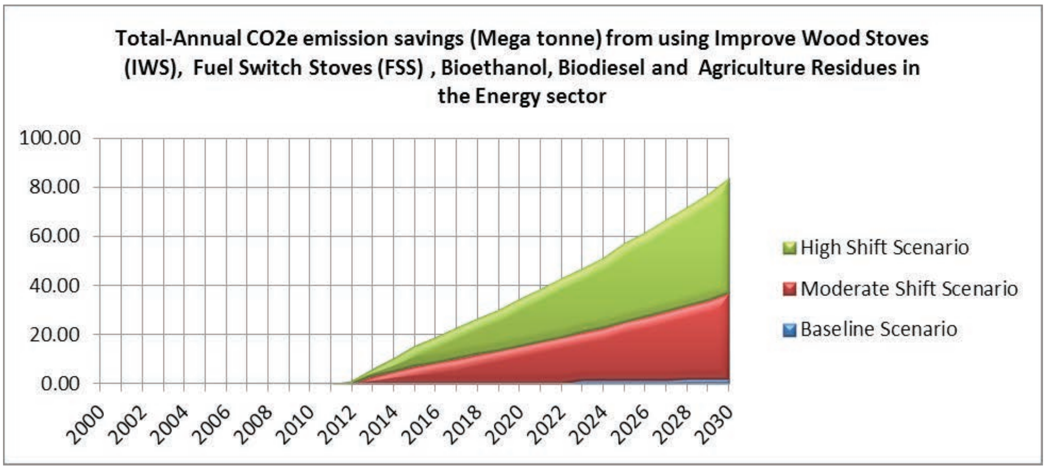


In summary under the moderate shift scenario, the primary effect is that urban households shift significantly towards electricity and away from charcoal, while rural households switch to improved wood cook-stoves. In the high shift scenario, more households switch to efficient stoves and there is also some use of biogas in rural areas and bio-ethanol in urban areas. In the baseline scenario, biomass demand doubles by 2030 compared with 2010. In the moderate and high shift scenarios, biomass use decreases by 53 per cent and 67 per cent, respectively, compared with the baseline case. Significant health and environment benefits can be achieved if these scenarios are realized. Estimated GHG savings in 2030 from due to improved stoves and fuel switching is 33–44 million tons CO_2e, or 21-28 per cent of the government's targeted GHG reductions (Table 4-4).

Thus for the household subsector mitigation options, the shift to improved stoves, along with fuel-switching, would significantly reduce wood consumption. In addition, the use of solar home systems and mini hydropower plants for off-grid rural areas will greatly contribute to reducing

GHG emissions from the household subsector. Figure 4-5 summarizes total annual CO_2 equivalent emissions savings in megatons from using improved wood stoves (IWSs), fuel switch stoves (FSSs), bioethanol, biodiesel, and agricultural residues in the energy sector. Estimated GHG savings from these interventions could result in a cumulative reduction of 80 million tons of tCo_2e by 2030 in the high-shift scenario.

Figure 4-5: Total Annual CO2e Emission Savings from Using Improved Wood Stoves, Fuel Switch Stoves, Bioethanol, Biodiesel, and Agricultural Residues (megatons)



4.2.3.3. Stove Efficiency Improvement

Governmental and non-governmental organizations have made various efforts to introduce and disseminate improved stoves known as Mirt, Gonzie and Lakech in the society. Lakech utilizes charcoal and is used for non-*Injera*[13] cooking activities. It reduces charcoal consumption by up to 25 per cent compared with the conventional charcoal stoves made of sheet steel. Mirt is designed for baking *Injera*. It saves energy, reduces the expenditure on fuel by one third compared with the traditional Mitad stove and removes smoke through a short chimney at the back.

4.2.3.4. Fuel Switching

Use of Liquefied petroleum gas (LPG), compressed natural gas (CNG), ethanol or wood based fuels instead of kerosene for cooking, baking and boiling is proposed as an option to reduce GHG emissions. Other technology options that have the potential to address climate change were investigated for the transport and power generation subsectors of the energy sector (FDRE, 2007). The following section summarizes mitigation options in the subsectors.

4.2.4. Mitigation Options for the Transport Subsector

The Transport subsector's eight mitigation options fall into the following four categories:

- **i.** Improving the public transport system in Addis Ababa;
- **ii.** Improving vehicle efficiency;
- **iii.** Changing the fuel mix; and
- **iv.** Constructing an electric rail network for efficient freight transport.

13 *Injera* is a staple food in Ethiopia.

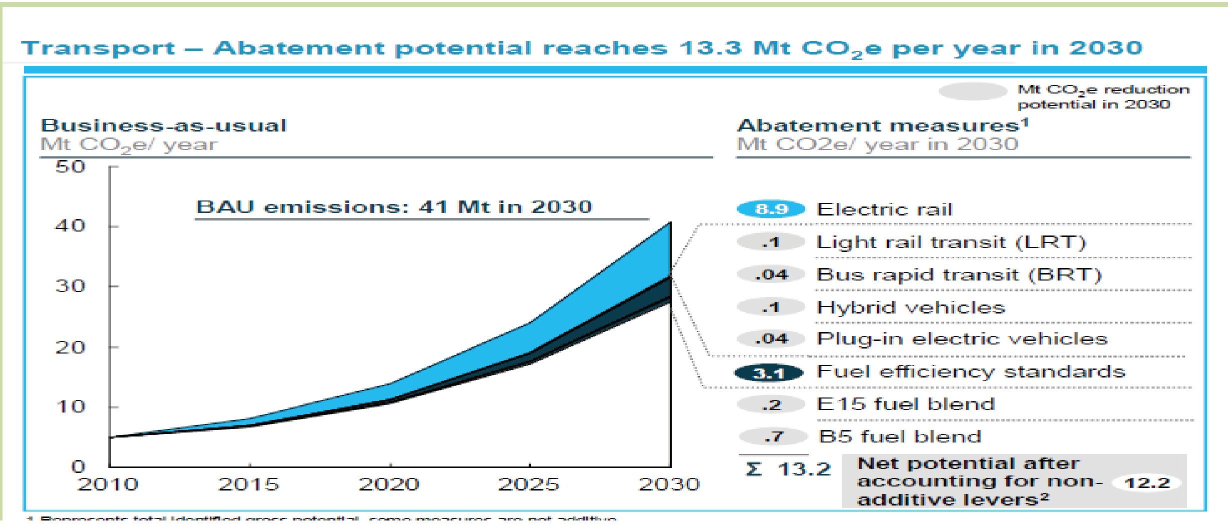
According to the CRGE strategy, the country has a total abatement potential of up to 12.2 million tons of CO_2e in 2030. The mitigation options for the transport subsector are summarized in the following paragraphs.

4.2.4.1. Intra-urban Electric Rail NAMA

The overall objective of the Intra-urban Electric Rail NAMA is to replace 50 per cent of the transport of cargo with electric rail through routes that will connect the main economic hubs of the country. It is part of the CRGE and has been submitted to the UNFCCC on a voluntary basis to solicit funding. It is expected to contribute to the attainment of the Federal Government's goal of building a carbon-neutral green economy by 2025. The electric rail was identified as having the highest potential for GHG abatement in the transport sector and implementation of the NAMA is expected to lead to a GHG emissions abatement of 8.9 million tons of CO_2e per annum by 2030. High GHG abatement potential is also expected from raising fuel efficiency standards, which is expected to result in GHG abatement of 3.1 million tons of CO_2e per annum by 2030. All in all, the transport sector has the potential to contribute to a total GHG emissions reduction of 13.2 million tons CO_2e per annum by 2030 if all the options are fully implemented (Figure 4-6).

Due to emerging industrialization and the intensification of trade-related activities, road freight transportation has increased rapidly in Ethiopia. Freight transport is expected to increase by more than 13 per cent annually from 2011 to 2030 despite high fuel prices. Demand for passenger transport will also increase by approximately 9 per cent annually with overall transport emissions being projected to grow by 300 per cent from around 2 million tons CO_2e in 2013 to 15.83 million tons CO_2e in 2025. More than 90 per cent of Ethiopia's exports and imports are transported by road on the Addis Ababa-Djibouti route. Until the end of the 20th century, Ethiopia was operating a 681 km narrow gauge diesel railway from Addis Ababa to the border with Djibouti that had been built more than 100 years ago. This was the only railway route in the country but because of its age and deteriorating condition, it is no longer operable.

Figure 4-6: Abatement Potential in the Transport Subsector, 2010-2030 (Million tons CO2e);



Source: FDRE, 2011a.

In Ethiopia's Growth and Transformation Plan (GTP), connecting the country's various regions was recognized as a way of achieving the plan's economic development priorities. The Government put forward ambitious plans to build railways in order to connect communities and create the conditions necessary for developing local resources and generating employment and income-enhancing opportunities that will raise living standards.

In 2007, the Government established the Ethiopian Railway Corporation to implement these plans and in 2010 the railway projects were submitted as part of Ethiopia's NAMA submissions to the UNFCCC on a voluntary basis along with an open request for support. It is expected that by 2030, there will be a railway system with over 5,000 km of track operating, which will shift 50 per cent of the business-as-usual growth in road freight transport to rail. This will significantly reduce GHG emissions and provide many economic, social and environmental benefits.

This NAMA is also part of Ethiopia's Climate Resilient Green Economy (CRGE) initiative. That seeks to transform the country into a carbon neutral green economy and attain middle-income status by 2025. Electric rail was identified as the lever with the largest mitigation potential in the sector with an estimated GHG abatement potential of 8.9 million tons of CO_2e per annum by 2030 - compared to the business-as-usual pathway. This transformative NAMA will replace 50 per cent of the transportation of road cargo with electric rail through eight routes that will connect the main economic hubs of the country.

4.2.4.2. Use of Efficient Vehicles

Use of modern vehicles, such as cars with electronic injection systems and hybrid vehicles, results in lower fuel consumption. Hybrid vehicles have very low fuel consumption. However, they might not be technically viable until the auto mechanics in the country become familiar with their maintenance. Thus, replacement of old cars in the country by new ones with better technology, including electric cars, is required, and limiting imports of overused vehicles may have to be an additional option. This could start, for example, with a revision of existing taxation policy to encourage the importation of new vehicles.

4.2.4.3. Use of Alternative Fuels

Liquefied petroleum gas (LPG) and compressed natural gas (CNG) are reported to result in 10-30 per cent GHG emission reductions per kilometre and also have less conventional emissions compared with gasoline and gas oil. The use of CNG/LPG as a fuel reduces carbon dioxide exhaust by 50 per cent compared with coal and 20-25 per cent compared with gasoline and gas oil. Carbon monoxide emissions are reduced by 70-90 per cent and hydrocarbon emissions by 40-60 per cent compared with vehicles that use conventional fuel. The second method is to install a conversion kit. The conversion kit allows diesel injection to supply the fuel required to maintain idle conditions, and the gas/air mixture is designed to respond to cruise and full load power requirements. The conversion equipment generally consists of fuel tanks, fuel lines, a pressure regulator and a mixer to mix natural gas with incoming air.

4.2.4.4. Use of Biodiesel

A significant potential advantage of biodiesel is that the raw materials can be produced without large amounts of fossil fuel. This process produces less greenhouse gases. Though the combustion of biodiesel leads to carbon dioxide release into the atmosphere, the quantity will not be more than what was previously extracted from the atmosphere during growth of the crop. Thus, biodiesel can result in a substantial reduction (by about 80 per cent) of net GHG emissions.

4.2.4.5. Use of Gasohol

Gasohol is 10 per cent ethanol and 90 per cent gasoline blend (E10). Ethiopia has the potential to produce 150 million litres of ethanol in five years after completion of the expansion of sugar factories. Gasohol can be used as fuel to spark engine ignition. It he reduces GHG emissions by about 5 per cent below those produced by compared to pure gasoline. Using E10 or E15 instead of pure gasoline can result in a 10-15 per cent decrease in gasoline demand. The cost of E10 is slightly lower than gasoline.

4.2.4.6. Infrastructure Improvement

Improvement of urban road transport infrastructure and efficient traffic control systems can reduce fuel consumption caused by unnecessary traffic congestion.

4.2.4.7. Promoting Use of Mass Transportation

By increasing the bus fleets in Addis Ababa and using electric trains between Addis Ababa and Nazareth, the taxi and minibus fleet can be reduced, leading to an overall reduction in fuel consumption and the related GHG emissions. Use of hybrid electric engines in buses will result in a drastic reduction in GHG and conventional emissions.

4.2.4.8. Use of Non-Motorized Transport

Use of bicycles and other types of intermediate transport have to be encouraged in the different parts of the country. The above options together with enhanced monitoring and inspection of petroleum products downstream operation to protect adulteration of fuel (adulteration increases impurities of fuel which increases GHG emissions), would greatly contribute to reduced GHG emissions from the transport subsector.

4.2.4.9. Use Hybrid and Plug-in Electric Vehicles

This mitigation option is meant to improve the fuel efficiency of the vehicle fleet. Increasing the fleet share of hybrid and electric vehicles to 13.0 per cent and 2.2 per cent respectively by 2030 would significantly reduce annual gasoline consumption. It is estimated that the initiative would have a combined abatement potential of approximately 0.09 million tons of CO_2e in 2030.

4.2.5. Mitigation Options for the Power Generation Subsector

Reduction of electrical energy consumption for domestic purposes through the use of compact fluorescent lamps and solar water heaters will save electrical energy that can be made available for other activities that can replace fossil fuels. This can be achieved through the use of photovoltaic (PV) systems consisting of solar home systems with white light emitting diodes (WEDs). Using hydropower for exports of electricity and micro- and pico-hydropower to supply power to small towns and villages is suggested as an option to reduce the emission of GHGs. Exploitation of wind and geothermal energy sources, biogas and waste to generate energy are also other options.

4.2.6. Challenges and Barriers in the Energy Sector

Challenges and barriers to the implementation of mitigation options in the energy sector still remain. One of the main challenges is to develop technologies that will encourage the utilization of sources of energy that are not only sustainable but environmentally friendly. Other barriers include: inadequate awareness about energy conservation, inadequate skills to evaluate the feasibility of energy conservation, the huge investment finance required for the implementation of generation and transmission projects/ programmes, the price of technologies, market structure, institutional capacity, access to information, and social and cultural behaviour.

Realizing the bio-energy shift scenarios would require rather aggressive policy actions, due to the income constraints of all but the wealthiest households, the uneven availability of electricity and improved cook stoves, and inadequate physical infrastructure and supporting institutions. Electricity access and affordability will have to be rapidly expanded and/or improved in urban areas, while improved stoves will need to be made widely available in rural areas. In peri-urban areas, other solutions may be appropriate, including off-grid electricity access and wider distribution options for alternative fuels.

4.3. AFOLU Sector Analysis, Assessment and Mitigation Options

4.3.1. The Agriculture Sector

Ethiopia has a land area of 1.1 million sq km with a diverse agricultural industry. Agricultural crops currently make up 67 per cent of agricultural GDP (27 per cent of total GDP). The main crops are cereals, pulses, coffee, oil seeds, spices, herbs, vegetables, fruits, and sugarcane and its fibres. Small-scale subsistence farming based on rain-fed agriculture and traditional farming techniques predominates. Emissions from cropland totalled 75,582.577 Gg CO_2e in 2013.

Emissions from crop cultivation mainly derive from the use of fertilizer and from N_2O released by crop residues reintroduced into the soil. Agricultural crop production will increase from around 19 million tons today (2015) to more than 71 million tons in 2030. This is primarily due to increased fertilizer usage and an increase in land used for agriculture, and will result in an increase in emissions from the current 127,65.67 Gg CO_2e to more than 34,894.17 Gg CO_2e per annum by 2025 under a business as usual scenario. Improving crop and livestock production practices to attain higher food security and farmers' incomes while reducing emissions is one of the pillars under the CRGE initiative.

Livestock contributes 26 per cent of agricultural GDP (around 10 per cent of total GDP). Ethiopia has the largest livestock population in Africa mainly made up of cattle (53 million), sheep (26 million), goats (23 million) and birds (50 million). Like agricultural cropping, livestock cultivation is mainly based on traditional techniques, whether mixed farming or pastoralism. A large proportion of livestock holders own just a few animals. Livestock, especially cattle, are the largest important source of GHGs in Ethiopia and currently account for 65 million tons of CO_2e a year, which is around 45 per cent of total current national emissions. The cattle population is expected to increase from close to 53 million today to more than 90 million in 2030. This will increase emissions from the current 66, 160.86 Gg CO_2e today to almost 125,433.75 Gg CO_2e per annum by 2030. The agriculture sector has a total abatement potential for soil and livestock related emissions of 121,446.41 Gg CO_2e, representing around 45.6 per cent of the total domestic abatement potential.

4.3.1.1. Soil Mitigation Options

The introduction of lower-emitting techniques, such as conservation agriculture, watershed management, and nutrient and crop management, could reduce emissions by 27,799.967 Gg CO_2e in 2030 from their 2013 level. Agricultural intensification and the capture of new agricultural land in arid areas through irrigation and the introduction of new techniques of crop production will help to increase the abatement potential from saved forests. The possible initiatives in soil mitigation include; improved agronomic practices that increase soil carbon storage, nutrient management to use carbon/nitrogen more efficiently, improved tillage and soil management, integrated systems (mixed crop-livestock, agro-forestry), and water management (irrigation, terracing, and other water-harvesting techniques). Such a programme would build on existing government plans to strengthen the agriculture extension system.

i. Soil nutrient and crop management: These includes agronomic practices that can used to increase soil carbon storage i.e. introduction of more responsive crop varieties to optimum external inputs (fertilizers and pesticides), sowing forage legumes in growing cereal crops; double cropping of cereals, and the use of beneficial microorganisms and earthworms in compost making.

ii. Tillage/residue management: This will reduce soil disturbance, which, in turn, decreases the rates of decomposition and erosion leading to soil carbon gain and the reduction of CO2 emissions.

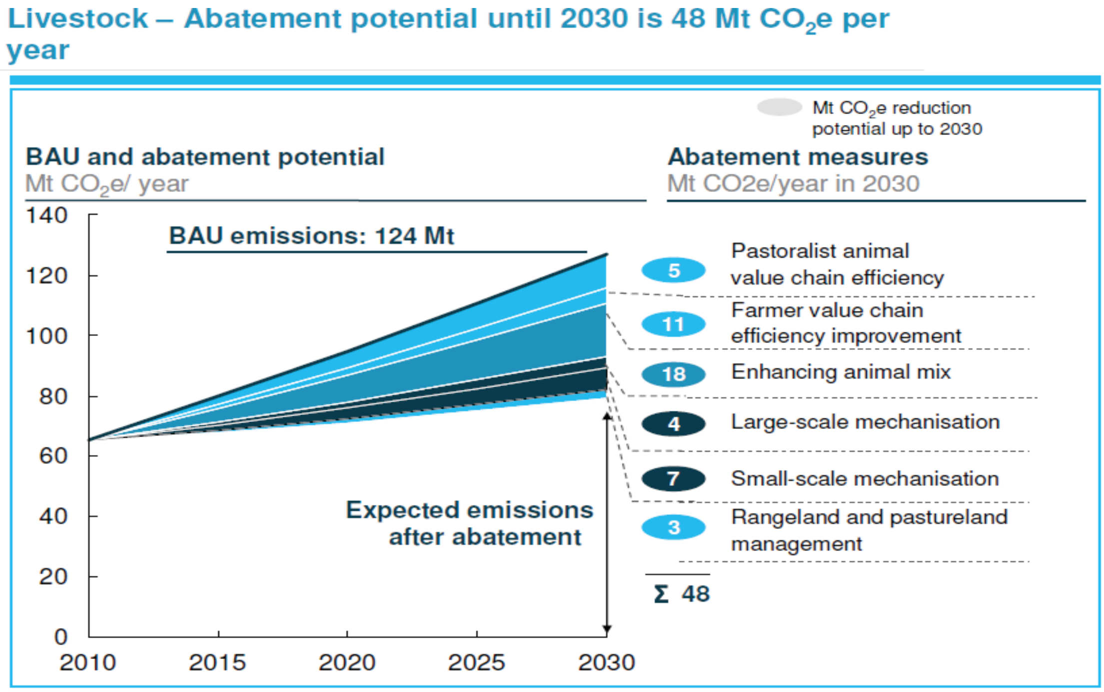
iii. Water management: This includes the promotion of terracing in hilly regions with high soil erosion hazards, the improvement of water harvesting and irrigation structures, enhancing water use efficiency to enhance carbon storage in soils through improved yields and residue returns per unit of water.

iv. Watershed-based integrated farming systems: Under this option, the production practice uses land for a combination of livestock and food crops, on the one hand, and trees for timber, firewood or other tree products, on the other, to increase the standing stock of carbon above ground relative to equivalent land use without trees.

4.3.1.1. Livestock Mitigation Options

There is the potential to increase the efficiency of the cattle value chain via higher productivity of cattle (for both meat and milk) and an increased off-take rate (decreasing the age at which livestock are sold). Several initiatives would fall underneath this umbrella, including improving the market infrastructure, health facilities and feeding for livestock. These steps could reduce emissions by more than 93,532.41 Gg CO_2e in 2025 below their business-as-usual level. The CRGE strategy's target is shown in Figure 4-7.

Figure 4-7: Livestock Abatement Potential



Source: FDRE, 2011a.

The following mitigation options being implemented require up-scaling; treatment of forage to improve digestibility by using improved genetic characteristics, promoting mixed crop/livestock farming practices, and promoting bio-digester construction. The others include adopting appropriate fertilizer application; promoting conservation tillage techniques to sequester carbon in cultivated soils; rehabilitation of overgrazed watering points, hill sides and long-term settlement; intensifying high performance livestock species, and reducing the stock size and the number of oxen (used for tillage) by introducing farm machineries.

4.3.1.2. Mixed Crop/Livestock Farming

Increased population pressures on limited land will lead to the intensification of agriculture. Growing competition between crop and livestock farming systems is the most efficient and sustainable means of increasing food production. Key elements in the contribution of livestock to intensification are traction, manure. Crops and livestock can no longer be viewed as separate and inevitably competitive enterprises. Somewhat, mixed farming systems optimize resource use and will reduce carbon dioxide and methane generation in agricultural systems. Mixed farming will maximize the degree of self-reliance of the system, since a variety of products will be obtained with minimum inputs to maintain soil fertility. The integration of livestock into agricultural systems based on food crops calls for efficient use of crop residues and agro-industrial by-products by the ruminants.

4.3.1.3. Improved Production Through Improved Genetic Characteristics

The livestock species in Ethiopia are indigenous types characterized by low productivity. However, they are well adapted to the environment and have resistance to a number of endemic diseases. Little activity has been done to improve the productivity of local stocks through selection and breeding. Continued improvements in genetic potential through cross-breeding and selection of the indigenous stock will increase productivity and thereby reduce methane emissions per unit of product. Production efficiency can further be improved through proper veterinary care, sanitation, ventilation, nutrition and animal comfort, improved sheltering, and enhancing farmers' skills.

4.3.1.4. Manure Management

Manure related emissions result from the anaerobic decay of organic material in livestock manure. Manure management systems that promote anaerobic conditions such us liquid/slurry storage facilities and anaerobic lagoons produce the most methane. Methane emissions from such sources can be recovered and used for energy generation or flared. Methane recovery technologies have been successfully used and demonstrated under a variety of conditions, and have been shown to reduce methane emissions by up to 70-80 per cent (USEPA, 1993). This emission reduction option will be effective or feasible for large or small to medium, confined or semi-confined farm operations. A relatively small percentage of livestock manure is managed in this manner and emissions of methane from these systems are negligible. Manure spreading directly on soils, crops and pastureland and composting maintains aerobic conditions and has limited methane production potential. Since manure spreading on soils, crops and pastureland is the most common practice in extensive systems of Ethiopia, it should be further encouraged and maintained. Using dung as a fuel releases methane because of combustion.

4.3.1.5. Soil Carbon in Cultivated Soils

While there are uncertainties in the estimates of carbon dioxide emissions from cultivated soils, the use of conservation tillage techniques has been shown to be effective in reducing soil organic carbon (SOC) loss and, in some cases, in fostering SOC accumulation.

Each of these mitigation options, however, requires both farmers to change their existing practices and technology transfer. Adoption and implementation of mitigation options in the agriculture sector not only provides benefits for the environment but also increases farmers' incomes through increased milk and meat production. However, the adoption of the mitigation technologies is very limited at present due to a number of barriers. These barriers are related to resistance to the farm-level adoption of new methods and practices, the availability and cost of technologies, a tradition that rigidly favours huge animal numbers, the lack of government subsidies, inadequate information, and a lack of capacity and skills among farmers.

4.3.2. The Forestry and Land-Use Change (LUCF) Sector

The wide range of altitudes and associated agro-ecological zones in Ethiopia present varied landscape and vegetation types, from tropical moist forests (high forest) in the south-west and on the Bale Mountains, to desert shrubs in the east and north-east and parkland agroforestry in the southern highlands (Demel and others, 2010). It is a challenge to get a reliable estimate on forest cover and change in Ethiopia, due to limited and conflicting data sources, partly attributable to the use of different definitions of forest in the country. However, the total forest cover of Ethiopia has increased in size as a result of large-scale reforestation campaigns launched all over the country since the last decade. The Food and Agriculture Organization of the United Nations (FAO) estimates that total forest cover is about 12.29 million ha, 11 per cent of the total land area (FAO, 2010). The FAO assessment draws on national data and a reclassification, calibration and extrapolation of the data from the Woody Biomass Inventory and Strategic Planning Project (WBISPP). Determining the average annual rate of deforestation is also difficult. The FAO (2010) estimated that 141,000 ha of forest had been lost annually between 1990 and 2010 and that the average annual deforestation rate, based on the change in forest cover from 2005 to 2010, amounted to 1.1 per cent of total forest cover. However, by combining a number of studies it is possible to estimate that the average deforestation rate lies somewhere between 1.0-1.5 percent annually (FDRE, 2011d; Mulugeta and Tadesse, 2010).

The main direct drivers of deforestation are small-scale agricultural expansion and fuel wood consumption, and to a lesser extent, illegal logging and forest fires (FDRE, 2011c) Another important driver has been identified as large-scale agricultural investment, which until recently was promoted by the Government as a vehicle for rural development and economic growth. Pressure on forestlands from agricultural expansion and woodfuel consumption are likely to increase in the future if population growth in Ethiopia continues at the current trend rate of increase of 2 per cent per annum.

Deforestation leads to CO_2 emissions, and is mostly caused by the conversion of forested areas to agricultural land, fuelwood consumption and logging in excess of the natural yield of the forests. Emissions are projected to grow from 25 million tons CO2e in 2010 to almost 45 million tons in 2025. However, the forestry sector also offers huge abatement potential through reduced deforestation and forest degradation. In addition, the potential for sequestration is large, which is underlined by the fact that already today Ethiopia has one of the largest afforestation and reforestation programmes in the world. The Government in partnership with all other stakeholders, mainly NGOs and local communities, hopes to address deforestation through the Climate Resilient Green Economy (CRGE) initiative, which aims to reduce emissions from land use and forestry, through continued large-scale reforestation campaigns.

Forest-related interventions for greenhouse gas mitigation fall into three broad categories, namely better management of existing forests; forest cover expansion; and usage of woodfuels as a substitute for fossil fuels. The technology options and their potential to reduce GHGs are highlighted below.

4.3.2.1. Forestation

Afforestation (on what was previously cropland or pasture) and reforestation (establishing forest on clear areas) have the potential to absorb carbon dioxide from the air and store it, substitute fossil energy, and maintain coolness of the microclimate, and slow the decomposition and release of CO_2.

4.3.2.2. Conservation

This involves extending the harvesting age, reducing or avoiding deforestation, and forest preservation. It has the potential to increase carbon storage in plants, increase storage of carbon in the soil and slow of the decomposition and release of carbon into the air.

4.3.2.3. Substitute Management

This involves the reduction of CO_2 emissions from fossil fuel by replacing with biomass fuel through the cultivation of perennial grasses, short rotation woody crops, and traditional crops. This has mitigation potential by minimizing the use of fossil fuel and the release of carbon dioxide into the atmosphere.

Besides the agricultural initiatives to reduce the pressure on forests (see above), the CRGE initiative has prioritized two strategies that could help to develop sustainable forestry and reduce fuel wood demand.

i. Reduce demand for fuel wood via the dissemination and usage of fuel-efficient stoves and/or alternative-fuel cooking and baking techniques (such as electric, LPG or biogas stoves) leading to reduced forest degradation, offering a potential of almost 35 million tons CO2e of emissions reductions. Capturing this abatement potential requires the switch of more than 20 million households to more efficient stoves.

ii. Increase afforestation, reforestation, and forest management to increase carbon sequestration in forests and woodlands. These initiatives would result in an increased storage of carbon in Ethiopia's forests and provide a basis for sustainable forestry. Afforestation (2 million ha), reforestation (1 million ha) and forest management (2 million ha of forests and 2 million ha of woodlands) can help to increase sequestration by more than 40 million tons of CO_2e.

Pressure to convert forested land to agriculture can be reduced by agricultural intensification on existing land or unlocking degraded land by irrigation, with the potential to lower deforestation and associated emissions.

