Federal Republic of Nigeria

Third National Communication (TNC) of the Federal Republic of Nigeria

under the

United Nations Framework Convention on Climate Change (UNFCCC)

March 2020

Federal Republic of Nigeria

Third National Communication (TNC) of the Federal Republic of Nigeria

under the

United Nations Framework Convention on Climate Change (UNFCCC)

Address: Block C, Mabushi, Abuja, Nigeria
Phone: +234 9 523 3611

Foreword

Nigeria has been actively engaged in international climate policy negotiations since it became a Party to the United Nations Framework Convention on Climate Change (UNFCCC) in 1994. It ratified the Kyoto Protocol in 2004 and the Paris Agreement in 2017. Nigeria submitted its First National Communication in 2003, Second National Communication in February 2014 to honour the reporting obligations and recently within the framework of the Paris Agreement its National Determined Contributions (NDC) commitments in November 2015.

Dr. Mohammad Mahmood Abubakar
Honourable Minister
Federal Ministry of Environment

The unwavering decision of the Federal Government of Nigeria to fully comply with commitments of the UNFCCC informed the submission of the country's Third National Communication (TNC).

Accordingly, during the preparation of the Third National Communication (TNC), the country adopted a participatory process at both national and local level. This included continuous and collaborative consultations, various technical studies, collaborative activities and workshops as part of the preparatory process. To enhance transparency, the TNC was also subjected to intensive peer review in accordance with a standard of best practice. This document looks critically at Nigeria's National Circumstances, National Greenhouse Gas Inventory, Mitigation Assessment, Vulnerability & Adaptation and Other Information relevant to the UNFCCC convention which covers the Agriculture, Forest and Land Use (AFOLU), Energy (Renewable & Non-renewable Energy), Human Health, Gender, Transportation, Mining & Quarrying, Education Sector and Waste Sectors, information on Mitigation actions and their effects, the Monitoring, Reporting and Verification System, Constraints and Gaps as well as Support received and needed.

The Federal Government of Nigeria, with its ambitious emission reduction target and a sustainable green economy, is poised towards implementing an all-inclusive national response to Climate change through emission reduction, adaptation and contribution to global discourse on optimal solutions to climate change response. Within this context, the Federal Republic of Nigeria will continue to engage actively and meaningfully in regional and international climate change negotiations, specifically the United Nations Convention on Climate Change (UNFCCC) negotiations in order to secure an equitable, inclusive and binding multilateral international agreement.

The Federal Ministry of Environment is delighted to submit its Third National Communication (TNC) to the United Nations Framework Convention on Climate Change, with the intent that the information contained therein will prove useful towards achieving the ultimate objectives of the Convention and Sustainable Development Goals (SDGs).

Dr. Muhammad Mahmood Abubakar
Honourable Minister of Environment

Acknowledgements

The Federal Government would like to express its profound appreciation for the valuable contributions of individuals, corporate entities, development partners, Ministries, Departments and Agencies of government and indeed, the critical stakeholders leading to the final production of the Third National Communication . We also acknowledged the management and staff of the Department of Climate Change, Federal Ministry of Environment who spearheaded the whole Third National Communication preparatory process, especially the Director, Dr. Yerima Peter Tarfa for his leadership and guidance.

Special thanks go to the UNDP Country Office, Nigeria as the Project Implementing Agency. We also appreciate the support of Triple E Consulting Firm and CLIMAGRIC LTD for the compilation, harmonization and quality assurance of the TNC.

The main contributors are listed below.

Project team

- National Coordinator – Dr Yerima Peter Tarfa
- Head, Technical Team – Iniobong Abiola-Awe
- Technical & Advisory Support – Muyiwa Odele, UNDP Nigeria
- Assistant Chief Scientific Officer – Chukwuemeka Okebugwu
- Principal Scientific Officer – Ann Ogechi Umar
- Senior Scientific Officer – Andrew Pindar

Project Management Team:

- Team Lead - Prof Felix Dayo
- Mitigation, Lead Consultant: Prof M. E. Aluko.
- Climate, Climatic Trends and Climate Change Scenarios; Lead Consultant: Dr. A. Gilau
- National Circumstances; Lead Consultant: Prof. Theophilus Odekunle
- Cross Cutting Issues; Lead Consultant: Bunmi Dipo Salami
- Actions to Adapt to Climate Change; Lead Consultant:
- GHG Emissions Inventory; Lead Consultant: Lawrence Ibhafidon

Main Institutional Contributors

- Department of Petroleum Resources
- Energy Commission of Nigeria
- Federal Ministry of agriculture & Rural Development
- Federal Ministry of Budget & National Planning
- Federal Ministry of Transport
- Federal Ministry of Water Resources
- Federal Ministry of Power, Works & Housing
- Federal Ministry of Education
- Federal Ministry of Environment

- Federal Ministry of Finance
- Federal Ministry of Foreign Affairs
- Federal Ministry of Health
- Federal Ministry of Justice
- Federal Ministry of Science & Technology
- Federal Ministry of Trade & Investment
- Federal Ministry of Women Affairs & Social Development
- National Space Research & Development Agency (NASDAR)
- National Bureau of Statistics
- National Emergency Management Agency (NEMA)
- National Planning Commission
- Nigerian National Petroleum Corporation
- Nigerian Maritime Administration & Safety Agency (NIMASA)
- Nigerian Meteorological Agency (NIMET)

Quality Assurance team / Peer Review

- Prof. Babajide Alo-Dept of Chemistry, University of Lagos
- Dr Samuel Adejuwon – CEO Digital Environmental Management Systems Nigeria
- Engr James Chidi Okeuhie
- Rasack Nayamuth – CLIMAGRIC LTD

Table of Contents

List of Tables

List of Figures

Abbreviations and acronyms

Acronym	Definition
AD	Activity Data
AFOLU	Agriculture, Forest and Other Land Use
AGO	Automotive Gas Oil
Al_2O_3	Alumina (aluminium oxide)
AP	Ammonia Production
ASB	Annual Statistical Bulletin
ATK	Aviation Turbine Kerosene
bbls	Billion barrels
BOF	Basic Oxygen Furnace
BRT	Lagos Bus Rapid Transit
BUR	Biennial Update Report
$CaCO_3$	Calcium Carbonate
CaO	Calcium Oxide
CBN	Central Bank of Nigeria
CBO	Community Based Organization
CCF	Carbon Content Factor
CH_4	Methane
CDM	Clean Development Mechanism
CEMAN	Cement Manufacturers of Nigeria
CEO	Chief Executive Officer
CER	Certified Emission Reduction
CFE	Carbon Fund for Europe
CFL	Compact Fluorescent Lamps
CGE	Consultative Group of Experts
CHP	Combined Heat and Power Generation
CMAN	Cement Manufacturers Association of Nigeria
CMS	Content Management System
CO	Carbon Monoxide
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
COP	Conference of Parties
CRAFF	Commercial, Residential and Agriculture/Forestry/Fish farms
CSO	Civil Society Organisation
TC	Tropical Continental
CV	Coefficient of variance
DARE	Nigeria Developmental Association for Renewable Energies
DCC	Department of Climate Change
DFID	Department For International Development – UK

Acronym	Definition
DNA	Designated National Authority
DPR	Department of Petroleum Resources
EA&O	Education, Awareness and Outreach
ECN	Energy Commission of Nigeria
ECO_2	Emission of CO_2
EEA	European Environment Agency
EF	Emission Factor
EMEP	European Monitoring and Evaluation Program
EPCL	Eleme Petrochemicals Company Limited
ER	Emission Reduction
EU	European Union
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistics
FBO	Faith Based Organization
FCCC	Framework Convention on Climate Change
Fe_2O_3	Iron oxide
FEC	Nigerian Federal Executive Council
FMARD	Federal Ministry of Agriculture and Rural Development
FMC	Federal Medical Centre
FME/FMEnv	Federal Ministry of Environment
FMJus	Federal Ministry of Justice
FMPWH	Federal Ministry of Power, Works and Housing
FMWR	Federal Ministry of Water Resources
FNC	First National Communication
FOLU	Forest and Other Land Use
FORMECU	Forestry Management, Evaluation and Coordination
FR	Fuel Requirement
g	gram (1 g = 0.001 kg)
GCF	Green Climate Fund
GDP	gross domestic product
GEF	Global Environment Facility
Gg	Gigagram
GHG	Greenhouse Gas
GL	Guidelines
GPG	Good Practice Guidance/Guidelines
GWP	Global Warming Potential
ha	Hectare
HFCs	Hydrofluorocarbons
HHK	Household Kerosene
HNO_3	Nitric acid

Acronym	Definition
HWP	Harvested Wood Product
IA	Institutional Arrangements
ICA	International Consultation and Analysis
ICCC	Inter-ministerial Committee on Climate Change
ICEED	International Centre for Energy Environment and Development
ICREEE	Inter-ministerial committee on renewable energy and energy efficiency
ICT	Information and Communications Technology
IEA	International Energy Agency
IMB	International Marine Bunkers
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IWMF	Integrated Waste Disposal & Management Facility
J	Joule
KCA	Key Category Analysis
kg	Kilogram
kg/hr	Kilogram per hour
$kg\ hr^{-1}$	Kilogram per hour
km	Kilometre
KRPC	Kaduna Refining and Petrochemical Company
LAMATA	Lagos Metropolitan Area Transport Authority
LAWMA	Lagos Waste Management Authority
LED	Light-Emitting Diode
LFG	Liquefied Flammable Gas
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LSMenv	Lagos State Ministry of Environment
LSWMO	Lagos State Waste Management Organisation
LULUCF	Land Use, Land-Use Change and Forestry
LUTH	University of Lagos Teaching Hospital
m	Metre
m^2	Square Metre
m^3	Cubic Metre
MAN	Manufacturer's Association of Nigeria
MDAs	Ministries, Departments and Agencies
MDGs	Millenium Development Goals
Mg	Megagram (1Mg = 1 t = 1000 kg)
mg	Milligram (1mg = 0.000001 kg = 0.001 g)
M J	Mega Joule (1000 000 J)
mm	Millimetre

Acronym	Definition
MMS	Manure Management System
MoU/MOU	Memorandum of Understanding
MRV	Measuring, Reporting and Verification
Mscm	Million standard cubic meters
MSW	Municipal Solid Waste
Mt	Megatonne (1 Mt = 1 Gg = 1000000 t = 1000000000 kg)
mt	Metric tonnes (1 mt = 1 t = 1000kg)
MW	Mega Watt
₦	Nigerian Naira
N_2O	Nitrous Oxide
NAMA	Nationally Appropriate Mitigation Action
NARSDA	National Airspace Research & Development Agency
NASPA	National Adaptation Strategy and Plan of Action
NASPA-CCN	National Adaptation Strategy and Plan of Action for Climate Change Nigeria
NBET	Nigerian Bulk Electricity Trading Company
NBS	National Bureau of Statistics
NC	National Communication
NCCPRS	National Climate Change Policy Response and Strategy
NCV	Net Calorific Value
NDC	Nationally Determined Contribution
NE	Not Estimated
NEEAP	National Renewable Energy Action Plan
NEMA	National Emergency Management Agency
NEP	National Energy Policy
NERC	National Electricity Regulatory Commission
NESI	Nigerian Electricity Supply Industry
NG	Natural Gas
NGL	Natural Gas Liquids
NGO	Non-Governmental Organizations
NH_3	Ammonia
NIAF	Nigeria Infrastructure Advisory Facility
NIE	NAMA Implementing Entity
NIMET	Nigeria Meteorological Agency
NIMS	National (GHG) Inventory Management System
NIR	National Inventory Report
NMVOC	Non-Methane Volatile Organic Compound
NNPC	Nigerian National Petroleum Corporation
NO_X	Nitrogen Oxides
NPC	National Population Commission
NREAP	National Renewable Energy Action Plan

Acronym	Definition
NREEEP	National Renewable Energy and Energy Efficiency Policy
NSHDP	National Strategic Health Development Plan
OGPP	Open Government Partnership Principles
OHF	Open Hearth Furnace
OPEC	Organization of Petroleum Exporting Countries
PC & EH	Pollution Control & Environmental Health
PDNA	Post Disaster Need Assessment
PFCs	Perfluorocarbons
PIC	Presidential Implementation Committee
PMS	Premium Motor Spirit
POA	Program of Activities
QA	Quality Assurance
QC	Quality Control
RE	Renewable energy
REDD	Reducing Emissions from Deforestation and Degradation
REMP	The Renewable Energy Master Plan
RFO	Residual Fuel Oil
RUWES	Rural Women Energy Security
R&D	Research and Development
SAR	Second Assessment Report
SCCU	Special Climate Change Unit
Scm	Standard cubic meter (1 Scm = 1 m^3)
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
SF_6	Sulphur hexafluoride
SHP	Small Hydro Power
SiO_2	Silica
SNC	Second National Communication
SO_2	Sulphur dioxide
t	Tonne (1t = 1Mg = 1000kg)
TACCC	Transparent, Accurate, Consistent, Complete and Comparable
TJ	Terajoule (1 trillion joule)
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and adaptation
WB	World Bank
WEC	World Economic Council
WRPC	Warri Refining and Petrochemical Company

Executive Summary

ES 1. National Circumstances

General Background

Articles 4.1 and 12.1 of the United Nations Framework Convention on Climate Change (UNFCCC), require each Party to the Convention to communicate periodically in National Communications (NCs), actions being taken to mitigate and adapt to climate change within its geographic boundaries.

Nigeria ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 29th August 1994 as a Non-Annex 1 Party. Thus, the country is obliged to report certain elements of information in accordance with Article 4, paragraph 1 of the Convention. These are:

i. *A national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties (COP);*
ii. *A general description of steps taken or envisaged by the Party to implement the Convention; and*
iii. *Any other information that the Party considers relevant to the achievement of the objective of the Convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emission trends.*

As a Party to the Convention, Nigeria has submitted its First and Second National Communications to the Conference of the Parties in 2003 and 2014 respectively. It has also submitted its first Biennial Update Report (BUR) in 2018, which contains updates of national Greenhouse Gas (GHG) inventories. This Third National Communication (TNC) is set to provide a robust update of climate actions in the country and, as a policy document, pave the way for the efficient implementation of the Convention.

Nigeria is located approximately between latitudes 3°15' to 13°30' N and longitudes 2°59' to 15°00' E, sharing boundaries with the Republic of Benin to the west, Niger to the north, Chad to the north-eastern corner and Cameroon to the east, as well as the Atlantic Ocean to the south. It has a land mass of about 923,768 km^2 and is the 14th largest country in Africa. The country runs a presidential system of governance, with three tiers - the Federal, State and Local Governments. It is divided into 36 States with a Federal Capital Territory (FCT). The States are further subdivided into 768 Local Government Areas (LGAs). However, with six Area Councils into which the FCT is divided, there are 774 officially recognized Local Authorities in all.

In general, the relief of the country is characterized by a gradual rise from the coastal plains to the northern savanna regions, generally reaching an elevation of 600 to 700 meters. The eastern and western sections of the coastal plain are separated by the Niger Delta, which extends over an area of about 10,000 square kilometres. The main drainage systems are the Niger-Benue, the Chad, and the coastal river systems. Some rivers flow into Lake Chad, others are tributaries to the Niger and Benue Rivers while quite a number flows directly into the Atlantic Ocean.

The main vegetation types found in the country from the coast inland are the salt- and fresh-water swamps, the lowland rainforests, guinea savanna, Sudan savanna, and Sahel savanna. This distribution of vegetation largely dovetails that of climate. However, the human factors remain critical in the distribution of the vegetation types. Everywhere, human impact on the vegetation is magnifying as population increases and the associated need for natural resources as well as the land under them grows.

Natural Resources Endowment of the Country

The country's land resource is huge and is useful mainly for socio-economic development, particularly agriculture and water resources, human settlement, transportation infrastructures, as well as exploitation of mineral resources. These uses have led to the conversion of more than 60% of the country's pristine land to anthropic derivatives.

Nigeria's coastal environment, which spans over 853 km, harbours more than 20% of the country's population in major centres such as Lagos, Port Harcourt and Benin City, and is the main source of the country's oil and gas resources. This environment faces a number of threats from the shipping and fishing industries, oil pollution and wastes from the hinterlands.

The Nigerian Economy

Nigeria's economy is the largest in Africa. It has a Gross Domestic Product (GDP) of more than US$500 billion and witnessed a steady growth of over 7% per annum between 2005 and 2014. The relatively stable growth was due to strong and stable macroeconomics, supported by the oil sector growth, as well as the inclusion of the previously neglected sectors such as the entertainment industry and ICT in the GDP computation.

Imports to the country are predominantly non-oil goods and services, including among other food and beverages, primary and processed industrial goods and capital goods. These goods and services come mainly from the European Union (EU), United States of America (USA), China, Japan, India, South Africa and Korea. EU and USA are the traditional suppliers.

Agriculture is a key element of the country's economy. It is the largest sector and employer of labour. It contributed 23% of the GDP in 2013 and employed approximately 70% of the country's labour force. On average, the agricultural sector contributed 40.3% of GDP between 1999 and 2011. It rose from 36.7% in 1999, peaked at 43.9% in 2000 and stabilized at 40.2 % in 2011. The significant growth in the sector in the early part of 2016 was attributed largely to increased output in crop production.

The human health status is a key factor of development of the country. With features such as low life expectancy at birth (49 years) and increasing vaccine-preventable diseases, Nigeria's health status indicators are among the worst worldwide. As at 2000, the country's overall health system performance was ranked 187th amongst 191 member States. Some of Nigeria's critical health status indicators include an estimated under five mortality rate of 128 per 1,000 live births; 61% of women with live birth seeking antenatal care from skilled health providers; and large movement of health professionals to Europe and America, among others.

The transportation sector in the country involves six key activities i.e. road, rail, pipelines, water and air Transport Services; and Post and Courier Services. Of these, road transport is the most significant. The country has the largest road network in West Africa, although many areas of the country are still poorly connected. The sea ports play major roles in the country's imports. The major ones are Apapa, Tin Can Island, Delta and Onne. The contribution from air transport is low but is growing. Rail services are almost non-functional resulting from neglect over the years. There are growing efforts to revamp the transport sector in response to the vastly increasing demand.

The country's Information and Communication sector comprises Telecommunications and Information Services; Publishing; Motion Picture, Sound Recording and Music Production; and Broadcasting. There are four major GSM operators in the country. These are MTN, GLO, Airtel and Etisalat. As at 2015, MTN had the largest market share with over 62 million subscribers. This is followed by Glo and Airtel, with over

31million subscribers each, and Etisalat, with 23 million subscribers. GSM usage has increased value creation tremendously within the Information and Communication sector. Its contribution to the total Nominal GDP since 2001 went up to 11.93% and 12.25% in the first quarters of 2015 and 2016 respectively.

The Art, Entertainment and Recreation sector comprises film, music, broadcasting and publishing activities. The country's film industry is the second largest in the world in terms of the number of films produced and is the second largest source of employment after agriculture. It stands out as one of the fastest growing sectors in the country.

Prior to the rebasing of the economy in 2014, the manufacturing sector comprised three key activities, namely, Oil Refining, Cement and Other Manufacturing. However, after rebasing, the 'Other Manufacturing' category was broken down into eleven different activities. Thus there are presently thirteen main activities in the country's Manufacturing sector: Oil Refining; Cement; Wood and Wood products, Food, Beverages and Tobacco; Textile, Apparel, and Footwear; Chemical and Pharmaceutical products; Pulp, Paper and Paper products; Non-metallic Products, Plastic and Rubber products; Basic Metal and Iron and Steel; Electrical and Electronic, Motor Vehicles and Assembly; and Other Manufacturing. The manufacturing outputs of the activities of the sector vary significantly. Between 2010 and 2013, the sector's output was dominated by Food, Beverages and Tobacco. This is followed by Textiles, Apparel and Footwear; Cement; and Oil Refining. The output contributions from Food, Beverages and Tobacco activities between 2010 and 2013 were ₦ 4,930,494.55 million (72.02%), ₦ 5,419,349.61 million (66.32%), ₦ 6,132,108.96 million (62.42%), and ₦ 3,814.50 billion (52.74%) respectively.

Nigeria is endowed with a large number of renewable and non-renewable energy resources in commercial quantities and in some of the best natural forms. The prominent renewable energy resources include sun, wind, hydro, biomass, and tidal wave while crude oil, coal, lignite, tar sands, natural gas, and nuclear elements constitute the major non-renewable energy resources. Despite these huge energy endowments, the country is energy deficient in terms of its energy consumption needs. Some of the key challenges in the sector are ageing plants, poor/lack of maintenance culture, inadequate funding and poor electricity pricing. Of all the renewable energy resources in Nigeria, solar appears to be the most promising. The country's s average annual solar radiation ranges between 25.2 $MJ/m^2/day$ in the north and 12.6 $MJ/m^2/day$ in the south. With an average sunshine of 6.5 hours per day, the available annual solar energy is about 27 times the country's total fossil fuel resources. Hydro Electric Power (HEP) remains the dominant commercial renewable energy in Nigeria. The country's HEP potential is 14,750 MW, but only 1,930 MW (14 %) was generated at Kanji, Shiroro, and Jebba, which represents about 30 % of the gross installed grid-connected generation capacity in Nigeria in 2005.

The Nigeria's Mining & Quarrying sector is made up of four major activities: Crude Oil and Natural Gas, Coal Mining, Metal ore and Quarrying of other minerals. The country is endowed with a large number of mineral deposits such as crude oil, gas, gold, barite, bentonite, limestone, coal, bitumen, tantalite, lead, zinc, tin and columbite. However, only seven of these have been identified by the Ministry of Mines and Steel Development (MMSD as priority minerals for development, due to the commerciality of the estimated deposits and their capacity to accelerate overall economic development through industrial linkages. These are Coal, Bitumen, Limestone, Iron Ore, Barites, Gold and Lead/Zinc. Except for the crude oil and gas, most of the available mineral resources are minimally exploited, hence their limited contributions to the economy. The Nigeria's Oil and Gas sector constitutes the single largest source of Government revenues and total export earnings. In the past 30 years, it has accounted for about 90% of the country's total foreign exchange earnings. However, the sector's contributions in these respects have being on decline since 2011.

The Nigerian education system comprises three tiers: basic education, post-basic/senior secondary education, and tertiary education. The post-basic education is designed to prepare students for entry into the tertiary level of education or to groom them to join the labour market. The basic function of the tertiary sector is to provide opportunities for undergraduate, graduate, and vocational and technical education. Although the number of education institutions increased significantly in recent years as governments established more institutions, the country is far from meeting the demand for tertiary education. For instance, in 2013, the combined capacity of the Nigerian tertiary institutions to admit students was estimated to be less than 400,000, whereas 1.7 million candidates registered for its centralized tertiary admission examinations. Although the successive Governments in Nigeria, during the period under consideration, provided more education facilities to keep pace with the country's exponential population increases. The available statistics indicated that the country's education sector was among the worst in the world. The obvious challenges facing the sector were: shortage of teachers at all levels of education; poor quality of teaching personnel at the nation's basic education level, primary and secondary schools; the non-enrolment in school of a significant proportion of school-aged children; gender disparity at all levels of education; poor funding of education; and severe cuts in public spending as a result of the economic recession. Notwithstanding the challenges and the associated poor statistics of Nigeria's education sector outlined above, the country emerged as Africa's leading origin for international students.

Demography

Nigeria's population has grown phenomenally, especially since the 1960s. By 2000, the population stood at 122.9 million. It rose to 140.43 million in 2006, with a national growth rate estimated of 3.2 % per annum. By projection this figure reached 188.59 million in 2016 and remained the highest in Africa. In 2015, Nigeria's population was the seventh largest in the world and its growth rate was also one of the fastest. The two main features of this growth are the young age structure with more than two-fifths of the population (42.8%) falling below 15 years and the persistently high fertility rate of 5.7 children per woman.

Environmental Challenges in Nigeria

The country faces a wide range of environmental challenges. Some of the specific phenomena include Climate Change, which is negatively affecting every sector of the country's economy, particularly agriculture and water resources. Other challenges are deforestation and de-vegetation, causing biodiversity loss and land degradation; floods, drought and desertification which are degrading the environment especially in the semi-arid areas of the country; environmental pollution encompassing air, water, land and noise; waste generation; mineral excavation and the accompanying environmental degradation as well as limited access to safe water and poor sanitation.

Socio-economic Challenges

The country also faces a wide range of socio-economic challenges. One of these is inflation, which has remained in double digits for many years. The other prominent challenges are economic recession with its associated growing youth unemployment, high cost of living and corruption, which is creating a clog in the wheels of the nation's development.

Socio-Political-Religious Challenges

Nigeria is also confronted with a number of social and religious conflicts, prominent among which are the Boko Haram insurgency, Niger Delta militancy, kidnapping, farmers/herders' clashes, agitation for self-determination and ethnicity challenges. All of these have led to colossal loss of lives and properties. They have also generated wider divides, especially along religious and ethnic lines. This situation is unlike what is happening in many other countries such as the USA where diversity in ethnicity and languages have been exploited to foster strength and unity.

ES 2. Greenhouse Gas Inventory

Introduction

In accordance with Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), which state that non-Annex I Parties should include information on a national inventory of anthropogenic emissions by source and absorption by sinks of all GHGs not controlled by the Montreal Protocol, within the limits of their possibilities, using in its preparation the comparable methodologies promoted and approved by the Conference of Parties, Nigeria has prepared and submitted three GHG inventories, two for the years 1994 and 2000 in its Initial and Second National Communications and a third one in its First Biennial Report, submitted in 2018.

The Federal Republic of Nigeria has prepared its fourth national inventory of GHGs within the framework of the preparation of its TNC, in accordance with the UNFCCC guidelines for the preparation of national communications from non-Annex I Parties (Decision 17/CP.8).

Institutional arrangements

The Department of Climate Change (DCC) of the Federal Ministry of Environment has the responsibility of implementing Climate Change activities in the country. DCC is one of six technical departments of Nigeria's Federal Ministry of Environment. It has four Divisions, each responsible for a major thematic area of climate change. One of these Divisions is the GHG Division that has the responsibility of producing the GHG inventory for reporting to the Convention.

The compilation and production of a national GHG inventory requires a successful implementation of well-defined steps. Nigeria lacked a full-fledged GHG Inventory Management System (IMS) and adequate institutional arrangements (IA) when producing the inventory for the TNC. This is because inventories in previous national communications were prepared on an ad-hoc basis with the support of international consultants. Nonetheless, as per existing IMS and IA, the country implemented the steps for the compilation of this GHG inventory and intends to further improve in future compilations.

Coverage

This GHG inventory covers the whole territory of the Federal Republic of Nigeria and estimates are computed at the national scale. It includes estimates from the four IPCC sectors, Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry and Other Land Use (AFOLU) and Waste. However, the categories and subcategories have not been exhausted due to lack of activity data in some cases. The GHG inventory addressed emissions of the direct GHGs carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Additionally, estimates of the GHG precursors NO_X, CO, NMVOCs, and SO_2 have been compiled whenever activity data were available.

Estimates have been made for the year 2016. In line with the recommendation to provide a trend of estimates, the time series 2000 to 2016 have been adopted. Furthermore, for the sake of consistency for reporting, estimates for the years 2000 to 2015 have been recalculated whenever required using the same methodology but to reflect improved activity data or emission factors as appropriate.

Global Warming Potentials adopted for uniformizing emissions of all GHGs in CO_2 equivalent are those from the IPCC Second Assessment Report. The GWPs used in this report for the direct GHGs are 1 for CO_2, 21 for CH_4 and 310 for N_2O.

Methods

Estimates of GHG emissions have been compiled using the IPCC 2006 Guidelines for National GHG Inventories (IPCC 2007) and the IPCC Good Practice guidance and Uncertainty Management (IPCC 2000) to ensure that the estimates are Transparent, Accurate, Complete, Consistent and Comparable (TACCC). Selection of the tier level for all sectors was based on availability of relevant activity data and national emission factors. In all cases except for the Land category where national stock factors were developed, the Tier 1 level was adopted with IPCC default emission factors (EFs).

Completeness

Results of the GHG inventory of the second national communication (SNC), availability of resources, existing capacity, availability of activity data and national emission factors dictated the choice of source categories to be included for compilation. A prioritization exercise was conducted, and the highest emitting source categories were privileged.

Data Sources

The activity data used for this inventory were sourced from a combination of national and international institutions. During data collection, priority was given to data generated within the country. However, in cases where the required data was not available in the country, data from international databases of organizations such as IEA, United Nations, World Bank, USGS and FAO were used.

QA/QC procedures

Given the lack of capacity, insufficient institutional arrangements and inexistence of a fully-fledged IMS, QA/QC mostly rested with the consultants allocated the contract for preparing the inventory. Due to the importance of having an appropriate QA/QC system, DCC started the development and implementation of such a system in line with the 2006 IPCC Guidelines for National GHG inventories.

DCC resorted to the collaboration of the UNFCCC to perform a full QA of the final inventory and the draft chapter of the TNC thereon with the support of the Global Support Programme of UNDP and the UN Environment, assisted by the international expert offering capacity building to Nigeria. Recommendations made by the UNFCCC/GSP team were discussed and improvements brought in the GHG inventory compilation where possible. The remaining improvements will be done during the preparation of future inventories.