4.3.2.4. Reducing Emissions from Deforestation and Forest Degradation (REDD+)

REDD+ offers the opportunity to implement forestry abatement levers and monetize the abatement potential in a structured way. Ethiopia has already prepared a Readiness Preparation Proposal (R-PP) that lays out its plan to prepare for REDD+ implementation. The preparation phase included setting up an organizational structure, the definition of a REDD+ strategy, as well as the preparation for implementation of concrete mitigation actions within REDD+ (FDRE, 2011a).

The development of the REDD+ strategy builds on the existing experience and structures developed locally, and will offer a broader learning experience for all affected stakeholders. It aims at leveraging the assessment of the main initiatives to mitigate deforestation and forest degradation, to identify implementing options, and to define the key enablers required at regulatory and institutional level. The mitigation levers identified, based on the work carried out by the CRGE initiative, focus on addressing the main two drivers of deforestation and degradation (conversion to agricultural land and unsustainable fuelwood consumption), through a combination of proposed measures to increase agricultural yields, manage soils and forests better, and adopt alternative energy sources and energy efficient cooking technologies. Particularly for the latter initiative, REDD+ will interact strongly with the rural energy initiative.

The still to be identified REDD+ pilots could range from Participatory Forest Management and Conservation approaches, which support strengthened local user rights and sustainable forest management, to various initiatives designed to take pressure off forest resources. The latter could include better management of existing plantations, and support for bamboo growth and use as well as intensified agro-forestry. Other key aspects of this work are the development of a REDD+ learning network and a REDD+ good governance project that supports the development of good governance in the REDD+ pilots.

Taken together, REDD+ and its associated activities are intended to help capture the mitigation potential from forestry that could reach an estimated 130 million tons CO_2e in 2030. The REDD+ initiative will help not only to put in place an institutional structure that supports the implementation of abatement levers in forestry, but also to finance these levers, for instance by monetizing abatement potential and establishing the necessary prerequisites such as a reference scenario and an MRV (monitoring, review and verification) system.

Climate Focus has started implementing a World Bank supported assignment in Ethiopia to create legal and institutional frameworks for the implementation of the national REDD+ programme and a jurisdictional landscape programme in the country's Oromia region. The project has supported the Government of Ethiopia's preparations to receive REDD+ investments, including from the World Bank's BioCarbon Fund

4.4 IPPU Sector -analysis, assessment and mitigation options

Ethiopia's Growth and Transformation Plan (GTP), now in its second phase, is an ambitious development plan that lays out growth, development, and industrialization targets up to 2015. It reflects the government's ambition to lift the country to middle-income status by 2025. Some of the proposed technology options identified for carbon dioxide emissions reduction include industrial processes energy efficiency improvements; materials substitution (blended cement); carbon dioxide gas separation and storage switching to low carbon and renewable energy sources; and carbon dioxide sink enhancement.

The share of organized industrial economic activity is comparatively small, and industry accounts for only 4 per cent of GHG emissions. At nearly 2,228.5 Gg CO_2e or 99 per cent of the emissions from industry, cement is the single largest industrial source of emissions. Emissions from steel, other types of engineering, the chemicals industry (including fertiliszer), the pulp and paper industry and food processing together account for the remainder of industrial GHG emissions. The main drivers are emissions related to solid and liquid waste (6,409 Gg CO_2e) and the use of private off-grid power generators in cities (2 million tons of CO_2e) (FDRE, 2011a).

Several mitigation options have been identified to address industrial process emissions, including raw materials conservation, efficient use of products, material recycling and technology improvement, and demand reduction. The primary mitigation options focus on emissions from the cement and lime industries, and include:

i. Industrial process energy efficiency improvements;

ii. Materials substitution (blended cement);

iii. Switching to low carbon and other energy sources; and

iv. Carbon dioxide sink enhancement.

4.5 Waste Sector Analysis, Assessment and Mitigation Options

The waste sector contributes about 3 per cent of Ethiopia's total aggregated GHG emissions. Methane emissions in the waste sector originate from several anthropogenic sources that include municipal solid waste landfills and open dumps, and wastewater treatment. Methane emissions from the Addis Ababa City landfills account for 18 per cent of the total emissions from Ethiopia's urban centres, 20 per cent of the total emissions of the waste sector and 2 per cent of the country's total emissions. The Addis Ababa City landfill could be the focus for mitigating methane emissions. Two different scenarios are defined in the methane mitigation analysis, one reflecting a baseline case and the other the impact of mitigation options. Options like composting, incineration, and landfill gas recovery have the potential to mitigate methane emissions from Addis Ababa City's solid waste. Selection and adoption of an option for mitigation depend on the cost of technology, the cost of labour and energy, and the socio-cultural attitudes of the community.

4.5.1. Composting

Composting is the most promising and reliable solid waste treatment option for Addis Ababa City because 68 per cent by weight of the solid waste is organic. Compost from such types of waste can be of good and consistent quality, and thus acceptable to customers/end users

4.5.2. Incineration

Establishing and operating incineration plants will not only deliver GHG emissions reductions, but will also assist the solid waste management service in the improvement of collection and transport of wastes by increasing the number of disposal sites and the frequency of collection.

4.5.3. Sanitary Landfill

Sanitary landfill is an essential tool for mitigating GHG emissions and disposing safely of all types of solid waste. It is the only option for the disposal of the unwanted product of other solid waste treatment options. The recommended option for methane emission mitigation in this case, therefore, is composting and landfill gas recovery since this is a less costly way of mitigating emissions from the Addis Ababa landfill. Even though the investment cost of incineration is not attractive, its impact on methane emissions from solid waste is significant. Other technology options for the sector are integrated solid waste management, open dumping, reduction, and waste stabilization ponds.

It is expected that waste generation will continue to increase with population growth and changes in lifestyle, since the rate of waste generation is directly correlated with population growth. Without a sustainable waste management system the rate of emission of GHGs and other waste-related hazardous substances will also continue to increase. Waste management, therefore, needs to be improved not only for the purpose of combating global warming but also for other associated co-benefits such as improved air quality and human health. This directly points to the need to improve waste management technologies and practices.

Some barriers to the implementation of the waste management mitigation actions have been identified. They include the following.

i. Policy and Regulatory Barriers: These include, but may not be limited to, unclear legal and regulatory frameworks, weak policies with regard to services for protection of public health and the environment, and weak law enforcement in waste management.

ii. Institutional Barriers: Several agencies are involved in waste management, with potential for conflicting roles and/or functions.

iii. Technological Barriers: These include the cost of the requisite technology, the availability of the technologies, and inadequate technical expertise for solid waste management planning and operation.

iv. Socio-economic Barriers: Socially, people have a negative perception of waste handling, and therefore public support for interventions may be low.

4.6 Response actions in the NAPA

Ethiopia's National Adaptation Programme of Action (NAPA) was finalized in June 2007, in line with Decision 5/CP.7 of the Conference of the Parties to the UNFCCC of 2001. The NAPA highlights several initiatives to address Ethiopia's vulnerability to the adverse impacts of climate change, including extreme climate events like drought. The NAPA proposes an initial list of 37 activities that were further prioritized into 11 projects using the multi-criteria assessment approach. Several adaptation initiatives with mitigation benefits have also been proposed as part of various sectorally- and regionally-specific strategies. It is worth noting that many of the climate adaptation options have mitigation co-benefits, and will thus contribute to the abatement of GHG emissions. In the case of Ethiopia, however, these co-benefits have not been quantified (FDRE, 2007; NMSA, 2007).

4.7. Conclusions and Recommendations on Mitigation

Although Ethiopia remains a net carbon sink, the country is implementing policies and measures that should ensure that ultimately it will enjoy the benefits of climate mitigation, as well as contributing to sustainable development. At the policy level, the country has started implementing the Climate Resilient Green Economy (CRGE) strategy that will steer the country towards a low carbon development pathway. Using a broad descriptive approach this chapter has shown some of the mitigation measures currently being implemented and identified other potential measures to reduce or abate emissions. There is, however, a need to conduct more elaborate analysis of the potential measures available and especially to focus on monetizing the costs and benefits involved. As is the case in many other developing countries, lack of reliable activity data for all the sectors is still a challenge for GHG emissions monitoring and mitigation. A major recommendation of this report is thus to enhance systemic, institutional and human capacity so that the country can comfortably meet its obligations under the UNFCCC. In addition, the implementation of mitigation measures will require financial resources which are beyond the country's capacity. It is thus highly recommended that concerted efforts be put in place to mobilize more resources from within and among development partner states to support the implementation of climate change mitigation projects and policies. It is also highly recommended that Ethiopia considers packaging some of the proposed mitigation options as Nationally Appropriate Mitigation Actions (NAMAs) so as to take advantage of related funding avenues.

Livestock Farming Practices in Ethiopia[14]

14 Pictures showing livestock farming practices in Ethiopia (Sorce: Andwalem and Eyob Ministry of Agriculture)

CHAPTER FIVE:

CLIMATE CHANGE IMPACTS, VULNERABILITY AND ADAPTATION OPTIONS

5.1. Introduction

Ethiopia is one of the countries most vulnerable to climate variability and changes due to, among others, its high dependence on rain-fed agriculture and natural resources. The country is indeed rated as among the most vulnerable to climate change as a result of its low adaptive capacity (FDRE, 2011a). It has frequently experienced extreme events like droughts and floods, and other climate-related hazards. The variability of rainfall and the increasing temperature are blamed for the frequent droughts that at times lead to famine, affecting the people's livelihood. Since the early 1980s, the country has suffered seven major droughts, five of which led to famines in addition to dozens of local droughts. Major floods also occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 (World Bank, 2010; FDRE, 2011c; FDRE, 2011e).

At the national level, climate change may reduce Ethiopia's GDP, compared with a baseline scenario, by 2-6 percent by 2015, and by up to 10 percent by 2045. Past assessments have shown agriculture, water and human health as the most vulnerable sectors. From a livelihood approach, smallholder farmers who depend heavily on rain-fed operations and pastoralists are found to be the most vulnerable. The arid, semi-arid and the dry sub-humid parts of the country are affected most by drought (Kidanu, Rovin and Hardee, 2009) Vulnerability therefore varies from one region to the other, based on differing social, economic, institutional and environmental conditions. Pastoralists, for example, tend to be more vulnerable to climate change than crop producing farmers (Oxfam International, 2010).

The purpose of this chapter is to identify the impacts of climate change and the vulnerabilities of selected sectors of Ethiopia, identify the potential adaptation options, and present measures the country has put in place to facilitate adequate adaptation to climate change; in accordance with Article 12, paragraph 1 (b) and (c), of the Convention.

Adaptation is a critical response to the impacts of climate change because current agreements to limit emissions, even if implemented, will take a long time to stabilize the atmospheric concentrations of greenhouse gases (GHGs) that are responsible for climate change. In addition, some of the GHGs already in the atmosphere have long lifetimes and their effect will therefore continue to be experienced long after their removal. Adaptation can reduce present and future losses from climate variability and change. It is neither a one-off intervention nor a stand-alone activity, but rather an iterative process that needs to be mainstreamed in development planning, including the design and implementation of projects and programmes across the relevant sectors (NMSA, 2007).

It is well recognized that climate change poses a serious threat to agricultural production, the natural resource base, and the livelihood of communities, more particularly in the dry lands. In line with this, the Government has demonstrated its determination to address climate change through the mainstreaming of response measures in national and sectoral development plans. Several regional administrations have also developed and are implementing regional climate change adaptation programmes. At the international level, the Federal Government has signed and ratified all the Rio Conventions, namely the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, the Convention on Bio-diversity (CBD) and the Convention to Combat Desertification (CCD (Kidane, Alemneh and Meshack, 2009; Gashaw and others, 2014).

5.2. Methodology

The methodology used to analyse the impacts of and vulnerability to climate change and variability involved five steps, namely:

i. Generation of current and historic climate: this involved the analysis of current and historic trends in rainfall, temperature, and major climate related hazards at national and regional levels.

ii. Assessment of current vulnerability to climate variability.

iii. Projection of the future climate using climate model outputs to outline a range of scenarios for future rainfall, temperature and other climate variables.

iv. Assessment of future impacts and costs of climate change.

v. Review of ongoing adaptation measures and identification of new options.

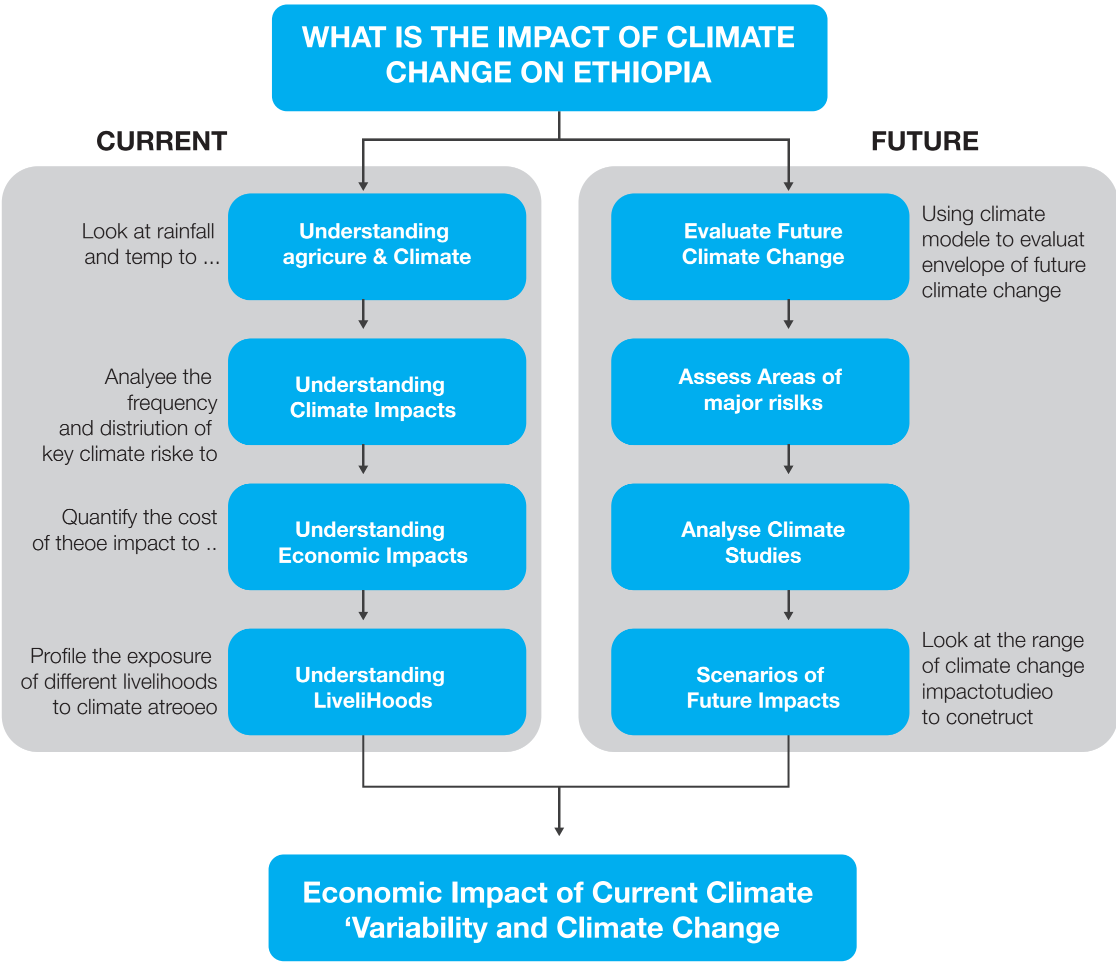
These steps are summarized in Figure 5-1, which was adopted from the Agriculture Sector Strategy. Similar steps were followed for the other sectors.

5.3. Factors Determining Vulnerability

The main environmental problems in Ethiopia are soil erosion, deforestation, recurrent droughts, desertification, land degradation, and loss of biodiversity including wildlife. On the other hand, the main causes of Ethiopia's vulnerability to climate variability and change include very high dependence on rain-fed agriculture which is very sensitive to climate variability and change. The other causes include; under-development of water resources, low health service coverage, a high population growth rate, low economic development, low adaptive capacity, inadequate road infrastructure in drought prone areas, weak institutional structures, and lack of awareness. .

Vulnerability to climate change is determined by the exposure to hazards that result from the changing climate, sensitivity to the impacts, and adaptive capacity. Vulnerability is thus high if changes in climate increase the exposure of populations to events such as drought and floods. Hence, vulnerability increases with increased frequency and severity of the climate event, and is highest where the ability of people to cope is limited.

Figure 5-1: The Process Used to Assess Vulnerability in the CRGE



Source: FDRE, 2011a.

Capacity to cope is most limited, and thus sensitivity highest, where livelihoods are based on a narrow range of assets that are easily damaged by climate hazards, with few other options or means of managing risks. Vulnerability is therefore especially high for the poor in the marginal areas where climate change exacerbates exposure to climatic hazards.

Since vulnerability is a combination of exposure and sensitivity, then reducing vulnerability demands actions that will:

i. Reduce exposure to hazards;

ii. Reduce sensitivity to their effects, and

iii. Build capacity to adapt.

The latter component (of building adaptive capacity) enables communities and nations to mobilize the decisions and resources needed to reduce vulnerability and adapt to climate change (Nelson, Lamboll and Arendse, 2007).

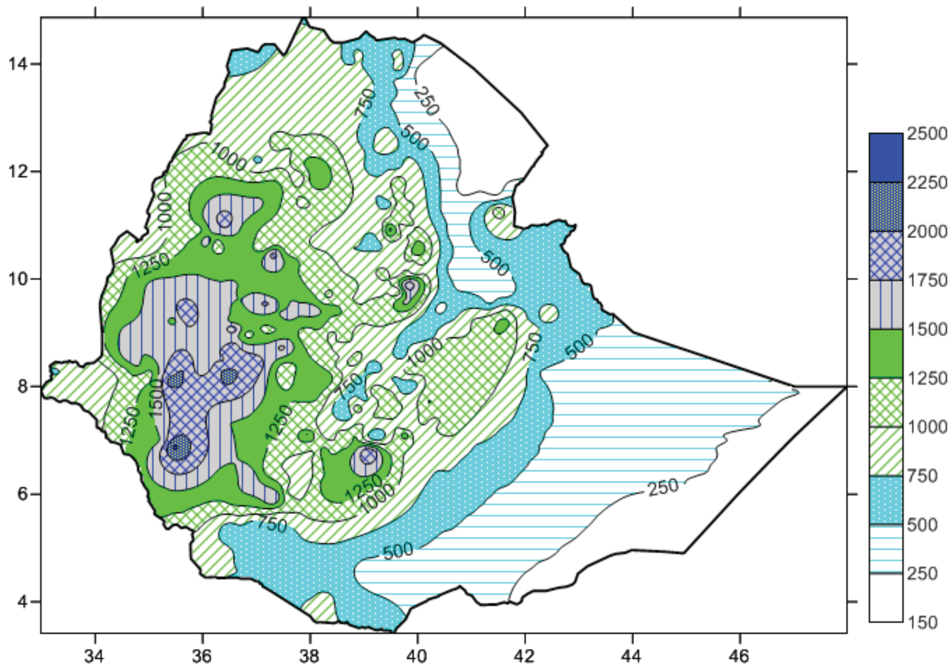
5.4. Climate Change in Ethiopia

5.4.1. Current climate variability and observed trends in temperature and rainfall

Ethiopia has three rainy seasons, namely, June–September (called Kiremt), October–January (Bega), and February– May (Belg). Kiremt rains account for 50–80 percent of the annual rainfall totals over the regions having high agricultural productivity and major water reservoirs. It is for this reason that most severe droughts usually result from the failure of the Kiremt (June, July, August and September-JJAS) rainfall to meet Ethiopia's agricultural and water resources needs.

The spatial variation of the mean annual rainfall for the period 1951-2010 is shown in Figure 5-2, which shows that rainfall is characterized by large spatial variations, ranging from more than 2000 mm over some areas in the southwest to less than 250 mm to the south east and over the Afar lowlands in the northeast. The seasonal rainfall characteristics are closely associated with large-scale global circulation systems, especially the movement and characteristics of the Inter-Tropical Convergence Zone (ITCZ). Southern Ethiopia consequently experiences a bimodal distribution (two rainy seasons), while the north, east and west experience a unimodal distribution (one season).

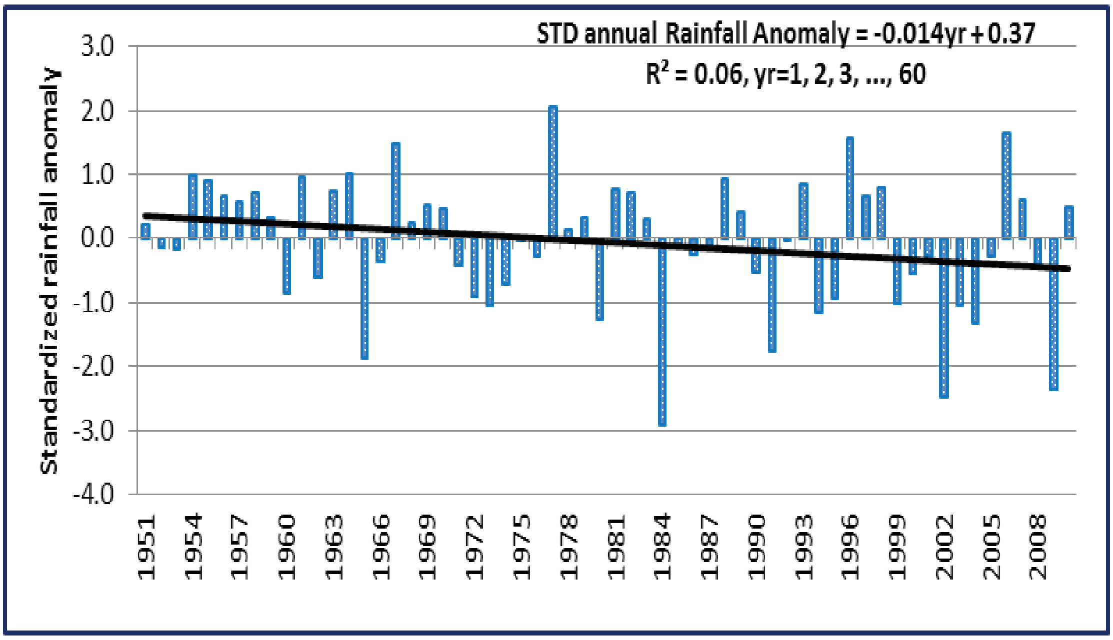
Figure 5-2: Spatial Distribution of Mean Annual Rainfall



Source: Koresha, 2014b.

Analysis of the inter-annual variation of rainfall for the period 1951-2010 shows fluctuations of the total annual rainfall, with some years experiencing above normal rainfall, others below normal, and still others around the average value (Figure 5-3). The mean annual rainfall also shows a slight decreasing trend, indicative of a decrease in the total annual rainfall over the years.

Figure 5-3: Year-to-year variation of Ethiopia's rainfall (1951-2010) relative to the 1961-1990 norm



Source: Koresha, 2014b.

Studies have indicated that the total annual trend, however, varies from region to region, with some regions in the south showing as much as a 20 per cent decline in spring and summer rains in some heavily populated areas in south and central Ethiopia.

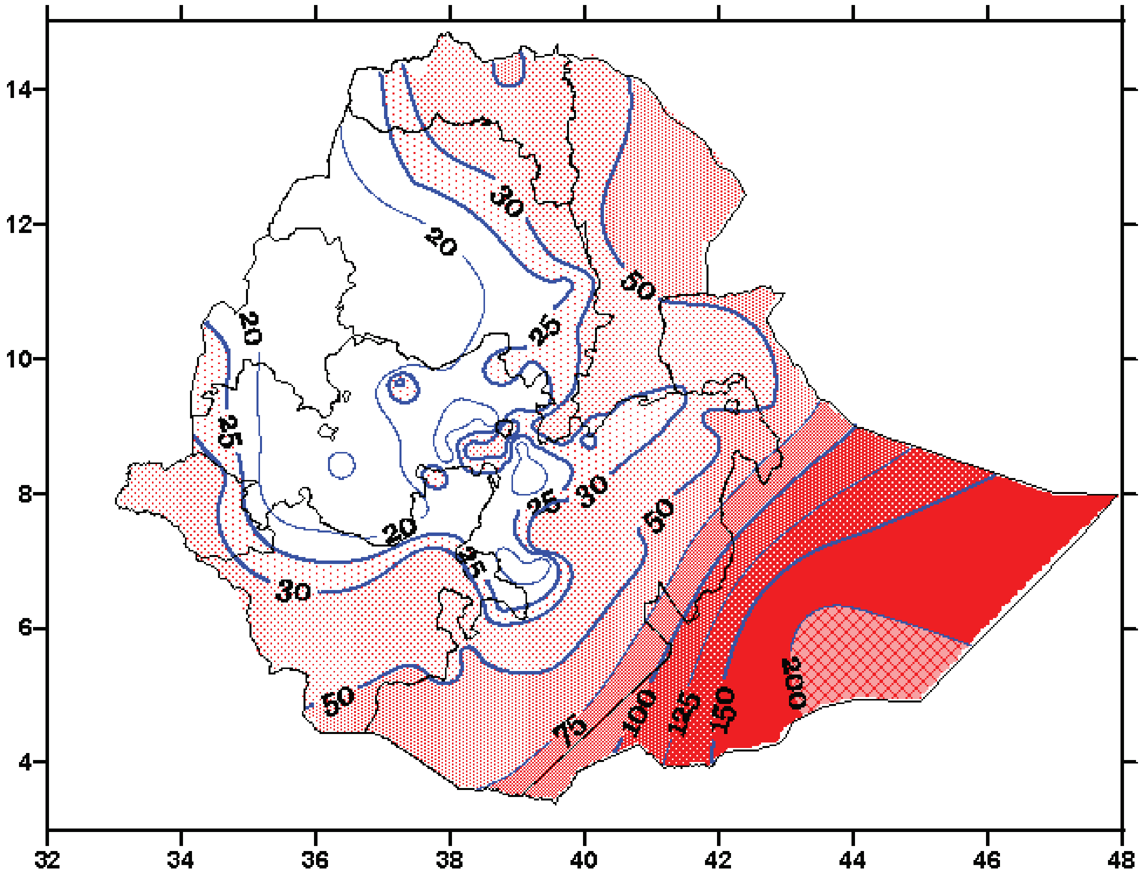
The projected warming across the entire country is likely to exacerbate the observed declining rainfall trends, leading to increased water stress. Some recent studies also indicate that the annual rainfall in southern Ethiopia has decreased from 1971 to 2010 during the March-April-May (MAM) (Belg) and June-July-August (JJA) (Kiremt) seasons, with no clear trends detected for central and northern Ethiopia. The February–May (Belg) precipitation has declined at the rate of 2.6 mm/year during the same period. This amounts to a reduction of 30 per cent based on the recorded values for the period 1971 to 2010. The study also showed a reduction of 2.2 mm/year in the wetter June–September (Kiremt) season, amounting to a reduction of more than 50 percent. The total annual reduction in the spring season is 32 per cent (5.4 mm/year) (FEWS NET, 2012).

The country's total annual rainfall variability is shown in Figure 5-4, which shows a close relationship between the variability and the total annual rainfall, with areas receiving the highest rainfall showing the lowest variability (highest reliability) (Figure 5-2), while the drier areas show the lowest rainfall reliability (highest variability). It is worth noting that some of the drier areas to the south east and north east show variability in excess of 50 per cent. These are the areas with the highest vulnerability to climate change and variability, a situation expected to worsen in the future with the projected higher temperatures.

Studies have indicated a link been the El-Niño /La Niña phenomena and Ethiopian rainfall; and hence the phenomenon may be responsible for some of the observed variability. During the June–September (Kiremt) season, for example, suppressed rainfall has been observed during El-Niño years over much of Ethiopia, often with severe socio-economic impacts.

Analysis of the inter-annual variation of temperature for the period 1954-2006 reveals an increasing trend for both the minimum (night time) and maximum (day time) temperature as shown in Figure 5-5. The analysis covered two representative areas, namely central (high rainfall highlands) and north eastern Ethiopia (the drier lowlands). The trends for the central region are, however, higher, explaining up to 60 percent and 40 per cent of the total variance of minimum and maximum temperature, respectively.