Uncertainty Assessment

A Tier 1 uncertainty analysis of the aggregated figures as required by the 2006 IPCC Guidelines, Vol. 1 (IPCC, 2006) was performed. Based on the quality of the data and the default EFs used, uncertainty levels within the range recommended by the IPCC Guidelines were assigned for the two parameters and the combined uncertainty calculated using the IPCC 2006 software. Lower uncertainties were assigned to AD obtained from national measurements made and recorded, higher values for interpolated and extrapolated AD and the highest ones when the AD is subject to expert knowledge. Since default EFs have been used in the compilation of the inventory, the mid value recommended in the IPCC Guidelines were adopted for calculating uncertainties. In cases where IPCC recommended a particular methodology, the uncertainty level was derived according to the proposed procedure and used in the uncertainty analysis. Uncertainties in total emissions, including emissions and removals from the Land sector, for the period 2000 to 2016 varied from 9.17% to 21.16% while the trend assessment when adding one successive year on the base year 2000 for the years 2001 to 2016 ranged from 11.95% to 14.52%.

National Emissions

Total net national emissions (Table ES 1) for the three direct GHGs, including removals, amounted to 609,783.8 Gg CO_2-eq from the four IPCC sectors. AFOLU headed the sectors with 366,733.9 Gg CO_2-eq (60.1%) of total aggregated emissions followed by Energy with 206,452 Gg CO_2-eq (33.9%), Waste 23,330.3 Gg CO_2-eq (3.8%) and the remaining 13,267.1 Gg CO_2-eq (2.2%) from IPPU. CO_2 was responsible for 72.9% of the emissions, CH_4 for 21.2% and N_2O for 5.8%.

Table ES 1 - National emissions for the year 2016

Categories	Net CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total (Gg CO_2-eq)	NO_X (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
Total National Emissions and Removals	444,668.7	6,170.4	114.6	609,783.8	756.1	13,875.9	2,107.0	121.4
1 - Energy	124,021.6	3,762.3	11.0	206,452.4	473.6	10,268.0	1,638.4	64.5
2 - IPPU	13,254.9	0.6	0.0	13,267.1	0.0	0.0	0.9	0.0
3 - AFOLU	307,320.4	1,640.0	80.6	366,733.9	0.2	5.9	0.0	0.0
4 - Waste	71.8	767.6	23.0	23,330.3	59.0	835.9	0.0	9.8
5 - Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Memo Items (5)								
1.A.3.a.i - International Aviation (International Bunkers) (1)	1,241.3	0.0	0.0		5.0	0.4	0.2	0.4
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	70.0	0.0	0.0		1.8	0.2	0.1	0.4

On an individual gas basis, AFOLU was the major contributor for CO_2 and N_2O with 69.1% and 70.3% respectively while the Energy sector recorded highest CH_4 emission with 61.0%. Energy emitted 62.6% NO_X, 74% CO and 53.2% SO_2. 77.8% of NMVOCs also came from the Energy sector.

Emissions intensity

Per capita emissions of GHG varied between 3.26 and 3.59 tonnes CO_2-eq during the period 2000 to 2016 with a tendency for a marginal decrease (Figure ES 1). On the other hand, the GDP emissions index decreased steadily from 100 in the year 2000 to 46.7 in 2016 with a sharp drop in 2004 (Figure ES 1).

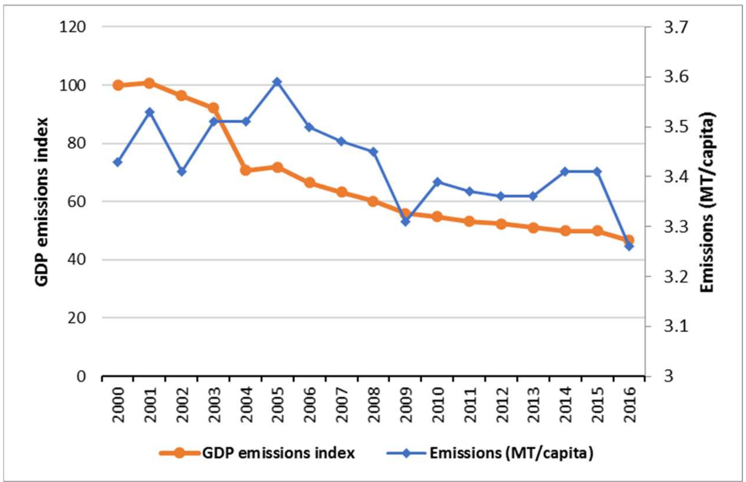


Figure ES 1 - GHG emissions and GDP emissions index

Key Category Analysis

The Tier 1 level and trend assessments were conducted to identify key categories. For the level assessment for 2016, there are 15 key categories with Forest Land Remaining Forest Land identified as the most significant of the key categories (contributing about 50.39%) of national emissions in 2016. The remaining 14 key categories in descending order of importance in 2016 were Energy Industries-Gaseous fuels, Oil, Road Transportation, Enteric Fermentation, Natural gas, Direct N_2O Emissions from managed soils, Other sectors-liquid fuels, Wastewater treatment and discharge (CH_4), Other sectors-Biomass, Manufacturing Industries and Construction, Cement Production, Wastewater treatment and discharge (N_2O), Rice cultivations and Iron and Steel Production. When considering the trend assessment, the sequence changes somewhat, and the number of categories decreased from 15 to 12. As well, the importance becomes more diluted with the category Forestland Remaining Forestland being still the main key category but with only 29.31% contribution. The next two categories of importance are Energy Industries – Gaseous Fuels with 21.86% and the Oil industry with 17.16%. The remaining key categories contributed between 7.62% and 0.75%.

Constraints and Gaps

Several constraints and gaps were encountered during the preparation of this inventory, especially during data collection and estimation of emissions for the various sectors. These gaps and constraints consisted repeatedly of lack of reliable good quality activity data, inexistence of country specific emission factors, inadequate IAs and the lack of a fully operational IMS to cater for the steps of compilation. Given these circumstances, international databases were extensively sources of activity data, default IPCC EFs were adopted while efforts were deployed to develop the inventory management system for the sustainable compilation of inventories in the future. In addition to these, there is still need for substantial capacity building of national experts.

National GHG Inventory Improvement Plan

The salient features prioritized for improvement when compiling the next GHG inventory are:

- DCC should implement a fully-fledged IMS to sustainably prepare GHG inventories to report to and implement the Convention.
- The present IA for compiling the GHG inventory should be further strengthened to smoothly implement the IMS.
- The NBS in close collaboration with the DCC must develop a network for collecting appropriate activity data for the compilation of good quality future inventories.
- A functional QA/QC system must be developed in the shortest timeframe to guarantee the quality of future inventories.
- Officers of the DCC and members of the sectoral working groups should be imparted adequate capacity to deliver to the required standards.
- Nigeria must develop national emission factors, namely for the key categories, to enable adoption of higher Tier methods.
- The need to develop land use cover and change maps and overlay them with the climate and soil maps is most urgent to refine estimates in the Forestry and Other Land Use (FOLU) category.
- Biomass stocks have to be assessed for use in the FOLU emissions assessment.
- Information on technologies used in manufacturing processes and in other emitting activity areas must be collected along with the appropriate activity data.

Energy sector

Total aggregated emissions from the Energy sector increased from 116,057.44 Gg CO_2-eq in the year 2000 to 206,452.45 Gg CO_2-eq in 2016. Of the two main sources, Fuel Combustion Activities recorded an increase of 206% compared to a decline of 1% for Fugitive emissions during the period 2000 to 2016. Fuel Combustion Activities contributed 65.6% of total emissions of the Energy sector in 2016 with the remaining 34.4% originating from fugitive processes.

In 2016, within the Fuel Combustion sub-sector, Energy Industries was the highest contributor with 40.7% of total emissions followed by Transport (28.4%), Other Sectors (22.2%) and Manufacturing Industries & Construction (8.7%). During the period 2000 to 2016, emissions increased by 539% for Energy Industries, 315% for Manufacturing Industries and Construction, 150% for Transport and 73% for Other Sectors.

Carbon dioxide was the dominant gas in the energy sector with some 60% of total emissions in 2016. In the same year, CH_4 contributed (38%) and N_2O (2%). These emissions exclude CO_2 from Biomass burning for energy production. CO_2 emissions from Biomass are accounted for under the AFOLU sector and reported also under Memo Items for informative purposes. In general, there was a steady increase in CO_2 emissions from 37,253.0 Gg in the year 2000, to an apex level of 133,225.1 Gg in 2015 which then declined to 124,021.6 Gg in 2016. The increase is of the order of 233% from the year 2000 to 2016. CH_4 emissions followed the same pattern as CO_2 over the same time period, from 3653.8 Gg or 76,352.7 Gg CO_2-eq in 2000 to 3762.3 Gg or 79,007.3 Gg CO_2-eq in 2016 which represented a 1.3% increase in emissions. Likewise, N_2O emissions increased by 40%, from 2,451.7 Gg CO_2-eq in 2000 to 3,423.6 Gg CO_2-eq in 2016.

Emissions of all three precursors increased during the period 2000 to 2016, NO_X by 76% from 243.7 Gg to 429.0 Gg, CO by 34% from 6,870.4 Gg to 9,207.8 Gg (34%) and NMVOCs by 27% from 1,370.9 Gg to 1,734.9 Gg. SO_2 also increased, from 38.4 Gg to 59.4 Gg representing 55% more emissions in 2016 compared to the year 2000.

Memo items

Emissions from fuels used for international aviation and international marine bunkers (IMB) are excluded from the nation's totals and reported as memo items. Emissions of CO_2, CH_4 and N_2O from the international bunkers (marine and aviation bunkers) increased from 501.67 Gg CO_2-eq in 2000 to 1,322.95 Gg CO_2-eq in 2016. In the year 2000, IMB contributed 85.9% of total emissions from International Bunkers, while the balance came from international aviation bunkers. On the other hand, in the year 2016, international aviation contributed 94.7% of the emissions of international bunkering with that of IMB being only 5.3% for that year.

In order to avoid double counting, CO_2 emissions from biomass combustion for energy production are also reported under the memo items and not included in the Energy sector emissions. They are estimated and reported in the AFOLU sector as part of emissions from the Forest land sub-category (3.B.1.a). This includes CO_2 emissions from transformation of fuel wood to charcoal in energy industries, as well as CO_2 emissions from the use of biomass for energy purposes in the residential and commercial/institutional sectors. In the year 2000, CO_2 emissions from this activity amounted to 202,167 Gg CO_2, while in 2016, the total CO_2 emission from this activity was 256,091 Gg CO_2.

Industrial Processes and Product Use (IPPU)

The IPPU sector comprises GHG emitted as by-products during industrial processes for the manufacture of new products. The categories covered are Mineral Industry (Cement Production), Chemical Industry (Ammonia Production) and Metal Industry (Iron and Steel Production).

Total aggregated emissions for the IPPU sector ranged between 2,510.185 Gg CO_2-eq and 13,267.142 Gg CO_2-eq during the period 2000 to 2016 with an annual average of 7,844.193 Gg CO_2-eq. In 2016, the cement industry was responsible for 53.4% of the aggregated emissions followed by the iron and steel industry with 46.5%. The contribution of the ammonia industry was marginal.

Agriculture, Forestry and Other Land Use (AFOLU)

Activities in the AFOLU sector are among the main contributors to emission of GHGs in Nigeria which makes it a key category. For this inventory, livestock (3.A), and Aggregated sources and non-CO_2 emissions from land (3.C) subcategories were fully covered. For land (3.B), emission from changes within forestland only was estimated. Under Other (3.D) removals for harvested wood products (HWP) only was estimated.

Total emissions were 371,022 Gg CO_2-eq in 2016 with a removal of 4,288 Gg CO_2-eq under HWP to give net emissions of 366,734 Gg CO_2-eq which is the highest emissions for the entire period under consideration. Compared to the year 2000 emissions, 295,444 Gg CO_2-eq, those of 2016 represented an increase of about 25.6%. The highest emitter of the AFOLU sector is the Land category, Forestland remaining Forestland which is the only activity area computed in this inventory, with 84.0% of total emissions. Aggregated sources and non-CO_2 emission source on land followed with 8.1% and Livestock with 7.9%. HWP removed 1.2 % of total emissions.

Net emissions increased from 289,476 Gg CO_2-eq in the year 2000 to 366,734 Gg CO_2-eq in 2016, an increase of 26.7%. Emissions from Land (Forestland remaining Forestland) represented about 85.0% of 2016 net emissions of 366,734 Gg CO_2-eq. Livestock and Aggregated sources and non-CO_2 source on land contributed 8.0 % and 8.2 % of net emissions respectively.

Waste

Total aggregated emissions for the Waste sector was 23,330.275 Gg CO_2-eq in 2016 compared with 13,894.041 Gg CO_2-eq in 2000. This represents a 67.92% increase over the emissions of the year 2000. In 2016, emissions from Wastewater handling represented 83.4% (19,453.741 Gg CO_2-eq) of total Waste sector emissions followed by the Solis Waste Disposal Systems (SWDS) category with 13.1% (3050.473 Gg CO_2-eq) and the remaining 3.5 % (826.061 Gg CO_2-eq) came from open burning (Figure 2.14). From 2014 to 2016, the highest increase in emissions occurred under SWDS with 7.6 % followed by 6.5% in Wastewater handling and 5.2% from Open Burning.

ES 3. Mitigation Assessment

National Development Plans and Policies on Climate Change Mitigation

Mitigation is guided by the National Climate Change Policy Response and Strategy (NCCPRS) which was adopted in 2012 to better frame and implement the GHG reduction options. The goals of the NCCPRS are to foster low-carbon high economic growth and build a climate resilient society.

Within the framework of this strategy, several policies have been developed and the main ones are:

- The National Energy Policy that offers the framework for sustainable energy development to provide clean, affordable, adequate and reliable energy with participation of the private sector.
- The Sustainable Energy for All (SE4ALL) Action Agenda to ensure universal access to modern energy services, double the share of renewable energy in the national energy mix and improve energy efficiency.
- The National Renewable Energy and Energy Efficiency Policy (NREEEP) which seeks to achieve a renewable electricity target of 16% by 2030 as opposed to the current 1.3%.

- The Renewable Energy Master Plan (REMP) that aims to articulate a roadmap for national development of renewable energy.
- The Nigeria Feed-in Tariff for Renewable Energy Sourced Electricity, an optimal economic instrument for hydro schemes not exceeding 30 MW, all biomass cogeneration power plants, solar and wind-based power plants, irrespective of their size.
- The UN-REDD Programme aims at consolidating the countries' efforts to reduce emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks.
- The Solid Waste Program Interventions of the Federal Ministry of Environment to implement an integrated solid waste management programme; and
- The natural Gas Flare Out policy to phase out flaring for utilization in the country.

Methods

The Key Category Analysis for the level assessment for the year 2016 and the trend assessment for the period 2000-2016 have been used to guide the prioritisation exercise and choice of activities offering the highest potential for mitigation. These are the Energy and Land sectors.
The Long-Range Energy Alternatives Planning Tool (LEAP) was utilized to assess the GHG emission implications of various activities of the Nigerian economy. LEAP employed the development of Business as Usual (BaU) and Low Carbon Development (LCD) scenarios.

The two key scenarios covered in the LEAP study are:

- Business as Usual (BaU) – where the historical path of the development of energy use in the sectors was extrapolated from the base year 2015 to the future (2035), and
- Low Carbon Development (LCD), where LCD technologies were deliberately introduced in each sector, during the time period of analysis (2016 - 2035).

Emission projections for both the BaU and LCD scenarios are based on key parameters which include, the national GDP and its sectoral value added, national GDP growth rate, national population (total, urban and rural) and population growth rate. These key parameters are drivers of the economy and national development plans provide for the projected changes in the future.

GHG Emissions under the BaU Scenario

Under the BaU scenario, national GHG emissions from the different IPCC Sectors are expected to grow from about 609,836.74 Gg CO_2-eq in 2016 to about 966,673.69 Gg CO_2-eq by the year 2035. This translated to an emission increase of about 58.5% within the period under review.

GHG Emissions under the LCD Scenario

Implementing all the energy saving LCD options, total energy demand of the economy is projected to decrease to 2,730.3 Million TOE in 2035 from the 3,054.5 Million TOE forecasted in the BaU scenario. This represent a reduction of about 11% in energy consumption across sectors by 2035 as a result of a significant energy efficiency programme.

Considering the progress and targets of previous activities and other efforts in the country on reforestation and on combating deforestation, we have modelled a scenario of increasing the total forest cover in Nigeria from the base-year level of 13,964,523 ha in 2016 by 150,000 ha annually to offset the 114,492 ha of annual deforestation. This will increase the total land area of Forestland in the country to 14,639,169 ha by 2035.

With the implementation of all the LCD opportunities, it is expected that in 2035, GHG emissions for the BaU Scenario will decrease from the BaU level of 967.2 Gg CO_2-eq to an LCD level of 797.2 Gg CO_2-eq. The mitigation potential at national level and by sector and category is presented in Table ES 2. The potential amounts to 170,016.5 Gg CO_2-eq in 2035, representing a decrease of 18% on the BaU scenario emissions. The highest saving is from the Land sector followed by the Energy sector. The negative value obtained for Commercial/Institutional is explained by the intervention fuel switch from fuelwood to LPG with the CO_2 accounted for under Land rather than under this energy category and as per the IPCC guidelines. Only the CH_4 and N_2O emissions have been accounted for under the Energy sector.

Table ES 2 - Mitigation potential of the interventions by sector and category

Sector and Category	Mitigation potential (Gg CO_2-eq)
National	**170,016.51**
Energy	60,002.18
Fuel Combustion	53,426.80
Energy Industries	45,248.40
Electricity Generation	45,248.40
Manufacturing Industries and Construction	405.30
Transport	4,897.90
Road Transportation	4,897.80
Other Sectors	2,875.20
Commercial/Institutional	-3,196.80
Residential	6,072.00
Fugitive Emissions (Oil & Natural Gas)	6,575.38
AFOLU	110,014.33
Land	110,014.33

Financing mitigation actions

Nigeria has taken measures to identify various financing channels for the climate change mitigation opportunities modelled in LEAP in line with government policies. In the preparation of its Market Readiness for Nationally Appropriate Mitigation Action (NAMA), various financing options including multilateral, bilateral and funding from the private sector were identified. Some of the sources of climate funding with whom Nigeria has worked or is working with as well as new potential partners are provided below.

Multilateral Climate Finance Funds

- The Green Climate Fund (GCF).
- The Emerging Africa Infrastructure Fund (EAIF).
- Adaptation Fund established under the Kyoto Protocol.
- The ASAP, a multi-donor grant co-financing program, launched by the International Fund for Agriculture and Development (IFAD).
- The Clean Technology Fund (CTF) is one of four key programs under the Climate Investment Funds (CIFs).
- The Forest Carbon Partnership Facility (FCPF) operating under the World Bank Programme.
- The Global Climate Change Alliance + (GCCA+) established by the European Union (EU).
- The Global Energy Efficiency and Renewable Energy Fund (GEEREF), a Public-Private Partnership (PPP) designed to maximize the private finance leveraged through public funds, funded by the European Commission and managed by the European Investment Bank.

Bilateral Climate Finance Funds

- The Global Climate Partnership Fund (GCPF), a public-private partnership investment fund based in Luxembourg.
- The International Climate Fund (ICF) operational under the UK government.
- Norway's International Climate and Forest Initiative (NICFI).
- The International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).
- The NAMA Facility of the UK Department of Energy and Climate Change (DECC) and
- The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Private Climate Finance Funds

- Ariya Capital Sub-Saharan Africa Cleantech Fund (ARIYA).
- Emerging Africa Infrastructure Fund (EAIF), a Public Private Partnership of the Private Infrastructure Development Group (PIDG).
- Energy Access Ventures (EAV); a partnership including Schneider Electric, the European Investment Bank (EIB), the UK government-owned development finance institution – the CDC Group, Investment and Support Fund for Businesses in Africa (FISEA), the OPEC Fund for International Development (OFID), and the French Facility for Global Environment (FFEM).

ES 4. Vulnerability and Adaptation

Historical Climate and Projections

The multi-model ensembles dynamic downscaling analysis method using 11 Global Circulation Models (GCMs) has been used to develop future climate change scenarios for Nigeria. All the 11 models applied in this analysis are the 5th Phase GCM models of the Coupled Model Inter-comparison Project (CMIP5) used in the development of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The emissions scenarios considered in the analysis is the third generation Representative Concentration Pathways (RCP) used in the IPCC AR5 (Moss, R. et al., 2011). The two RCPs adopted for the analysis are RCP 8.5 (high emissions scenario) and RCP 4.5 (intermediate / medium emissions scenario).

The model performance was validated by comparing the locally derived observed baseline climate with the modelled historical baseline climate derived from the global data set of WorldClim. The modelled data surprisingly simulated well the observed climate both in pattern and magnitude. Moreover, the observed spatial baseline (1961-1990) mean monthly precipitation and spatial baseline (1960-1990) mean annual temperature derived from the global data set (WorldClim) of the *ensemble* data output are highly correlated with a coefficient of 99.68%.

The spatial mean annual precipitation of the baseline (1960-1990) and for time horizons of 2050 (mean 2041-2060) and 2070 (mean 2061-2080) for the emission scenarios, RCP4.5 and RCP8.5, are shown in Figure 4.4. Both RCP 4.5 and RCP8.5 predict that there is likely to be a variable increase in precipitation up to the year 2070 in all agroecological zones of Nigeria. The Sahel savannah is projected to have the highest increase of around 30% under both RCPs for the 2050-time step followed by the Sudan savanna with about 10% while the remaining zone are at less than 55. The projections follow the same trend for the 2070-time horizon, with higher increases under RCP8.5 and even a 45% peak for the Sahel savanna. In terms of an aggregated mean annual precipitation, the southern part of the country is expected to have a bigger area that could get more than 3,000 mm annually. On the other hand, the northern part of Nigeria, the Sahel and Sudan savannas could experience an increase of 29% to 45.8% and 9% to 14.2%, respectively. Though the Sahel savanna could experience the highest percentage increase, this could be insignificant when considering the annual mean precipitation, which ranges from 286 mm to about 400 mm annual maximum historically over this zone.

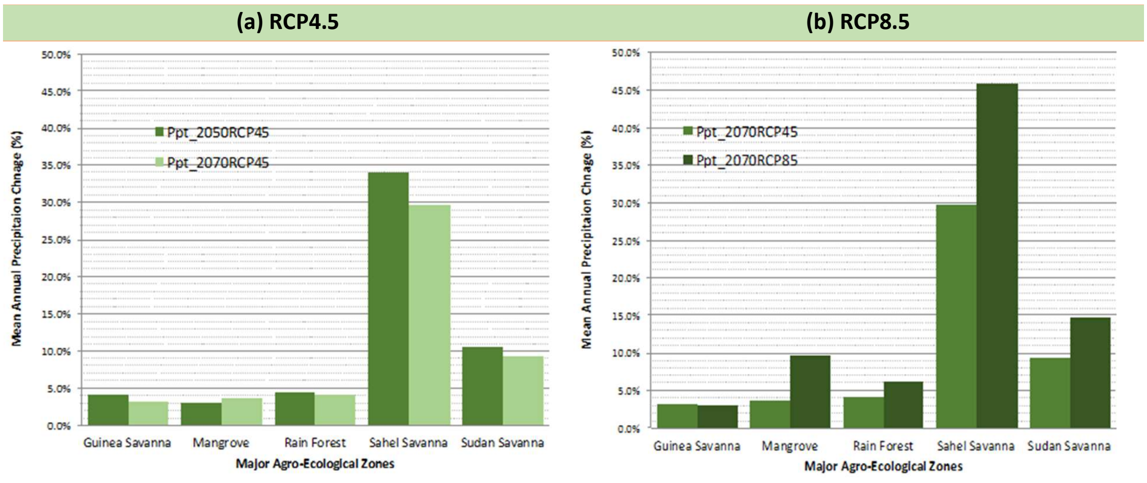


Figure ES 2 - Mean Annual Precipitation Change Compared to Historical Mean Annual Precipitation by Agro-Ecological Zones at RCP4.5 and RCP8.5

Under the RCP4.5 for 2050 and 2070, the temperature increase could range from a low of 1.48°C to 1.78°C to a high of 3.08°C to 3.48°C compared to the baseline (Table 4.2ES 3). On average, the temperature increase is projected to vary between 1.95 to 2.31°C under the RCP 4.5 scenario increasing to the range 3.15 to 3.54°C for the RCP 8.5 one across the country. The lower increase is predicted for the southern part of the country and the magnitude increases northward. Under the RCP 8.5 scenario for 2050 and 2070, the low range temperature increase is from +2.41°C to +2.68°C and the highest ranges from +4.25°C to +4.63°C compared to the baseline. Under RCP 8.5 almost all parts of Nigeria could experience an increase of a minimum of 2°C and a maximum of 4°C or higher, with the highest increase being felt in the northern parts of Nigeria.

Table ES 3 - Annual temperature changes for time series of 2050 and 2070 at RCP 4.5 and RCP8.5 compared to the historical baseline of 1960-1990.

Annual Temperature Change	Projected Temperature Increase Compared to 1960-1990			
	RCP 4.5		RCP 8.5	
	2050	2070	2050	2070
Low Temperature Change	+1.48	+1.78	+2.41	+2.68
Average Temperature Change	+1.95	+2.31	+3.15	+3.54
High Temperature Change	+3.08	+3.48	+4.25	+4.63

Climate Change Impact Assessment and Adaptation

Agriculture

Climate impact on agriculture varies considerably by agro-ecological sub zone (AESZ) and crop type. The results of the World Bank case study indicate lower yields in the longer term (2050) with negative median values for all crops in 2050. The consensus of models is clearer for 2050, with 70 % pointing to lower yields and rice appears to be the most vulnerable crop throughout, with yields falling as much as 7 % in the short term and 25 % in the longer term. Despite the significant level of variability across space, by 2050 the aggregated yield decline is pronounced in the northern part of Nigeria. On the other hand, while an increase in total annual rainfall could have a beneficial effect on the productivity of cassava and ginger, the productivity of yam, maize, tomato, and melon is threatened by an increase in total annual rainfall. According to the results under RCP4.5 and RCP8.5, the projected mean annual precipitation could also threaten such productivity. On the other hand, extreme temperatures have a negative association with cassava and sweet potato yields, which indicate that temperature change is likely to be the major driver of yields shocks, rather than precipitation. As the annual maximum temperature increase in 2050 and 2070 under both scenarios (RCP4.5 and RCP8.5) could range from +3°C to +4°C, the impact on cassava and sweet potato could be a negative impact on the productivity of these crops.

The most prominent adaptation options to counter the negative yield impacts are:

- Provision of accurate and timely weather forecasting,
- Adoption of drought-tolerant and early maturing crop varieties,
- Diversifying of livelihoods to improve income,
- Increasing and upgrading crop storage facilities,
- Control of pests, insect and birds,
- Growing more cover crops like potatoes and melon to protect soil from erosion,
- Enhancing agricultural extension services,
- Irrigation,
- Flood control,
- Drainage, and
- Improving transportation between rural areas and urban centres.

Livestock

Livestock production accounts for one third of Nigeria's agricultural GDP, providing income, employment, food, farm energy, manure, fuel and transport (Nuru, 1986). Approximately 75% of all the livestock in Nigeria are in the northern region (World Bank, 1992). The climate change hazards affecting livestock in Nigeria include late onset of rains, higher than normal temperatures, flooding, salt-water intrusion and windstorms. The late onset of the rainy season causes a lack of available water for livestock and reduces forage production. Higher than normal temperatures lead to poor livestock health which reduces their market value, thereby reducing the farmers' income. Flooding leads to loss of livestock, destruction of livestock enclosures and outbreak of diseases. The livestock sub-sector is particularly susceptible to climate change due to the extent that livestock depend on water for survival. Shortage of rainfall, late onset of rains and rising temperature in the Sahel and Sudan savannas will result in declining livestock productivity and production as well as increased incidence of diseases. In the rainforest and coastal zones, flooding and erosion will displace livestock farmers, destroy their assets and increase disease infestation on livestock farms. This trend will ultimately reduce animal protein supply in the country as much as the livestock production in Nigeria comes from these regions.

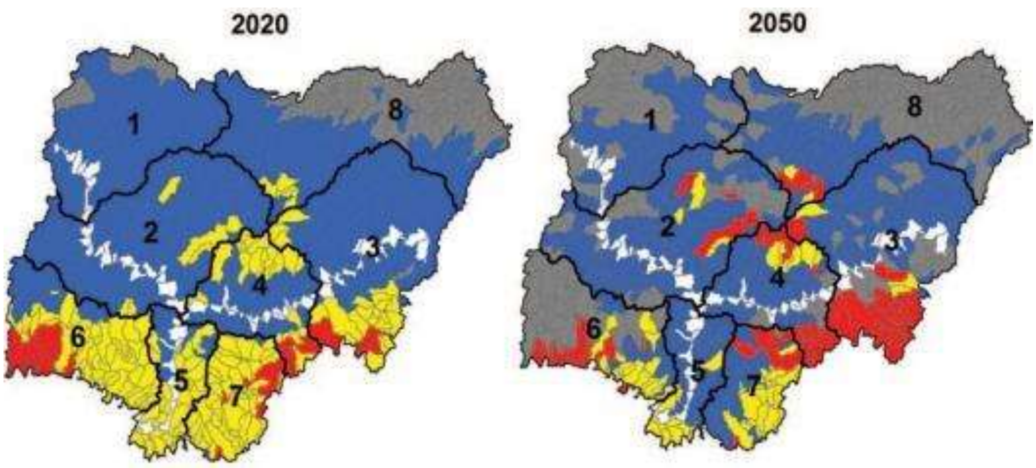
Some of the adaptation strategies identified for the livestock sector are:

- Intensive livestock keeping,
- Planting trees near livestock houses and on pastureland,
- Greater support for insurance,
- Developing improved livestock breeds,
- Institutionalize Early Warning Systems,

- Provision of potable water for livestock,
- Construction of embankment (dikes),
- Culling animals,
- Vaccination of livestock and cross border diseases surveillance, and
- Encourage rainwater harvesting practices.

Water Resources

Despite the abundant water resources that Nigeria is endowed with, the country suffers from access to a regular supply of good quality water for domestic use. A recent report by UNICEF indicates that over 57 million Nigerians do not have access to potable water. Using the ArcSWAT Soil and Water Assessment Tool (SWAT) model in consultation with local experts, especially in electing input data to support the hydrological analysis, the World Bank conducted a climate impact analysis on water resources in Nigeria (Cervigni et al. 2013). In the study, data from some 893 sub-basins, including their reach and falling inside the boundaries of the country were extracted. According to the results of the study, by 2020, about 62% of the country is expected to be wetter, 4% drier, and 23% stable. Similarly, by 2050 it is expected that significant parts of the country could face wetter or drier conditions while 11% of the projections are uncertain. The distribution of classes of risks for Water Flows for 2020 and 2050 indicated as Dry Risk areas and integrating the projected mean annual temperature increase for the 2050 and 2070 time horizons for the RCP 4.5 and RCP 8.5 scenarios are presented in Figure 4.14ES 3. In both maps, the South Eastern tip of Nigeria and smaller areas of the south west and centre, especially by 2050 are observed to be subject to the Dry Risk. Substantial areas also are projected to suffer the Wet Risk, meaning that this could also result in negative impacts on activities such as agriculture and health with potentially higher occurrences of floods.



		1st Percentile	
		< -15%	> -15%
99th Percentile	<15%	Dry Risk	Stable
	>15%	Uncertain	Wet Risk

Figure ES 3 - Distribution of classes of risk for Water Flows, 2020 and 2050 compared to 1990

The two main avenues to support measures already adopted by the country to further adapt in the Water Resources sector are:

- Improved management of water resources; and
- Improved exploitation of groundwater.

Health

Impacts of climate change on health can prove to be very detrimental to the population and the economy with higher order effects on the social fabric and the society. Though there is no national level extensive assessment of the impact of climate change on health in Nigeria, the few studies conducted to-date indicate that climate-induced hazards on health are evident. For example, (Tunde et al., 2013) indicated a relationship between climate and the major causes of mortality in Ilorin (South Western Nigeria) in the rainy season. There is evidence that some vector-borne diseases like malaria, fever and dengue transmission are highest during the months of heavy rainfall and high humidity (More, 1992). Moreover, heavy rainfall events, which are common in Nigeria, can also carry terrestrial micro-biological agents into drinking water sources, which could eventually lead to outbreaks of cryptosporidiosis, giardiasis, amoebiasis, typhoid and other infections (Lisle, 1995; Rose, 2000). Typhoid is mostly triggered by high temperatures and increased humidity. Two case studies providing information on malaria and climate change from the Ilorin (South Western Nigeria) and Port Harcourt (Southern Nigeria) regions, and meningitis and climate change in the northern region of the country support the relationship between climate changes anticipated in Nigeria and the increased impacts and vulnerability of the health sector.

For malaria, the most effective preventive method is through the control of the mosquito vector. This can be achieved through the provision of mosquito nets preferably the insecticide-treated ones, controlled breeding of the mosquito vector and the use of mosquito repellents while not neglecting the important aspect of education and awareness of communities.

The best adaptation strategies for meningitis are mass vaccination even if it is costly, early detection and an early warning system through the monitoring and forecasting of weather conditions conducive to the spread of the disease.

Other longer-term strategies are education of the communities to change their behaviour to avoid transmission of meningitis, improve research on the impacts and interaction of climate change on health, improved weather forecasting, training of health workers, improved water management and community awareness.

Infrastructure

Nigeria's economic environment and social system (education, health and housing), production-wise (agriculture, manufacture, commerce and oil industry), infrastructurally (water and sanitation, electricity and transport) and cross-sectoral (environment) are at risk mainly due to flooding. Based on the October 2012 flooding, it can be concluded that the population at risk in Nigeria to such an event amounts to a total of about 23 million. In Yenegoa, there are 302,782 people estimated to be exposed to high flood risk along the Niger-Benue basin in the Niger Delta area with 630 km^2 of land susceptible to flooding. The city of Lagos is one of the world's mega cities, which is also exposed to flooding. The city is one in the top 20 countries ranked in terms of population exposed to coastal flooding in the 2070s (Nicholls et al., 2007). Currently, about 357,000 people are exposed and by 2070 about 3.2 million people could be at risk due to flooding. The direct estimate of damage and loss caused by the 2012 flooding is about ₦1.48 trillion

(US$9.5 billion). The total damage and loss, including indirect ones, due to the flooding is about ₦2.6 trillion (US$16.9 billion).

The vulnerability of the oil sector to climate change is potentially high in Nigeria (FME, 2014). It is expected, with a high level of certainty, that coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion due to relative sea level rise (IPCC, 2014). This will greatly limit oil production due to the serious damages to existing oil infrastructures, including settlements.

Adaptation strategies for human settlements and physical infrastructures require knowledge of the particular climate vulnerability and the economic, institutional and socio-economic characteristics of the settlement area. In the Nigerian context, the best adaptation strategy is proper town and country planning. Government should strengthen the norms in relation to the impacts of climate change and empower Planning Authorities to regularly verify and inspect buildings construction to ensure that properties are not developed against planning regulations. In addition, a Planning Enforcement Agency should be created with the mandate to demolish property that are not within the prescribed norms to allow for adaptation to climate change. Adaptation strategies for the transport sector are the development of alternatives to road transportation, expansion of major highways and improved road maintenance.

Forest, Forestry and Desertification

Forest resources in Nigeria have undergone changes from both natural and human-induced activities. Global climate change is a new challenge as it is having a significant negative impact on this natural resource and weakening its capacity to provide critical ecological resources and services.

The direct and indirect climate change hazards that affect the forest ecosystem include:

- Land use change and deforestation,
- Drought,
- Flooding of low-lying landscapes,
- Erosion,
- Sea level rise,
- Changes in precipitation, and
- Warmer temperatures.

Adaptation strategies in the Forest sector including Desertification are:

- Afforesting with suitable indigenous and exotic species,
- Controlling access to the forest which includes human and wildlife population, particularly in fragile ecosystems using physical fencing and legislation,
- Improving forest management through a community-based natural forest resources management programme,
- Establish and restore community and private natural forests, plantations and nurseries, and
- Develop and maintain a frequent forest inventory system to facilitate monitoring of forest status.

Tourism

For tourism, climate change is not a remote event, but a phenomenon that already affects the sector and certain destinations, mountain regions and coastal destinations among others. This is due to the adverse impacts of climate change, reflecting the many species of plants and animals rapidly becoming extinct, the decreasing tree density and floristic richness, the disruption and reduction of the fruiting intensity of some trees and the changes in the migratory patterns of birds and other animals.

The main adaptation options are:

- Mass tree planting to conserve the natural environment,
- Producing and promoting environmentally friendly products, and
- Tourists and the local resident's participation in environment friendly tourism activities.

Vulnerable groups and the gender issue

Certain socio-economic and demographic groups exhibit particular vulnerability in the face of climate change. These include women and female heads of household, children and the elderly, the chronically sick and indigenous people. It has been observed from studies that women in developing societies are more vulnerable to environmental change because they are very often socially excluded and lack equal access to resources, culture and mobility. Children, the elderly and chronically sick people also typically exhibit high levels of vulnerability. This arises from their physiological sensitivity. These groups also typically have a low adaptive capacity through high levels of dependence on others for their living, including their food security, mobility, and access to information.

Adaptation strategies include:

- Capacity building on climate change risks and opportunities,
- Incorporate climate change into on-going business planning, and
- Promote and market emerging opportunities from Climate Change.

ES 5. Other Information Relevant to the Convention

Science, Technology and Innovation

Developing countermeasures to address the cause and impacts of climate change in Nigeria is a strategy that can only be achieved with the rolling out of appropriately engineered and technological mitigation and adaptation strategies. Research and development; improved knowledge on climate change concepts; and access to technology via technology transfer or any other means will enhance capacity to mitigate and adapt.

Technology Transfer

It has been reported that apart from reducing emissions, technological innovations do help also in adaptation to climate change. Thus, the adoption and transmission of technology between and among nations and non-state actors is very critical in responding to the impacts of climate change as rightly embedded in the Convention. However, up to now Nigeria like many other developing countries are facing various barriers for a successful technology transfer and absorption within the climate change context. Some of these are Inadequate awareness on available technologies; Low capacity of acquiring country; Poor perception of commercial applications; Intellectual property rights; Understanding of the innovation process; Availability of funds, Restrictive tariffs and Heavy bureaucratic processes. It is crucial that all stakeholders concerned with efficient technology transfer and absorption invest on this critical issue for mitigating and adapting to climate change.

Education, Training and Public Awareness

The level of public awareness is a causative factor for vulnerability and poor adaptation to impacts, as well as mitigation of climate change. Overall, Nigerians are mostly not aware of changing climatic patterns and their consequences. They also have little appreciation of their contribution and vulnerability to climate change impacts. As presently designed, national educational curricula across the education sector are not yet ready to provide education to the tune required to fill that gap and prepare the population. It is thus imperative that Government addresses this issue as per the declared National Policy on Environment of 2016.

Research and Systematic Observation

Various academic institutions, research centres as well as agencies have the responsibility for conducting relevant research and observations on climate change mitigation and adaptation including disaster risk reduction and management to complement local indigenous knowledge for early warning capacities. It is important to note that these state and non-state actors often work independently of one another instead of working collectively to ensure that Nigerians can deal with issues of vulnerability, mitigation and adaptation of climate change-related issues. Thus, more effort should be put into fostering collaboration between and among stakeholders with similar objectives.

The Gender and Social Inclusion Dimensions of Climate Change

The vulnerability of any segment of the population to climate change depends largely on some inter-related factors, which determine the extent of exposure to climate change; sensitivity to these impacts; and the capacity for adapting to these changes, among others (Yila et al., 2014). These factors include gender; economic, social and political status; access to and control over resources.

Nigerian government is aware of the situation and is geared to addressing them as contained in the National Policy on the Environment of 2016 for the promotion of a gender-responsive approach to the stemming impacts of climate change on vulnerable groups.

Other cross-cutting issues

Conscious of the threats posed by climate change, the government is also committed to address the challenges listed below for implementing a low carbon strategy inclusive within a sustainable development agenda. These challenges, not exhaustively, are:

- The environmental security and climate change,
- Mainstreaming climate change mitigation and adaptation strategies within the development agenda,
- Climate finance to support Nigeria in meeting its obligations under the Convention, and
- Capacity building on the various thematic areas of climate change.

1. National circumstances and institutional arrangements

1.1. Convention Obligations

Articles 4.1 and 12.1 of the United Nations Framework Convention on Climate Change (UNFCCC), require each Party to the Convention to communicate periodically in National Communications (NCs), actions being taken to mitigate and adapt to climate change within its geographic boundaries.

Nigeria ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 29th August 1994 as a Non-Annex 1 Party. Thus, the country is obliged to report certain elements of information in accordance with Article 4, paragraph 1 of the Convention. These are:

iv. *A national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of the Parties (COP);*

v. *A general description of steps taken or envisaged by the Party to implement the Convention; and*

vi. *Any other information that the Party considers relevant to the achievement of the objective of the Convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emission trends.*

As a Party to the Convention, Nigeria has submitted its First and Second National Communications to the Conference of the Parties in 2003 and 2014, respectively. It has also submitted its first Biennial Update Report (BUR) in 2018, which contains updates of national Greenhouse Gas (GHG) inventories. This Third National Communication (TNC) is set to provide a robust update of climate actions in the country and, as a policy document, pave the way for the efficient implementation of the Convention.

This section presents the national circumstances of Nigeria, with emphasis on the national development priorities, objectives and circumstances that serve as the basis for addressing issues relating to climate change in the country.

1.2. Location and extent

The Federal Republic of Nigeria, commonly referred to as Nigeria, is located at the extreme inner corner of the Gulf of Guinea on the west coast of Africa and lies between latitudes 3°15’ to 13°30’ N and longitudes 2°59’ to 15°00’ E. Nigeria shares borders with the Republic of Benin to the west, Niger to the north, Chad to the north-eastern corner and Cameroon to the east. Its southern boundary is defined by the Gulf of Guinea portion of the North Atlantic Ocean, which spans over some 853 kilometres between the country’s borders with the Republic of Benin in the west and Cameroon in the east (Figure 1.1).

Figure 1.1 - Location map of Nigeria

Nigeria stands as the 14th largest country in Africa with a land area of 923,769 km^2 (that is, almost twice that of France) of which land accounts for 910,769 km^2 and water for 13,000 km^2. Nigeria extends over a maximum distance of 1,046 km from North (Sahel region) to South (Gulf of Guinea), its maximum breadth from East to West is 1,127 km and it has a total boundary length of 4,900 km, inclusive of the 853 km-long coastline.

Noted geographical features in the country include the Adamawa highlands, the Mambilla, Jos and Obudu Plateaus, the Niger and Benue Rivers, and the Niger Delta.

1.3. Governance Structure of Nigeria

Nigeria is a federal republic comprising 36 states and the Federal Capital Territory (FCT), where the capital, Abuja is located. Nigeria is officially a democratic secular country. The States and FCT are further sub-divided into 774 Local Government Areas or Area Councils for grassroot administration. The states are grouped into six geopolitical zones for political and developmental purposes (Figure 1.2). The Constitution of the country provides for a presidential system of government in which there is an Executive, a Legislature and a Judiciary. The legislative structure is bicameral with upper and lower chambers at the Federal level while State governments and Local Councils operate a single legislative chamber.

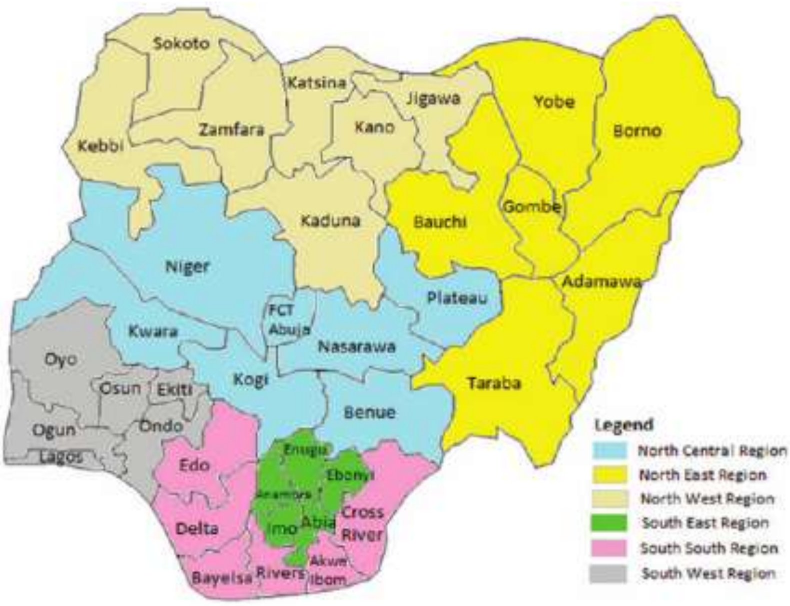


Figure 1.2 - Geopolitical zones of Nigeria

A judicial structure erected in all three tiers of government completes the operational framework for checks and balances and separation of powers in governance as enshrined in the Constitution. The Constitution further provides for the operation of three tiers of government, at the Federal, State and Local levels (Nigeria, 2014).

1.4. Institutional arrangements

Nigeria has been outsourcing the preparation of its reports for reporting to the UNFCCC to honour its obligations. Despite the capacity building initiatives provided to national experts, Nigeria is still heavily dependent on consultants to commission its reports. Efforts have been deployed to provide for the necessary enabling environment including robust institutional arrangements to implement the Convention in addition to reporting. However, given the more stringent reporting requirements and the enhanced transparency framework for action and support (Article 13) of the Paris Agreement of which Nigeria is a signatory Party, the country seriously believes that it should raise its ambition in terms of its reporting and implementation under the UNFCCC. In line with this decision, Nigeria has strengthened its permanent staff which is expected to take over full reporting and implementation of the Convention, including its NDC, to fulfil its obligations to the COP as laid out in the Paris Agreement and subsequent COP decisions. The institutional arrangements being developed and implemented is described below.

The Department of Climate Change (DCC) of the Federal Ministry of Environment has been set up to demonstrate the Nigerian Government's *"commitment to introducing and implementing adaptation and mitigation measures necessary to reduce vulnerability to climate change"*. The mandate of the department is:

> *"To co-ordinate national implementation of the United Nations Framework Convention on Climate Change, its protocol and any other legally binding agreement for implementing climate change activities"* (DCC, 2017).

The DCC is Nigeria's focal point to the UNFCCC and as such its mission is:

> *"To regularly update information regarding national inventory of the Green House Gas emission and mitigation options, vulnerability assessment and adaptation measures and to satisfactorily provide a sustainable policy framework and enabling environment for the implementation of the UNFCCC and Kyoto Protocol and any other climate change guidelines, laws and control in Nigeria"* (DCC, 2017).

The DCC comprises four divisions to track implementation of the Convention and report thereon. The four divisions are:

- Greenhouse Gas (GHG) and Flexible Mechanism division
- Vulnerability and Adaptation division
- Mitigation division
- Education, Training, Public Awareness and other information division

In addition to the operations carried out by these divisions, the DCC is also the convener and chair of the Inter-Ministerial Committee on Climate Change (ICCC). The present institutional arrangements are depicted in Figure 1.3.

1.5. Climate

On a global scale, Nigeria is a tropical country, with Tropical Wet (Af), Tropical Wet-and-Dry (Aw) and Semi-Arid (BS) climates (Koeppen, 1936; Trewartha, 1968; Ojo, 1977). Over the entire country, the structure of the lower troposphere is characterised by two main air masses, namely the Tropical Maritime (mT) and Tropical Continental (cT). There are also two principal lower tropospheric winds, the south-westerly (Monsoon) and north-easterly (Harmattan) winds. The two winds are associated with the two air masses respectively and together form two distinct air streams. The two air streams converge at the Inter-tropical Discontinuity (ITD) surface, where the former forms a wedge under the latter as a result of differences in their densities. The prevalence of any of the two air streams depends on the spatio-temporal migratory patterns of the ITD. Hence, the seasonal northward and southward oscillatory movement of the ITD largely dictates the weather pattern of Nigeria. When an area is overlain by the mT

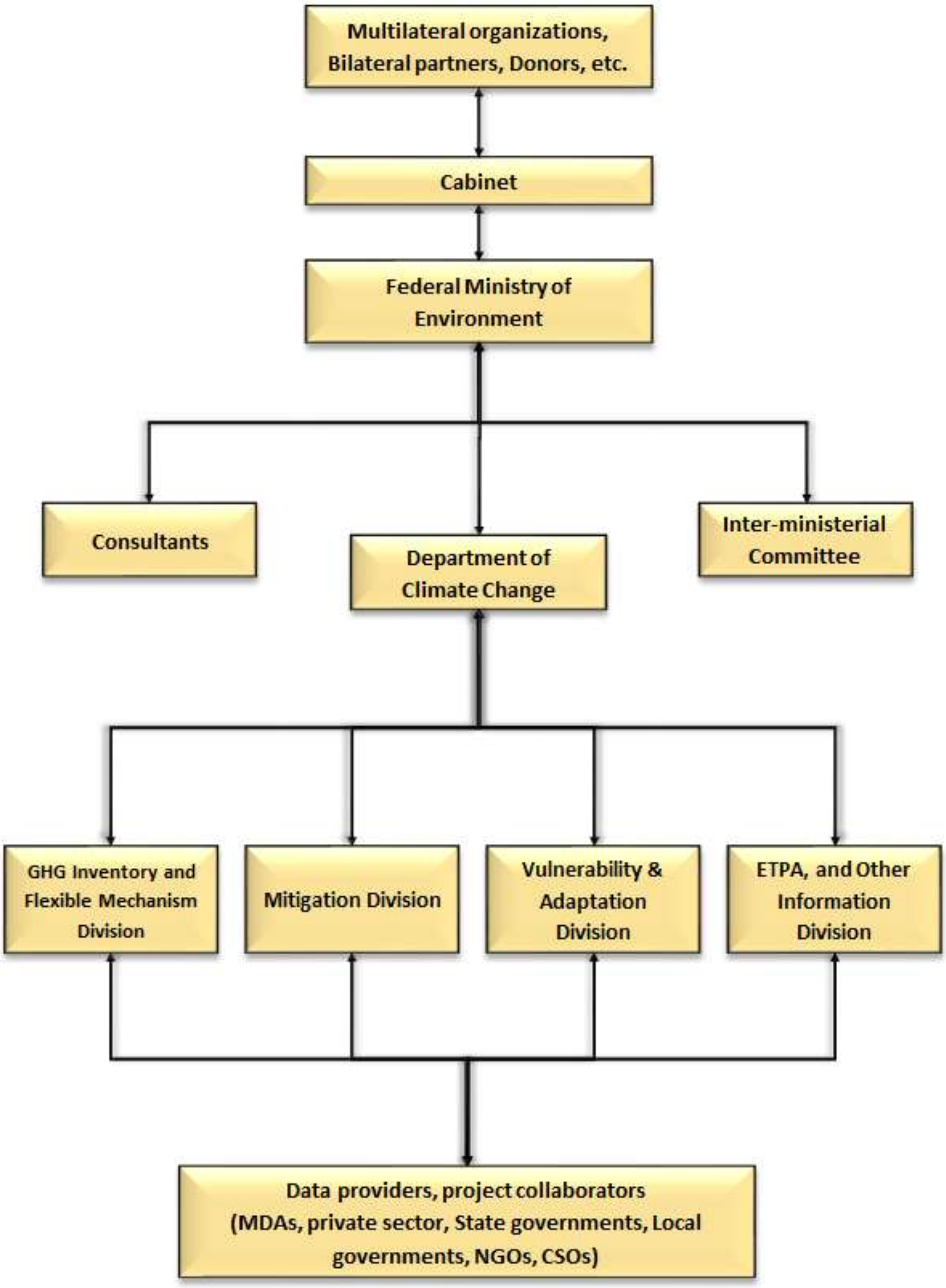


Figure 1.3 - Institutional arrangements for implementing the UNFCCC

air mass and its associated monsoon wind at sufficient depths, frequent convection, overturning, general atmospheric disturbances and precipitation of different amount, duration and intensities occur. The prevalence of cT air mass and the combined Harmattan wind over an area is associated with dry conditions. Generally, the former situation is experienced over Nigeria in the northern summer while the latter prevails in the northern winter. Another important trade wind is the equatorial easterlies, which is a rather erratic cool wind, originating from the east and flowing in the upper atmosphere along the ITD. It dives occasionally to undercut the mT or cT air mass and gives rise to squall lines or dust devils (Iloeje, 1981).

The climate of Nigeria is characterised by two main rainfall regimes: a single maximum rainfall, once a year and a double maxima rainfall, twice a year regime. The trough in-between the double maxima is generally known as the ‘‘Little Dry Season’’ (Omotosho 1988; Adejuwon and Odekunle 2006). The double maxima rainfall regime is confined south of latitude 10° N (that is, Af type of climate) while the single maximum rainfall regime, occurs north of this latitude (that is, Aw and BS types of climate) (Omotosho, 1988). Generally, the length of the rainy season decreases from south to north. In the far north, rainfall seasonality has largely been characterised by its occurrence over a period of 3 months (July to September) with the maximum in August. On the other hand, around the coastal area, rainfall is also seasonal but with a short drier season and most rain occurring over a period of 8 months (March to October), with rainfall maximas in June/July and September/October, August being the short dry season (Odekunle and Adejuwon, 2010). The mean annual rainfall varies from about 1,800 mm to over 3,500 mm along the southwest and southeast coastal areas, respectively, to 450 mm in the far hinterlands of the north (Figure 1.4). The annual variation of rainfall, particularly in the northern parts, is large. This often results in climatic extremes, especially floods and droughts, which bring in their wake much suffering with devastating effects on food production and the nation’s economy.

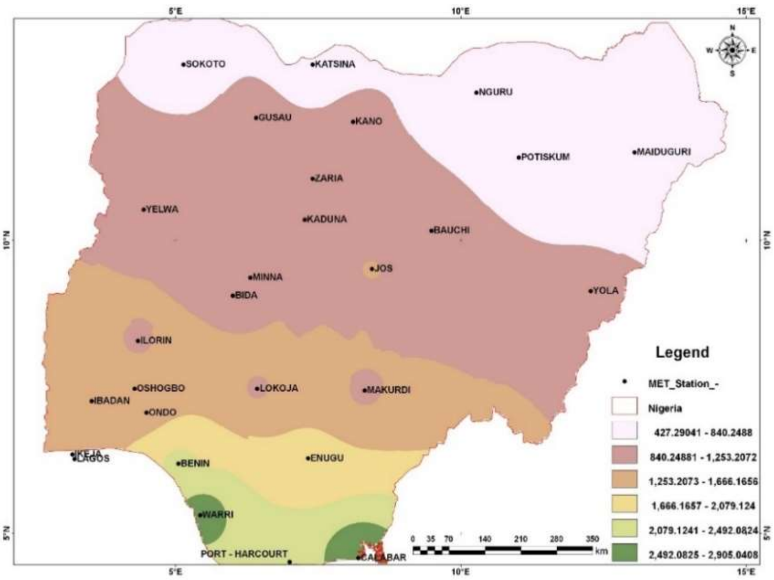


Figure 1.4 - Long-term (1961 – 2008) Mean Annual Rainfall for Nigeria (mm)
Source: Prof. Odekunle (University of Ife, Nigeria)

The most clearly marked temperature difference is between the coastal areas and the interior as well as between the plateaux and the lowlands. On the plateaux, the mean annual temperature varies between 21°C and 27°C whereas in the interior lowlands, it is over 27°C. The coastal fringes have lower means than the interior lowlands (Iloeje, 1981). The intra-annual temperature range is low with an average value of 6°C. In fact, in some southern stations, it may be as low as 3°C (Iloeje 1981). Figure 1.5 illustrates the mean air temperature over the country. Like rainfall, the relative humidity decreases from the south to the north, with an annual mean of 88% around Lagos (Adejuwon and Jeje 1976).

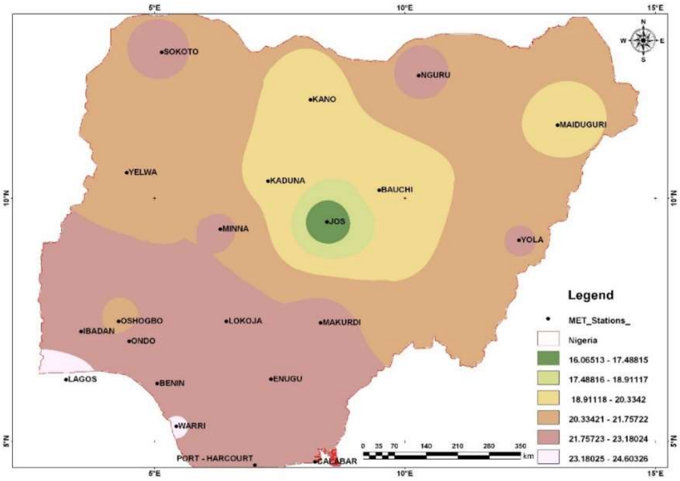


Figure 1.5 - Long-term (1961 – 2008) Mean Annual Temperature for Nigeria (^{0}C)

Source: Prof. Odekunle (University of Ife, Nigeria)

1.6. Relief and drainage

A large extent of Nigeria's surface is made up of the ancient crystalline rocks of the African Shield. Prolonged weathering and erosion have given rise to the major landscape of the country which is now made up of the characteristic features consisting of extensive level plains interrupted by granitic hills and mountains. There are also smaller areas of younger granites, found on the Jos Plateau for example.

The relief of most of Nigeria is characterized by a gradual rise from the coastal plains to the northern savanna regions, generally reaching 600 to 700 m. Higher altitudes exceeding 1,200 m are found around the Jos Plateau and in parts of the Eastern Highlands along the Cameroon border. The coastal plain extends inland for about 10 km and rises to elevations of up to 50 m above sea level at its northern boundary. The eastern and western sections of the coastal plain are separated by the Niger Delta, which extends over an area of about 10,000 km^2. Much of this is swampland, separated by numerous islands. The coastal plain region penetrates inland about 75 km in the west but extends further in the east. This region is gently undulating, the elevation increasing northward with a mean of about 150 m above sea level (Figure 1.6) (Mathews, 2002).