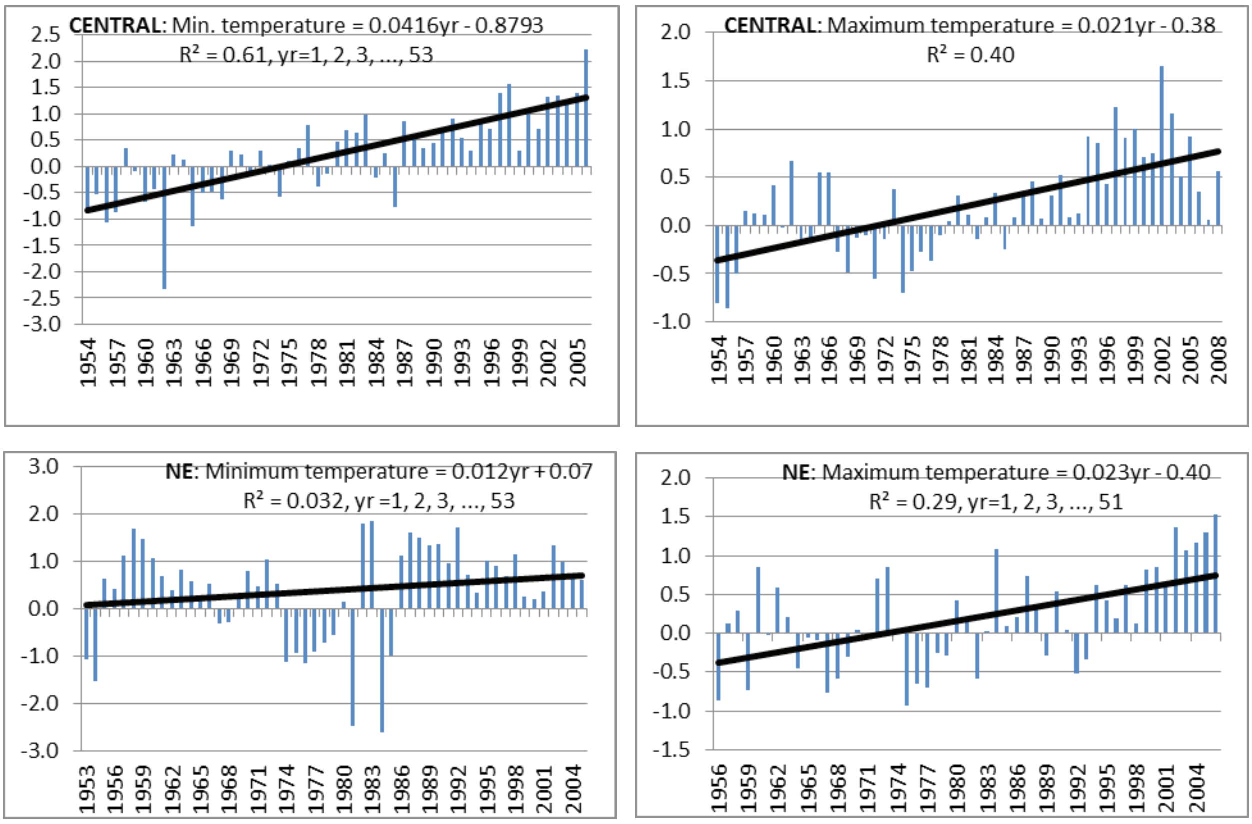
Figure 5-4: June-September (Kiremt) Seasonal Rainfall Variability Expressed as the Coefficient of Variation (%).



Note: The seasonal rainfall performance is highly dependable over regions where the coefficient of variations is under 30 per cent. The high rainfall areas hence show a higher rainfall reliability (less variability) while the low rainfall areas lower rainfall reliability (higher variability).

These graphs generally provide a signal of warming for Ethiopia during the period under investigation, and are consistent with the CRGE analysis that indicates a temperature increase 0.1 - 0.4°C per decade, resulting in an average temperature increase of around 0.25°C per decade, since the 1960s (FDRE, 2011c). Similar results were reported in the NAPA and EPACC (FDRE, 2011b). The CRGE indicates that the observed temperature increase has also been supported by increases in the minimum and maximum temperature; an increased frequency of hot days and nights; and decreases in the frequency of cold days and nights.

Figure 5-5 Inter-annual Variation of the Mean Minimum and Maximum Temperature (R) for Central Ethiopia (Top Row); North Eastern Ethiopia (Bottom Row)



Source: Koresha, 2014b.

The observed temperature increase is expected to lead to increased evapotranspiration and reduced soil moisture content and atmospheric humidity. The higher warming rates for central Ethiopia could lead to serious socio-economic consequences for the country, given that this is representative of the high rainfall highland areas that "account for over 80 percent of the total population and for 95 percent of the cropped land" (FDRE 2001d).

5.4.2. Climate Change Scenarios

Climate change scenarios generated during the preparation of the Ethiopia's Initial National Communication used three equilibrium models and one transient General Circulation Model (GCMs): the Canadian Climate Model (CCCM); the Geophysical Fluid Dynamics Laboratory's model (GFDL); the United Kingdom Meteorological Office-1989 model (UKMO-89); and the GFDL-Transient model. Projections for rainfall did not show any systematic change (increase or decrease).

BOX 5-1: Projected Future Climate

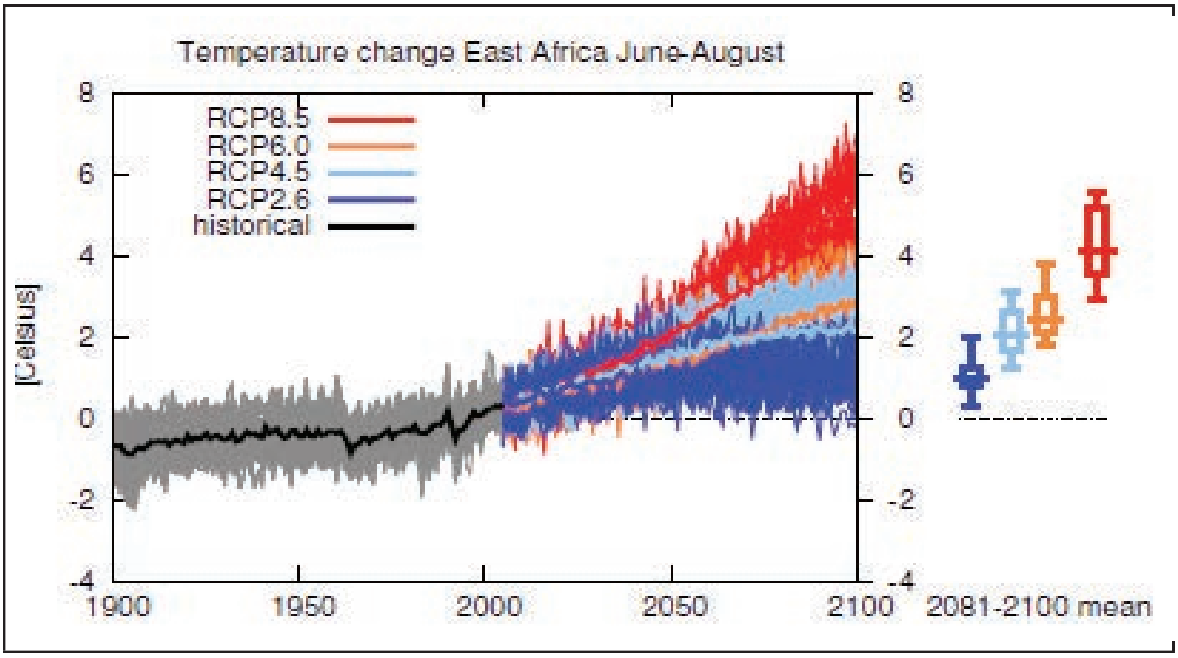
There is a high degree of uncertainty in future projections of temperature and rainfall patterns in Ethiopia. While temperatures will increase, the level of increase is uncertain, with a range of projections indicating between 1°C to 2°C by the 2050s relative to today. There is greater uncertainty as to whether rainfall will increase or decrease (projections range from -25% and +30% in the 2050s).

Source: FDRE, 2011c.

For the Kiremt season, the GFDL indicated a 10-20 per cent increase for places north of 8 degrees latitude and west of 41 degrees longitude. The CCCM projected an increase of about 50 per cent for northern extreme areas. For the Belg season, a 5 per cent increase in rainfall is projected over the south west, south and south east while all models expect a decrease over northern parts. For the Bega season, all models projected a general increase in rainfall. Incremental scenarios were developed by assuming a 2ºC and 4ºC increase in temperature and a change of ±20 per cent, ±10 per cent and no change in rainfall over the 1961-90 mean.

The Fifth Assessment Report of the IPCC mid-range emission scenarios indicate that the mean annual temperature is projected to increase in the range of 0.9 -1.1 °C by 2030 compared with the 1961-1990 base period. Further, an increase in the range of 1.7 - 2.1 °C by 2050, and in the range of 2.73.4°C by 2080 over Eastern Africa (including Ethiopia) is expected when compared with the 1961-1990 base period (Figures 5-6 and 5-7). The IPCC projections are in line with those reported in the CRGE, which indicated that temperatures over Ethiopia are likely to increase by 0.5-1.5 ºC by 2020 and 1.5-3 ºC by the 2050s relative to the 1960-1990 base period (FDRE 2011c).

Figure 5-6: Time Series of Temperature Averaged over Land Grid Points in East Africa (11.3_S–15_N, 25_–52_E) in June–August.

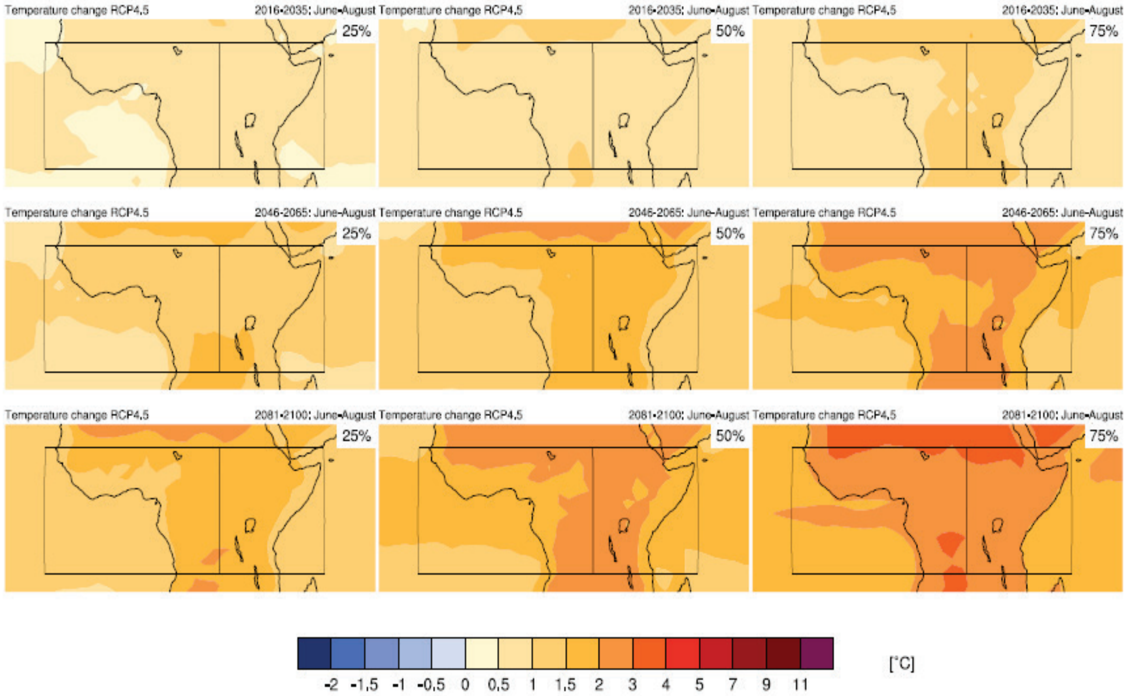


Source: IPCC, 2014

Note: Thin lines denote one ensemble member per model, thick lines the CMIP5 multi-model mean. On the right hand side the 5th, 25th, 50th (median), 75th and 95th percentiles of the distribution of 20-yr mean changes are given for the period 2081–2100 (relative to 1986–2005) for the four RCP scenarios.

The projected change in the number of hot days up to the year 2100 indicates substantial increases in the frequency of days considered "hot" in the current climate, and are consistent with other temperature projections for the country (Figure 5-8). The trend explains a very high proportion of the total variance (R^2 = 0.910 ≈ 91%). Figure 5-9 shows a similar projection for each of the four seasons of the year, namely, January-March (JFM); April–June (AMJ); July-September (JAS); and October–December (OND).

Figure: 5-7: Temperature Changes in 2016–2035, 2046–2065 and 2081–2100 with respect to 1986–2005 in the RCP4.5 Scenario



Note: For each point, the 25th, 50th and 75th percentiles of the distribution of the CMIP5 ensemble are shown, this includes both natural variability and inter-model spread. Hatching denotes areas where the 20-yr mean differences of the percentiles are less than the standard deviation of model-estimated present-day natural variability of 20-yr mean differences. Source: IPCC, 2014.

The figure indicates a consistent warming in all the seasons of the year. Similar results were obtained for the number of "hot" nights, an indication of hotter days and nights in the future. This will have serious socio-economic implications, and especially on water resources and agricultural production as a result of the consequent increase in evapotranspiration rates.

BOX 5-2: Definitions

Heavy Rainfall Event

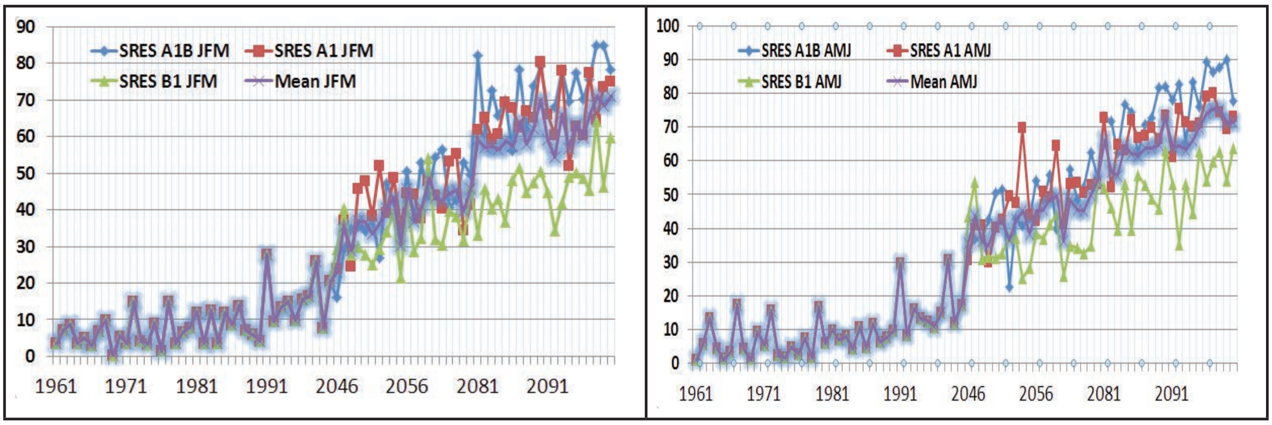
A 'heavy' rainfall event is defined by daily rainfall amount exceeded by the 5% of heaviest events in a given region or season. The total rainfall which falls in any events which are greater Than this fixed threshold is then totaled, and expressed as a percentage of the total monthly rainfall in that season or year. This is then expressed as an anomaly against the total rainfall falling in 'heavy' events in the standard climate period (1970 - 99).

Hot Day

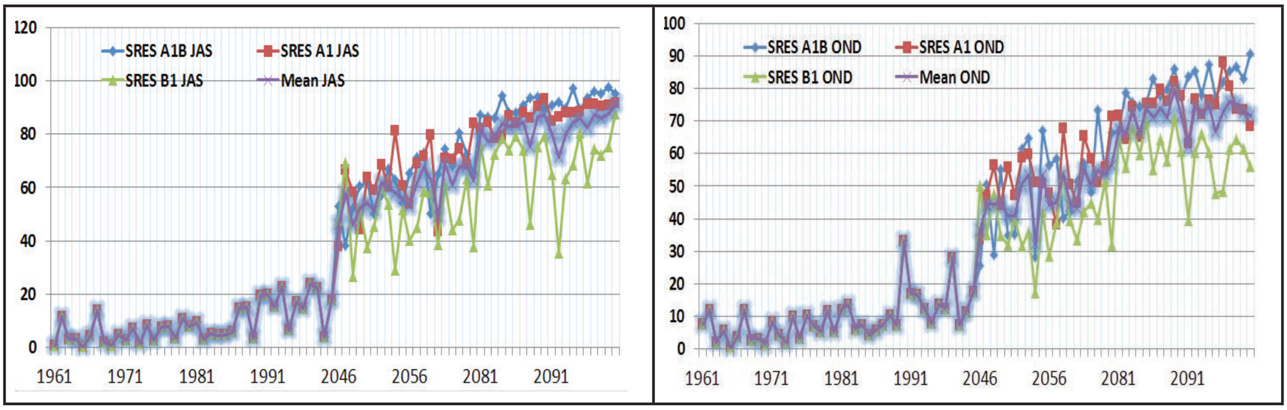
The temperature threshold for a 'hot day' in any region or season Is defined as the daily maximum temperature (Tx) which is exceeded on 10% of days in the standard climate period (1970 - 99). The Tx90p index is then defined as the frequency with which daily maximum temperature exceeds this threshold in any month, season or year.]

Source: McSweeney, New and Lizcano,2014.

Figure 5-8: Projected Seasonal Number of Hot Days

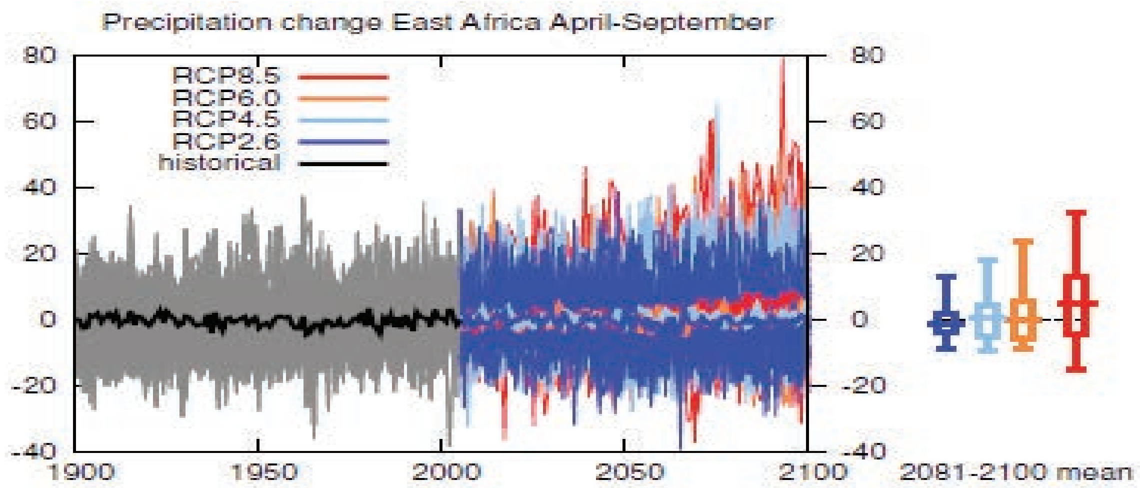


Source: McSweeney, New and Lizcano, 2014.



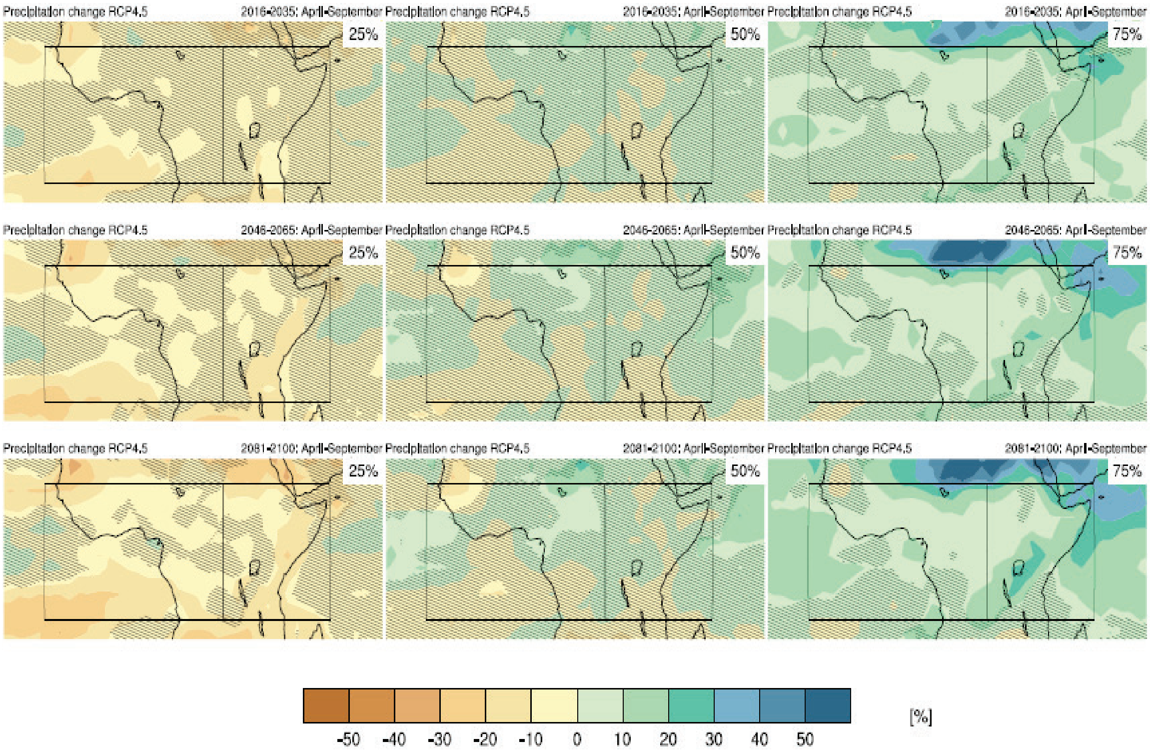
The Fifth Assessment Report of the IPCC projects a small increase in the annual precipitation over the country (Figures 5-9 and 5-10). This projected minimal rainfall increase is, however, likely to be overshadowed by the expected increase in evapotranspiration rates. Projections used for the CRGE indicate the possibility of the intensity and frequency increasing (with heavy rainfall days increasing by 20 per cent and rainfall intensity by 10 per cent).

Figure 5-9:Time Series of Relative Precipitation Averaged over Land Grid Points in East Africa (11.3_S–15_N, 25_–52_E) in April–September



Note: Thin lines denote one ensemble member per model, thick lines the CMIP5 multi-model mean. On the right-hand side the 5th, 25th, 50th (median), 75th and 95th percentiles of the distribution of 20-yr mean changes are given for the period 2081–2100 (relative to 1986–2005) for the four RCP scenarios

Figure: 5-10: Maps of Relative Precipitation Changes in 2016–2035, 2046–2065 and 2081–2100 with respect to 1986– 2005 in the RCP4.5 scenario

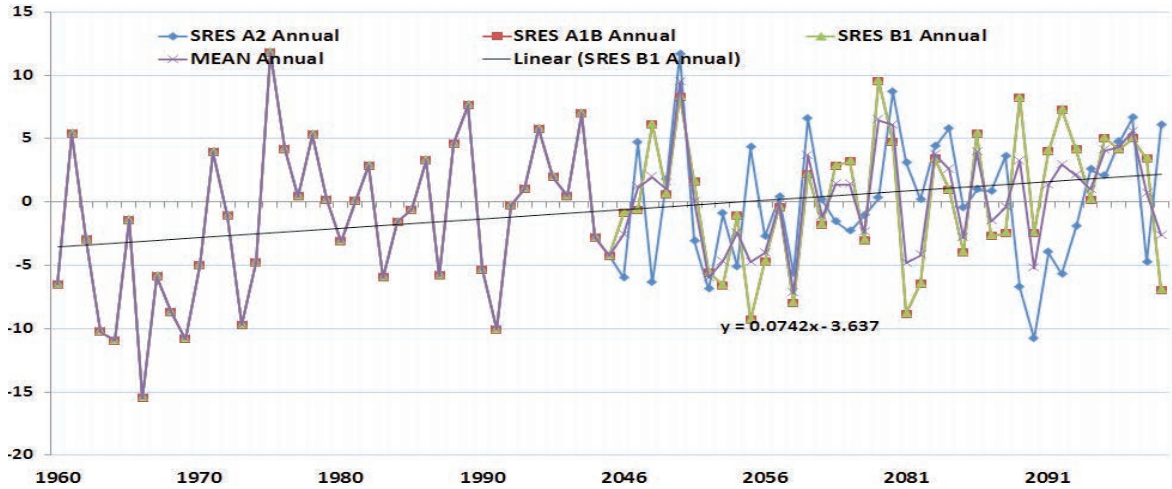


Note: For each point, the 25th, 50th and 75th percentile of the distribution of the CMIP5 ensemble are shown, this includes both natural variability and inter-model spread. Hatching denotes areas where the 20-year mean differences of the percentiles are less than the standard deviation of model-estimated present-day natural variability of 20-year mean differences.

A consistent increase in the proportion of the total precipitation occurring in “heavy” rainfall events is observable in Figure 1-11. This is indicative of an increase in “stormy” weather up to the year 2099 and is consistent with previous studies that have indicated that climate change will lead to an increase in the frequency and intensity of extreme climate and weather events like droughts, floods, and storms. Figure 5-11, however, shows almost no trend for the January–March (Belg) and the July–September (Kiremt), with the October–December (Bega) season showing only a slight trend.

The lack of an appreciable trend during the JAS season is an indication of no change in the frequency of “heavy”rainfall events during Kiremt (JJAS), the main season for the high rainfall highland areas. The steepest trend is for the April–June season, which coincides with the Belg season. The results may therefore be an indication that the Belg season may be dominated by stormy weather in the coming years. Figure 5 16 shows projected seasonal variation trends of total rainfall occurring in “Heavy” Rainfall Events

Figure 5-11: Projected Variation Trends of Total Rainfall Occurring in "Heavy" Rainfall Events

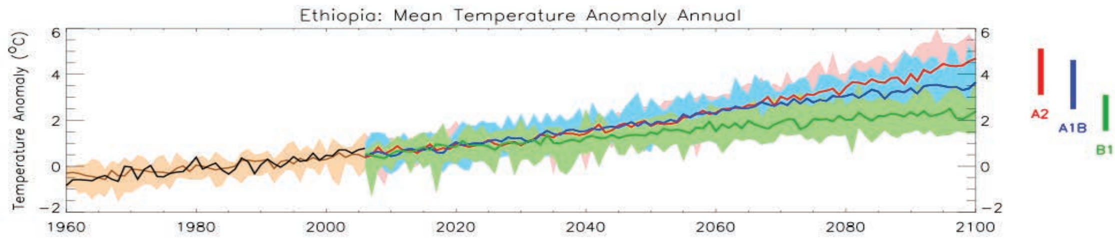


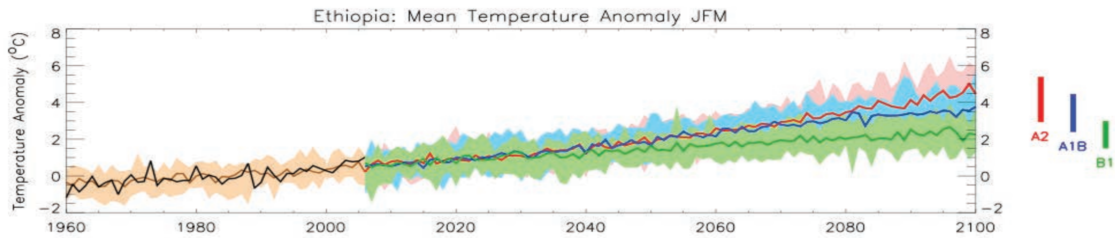
Source: McSweeney, New and Lizcano, 2014.