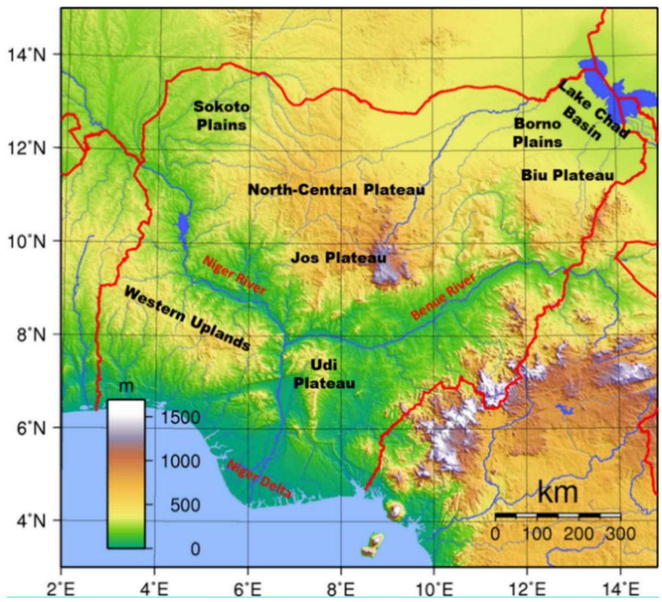


Figure 1.6 - Relief Map of Nigeria

The main drainage systems in Nigeria are the Niger-Benue, the Chad, and the coastal river systems (Figures 1.6 and 1.7). The main sources of the rivers include the Jos Plateau, the Western Uplands, the Eastern Highlands, and the Udi Plateau. While some of these rivers, such as those associated with the Komadugu-Yobe basin, flow into Lake Chad, others are tributaries to the Niger and Benue rivers. Some of the rivers which arise from the Western Highlands flow northwards into the Niger and some flow into the Atlantic Ocean. Rivers which arise from the Eastern Highlands flow mainly into the Benue River; while some of those that arise from the Udi Plateau, flow into the Niger. Some of the smaller rivers flow into the Cross River. Most of the coastal areas are poorly drained and this is clearly observed during the rainy season when the rivers and creeks overflow their banks.

The largest river in Nigeria is the Niger originating from Fouta Jallon highlands in the republic of Guinea. It is worth noting that the water resources of the Niger River are under pressure due to increased water abstraction for irrigation from riparian countries and also on account of the impact of climate change. The construction of dams for hydropower generation is underway or envisaged in order to alleviate chronic power shortages in the countries of the Niger basin. The second largest river is the Benue which arises from the Cameroonian Highlands to join the Niger at Lokoja. An important expanse of the Chad is located to the north-east of the country and constitutes the largest natural lake while the rest is shared with Niger, Chad and Cameroon at their conjunction in the Chad Basin. Lake Chad is generally shallow but extensive, covering about 10,000 to 13,000 km^2 with marked seasonal fluctuations. It has significantly shrunk from its original size since the end of the 1960s (Dami, 2008). The largest man-made lake in the country is the Kainji which is located on River Niger and covers a land area of about 130,000 ha.

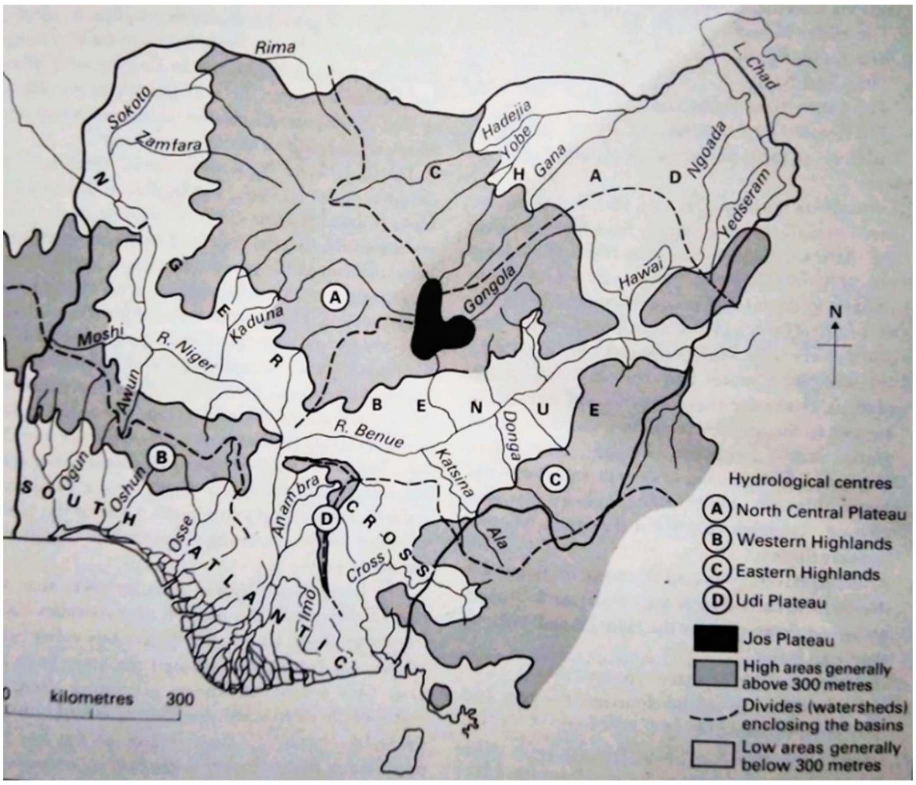


Figure 1.7 - Nigeria's Drainage System

1.7. Soils

Soils are largely a product of the interplays among the various parameters of the physical environment particularly geology, vegetation, climate, slope, relief and drainage. Nigeria's soils can be grouped into four belts from the coast inland (Figure 1.8). These are the hydromorphic, ferralitic, ferruginous and the semi-arid to arid tropical soils. The hydromorphic soils are found in the coastal zones and along the major rivers. The ferralitic soils occur in the rainforests, mainly on sedimentary rocks. They are mostly clayey in texture with poorly differentiated horizons. Ferruginous soils are found at the drier margins of the forest belt and more extensively in the Guinea and Sudan savannas. The soils are red or reddish in colour, rich in iron and are often low in organic matter. The arid and semi-arid soils are found in the northernmost regions (FME, 2006).

The most predominant soil type in the country is the *Ultisols* which covers more than 46% of the country (FME, 2009). *Ultisols* are mineral soils with no calcareous material within it, have less than 10% weatherable minerals in the extreme top layer and less than 35% base saturation throughout the soil. Although this type of soil is of moderate to low productivity, it does very well under good management practices. Only a small fraction (6%) of the country is covered by high productive soils, namely the *Entisols* (FME, 2009). *Entisols* do not show any profile development other than an A horizon. They do not have a diagnostic horizons and most are basically unaltered from their parent material.

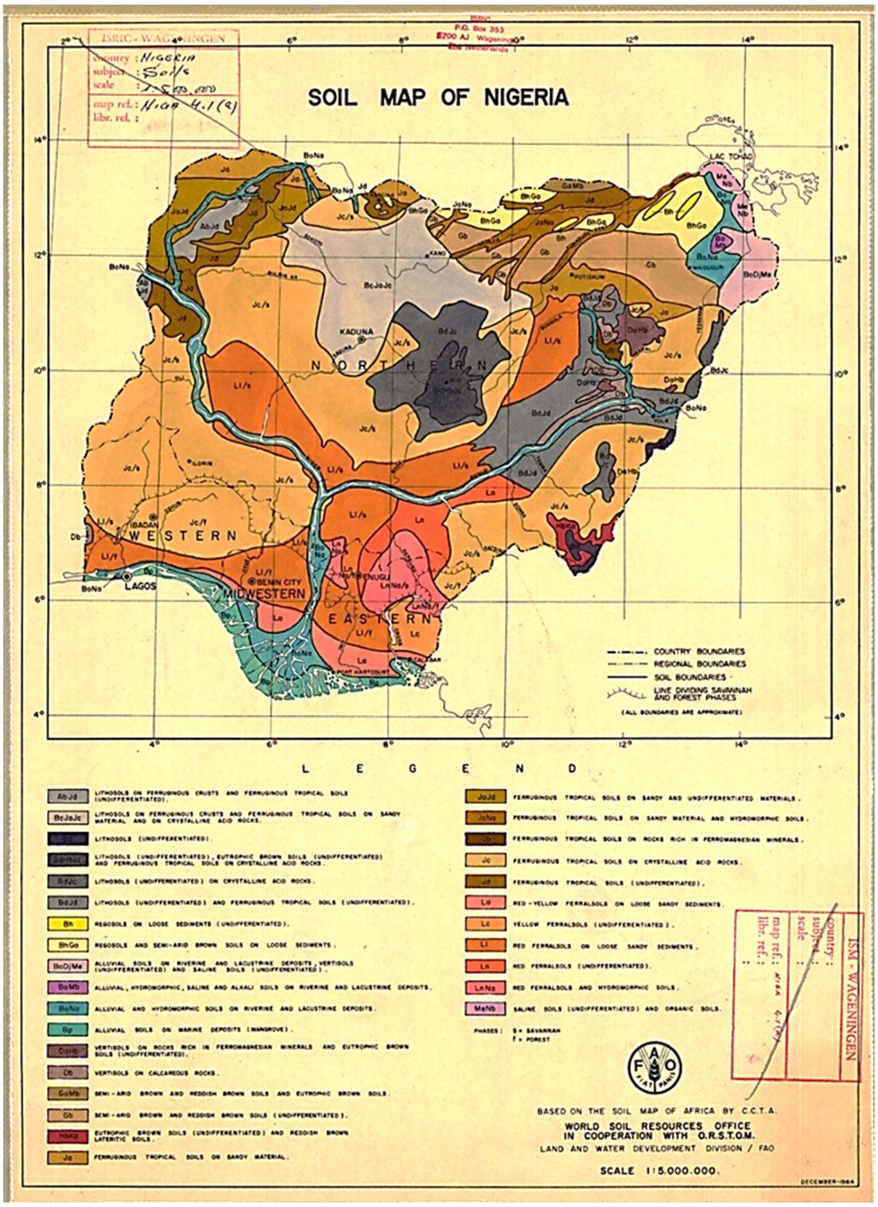


Figure 1.8 - Soil Map of Nigeria

1.8. Vegetation

Nigeria's vegetation is largely a reflection of its tropical climate as observed in the large diversity of tropical plants dominated by trees in the forest areas. These plants have the capacity to tolerate the all-year-round high temperature and heavy rainfall, characteristic of the tropical environment. Many of the plants are also able to establish themselves in overlapping ecological zones. Additionally, the effect of local conditions, particularly the azonal distribution of soils, the influence of the Atlantic Ocean and the high altitudes, especially around the Jos Plateau and the Adamawa mountains, are also noticeable in many areas. Hence, the distribution of the native vegetation types tends to follow the climatic patterns with changes because of these local conditions. Much of the original vegetation no longer exists as a result of human activities. The re-establishment of the original vegetation will depend on:

- the control which may be exercised on anthropogenic activities as they are adjacent to human settlements,
- the availability of resources including from support of the international community, and
- the extent to which it may be affected by climate change.

The main vegetation types of the country are the saltwater and freshwater ecosystems, tropical lowland rainforests, Guinea savanna, Sudan savanna, and Sahel savanna (Figure 1.9). Salt and freshwater swamps are found along the coast, stretching inland for 1 to 2 km in the Lagos region to over 30 km in areas regularly inundated by salty tidal waters. They occupy 2,130,000 and 858,000 ha of the terrestrial lands respectively, making a total of 2,988,000 ha (Nigerian Environmental Study/Action Team, 1991; Olalekan et al., 2014). The saline wetlands are dominantly covered with mangrove species *Rizophora mangle* (red mangrove) and *R. racemosa*. Beyond the reach of the tidal waters, the mangroves give way to freshwater plants, the most important ones being *Pandanus sp.*, *Dalburger escatophylum* and *Machaerum lunatus*. Outside the lagoons, the swampy vegetation is replaced by the tropical lowland rainforest. The latter is a dense evergreen vegetation of tall trees with undergrowth of small trees, shrubs, and grasses. The rainforests are dominated by three layers of tree crowns, with the tallest trees being more than 36 m (Richards 1977) in height. Wherever the forest is relatively untouched, the top canopy becomes closely interlocked, preventing the sun from reaching the ground, resulting in the forest floors being completely devoid of plants.

The Guinea savanna is the most extensive vegetation belt in Nigeria and is associated with areas receiving 1,000 to 1,500 mm of annual rainfall spread over up to 6 months. It consists of a mixture of trees and grasses, with trees being more numerous in sparsely settled areas. The trees are distinctive, typically fire-tolerant to the annual bush fires that are common in the savanna. Some of the common species are *Vitellaria paradoxa*, *Parkia biglobosa* and *Danielia oliveri.* Along the riverbanks of the savanna are finger-like extensions of the lowland rainforests known as gallery forests.

The Sudan savanna belt occurs north of the Guinea savanna with rainfall of about 600 to 1000 mm and up to 6 months of dry season. It stretches from the Sokoto Plains to the Chad Basin, covering over a quarter of the country's land area. The vegetation consists of grasses 1 to 2 m high and often stunted trees such as the acacia, gum Arabic, date palm, and baobab.

The Sahel savanna, the last of the main vegetation belts of Nigeria, occurs in the extreme northeast where the annual rainfall is less than 500 mm and the dry season exceeds 8 months. The atmosphere is dry except for one to two months in the middle of the short-wet season. The grasses are short and tussock, 0.5 to 1.0 m high between sand dunes. Acacia is the dominant species in this zone, although date palms appear here and there. The swampy shores of Lake Chad support tall reeds growing on seasonally flooded flat land.

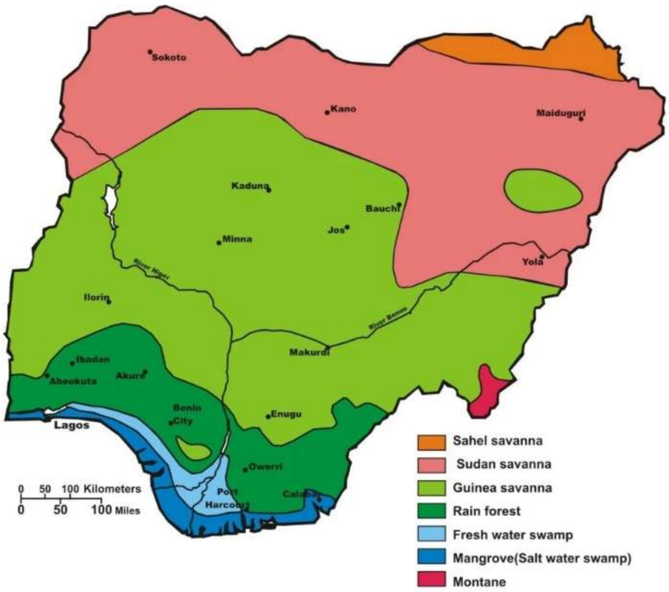


Figure 1.9 - Nigeria Agro-Ecological Zones / Vegetation

1.9. Land Resources and uses

The total land area of about 923,769 km^2 constitutes a huge resource for Nigeria. It is a critical factor of Nigeria's environment since it significantly supports basic socio-economic and cultural activities. Land use is thus the critical factor responsible for the environmental changes taking place at various scales in the country. The demographic increase associated with the needs of the population have led to the conversion of more than 60% of the country's pristine land for anthropogenic activities, with agriculture responsible for the larger proportion of this. Conversion of land to agriculture is predominant in the savanna. Concurrently, high rates of change are also observed to account for settlements and open mines, with changes increasing between 1 to 2% annually (USAID, 2017).

History shows that Nigeria was originally covered by a variety of forests and wooded savannas, some of the richest ecosystems in terms of biodiversity (Keay, 1989). These natural plant covers had been sources of wood and other nature-based resources for several centuries, and as long as population pressure was light, their exploitation was sustainable. With the rapid population growth and its demands, the extraction has resulted in deforestation as well as de-vegetation of the savanna at unsustainable scales. The reported deforestation rate of 409,650 ha or 2.38% per annum has been considered as a serious overestimate of the current situation. A review of data available from national sources, USGS and FAO indicated a much lower rate. In this report, the rate of change of Forestland to other land classes of IPCC is around 114,000 ha or 0.72 % annually. The effect of deforestation and de-vegetation is considerable for the country as the two related phenomena amount to resource degradation and ecological losses especially with respect to biodiversity loss, soil erosion, and reduction of the carbon "sink" of the country.

1.10. Coastal and Marine Environment

The marine and coastal environment is an important ecological zone in Nigeria. It extends inland by about 15 km in the Lagos area, 150 km in the Niger Delta and 25 km east of the Delta. It consists of barrier bar / lagoon systems, the Mahin mud coast, the Niger Delta, Strand coast and a moderately wide continental shelf. The dominant feature of this environment is the Niger Delta, which covers an area of about 70,000 km^2 and one of the largest wetlands in the world (FAO, 2006). The marine and coastal environment harbours more than 20% of the country's population with major centres such as Lagos, Port Harcourt and Benin City.

The coastal environment houses the oil and gas industry of Nigeria. Although the oil sector has experienced some setbacks in the recent past, particularly due to the down turn in the world oil market, the sector has remained the main source of foreign exchange earnings for Nigeria. The coastal environment also has non-fuel minerals like sand and heavy minerals It also supports agriculture and fish production. Many recreational and touristic resources including beaches, coastal lagoons and estuaries are also found in this zone. For many reasons such as vibrant local economies, population concentrations and closeness to shipping facilities, almost half of Nigeria's industries are located within the coastal zone (HBF, 2008).

1.11. The Nigerian Economy

1.11.1. Introduction

In 2012, Nigeria overtook South Africa to become the largest economy of the African continent, recording an estimated Gross Domestic Product (GDP) of US$ 457 billion in 2016. However, despite the considerable size of Nigeria's economy, its abundant human and natural resources, the country was classified as a lower middle-income country (World Bank, 2018a).

Between 2006 and 2016, Nigeria's GDP grew at an average rate of 5.7% per year, as volatile oil prices led to a high of 8% in 2006 and a low of -1.5% in 2016 (Figure 1.10). While Nigeria's economy has performed much better in recent years than it did during previous boom-bust oil-price cycles, such as in the late 1970s or mid-1980s, oil prices continue to dominate the country's growth pattern. Moreover, the volatility of Nigeria's growth continues to impose substantial welfare costs on Nigerian households. The onset of the oil price shock in mid-2014 confronted the government with the pivotal challenge of building an institutional and policy framework capable of managing the volatility of the oil sector and supporting the sustained growth of the non-oil economy.

The main economic sectors of the country, namely Agriculture, Industry and Services, have known contrasting fates during the decade 2007 to 2016. In 2007, the Industry sector was the most important component of the economy, contributing as much as 40.7% to national GDP. It was followed by the Agriculture sector (32.7%) and the Services sector (26.6%). Over the years, the situation has completely changed and in 2017, the economy was driven by the Services sector with a contribution to national GDP of 60.4 % followed by the Agriculture and Industry sectors with 21.2% and 18.5% respectively. Figure 1.10 details out the annual GDP contribution of the three main economic engines of Nigeria over the period 2000 to 2016.

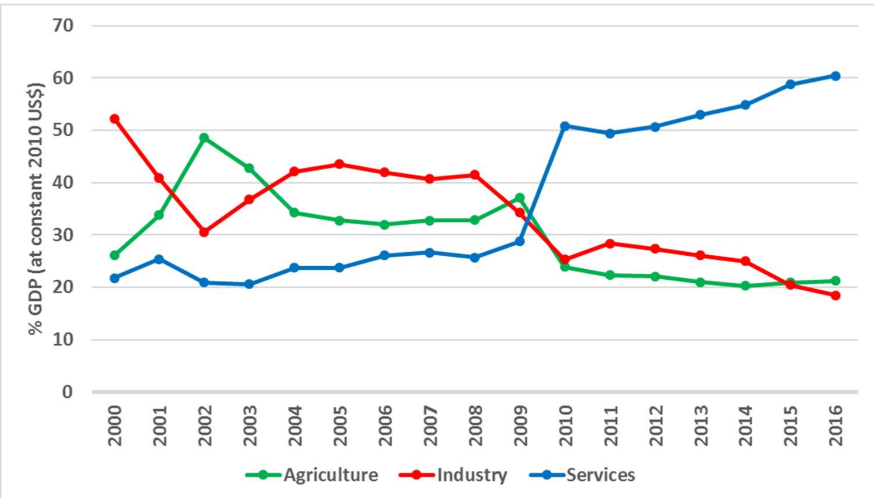


Figure 1.10 - Evolution of GDP by main economic engine and GDP growth of Nigeria (2000 - 2016)

A sectoral analysis shows that within the whole economy, it was the oil sector which regressed most. However, despite this regression, Nigeria remains heavily dependent on oil revenues since, in recent years, oil and gas have accounted for more than 90% of the country's exports and more than 70% of consolidated budgetary revenue. Hence, while the oil sector contributes less than 15% to total GDP and despite the contraction of that sector, inflows from oil sales still play a significant role in the economy and have helped bolster domestic demand, thereby driving economic growth (World Bank Group, 2015).

On the other hand, the other sectors of the economy have exhibited relatively more resilience. Hence, over the last five years ending 2016, the agriculture sector grew on average by 4.3% and the services sector grew on average by 6.0% from 2012 to 2015 to regress only in 2016 by 0.8%. In 2016, the real contributions of the agriculture, industry and services sectors to national GDP were 24.4, 22.0 and 53.6% respectively. Trade, Information and Communications Technology, and real estate together accounted for around 70% of the output of the services sector.

1.12. Agriculture

Nigeria's Agriculture comprises crop production, livestock rearing, forestry and fishing. In 2016, the agriculture sector accounted for 21.2 % of GDP and employed 39.5 % of the labour force ((World Bank, 2018c)). However, it is often reported that as much as 70% of the labour force may be involved with agricultural activities to varying extents. Crop production is subdivided into subsistence and cash crops. The most important subsistence crops are maize, cassava, sorghum, yam, beans, rice, groundnut and to a lesser extent millet, soyabean and cocoyam. The main cash crops are palm oil, cotton seed, cocoa, cashew and sugarcane.

The livestock sector had an estimated 20.6 million heads of cattle in 2016 (FAO, 2018), the largest herd in Africa. During the same year, the rapidly growing poultry sector supplied an estimated 146 million birds while the number of goats and sheep amounted to 73.8 million and 42.1 million respectively (FAO, 2018).

The food security challenge in Nigeria is significant, not only because of the tremendous pressure from a population projected to be above 193 million individuals and growing at an estimated rate of 3.2% annually (NBS, 2018), but also because the agriculture sector can be significantly impacted by climate change. Depletion of water resources and unpredictable rainfall patterns are having a significant impact on production systems and in places leading to crop failures. Currently, Nigeria is major food importer; it is one of the world's largest importer of rice and a significant net importer of wheat, dairy products and horticultural crops.

Despite the challenges for the agriculture sector, there are also opportunities for economic development due to the potential for the agriculture sector to be highly productive. There are areas where land and water resources are currently underutilized, and production can be expanded in an environmentally sustainable manner with a climate smart approach, reducing GHG emissions compared to traditional agriculture. The foundations of a vibrant agricultural industry are in place with approximately 79 million ha of arable land, 214 billion m^3 of surface water and 87 billion m^3 groundwater both of which can partly be used for irrigation (FAO, 2016).

1.13. Human Health

Nigeria's health status indicators are still below country targets and international benchmarks (Nigeria. FMoH, 2010). Given the life expectancy at birth of 49 years, disability adjusted life expectancy at birth of 38.3 years, increasing vaccine-preventable diseases, high number of HIV infected persons (highest in Africa) and the very high tuberculosis burden (fourth in the world), the country's health status indicators are among the worst worldwide (Omoluabi, 2014 in Okafor, 2016). As at 2000, the performance of the country's overall health system was ranked 187th amongst 191-member States (WHO, 2008).

Although the last few years' health statistics in Nigeria pointed to poor health status indicators and many health-related socio-economic challenges, the recent developments in the health sector suggest measurable improvements. For instance, the Nigerian medical register indicated that the number of Medical Doctors increased persistently from 39,210 in 2005 to 52,408 and 55,376 in 2007 and 2008, respectively. This ranked Nigeria as having the largest stocks of human resources for health in Africa, comparable only to Egypt and South Africa (ADBG, 2013; Omoluabi, 2014). Also, there are significant declining trends in the country's four mortality indicators, namely infant, child, under-five and maternal mortality rates. As indicated by the 2013 National Demography Health Survey, infant and under-5 mortality rates declined by 26% and 31%, respectively over the last 15 years. These trends are expected to continue positively in the coming decades (Inter-Agency Regional Analysts Network, 2016). However, climate change could prove to be a driving factor impacting on future improvements of the health system since most of these diseases are vector- and water borne, the latter two factors possibly being exacerbated by climate change.

1.14. Transportation

Nigeria's passenger and freight transportation sectors comprise six modes, namely: Road, Rail, Pipelines, Water, Air, and Post and Courier Services (NBS, 2016). Road transport plays a dominant role, representing 86.35% of the sector's contribution to national GDP in 2016. It is the mainstay of Nigeria's transport network and the principal means for freight and passenger movements across the country. With an estimated 200,000 km of road network, the country's road network has been ranked the largest in West Africa and the second largest south of Sahara. This mode of transportation has become predominant due to the inadequacy of other forms of transportation and the collapse of the rail system since the 1970s/80s.

Presently, there are few areas of the country that are still not connected to the national main roads. These are mostly concentrated in the central, western and eastern parts. The regional connections are generally fair, with several transnational corridors such as those connecting the hinterlands of the neighbouring countries like Niger, Chad, Cameroon and Benin and connections along the coast to Dakar and Abidjan. There are also a few cross-African roads connecting Nigeria through the neighbouring countries to other African countries. These include the Trans-Sahara Highway to Algeria through Niger and the Lagos-Mombasa Highway, connecting Nigeria with Cameroon, the Central African Republic, the Democratic Republic of Congo, Uganda and Kenya (PricewaterhouseCoopers, 2013). Although the Federal roads account for only about 17% of the total national road network, they accommodate more than 80% of national vehicular and freight traffic.

The major ports in Nigeria are Apapa, Tin Can Island, Delta and Onne. The Apapa container terminal, the largest in West Africa and Tin Can Island ports together form the Lagos port complex serving the whole country. The Delta Port, located in the petroleum and natural gas producing Niger River Delta region and Onne Port, located about 19 km from the city of Port Harcourt serve the oil and gas sector. The latter has been designated as an Oil and Gas free zone by the Federal Government and it serves as a hub port for oil and gas operations throughout Western and Central Africa. Presently, the Federal Government of Nigeria is planning to construct two deep-water ports in Lekki near Lagos and Ibaka in Akwa Ibom, River State.

Nigeria's air transport services are predominantly passenger and mail. With four international and eighteen domestic airports and rapid expansion of the domestic network in the recent years, Nigeria's air market ranked second after South Africa in sub-Saharan Africa.

The rail network comprises 3,505 km of narrow gauge (1.067 m) single track, crossing south-west to north-east and south-east to north-west of the country. The existing network is largely a relic of colonial administration (Odeleye, 2000). Although the railway system was identified as the easiest and cheapest means of transportation for both freight and passengers, its neglect by successive governments, led to the collapse of the system. Presently, most of the railway network is dilapidated and largely out of use. With respect to investment and transformation, railway remains the most neglected of all transport modes in Nigeria (PricewaterhouseCoopers, 2013; Amba and Danladi, 2013).

1.15. Manufacturing

Prior to rebasing, Nigeria's manufacturing sector comprised three key activities, namely, Oil Refining, Cement and Other Manufacturing. After rebasing, the 'Other Manufacturing' category was broken down into eleven different activities. Thus, there are presently thirteen main activities in Nigeria's Manufacturing sector. In 2016, Manufacturing activities contributed ₦8,903 billion (8.8%) to national GDP. The three most important manufacturing activities in decreasing order of importance are Food, Beverage and Tobacco, Textile, Apparel and Footwear, and Cement. These together accounted for 76.1% of GDP from the manufacturing sector.

1.16. Energy

Nigeria is endowed with a large number of renewable and non-renewable energy resources in sizeable commercial quantities and in some of the best natural forms. The prominent renewable energy resources include sun, wind, hydro, biomass, and tidal wave while crude oil, coal, lignite, tar sands, natural gas, and nuclear elements constitute the major non-renewable energy resources.

1.16.1. Renewable Energy

Of all the renewable energy resources of Nigeria, solar appears to be the most promising one because the country is located within the heart of the tropical region where sunshine and solar radiation are very abundant and well distributed. Nigeria's average annual solar radiation ranges between 25.2 MJ/m^2/ day in the north and 12.6 MJ/m^2/day in the south. With an average sunshine duration of 6.5 hours per day, the available annual solar energy is about 27 times the country's total fossil fuel resources and over 115,000 times the electrical power generated (Augustine and Nnabuchi 2009; Emodi, 2016)

Hydro energy technology remains the dominant commercial renewable energy resource in Nigeria. The country's total hydropower potential stands at 14,750 MW, but only 1,930 MW (14 %) was tapped at Kanji, Shiroro, and Jebba, which represents about 30% of the gross installed grid-connected generation capacity in Nigeria (CBN 2005). There are also a good number of small hydropower generation. These were estimated to generate up to 3,500 MW, representing about 23 % of the entire national hydro power potential. However, only 5 % of these small hydropower capacities is being exploited, while the remaining sites are set aside for future development (Sambo, 2009b).