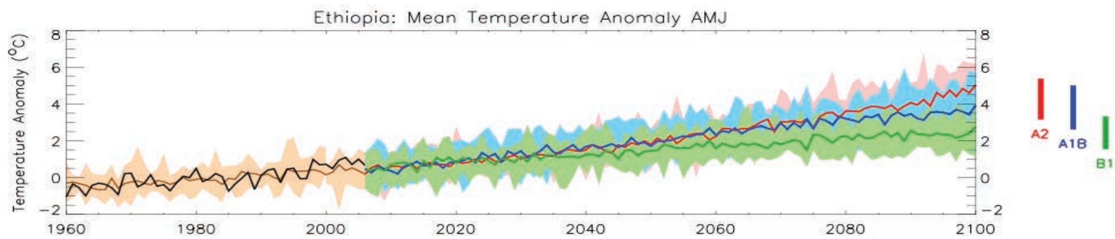
5.4.3. Spatial and Temporal Changes in Rainfall and Temperature Projected Forward

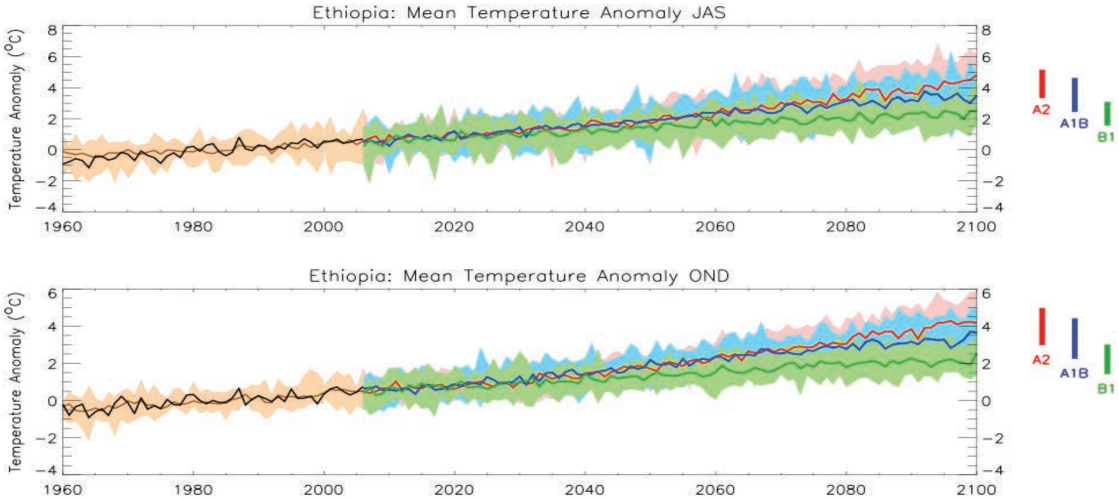
Figure 5-12 below shows the trends in annual and seasonal mean temperature for the recent past and projected future while figure 5-13 indicates the spatial patterns of projected change in mean annual and seasonal temperature for 10-year periods in the future under the SRES A2 Scenario

Figure 5-12: Trends in Annual and Seasonal Mean Temperature for the Recent Past and Projected Future



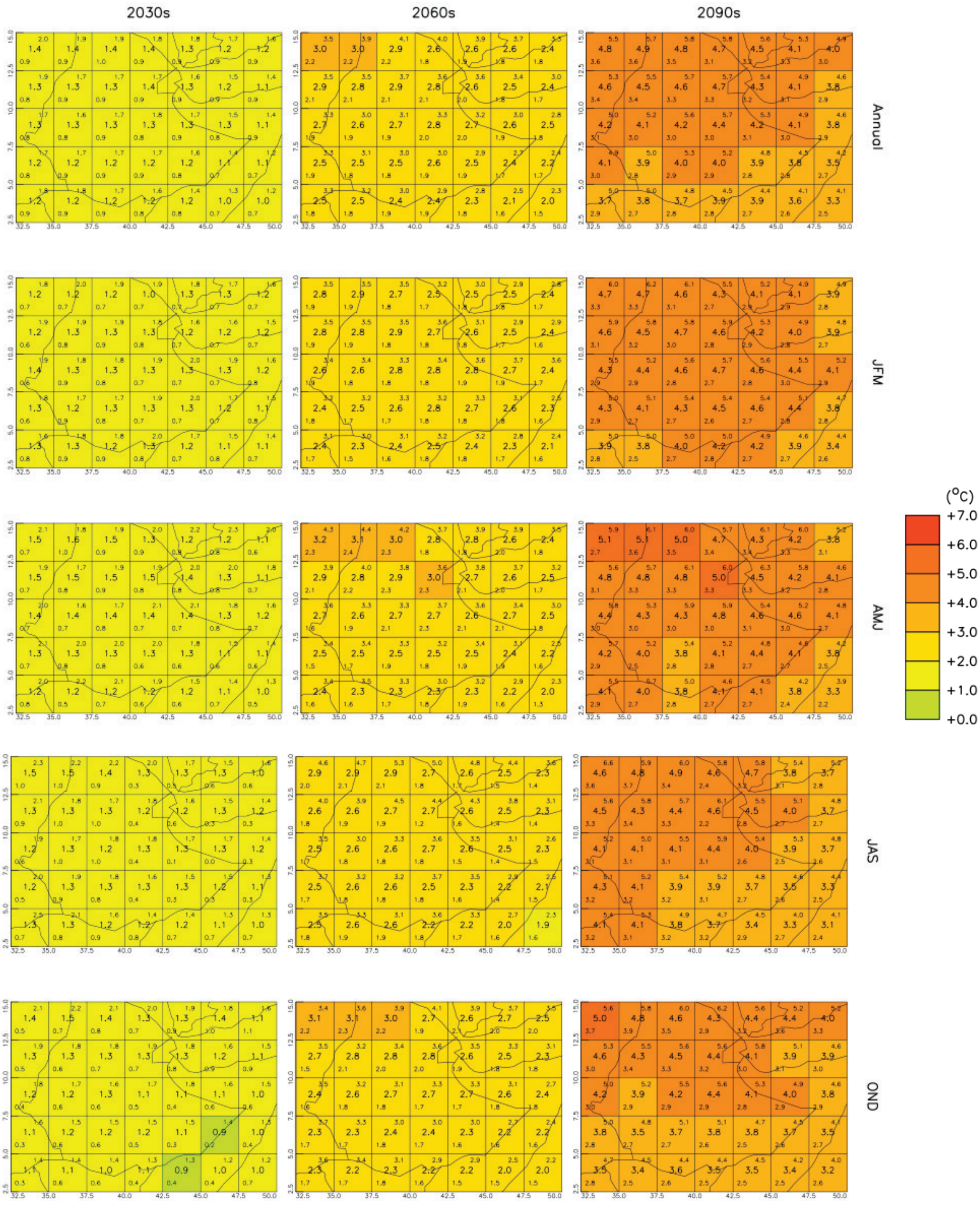






Source: McSweeney, New and Lizcano, 2014.

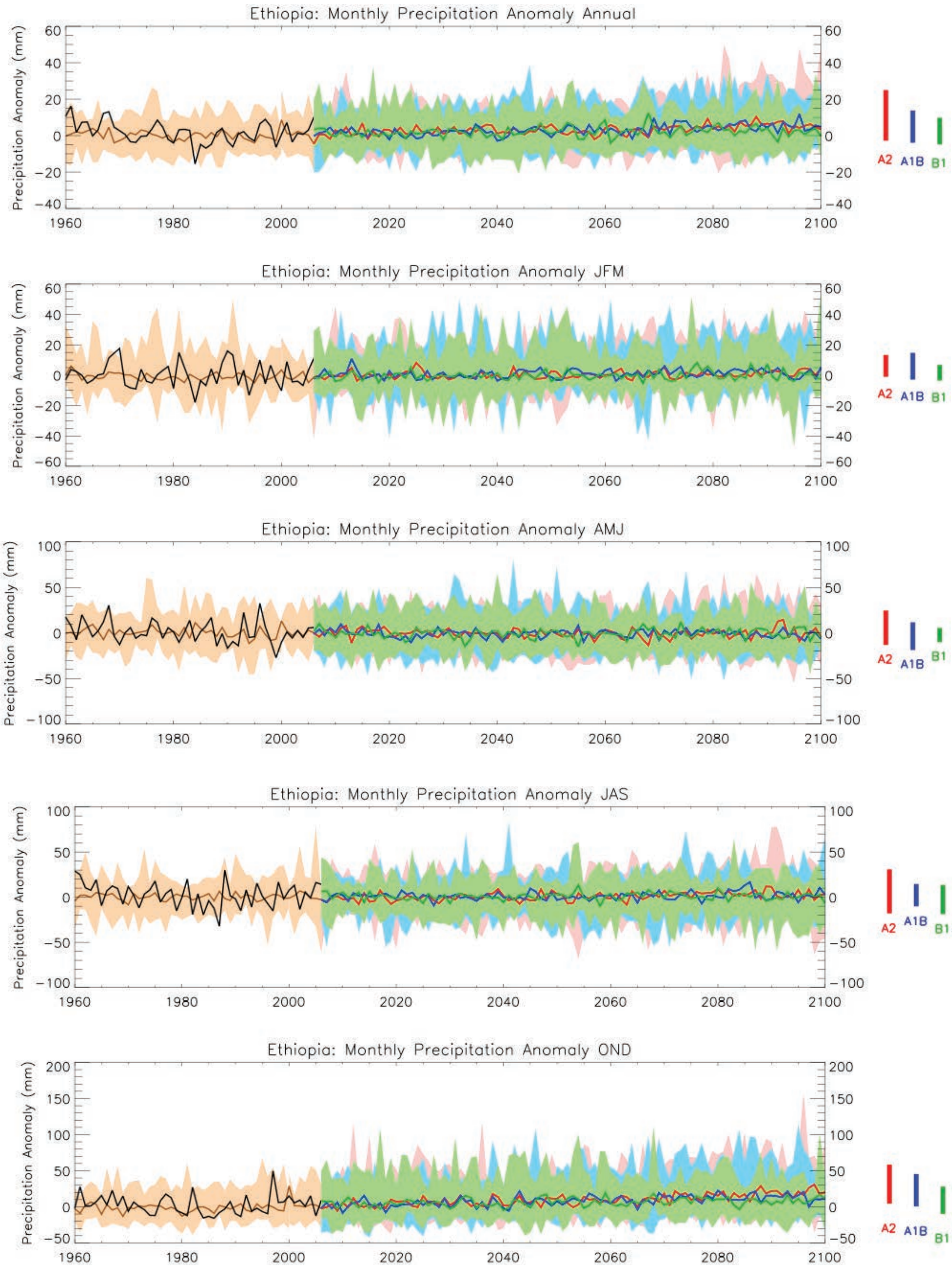
Figure 5-13: Spatial Patterns of Projected Change in Mean Annual and Seasonal Temperature for 10-year Periods in the Future under the SRES A2 Scenario



Source: McSweeney, New and Lizcano, 2014.

Figure 5-14 below shows the trends in Monthly Precipitation for the Recent Past and Projected Future while figure 5-15 indicates the spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 Scenario

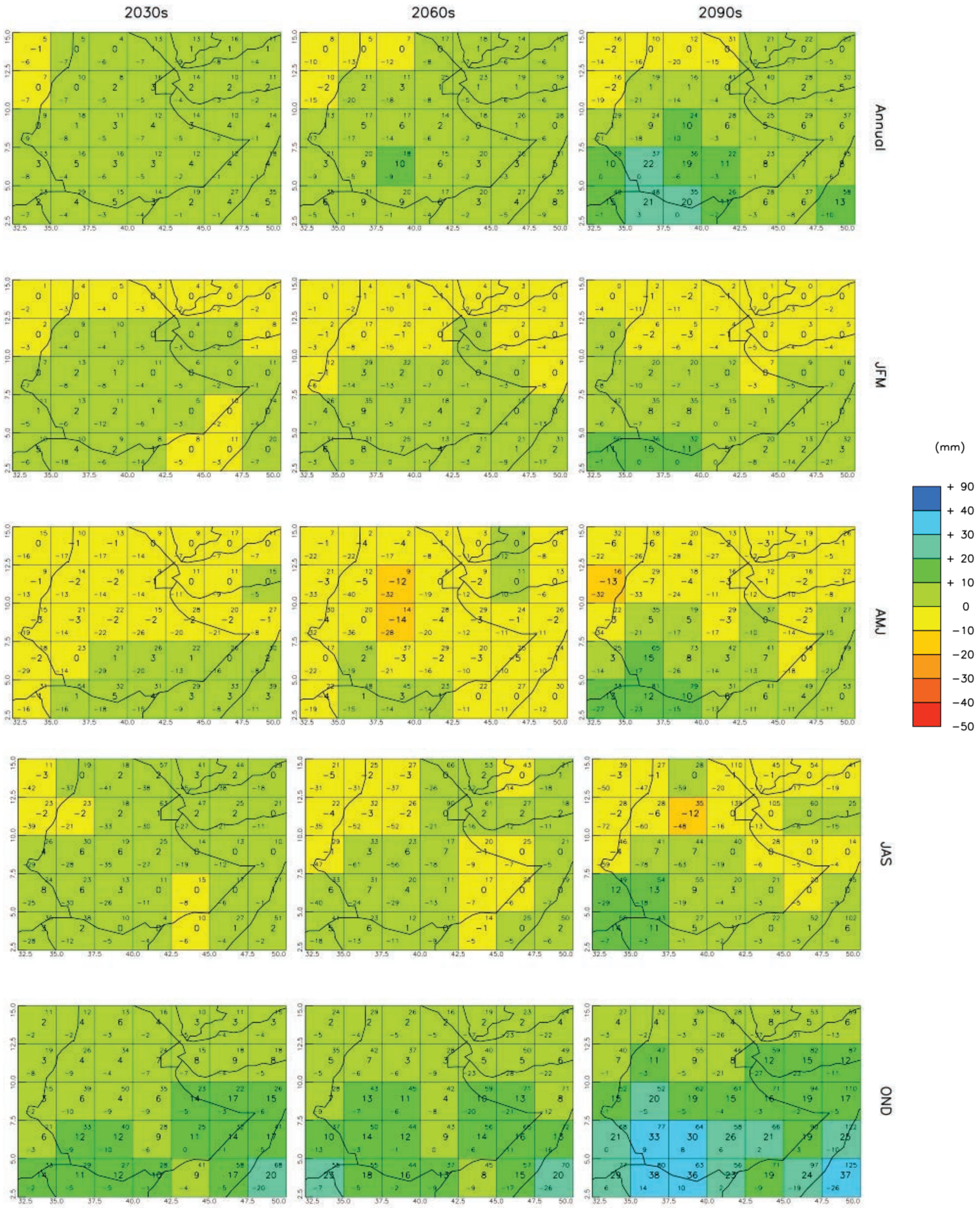
Figure 5-14 :Trends in Monthly Precipitation for the Recent Past and Projected Future



Source: McSweeney, New and Lizcano, 2014.

Note: All values shown are anomalies, relative to the base period of 1970-1999.

Figure 5-15: Spatial Patterns of Projected Change in Monthly Precipitation for 10-year Periods in the Future under the SRES A2 Scenario

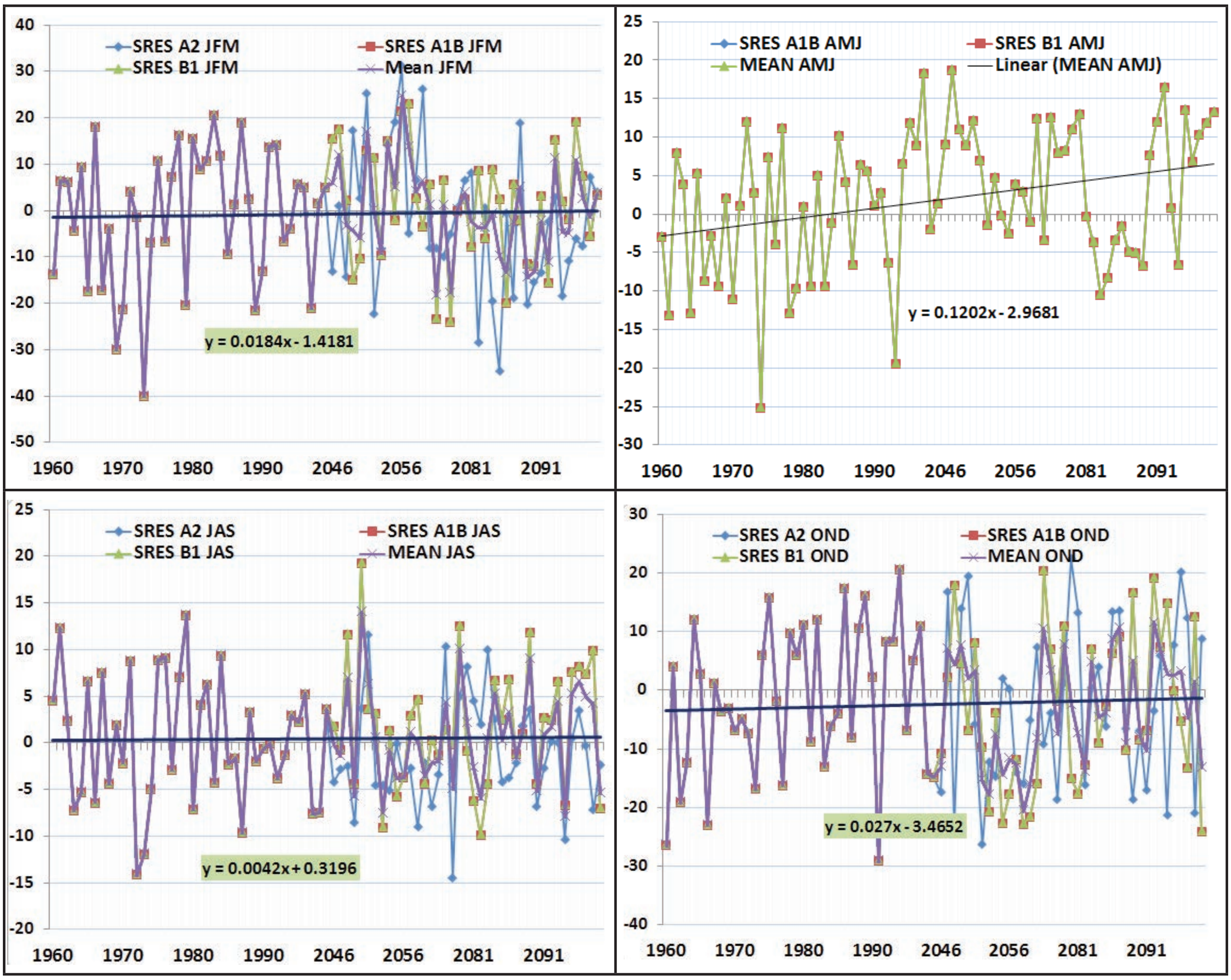


Source: McSweeney, New and Lizcano, 2014

Note: All values shown are anomalies, relative to the base period of 1970-1999.

The spatial patterns and quantities of projected future rainfall reductions and temperature increases are projected in Figure 5-15. The changes for each season were estimated by extending the rate of observed 1960–2009 rainfall, through 2013–2039 based on the persistent observed trends. For the Belg rains, there was a decline in rainfall ranging from -150 to -50 mm across the south-central and eastern parts of the country.

Figure 5-16: Projected Seasonal Variation Trends of Total Rainfall Occurring in "Heavy" Rainfall Events

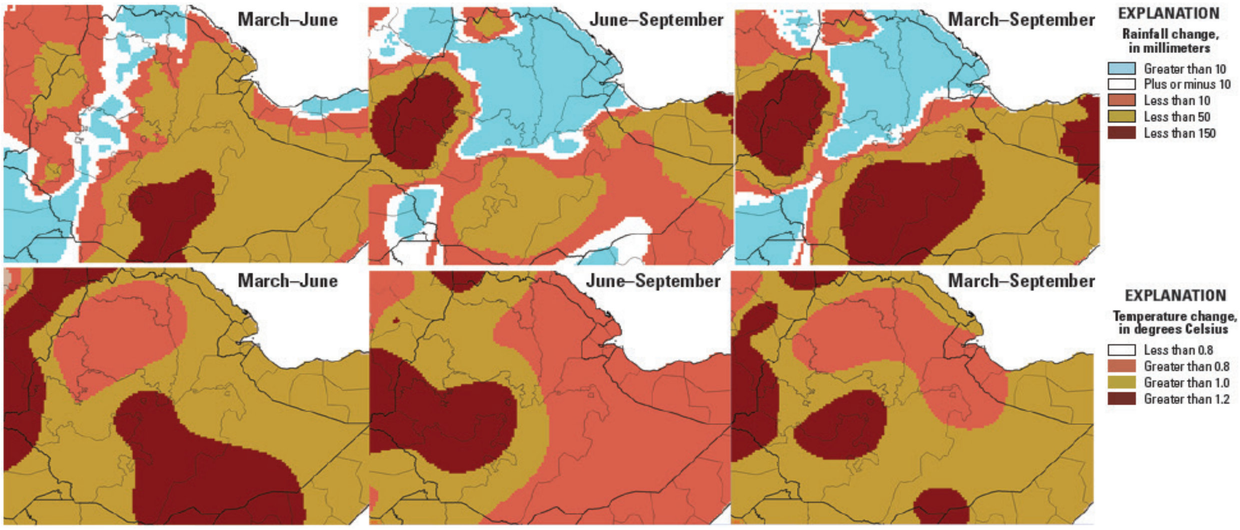


Source: McSweeney, New and Lizcano, 2014.

This is confirmed using Geo-Clim model, which indicates extensive reduction in rainfall in the range of -30 to -50mm in the eastern parts from south-east to north-east with the southern parts having the greatest reductions, ranging from -100 to -50 mm of rainfall. These results are shown in Figure 5-15 as changes in average rainfall over the March-June season, by comparing averages for 1997-2010 with those for 1981-1996 (Belg Season). These areas are associated with lower Belg harvests and poorer pastoral rangelands during the summer and early autumn. This may be particularly disruptive for pastoralists and agro-pastoralists living in southern Oromia and western Somali regions that currently (as of 2012) rely upon meagre Belg rains for their livelihoods. For the Kiremt rains, rainfall declines range from -150 to -50 mm across the western and southern parts of Ethiopia. The combined Belg and Kiremt rainfall reductions total a loss of more than 150 mm of rainfall per year in the most densely populated long cycle crop growing area of the country.

A similar trend is confirmed through the Geo-Clim modelling as shown in Figure 5-17, indicating changes in average rainfall over the June-September Season, comparing averages for 1997-2013 with 1981-1996 (Kiremt season).

Figure 5-17: Observed and Projected Change in March–June, June–September, and March–September rainfall (top)



Further, the Geo-Clim model shows a reduction of over 100mm of rainfall in the hotspot areas with changes over the March-September Season averages for 1997-2013 minus 19981-1996 (Long Cycle Rain).

Figure 5-17: a) shows change in average rainfall over the March-September season, comparing averages for 1997-2013 with 1981-1996 (Long Cycle Rain);

b) shows change in average rainfall over the June-September Season, comparing averages for 1997-2013 with 1981-1996 (Kiremt season);

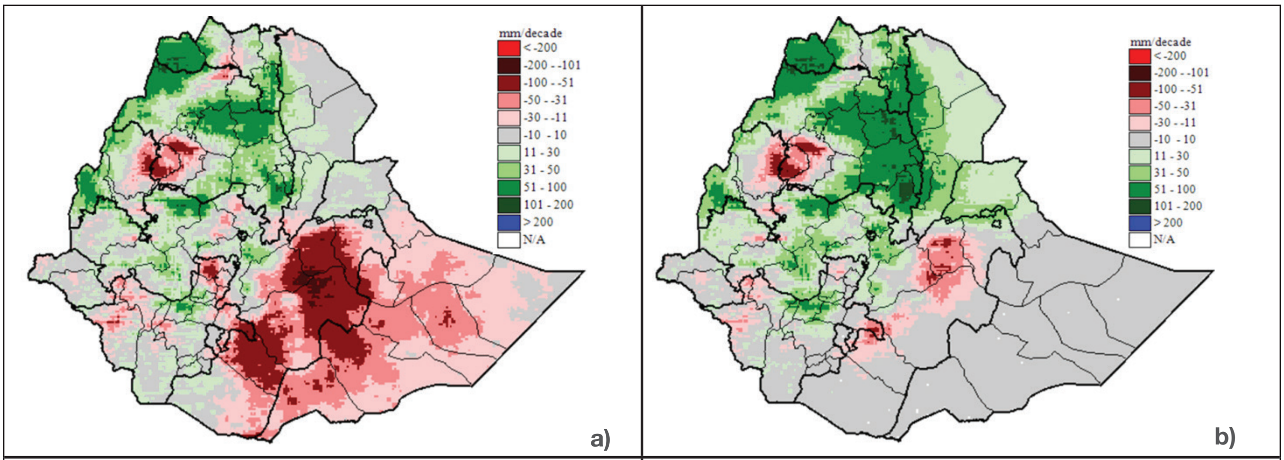
and c) shows change in average rainfall over the March-June Season, comparing averages for 1997-2013 with 1981-1996 (Belg season)

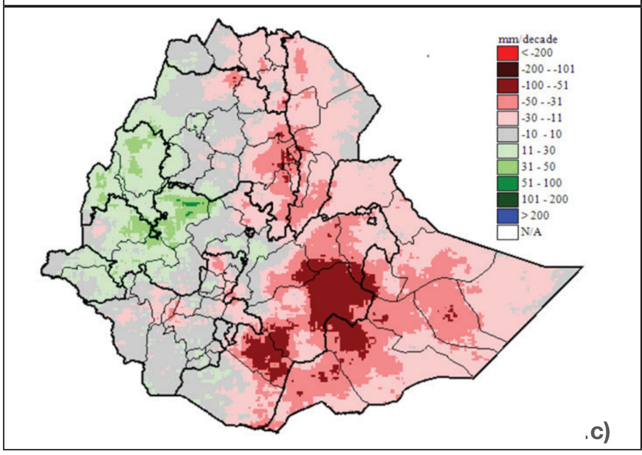
Figures 5-18 and 5-19 indicate the results generated from the GeoClim modelling of the rainfal data.

Water Resource Management




Figure 5-18: Seasonal Rainfall Changes in Ethiopia[15]





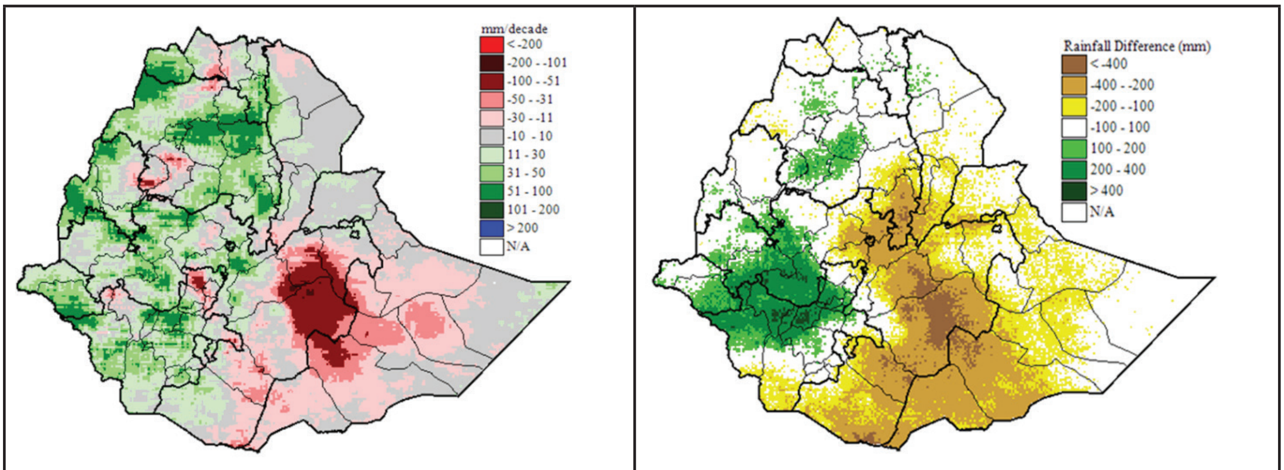
Note: a) Shows change in average rainfall over the March-September season, comparing averages for 1997-2013 with 1981-1996 (Long Cycle Rain).

b) Shows change in average rainfall over the June-September season, comparing averages for 1997-2013 with 19981-1996 (Kiremt season).

c) Shows change in average rainfall over the March-June Season, comparing averages for 1997-2013 with 1981-1996 (Belg season).

Figure 5-19 shows the change in the average total annual rainfall (January-December) compared with the average total annual rainfall for 1997-2013 minus 1981-1996 (left) and the deviation from the average rainfall for the period July 1981 to August 2014. The figure once again confirms a rainfall reduction over the hotspot areas.

Figure 5-19: Annual Change and Differences in Average



Note: a) The left side shows change in average rainfall over January to December, comparing averages for 1997-2013 with 1981-1996 (annual).b) The right side shows Ethiopia's difference from average rainfall for the period July 1981 to August 2014.

15RFE rainfall data sets (1981-2013) were used for estimation of seasonal rainfall changes using the GeoClim model.

5.4.4. Climatically Secure Areas

Most areas in Ethiopia are climatically secure in spite of the erratic rainfall patterns. However, the Belg season is, becoming drier, particularly in the regions of Oromiya, Somali, and SNNP; while the Kiremt season continues to be wetter in some areas of Amhara. Ethiopia does not, therefore, face a catastrophic national failure of rainfall, but rather regional hotspots with a tendency towards more frequent and more intense droughts. These droughts will tend to affect most pastoralists and agro-pastoralists living in marginal climatic areas. Figure 5-20 shows both positive and negative changes in average rainfall over the Belg and Kiremt seasons and the regions most affected.

Figure 5-20: Regions Affected by Changes in Average Rainfall

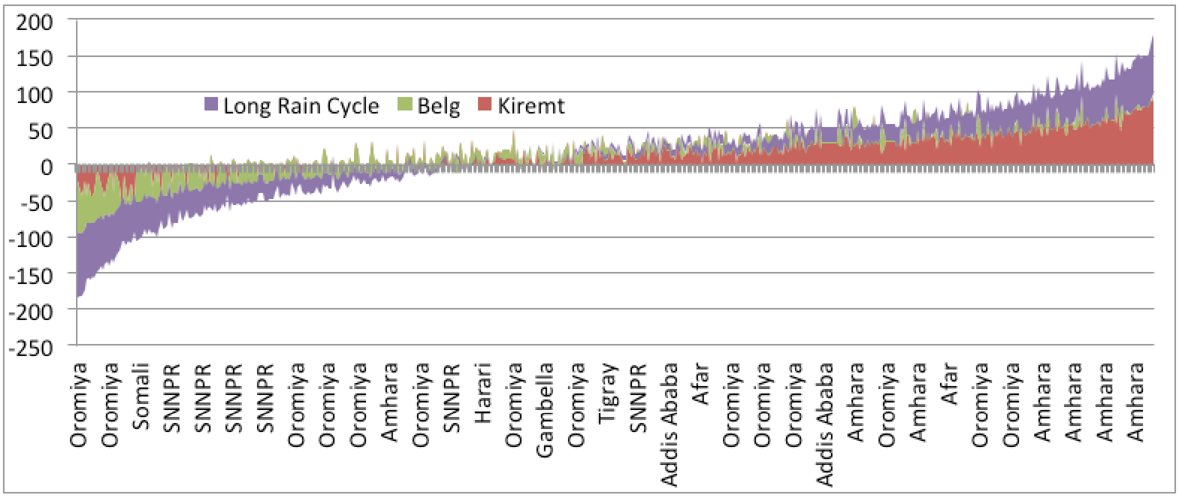


Figure 5-21 below shows the zones affected by rainfall reduction in the Kiremt season as indicated. The figure shows that there is an increase in rainfall in the Belg season in some areas especially in the Amhara and Benshangul Gumuz regions, although the Kiremt season indicates significant reductions.