Nigeria's average wind speed falls within a moderate wind regime. Except for the coastal and offshore areas in the south and the north, the wind speed in the southern part of the country is relatively low (Vincent and Yusuf 2014). The total exploitable wind energy reserves at 10 m height vary from 8 MWh/year in Yola through 51 MWh/year in the mountainous area of the Jos plateau, to about 97 MWh/year in Sokoto. As at 2016, there were no commercial wind power plants connected to the national grid in the country and no significant progress are in the process to harness the potential of wind energy. The few existing power plants are those installed in the 1960s in five of the northern States and the ongoing installation of a 20 MW wind turbines in Katsina State. The progress in harnessing the potential of wind energy is too slow (Emodi, 2016).

The commonest form of biomass energy in Nigeria is fuelwood. It has been estimated that about 80 million m^3 of fuelwood are used annually for cooking and various other domestic purposes (Sambo, 2005). The increasing population and the concomitant increasing demand for wood for various purposes, especially in the furniture and construction industries, are severely depleting the country's woody biomass resources.

1.16.2. Non-renewable Energy

Nigeria has the second largest proven oil reserves in Africa after those of Libya. It has oil reserves of about 35 billion barrels and gas reserves of about 5 trillion m^3, ranking 10th and 9th in the world respectively. The oil fields are located in the south, in the Niger delta and offshore in the Gulf of Guinea. Current exploration activities are mostly found in the deep and ultra-deep offshore areas, with some activities in the Chad basin, located in the northeast of the country. Nigeria operates four oil refineries, namely: Port-Harcourt I, Port-Harcourt II, Warri, and Kaduna. The four refineries had a combined crude oil distillation capacity of 445,000 barrels per day, which exceeds domestic fuel demand, but significantly operating below this capacity because of operational failures, fires, and sabotage on the crude oil pipelines feeding the refineries. The resultant effects of these challenges are that the combined refinery utilization rate declined from 22% to 14.4% between 2013 and 2014 and the country resulted into importing petroleum products for domestic use. The country's petroleum product importation was 156,000 barrels per day in 2014. A significant amount of Nigeria's gross natural gas production is flared because some of Nigeria's oil fields lack the infrastructure needed to capture the natural gas produced with oil, known as associated gas.

By the end of 2011, Nigeria had 21 million tonnes of proven recoverable bituminous coal reserves, including anthracite (WEC, 2013). It is among the top 5 countries in Africa, by reserves, the others being South Africa, Zimbabwe, Mozambique and Tanzania.

The development and exploitation of these energy resources have been dominated by hydropower, petroleum and natural gas. The country has an untapped potential to produce 93,950 MW from carbon-emission-free energy sources from small and large hydroelectric power plants (68%), nuclear power (21%), solar and photovoltaic (7%) and onshore wind (2%) (Olaoye et al., 2016; United Nations Economic Commission for Africa, 2016).

Despite these huge energy endowments, the country is highly energy deficient in terms of its energy consumption needs (Tallapragada, 2009; CBN, 2014). The country was ranked 141st out of 148 countries in terms of the quality of electricity supply (The World Economic Forum's Global Competitiveness Report 2014-2015); 182nd out of 189 economies for ease of getting access to electricity; and at the top of the list of African countries with high numbers of power outages. The power outages have been estimated to cost the country about 3% of its GDP annually (African Development Bank Group, 2013).

Nigeria's electricity production has been characterised with low and unstable capacity utilisation and a large gap between installed and actual operational capacity (Iwayemi, 2008), with a total installed capacity of 12,522 MW (Advisory Power Team, 2015) but an available capacity of only about 4,500 MW (United Nations Economic Commission for Africa, 2016). The average generation capacity of electricity has been oscillating between 1,700 MW/hr in 2001 and 4,500 MW/hr in 2014 against the estimated demand of 10,000 MW per day. Thus, in spite of Nigeria's huge energy resources, about 50% of the population depends on traditional biomass for their energy needs while electricity, and oil and gas provide only a small fraction of the energy use of the rural poor. On average, only 45% of the population had access to electricity (IEA, 2016). In a bid to meeting off-grid heating and cooking needs in the rural communities, most people resulted into using traditional biomass and waste. For instance, in 2014, up to 76% of Nigeria's population still relied on traditional biomass and waste, typically consisting of wood, charcoal, manure and crop residues (IEA, 2016; United Nations Economic Commission for Africa, 2016).

Table 1.1 - 2012 Energy Basket of Nigeria in ktoe on Net Calorific Value Basis

	Coal	Crude Oil	Oil products	Gas	Hydro	Biomass	Elect	Balances
Production	30	129,409	-	33,645	487	108,142	2,469	274,182
Imports	-	-	8,440	-	-	-	-	8,440
Export	-	126,413	755	21,032	-	-	309	148,509
Domestic Consumption	30	2,996	7,685	12,613	487	108,142	2,160	134,113

Source: International Energy Agency (2015)

1.17. Mining & Quarrying

Nigeria's mining & quarrying sector comprises four major areas: crude oil and natural gas, coal, metal ore and quarrying of other minerals (The World Bank, 2016).

The country is endowed with a large number of mineral deposits including crude oil, gas, gold, barite, bentonite, limestone, coal, bitumen, lead, zinc, tin, columbite, tantalite, wolfram, kaolin, clay, shale, marble, radio-active minerals, bartyles, cassiterite, gemstones, granite, gypsum, talc, iron ore, lithium, and silver. Seven of these minerals have been identified by the Ministry of Mines and Steel Development (MMSD as priority minerals to be focused for development, due to the commercial value of the estimated deposits and their capacity to accelerate overall economic development through industrial linkages. These are coal, bitumen, limestone, iron ore, barites, gold and lead/zinc. Except for crude oil and natural gas, most of the available mineral resources are unexploited, hence their limited contributions to the economy. The estimated proven reserves of some of these are 639 million MT of coal, 1.6 billion barrels of bitumen, 4.2 billion barrels of tar sands and heavy oil, 31 million m^3 of limestone, over 600,000 ounces of high quality gold and 5 million MT of lead and zinc reserves (KPMG, 2017). Despite Nigeria's large number of mineral deposits, its mining & quarrying sectors (excluding oil and gas) were ranked among those with the lowest outputs in the national economy. The sector's contributions to GDP have been on the decline from 1980 to 2015.

1.18. Education Sector

The Nigerian education system comprises three tiers: basic education, post-basic/senior secondary education, and tertiary education. As entrenched in the 2004 Nigeria's National Policy on Education, the basic education encompasses compulsory six years of elementary and three years of junior secondary education. Beyond this however, Early childhood Care and Development (or pre-primary education), which is designed for younger children who are not yet of primary school age; and Nomadic education, which is intended for special groups of migrants are also viewed as part of basic education. Adult and non-formal education partly belongs to the basic education and partly, post-basic education (FGN, 2009; International Organization for Migration, 2014). The post-basic education, of a duration of 3 years, is designed to prepare students for entry in tertiary education or to groom them to join the labour market. The tertiary sector as a whole offers opportunities for undergraduate, graduate, and vocational and technical education. The basic function of the Polytechnics is to train middle-level technical manpower, while the Colleges of education are designed to produce middle manpower in teacher education (International Organization for Migration, 2014; NEFARR, 2015; WES Staff, 2017).

By 2010, there were 7,104 secondary schools with 4,448,981 students and a teacher-pupil ratio of approximately 32:1. As at the end of 2013 the country had 40 Federal, 39 State and 50 private universities; and 21 Federal, 43 State-owned and 24 privately-owned colleges of education. Although available statistics indicated a significant growth in the number of the various institutions in recent years, the country is far from meeting the demand for tertiary education (Aremu, 2014). For instance, during the same year, the combined capacity of the Nigerian tertiary institutions to admit students was estimated to be less than 400,000, but about 1.7 million candidates registered for its centralized tertiary admissions examinations, implying that more that 75% of the candidates will be left without a post-secondary education that year (IOM, 2014). Although the successive Governments made frantic efforts to provide more schools and universities to keep pace with the country's exponential population increase, the available statistics indicated that the education sector is among the worst in the world.

1.19. Demography

Nigeria's population has shown spectacular growth over time. According to the World Bank estimates, the population of 52.47 million in 1967 reached 186.99 million in 2016 (Figure 1.11). In 2015, Nigeria had the seventh largest population in the world and its growth rate was also one of the highest. The population is projected to exceed that of the United States somewhere around 2050 making it the country with the third largest population in the world (United Nations, 2015). The two main factors of this phenomenal growth are young age structure with more than two-fifths of the population (42.8%) falling below 15 years and persistent high fertility rate of 5.7 children per woman. Additionally, the death and childhood mortality rates are decreasing. With more than 40% of the population below 15 years, and its growth rate of 3.2%, the population could double by 2035.

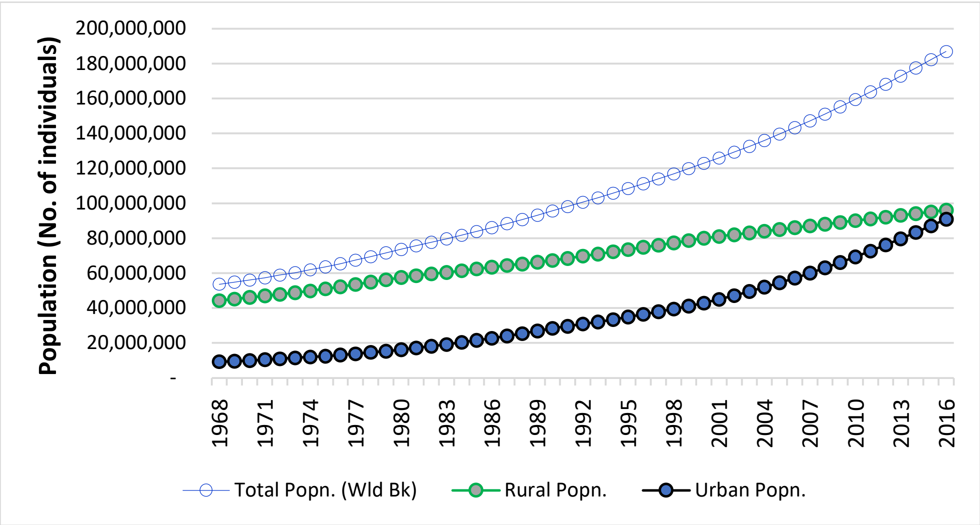


Figure 1.11- Evolution of the population of Nigeria

Source: World Bank

1.20. Environmental Challenges

1.20.1. Pollution

Environmental pollution encompassing air, water, land, noise and light is growing, especially around large human settlements and in mining areas. Industries were the major sources of pollutants in the 1980s and 1990s when well over 5,000 industrial facilities and 10,000 small scale industries were in operation. Many of these industries have collapsed but this sector remains an important source of pollution.

Other contributing factors are rapid population growth and urbanization with their impacts, large and growing number of vehicles with aging engines, cluttered road arteries that causes extended running of vehicle engines, mining activities, use of agrochemicals and poor institutional, logistic and policy frameworks. With respect to air, Nigerians suffer some of the highest level of pollution in the world even in the rural environment. In the rural areas, mining and bush burning are the key resulting factors as well as pollution stemming from vehicular use, domestic energy consumption and industrial activities. In 2015, 94% of the population was exposed to air pollution levels measured in Particulate Matter (PM) that exceeded the 2.5 levels specified by WHO guidelines. Major cities such as Lagos, Onitsha, Aba and Abuja have some of the highest perceived values. If the trend is on the increase which is most likely the case, the PM levels must be growing. The day and night time noise levels in many parts of the country are far higher than the recommended levels for human safety. For example, many parts of Abuja had unsatisfactory levels of noise ranging from 73 to 92 dB in 2015 (Ibekwe et al., 2016). These are far higher than the highest level of 60dB recommended for industrial areas (FGN, 2009). The situation in Lagos is not by any means different (Shabi, 2016) and indeed in many other cities in the country. Water quality, even from underground, is worsening as we tamper more and more with the various sources of water. Water indices such as pH, BOD, nitrate and phosphate have increased significantly compared with levels recorded previously (FGN, 2010). Oil spills from leaking underground pipelines and storage tanks are regular occurrences, rendering water bodies unfit for human use according to the National Oil Spill Detection and Response Agency. Light pollution is also a problem in the Niger delta where the occurrence of gas flaring subjects the living organisms around the vicinity of the flare to 24-hour daylight. Thus, environmental pollution must be a front-line issue to make Nigeria's environment suitable for sustainable development.

1.20.2. Land Degradation

Land degradation is an increasingly critical environmental challenge in Nigeria and is adversely impacting on agronomic productivity and the environment, including biodiversity, food security and overall quality of life. Large areas of the country's arable land are continually being impoverished through overuse, poor land use practices, urbanization, rapid deforestation and de-vegetation resulting from multiple uses of forest resources (e.g. fuel wood and energy, housing). For instance, there is an increasing number of devastating gullies, with multiple fingers all over the country's landscape. In the south eastern states, there are particularly spectacular gullies which have increased from about 1.33% (1,021 km^2) in 1976 to about 3.7% (2,820 km^2) in 2006. These gullies have destroyed vast areas of land in Nanka, Agulu and Oko in Anambra State, Okigwe in Imo State, and parts of Abia, Enugu, and Ebonyi States (FME 2016).

Although specific national statistics on the extent and dynamics of the degradation is sketchy, the global figure provided by UNCCD (2013) which indicates that close to 70% of the productive lands in Africa are already degraded, gives a glimpse of the severity of the problem in the country. Given that land is an essential resource for farming, the impacts of land degradation and the depletion of soil resources have profound economic implications for the country. The country must address this challenge as it will be on top of the growing impacts of climate change.

1.20.3. Waste

The US Environmental Protection Agency (EPA) (2015) recognizes 20 classes of waste, ranging from those emanating from mining and related activities to those associated with agricultural activities or of municipal origin. Virtually all these classes of waste, including e-wastes, are abundant in Nigeria and they are demanding for serious actions to limit their growing deleterious impacts (arising from poor management) on the physical, social and economic environments. Of all these categories, municipal wastes take the fore in Nigeria and they are most visible in the country's urban spaces. Urban wastes originate from three major sources: residential, commercial and industrial. Sometimes, institutional wastes are separated from commercial sources and give thus a fourth source.

The amount of waste generated and the challenges of managing them sustainably have remained critical issues for a long time (Adebilu and Okenkule, 1989). Although figures relating to the quantities of municipal wastes generated in the country are not well known, it is estimated that about 63 million tonnes (0.45 tonne/capita/annum) are generated annually (FGN, 2010). More specific data for Lagos State underscore the amount of waste generated and the disposal challenges. For Lagos State, the volume of waste generated per day was 9,000 tonnes in 2008, rising to 12,000 in 2012 and 13,000 by 2015 (Lagos State Waste Management Agency, 2016). Population growth and urbanization are the major factors behind this increase in waste generation. Unfortunately, disposal resources and strategies are not matching this situation, resulting in illegal dump sites thriving with many of the official dumpsites remaining permanently full. The trends observable in Lagos are noticeable elsewhere in the country and it is reasonable to project that although the quantity of waste produced in other urban areas would be less than that of Lagos, they must be increasing.

1.20.4. Desertification

Desertification, which is associated with the degradation of lands in arid, semi-arid and sub-humid dry areas, is due to climatic variations and change, as well as a wide range of human activities that impact negatively on the vegetation cover (UNCCD, 1992). More specific factors include declining rainfall, rising temperatures and therefore a negative Standardized Precipitation Index (SPI); growing human exploitation such as expanding agriculture and increasing livestock populations, meaning higher demand and intensity of grazing, poor irrigation and detrimental management practices, as well as poverty. The desertification process involves a gradual shift in vegetation from grasses, bushes and occasional trees, to grass and bush and in the final stages, extensive areas of sand. The movement of sand which is characteristic of tropical arid environment has become a common feature in desertification frontline States such as Sokoto, Kebbi, Jigawa, Borno, and Yobe.

Desertification has long been a challenge in northern Nigeria specifically along the Sudano-Sahelian belt. As vulnerable as it is, the zone has a high carrying capacity and is home to over a quarter of Nigeria's population. It supports about 90 % of the cattle population, about two-thirds of the goats and sheep and almost all the donkeys, camels and horses found in the country. The zone has also played a dominant role in the agricultural modernization of the country, promotion of export crops such as cotton, groundnuts, gum arabic and of food crops, and most specially, in the production of import substitution crops such as rice and wheat. The challenge of desertification rose into a noticeable dimension during the severe drought of 1972-1973 in the Sudano-Sahelian areas of West Africa which led to a catastrophic loss of human life and livestock. Since then, desertification has remained a major concern for the socio-economic development of Nigeria and is reaching a catastrophic dimension as close to 50% of the land of the region is threatened. Although statistics on the rate of the southward expansion of the phenomenon are uncertain, the expansion of desert like conditions is palpable. It is not unlikely that the rise in conflicts between herdsmen and farmers in recent times is an outcome of the desertification process.

1.20.5. Mining Issues

Modern mining in Nigeria began during the colonial era. Oil was struck in commercial quantities at Oloibiri in 1956 and exploitation has continued since then. Mining of tin and columbite in northern Nigeria, around Kano in particular, started before the 1880s. In the early 1900s large deposits were located around the Bauchi Plateau increasing the exploitation of this mineral in the country (Hodder, 1959). Since then, the mining of these and other minerals have expanded at varying scales with growing negative impacts on the environment. As from the 1960s the country shifted attention to crude oil and gas which brought significantly huge foreign exchange earnings to the country. The emphasis on crude oil has led to near-irreversible negative environmental impacts in many parts of the Niger Delta, and is attracting considerable interest from the government, especially to assuage the feeling of neglect by the inhabitants of the area. The effect of exploiting other minerals is also considerable. For example, unproductive lands created by mining, especially of tin and columbite, dominate the landscape in Jos plateau. The growing demand for cement is also taking its toll on the environment of the country. Limestone is found in large deposits in various parts of the country and virtually every large deposit supports a cement factory.

An important aspect of mining which has exacerbated the situation is the “take over” of the solid mineral sector by artisanal miners because of its near abandonment by government over the years. Artisanal mining can even be more destructive to the environment because it is normally not based on any Environmental Impact Assessment and the crude methods used by miners expose them to health dangers and cause varying levels of damages to the environment (Figure 1.12) (Kendall, 2013; Adesina and Odekunle, 2017).

Figure 1.12 - Land degradation due to gold mining

Source : http://thenationonlineng.net/the-doom-behind-the-glitter/

1.21. Safe Water and Sanitation

Adequate drinking water, sanitation and hygiene are essential to ensure human health. Water and sanitation are central to human needs, equitable growth and development, and affect every sector of the economy. Promoting access to these brings economic gains and help build resilience to the growing impact of climate change and variability.

Nigeria remains one of the poorest countries in the world when it comes to access to safe water and sanitation. It is third, after India and China, on the list of the top 10 countries with the most urban dwellers without safe, private toilets (by numbers) (UNICEF sponsored Water and Sanitation Summary Sheet for Nigeria, 2013). Nigeria is ranked third and tenth on the lists of countries with the largest number and highest percentage respectively of urban dwellers practicing open defecation. The economic impact of poor sanitation and hygiene costs the Nigerian economy the equivalent of almost 1.3% of its GDP. The situation has remained critical since 1990 and is even getting worse for sanitation. Between 2000 and 2015, there has been a significant increase in the number of urbanites without improved sanitation (nearly

31.5 million people). Clearly, access to safe water and sanitation remains a most critical environmental challenge in Nigeria.

In the year 2000, only about 50% of the urban and 20% of the semi-urban population had access to reliable water supply of acceptable quality (i.e. something better than a traditional source). Overall effective urban water supply coverage may be as low as 30% of the total population due to poor maintenance and unreliability of supplies. Rural coverage is estimated at 35%. As at 2013, about 70 million people, out of a population of 171 million, lacked access to safe drinking water, and over 110 million lacked access to improved sanitation (UNICEF, 2013). Open defecation rate, at 28.5%, poses grave public health risks. Many schools in the country lack safe private toilets and hand-washing facilities. This affects enrolment and performance, particularly in the case of girls. The impact of water, hygiene and sanitation falls disproportionately on women and girls, the main carriers of waters.

1.22. Biodiversity

In Nigeria, as in other countries, biodiversity plays an important role in the supply of food, raw materials, goods and services and provides materials, for agricultural, medicinal, socio-economic, aesthetic and cultural uses among others. Biodiversity is the base of livelihoods and economy for a large proportion of people in the country especially in the rural areas. It has produced a large network of market interactions and continues to provide employment opportunities for about a fifth of Nigeria's population. Biodiversity also has impacts on watershed protection and sustains the drainage systems and their associated wetlands as well as floodplains. Biodiversity is at the heart of Nigeria's unique culture, heritage, arts and crafts. For instance, it is this aspect that has led to the listing of Osun-Osogbo grove in Osun State as a UNESCO World Heritage site in 2005 (http://whc.unesco.org/en/list/1118) .

As significant as biodiversity is, Nigeria has over the years been degrading its stock. This is closely linked to deforestation, de-vegetation and degradation/over-exploitation of land, fresh and saltwater resources. These phenomena as earlier indicated are intensifying. Substantial areas of Nigeria's original forest has disappeared and the area occupied by forests is estimated to be at around 14% in 2016. According to the IUCN Red list 2013, Nigeria has a total of 309 threatened species in the following taxonomic categories: mammals (26), birds (19), reptiles (8), amphibians (13), fishes (60), molluscs (1), other invertebrates (14) and plants (168) (Sedghi, 2013). Furthermore, a National Assessment in 2012 (NCF, 2012) pointed to the reality of high rising and worrying increase in biodiversity loss in Nigeria.

1.23. Socio-political challenges

Nigeria has to face several socio-political challenges, the most important ones being:

- Terrorism / Extremism (Boko Haram)
- The Niger Delta militancy
- Ethnic and religious clashes
- Kidnapping
- Corruption

These issues have been ascribed to many more complex causes, among which, the country's colonial legacy, poor governance, international intrigue, poverty, cultural, ethnic and religious conflicts. These problems reach such proportions as to bring Nigeria at the fringe of instability and liable to fracturing.

However, the root cause for these and other problems may be the result of the political economy of Nigeria. The political economy of a country refers to the way in which politics, economics, and culture are strong interrelated influencers. Hence, the term “political economy” is concerned with the “interconnection of economic and political structures in social formation”.

Under conditions of robust equitable per capita economic growth, intrastate political and social rivalries are rare or can be ignored so as to not upset the shared benefits of growth. However, when relative standards of living decline or are inequitable, conditions often deteriorate, and problems manifest themselves as political or cultural cleavages arise due to competition for rare or diminishing economic gains. This is the present conundrum of Nigeria whose economy, for most of its history, has woefully underperformed, with the resulting expected competition along a variety of traditional and modern self-interest groups.

Analysis of the 2010 communal clashes by a Nigerian professor in the chronically violence-prone central city of Jos pointed to a combination of political economic factors, including social apathy, economic deprivation, and political frustration, all resulting from the failure of good governance and the exhibition of a very serious economic problem. As a result, and as is often the case amid serious economic crisis, people often lose sight of the real problem to exploit the most visible difference between groups, in the case of Jos, the religious difference. For example, Nigeria’s frequent and bloody turmoil throughout its history is often a result of manipulated groups clashing for a bigger share of an inadequately sized pie.

This poor record of economic development in Nigeria, despite its potential, is in large part due to two political economic causes which explain why economic policies have not fared better. The first is the inability of its leaders to promote a unified nation out of the “fragmented geographic and ethnic components”. The second is the unstable government structure from colonial to alternating elected and authoritarian regimes, with numerous military coups and different forms of governments. Nigerians did not possess a strong sense of unity before or during the colonial period, which discouraged a sense of nationhood. Economic development was also not seriously stressed in colonial times, beyond infrastructure development needed to exploit native resources and markets for imperial interests. Since independence, demagogic politicians have sought to gain regional, ethnic, and confessional group support for their own interests and have severely divided Nigeria’s society and polity. Self-determination, a method used by minorities to mobilize themselves against the central authority and leverage their position for concessions, is a common tactic in Nigerian politics. Nigeria’s wealth continues to be a source of exploitation by its elite, often pitting groups against each other in pursuit of controlling national wealth. Thus, historic and modern economic, political, and social forces have influenced each other, resulting in a chronically weakened state.

The relevance of these socio-political challenges in the context of climate change resides in the fact that if no steps are taken to address both areas, they will have a mutually reinforcing effect. Hence, climate change may exacerbate the ill-effects of the socio-economic challenges, some of the most important ones being:

(i) Social, economic and political instability, leading to the risk of total fracture of the country’s social fabric,
(ii) Human suffering, including death, disease prevalence, displacement and modern-day slavery, and
(iii) Environmental degradation, which will weaken vital economic sectors of the economy such as agriculture and industry

2. National Greenhouse Gas Inventory

2.1. Introduction

In accordance with articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), which state that non-Annex I Parties should include information on a national inventory of anthropogenic emissions by source and absorption by sinks of all GHGs not controlled by the Montreal Protocol, within the limits of their possibilities, using in its preparation the comparable methodologies promoted and approved by the Conference of Parties, Nigeria has prepared and submitted three GHG inventories, two for the years 1994 and 2000 in its Initial and Second National Communications and a third one in its First Biennial Report, submitted in 2018.

The Federal Republic of Nigeria has prepared its fourth national inventory of GHGs within the framework of the preparation of its Third National Communication, in accordance with the UNFCCC guidelines for the preparation of national communications from non-Annex I Parties (Decision 17/CP.8).

2.2. National GHG Inventory Institutional Arrangement

The Department of Climate Change (DCC) of the Federal Ministry of Environment has the responsibility of Climate Change activities in the country. The mandate of the DCC is:

"To co-ordinate national implementation of the United Nation Framework Convention on Climate Change, its protocol and any other legally binding agreements for implementing climate change activities"1.

DCC's mission, as the country's focal point to the UNFCCC, is

> *"To regularly update information regarding national inventory of the Green House Gases, mitigation, and vulnerability and adaptation to satisfactorily provide a sustainable policy framework and enabling environment for the implementation of the UNFCCC and Kyoto Protocol and any other climate change guidelines, laws and control in Nigeria".*

In terms of the institutional setup, DCC is one of six technical departments in Nigeria's Federal Ministry of Environment. It has four divisions, each responsible for a major thematic area of climate change. One of these divisions is the GHG Division with which rest also the responsibility of producing the GHG inventories for reporting to the Convention. DCC is supported by the Inter-Ministerial Committee on Climate Change (ICCC) which it chairs.

As reported in the BUR1, Nigeria still lacks the appropriate institutional arrangements and GHG inventory management system for producing good quality GHG inventories, to properly track and report emissions in accordance with the Paris Agreement. Conscious of this commitment, Nigeria is further investing and developing these with the support of the UNFCCC, the Global Support Programme and international consultants to meet its reporting obligations. The GHG inventory Division has been strengthened with additional permanent staff and works closely with the four sectoral groups under the guidance of an international consultant in view of preparing the next inventory inhouse. Training of the working groups and the GHG Division staff is ongoing while the system is also being developed to centralize all GHG inventory work, including the database and archives. The institutional arrangements under development is pictured in Figure 2.1.

1 The GHG inventory cycle

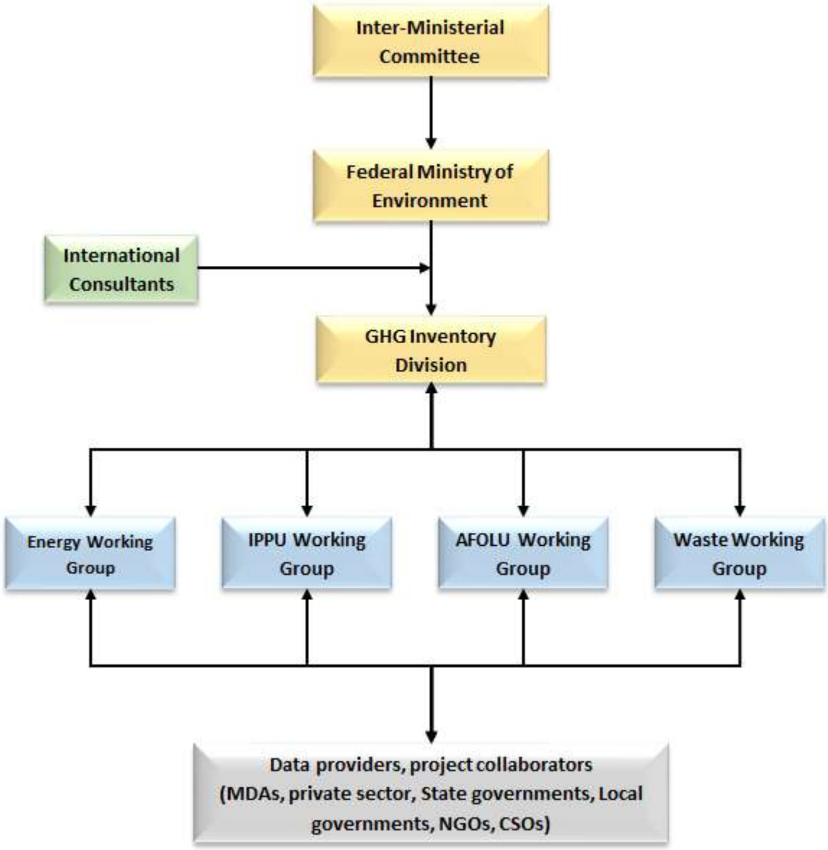


Figure 2.1 - Institutional arrangements for preparing GHG inventories

The compilation and production of a national GHG inventory requires the successful implementation of well-defined steps. Though Nigeria lacked a fully-fledged IMS and appropriate IAs, the inventory for the TNC offered the platform for implementing the steps of the inventory cycle. This was done within the existing IMS and IA, the objective being to enable the country implement fully the steps provided in Figure 2.2 for future compilations.

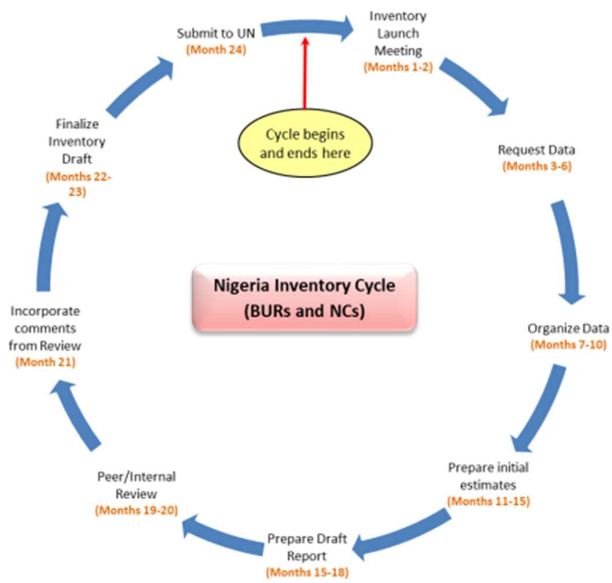


Figure 2.2 - The Inventory cycle of Nigeria for BURs and NCs

2.3. Overview of the inventory

2.3.1. Coverage

This GHG inventory covers the whole territory of the Federal Republic of Nigeria and estimates are computed at the national scale.

The national GHG inventory includes estimates for the four IPCC sectors, Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry and Other Land Use (AFOLU) and Waste. However, the categories and subcategories have not been exhausted due to lack of activity data in some cases. The level of details is provided under the completeness section of this report.

The GHG inventory addressed emissions of the direct GHGs carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Additionally, estimates of the GHG precursors NO_X, CO, NMVOCs, and SO_2 were possible with available activity data.

Estimates have been made for the year 2016. In line with the recommendation to provide a trend of estimates, the period 2000 to 2016 have been adopted. Furthermore, for the sake of consistency for reporting, estimates for the years 2000 to 2015 have been recalculated whenever required using the same methodology but to reflect improved activity data or emission factors as appropriate.

Global Warming Potentials (GWPs) adopted for uniformizing emissions of all GHGs in CO_2 equivalent are those from the IPCC Second Assessment Report (SAR). The GWPs used in this report for the direct GHGs are:

CO_2 = 1	**CH_4 = 21**	**N_2O = 310**

2.3.2. Methods

Estimates of GHG emissions provided in this report have been compiled in line with the IPCC 2006 Guidelines for National GHG Inventories (IPCC 2007) and the IPCC Good Practice Guidance (GPG) and Uncertainty Management in National GHG Inventories (IPCC 2000). The purpose of adopting these guidelines and GPG is to ensure that the GHG emission estimates are Transparent, Accurate, Complete, Consistent and Comparable (TACCC).

Selection of the Tier level was guided by the general decision-tree reproduced in Figure 2.3 and category specific decision trees provided in the Guidelines. Generally, the selection of the Tier level for all sectors was constrained by the availability of disaggregated activity data (e.g. facility level data) and national emission factors. This led to the adoption of the tier 1 level for all categories estimated. National activity data was complemented with those available in international databases and default emission factors (EFs) were used. Detailed descriptions of the methods adopted for each sector, including activity data and EFs adopted, are provided in the relevant sections of this report.

2.3.3. Completeness

A source category analysis was conducted to identify activities in the four IPCC sectors responsible for emissions and sinks within the economy, the objective being to be as exhaustive as possible in the coverage. Results of the GHG inventory of the BUR1, availability of resources, existing capacity and availability of activity data dictated the choice of source categories to be included for compilation. A prioritization exercise was conducted, and the highest emitting source categories were privileged. The completeness results (Table 2.1) presents the coverage and exhaustivity of this inventory. In order to simplify the completeness table, the sub-categories within a category where activities are not occurring in the country have not been spelt out fully but kept rather at the category level only.

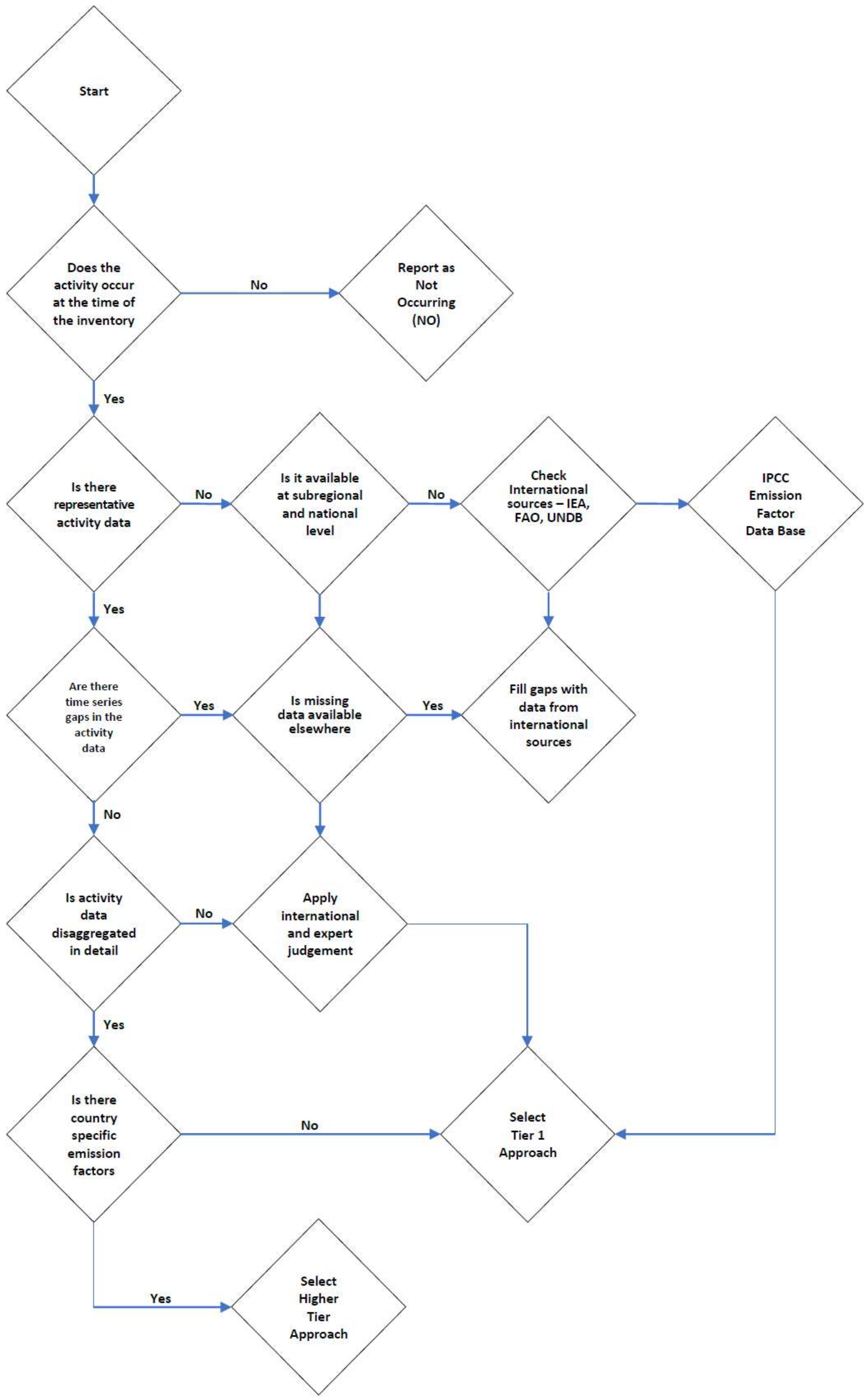


Figure 2.3 - Decision tree used to determine Tier Level method

Table 2.1 - Completeness of the GHG inventory

Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
Total National Emissions and Removals	X	X	X	NE	NE	NE	NE	NE	X	X	X	X
1 - Energy	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A - Fuel Combustion Activities	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.1 - Energy Industries	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.2 - Manufacturing Industries and Construction	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.3 - Transport	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.4 - Other Sectors	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.5 - Non-Specified	NE	NE	NE	NA	NA	NA	NA	NA	NE	NE	NE	NE
1.B - Fugitive emissions from fuels	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.B.1 - Solid Fuels	NO	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NO
1.B.2 - Oil and Natural Gas	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.B.3 - Other emissions from Energy Production	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NA
1.C - Carbon dioxide Transport and Storage	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.C.1 - Transport of CO_2	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.C.2 - Injection and Storage	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1.C.3 - Other	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2 - Industrial Processes and Product Use	X	X	NE	NE	NE	NE	NE	NE	X	X	X	NE
2.A - Mineral Industry	X	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.A.1 - Cement production	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.2 - Lime production	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.3 - Glass Production	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.4 - Other Process Uses of Carbonates	NO	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.A.5 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B - Chemical Industry	X	NO	NE	NO	NO	NO	NO	NO	X	X	NO	NO
2.B.1 - Ammonia Production	X	NA	NA	NA	NA	NA	NA	NA	X	X	NO	NO
2.B.2 - Nitric Acid Production	NA	NA	NE	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.B.3 - Adipic Acid Production	NA	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production	NA	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.5 - Carbide Production	NO	NO	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.6 - Titanium Dioxide Production	NO	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO

Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
2.B.7 - Soda Ash Production	NO	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.8 - Petrochemical and Carbon Black Production	NO	NO	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.B.9 - Fluorochemical Production	NA	NA	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.B.10 - Other (Please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.C - Metal Industry	X	X	NO	NO	NO	NO	NO	NO	NO	NO	X	NO
2.C.1 - Iron and Steel Production	X	X	NA	NA	NA	NA	NA	NA	NO	NO	X	NO
2.C.2 - Ferroalloys Production	NO	NO	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.C.3 - Aluminium production	NO	NA	NA	NA	NO	NA	NA	NO	NO	NO	NO	NO
2.C.4 - Magnesium production	NO	NA	NA	NA	NA	NO	NA	NO	NO	NO	NO	NO
2.C.5 - Lead Production	NO	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.C.6 - Zinc Production	NO	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.C.7 - Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.D - Non-Energy Products from Fuels and Solvent Use	NE	NO	NO	NA	NA	NA	NA	NA	NO	NO	NE	NO
2.D.1 - Lubricant Use	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.D.2 - Paraffin Wax Use	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.D.3 - Solvent Use	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NE	NA
2.D.4 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA	NA	NA
2.E.1 - Integrated Circuit or Semiconductor	NA	NA	NA	NO	NO	NO	NO	NO	NA	NA	NA	NA
2.E.2 - TFT Flat Panel Display	NA	NA	NA	NA	NO	NO	NO	NO	NA	NA	NA	NA
2.E.3 - Photovoltaics	NA	NA	NA	NA	NO	NA	NA	NO	NA	NA	NA	NA
2.E.4 - Heat Transfer Fluid	NA	NA	NA	NA	NO	NA	NA	NO	NA	NA	NA	NA
2.E.5 - Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA	NA	NA
2.F - Product Uses as Substitutes for Ozone Depleting Substances	NA	NA	NA	NE	NE	NA	NA	NA	NA	NA	NA	NA
2.F.1 - Refrigeration and Air Conditioning	NA	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA
2.F.2 - Foam Blowing Agents	NA	NA	NA	NO	NA	NA	NA	NA	NA	NA	NA	NA
2.F.3 - Fire Protection	NA	NA	NA	NE	NE	NA	NA	NA	NA	NA	NA	NA
2.F.4 - Aerosols	NA	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA
2.F.5 - Solvents	NA	NA	NA	NE	NE	NA	NA	NA	NA	NA	NA	NA
2.F.6 - Other Applications (please specify)	NA	NA	NA	NO	NO	NA	NA	NA	NA	NA	NA	NA
2.G - Other Product Manufacture and Use	NO	NO	NE	NO	NE	NE	NO	NE	NA	NA	NA	NA

Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
2.G.1 - Electrical Equipment	NA	NA	NA	NA	NE	NE	NA	NE	NA	NA	NA	NA
2.G.2 - SF_6 and PFCs from Other Product Uses	NA	NA	NA	NA	NE	NE	NA	NE	NA	NA	NA	NA
2.G.3 - N_2O from Product Uses	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.G.4 - Other (Please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA	NA	NA
2.H - Other	NE	NE	NO	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.H.1 - Pulp and Paper Industry	NE	NE	NA	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.H.2 - Food and Beverages Industry	NE	NE	NA	NA	NA	NA	NA	NA	NE	NE	NE	NE
2.H.3 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3 - Agriculture, Forestry, and Other Land Use	X	X	X	NA	NA	NA	NA	NA	X	X	NE	NO
3.A - Livestock	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NE	NA
3.A.1 - Enteric Fermentation	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.A.2 - Manure Management	NA	X	X	NA	NA	NA	NA	NA	NA	NA	NE	NA
3.B - Land	X	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.1 - Forest land	X	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.2 - Cropland	NE	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.3 - Grassland	NE	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.4 - Wetlands	NO	NA	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.5 - Settlements	NE	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.B.6 - Other Land	NE	NA	NA	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.C - Aggregate sources and non-CO_2 emissions sources on land	NE	X	X	NA	NA	NA	NA	NA	X	X	NA	NA
3.C.1 - Emissions from biomass burning	NA	X	X	NA	NA	NA	NA	NA	X	X	NA	NA
3.C.2 - Liming	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.3 - Urea application	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.4 - Direct N_2O Emissions from managed soils	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.5 - Indirect N_2O Emissions from managed soils	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.6 - Indirect N_2O Emissions from manure management	NA	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.7 - Rice cultivations	NA	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.C.8 - Other (please specify)	NA	NO	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.D - Other	X	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
3.D.1 - Harvested Wood Products	X	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.D.2 - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO

Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
4 - Waste	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
4.A - Solid Waste Disposal	NA	X	NO	NA	NA	NA	NA	NA	NO	NO	X	NA
4.B - Biological Treatment of Solid Waste	NA	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NA
4.C - Incineration and Open Burning of Waste	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
4.D - Wastewater Treatment and Discharge	NA	X	X	NA	NA	NA	NA	NA	NO	NO	X	NA
4.E - Other (please specify)	NO	NO	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
5 - Other	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO	NO
5.A - Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3	NA	NA	NE	NA	NA	NA	NA	NA	NA	NA	NA	NA
5.B - Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Memo Items (5)												
International Bunkers	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.3.a.i - International Aviation (International Bunkers)	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.3.d.i - International water-borne navigation (International bunkers)	X	X	X	NA	NA	NA	NA	NA	X	X	X	X
1.A.5.c - Multilateral Operations	NE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

"X " indicates that emissions/removals have been estimated, "NE" means Not Estimated, "NO" means Not Occurring, and "IE" means Included Elsewhere
“NA” means Not Applicable

2.3.4. Data Sources

The activity data used for this inventory were sourced from a combination of national and international institutions. During data collection, priority was given to data generated within the country. However, in cases where the required data was not available in the country, data from international databases of organizations such as IEA, United Nations, World Bank, USGS and FAO were used. Table 2.2 provides an overview of data sources used in the GHG estimation along with the data providers and sources.

Table 2.2 - Overview of Activity Data sources and providers

Sector/Source category	Data Type	Data Source	Data Providers
1 – Energy			
1.A.1 - Energy Industry	Oil & Gas Statistics	NNPC, DPR	
	Petroleum Products & Natural Gas Distribution/consumption	NNPC, ECN, IEA, NERC, NLPGA	
	National non-conventional energy consumption	ECN, UN Database, IEA	
2 - Industrial Processes and Product Use (IPPU)			
2.A - Mineral Industry			
2.A.1 - Cement Production	Annual production of cement	CMAN	CMAN
2.B - Chemical Industry			
2.B.1 - Ammonia Production	Annual ammonia production	NBS	NBS
2.C - Metal Industry			
2.C.1 - Iron and Steel Production	Annual production of Iron and Steel	NBS	NBS
3 - Agriculture, Forestry, and Other Land Use (AFOLU)			
3.A.1 - Enteric Fermentation	Average Annual Animal population	FAOSTAT	FAO
3.A.2 - Manure Management	Average Annual Animal population	FAOSTAT	FAO
3.C.1 - Emissions from biomass burning			
3.C.1.b - Biomass Burning in croplands	Actual mass of biomass burnt	FAOSTAT	FAO
3.C.1.c - Biomass Burning in grasslands	Actual mass burnt	FAOSTAT	FAO
4 – Waste			
4.A - Solid Waste Disposal	Annual Solid Wastes generated in metric tonnes	LAWMA, FMEnv, ECN, NBS	DCC
4.D - Wastewater Treatment and Discharge	Annual Wastewater collected in cubic metres	LSMEnv	LSWMO

2.3.5. QA/QC procedures

Given the lack of capacity, insufficient institutional arrangements and inexistence of a fully-fledged IMS, QA/QC mostly rested with the consultants allocated the contract for preparing the inventory. Due to the importance of having an appropriate QA/QC system, DCC started the development and implementation of such a system in line with the 2006 IPCC Guidelines for National GHG inventories. The staff of the GHG inventory Division and working groups members followed training and were initiated on performing QA/QC. DCC facilitated technical reviews and trainings with regard to the project.

Thus, DCC resorted to the collaboration of the UNFCCC to perform a full QA of the final inventory and the draft chapter of the TNC thereon with the support of the experts of the Global Support Programme of UNDP and the UN Environment, assisted by the international expert offering capacity building to the Nigeria GHG inventory experts. Recommendations made by the UNFCCC/GSP team were discussed and improvements brought in the final report of this TNC jointly by the sectoral inventory teams under the guidance of the international expert. Table 2.3 presents the general quality control procedures followed during the preparation of the final draft report.

2.3.5.1. General QC procedures

The QC procedures implemented by the consultants up to the production of the final draft report are given in Table 2.3.

Table 2.3 - General QC procedures followed

QC Activity	Procedures	Responsible Party
Check integrity of activity data source	• Ensured that all activity data were sourced from the database of national organizations primarily responsible for preparing and disseminating such information. • Ensured adequate documentation and archiving of database.	Inventory compilers and Database administrator
Check for correctness in parameters, units of activity data and conversion factors.	• Ensured correct labelling of units in calculation sheets • Ensured the correct conversion factors were used during activity data preparation. • Checked and documented unusual and unexplained trends noticed for activity data across the time series.	Inventory compilers
Check that assumptions and criteria for AD and Emission Factors selection are documented	• Cross-checked AD description for each category, eliminating all possible double counting. • Documenting information on estimations for all categories to ensure transparency.	Inventory compilers

The UNFCCC/GSP/International consultant performed a QC of the inventory, deeply scrutinizing the data quality and its consistency over the time series, comparing with international databases, appropriate units used and conversions made, identification of outliers and making proposals for their correction and correctness of data entry in the software. Recommendations were made and the working groups members agreed to implement them as far as possible under the guidance of the international expert when finalising the inventory for the TNC report.

2.3.6. General QA Procedures

Quality assurance review procedures for this inventory were conducted by personnel not directly involved in the inventory development process. Reviews were organized and coordinated by the DCC for QA, namely by an international consultant and the UNFCCC/GSP team. The exercise consisted in ascertaining that the proper choice of emission and stock factors have been done, workings done for correction of outliers are appropriate, best methods have been adopted to generate data for filling gaps, assumptions made suited the national context, data entered in software were in agreement with those reported, Key Category Analysis and Uncertainty assessments performed and reported correctly, factual reporting of results from software into report, recommended GWP adopted and reporting is transparent enough to allow reproduction of the inventory.

2.3.7. Uncertainty Assessment

Estimating Uncertainties is an important component of a GHG inventory. Estimating uncertainties attached to emissions provides crucial information on the categories to be prioritized for maximizing resource allocation to improve the quality of the inventory. Inventories prepared in accordance with the 2006 IPCC guidelines (IPCC, 2007) will typically contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data on emissions to order-of-magnitude estimates of highly variable emissions such as N_2O fluxes from soils and waterways.

For this Inventory, a Tier 1 uncertainty analysis of the aggregated figures as required by the 2006 IPCC Guidelines, Vol. 1 (IPCC, 2006) was performed. Based on the quality of the data and the default EFs used, uncertainty levels within the range recommended by the IPCC Guidelines were assigned for the two parameters and the combined uncertainty calculated using the IPCC 2006 software. Lower uncertainties were assigned to AD obtained from measurements made and recorded, higher values for interpolated and extrapolated AD and the highest ones prescribed in the IPCC range when the AD is subject to expert knowledge. Since default EFs have been used in the compilation of the inventory, the mid value recommended in the IPCC Guidelines were adopted for calculating uncertainties. In cases where IPCC recommended a particular methodology, the uncertainty level was derived according to the proposed procedure and used in the uncertainty analysis. The uncertainty analysis has been performed using the tool available within the IPCC 2006 Software. Uncertainties in total emissions based on the IPCC tool including emissions and removals from the Land sector is presented in Table 2.4. Uncertainty levels for the individual years of the period 2000 to 2016 varied from 9.17% to 21.16% while the trend assessment, when adding one successive year on the base year 2000 for the years 2001 to 2016, ranged from 11.95% to 14.52%. The full set of results from the software for the inventory year 2016 is given in Table 2.82 at the end of this chapter.

Table 2.4 - Overall uncertainty (%)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Annual	21.16	9.78	9.93	9.68	9.63	9.44	9.50	9.43	9.42
Trend (base year 2000)	-	11.95	12.10	12.25	12.40	12.59	12.74	12.89	13.06

Year	2009	2010	2011	2012	2013	2014	2015	2016
Annual	9.65	9.43	9.34	9.23	9.24	9.19	9.17	9.37
Trend (base year 2000)	13.22	13.41	13.57	13.72	13.91	14.18	14.38	14.52

2.3.8. Results

2.3.8.1. 2016 emissions

Total net national emissions (Table 2.5 and Figure 2.4) for the three direct GHGs, including removals, amounted to 609,783.8 Gg CO_2-eq from the four IPCC sectors. AFOLU headed the sectors with 366,733.9 Gg CO_2-eq (60.1%) of total aggregated emissions followed by Energy with 206,452 Gg CO_2-eq (33.9%), Waste 23,330.3 Gg CO_2-eq (3.8%) and the remaining 13,267.1 Gg CO_2-eq (2.2%) from IPPU. Regarding the direct GHGs, CO_2 was responsible for 72.9% of the emissions, CH_4 for 21.2% and N_2O for 5.8%.

On an individual gas basis, AFOLU was the major contributor for CO_2 and N_2O with 69.1% and 70.3% respectively while the Energy sector recorded highest CH_4 emissions with 61.0%. Energy emitted 62.6% NO_X, 74% CO and 53.2% SO_2. 77.8% of NMVOCs also came from the Energy sector.

The summaries and sectoral results from the software are given in the Annexes at the end of this report. It should be noted that the software output tables are presented as such without the notation keys as the process of inventory preparation is gaining in efficiency and will be further expanded in the future. Readers are referred to the completeness table (Table 2.1) which exhaustively detail the coverage of categories of the inventory.

Table 2.5 - National emissions for the year 2016

Categories	Net CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total (Gg CO_2-eq)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
Total National Emissions and Removals	444,668.7	6,170.4	114.6	609,783.8	756.1	13,875.9	2,107.0	121.4
1 - Energy	124,021.6	3,762.3	11.0	206,452.4	473.6	10,268.0	1,638.4	64.5
2 - IPPU	13,254.9	0.6	0.0	13,267.1	0.0	0.0	0.9	0.0
3 - AFOLU	307,320.4	1,640.0	80.6	366,733.9	0.2	5.9	0.0	0.0
4 - Waste	71.8	767.6	23.0	23,330.3	59.0	835.9	0.0	9.8
5 - Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Memo Items (5)								
1.A.3.a.i - International Aviation (International Bunkers) (1)	1,241.3	0.0	0.0		5.0	0.4	0.2	0.4
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	70.0	0.0	0.0		1.8	0.2	0.1	0.4

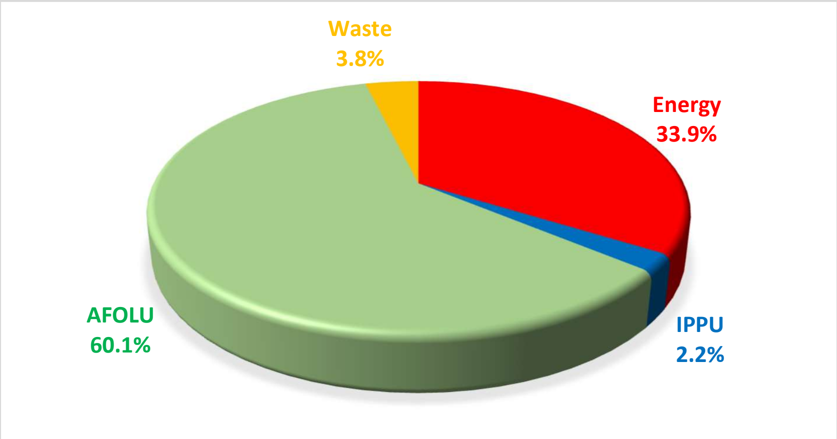


Figure 2.4 - Contribution of each IPCC Sector to National Total Emissions

2.3.8.2. Emissions Trends for the period 2000 - 2016

During the period 2000 to 2016, emissions of all GHGs and precursors as well as SO_2 increased. Total aggregated emissions of the direct GHGs increased by 45%. By gas, this increase is accounted for by 53% from CO_2, 18% from CH_4 and 58% from N_2O. Emissions of the GHG precursor NO_X progressed by 85%, CO by 39%, NMVOCs by 31% while SO_2 increased by 64%. The emissions for the time series are given in Table 2.6.

Table 2.6 - Trend of National aggregated and absolute emissions for the period 2000 - 2016

Year	Net CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)	Total (Gg CO_2-eq)	NO_x (Gg)	CO (Gg)	NMVOC (Gg)	SO_2 (Gg)
2000	289718.0	5223.7	72.7	109697.4	22522.3	421937.7	265.4	7590.2	1469.3	40.9
2001	305342.8	5479.2	76.8	115063.9	23794.7	444201.4	295.1	7906.5	1541.6	53.9
2002	311074.7	5036.7	77.4	105771.3	24007.8	440853.8	308.3	8121.1	1534.9	52.7
2003	325102.3	5512.0	78.8	115752.2	24427.3	465281.8	342.6	8249.9	1595.2	53.2
2004	328881.6	5874.5	80.7	123364.1	25031.7	477277.4	312.8	8322.6	1622.3	47.5
2005	349282.6	5963.0	85.0	125222.3	26356.4	500861.3	349.8	8479.9	1654.2	57.2
2006	351186.0	5912.2	86.6	124155.7	26844.6	502186.4	325.6	8554.7	1647.2	49.1
2007	361258.1	5808.6	87.7	121981.6	27173.8	510413.5	348.7	8829.1	1671.3	47.2
2008	373460.3	5694.0	89.8	119574.2	27834.7	520869.2	364.0	8900.5	1678.0	54.1
2009	369187.9	5529.7	91.9	116123.6	28479.4	513790.9	336.8	8866.9	1671.1	47.9
2010	380850.4	6221.5	95.8	130651.5	29688.8	541190.7	330.2	8067.1	1580.3	46.5
2011	388140.0	6296.3	101.2	132222.7	31357.8	551720.5	334.2	8154.1	1587.5	50.0
2012	397778.1	6442.0	104.5	135281.9	32380.1	565440.1	343.0	8256.5	1599.8	48.6
2013	416635.7	6230.1	108.5	130832.8	33625.9	581094.4	402.3	8952.1	1726.2	64.3
2014	437273.8	6386.4	110.2	134114.6	34157.4	605545.7	430.0	9206.4	1749.9	64.0
2015	450553.4	6523.9	109.4	137002.4	33904.4	621460.2	428.2	9224.4	1744.5	57.9
2016	444668.7	6170.4	114.6	129578.1	35537.0	609783.8	428.6	9231.2	1745.4	57.9

2.3.8.3. Emissions intensity

Per capita emissions of GHG varied between 3.26 and 3.59 tonnes CO_2-eq during the period 2000 to 2016 with a tendency for a marginal decrease (Figure 2.5). On the other hand, the GDP emissions index decreased steadily from 100 in the year 2000 to 46.7 in 2016 with sharp drops in 2004 and 2015 (Figure 2.5).