Figure 5-21: Regions and Zones affected most during the Kiremt season

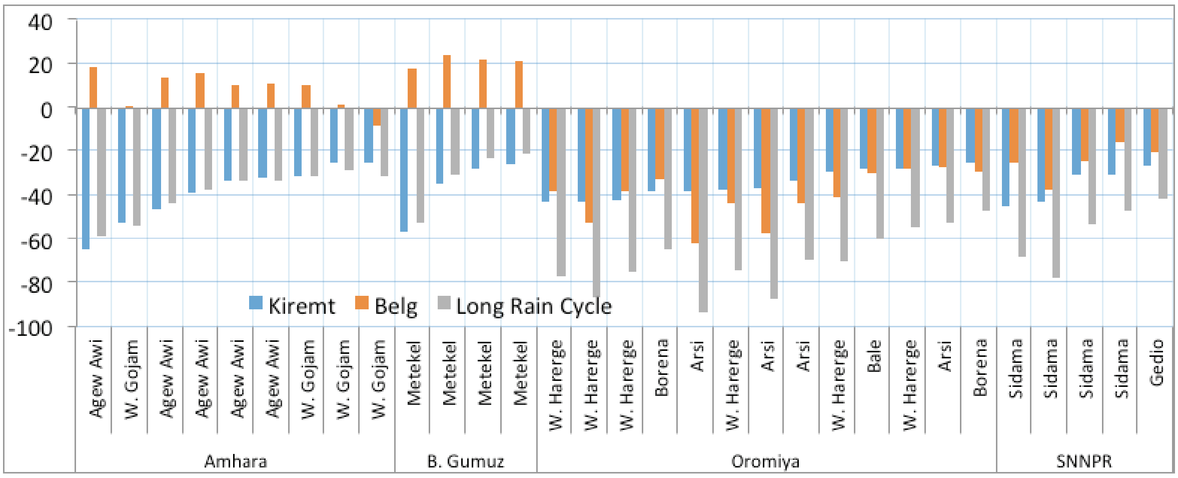
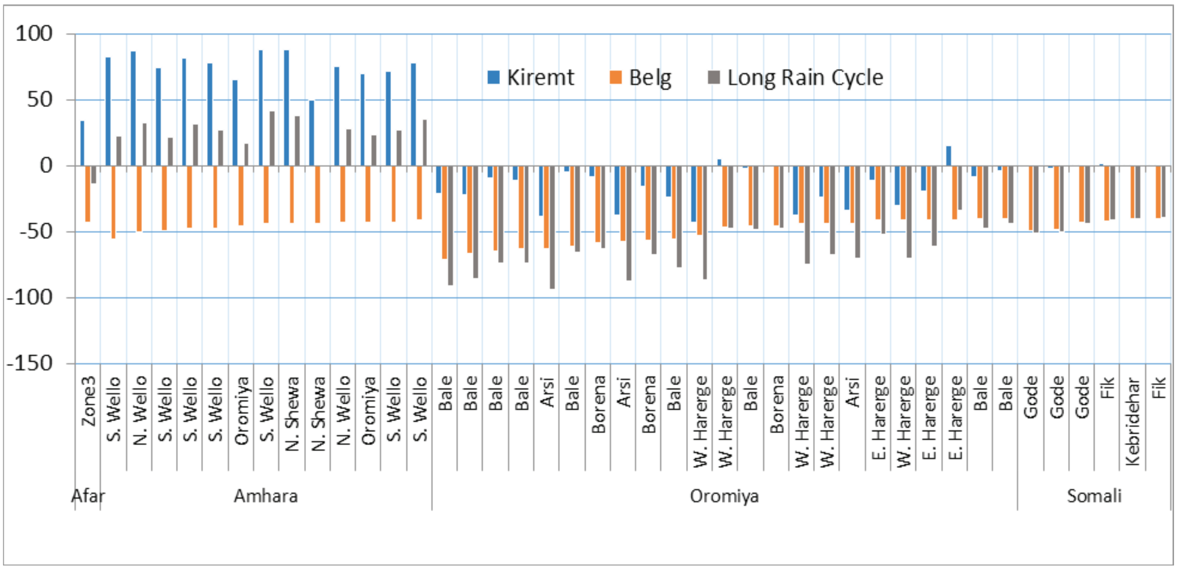


Figure 5-22 below shows the zones and regions affected by rainfall reduction in the Belg season as indicated. The figure shows that there is an increase in rainfall in the Kiremt season in some areas especially in the Amhara and Afar regions, although the Belg season indicates significant reductions

Figure 5-22: Regions and Zones affected most during the Belg Season



5.4.5. Climate Change Vulnerability Assessment

The Intergovernmental Panel on Climate Change (IPCC) conceptual framework for mapping vulnerability was applied to identify the climate change hotspots. In this approach vulnerability was separated into three components: exposure; sensitivity; and adaptive capacity to climate stressors. This framework and variants have also been commonly applied in vulnerability mapping exercises in Africa and globally. In the interest of identifying the climate change hotspots and the most vulnerable communities, this assessment focused on generic vulnerability based on the populations rather than the separate vulnerability of natural systems (e.g., ecosystems); sectors (e.g., water or agriculture); or population sub-groups (e.g., pastoralists).

The spatial indicators used in the vulnerability assessment are found in Table 5-1 below. In the assessment, a limited number of high-quality spatial data sets (most of which were sourced from the CSA) that best represent the component of interest were selected while avoiding low-quality data (data of high uncertainty or coarse spatial resolution). The data sets were converted from the original formats in excel to spatial data layers and rasterized[16].

16 Before conversion, grids were converted to tabular comma-separated values (CSV)-format files using a common grid referencing system. All data transformations and aggregations were performed in the R statistical package, and re-exported to ArcGIS for mapping. The aggregate indices were normalized (rescaled) from the raw data values to indicator scores on a 0-100 scale, where 0 equates to lower vulnerability and 100 equates to high vulnerability.

Table 5-1: Indicators Utilized by Component of Vulnerability

Component	Data Source	Data Layer
Exposure	RFE from the CHIRPS database for Africa; precipitation in decadal, and monthly averages[17]	Change in average rainfall over the March to June season, comparing averages for 1997-2013 with 19981-1996
		Per cent of precipitation variance explained by decadal component (1950–2009)
	Synoptic station data NMA (1981-2014)	Annual and Monthly Average rainfall
	Synoptic station data NMA (1981-2014)	Trend in temperature
	Synoptic station data NMA (1981-2014)	Annual and Monthly Average maximum and minimum temperatures
	ISRIC - World Soil Information	Coefficient of variation of the Normalized Difference Vegetation Index (NDVI) (1981–2006)
	FEWS NET	Long-term trend in temperature in July-August-September (1950–2009)
	Center for Hazards and Risk Research (CHRR); Center for International Earth Science Information Network (CIESIN), Columbia University	Flood Hazard Frequency and Distribution
Sensitivity	CSA and ICF, 2012	Household wealth; Building Material
	CSA and ICF, 2012	Child Stunting
	CSA and ICF, 2012	Infant mortality
	CSA and ICF, 2012	Disease preference (Malaria and)
	CSA and ICF, 2012	Child mortality
		Malaria Stability Index
	Center for Hazards and Risk Research (CHRR); Center for International Earth Science Information Network (CIESIN), Columbia University	Flood Proportional Economic Loss Risk Deciles.
	ISRIC - World Soil Information	Soil Organic Carbon
Adaptive Capacity	Irrigated areas (FAO/CIESIN/JRC)	Irrigated areas (area equipped for irrigation)
	CSA and EDHS 2011	Access to basic facility (Hospital/school/market)
	CSA and EDHS 2011	Access to safe water
	CIESIN/JRC	Anthropogenic Biomes
	CSA and EDHS 2011	Mother Education Level

5.4.5.1. Exposure Component

The Belg and Kiremt seasons were considered in the assessment of exposure to climate changes and the component was analyzed based on seasonal variability. As shown in Figures 5-23 and 5-24 the exposure results indicate extremes running from south to north through central regions Ethiopia in the Belg season. In the Kiremt season there is very high exposure I in southern and eastern regions, mainly covering the Regional State of Somalia and some parts of SNNP. During this season extreme exposures are localized and distributed over the country.

17

Figure 5-23: Belg Season Exposure

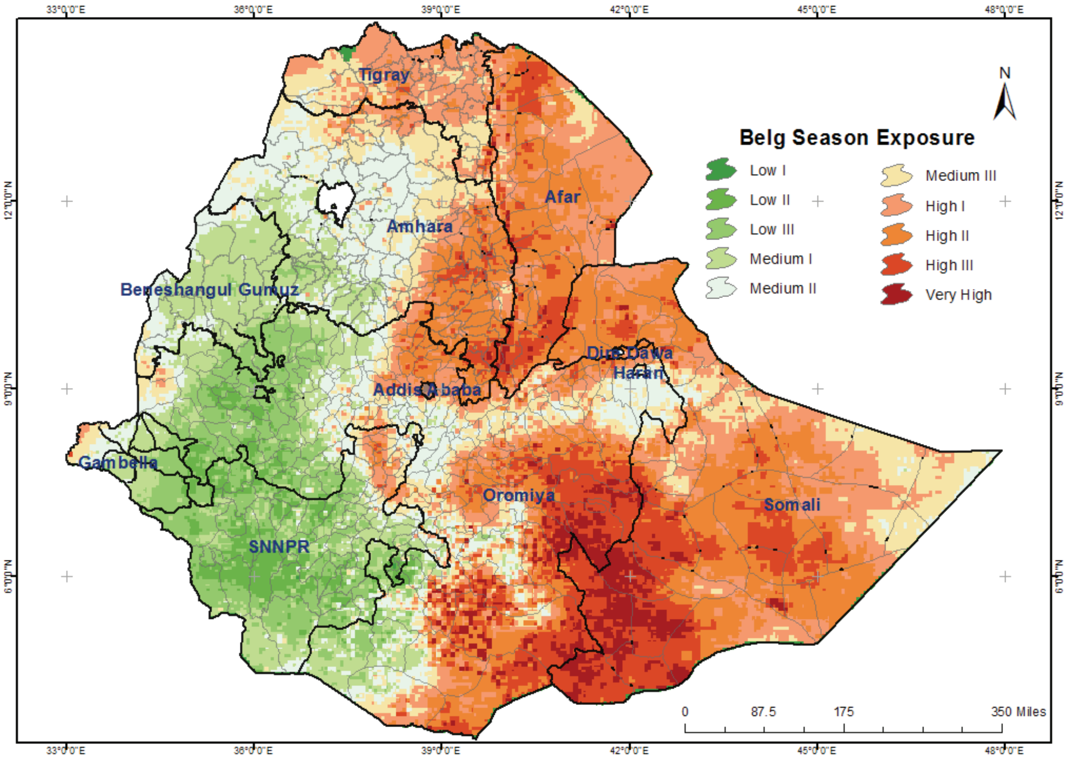
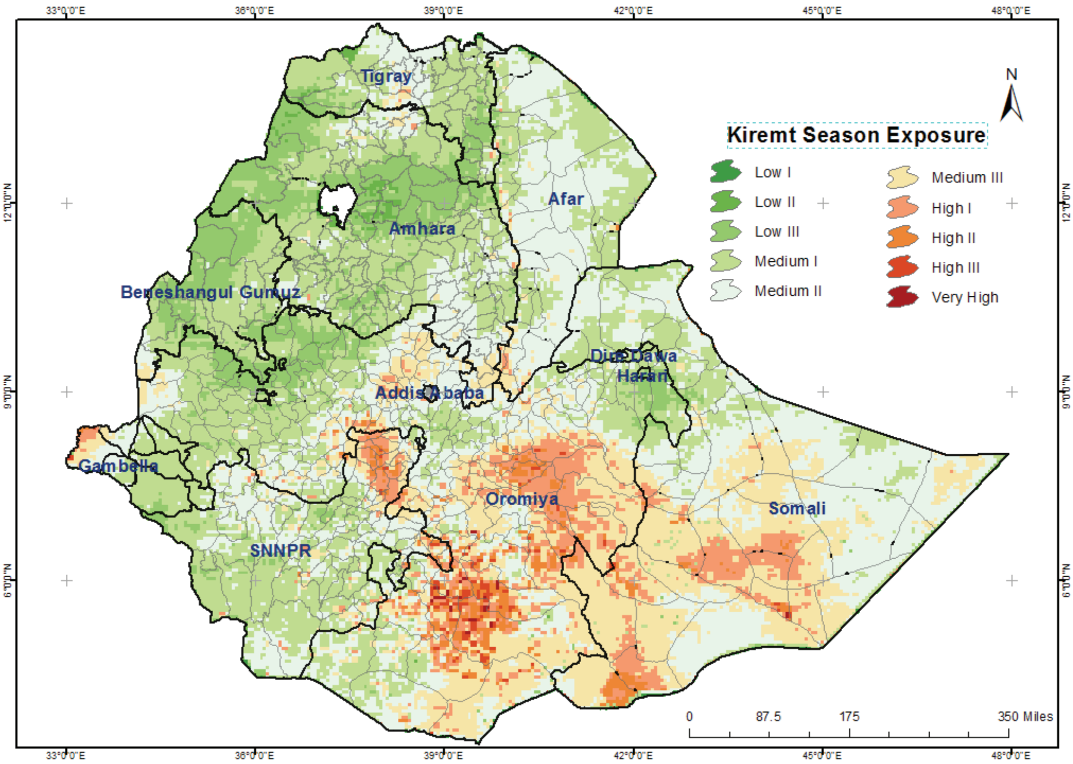


Figure 5-24: Kremit Season Exposure



5.4.5.2. Sensitivity

Box 5-3: Dns

Hazard

A physically defined source of potential harm, or a situation with a potential for causing harm, in terms of human injury; damage to health, property, the environment, and other things of value; or some combination of these (CARICOM, 2003).

Perturbations

These are small variations from the norm in the physical system, typically of lesser magnitude than a hazard, but possibly of longer duration. Perturbations may retrospectively be identified as incremental change.

Sensitivity

This is the extent to which a unit of analysis reacts to stimuli. In climate terms, biomes, ecosystems, countries and sectors are all examples of units, which may have different levels of sensitivity when exposed to the same climate hazard (depending on the scale of the analysis).

Adaptation

Adjustment in natural or human systems in response to actual or expected climate changes or their impacts, so as to reduce harm or exploit beneficial opportunities

Adaptive Capacity

The potential or capability of a system to adjust its characteristics or behavior to anticipate, cope with and respond to climate variability and change.

Climate change vulnerability

Refers to the state of susceptibility to harm from exposure to climate hazards, and the ability of the sub-national territory (or other unit of analysis) to cope with, and recover from, such exposure as well as manage incremental and long-term change in climate

Source: UNDP, 2010.

This component of the vulnerability assessment considered the fact that different physical environments respond differently when exposed to the same manifestation of climate change, a hazard or perturbation. It is for instance considered that marginal or semi-arid areas will respond more to an increase of temperature of 1^0C than a desert ecosystem subjected to a similar change. The sensitivity of the physical environment to climate change has knock-on effects for the human use of that environment. Climate changes are either negative or positive; thus the effects can lead to the emergence of both detrimental and beneficial situations. The impact on economic sectors; such as population, agriculture, water, energy, tourism, fisheries, health, and biodiversity will differ depending on their sensitivity to the effects of the climate change to which they are exposed

The assessment of sensitivity was carried out using the following indicators: household wealth; type of building material; child stunting; infant mortality; disease prevalence (malaria stability index); poverty index; population density; and child mortality. The results indicate that the most sensitive areas are in the central and southern parts of the country which include most parts of Oromiya region, Amhara region and SNNP region. Figure 5-25 below shows the sensitivity of different parts of the country.

5.4.5.3. Adaptive Capacity

Hazards, perturbations and sensitivity of the affected environment form the main variables for the function used in determining the impacts of climate change. The extent of the effects of climate change is further mediated by the human characteristics of the exposed communities and populations. The adaptive capacity of society is correlated with various social factors, including gender, class and age. These in turn give rise to differences in human capital (such as levels of education and status of health), financial capital (wealth) and access to facilities and institutions. All these factors affect the ability of the population or society to anticipate, cope with, and respond to climate changes. Figure 5-26 shows lack of capacity to adapt to climate changes.

Figure 5-25: Sensitivity to Climate Change

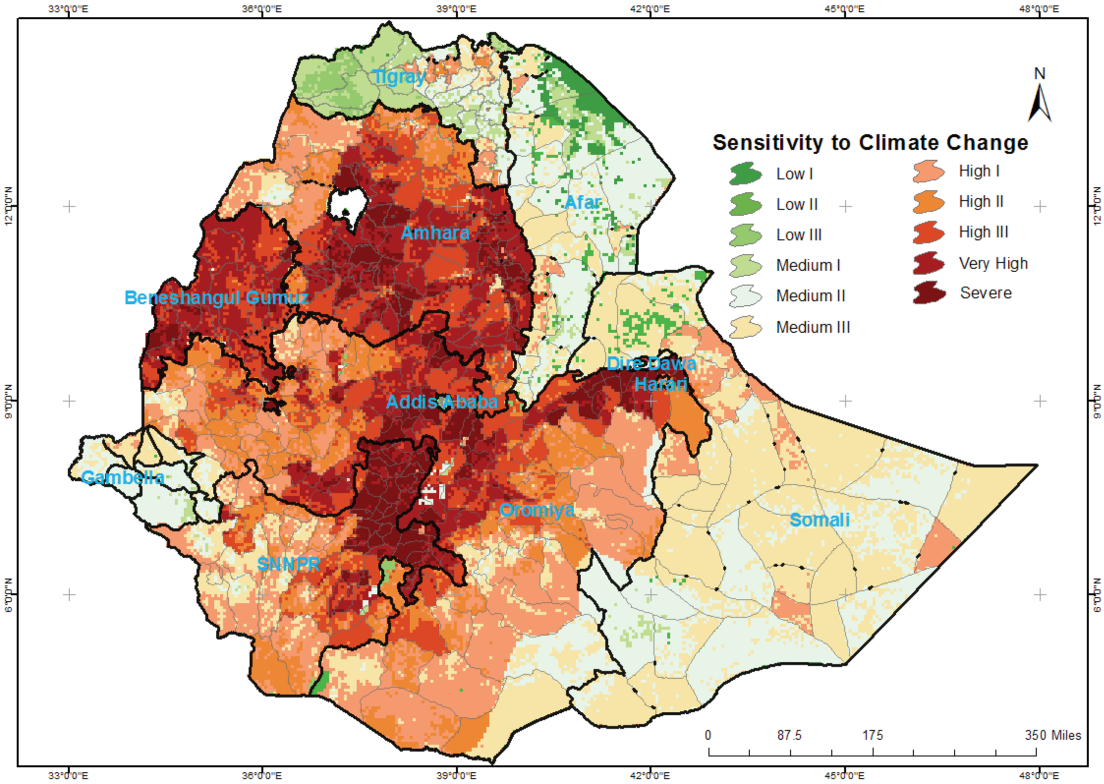
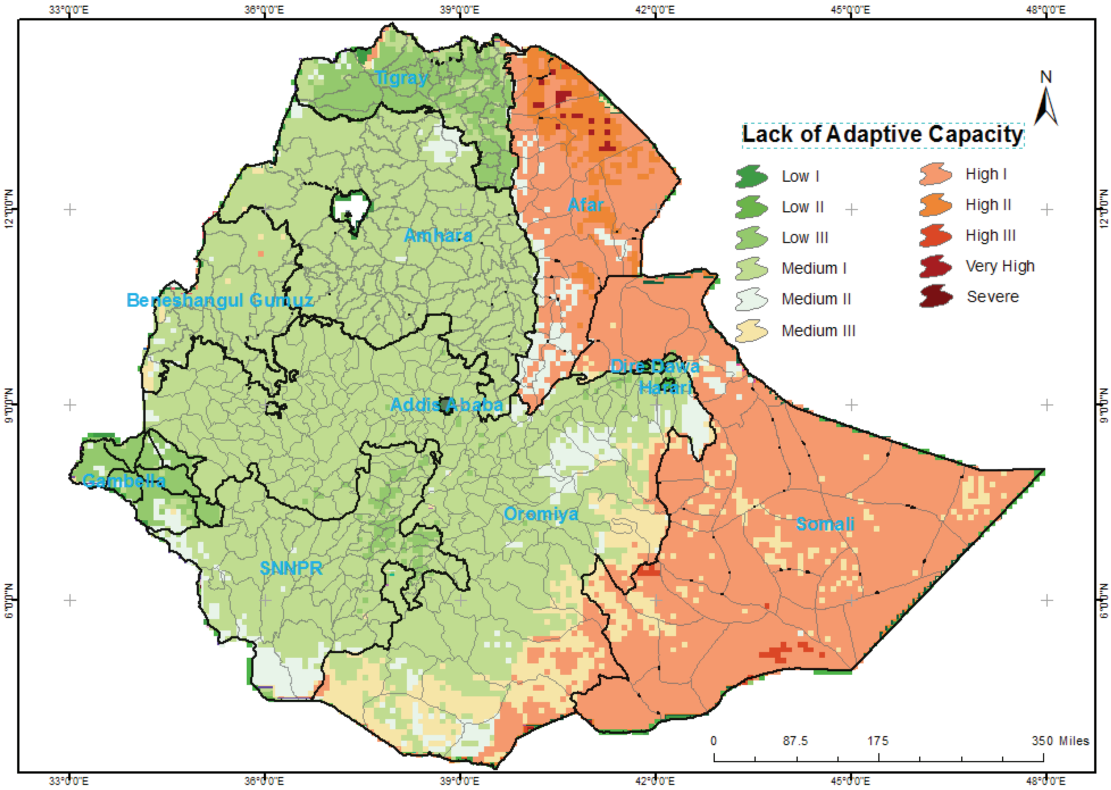


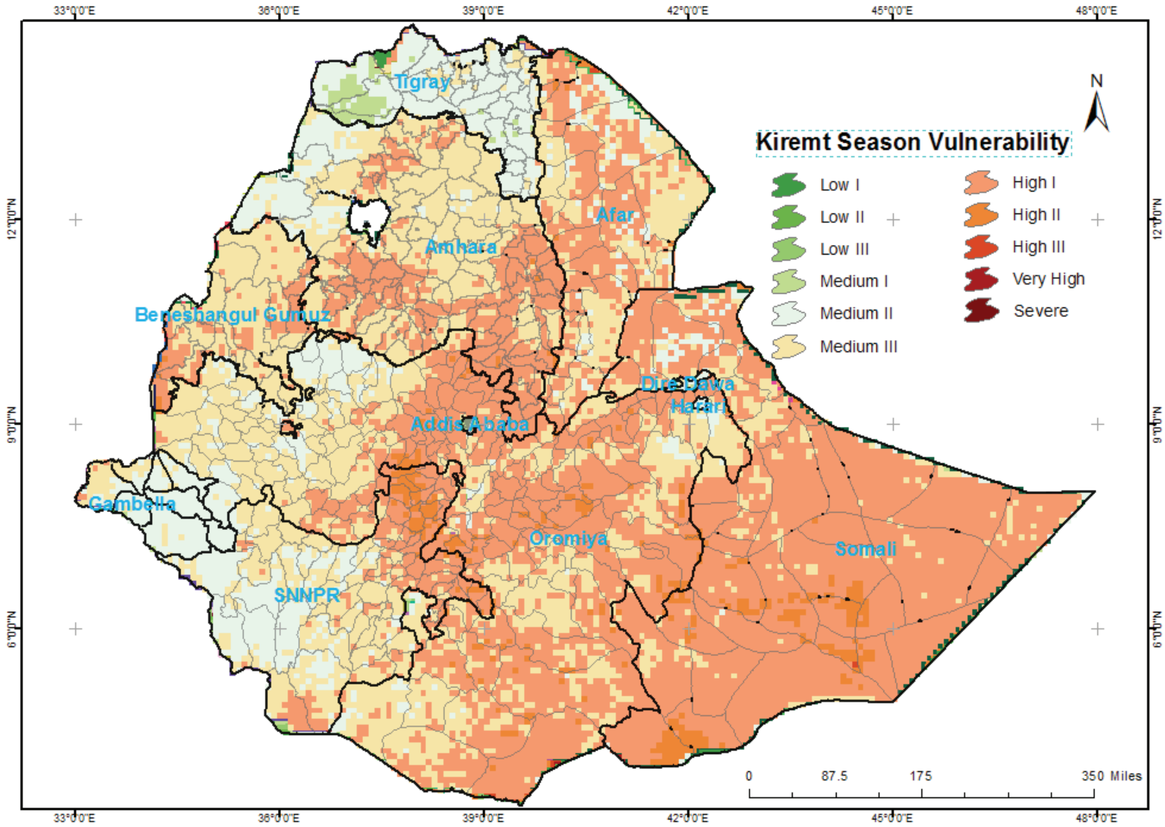
Figure 5-26: Lack of Adaptive Capacity to Climate Change



Vulnerability assessment was done by combining the three components in the ArcGIS spatial analyst environment using the equation below.

The assessment produced results for both Kiremt and Belg seasons as shown in Figures 5-27 and 5-28.

Figure 5-27 Kremit Season Vulnerability



This assessment indicates that climate vulnerability for both Belg and Kremt seasons varies widely across the country and its impacts are experienced at the local level. This will therefore require local responses and solutions as part of the national plan for climate change adaptation. This climate change analysis, along with common perceptions derived from other research findings demonstrates that temperatures are projected to increase significantly, while rainfall is expected to increase in some areas during the Kremit season, whereas significant reductions in the Belg season rainfall are being experienced. The increasing temperatures may affect the phenological cycles of crop production, increase pest populations and disease occurance in crop and livestock production systems. This changes are also expected to result in more frequent dry spells and severe storms that compromise productivity. Farmers have consistently noted that the nature of the rainy season(s) is changing, insects and crop disease have increased and severe weather events are more common.

Figure 5-28: Belg Season Vulnerability

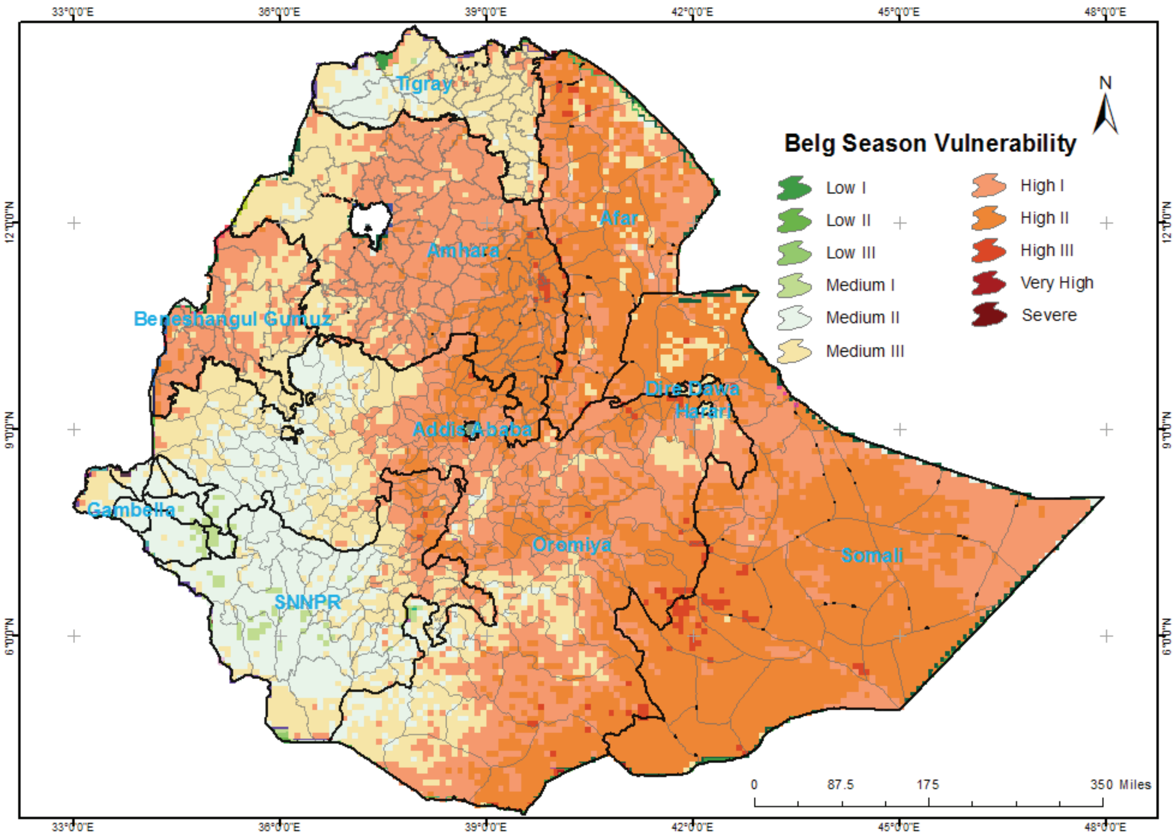


Table 5-2 below shows the scale used in the assessment of vulnerability

Table 5-2: Scaling of the Vulnerability Assessment Results

Category	Scale Ranges
Low I	0 to 10
Low II	10 to 17
Low III	17 to 22
Medium I	22 to 27
Medium II	27 to 32
Medium III	32 to 36
High I	36 to 40
High II	40 to 44
High III	44 to 48
Very High	48 to 62
Severe	62 to 67
Very Severe	67 to 75
Extremely Severe	75 and Above

5.5 Ethiopia's Vulnerability to climate change: Disaster Risk Management

Disasters pose serious impediments to Ethiopia's socio-economic development, and have the potential to reverse gains made over the years, squander vast resource investments, and exacerbate poverty levels. Some of the impacts of natural disasters include damage to infrastructure and the natural environment, and diversion of national priorities and development resources to emergency management operations. A wide range of natural and human-induced hazards are associated with Ethiopia`s diverse geo-climatic and socio-economic conditions. Disasters arising from some of the hazards have caused widespread damage and loss, while others remain potential threats. Ethiopia's National Adaptation Programme of Action (NAPA) recognizes that while the causes of most disasters are climate-related, the deterioration of the natural environment due to unchecked human activities and poverty has further exacerbated the situation.

Table 5-3 shows some of the impacts of disasters in Ethiopia. Some of the natural hazards that have affected Ethiopia include extreme climate events like droughts, floods, increased incidences of human and livestock diseases and crop pests, and seismic and volcanic activities. Based on the frequencies of the events, the number of people affected (including losses of life), and the estimated damage, the biggest impacts are from droughts and floods. The related hazards have many times led to loss of life and livelihoods, among other socio-economic impacts like poverty exacerbation. Sometimes this has resulted in communities losing their whole economic base. The frequency and intensity of these extreme climate events are expected to increase as a result of climate change, an outcome likely to make the situation worse for the country.

The country's vulnerability is aggravated by several factors, among them, poor agricultural and livestock practices, a fragile and degraded natural environment, high levels of poverty, high population growth, and competition over diminishing resources. Several mechanisms have been put in place to address disaster risks, including the formulation of a National Policy on Disaster Prevention and Preparedness, whose main objective is to reduce disaster risks and potential damage caused by disasters through the establishment of a comprehensive and coordinated disaster risk management system in the context of sustainable development (IFRC, 2013). In addition, climate disaster risk management should be integrated in all policies, and the relevant institutional structures put in place. This was also a recommendation of the EPACC (FDRE, 2011b).

Table 5-3: Impacts of Natural Disasters in Ethiopia, 1900 – 2012

Disaster/hazard	Type	No. of events	No. of deaths	Total affected	Damage (in 000 US$)
Drought	Drought	15	402,367	66,941,879	92,600
Earthquake (Seismic activity)	Earthquake (ground shaking)	7	24	585	7,070
Epidemic	Unspecified	4	429	32,948	-
	Bacterial infectious diseases	15	10,984	133,680	
	Parasitic infectious diseases	1	157	2,500	-
	Viral infectious diseases	2	46	531	
Flood	Unspecified	13	136	195240	920
	Flash flood	6	735	436,278	9,400
	General flood	31	1,105	1,758,478	6,700
Insect infestation	Locust	4	-	-	-
Mass movement dry	Landslides	1	13	-	-
Mass movement wet	Landslides	2	26	194	-
Volcano	Volcanic eruption	3	69	11,000	-
Wildfire	Forest fire	1	-	5	-

Source: IFRC, 2013.

In the drought-prone highlands, the situation is somewhat different, with land productivity and crop yield expected to decline as a result of climate change more or less continuously throughout the period of study.

5.6. Sectoral Impacts, Vulnerability and Adaptation Assessment

Ethiopia is highly vulnerable to drought, it being the single most important climate-related natural hazard impacting the country. Recurrent drought events in the past have resulted in huge losses of life and property as well as migration of people. Another climate-related hazard that affects Ethiopia is floods, with major floods having caused loss of life and property in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 (FDRE, 2011c).

The major adverse impacts of climate variability and change in Ethiopia include:

i. Food insecurity arising from occurrences of droughts and floods;

ii. Outbreak of diseases such as malaria, dengue fever, water borne diseases (such as cholera, dysentery) associated with floods and respiratory diseases associated with droughts;

iii. Land degradation due to heavy rainfall;

iv. Damage to infrastructure by floods; and

v. Loss of life and property.

BOX 5-4: Future impacts and costs of climate change

Future climate change could have significant economic impacts. Under some scenarios the impact of climate change on all sectors could be over 10 per cent of GDP by 2050. This could put our middle-income ambition at risk.

Source: FDRE, 2011c.

Vulnerability assessment based on existing information and assessments in EPACC has indicated that the most vulnerable sectors to climate variability and change are agriculture, water and human health. In terms of livelihood, smallholder rain-fed farmers and pastoralists are found to be the most vulnerable. The arid, semi-arid and the dry sub-humid parts of the country are affected most by drought.

Climate change is expected to have adverse ecological, social and economic impacts. Efforts have been made to compile information on climate change impacts from various sources such as the Initial National Communications of Ethiopia to the UNFCCC, the CRGE Strategy and related sector strategies, the IPCC reports, and local studies, among others. Impact and vulnerability assessments in priority sectors were undertaken as part of the process of developing the Initial National Communications. This was updated in the NAPA and EPACC, regional programmes, and sectoral strategies (e.g. the CRGE Strategy). There was a general observation from the regional consultative meetings during the NAPA development process that the temperature has increased over the country and that recurrent drought and flood are the most severe problems that affected millions of the country's population almost every year (FDRE, 2012). This perception of change in temperature and in the frequency of drought could be linked to a changing climate. Climate change will also affect the land resources of the country by exacerbating desertification and its consequences.

The country has already put in place policies, strategies and programmes that enhance adaptive capacity and reduce the vulnerability to climate variability and change. Such programmes include the Climate-Resilient Green Economy (CRGE) Strategy; the 5-year Growth and Transformation Plans (GTPs); the Plan for Accelerated and Sustainable Development to End Poverty (PASDEP), the Environmental Policy of Ethiopia, and different sectoral strategies, among others. Improved economic growth has been registered over the past four years as a result of these policies, strategies and programmes. However, the country needs financial and technological support and capacity-building to fully implement these policies and strategies (NMSA, 2007).

5.6.1. Water Resources

Ethiopia's annual rainfall is about 850 mm/year equivalent to 940 km^3 per year. About 13 per cent of the total rainfall is diverted into blue water, i.e. river flows or fresh water flows into lakes. Most rainfall is allocated to green flows: water transpired and evaporated from different land use systems. Ethiopia has 12 major river basins, with a total estimated annual flow of approximately 122 billion m^3 of water. Though this is a relatively big endowment, about 80 per cent of the country's water resources are concentrated in the western part, where only 33 per cent of the population resides, while the eastern part with 67 per cent of the population has only 11 per cent of the surface water resources. This means that there are fewer water resources in the area with higher demand and substantially more available in areas with a relatively low population. Further, even though the country has abundant water resources, its distribution is uneven, with the semi-arid and drier areas of the country experiencing regular water stress. It is projected that climate change will further reduce water availability in all water scarce regions, particularly in the arid and semi-arid areas, due to increased frequency of droughts, increased evapotranspiration, and potential changes in rainfall patterns and run-off. Just like droughts, floods will lead to adverse impacts on water resources.

A vulnerability assessment study of the Lake Tana sub-basin, with the objective of assessing the vulnerability of water resources under various climate change scenarios and evaluating adaptation options for reducing the potential adverse effects on the water resources of the sub-basin, was undertaken using the WatBal model. The study concluded that climate change would have serious implications for the hydrology of the sub-basin, affecting the magnitude and seasonality of surface flows. Further, the projected increase in the frequency and intensity of extreme climate events such as droughts and floods will exacerbate the problem. Generally, there is agreement between different models that river flow would be reduced, by amounts ranging from 15 per cent to 80 per cent of the monthly mean, in some months of the year all over the basin (Tarekegn and Tadege, 2006). This decrease may lead to the drying up of small streams, resulting in a significant decrease in the magnitude of flow of the medium to large rivers, including the tributaries of trans-boundary rivers. This has the potential to impair the supply of water for domestic and agricultural use within Ethiopia, and along the whole Nile Basin. Another adverse impact is on the rain-fed agriculture along the whole Nile Basin because of the projected reduced rainfall. On the other hand, the predicted increase in river flow in some months of the year will cause floods, as the natural river and stream channels may not be able to accommodate the increase, which may lead to a rise in the lake levels and the subsequent flooding of agricultural fields and human settlements (Tarekegn and Tadege, 2006).

An earlier vulnerability assessment done for the Initial National Communication on the level of the rivers Awash and Abay (Blue Nile) water supply (runoff) indicated that the Awash River is highly vulnerable to climate change; and that due to population pressure, there is already a water stress even without climate change. The results indicated a considerable water deficit ranging from 10 to 33 per cent. The study further indicated that the Abay River basin is highly sensitive to climate change. Runoff was projected to decrease by 33.6 per cent and 2.6 per cent, respectively, according to the CCCM and GFDL R-30 models. These results are in agreement with those of a study to assess climate change impacts on the hydrology of the Gilgel-Abay Catchment in Lake Tana Basin. The study predicted a 33 per cent reduction in the annual and seasonal runoff and a 20 per cent rainfall reduction with a temperature increase of 2 ºC (Shaka, 2008).The first study points to serious implications for the country, given that this is the only non-transboundary river basin, and hence the country's irrigated agriculture depends solely on it. The second study, on the other hand, paints a similar picture not only for Ethiopia, but also for other riparian countries along the Nile Basin. The UKMO projections indicated that runoff would increase by 10 per cent, which is likely to lead to more land and environmental degradation.

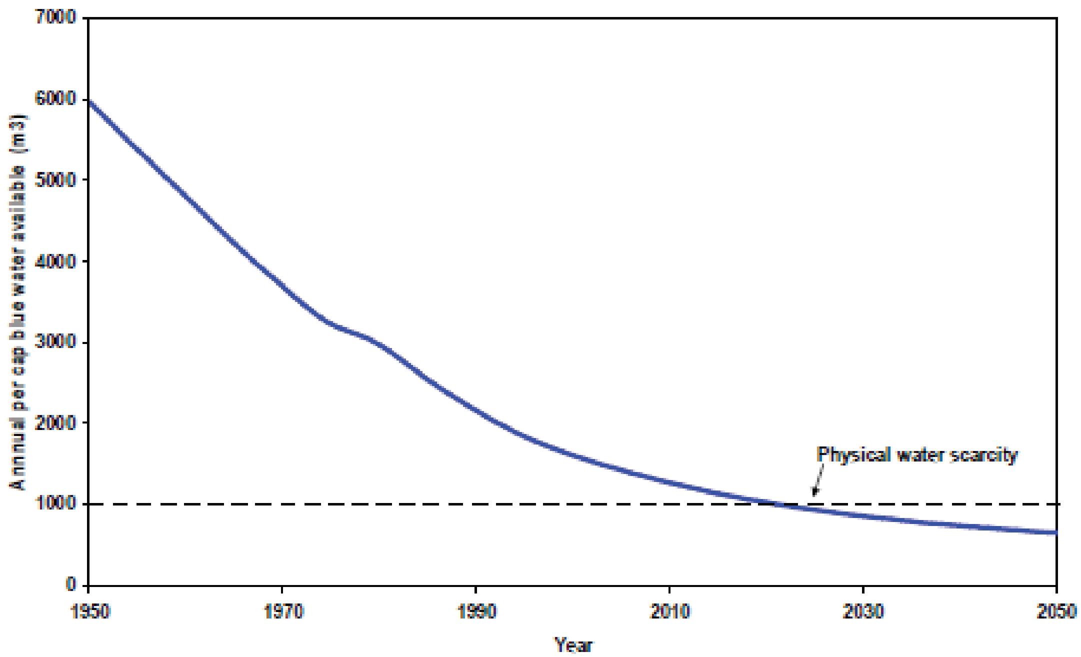
Apart from the coastal and marine-related wetlands and extensive swamp-forest complexes, all forms of wetlands are represented in Ethiopia; including riverine, lacustrine, palustrine and floodplain wetlands. Floodplains are found both in Ethiopia's highlands and lowlands, although they are most common in the North-Western and Western Highlands, Rift Valley and Eastern Highlands. It is estimated that wetlands cover 1.14 per cent of the total landmass of the country (approximately 13,699 km^2), while forests cover approximately 14 per cent. Wetlands (their hydrological and ecological functions) support various economic activities, life support systems and human welfare, including ground water recharge, flood control, nutrient cycling, erosion control and sediment traps, climate regulation, habitats for migratory wildlife and pest control. Wetlands thus produce an ecological equilibrium in the environment by maintaining the integrity of life support systems for sustainable socio-economic development. Wetlands are subject to continuing threats and degradation, because of human activities and development, a problem expected to worsen as a result of climate change.

Groundwater is the major source of drinking water in Ethiopia, providing more than 80 per cent of the country`s potable water supply (Kebede and others, 2006).This is especially the case in the arid and semi-arid areas of the country. Groundwater pollution was not considered as a major problem in Ethiopia until recent times. Currently there is an ever increasing demand for application of fertilizers and pesticides to enhance food production. At the same time, when there is expansion of settlements, widespread disposal of domestic and industrial effluents into the environment occur. It is inevitable that these human activities pose pollution problems in the groundwater system, with indications that it is already getting polluted in some big cities. The vulnerability of Ethiopia's ground water system is expected to worsen with the projected reduced rainfall combined with the projected increased evapotranspiration rates driven by climate change.

Figure 5.29 shows the decreased per capita blue water availability for Ethiopia due to population growth. It is predicted that by 2020, Ethiopia will be physically water scarce as the per capita blue water availability becomes lower than 1000 m3/cap/year. Increased groundwater use can postpone the critical decrease in readily extractable water for different consumptive uses. The problem is likely to worsen as a result of climate change.

Among the measures the Government has put in place to address the problem are plans to harvest runoff and harness the blue water resources for irrigation. The Government is also promoting small-scale farmer-targeted irrigation aimed at alleviating poverty.

Figure 5-29: Per Capita Blue Water Availability for Ethiopia, 1950-2050



Source: Awulachew and others, 2007.

Although precipitation is projected to increase in some areas of East Africa as a result of climate change, evapotranspiration will also increase due to a rise in temperatures, thus reducing the benefit of the increase (IPCC, 2014). Prolonged and severe droughts can lead to low water levels in rivers, underground aquifers and reservoirs, impacting on the hydrology, biodiversity and water supply. Low reservoir levels can also reduce the potential for hydropower generation, leading to power rationing in the domestic and commercial sectors, thus resulting in interruption of economic activities and decline in manufacturing output. Droughts have resulted in lowering of the water table, and drying of boreholes.

Given the importance of water in climate change impacts, water management and the water sector are fundamental to each of the three components of reducing vulnerability. With appropriate actions, water managers can reduce exposure to hazards, reduce sensitivity and build adaptive capacity. In each case, the environment, its natural infrastructure and related institutions and governance have key roles to play, among them:

i. Exposure to flood is reduced by restoring the function of floodplains in combination with sound land-use planning, to drought by maintaining groundwater recharge by protecting the watershed;

ii. Sensitivity to climate hazards is reduced by using sustainable management of river basins to expand livelihood assets and enable economic development, such as through enterprise development related to irrigated agriculture diversification of crops and agroforestry; and

iii. Adaptive capacity is built through water governance that builds flexible and coordinated institutions, learning and dissemination of knowledge needed to empower the community in planning and decision-making related to adaptation.

Water is convolutedly interlinked with the well-being and resilience of ecosystems and human societies. Many options for adaptation of water management to climate change can therefore be designed to achieve urgent environmental and social objectives related to present climate conditions, such as protection of water sources during flooding conditions and water conservation practices in drought-prone areas.

Ethiopia is already implementing the adaptation options as reflected in its draft Climate Change Adaptation Action Plan of Water and Energy Sector, the NAPA and EPACC, the Water Sector strategy and also in the GTP. The following are further examples of adaptation options that Ethiopia needs to scale up to increase the resilience of the people and ecosystems by improving access to water and ecosystem services for sustainable environments and livelihoods:

i. Expansion of rainwater harvesting for groundwater recharge for cultivation through irrigation;

ii. Adoption of water transfer schemes;

iii. Increased storage capacity by building reservoirs;

iv. Improvement of water-use efficiency;

v. Expanded use of economic incentives to encourage water conservation;

vi. Improvement of urban water and sanitation infrastructure;

vii. Improving flood protection through the construction of infrastructure and enlargement of riparian areas;

viii. Understanding water quality and quantity linkage and making surveillance of ground/surface water sources

ix. Improved flood forecasting; and

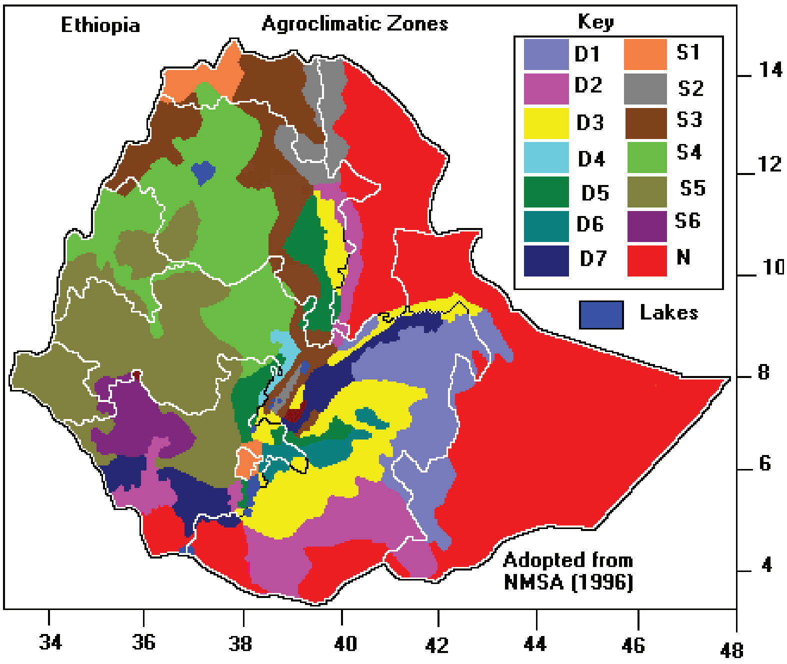
x. Upgrading of the climate and hydrological information systems and networks

Effective utilization of weather and climate information in the management of water resources could also yield substantial socio-economic benefits, particularly during drought periods and floods.

There is also the need to develop an integrated water resources management plan based on future climate projections. Another recommendation that could be considered is cross-basin transfer, feasible where projections for one basin are for increased flow, whilst the other is projected to have reduced flow.

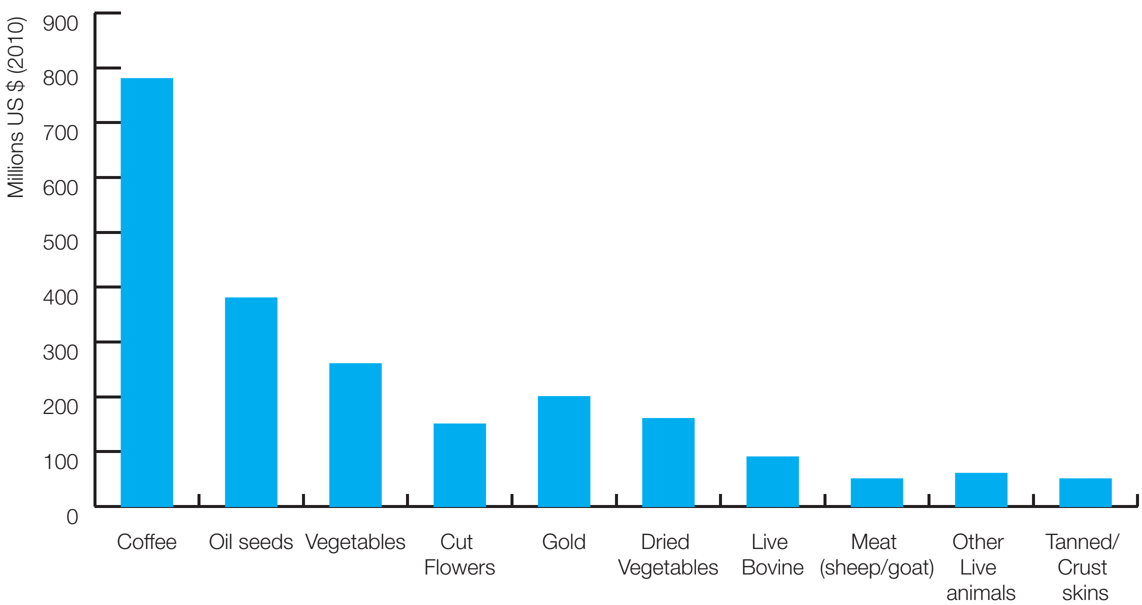
5.6.2 Agriculture sector

Figure 5-30: Ethiopia's agro-climatic zones.



Among the four pillars of Ethiopia's Climate Resilient Green Economy (CRGE) Strategy is improving crop and livestock production practices for higher food security and farmer income while reducing emissions. The Köppen-Geiger climate classification system indicates that Ethiopia has the following 10 climate types: the hot arid; hot semi-arid; tropical with distinct dry winter; tropical Monsoon; rainy with short dry winter; warm temperate; rainy with dry winter; and, warm temperate, rainy without distinct dry season (World Bank, 2007). The country is further divided into 30 agro-ecological zones, mainly defined by temperature and moisture regimes (Figure 5-30); (Koresha, 2014b)

Figure 5-31 : Ethiopia's top ten export commodities by value



The main crops grown in Ethiopia include; **cereals** (teff, maize, sorghum, wheat, barley, millet, oats); **pulses** (horse beans, field peas, lentils, chick-peas, haricot beans, vetch, etc.); **oilseeds** (linseed, niger-seed, fenugreek, rapeseed, sunflower, castor bean, groundnuts). The others are; **spices and herbs** (pepper, garlic, ginger, mustard); **stimulants** (coffee, tea, chat, tobacco); **vegetables** (onion, tomato, carrot, cabbage); **roots and tubers** (potato, enset, sweet-potatoes, beetroot, yams); **Fruits** (banana, orange, grape, papaya, lemon, mandarin, apple, pineapple, mango, avocado); **Fibres** (cotton, sisal);.and **Sugarcane**. (CSA, 2012; FAOSTAT, 2014; FDRE, 2011b; and FDRE 2011c). The vulnerability of the agriculture sector and the proposed adaptation actions are comprehensively discussed in the CRGE Climate Resilient Strategy for Agriculture (FDRE, 2011b).

The CRGE Strategy is supported by a number of technical analytical reports, and has three main objectives, namely:

i. To identify the impact of current climate variability and projected future climate change on Ethiopia (the challenge).

ii. To identify and cost options to build climate resilience and reduce the impact of current climate variability and climate change (response).

iii. To map the steps necessary to finance and implement efforts to build climate resilience (making it happen).

BOX 5-5: Projected Growth in Agriculture

Agricultural development will continue to be the basis for economic growth. The overall targeted growth rate for the sector is 8.6 per cent. Production of major food crops (e.g., teff, wheat, maize) is targeted to increase from 19 million tons to 27 million tons. Fruit and vegetable production is projected to increase fourfold to 5 million tons.

This implies increasing crop productivity from 19 quintals per hectare to 22. The total value of coffee exports, by far the most important cash crop, is to increase from US$0.5 billion today to more than US$2 billion in 2015, while exports of live animals are projected to grow from US$0.1 billion to US$1 billion.

Source: FDRE, 2011c.

The Strategy focuses on the crops, livestock, and forestry sectors that have been identified as the most vulnerable to the impacts of climate change. These sectors play a major role in Ethiopia's economy, contributing 41 per cent of GDP, 85 per cent of employment and 75 per cent of export commodity value, and nine of the top ten export commodities by value (Figure 5-31). Agricultural development is projected to continue to play a major role in the country's economic growth, albeit with a lower overall share of the economy (Box 5-5).

Box 5-6 gives a summary of the three sectors. Understanding the potential economy-wide impacts of climate change is critical for designing a national adaptation strategy. The future development of the Ethiopian economy over the next 50 years was simulated using results from a Ricardian model and two different scenarios for the total factor productivity growth (Gebreegziabher and others, 2011). The impact of climate change was assessed in terms of its effect on crop and livestock farming and how these effects translate into the entire economy, in terms of economic growth and poverty reduction. Looking at the two zones that dominate Ethiopia's agricultural production today (i.e., the moisture-sufficient highlands areas with cereal-based agriculture and the drought-prone lowlands), their projected outcomes are somewhat different, but climate change is expected to have a huge impact on both. In the moisture-sufficient highlands where cereals dominate, which currently account for the largest share of agricultural production, the overall productivity is projected to increase until around 2030 as a result of climate change, but will thereafter decline sharply. This is true for both crop and livestock production. The apparent explanation for the results is the nonlinear effect of temperature on yields. Yields will increase with an increase in temperature until the optimum limit, after which temperatures above the threshold level quickly start having a negative influence, leading to a significant decline in the yield. Studies have indicated that temperature and rainfall characteristics have the biggest impact on the agriculture and livelihoods of the people.

BOX 5-6: Agriculture Sectors

Agricultural crops, Ethiopia has a land area of 1.1m km2 and a diverse agricultural industry. Agricultural crops currently make up 67% of agricultural GDP (27% of total GDP). The main crops are cereals, pulses, coffee, oil seeds, spices, herbs, vegetables, fruits, sugar cane and fibre. Small-scale subsistence farming based on rain-fed agriculture and traditional farming techniques predominates.

Livestock contributes 26% of agricultural GDP (around 10% of total GDP). Ethiopia has the largest livestock population in Africa mainly made up of cattle (53m), sheep (26m), goats (23m) and birds (50m). Like agricultural cropping, livestock cultivation is mainly based on traditional techniques, whether mixed farming or pastoralism. A large proportion of livestock holders own just a few animals.

Forestry makes up 7% of agricultural GDP (3% of total GDP). Forest and woodlands contribute to the national economy and to livelihoods. This is through the provision of timber, fuel-wood and non-timber forest products. Forests also provide benefits for food security, health, employment and support wider ecosystem services (such as water filtration, flood control, and soil retention), which in turn provide economic benefits. For example, honey production (much of which occurs in forests) was reported as 42,000t in 2010/11. Although it provides a low proportion of agricultural GDP (<1%) and exports at the national scale, it is a valuable source of additional income for rural households in some regions.

Source: FDRE, 2011c

The vulnerability situation is further exacerbated by inadequate and unaffordable agricultural inputs, landlessness, unemployment, and water shortage.

Among the indirect effects of climate change are its influence on the emergence and distribution of crop pests and livestock diseases, exacerbating the frequency and distribution of adverse weather conditions, reducing water supplies and irrigation, and enhancing the severity of soil erosion.

A study undertaken to measure Ethiopian farmers' vulnerability to climate change in different Regional States identified several indicators for adaptive capacity, among them, household wealth, access to and use of technology, availability of infrastructure and institutions, potential for irrigation, and literacy rates. The key climate stresses and their impacts on agriculture are summarized in Table 5-4, while Table 5-5 summarizes some of the prioritized adaptation options for the agriculture sector.

Table 5-4: Climate Stresses and Key Impacts on Agriculture

Climate stresses	Key impacts
High mean temperature	Shifting agro-ecological zones;
Days with a max temperature above 35 °C	Heat stress for some crops
Days with a max temperature above 40 °C	Leads to heat stress on people and livestock
Lower mean rainfall	Shifts in agro-ecological zones; plus drought regimes
Higher mean rainfall	Landslides, damage to crops and livestock
Large scale floods	Damage to crops, livestock, infrastructure and people
Flash floods	Local damages to crops, livestock, infrastructure, people
High 1-hour rainfall intensity	Soil erosion and landslides, some local damages to crops
Heavy hail events	Crop damage at certain times in the growing season
Rainfall distribution (variability) within season	Significant impact on some crops
10-day dry spells	Significant impact on some crops
Seasonal droughts	Significant impact on most crops
Consecutive seasonal droughts	Significant impact on livelihoods and economic growth
Later onset of rainfall season	Shortens growing period - impacts on crops, fodder
Earlier end date of the rainfall season	Shortens growing period - impacts on crops, fodder
Decreased predictability of the rainfall season	Less reliable forecasts affects some enterprises
Increased uncertainty in rainfall distributions	Increases risk, important for some enterprises
Increases in cloudiness and humidity	Reduces radiation, increases thermal stress for people

Source: FDRE 2011c.