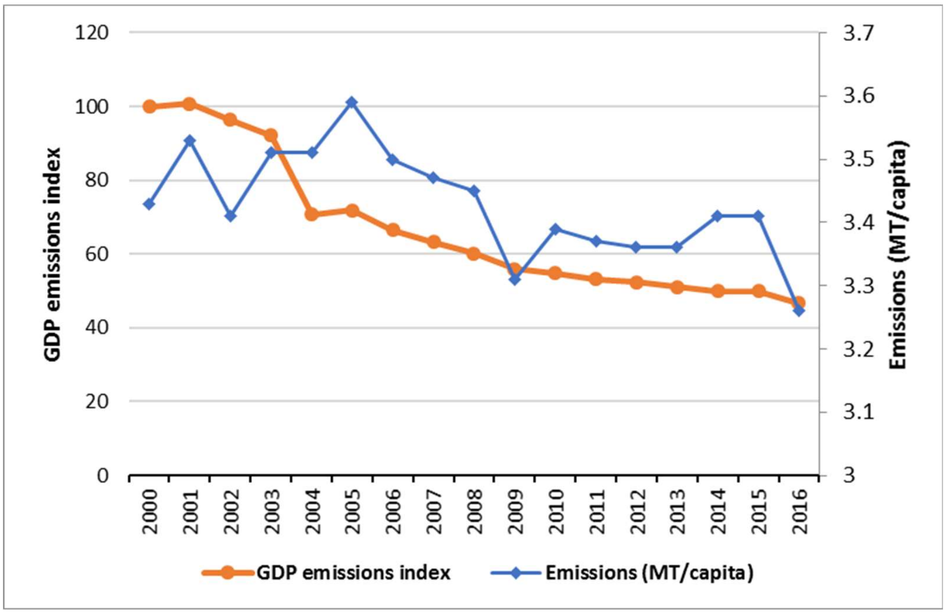


Figure 2.5 - GHG emissions and GDP emissions index

2.3.9. Key category analysis

The 2000 and 2003 IPCC Good Practice Guidance provides guidance on steps for the identification of key categories. The guidance explains the significance of key categories in influencing the country's total GHG inventory in terms of absolute levels of emissions or removals as well as the trend in emissions or removals. This compilation of the inventory utilizes the tier 1 level and trend assessments. The approach identifies GHG sources that cumulatively contribute to 95% of total emissions or trend of emissions in the inventory in absolute terms. The method used for the identification of key categories was the level assessment for 2016, and trend assessment for 2016 with respect to the 2000 base year. The results of the Key Category Analysis including the AFOLU sector for the Level and Trend assessments are presented in Tables 2.7 and 2.8 respectively,

For the level assessment for 2016, there are 15 key categories with Forestland Remaining Forestland identified as the most significant of the key categories (contributing about 50.39%) of national emissions in 2016. The remaining 14 key categories in descending order of importance in 2016 were Energy Industries-Gaseous fuels, Oil, Road Transportation, Enteric Fermentation, Natural gas, Direct N_2O Emissions from managed soils, Other sectors-liquid fuels, Wastewater Treatment and Discharge (CH_4), Other Sectors-Biomass, Manufacturing Industries and Construction – Gaseous Fuels, Cement production, Wastewater Treatment and Discharge (N_2O), Rice cultivations and Iron and Steel Production. The contribution of these categories along with the GHG concerned is given in Table 2.7.

Table 2.7 - Identified Key Categories using the Approach 1 Level Assessment

IPCC Category code	IPCC Category	Greenhouse gas	2016 Ex,t (Gg CO_2 eq)	|Ex,t| (Gg CO_2 eq)	Lx,t	Cumulative Total of Column F
3.B.1.a	Forest land Remaining Forest land	CO_2	311608.64	311608.64	50.39%	50.39%
1.A.1	Energy Industries - Gaseous Fuels	CO_2	53501.40	53501.40	8.65%	59.04%
1.B.2.a	Oil	CH_4	43940.55	43940.55	7.11%	66.15%
1.A.3.b	Road Transportation	CO_2	36112.99	36112.99	5.84%	71.99%
3.A.1	Enteric Fermentation	CH_4	26300.40	26300.40	4.25%	76.24%
1.B.2.b	Natural Gas	CH_4	22389.52	22389.52	3.62%	79.87%
3.C.4	Direct N_2O Emissions from managed soils	N_2O	17323.68	17323.68	2.80%	82.67%
1.A.4	Other Sectors - Liquid Fuels	CO_2	15611.85	15611.85	2.52%	85.19%
4.D	Wastewater Treatment and Discharge	CH_4	12437.50	12437.50	2.01%	87.20%
1.A.4	Other Sectors - Biomass	CH_4	12039.80	12039.80	1.95%	89.15%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	10677.45	10677.45	1.73%	90.88%
2.A.1	Cement production	CO_2	7083.35	7083.35	1.15%	92.02%
4.D	Wastewater Treatment and Discharge	N_2O	7016.25	7016.25	1.13%	93.16%
3.C.7	Rice cultivations	CH_4	6889.59	6889.59	1.11%	94.27%
2.C.1	Iron and Steel Production	CO_2	6169.86	6169.86	1.00%	95.27%

When considering the trend assessment, the sequence changes somewhat, and the number of categories decreased from 15 to 12. As well, the importance becomes more diluted with the category Forestland Remaining Forestland being still the main key category but with only 29.31% contribution. The next two categories of importance are Energy Industries – Gaseous Fuels with 21.86% and the Oil industry with 17.16%. The remaining key categories contributed between 7.62% and 0.75% as provided in Table 2.8.

Table 2.8 - Identified Key Categories using the Approach 1 - Trend Assessment

IPCC Category code	IPCC Category	GHG	2000 Year Estimate Ex0 (Gg CO_2 Eq)	2016 Year Estimate Ext (Gg CO_2 Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column
3.B.1.a	Forest land Remaining Forest land	CO_2	255877.229	311608.645	0.134	29.31%	29.31%
1.A.1	Energy Industries - Gaseous Fuels	CO_2	6999.193	53501.399	0.100	21.86%	51.17%
1.B.2.a	Oil	CH_4	53977.417	43940.551	0.079	17.16%	68.33%
1.A.3.b	Road Transportation	CO_2	14518.020	36112.995	0.035	7.62%	75.95%
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	1705.425	10677.450	0.019	4.14%	80.09%
1.A.4	Other Sectors - Liquid Fuels	CO_2	5423.615	15611.854	0.018	3.92%	84.01%
2.A.1	Cement production	CO_2	713.597	7083.348	0.014	3.05%	87.06%
1.B.2.b	Natural Gas	CH_4	12088.532	22389.523	0.011	2.48%	89.53%
2.C.1	Iron and Steel Production	CO_2	1791.026	6169.861	0.008	1.80%	91.34%
1.B.2.a	Oil	CO_2	5626.140	4580.303	0.008	1.79%	93.13%
1.A.4	Other Sectors - Biomass	CH_4	10032.154	12039.804	0.006	1.24%	94.37%
4.D	Wastewater Treatment and Discharge	N_2O	3819.075	7016.246	0.003	0.75%	95.12%

2.3.10. Constraints and Gaps

Several constraints and gaps were encountered during the preparation of this inventory, especially during data collection and estimation of GHGs for the various sectors. These gaps and constraints are listed below:

- First and foremost, as constraint is the lack of appropriate IAs and IMS which is being addressed presently.
- Lack of country-specific emission factors limited the inventory compilers to the use of Tier 1 method.
- Lack of disaggregated information in the Manufacturing Industries and Construction source category also dictated the inventory compilers to adopt the Tier 1 method.
- Lack of information on classification of vehicles by the recommended IPCC types and vehicle kilometres run annually restricted the inventory compilers to use the Tier 1 approach.
- Fugitive emissions from coal mining, processing, storage and transportation could not be estimated due to unavailability of relevant data.
- Emissions from fuels combusted for inland, coastal and deep-sea fishing could not be estimated due to lack of activity data.
- The NNPC and DPR Annual Statistical Bulletins, which were the primary sources of national activity data for the energy sector, did not provide information on importation of petroleum products by independent and major oil marketers for the years 2000-2009.
- The NNPC Annual Statistical Bulletins have no records on Aviation Turbine Kerosene (ATK) sales for international bunkers.
- Information on domestic utilization of natural gas for power generation and industrial use was only reported up to the year 2005 in the NNPC Annual Statistical Bulletins.

- All the source categories occurring in the country were not covered due to paucity of data. In some cases, estimates relied almost entirely on international databases such as in the AFOLU sector, where the FAOSTAT and USGS data were used.
- Lack of coordination among relevant agencies for waste management due to problems associated with the absence of archiving of relevant waste management data. While very limited data could only be obtained for the estimation of GHG emissions of municipal solid wastes, enormous data gaps exist in the waste water category, hence the high reliance on extrapolation to generate the data required for estimating emissions in the wastewater category.
- There were no alternative sources to verify activity data used for GHG emission estimates in the AFOLU sector. Therefore, the study could not determine the validity, authenticity and otherwise the correctness of the only source of the FAOSTAT dataset used.
- Lack of disaggregated activity data in all sectors prevented the compilers to move to higher tiers for estimating emissions in this inventory.
- Reliance on default emission factors (Tier 1) in all cases in this inventory may have contributed to lower accuracy of this inventory.
- Institutional arrangements for data collection, archiving, monitoring and reporting are weak.
- Activity data are in most cases scattered among various agencies which makes the collection difficult.
- Inability of the National Bureau of Statistics to carry out due quality checks on all data sent to it by all relevant agencies questions the reliability of activity data from this office.

2.3.11. National GHG Inventory Improvement Plan

Nigeria is committed to improve on its reporting and this has led to the creation of the DCC with a dedicated division for compiling the GHG inventory on a sustainable basis. The way is now paved for improvement in reporting, inclusive of proper tracking of emissions in all categories. However, the challenges are numerous and resource demanding. Nevertheless, Nigeria is committed and will invest to meet these challenges, counting on the support of the international community.

The salient features prioritized for improvement when compiling the next GHG inventory are:

- The DCC should implement a fully-fledged GHG IMS to sustainably prepare GHG inventories to report to and implement the Convention.
- The present IAs for compiling the GHG inventory should be further strengthened to smoothly implement the GHG IMS.
- The NBS in close collaboration with the DCC must develop a network for collecting appropriate activity data for the compilation of good quality future inventories.
- A functional QA/QC system must be made operational in the shortest timeframe to guarantee the quality of future inventories.
- Officers of the DCC and members of the sectoral working groups should be imparted adequate capacity to deliver to the required standards.
- Nigeria must develop national emission factors, namely for the key categories and enable adoption of higher Tier methods.
- The need to develop land use cover and change maps and overlay them with the climate and soil maps is most urgent to refine estimates in the FOLU category.
- Biomass stocks have to be assessed for use in the FOLU emissions assessment.

- Information on technologies used in manufacturing processes and in other emitting activity areas must be collected along with the appropriate activity data.

2.4. Energy Sector

2.4.1. Introduction

The process of fuel combustion to generate heat used directly or to produce energy to drive mechanical and electrical systems releases CO_2, other GHGs, GHG precursors, water and SO_2. Extraction of hydrocarbons, oil and gas also produce GHGs.

In Nigeria, fuel combustion activities and extraction of hydrocarbons are responsible for emissions of the Energy sector, the contribution coming from the following activities:

- Upstream exploration and exploitation of primary energy sources:
    - Emissions from burning of natural gas and fuel oils for steam and other extraction processes.
    - Fugitive emissions resulting from flaring during oil and gas production.
    - Fugitive emissions of methane during coal mining.
- Transformation of primary energy sources into more usable energy forms in refineries and power plants:
    - Emissions from flaring and fuel combustion in refineries and power plants for steam, heat for use in process units and electricity generation.
- Transmission and distribution of fuels:
    - Fuel combustion to generate electrical power for pipelines.
    - Fuel combustion in transport trucks/vessels.
    - Fugitive emissions during transmission and distribution.
- Use of fuels in stationary and mobile applications:
    - Fuel combustion in the transport sector.
    - On-site power generation plants.
    - Industrial use for heat generation and to power equipment.

Nigeria is a producer and exporter of crude oil, petroleum products and natural gas. However, in recent years, the country relied more on imports of petroleum products to meet its growing demand, especially with the low performance of the local refineries. The main secondary sources of liquid, biomass and gaseous fuels are diesel, gasoline, LPG, kerosene, AGO/Diesel, ATK, fuel wood, charcoal, bagasse, vegetal wastes, natural gas and household kerosene (HHK) amongst others. Natural gas is utilized for public power generation with diesel and Fuel Oil (FO) as back-up fuels as well as in industries for heat and own-use power generation. Transport fuels include gasoline & AGO/Diesel for road transportation, inland water navigation and railway, ATK for civil aviation and FO for international water navigation. Fuels consumed in the Commercial/Institutional and Residential sectors include HHK for cooking and lighting, LPG for cooking, gasoline and AGO/Diesel for auto-generation of electricity and other biomass fuels (fuel wood and charcoal). Table 2.9 presents the total consumption of primary and secondary fuels in the country for the period 2000-2016.

Table 2.9 - Total and share of Fuels consumed in Nigeria (2000-2016)

Year	Total (PJ)	% Share of Solid Fuel	% Share of Liquid Fuel	% Share of Gas	% Share of Biomass
2000	2333.90	0.02	13.62	7.06	79.30
2001	2547.13	0.09	17.39	8.81	73.71
2002	2637.91	0.15	16.51	11.12	72.21
2003	2756.85	0.06	19.13	10.61	70.20
2004	2811.33	0.05	15.32	14.74	69.89
2005	3121.82	0.05	15.15	20.77	64.03
2006	3160.65	0.01	12.40	23.28	64.31
2007	3353.73	0.02	11.48	25.94	62.56
2008	3505.01	0.03	12.79	26.73	60.45
2009	3377.56	0.03	12.30	24.55	63.12
2010	3551.67	0.03	10.77	27.67	61.53
2011	3670.21	0.02	10.89	28.13	60.96
2012	3806.83	0.03	10.19	29.17	60.60
2013	3982.06	0.03	19.31	22.70	57.96
2014	4229.75	0.04	19.82	25.72	54.42
2015	4443.15	0.03	16.72	30.66	52.59
2016	4317.03	0.04	18.10	26.99	54.88

2.4.2. Methodology

Emission estimates were computed using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2007) for fossil fuel combustion activities and for fugitive emissions. The IPCC Tier 1 Reference and Sectoral approaches were adopted as per the decision trees provided in Figures 2.1-2.4 of the guidelines (Vol 2 Energy, Chapter 1, page 1.7).

The Reference Approach is a Top-Down method which estimates net GHG emissions from combustion of primary and secondary fuels supplied to the economy while the Sectoral Approach is a Bottom-up method for a more accurate estimation of GHG emissions occurring in each source category from both fuel combustion and fugitive processes.

2.4.3. Methods - The IPCC Reference Approach

The Reference approach, which is a component in the recommended QA/QC procedures, was used to validate the Sectoral approach for the energy sector and involved the following steps:

- Estimation of apparent consumption of fuels by type in the country for the inventory years (2000-2016)
- Conversion of fuel amounts to energy units (TJ)
- Compute total carbon by multiplying apparent consumption by the respective carbon content of each fuel type
- Subtraction of stored carbon (excluded carbon) from fuel carbon
- Convert carbon burned to CO_2 emissions

The Reference Approach for estimating CO_2 emissions for combustion processes is expressed as follows:

$$CO_2\ Emissions = \sum_{all\ fuels}\left[\begin{matrix}((Apparent\ Consumption_{fuel} \bullet Conv\ Factor_{fuel} \bullet CC_{fuel}) \bullet 10^{-3} \\ - Excluded\ Carbon_{fuel}) \bullet COF_{fuel} \bullet 44/12\end{matrix}\right]$$

Where:

Apparent Consumption =	production + imports – exports - international bunkers - stock change
Conversion Factor =	factor to convert fuel to energy units (TJ) on net calorific value basis
CC =	Carbon content (tonne C/TJ)
Excluded Carbon =	carbon in feed stocks and non-energy use excluded from fuel combustion emissions (Gg C)
Carbon oxidation factor (COF) =	fraction of carbon oxidized. For this inventory, the factor is 1, assuming complete oxidation
44/22 =	molecular weight ratio of CO_2 to C

2.4.4. Activity Data

Estimation of apparent consumption of fuels for the Reference Approach requires a supply balance of primary and secondary fuels. That is primary and secondary fuels production, imports, exports, international bunkers, changes in fuels stocks as well as fuels used for non-energy purposes. The activity data for computing apparent consumption of primary and secondary fuels (Tables 2.10 and 2.11) were obtained primarily from three sources of energy statistics: the NNPC Annual Statistical Bulletin for the full time series 2000 to 2016, the DPR Annual Statistical Bulletin for 2013 to 2016, and the UN database. Data gaps were filled by interpolations and extrapolations to ensure time-series completeness in accordance with the Good Practice Guidance and Uncertainty Management (IPCC, 2000). The activity data for calculating fugitive emissions from Oil and Gas processes by the Sectoral Approach were also derived from Tables 2.10 and 2.11. Only the activities occurring for each fuel type are presented.

Table 2.10 - Flow of Primary and Secondary Liquid Fuels into the Economy

Fuel/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Crude Oil (000 bbls)																	
Production	823031.2	863744.5	725860.0	844100.3	910156.5	918660.6	869196.5	803000.7	768745.9	780347.9	896043.4	867475.6	852776.7	800488.1	798541.6	773458.6	669997.9
Imports																	
Exports	714356.2	780093.7	663326.5	791016.3	878077.3	844151.5	817996.1	791826.5	724479.8	769195.2	864702.1	822084.2	830772.0	762045.2	796654.1	780429.7	645435.2
Deliveries to Local Refineries	36189.1	82578.5	78160.6	42754.8	40529.3	72478.3	42471.7	18191.1	45533.3	19392.6	33633.9	40405.6	33595.3	36193.2	25839.4	9871.0	32720.5
Crude Processed	36282.8	81512.1	79579.0	44811.9	38027.0	70637.0	43445.4	19059.7	39264.5	17745.7	34871.7	39408.1	33628.6	35233.1	23360.4	7991.6	22503.4
Stock Change	72392.2	2138.7	-17045.5	8272.1	-5947.8	3872.1	7755.0	-7885.5	5001.6	-6592.9	-3530.4	5983.3	-11624.0	3209.8	-21472.9	-14962.6	2059.3
LPG (000 t)																	
Deliveries from local refineries	6.1	68.6	80.8	25.6	1.7	6.0	0.2	0.0	45.6	40.7	75.8	120.4	19.3	28.4	22.4	6.5	37.3
Input from NLNG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.0	41.0	57.0	106.7	100.1	120.0	136.0	132.0	141.0	250.0
Imports	8.5	0.0	94.4	0.0	170.3	0.0	0.0	0.0	0.0	14.0	18.0	22.8	7.0	39.0	82.0	163.0	48.0
Exports	0.0	5.5	16.8	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
International Bunkers																	
Local Consumption	48.6	43.0	50.0	50.0	58.0	36.0	50.0	60.0	70.0	90.0	110.0	120.0	140.0	162.0	192.0	304.0	390.0
Stock Change	-33.9	20.1	108.4	-26.9	114.0	-30.0	-49.8	-19.0	16.6	21.7	90.5	123.3	6.3	41.4	44.4	6.5	-54.7
PMS (000 t)																	
Deliveries from local refineries	2133.5	3012.5	3230.1	2459.9	533.9	2448.7	1552.8	971.0	1338.9	911.4	1249.2	1205.7	1413.2	1214.3	955.8	716.2	737.4
Imports	5736.9	5660.7	6079.0	7717.4	8316.1	8449.6	8767.6	9597.6	8905.5	10868.9	10558.2	10346.7	11855.2	11904.7	13473.0	14154.2	14271.9
Exports	0.0	0.0	15.3	9.5	9.5	0.1	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
International Bunkers																	
Local Consumption	3524.1	5287.0	6430.5	6458.9	6073.3	6398.4	6148.8	6558.0	7032.1	7036.0	4702.8	4210.5	3713.9	11765.0	12879.0	11765.0	12885.5
Stock Change	4346.3	3386.2	2863.4	3708.8	2767.1	4499.8	4166.7	4010.6	3212.3	4744.3	7104.6	7341.9	9554.4	1354.1	1549.8	3105.4	2123.8
Household Kerosene (000 t)																	

Fuel/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Deliveries from local refineries	940.9	1620.6	1525.8	934.6	629.7	1272.2	878.9	335.4	674.8	374.7	658.7	732.9	573.5	741.0	500.2	204.4	400.9
Imports	1208.3	522.2	476.3	720.5	514.6	783.8	1302.4	1485.9	1084.8	1374.5	1844.9	1643.3	2501.5	2970.2	3145.4	2145.2	589.2
Exports	0.0	0.0	14.8	1.9	1.9	9.8	8.2	4.8	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
International Bunkers																	
Local Consumption	885.6	1655.9	155.3	1113.0	1132.9	1127.2	751.9	434.3	794.8	572.8	542.7	731.1	512.1	2162.0	2341.0	2162.0	746.2
Stock Change	1263.6	487.0	1832.0	540.2	9.4	919.0	1421.1	1382.3	954.9	1176.4	1960.9	1645.1	2562.8	1549.1	1304.6	187.5	243.9
AGO/Diesel (000 t)																	
Deliveries from local refineries	1282.8	2579.5	2484.1	1525.7	1179.2	2115.7	1170.1	590.4	1222.0	515.8	970.0	1043.8	816.7	1031.9	629.0	242.9	701.7
Imports	2277.2	543.6	574.5	1730.9	2413.5	864.6	1051.8	1279.5	1556.6	1893.7	2303.7	1663.2	1774.8	2198.8	6409.7	3768.2	3828.3
Exports		42.4	14.1	19.6	0.0	30.3	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
International Bunkers	118.8	1.9	0.0	0.0	0.0	13.2	123.0	0.0	109.0	7.3	16.6	70.9	10.0	0.0	0.0	0.0	0.0
Local Consumption	2210.7	2289.1	2402.2	2286.1	1646.0	2034.5	1417.3	1189.8	1303.7	971.2	755.5	840.1	581.4	2431.9	2765.6	2431.9	3352.4
Stock Change	1230.5	789.7	642.4	950.9	1946.6	902.4	681.5	669.1	1365.9	1430.9	2501.6	1796.0	2000.1	798.8	4273.0	1579.2	1177.6
Fuel Oil (000 t)																	
Deliveries from local refineries	1247.9	2691.3	2592.9	1822.0	1847.5	2768.5	2165.2	966.1	1441.7	625.0	924.0	1280.6	809.7	1242.5	773.6	149.8	421.0
Imports	0.2	0.5	0.9	1.7	3.2	6.2	11.8	22.7	43.6	83.6	170.5	103.8	88.4	15.0	153.4	63.5	296.7
Exports	1145.8	2126.5	2126.7	118.0	878.7	2059.9	1869.7	1244.7	758.5	306.8	498.0	686.7	332.2	720.6	302.9	83.5	153.5
International Bunkers	66.8	13.3	0.0	0.0	0.0	0.2	0.0	0.0	0.0	3344.0	8.9	3.2	5.5	0.0	260.0	0.0	0.0
Local Consumption	237.5	231.7	252.0	1689.1	557.6	289.0	155.9	120.8	482.8	367.3	248.1	290.8	378.0	466.9	576.6	52.5	93.2
Stock Change	-202.0	320.2	215.1	16.7	414.4	425.5	151.4	-376.7	244.0	-3309.5	339.5	403.8	182.4	70.0	-212.4	77.3	471.0
ATK (000 t)																	
Deliveries from local refineries																	
Imports	208.3	225.2	243.5	263.2	496.0	307.6	332.6	359.5	388.7	420.2	454.3	479.3	525.1	413.0	344.1	440.7	538.8
Exports																	

Fuel/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
International Bunkers																	
Local Consumption	148.9	254.5	277.5	320.7	72.1	228.0	230.1	278.1	850.6	645.2	166.4	185.4	43.9	346.1	308.6	346.1	432.6
Stock Change	59.5	-29.3	-34.0	-57.5	423.9	79.7	102.4	81.4	-461.9	-225.0	287.8	293.9	481.1	66.9	35.6	94.6	106.2
Returns of Other Products from Local Refineries																	
LRS (000 t)	231.6	485.2	354.1	154.6	0.0	-0.6	0.0	0.0	0.4	0.0	1.0	0.0	0.0	0.0	0.0	11.8	0.0
Asphalt (000 t)	0.0	0.0	0.0	2.5	0.0	42.0	0.0	0.0	22.3	0.0	11.3	33.4	0.0	5.3	0.0	0.0	7.0
VGO (000 t)	0.0	0.0	0.0	0.0	0.0	18.9	-1.1	11.2	9.0	1.5	55.0	55.8	46.7	1.5	16.5	80.0	-10.8
Kero solvent (000 t)	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.1	5.3
Interm. Products (000 t)	125.1	108.7	58.5	248.8	0.0	509.8	129.7	220.3	407.5	199.6	936.5	779.9	374.9	558.8	247.7	297.8	474.8

Table 2.11 - Natural Gas Accounting Data (MMscm) for Nigeria (2000-2016) (NNPC Annual Statistical Bulletin)

Year	Production	Gas Flared	% Flared	Gas Utilized	Re-injection	Gas for Field Use	Gas for LNG	Gas for NGL	Gas Lift	Fuel Gas for EPCL	Domestic Sales
2000	45,282.27	24999.77	55.21	20282.51	8488.58	2220.6	7,168.41	653.08	609.9	203.05	1886.42
2001	51,644.24	26080.17	50.5	25564.07	9482.95	2663.18	8,286.72	1214.18	740.35	259.41	2917.28
2002	46,773.07	21073.14	45.05	25699.93	7657.79	2036.08	8,214.09	1351.46	485.73	259.41	5420.85
2003	51,784.31	23959.11	46.27	27825.2	5302.81	1875.76	13,122.93	1020.83	550.14	255.95	5726.08
2004	58,970.26	25106.82	42.58	33863.44	9425.08	2025.84	11,615.94	1333.9	336.53	282.62	8843.53
2005	59,291.57	23005.27	38.8	36286.3	11264.13	2382.79	5,303.98	1312.27	854.62	292.82	14904.79
2006	61,806.48	22655.95	36.66	39150.52	9450.02	2174.9	6,822.73	1257.71	1,286.75	224.47	17830.18
2007	68,411.18	22359.95	32.68	46051.23	10042.57	2167.16	10,439.50	990.66	1,445.84	266.71	21544.37
2008	64,638.71	17875.26	27.65	46763.45	11075.26	2277.01	9,390.04	657.67	1,658.43	216.37	23296.37
2009	52,031.72	14424.85	27.72	37606.88	11606.92	2281.85	7,620.80	1200.81	1,584.68	229.01	13082.81
2010	67,765.20	16470.02	24.30	51295.18	13970.53	2045.66	4,734.83	732.55	4,787.69	147.39	24876.53
2011	67,979.41	17531.01	25.79	50448.4	9864.74	2960.61	8,866.63	1093.36	2,236.43	267.19	25159.44
2012	73,070.29	16671.04	22.82	56399.25	13108.65	3275.98	9,341.72	1336.32	2,064.65	435.2	26836.73
2013	65,847.89	11591.7	17.6	54256.19	18082.51	3639.79	8,520.85	1588.09	1,328.15	261.12	20855.65
2014	71,487.28	8201.47	11.47	63285.81	18232.61	4371.78	11,083.58	1098.68	2,961.64	311.69	25225.84
2015	82,973.42	9667.66	11.65	73305.76	20601.54	4508.29	11928.21	1187.00	2182.64	308.93	32589.15
2016	78,667.05	8848.53	11.25	69818.52	21176.14	4175.53	28544.13	2569.54	-	1131.56	12221.62

2.4.5. The Sectoral Approach

Methods

The equations used for the estimation of GHGs under the Tier 1 level for all categories are:

Stationary combustion

$$\text{Emissions}_{GHG,fuel} = \text{Fuel Combustion}_{fuel} * \text{Emission Factor}_{GHG,fuel}$$

where:

Emissions GHG,fuel = emissions of a given GHG by type of fuel (kg GHG)
Fuel Combustion fuel = amount of fuel combusted (TJ)
Emission Factor GHG,fuel = emission factor of a given GHG by type of fuel (kg gas/TJ).

Mobile combustion

$$\text{Emission} = \sum [\text{Fuel}_a * \text{EF}_a]$$

where:

Emissions = emission in kg
EF_a = emission factor kg/TJ
$Fuel_a$ = fuel consumed, (TJ) (as represented by fuel sold)
A = fuel type a (e.g., diesel, ATK, Gasoline, AGO etc.)

Fugitive emissions - Oil & Gas sector

$$E_{gas/oil,\ industry\ segment} = AD_{industry\ segment} * EF_{gas/oil,\ industry\ segment}$$

where:

E gas/oil, industry segment = Annual Emissions (Gg)
EF gas/oil, industry segment = emission factor (Gg/unit of activity)
AD industry segment = activity value (units of activity)

2.4.6. Activity data

The AD for the energy sector inventory includes data on energy production, processing (primary & secondary processing), transmission/transportation, and consumption. During the inventory, considerable attention was paid to data from both national and international sources, data preparation and documentation. Priority was given to using data sourced directly or estimated from available national sources covering the period 2000-2016. Existing gaps were filled either by sourcing for additional data from other public sources recommended by IPCC or by appropriate statistical methods.