Reduced rainfall amounts and duration, combined with factors as longer dry spells lead to a shortage of water and pasture have exacerbated increased conflicts over limited resources. The other factors aggravating the situation include an increase in human, livestock and crop diseases (e.g. maize lethal necrosis that can cause up to 80 per cent crop damage; wheat rusts; and Faba bean leaf and stem gall; bean chocolate spot; root rot; white mango scale), and increased incidences of pests. Prolonged droughts have resulted in loss of livestock assets, making restocking extremely difficult. Animals are also weakened by drought as they have less access to pasture, making them more susceptible to disease attacks. A recent study on the determinants and implied economic impacts of climate change adaptation strategies in the context of traditional pastoralism in the southern Ethiopian rangelands found the pastoralists' perception of climate change to be consistent with the recorded trends of increased temperature and declines in precipitation.

Table 5-5: Priority Resilience Options for Agriculture

Option	Remarks
Climate information, research and enhanced cooperation	Early priority as early capacity-building step; particularly important as provides information base for later decisions; need for sufficient data and research information in future periods.
Institutional strengthening and building	Early priority as early capacity-building step.
Meteorological and agro-meteorological Data	Early priority as early capacity-building step, particularly important as provides information base for later decisions.

Option	Remarks
Agricultural research and development	Early priority as early capacity-building step, particularly important because of time period for R&D and testing prior to scale-up (e.g. for developing new varieties).
Crop switching and new varieties	High existing adaptation deficit. Priority for early research given need to match emerging trends, and long time-scale for development programmes. Subject of existing programmes (the Ministry of Agriculture is the accountable institution) but there is still a need for further investment.
Conservation agriculture (zero or low tillage, cover crops, crop residue)	Significant opportunity for benefit, has co-benefits with mitigation and provides immediate benefits for resilience.
Soil and water conservation (SWC) structures (bunds, trees, grass strips, contour leveling, terraces, shade trees, waterways)	High existing adaptation deficit and thus provides immediate benefit.
Soil management	High existing adaptation deficit and thus provides immediate benefit.
Using forests for adaptation	Major programmatic gap identified in the investment and financial flow (IFF) analysis. Also provides an overlap with the CRGE Strategy. Improving conservation and management of remnant forests is a priority.
Resilience measures for forests	Major programmatic gap identified in IFF. Identified as stakeholder priority because of long lifetimes. Key for supporting the emissions reductions.
Payment for Ecosystem Services	Major programmatic gap identified in IFF.
Sugar plantations (irrigation)	Major programmatic gap identified in IFF.
Conservation and rehabilitation	Major programmatic gap identified in IFF.
Promoting biodiversity in agriculture	Major programmatic gap identified in IFF.

Source: FDRE 2011c.

The results of the study indicated that increased mobility and diversification of pastoral herd portfolios can have a highly significant positive impact on pastoral productivity. Several adaptation measures were identified in the southern Ethiopian rangelands study. These include; adjustment of pastoral practices like increased mobility (distance and frequency); adoption of drought-tolerant livestock species, especially browsers (goats, camels); use of hay (to supplement depleted grazing lands); diversification (livestock rearing, crop, and other alternative livelihoods); management of herd or stock (including conversion into other capital forms when imminent droughts are expected); and the banking of livestock assets.

The results and recommendations were affirmed by another study covering three representative districts of Gashamo (Somali Region), Awash Fentale (Afar Region), and Daasanach (Southern Region). This study found that “agro pastoralists with limited mobility were more vulnerable to climate change than nomadic pastoralists and that those who kept mainly cattle and sheep were more vulnerable than those rearing camels and goats, which are more resistant to drought” (GebreMichael and Kifle, 2009). Among the recommendations of the second was the documentation of local (indigenous) innovation in climate adaptation. Experience from other countries indicates that livestock and crop insurance, which is also recommended in Ethiopia’s Programme of Adaptation to Climate Change (EPACC), could cushion farmers from loses arising from climate related impacts (Deressa, Hassan and Ringler, 2008; FDRE, 2011b).

i. Crop and livestock agriculture

The adaptation options proposed in the NAPA for crop and livestock agriculture, and rural development are summarized in Table 5-6.

In addition, the Ministry of Agriculture Climate Change Adaptation Programme differentiates adaptation responses for the sufficient rainfall highlands from those of the rainfall deficient lowlands, and the pastoral areas as summarized in Table 5-7.

The Government has since 2003 developed and is implementing a Food Security Programme (FSP) that has several relevant adaptation and resilience building elements, and focuses on addressing vulnerability, which exists in different parts of the country (FDRE, 2009). The FSP has four components, namely:

ii. Resettlement programme — to enable chronically food insecure households attain food security through improved access to land.

iii. Productive Safety Net Programme (PSNP) — to provide transfers to the food insecure population in chronically food insecure districts in a way that prevents asset depletion at the household level and creates asset at the community level.

iv. Household Asset-Building Programme (HABP) — contributes to improved food security status of male and female members of food insecure households living in chronically food insecure *woredas*[18].

v. Complimentary Community Investment (CCI) — to create community assets and complement household investment through creating an enabling environment.

Table 5-6: Adaptation Options for Crop and Livestock Agriculture, and Rural Development

Crop agriculture and rural development	Livestock agriculture and rural development
i. Introduction of programmes/projects that promote improved farming practices, drought resistant and early maturing crop varieties; and supplying inputs that increase crop yield and productivity;	**i.** Promotion of improved/productive animal breeds to reduce herd size and the pressure on land;
ii. Improved land management, moisture & soil conservation & flood control method in both the high and lowland areas;	**ii.** Introduction/promotion of improved fodder crops and pasture management and the conservation and use of hay;
iii. Development of improved water use (water harvesting, small-scale irrigation, etc.) in drought prone areas to alleviate rain shortages that cause crop failure;	**iii.** Introduction of agro-forestry system to plant multipurpose trees that could be used to produce feed, conserve soil and produce fruits for human consumption;
iv. Improving farmers' knowledge of the proper use of weather information in carrying out agricultural activities to avoid risks of climate change; and	**iv.** Awareness creation on natural resource management, conservation and rational use; and environmental protection;
v. Introduction of off-farm activities to increase alternative household income sources.	**v.** Promotion and implementation of natural resource (soil, water, forestry, etc.) development and conservation programs and projects; and
	vi. Development of drinking water sources for human and animals in pastoral areas.

Source: NMSA, 2007.

18 *Woreda* **(also spelled** *wereda***) means districts (Amharic: ወረዳ?). They are the third-level administrative units of Ethiopia and are composed of a number of wards (***kebele***) or neighborhood associations.**

All the four FSP components contribute to climate change adaptation and resilience building, and hence the need to mobilize support for their full implementation. The scaling-up of best practices of the PSNP is also highly recommended.

Other studies have highlighted the need to ensure that investments in irrigation are equitable, poverty-reducing and have a sustainable impact in a variable climate (Tucker and Yirgu, 2010). Although small-scale irrigation is a policy priority in Ethiopia for rural poverty alleviation, growth, and climate adaptation; by the close of the last millennium, Ethiopia was irrigating fewer than 200,000 ha of the 3.7 million ha of irrigable farmland. Further, less than 5 per cent of the total renewable water resources are withdrawn annually (MoFED, 2006; NMSA, 2007; World Bank, 2006). The realization of this, has spurred the initiation of the Irrigation Development Program (IDP) to increase the irrigated area by 135 per cent of currently irrigated farmlands, within 15-year plan period of 2002-2016, There is, therefore considerable scope for expansion in the area of small-scale irrigation to reduce the high dependency of especially rural subsistence farmers on rain-fed agriculture and reduce their vulnerability to climate change (FAO, 2005). The planning and construction of medium-large scale multipurpose dams is highly recommended as it would help the country to withstand the impacts of climate change (both drought and flood).

Table 5-7:Proposed Adaptation Options for Agriculture

Area	Adaptation Options
Sufficient rainfall highlands	Efficient utilization of rainwater and promotion of irrigation where feasible to boost agricultural productivity; improvement of infrastructure; us of basic appropriate inputs; conservation of natural resources including vegetation, soil and water for continued agricultural productivity.
Rainfall deficient lowlands	Increasing the income of the community through enhancing food security, reducing the irregularity of production through irrigation and water harvesting, off-farm income opportunities, and where appropriate, voluntary resettlement to more productive areas; soil and water conservation, rehabilitation of natural resources, and livestock resource development.
Pastoral Areas	Livestock breeding and management (improving livestock quality); provision of clean water and feed; improvement of animal health services; feed production; development of market infrastructure and improved livestock marketing.

Source: NMSA, 2007.

A study on small-scale irrigation in the Ethiopian highlands, for example found that irrigation on average increased household annual income by 20 per cent, and in some cases up to 300 per cent.. This increase was associated with, among others, the cultivation of higher value crops, intensified production and reduced losses. There were numerous other benefits, among them, improved nutrition (Tucker and Yirgu, 2010).

i. Forestry Sector

Among the impacts on the forestry sector highlighted in the NAPA are the expansion of tropical dry forests and the disappearance of lower montane wet forests; loss of indigenous species and expansion of toxic weeds; increased prevalence of forest fires; increased incidences of diseases and pests; and the expansion of desertification. Considering the fact that the impact of climate change on the existing forest resources may be irreversible (e.g. death, species extinction, and loss of valuable ecosystem), a long list of adaptation options was proposed in the NAPA, among them:

i. Planting trees and establishing plantations;

ii. Adopting sustainable forest management practices;

iii. Environmental education and training;

iv. Maintain untouched forest lands and river banks as migration corridors;

v. Promoting conservation/ preservation; and

vi. Developing disaster resistant tree species.

In addition, there is a need for concerted capacity-building and public awareness to promote environmental conservation and management at all levels. In a related development, Ethiopia has already put in place mechanisms to benefit from the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative. This is expected to be particularly fruitful, as many of the activities under REDD+ also have adaptation co-benefits. Some of the mitigation initiatives with potential for resilience building in the sector include reforestation programmes and programmes to reduce demand for fuelwood (e.g. promotion of efficient cook stoves).

5.6.3. Health Sector

The Federal Government has put in place mechanisms to address the vulnerability of the Health Sector to climate change through the preparation of a comprehensive Adaptation Programme for the sector[19]. The Health Sector Adaptation Programme recognizes that:

i. Health is one of the sectors most affected by climate change.

ii. The initial health risks vary greatly, depending on where and how people live.

iii. Health effects will be more severe for the elderly and people with disabilities or pre-existing medical conditions; with children and the poor, especially women, being the most likely to bear the resulting disease burden. Other highly vulnerable groups are people living in arid, semi-arid, lowland and flood prone areas with high incidence of flooding.

The direct impacts of climate change on human health include; morbidity and mortality impacts of temperature extremes, vectors of infectious diseases, proliferation of non-vector-borne infectious diseases, air quality, floods, and storms. The indirect impacts will be felt through impacts on food supply and water resources, which are expected to translate into malnutrition, and increases in the severity of infectious diseases among vulnerable groups. It is worth noting that climate sensitive diseases like malaria, trypanosomiasis, onchocerciasis, schistosomiasis and leshmaniasis are already common in Ethiopia, a situation expected to worsen with climate change.

Among the factors that increase the vulnerability of the health sector to climatic change are poverty; lack of public awareness on climate sensitive diseases; harmful traditional practices; insufficient health services; and inadequate infrastructure and transportation facilities.

Table 5-8 summarizes some of the general impacts of climate change on human health. For Ethiopia, the major impacts of climate change in the health sector include the expansion of malaria to highland areas; the spread of Acute Water Borne Diarrhoea (AWD), resulting from flooding; infections associated with malnutrition; and non-communicable diseases (NMSA, 2001; NMSA, 2007; and FDRE 2011b). Climate change is expected to lead to reduced human resistance to disease attack, a situation likely to made worse by the projected higher temperatures and water stress. This is also expected to harm food security, compromising human nutrition supply, and leading to indirect impacts on human health.

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Table 5-8: Climate Change and its Impacts on Human Health

Change in Climate	Health Impact
Direct impact of extreme heat and cold	Cardiovascular disease deaths, skin cancer
Temperature effects on food and water borne diseases	Diarrhoeal Diseases
Temperature, rainfall effects on vector borne diseases	Malaria, Leshmaniasis, dengue Fever, RVF, Filariasis, RVF, Schistosomiasis
Risk of malnutrition via changing patterns of agricultural yield	Malnutrition
Effects of extreme rainfall and sea level rise on flooding	Fatal and non-fatal injuries and mental effects
Changes in air pollution aeroallergen Levels	Deaths and disease cases associated with air pollution, allergies

Sources: FDRE 2011f; Confalonieri and others, 2007.

To address the impact of climate change in the health sector, the Health Sector Adaptation Programme recommends five strategic objectives, namely:

i. Strengthening the health system and mainstreaming climate change adaptation to health care service delivery;

ii. Inter and intra collaboration, coordination and partnership;

iii. Implementation of the adaptation mechanism /activities;

iv. Advocacy, communication, social mobilization and education; and

v. Monitoring and evaluation of the strategy action plan.

The above strategic approaches are being implemented through several activities, among them:

i. Research, surveillance, and evidence based policy decisions: Undertake extensive reviews to identify and prioritize highly vulnerable areas, population segments and to identify climate-change sensitive diseases and adverse events in the country by adopting the standardized international methodologies and links with Metrological and GIS information systems.

ii. Inter-and intra-collaboration, coordination and partnerships (to put in place the optimum institutional structures for coordination in the sector, including the initiation of Climate Change Adaptation Programme Technical Working Groups (CCAP TWGs) with clear and applicable Terms of Reference at Federal and Regional levels.

iii. Health Systems Strengthening (HSS) including:

iv. Mainstreaming and prioritizing of climate sensitive diseases management.

v. Human capacity development/training (including in-service training of all health personnel and short course for teachers, students and scouts, police and fire brigade, community leaders, and CSOs, among others).

vi. Infrastructure development (design, strengthening and enforcement of building codes and standards; climate-proofing roads and other infrastructure; use of UV resistant materials in, among others, glasses, windows and shades, in existing and new facilities).

vii. Emergency Medical Services (including the development of an Emergency Medical Service plan to enable the country to deal with climate driven emergencies; climate proofing of construction to take into consideration the effect of extreme climate events and projected climate change; choice of building materials; roof water harvesting and storage).

viii. Climate Change Adaptation Programme Promotion and Communication including:

ix. The development of a communication strategy.

x. Systematic and planned evidence based advocacy for shaping policy and programming for results using different media at different levels.

xi. Social mobilization and community capacity enhancement through community conversations.

xii. Incorporate climate change adaptation and mitigation issues in institutions of higher learning as well as school curricula; Information, Education Communication/ Behavioural Change Communication (IE/BCC) interventions; Mass media.

xiii. Create experience-sharing platforms at different levels from communities to programmatic and scientific forums.

In addition, other studies have proposed the strengthening of research on climate change impacts and vulnerability in the health sector; and the utilization of climate and weather information in the planning and implementation of disease control programmes as possible adaptation options. It is worth noting that some of the (above) proposed interventions have been integrated in the "Environmental policy of Ethiopia: Natural resource and environment" and the "Health policy and program", in accordance with recommendations in the NAPA.

5.6.4. Mining Sector

The Ministry of Mines has suggested adaptation measures and strategies for salt and soda ash production from lakes which include:

i. Efficient utilization of water.

ii. Implementation of integrated licensing and administration between federal and regional institutions.

iii. Minimizing the loss of water through infiltration by using proper lining on production ponds.

iv. Ensuring proper and efficient storage and transportation of products to the intended places and for the intended purposes.

v. Ensure maintenance of the source of springs by planting salt tolerant species around Lake Afdera.

vi. Implementation of watershed management practices around the lakes to reduce siltation which aggravates evaporation water from the lakes.

The adaptation measures suggested for artisanal mining and communities living around geo-hazard prone areas include:

i. Planting trees;

ii. Development of water harvesting and irrigation schemes;

iii. Integrated water-shed management;

iv. Undertaking climate justified projects; and

v. Securing recent information on the current environmental condition of their area, education and social services.

5.6.5 Energy Sector

Ethiopia is mainly dependent on biomass and hydropower for energy supply. This makes the energy sector highly vulnerable since energy production and consumption patterns are influenced by climate change induced factors such as water shortages, temperature increase, variable rainfall, and extended drought. This is aggravated by the low adaptive capacity of the rural communities and low-income urban dwellers and by fossil fuel price fluctuations (kerosene). The following adaptation options are suggested to reduce the vulnerability of the sector to climate change by increasing its adaptive capacity.

i. Energy diversification by developing renewable energy;

ii. Dissemination of efficient energy technologies and avoiding obsolete energy technologies; and

iii. Building the capacity of both community and developers.

5.6.5.1. Energy Diversification by developing renewable energy

The country intends to diversify energy sources by exploiting its vast endowment of renewable energy resources including biomass, bio-fuel, biogas energy, hydropower, solar, wind and geothermal. The availability of these resources facilitates energy mixing capacity. This intervention will enhance the capacity of the sector to adapt climate change. In addition, the diversification will create job opportunities, provide decentralized modern energy production and utilization, improve the access to people living in remote areas to modern energy and resilience by switching from one energy system to another during power shortages due to extreme climate impacts and provide sustainable sources of energy.

5.6.5.2. Dissemination of efficient energy technologies and avoiding obsolete energy technologies

Traditional energy conversion systems (i.e. direct burning) are dominant in the country, leading to poor efficiency. This in turn leads to environmental deterioration such as depletion of forests, land degradation and extinction of biological species (biodiversity) and consequently aggravates vulnerability to climate change. The dissemination of efficient and modern energy technologies including solar PV and cookers, efficient stoves, biogas digesters, bio-fuel stoves etc., will increase the adaptive capacity of low-income communities.

5.6.5.3. Building the capacity of both community and developers.

Capacity-building by communities and developers to increase awareness of climate change, energy development and utilization will contribute immensely to improving the adaptive capacity of the population. There is a dire need to raise awareness in these areas.

5.6.6. Resilient Urban Development and Greening

The country is engaged in rapid and comprehensive development activities to transition towards sustainable and reliable growth and prosperity. This initiative will build cities that are clean, beautiful and green to provide a suitable living conditions for residents, attract investment and tourism, and achieve overall development in Ethiopia. This programme is included in the GTP and attention is now directed at reducing the impact of the expansion of industrial development, urban population growth and climate change on environmental and ecosystem services. The programme will also meet the rising service demand for green infrastructure in the urban and construction sector. The Green Infrastructure Components will include city parks, sports arenas, road dividers, roadsides and roundabouts, river and riverside areas, plazas and festival areas, lake and lakeside areas, watershed areas, urban agriculture development, woodlots and greenbelts and compounds and their surroundings.

5.7. Barriers to adaptation

It has been noted that most of the national climate change adaptation initiatives, action plans, policies, programmes and projects are based on the approach of building synergies. Implementation of the existing national initiatives is, therefore, core to the success of the country's climate change adaptation efforts. Potential barriers, however, exist and adjustments need to be made in order to optimize climate change adaptation gains from the ongoing national initiatives, and to ensure coordinated effort towards successful implementation of these initiatives, strategies and action plans.

Some of the major barriers to adaptation include:

- **i.** Inadequate current and reliable impact assessments for some of the sectors;
- **ii.** Inadequate overall coordination mechanisms both at the federal and regional levels;
- **iii.** Inadequate guidelines for the mainstreaming of climate change adaptation into the relevant policies and programmes;
- **iv.** Inadequacy of cross-sectoral links between ministries, departments and agencies;
- **v.** Inadequate linking elements such as cross-sectoral federal committees;
- **vi.** Low levels of capacity at different levels, including the absence of a centre or an institution for research and development (R&D) on climate change adaptation;
- **vii.** Inadequate outreach mechanisms on the environment to involve local communities;
- **viii.** Neglect of the long-term environmental impacts of short-term economic benefits;
- **ix.** Economic challenges, i.e., limited finance for environment and climate change;
- **x.** Low levels of awareness and public literacy; and
- **xi.** High levels of poverty.

For the country to realize the gains of climate change adaptation and related initiatives, the above barriers, among others, need to be addressed.

5.8. Conclusions and recommendations

This chapter presents evidence of climate related impacts and vulnerabilities in the major sectors of Ethiopia's economy. To meet the objective of Ethiopia's Second National Communication to the UNFCCC, selected national, sectoral and regional climate vulnerability and adaptation documents have been reviewed as examples and for the purpose of demonstrating the vulnerability of Ethiopia's economy to climate change. These were specifically the water resources; agriculture, forestry, land use and land use change (AFOLU); and health sectors. The AFOLU sector was viewed as particularly important not only because studies have indicated it as one of the most vulnerable to climate related impacts, but also because of its very significant contribution to the country's economic wellbeing. Any impacts on the sector, therefore, have the potential to translate into immediate and direct impacts on the economy and food security.

The health sector was viewed as important because it is an indicator of the health of the nation's workforce. The absence of any explicit discussion of other sectors, therefore, is not intended to downplay their vulnerabilities to climate change and related impacts, nor the need to address the relevant sector's vulnerabilities and adaptation needs. The country will, for example, not realize its vision of a being a CRGE middle income country by 2025 if the vulnerabilities of the energy sector are not addressed, because there cannot be any meaningful development unless the requisite energy needs are met.

In its synthesis report of the Fifth Assessment Report, the IPCC indicates that adaptation and mitigation responses are underpinned by common enabling factors that include "effective institutions and governance, innovation and investments in environmentally sound technologies and infrastructure, sustainable livelihoods, and behavioural and lifestyle choices". Ethiopia has, in this respect, put in place national policies and legislation, strategies, and guidelines with the potential to bring about integrated rural development. These are proven to be important tools to enable community resilience to both natural and man-made risks, and include:

- **i.** The Climate-Resilient Green Economy (CRGE) Strategy;
- **ii.** The 5-year Growth and Transformation Plans (GTPs); and 5-year sector development plans;
- **iii.** The Environmental Policy of Ethiopia;
- **iv.** Ethiopia's Programme of Adaptation to Climate Change;
- **v.** The Food Security Programme (FSP) and its components, namely, the Voluntary Resettlement Programme; the Productive Safety Net Programme (PSNP); the Household Asset Building Programme (HABP); and the Complimentary Community Investment (CCI);
- **vi.** The Water Resources Management Policy;
- **vii.** The National Policy on Biodiversity Conservation and Research;
- **viii.** The National Policy on Disaster Prevention and Preparedness;
- **ix.** The Conservation Strategy of Ethiopia;
- **x.** The Agriculture and Rural Development Policy and Strategy;
- **xi.** Agricultural Extension Packages;
- **xii.** Community-based Participatory Watershed Development (CPWD);
- **xiii.** The Disaster Prevention and Preparedness programme and its Early Warning System;
- **xiv.** Integrated Watershed Management; and
- **xv.** Participatory Forest Management.

The above policies, strategies, legislations and guidelines are complemented by several sectoral adaptation programmes and strategies and regional adaptation programmes. For any meaningful benefits to accrue from the different initiatives there is a need to enhance institutional coordination structures for both cross-ministerial and between national and sub-national authorities. The ideal overarching coordination could be done within the framework of the CRGE. The Federal Government is already taking action in this direction with the establishment of the Sectoral Reduction Mechanism (SRM) with the aim of enabling action on the priorities identified in the CRGE Strategies. The SRM is expected to direct sectors in their effort to reduce GHG emissions and vulnerability to climate change and compile a web-based CRGE Registry to monitor progress. The SRM is also mandated to increase public access to climate related information and initiate action to deliver the CRGE, by matching the identified needs with funding from a pool dubbed the CRGE Facility. Coupled with the new systems for monitoring, reporting and verifying impacts (MRV), and a proactive approach to knowledge management, the SRM represents a comprehensive mechanism to facilitate the country's response to climate change. The proposed coordination structures, however, still need to be enhanced for the effective implementation of the CRGE and other climate-adaptation relevant initiatives. This will ensure synthesis between the different initiatives and minimize duplication and reduce potential waste of resources. It will also ensure that every stakeholder across the different levels of governance, including non-state actors, have the space to play their rightful roles for the benefit of current and future generations.

Other relevant initiatives include the ongoing review of the Regular Education Curriculum to include environmental awareness and climate change and upgrading of climate change to a major category in the national statistical archiving system of the Central Statistical Agency (CSA) and the preparation of a Health sector CRGE Adaptation Strategy (in process),among others. The commitment of the Government of Ethiopia towards fighting climate change by putting in place appropriate regulatory instruments and funds from the meagre financial resource is clear. It is also to be noted that the Government has put in place a dynamic climate funding mechanism called the Climate Facility. The above initiatives demonstrate a determination to address climate change, and in particular address the vulnerability and enhance adaptation capacity of the different sectors to climate change and variability. The country will continue to bank on the support of its development partners to ensure the fast-tracking of these initiatives. With additional support, for example, the climate information system can be up-scaled to reach many more stakeholders than is currently the case.

The following is required to enhance the adaptation capacity of the nation:

- **i.** Improve on the current institutional structures for the coordination of adaptation to climate change and resilience building;
- **ii.** Fast-track the mainstreaming of climate change adaptation and resilience building in planning and development across the different sectors, with clear guidelines on deliverables, timelines and indicators;
- **iii.** Up-scale the relevant good practices in the Food Security Programme (FSP) and other initiatives;
- **iv.** Enhance capacity-building and public awareness not only on climate change, but also on the potential contributions to the climate change problem, and the opportunities available for stakeholder action at all levels;
- **v.** Reassess the country's climate change related technology needs with a view to up-scaling locally available technologies and addressing gaps identified;
- **vi.** Build the country's capacity to address climate change adaptation at all levels;and
- **vii.** Enhance the current mechanisms for climate finance mobilization and management.

CHAPTER SIX:

OTHER INFORMATION CONSIDERED RELEVANT FOR ETHIOPIA FOR IMPLEMENTATION OF THE CONVENTION

6.1. Introduction

Other information and activities considered relevant to the achievement of the objectives of the Convention include (i) technology transfer, (ii) research (iii) systematic observations, (iv) information on education, training, public awareness and capacity-building and (v) efforts to promote information sharing and the role of NGOs in the implementation of adaptation and mitigation activities with local communities. Also highlighted are constraints and gaps, and related financial technical and capacity needs taking into account Article 4, paragraph 7, and Article 4, paragraphs 3 and 5, of the Convention.

6.2. Technology Development and Transfer

The United Nations Framework Convention on Climate Change (UNFCCC) recognizes the importance of technology transfer as a key means to combat anthropogenic climate change. This is clearly articulated in Article 4, paragraph 5 of the Convention. Decision 4/CP.4 of the Fourth Conference of the Parties (COP 4) also urged Non-Annex I Parties to submit their priority technology needs for mitigation and adaptation.

Ethiopia, like most developing countries, is characterized by low levels of technological development. However there are various technologies available in the developed and in some developing countries which can be transferred to Ethiopia to mitigate greenhouse gas emissions. The priority sectors have been identified through various studies, including this SNC. These technologies need to be evaluated based on national criteria before being deployed locally. Any transferred technology needs to be well managed for national benefit, and also to ensure it does not displace locally available technology. Where relevant technological innovations are locally available, the priority should be to incubate and refine them with the goal of up-scaling or replicating them, as the case may be. There is also a need to build local technical capacity in the design and development of alternative technologies. This may include capacity in resource assessment, system design and development, and installation and service provision at national and regional levels.

The cost of technology research and innovation is high. There is therefore a need to ensure that the Ethiopia Climate Innovation Centre (ECIC) delivers on its mission; “to provide a holistic set of early-stage financing, business support and capacity building services to the Ethiopian private sector, including women and rural based entrepreneurs, and business owners who are working to develop, launch and grow innovative climate technology ventures that promote Ethiopia’s climate resilience and green growth”.[20]

6.3. Research and systematic observation

6.3.1. Climate & Hydrological Monitoring

Parties to the UNFCCC have committed to climate research and monitoring. The responsibility for monitoring climate in Ethiopia lies with the National Meteorological Agency (NMA) that currently manages a network of about 1,153 meteorological and climatological stations as shown in Figure 6-1. The NMA also maintains an upper air sounding station and primary data receiver systems for METEOSAT and National Oceanic and Atmospheric Administration (NOAA) satellites in Ethiopia.

20 The ECIC is funded by UKaid and the Norwegian Ministry of Foreign Affairs through the World Bank infoDev’s Climate Technology Program (CTP), and is part of a global network of CICs in the Caribbean, Ghana, India, Kenya, Morocco, South Africa, and Vietnam. See http://www.ethiopiacic.org/.

The Agency provides routine information on current climate conditions in the country, including monthly and seasonal climate outlooks. Through the NMA, Ethiopia actively participates in the World Weather Watch (WWW) programme of the World Meteorological Organization (WMO) by providing daily weather observations from 18 synoptic stations, which are disseminated worldwide for use in climate and weather monitoring and prediction. Ethiopia also participates in the activities of regional institutions like the African Center for Meteorological Applications and Development (ACMAD) and the IGAD Climate Prediction and Application Centre (ICPAC) in matters of climate research and prediction.

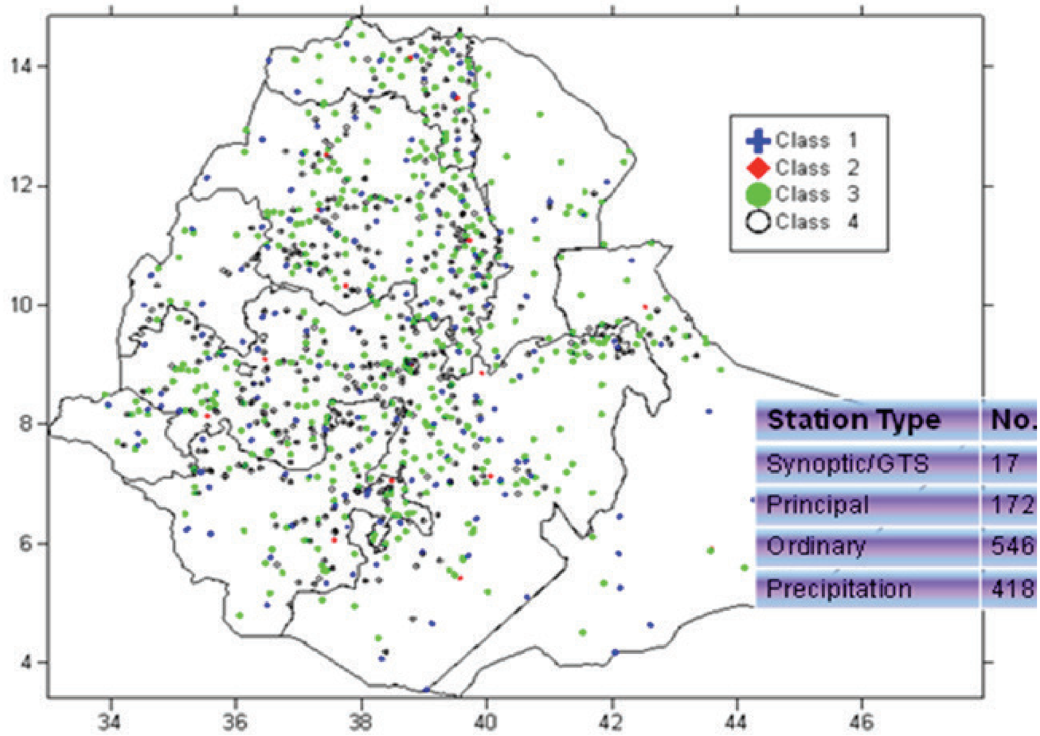
Hydrological monitoring in Ethiopia is carried out by the Hydrology Department of the Ministry of Water, Irrigation and Energy, which currently manages about 338 operational stream gauging stations distributed over the major river basins. The database on energy use and energy balance is maintained by the Ethiopian Rural Energy Promotion Centre (EREPC) of the Ministry of Water, Irrigation and Energy. The Central Statistical Authority (CSA) is responsible for the generation of statistical data related to the socio-economic conditions of the country. The CSA maintains a national data archiving system to support research and policy formulation and has recently upgraded climate change to a major category in the national statistical archiving system. It should be noted that the existing climatological and hydrological observation network in the country is not adequate. The management of the climatological, hydrological and other databases relevant to climate change also needs strengthening and financial support. The other data and information relevant for climatological monitoring and analysis include ecological, biodiversity, wildlife, land use and land use change. The management of the climatological, hydrological and other databases relevant to climate change also needs strengthening and financial support.

6.3.2. Climate Research

One of the mandates of the National Meteorological Agency (NMA) is to carry out research and studies in the field of Meteorology and the Agency implements this task through its Meteorological Research and Studies Department. Research related to climate change is also carried out by other institutions. So far, significant progress has been made in understanding the country's weather and climate. A number of research reports, publications and maps have been produced on several climate-related topics.

In addition, to address the issue of climate change research in the country, a team has been established under the Research and Studies Department of the NMA to coordinate and carry out research on climate change issues; and the country has also been participating in GEF-supported Climate Change Enabling Activities, since 1998. Long-term investment in research and development is critical in order to enhance capacity in research, development and innovation. This will play a major role in addressing challenges of climate change across key vulnerable sectors.

Figure 6-1: Distribution of Meteorological and Climatological Stations in Ethiopia



6.4. Public Education, training and awareness

Reporting of information on activities relating to climate change education, training and public awareness can serve as a basis for the periodic review of the progress made towards the implementation of Article 6 of the Convention. Ethiopia's citizens need to be made well aware about the commitments of the country under the Convention, about the impacts of climate change, adaptation and mitigation options as well as about measures that can be taken at the individual level to combat climate change.

Access to information is key to improved environmental protection and management and the promotion of an environmentally sustainable development programme. Additional activities to promote public awareness include publication of a monthly newsletter (*CRGE Highlights*) by the Ministry of Environment and Forest (MEF), broadcasting of environmental issues through radio and strengthening of environment clubs at schools and governmental and non-governmental institutions. A number of articles on climate change have been produced in the print media. There is also *Akirma*, a quarterly environmental magazine published and distributed by the Forum for Environment (an NGO), which highlights issues of climate change. Other relevant initiatives include climate change talks targeting environmental clubs established in secondary schools, teacher-training institutions and in environmental forums organized by GEOs and NGOs as well as radio-based distance education programmes under the Ministry of Education. Several technical and non-technical workshops and seminars on climate change have been organized at the national level. Climate change awareness among policymakers, professionals and the general public is crucial for the implementation of the country's obligations under UNFCCC. In this respect, press conferences and public releases on climate change have been conducted in collaboration with the mass media. The texts of the UNFCCC and the Kyoto

Protocol have been translated into Amharic, the official language of Ethiopia, in a summarized form, to ensure their accessibility in a language that is easily understood by most of citizens.

The Ministry of Education (MoE) has also made efforts to introduce environmental education in school curricula at various levels, from kindergarten to high school, including technical and vocational schools. Among recent relevant initiatives is the Green Award Program (GAP), initiated and implemented initially by the Forum for Environment[21] and most recently implemented by the MEF to recognize, acknowledge and celebrate initiatives and outstanding achievements by individuals and institutions in protecting and enhancing the environment.

However, a lot more needs to be done to enhance environmental and climate change education and awareness in Ethiopia. Graduate and undergraduate courses/programmes should be strengthened to include climate change related courses; awareness creation among policymakers, professionals and the public should be enhanced. The effort to raise awareness, to create educated and skilled experts to handle climate change issues should continue through various initiatives such as:

- **i.** Enhancing climate change information-sharing platforms;
- **ii.** Preparing and widely disseminating information and teaching materials as well as fact sheets on climate change; and
- **iii.** Using the mass media.

6.5. Roles and rresponsibilities of stakeholders

Civil society organizations have a role to play in climate change interventions and this is well recognized by the Government. Active participation of the public in climate change campaigns, access to climate change information and adoption of climate change interventions is encouraged from civil societies. Furthermore, the cross-cutting nature of the impacts of climate change requires collaboration and the establishment of strong partnerships between various stakeholders, including the private sector. There are many ways in which the private sector can contribute to climate change adaptation and mitigation. These include provision and mobilization of financial and other resources and technical assistance as well as capacity-building for climate change adaptation and mitigation. The private sector can also be engaged in low carbon development initiatives. The involvement of NGOs, faith and community based organizations is evident in awareness creation on climate change and also in the mobilization of financial and other resources for local communities for climate change adaptation and mitigation. Knowledge and information sharing can be expanded by involvement of the media.

However, decisions about interventions need to be informed by scientific knowledge. Research institutions, will therefore play an important role in generating relevant climate change scientific information accessible to the public and decision makers. The government encourages institutions of higher learning and research to undertake research to quantify the likely impacts of climate change and develop practical solutions for climate change interventions. In addition, support from development partners is essential for implementation of a climate change programme, and this has been clearly indicated in the Ethiopian Climate-Resilient Green Economy Strategy.

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21 The Forum for Environment (FfE) is a non-governmental and non-profit-making environmental communication and advocacy group established in 1997 to serve as a platform for advocacy and communication among people and institutions concerned about the Ethiopian environment. See http://ffe-ethiopia.org/.

6.6. International Obligations

Ethiopia has signed or ratified a number of multinational agreements having a bearing for sustainable development many of which are international conventions and protocols. These include;

i. Convention on Biological Diversity (CBD) (signed on 10 June 1992 and ratified on 5 April 1994);

ii. The United Nations Convention to Combat Desertification (UNCCD) in countries experiencing serious drought and/or desertification, particularly in Africa (signed on 15 October 1994 and ratified on 27June 1977).

iii. The United Nations Framework Convention on Climate Change (UNFCCC) (ratified on 31 May 1994) and the Kyoto Protocol (ratified on 21 February 2005).

iv. The Vienna Convention and Montreal Protocol on the Protection of the Ozone Layer (ratified on 11 Oct

v. 6Lober 1994).

vi. The Geneva Agreement on the Amendment to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal and the Basel Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and their Disposal (ratified on 8 October 2003).

vii. The Stockholm Convention on Persistent Organic Pollutants (signed on 17 May 2002 and ratified on January 9 2003).

viii. The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (ratified on January 9 2003).

The country also shares many transboundary water resources and rivers. For instance, Ethiopia is a member of Nile Basin Initiative (NBI) and participates together with the governments of Egypt and Sudan in the Eastern Nile Subsidiary Action Plan (ENSAP). Collaboration with other countries in Eastern Africa will promote dialogue and will effectively reduce potential conflicts within the region.

6.7. The Opportunities

Climate change interventions can bring economic opportunities. In respect to this fact, Ethiopia has embarked on implementing a climate-resilient green economy. The project is coordinated by the Ministry of Environment and Forest. The green economy strategy provides opportunities to promote sustainable development. Over 60 initiatives could be developed into bankable proposals through the CRGE implementation.

In order to achieve the Ethiopia’s vision of being a middle-income status by the year 2025, the GRGE is the main driver for sustainable economic transformation towards this goal. Its three main objectives are fostering economic development and growth, ensuring abatement and avoidance of future greenhouse gases, and improving resilience to climate change.

The CRGE objectives are in line with the current global trend to reduce GHG emissions, providing good possibilities of obtaining financial support for the projects that have low carbon co-benefits. Some of these initiatives are suitable for public-private partnership (PPP). The GRGE will further facilitate access to emerging environment financing mechanisms, such as NAMAs, the green climate fund, and the INDC.

It is important for Ethiopia to embark on human resource development in both administrative and technical skills instead of relying heavily on foreigners. It is encouraging to see that the government has started implementing some of the projects with some success. Among them are the National Clean Cook Stove Programme, the National Biogas Programme, and clean energy and wind energy investment project All these projects will reduce GHG emissions and the use of clean stoves will not only reduce fuel wood consumption but also reduce indoor air pollution. Programmes such as Sustainable Land Management have achieved tangible results, with about 50,000 households having adopted sustainable land management and about 77,000 ha of land having been rehabilitated. This has demonstrated that implementation of the green economy can achieve protection of natural resources. Such projects have attracted funding from local and international financial institutions and partners in development.

6.8. Financial, Technological and Capacity-Building Needs and Constraints

The Convention very well recognizes the need for the provision of financial and technical support, including technology transfer and capacity-building for developing country parties to fully participate in its implementation. As a developing-country party, prone to drought, desertification and other natural disasters, as a country which is land locked and as a country with a large proportion of arid and semi-arid land as well as a fragile mountainous ecosystem, Ethiopia needs special consideration in this respect, as stated in Articles 4.8 and 4.9 of the Convention. This section highlights Ethiopia's needs in the areas of financial, technical and capacity-building requirements to meet its commitments under the UNFCCC.

6.8.1. Finance Mobilization

Adequate resources, including finances, are required in order to undertake climate change adaptation and mitigation. Such funding sources should include adequate allocation for the exploration of appropriate off-setting opportunities in the various sectors. The CRGE has a finance mobilization strategy that addresses some climate change issues. A limited amount of finance will be generated locally. A national system will be built to help Ethiopia to build a carbon-free economy by 2025 and qualify for additional global environmental fund support. Some of the issues in the mobilization strategy include:

- **i.** Domestic revenue, particularly tax;
- **i.** Broadening the tax base;
- **ii.** Grants from partners in development;
- **iii.** Borrowing external and internal;
- **iv.** Non-tax revenue and development enterprises;
- **v.** Environment support funds from developing countries;
- **vi.** Climate Funds;
- **vii.** Climate change mitigation funds, technological and financial support, which will be available for mitigation work to be done in the developing countries;
- **viii.** Direct foreign investment; and
- **ix.** Remittances from foreign countries.

6.8.2. Data Collection and Monitoring

The data generating, gathering, archiving, and analyzing capability of the country is still inadequate and should be enhanced. Climatological, hydrological, ecological, biodiversity, wildlife, land use, and land cover monitoring are all essential in dealing with climate change.

Relevant institutions such as the Ministry of Environment and Forest, the Ministry of Agriculture, the Ministry of Water, Irrigation and Energy, the National Meteorological Agency and the Central Statistical Agency, need to be strengthened in terms of manpower training and facilities. Capacity-building in data collection and monitoring will improve the country's ability to produce timely and well-processed data to meet the requirements of different users, including climate change studies.

6.8.3. Training

Skilled human resource development to handle climate change issues is a priority for Ethiopia. There is a need to develop and implement a training programme which contains both short-term and long-term training in the following areas:

- **i.** Vulnerability and adaptation assessment;
- **ii.** Mitigation analysis;
- **iii.** Adaptation and mitigation costing;
- **iv.** GHG inventory;
- **v.** Mitigation and adaptation technology assessment, transfer and adoption;
- **vi.** Policy Analysis;
- **vii.** Programme and project development in climate change;
- **viii.** Formulation and implementation of adaptation and mitigation action plans;
- **ix.** Land use planning;
- **x.** Use of satellite remote sensing data, and of Geographic Information Systems,;
- **xi.** Statistical analysis techniques; and
- **xii.** Scenario development in different sectors.

6.8.4. Research and Studies

Long-term investment in research and development is required to enhance capacity in research, development and innovation to address the Ethiopian challenges of climate change across the key vulnerable sectors. A financing strategy for research and development should be created in partnership with all stakeholders. Continuous research on vulnerability and adaptation in agriculture, water resources, forestry, human health, and biodiversity including wildlife is needed in order to establish the level of the country's vulnerability to climate change and identify the best adaptation options and polices

6.8.5. Awareness Creation

Awareness among policymakers, professionals and the general public about climate change is crucial for the implementation of the UNFCCC. Therefore, financial support and capacity-building to develop and implement climate change awareness programmes/projects is necessary.

6.8.6. Capacity-Building

Capacity-building is a multidimensional activity. It involves individuals or organization at different levels. There is a need to have in place the necessary skilled manpower in all aspects of development and utilization to undertake development programmes and least-cost planning. Science and technology is an important pillar in present and future sustainable development of the country and it is important to create awareness of this, thereby building national capabilities not only in the science and technology for the optimal development and supply of energy resources, but also in all sectors of the economy.

6.8.7. Gender Mainstreaming

Understanding the structure and dynamics of gender relations in a specific community is central to a sustainable development. Gender mainstreaming is defined as "the process of assessing the implications for women and men of any planned action, including legislation, policies or programmes, in all areas and at all levels. It is a strategy for making women's as well as men's concerns and experiences to be an integral dimension of the design, implementation, monitoring and evaluation of the policies and programs in all political, economic and societal spheres so that women and men benefit equally and inequality is not perpetuated. The ultimate goal is to achieve gender equality".[22] The relative status of men and women, the interaction between gender and ethnicity, class and ethnicity, and questions of rights, control, ownership, power and voice all have a critical influence on the success and sustainability of every development intervention.

Capacity-building is required for gender analysis; development of accountability mechanisms; allocation of sufficient resources; explicit, coherent and sustained attention to gender equality. This should not just target "soft" areas for gender mainstreaming (such as health and education), but also supposedly "gender-neutral" areas, such as infrastructure development and economic policies; and strong political commitment and will are the basic principles to be followed at all levels.

6.8.8. Development of National Climate Change Network

The global nature of climate change requires exchange and sharing of data, information, and expertise at national, regional and international levels in order to enhance appropriate and effective responses. There is a wealth of data on climate change adaptation and mitigation programmes and activities. There are also "good practice" case studies from different parties to the UNFCCC which are available for sharing. The lessons learned and best practices could be accessed through cooperation and networking and could be developed and implemented through bilateral or multilateral frameworks. Many of the Ethiopian policies related to climate change make provision for international collaboration and networking. At national level, institutional linkages and communication should be strengthened by building a network of stakeholders through electronic means, such as the Internet. This will facilitate exchange of information and experience among experts. Consultation for project/programme preparation and implementation will also be enhanced if there is a fast and reliable means of communication..

22 The 1997 agreed conclusions of ECOSOC. See http://www.unwomen.org/en/how-we-work/un-system-coordination/gender-mainstreaming.

6.8.9. Strengthening of the National Focal Institutions

There is need to strengthen the national focal institutions for climate change in terms of manpower, training and facilities for better coordination of climate change issues in the country. Financial support and capacity-building to enhance the availability of relevant climate change materials for various audiences will be essential. Ethiopa's participation in climate change negotiation processes remains inadequate because of financial constraints. Since climate change is a complex and multi-disciplinary issue it is essential to have wider representation in the Conference of Parties (COP). Further, support is required for training in negotiation skills in the various aspects of the Convention.

6.9. Implementation strategy and monitoring

Environmental degradation is a key issue and, Ethiopia has already considered the environment in various investment plans and policy formulations. As noted, the Ministry of Environment and Forest is in charge of environmental issues in general. The Ministry has seen a number of environmental regulations and legislation formulated and approved. The policies and other environmental legal instruments include implementation issues like institutional coordination, evaluation and review provisions.

6.10. Other Policies and Institutions related to climate change

6.10.1. The Constitution

The Constitution of the Federal Democratic Republic of Ethiopia is the supreme law of the country. The national constitution sets the overall environment values to be preserved and protected in Ethiopia. Apart from the overall framework of national and regional development supported by the Constitution's diverse provisions, specific references to environmentally sustainable development are contained in Article 43 (the Right to Development) and Article 44 (Environmental Rights) in particular. The State's obligation is to protect and ensure Ethiopians' right to sustainable development in all the international agreements that it reaches. Article 24 of the constitution guarantees the right to leave in a clean and healthy environment and Article 92 requires that the design and implementation of programmes and projects shall not damage or destroy the environment. The constitution (Articles 24 and 92) provides that people are entitled to participation in development, to public consultations with respect to policies and projects affecting their community and to commensurate monetary or alternative means of compensation, including reallocation with adequate state assistance, if they are displaced or if their livelihoods are affected by Government programmes.

These articles are important because they provide the legal basis on which people can claim environmental rights. Furthermore, the constitution guarantees the right to gender equality and supports affirmative action. But in some cases traditional attitudes may impede implementation, especially in the rural areas.

6.10.2. Vision 2025

The Ethiopian Government's vision is to achieve middle-income status by the year 2025 in a climate-resilient green economy. The Government has put in place measures to guide the implementation of the process. The Climate-Resilient Green Economy (CRGE) initiative following a sectoral approach, has identified, and prioritized more than 60 initiatives. These could help the country achieve its development goals while limiting the 2030 GHG emissions to around today's 150 million tons CO_2e.The Growth and Transformation Plan (GTP), spanning three five year planning periods (2010 to 2015; 2015 to 2020 and 2020 to 2025), lays out the basis for building the CRGE. As set forth in the Growth and Transformation Plan (GTP), reaching this goal will require boosting agricultural productivity, strengthening the industrial base, and fostering export growth.

6.10.3. Ministry of Environment and Forest

MEF is responsible among other undertakings for spearheading environment-related initiatives. The task of environment protection requires multi-pronged activities that could play a significant role in improving the lives of many citizens. The ministry was established to effectively lead activities targeting at protecting the environment and boosting forest coverage at all levels of the government structure in collaboration with various stakeholders. The main objective of the ministry is to ensure that all matters pertaining to the country's social and economic development activities are carried out in a manner that will protect the welfare of human beings as well as sustainably protect, develop and utilize the resource bases on which they depend for survival.

6.10.4. Ethiopian Institute of Biodiversity Conservation (IBC)

The general objective of the Institute is to undertake conservation and promote the development and sustainable utilization of the country's biodiversity. The Institute has the powers and duties related to the conservation, research and utilization of biodiversity, including maintaining and developing international relations with bilateral and multilateral bodies having the potential to providing technical assistance for the support of biodiversity conservation and development.

6.10.5. National Meteorological Agency (NMA)

The National Meteorological Agency in was established in 1980. Its objectives are to investigate and study the weather and climatic conditions of Ethiopia; protect and control the atmospheric environment and discharge international obligations regarding meteorology. The agency collects meteorological data and is committed to exchange and disseminate information in accordance with international agreements, provide early warning on adverse weather conditions, disseminate advice and educational information through mass media and provide meteorological services.

6.10.6. The Ministry of Agriculture (MoA)

The Ministry of Agriculture (MoA) was established in 1907 during the reign of Emperor Menelik II. Its current mission is to create a modern and a highly productive agricultural system that uses advanced technology to reduce poverty. The ministry`s mandate includes: promotion of a market-oriented modern agricultural system; conservation, development and sustainable use of natural resources; building capacity on disaster prevention and preparedness; and empowering women and youth in development.

6.10.7. Ethiopia Wildlife Conservation Authority (EWCA)

The objectives of the Authority are: to ensure the proper protection, development, rational utilization and management of wildlife and forest resources; establish National Parks (NP) and Game Reserves; and involve local communities in the conservation of NPs.

6.10.8. Ministry of Transport

The Ministry of Transport is engaged in planning, construction, and maintenance and contract administration for road construction. Its objectives are:

i. Improve and expand the road network in an environmentally friendly way;

ii. Foster capacity-building of the staff in general, and of the Environmental Monitoring and Safety Branch in particular; and

iii. Engage in prolonged and sustainable cooperation with development partners and other relevant stakeholders.

The Environmental Monitoring and Safety Branch, is an integral part of the ministry, which is charged with environmental monitoring activities for both contract and own workforce projects of the ministry.

6.10.9. The Ethiopian Electric Power Corporation (EEPCO)

EEPCO is responsible for energy infrastructure development and the provision of hydroelectric power. Its Environmental Monitoring Unit produces the operational environmental manual, *Environmental Guidelines for the Power Sector,* which addresses environmental problems related to the power sector on the basis of the national environmental policy and legal framework. EEPCO has also produced the Environmental and Social Management Framework (ESMF), a document regarding potential impacts and mitigating measures to be taken in electric power generation projects.

6.10.10. Ministry of Water, Irrigation and Energy (MoWIE)

Established in 2010, the ministry has been making efforts to achieve the targets set in the Growth and Transformation Plan (GTP) for the water, irrigation, and energy sector. The major target areas are potable drinking water and sanitation programmes; irrigation and drainage development studies, design and construction; river basin and master plan studies; and energy development such as hydropower and alternative energies from solar, wind and biofuel as well. The ministry is also responsible for the generation and distribution of electric power.

6.10.11. Ministry of Industry

There are institutions under the Ministry of Industry that are responsible for each subsector, for example:

i. Leather Industry Development Institute in charge of leather industries

ii. Textile Industry Development Institute in charge of textile industries

iii. Chemical Industry Development Institute in charge of chemical industries

iv. Metal Industry Development Institute in charge of metal industries

v. Food, Beverage and Pharmaceutical Industry Development Institute in charge of food, beverage and pharmaceutical industries.

vi. Textile manufacturer's association

vii. Leather manufacturer's association

viii. Chemical manufacturers' association.

As demonstrated in CRGE's pillar four, the Government is determined to develop an industrial base using energy efficient and less polluting technologies and clean and renewable energy. To this end Environmental Impact Assessments have become a precondition for the establishment of new industries and environmental audits are required in already operational industrial plants.

6.10.12. Government Higher Learning Institutions (HLI)

Higher Learning Institutions (HLI) are engaged in activities relevant to environmental problems. Along with these programmes which are running in major universities, various research projects have been initiated under the respective graduate programmes. All these efforts demonstrate that environmental issues are gaining considerable attention among higher learning institutions, which will support the trained manpower requirements of the institutions dealing with environmental problems.

6.10.13. Ethiopian Cleaner Production Center (ECPC)

The Ethiopian Cleaner Production Centre (ECPC) was established in April 2000. In pursuit of its mandate, the ECPC gives priority to Small and Medium Enterprises (SMEs) and focuses on industrial sectors which have significant impact on economic growth and export earnings as well as showing good potential for cleaner production and the transfer of environmentally sound technologies. The centre ensures cleaner production projects that enable industries to conserve raw materials, eliminate toxic raw materials and to reduce toxicity of emissions and wastes in order to reduce the negative environmental impacts of products during production and their entire life cycle.

6.10.14. Non-State Actors

According to the registry of the Ministry of Justice as of 2007 a total of 2,305 organizations had acquired legal registration at federal level. Local NGOs accounted for 75 per cent (1,742) of the total, while there were 234 international NGOs, 149 national professional associations, and 125 civic advocacy groups. The number of national NGOs had risen significantly over its level five years previously. The number of regionally-based CSOs and NGOs has also increased greatly and this brings the total number of legally registered CSO/NGOs to above 3,000. Most of them are engaged in various fields including environmental protection and natural resource management.

6.11. Strengthening the National Focal Institutions

There is a need to strengthen the national focal institutions for climate change in terms of human resources, training and facilities for effective coordination of climate change affairs. The Financial, technological and capacity building support is needed for effective operationalization of the relevant focal institutions. This include; the UNFCCC National Focal Point; the CTCN National Designated Entity (NDE); the Education, Training and Public Awareness National Focal Point; and the Clean Development Mechanism (CDM) Designated National Authority (DNA). The others are, the National Implementing Entity (NIE) for the Adaptation Fund; the Green Climate Fund (GCF) National Designated Authority (NDA) and National Implementing Entities (NIEs); and the National Meteorological Agency (NMA); among others. Further, support is required for training in negotiating skills with specific reference to the aspects of the Convention and required wider representation in the negotiations. The Sectoral Reduction Mechanism (SRM), whose objective is enabling action on the priorities identified in the CRGE Strategies, also needs strengthening since most of the CRGE strategies have the potential to contribute to climate change adaptation and/or mitigation.

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ANNEX

Figure A 1: General Emission Trends and Low Carbon Pathway for Ethiopia (Gg)

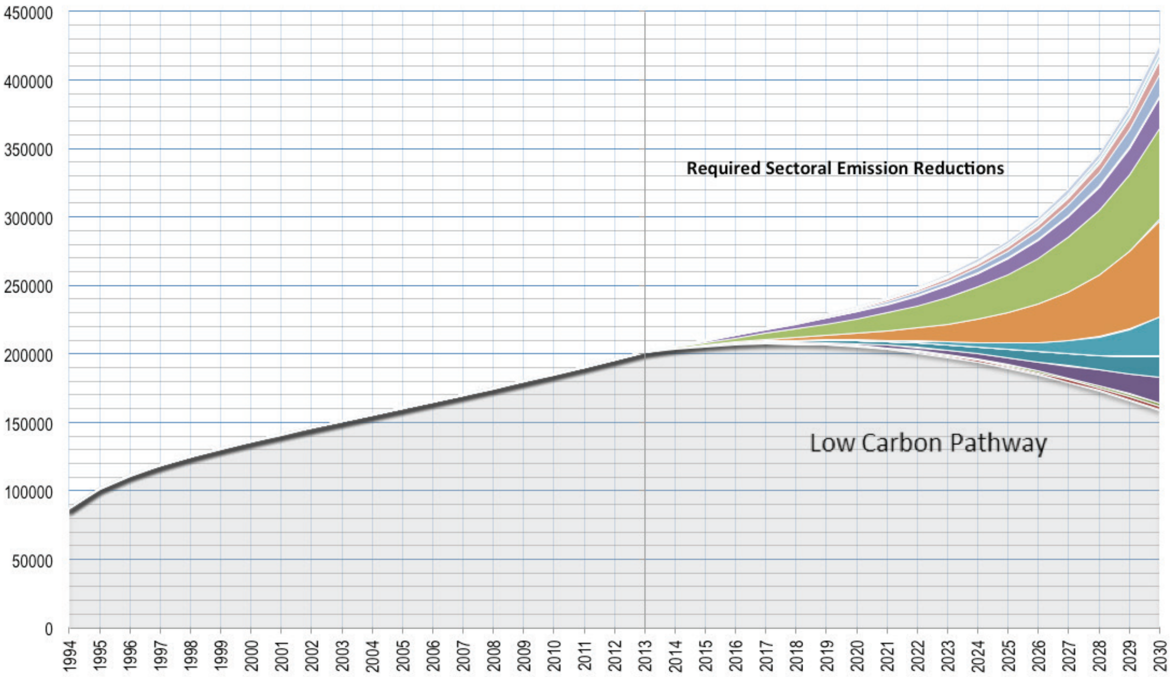

Figure A 2 Required Specific Sector Emission Reductions (Gg)