The main data providers were the NNPC (NNPC Annual Statistical Bulletin, 2000-2016), the Department of Petroleum Resources, The Nigerian LP Gas Association, the National Bureau of Statistic (NBS) Annual Statistical Bulletin, United Nations Database and the Organization of Petroleum Exporting Countries (OPEC) Annual Statistical Bulletin (2010-2016).

Patterns of energy consumption by sector were obtained from the Energy Commission of Nigeria (ECN) and other studies and reports, some of which were national project reports.

2.4.6.1. Sectoral Fuel Consumption Activity Data

Energy Industries (1.A.1)

Electricity Generation (1.A.1.a.i)

Emissions in the energy industries category result from fuel combustion in public electricity generation plants, for electricity and heat generation in the local petroleum refineries, in the manufacture of solid fuels (including transformation of fuel wood to charcoal) and fuel consumption in other energy industries such as natural gas for field use in the Upstream Oil & Gas Sector.

Emissions from public electricity generating stations in the country result from the combustion of natural gas in Steam Turbines, Single Cycle Gas Turbines and Combined Cycle Gas Turbine plants. The AD for activities in this category is provided in Table 2.12. Substantial gaps exist in the database of consumption of these fuels in the power sector. The database for Natural gas consumption in the power sector is very weak. However, existing data from NNPC ASB showed that about 66% of Natural gas sold for domestic use was used for grid power generation while the balance were sold to industries for heat and own-use power generation. This percentage was used to compute the share of natural gas for years with incomplete data.

Table 2.12 - Fuel Consumption (Natural Gas) in Public Electricity Generation Facilities[2]

Year	Million SCM	TJ
2000	1245.04	44821.32
2001	1925.41	69314.67
2002	3577.76	128799.28
2003	3779.21	136051.57
2004	5836.73	210122.39
2005	9837.16	354137.76
2006	11767.92	423645.15
2007	14219.28	511894.12
2008	15375.60	553521.64
2009	15897.06	572293.94
2010	16418.51	591066.23
2011	16605.23	597788.21
2012	17712.24	637640.75
2013	13764.73	495530.14
2014	16649.05	599365.89
2015	21508.84	774318.15
2016	22315.55	803360.00

[2]NNPC Annual Statistical Bulletin (2000-2016)
UNdata: Nigeria datamart(EDATA) 2000-2014, retrieved from
http://data.un.org/Data.aspx?q=Nigeria+datamart%5bEDATA%5d&d=EDATA&f=cmID%3aRF%3bcrID%3a566
http://data.un.org/Data.aspx?q=Nigeria+datamart%5bEDATA%5d&d=EDATA&f=cmID%3aDL%3bcrID%3a566
Energy Commission of Nigeria: Study for the Development of Energy Balance for Nigeria, 2009.
Energy Commission of Nigeria: National Energy Balance 2012-2013, February 2016.

Activity data for fuel consumption for electricity and heat generation in upstream and downstream segments of the Oil and Gas Industry, abstracted directly from the NNPC Annual Statistics Abstract for the period 2000-2016 is given in Table 2.13.

Table 2.13 - Fuel Consumption for Electricity and Heat Generation in the Oil & Gas Industry[3]

Year	Refinery Fuel Use, Gg					Upstream Fuel Use (Natural Gas)	
	AGO / Diesel	RFO	LPG	Petroleum Coke	Refinery Gas	Million scm	TJ
2000	63.49	217.81	22.2	10.53	125.17	2,220.60	79,941.48
2001	79.88	350.04	33.74	66.11	213.53	2,663.18	95,874.41
2002	88.25	335.99	31.01	89.55	238.72	2,036.08	73,298.96
2003	26.69	261.68	10.17	36.3	135.18	1,875.76	67,527.41
2004	16.44	143.99	5.67	34.3	201.35	2,025.84	72,930.39
2005	18.64	438.52	22.16	42.54	258.02	2,382.79	85,780.36
2006	21.89	226.24	3.34	4.93	100.00	2,174.90	78,296.48
2007	26.69	136.63	2.28	0.1	76.08	2,167.16	78,017.76
2008	29.53	256.2	34.86	6.62	69.40	2,277.01	81,972.51
2009	11.23	160.78	4.67	6.24	35.41	2,281.85	82,146.68
2010	26.93	289.09	11.75	2.81	49.93	2,045.66	73,643.90
2011	45.80	298.34	21.96	1.03	79.30	2,960.61	106,581.89
2012	19.98	316.96	18.96	1.05	65.14	3,275.98	117,935.12
2013	43.86	326.29	32.99	2.14	72.04	3,639.79	131,032.34
2014	24.69	225.93	11.22	9.64	33.89	4,371.78	157,384.00
2015	13.94	122.62	6.88	7.85	16.07	4,508.29	162,298.42
2016	26.66	227.01	19.94	9.46	36.08	4,175.53	150,319.12

Energy consumption activity data for the manufacture of solid fuels, namely fuel wood for charcoal manufacturing and obtained from FAOSTAT, are presented in Table 2.14.

Table 2.14 - Fuel Wood used for Solid Fuel (Charcoal) Manufacture (10^3 mt)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Fuel Wood	9524.00	10313.33	11177.55	12048.12	13048.35	14059.68	15095.08	19411.00	17674.91

Year	2009	2010	2011	2012	2013	2014	2015	2016
Fuel Wood	15177.44	16544.98	17986.76	19193.90	18304.24	19411.60	19544.70	19633.25

Manufacturing Industries and Construction (1.A.2)

The Manufacturing and Construction Industries category consumed fuels for electricity generation and heat production for own use in their plants. Available data from the ECN National Energy Balance Studies (2000-2008; 2012-2013) and the IEA database (2000-2014) indicate that AGO/Diesel used for energy generation in the manufacturing and construction sector out of the domestic consumption was about 3.1% for the years 2000-2005 and about 3.7% for the period 2006-2014, while the entire domestic consumption of RFO was for energy generation in the manufacturing sector. About 1% of this fraction is used for own-use electricity generation and the balance for industrial steam production. Data for Natural gas used in the Manufacturing and Construction Industries category was obtained by adding values from

[3]NNPC Annual Statistical Bulletin (2000-2016)

the NNPC Annual Statistical Abstracts (2000-2016)[4] for natural gas fuel sent to the Eleme Petrochemicals Company Limited (EPCL) to values for natural gas sent to the manufacturing sector for own-use electricity generation from the IEA database (2000-2014). Data for consumption of coal and other traditional fuels were obtained from ECN and IEA. These AD for all fuels consumed in this sub-category is given in Table 2.15.

Table 2.15 - Fuel consumption (Gg) by Type in the Manufacturing and Construction Industries

Year	AGO / Diesel	RFO	LPG	Wood / Wood Waste	Charcoal	Bargasse	Coal	Natural Gas (Dry)	
								MMscm	TJ
2000	68.02	237.51	2.43	5,011.01	15.06	117.00	3.00	844.44	30,399.73
2001	70.44	231.71	2.15	5,437.33	16.17	22.00	3.00	1,251.28	45,046.23
2002	73.91	252.02	2.50	5,907.27	17.00	22.00	43.00	2,102.49	75,689.81
2003	70.34	1689.09	2.50	6,369.72	15.58	0.00	23.00	2,202.82	79,301.54
2004	50.65	557.61	2.90	6,917.91	16.03	0.00	8.00	3,289.42	118,419.18
2005	62.60	289.04	1.80	7,448.31	17.93	0.00	8.00	5,360.45	192,976.08
2006	52.44	155.95	2.50	7,995.58	16.02	98.00	8.00	6,286.73	226,322.40
2007	44.02	120.76	3.00	8,217.65	16.14	179.00	23.00	7,591.79	273,304.49
2008	48.24	482.76	3.50	9,343.40	15.91	68.00	32.00	8,137.14	292,936.96
2009	35.93	367.34	4.50	10,453.32	17.24	122.00	34.00	4,677.17	168,378.01
2010	27.95	248.13	5.50	10,971.67	16.53	98.00	38.00	8,605.41	309,794.73
2011	31.08	290.82	6.00	11,590.65	16.78	98.00	32.00	8,821.40	317,570.40
2012	21.51	378.02	7.00	12,001.61	16.87	35.00	48.00	9,559.69	344,148.89
2013	89.98	466.86	8.10	11,611.30	17.25	35.00	44.00	7,352.04	264,673.46
2014	102.33	576.57	9.60	6,922.61	17.24	20.00	46.00	8,888.48	319,985.12
2015	89.98	52.50	15.20	6,970.07	17.48	15.80	48.10	11,389.24	410,012.47
2016	124.04	93.15	19.50	7,001.65	17.69	29.28	50.28	5,286.91	190,328.87

Transport (1.A.3)

In Nigeria, the transport sector comprises civil aviation (domestic & international), road transportation, water-borne navigation (domestic & international) and railway. There are no formal national statistics on the fuel consumption pattern in these transport sub-categories. For the purpose of this inventory, estimates of the fuel consumption pattern in these sub-categories were made from data on national fuel consumption by type reported in the NNPC Annual Statistical Bulletins for the years 2000-2016, and supported with results of studies carried out by the ECN for the National Energy Balance[5] as well as analyses done by the World Bank[6] on fuel consumption in the Nigerian transport sector (2013). The estimates are:

- 77% of total PMS consumed in the country is used in the transport sector of which 4.2% and 95.8% are allocated to the domestic water navigation and road transport sub-categories respectively.
- 75.3%, 8%, 16.3% and 0.4% of the total PMS used for road transport are used in passenger cars, motorcycles, Light-Duty Trucks/buses and Heavy Duty-Trucks/buses respectively.

---

[4]NNPC Annual Statistical Bulletin (2000-2016)

[5]Energy Commission of Nigeria: National Energy Balance 2012-2013, February 2016

[6]R. Cervigni, J. A Rogers, & I. Dvorak, (Editors). A WORLD BANK STUDY: Assessing Low-Carbon Development in Nigeria, pp 352-355.http://dx.doi.org/10.1596/978-0-8213-9973-6, Retrieved February 10th, 2017.

- 1.7%, 0.7% and 64.9% of national AGO/Diesel consumption are used for domestic water navigation, rail and other road transport respectively.
- 91% of total ATK supply is consumed in international aviation activities and the balance for domestic aviation.

The AD used in the computation of emissions for the transport sector by subcategory and fuel type is provided in Table 2.16.

Other Sectors (1.A.4) – Commercial/Institutional, Residential & Agriculture/Forestry/Fisheries (CRAFF)

Data for fuel consumption in the commercial, residential and agriculture sectors, obtained from ECN, IEA and UN databases, are presented in Table 2.17. Data gaps were filled by using extrapolation and interpolation methods. In the commercial and residential sectors, PMS and AGO/diesel are consumed for auto-generation of electricity while LPG, fuel wood, vegetal wastes and charcoal are used for cooking and heating. Existing data from ECN and IEA show that 70% of total national LPG consumption was in the residential sector while about 9% was used in the commercial/services sector and the balance was for non-specified industrial use.

In the Agriculture/Forestry/Fisheries sector, about 0.4% of total national diesel consumption is utilized in off-road vehicles such as tractors and other agricultural implements. About 0.6% of total national HHK consumption is used in the Agriculture sector for heating purposes and other non-specified uses.

Table 2.16 - Fuel Consumption (Gg) by type in the Transport Sector

Year	Civil Aviation		Road Transport							Water-borne Navigation			Rail
	ATK		PMS/Motor Gasoline				AGO/Diesel			AGO/Diesel	PMS	RFO	
	International Aviation Bunkers	Domestic Aviation	Cars	LD Trucks	HD Trucks & Buses	Motorcycles	Cars	HD Trucks & Buses	LD Trucks	Domestic Water Navigation		IMB	AGO/Diesel
2000	135.47	13.40	1957.50	423.73	10.40	207.97	61.55	1399.23	590.88	38.40	113.97	22.40	35.11
2001	231.57	22.90	2936.70	635.70	15.60	312.00	63.73	1448.84	611.83	39.76	170.98	22.40	36.35
2002	252.53	24.98	3571.87	773.19	18.97	379.48	66.88	1520.38	642.04	41.73	207.96	22.40	38.15
2003	291.88	28.87	3587.63	776.61	19.06	381.16	63.65	1446.90	611.01	39.71	208.88	22.40	36.30
2004	249.66	24.69	3373.48	730.25	17.92	358.40	45.83	1041.82	439.95	28.59	196.41	22.40	26.14
2005	207.44	20.52	3554.05	769.34	18.88	377.59	56.64	1287.66	543.76	35.34	206.92	22.40	32.31
2006	209.43	20.71	3415.38	739.32	18.14	362.86	27.60	627.33	264.91	24.09	198.85	22.40	9.92
2007	253.09	25.03	3642.67	788.52	19.35	387.00	23.17	526.64	222.39	20.23	212.08	22.40	8.33
2008	297.57	29.43	3906.04	845.53	20.75	414.98	25.38	577.05	243.68	22.16	227.42	22.40	9.13
2009	304.93	30.16	3908.19	846.00	20.76	415.21	18.91	429.86	181.52	16.51	227.54	22.40	6.80
2010	151.46	14.98	4469.52	565.46	13.88	277.53	14.71	334.38	141.21	12.84	260.22	22.40	5.29
2011	168.75	16.69	4696.94	506.27	12.42	248.48	16.36	371.85	157.03	14.28	273.46	22.40	5.88
2012	241.86	23.92	4924.36	446.56	10.96	219.17	11.32	257.33	108.67	27.81	286.70	22.40	4.07
2013	314.96	31.15	6534.95	1414.60	34.71	694.28	47.35	1076.41	454.56	41.34	380.48	22.40	17.02
2014	280.79	27.77	7153.72	1548.55	38.00	760.02	53.85	1224.11	516.92	47.02	416.51	22.40	19.36
2015	314.96	31.15	6534.95	1414.60	34.71	694.28	47.35	1076.41	454.56	41.34	380.48	22.40	17.02
2016	393.66	38.93	7157.34	1549.33	38.02	760.41	65.27	1483.83	626.60	56.99	416.72	22.40	23.47

Table 2.17 - Commercial/Institutional, Residential and Agriculture/Forestry/Fishing (CRAFF) Sectors Fuel Consumption ('000 mt)

Year	Commercial/Institutional Sector						Residential Sector					Agriculture/ Forestry/ Fish farms	
	AGO/Diesel	LPG	Wood/Wood Waste	Charcoal	PMS	HHK	AGO/Diesel	LPG	Wood/Wood Waste	Charcoal	Vegetal wastes	AGO	HHK
2000	5.48	5.34	3368.51	466.84	810.55	865.23	3.29	40.82	67,558.54	2575.17	36,734.25	8.78	5.31
2001	5.68	4.73	3074.05	457.32	1216.01	1617.78	3.41	36.12	67,139.76	2670.00	38,226.50	9.09	9.94
2002	5.96	5.50	2632.96	475.92	1479.01	151.69	3.58	42.00	66,774.86	2738.67	39,660.75	9.54	0.93
2003	5.67	5.50	2496.96	444.13	1485.54	1087.39	3.41	42.00	66,132.07	2847.87	41,362.75	9.08	6.68
2004	4.08	6.38	1885.03	520.07	1396.87	1106.82	2.45	48.72	65,776.23	2842.60	42,953.25	6.53	6.80
2005	5.05	3.96	1636.00	529.87	1471.64	1101.30	3.03	30.24	65,090.94	2910.19	44,859.00	8.08	6.76
2006	291.97	5.50	1391.15	545.98	1414.22	734.65	113.38	42.00	64,264.40	2958.99	46,822.25	5.67	4.51
2007	245.10	6.60	1377.96	557.22	1508.33	424.34	95.19	50.40	60,273.39	3011.98	51,508.50	4.76	2.61
2008	268.56	7.70	1288.24	591.18	1617.39	776.56	104.30	58.80	61,533.04	3130.93	52,270.25	5.21	4.77
2009	200.06	9.90	1476.02	597.60	1618.28	559.60	77.69	75.60	63,315.47	3147.43	52,486.00	3.88	3.44
2010	155.63	12.10	2173.27	624.37	1081.65	530.17	60.44	92.40	61,339.28	3210.87	56,091.50	3.02	3.26
2011	173.06	13.20	2385.14	643.28	968.43	714.28	67.21	100.80	59,620.81	3236.52	59,696.25	3.36	4.39
2012	119.76	15.40	4069.47	662.99	854.21	500.36	46.51	117.60	56,893.74	3295.12	64,801.50	2.33	3.07
2013	500.98	17.82	3205.42	669.70	2705.94	2112.30	194.55	136.08	59,634.55	3349.59	63,916.00	9.73	12.97
2014	569.71	21.12	3799.05	687.33	2962.16	2287.17	221.25	161.28	63,240.67	3436.64	62,323.00	11.06	14.05
2015	500.98	33.44	3825.09	697.13	2705.94	2112.30	194.55	255.36	63,674.30	3485.63	64,322.18	9.73	12.97
2016	690.59	42.90	3842.43	705.48	2963.66	729.02	268.19	327.60	63,962.81	3527.40	66,385.48	13.41	4.48

Fugitive Emissions

Oil and Gas (1.B.2)

The Primary Energy data for estimating fugitive emissions for the upstream sector in Nigeria was sourced directly from DPR (2013-2016), NNPC (2000-2016)[7], and OPEC (2011-2016). The NNPC Annual Statistical Bulletin (ASB) was the primary source of data for the Oil & Gas industries. Where data was incomplete or inconsistent, the DPR ASB and OPEC ASB were consulted and updating made as required. These AD have already been provided in Tables 2.10 and 2.11 above.

2.4.7. Emission Factors

Default emission factors for Tier 1 level from the IPCC 2006 Guidelines were used in the estimation of GHGs for the energy sector for the main gases CO_2, CH_4 and N_2O. EFs for other gases and GHG precursors not available in the IPCC 2006 Guidelines were supplemented by those from the EMEP/EEA guidebook as applicable.

Direct Gases

EFs for CO_2, CH_4 and N_2O for activity areas in the Energy Industries category is given in Table 2.18.

Table 2.18 - Emission Factors for the Energy Combustion categories

Fuel	Default Emission Factor (Kg of GHG per TJ on a Net Calorific Basis)		
	CO_2	CH_4	N_2O
Energy Industries			
Gas/Diesel Oil	74100	3	0.6
Residual Fuel Oil	77400	3	0.6
Liquefied Petroleum Gases	63100	1	0.1
Petroleum Coke	97500	3	0.6
Refinery Gas	57600	1	0.1
Natural Gas	56100	1	0.1
Wood / Wood Waste	112000	30	4
Manufacturing Industries & Construction			
Gas/Diesel Oil	74100	3	0.6
Residual Fuel Oil	77400	3	0.6
Other Bituminous Coal	94600	10	1.5
Natural Gas	56100	1	0.1
Wood / Wood Waste	112000	30	4
Charcoal	112000	200	4
Civil Aviation			
Jet Kerosene	71500	0.5	2
Road Transportation			
Motor Gasoline	69300	33	3.2
Gas/ Diesel Oil	74100	3.9	3.9

[7]NNPC Annual Statistical Bulletin (2000-2016)

Fuel	Default Emission Factor (Kg of GHG per TJ on a Net Calorific Basis)		
	CO_2	CH_4	N_2O
Railway			
Gas/ Diesel Oil	74100	4.15	28.6
Water-borne Navigation			
Gasoline	69 300	7	2
Gas/Diesel Oil	74 100	7	2
Residual Fuel Oil	77 400	7	2
Commercial/Institutional Category			
Motor Gasoline	69 300	10	0.6
Gas/Diesel Oil	74 100	10	0.6
Liquefied Petroleum Gases	63 100	5	0.1
Wood / Wood Waste	112 000	300	4
Charcoal	112 000	200	1
Residential & Agriculture/Forestry/Fish Farms			
Motor Gasoline	69 300	10	0.6
Other Kerosene	71 900	10	0.6
Gas/Diesel Oil	74 100	10	0.5
Liquefied Petroleum Gases	63 100	5	0.1
Wood / Wood Waste	112 000	300	4
Other Primary Solid Biomass	100 000	300	4
Charcoal	112 000	200	1

Table 2.19 applies to systems in developing countries and countries with economies in transition where there are greater amounts of fugitive emissions per unit of activity. Nigeria, being a developing country, the EFs from this table has been adopted for computing emissions.

Table 2.19 - Emission Factors for Fugitive Emissions

Category	Sub-category	CO_2	CH_4	N_2O
Fugitive Emissions from crude oil systems (Gg/10^3 m^3)				
Venting	Oil Production	0.00215	0.01035	Not available
	Oil transport/Loading of offshore production on tanker ships	Not determined	Not determined	Not available
	Oil Transport/Tanker trucks and rail cars	2.30E-06	2.50E-05	Not available
Flaring	Oil Production	0.0405	2.50E-05	6.40E-07
Production and Upgrading	Oil Production	0.00249	0.0196	Not determined
Transport	LNG transport	Not determined	Not determined	Not determined
	LPG transport	0.00043	Not determined	2.20E-09
	Oil pipeline transport	4.90E-07	5.40E-06	Not determined
Refining	Oil refining	Not determined	2.18E-05	Not available

Category	Sub-category	CO_2	CH_4	N_2O
Distribution of oil products	Refined product distribution	Not determined	Not determined	Not available
Fugitive Emissions from NG systems (Gg/10⁶ m³)				
Venting	transmission and storage	5.20E-06	0.000392	Not available
Flaring	Gas production	0.0014	8.80E-07	2.50E-08
Production	Gas production	9.7E-05	.01219	Not available
Transmission and storage	Storage	1.85E-07	4.50E-05	Not available
	Transmission	1.44E-06	0.000633	Not available
Distribution	Gas distribution	9.55E-05	0.0018	Not available

Indirect gases and SO_2

The IPCC guidelines do not provide emission factors for indirect GHGs such as NO_X, CO, NMVOCs and SO_X, but recommended the EMEP/EEA Guidebook[8] default Tier 1 emission factors for estimating these emissions. The Guidebook remains the recommended source of methodology and information for computing emissions of indirect GHGs. The EFs used in computing emissions for this inventory is provided in Table 2.20.

Table 2.20 - EMEP/EEA[9] Default Tier 1 Emission Factors for NO_X, CO and NMVOCs

Fuel	Default Emission Factor (kg of GHG per TJ on a Net Calorific Basis)		
	NO_X	CO	NMVOCs
Energy Industries			
Gas/Diesel Oil	65	16.2	0.8
Residual Fuel Oil	142	15.1	2.3
Liquefied Petroleum Gases	89	39	2.6
Petroleum Coke	142	15.1	2.3
Refinery Gas	63	12.1	2.6
Natural Gas	89	39	2.6
Wood / Wood Waste	81	90	7.31
Manufacturing Industries & Construction			
Gas/Diesel Oil	513	66	25
Residual Fuel Oil	513	66	25
Other Bituminous Coal	173	931	88.8
Natural Gas	74	29	23
Wood / Wood Waste	91	570	300
Charcoal	91	570	300
Aviation			
Jet Kerosene (International Aviation) (Civil Aviation)	2.90E-04 2.34E-04	2.49E-04 4.54E-05	1.13E-05 2.27E-06
Road Transportation: Cars (g/kg fuel)			
Motor Gasoline	8.73	84.7	10.05
Gas/ Diesel Oil	12.96	3.33	0.7

[8]EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016
[9]EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016

Fuel	Default Emission Factor (kg of GHG per TJ on a Net Calorific Basis)		
	NO_x	CO	NMVOCs
Road Transportation: LCV (g/kg fuel)			
Motor Gasoline	13.22	152.3	14.59
Gas/ Diesel Oil	14.91	7.4	1.54
Road Transportation: HDV (g/kg fuel)			
Gas/ Diesel Oil	33.37	7.58	1.92
Gasoline	13.22	152.3	14.59
Road Transportation: Motorcycles (g/kg fuel)			
Gas/ Diesel Oil Gasoline	6.64	497.7	131.4
Railway (g/kg fuel)			
Gas/ Diesel Oil	52.4	10.7	4.7
Water-borne Navigation (g/kg fuel)			
Gasoline (Domestic)	9.4	573.9	181.5
Gas/Diesel Oil (Domestic)	78.5	7.4	2.8
Residual Fuel Oil (International)	79.3	7.4	2.7
Commercial/Institutional Category			
Gas/Diesel Oil	306	93	20
Liquefied Petroleum Gases	74	29	23
Wood / Wood Waste	91	570	300
Charcoal	91	570	300
Residential (kg/TJ)			
Motor Gasoline	51	57	0.69
Other Kerosene	51	57	0.69
Gas/Diesel Oil	51	57	0.69
Liquefied Petroleum Gases	51	26	1.9
Wood / Wood Waste	50	4000	600
Other Primary Solid Biomass	50	4000	600
Charcoal	50	4000	600
Agriculture/forestry/fishing: stationary other (kg/TJ)			
Gas/Diesel Oil	306	93	20
Kerosene	306	93	20
Fugitive Emissions: (Oil)			
Venting: Oil production (Gg/10^^{3} m^3) Oil transport (Gg/10^^{3} m^3)	NA NA	NA NA	0.0019 0.00025
Flaring: Oil production (Gg/10^^{3} m^3)	NA	NA	0.00002
Production and upgrading: Oil production	NA	NA	NA
Transport: LNG (g/m^3) LPG (g/m^3) Pipelines (kg/Mg)	NA NA NA	NA NA NA	0.10 0.10 0.20
Refining (kg/Mg)	0.24	0.09	0.20
Distribution of oil products (kg/Mg)	NA	NA	0.20
Fugitive Emissions: Natural Gas			
Venting: Gas transmission and storage (g/m3)	NA	NA	0.1
Flaring: Gas production (kg/Mg)	1.4	6.3	1.8

Fuel	Default Emission Factor (kg of GHG per TJ on a Net Calorific Basis)		
	NO_x	CO	NMVOCs
Production: Gas production (Gg/10^6 m^3)	NA	NA	7.35E-07
Transmission and storage:			
Storage (Gg/10^6 m^3)	NA	NA	5.95E-07
Transmission (Gg/10^6 m^3)	NA	NA	1.15E-05
Distribution: Gas distribution (Gg/10^6 m^3)	NA	NA	2.6E-05

SO_2 emissions are directly related to the sulphur content of fuels. Therefore, it is recommended that where countries have data on the sulphur content of fuels, the specific equation provided in the Guidelines should be used to calculate SO_2 emissions. Since the sulphur content of some fuels only are known and this data is considered not always reliable, the EFs from the EMEP/EEA guidebook provided in Table 2.21 have been used to compute emissions.

Table 2.21 - SO_2 emission factors for Nigerian fuels

Category	Fuel type	Unit	EMEP/EEA Tier 1 SO_2 EF
Electricity generation	Natural gas	g/GJ	0.281
Petroleum refining	Diesel	g/GJ	46.500
	Residual fuel	g/GJ	495.000
	LPG	g/GJ	0.281
	Petroleum coke	g/GJ	495.000
	Refinery gas	g/GJ	0.281
Manufacture of solid fuels	Wood/wood waste	g/GJ	10.800
Other energy industries	Natural gas	g/GJ	0.281
Manufacturing	Diesel	g/GJ	47.000
	Residual fuel	g/GJ	47.000
	LPG	g/GJ	0.670
	Other bituminous coal	g/GJ	900.000
	Natural gas Dry	g/GJ	0.670
	Wood/wood waste	g/GJ	11.000
	Other primary solid fuels	g/GJ	11.000
	Charcoal	g/GJ	11.000
International aviation	Jet kerosene	kg/ton	1.000
Civil aviation	Jet kerosene	kg/ton	1.000
International marine bunkers	Residual fuel	kg/ton	20.000
Domestic navigation	Gasoline	kg/ton	20.000
	Diesel	kg/ton	20.000
Road transportation	Gasoline (2000 to 2004)	g/kg	0.130
	Gasoline (2005 to 2008)	g/kg	0.040
	Gasoline (2009 to 2016)	g/kg	0.005
	Diesel (2000 to 2004)	g/kg	0.300
	Diesel (2005 to 2008)	g/kg	0.040
	Diesel (2009 to 2016)	g/kg	0.003
Railways	Diesel	kg/ton	0.010
Other sectors			
Commercial	Diesel	g/GJ	94.000

Category	Fuel type	Unit	EMEP/EEA Tier 1 SO_2 EF
	LPG	g/GJ	0.670
	Wood/wood waste	g/GJ	11.000
	Charcoal	g/GJ	11.000
Residential	Gasoline	g/GJ	70.000
	Other kerosene	g/GJ	70.000
	Diesel	g/GJ	70.000
	LPG	g/GJ	0.300
	Wood/wood waste	g/GJ	11.000
	Other primary solid biomass	g/GJ	11.000
	Charcoal	g/GJ	11.000
Agriculture			
Stationary	Kerosene	g/GJ	94.000
Off road vehicles	Diesel	g/GJ	94.000
Fugitive Emissions			
Oil refining	Crude oil	kg/Mg	0.620
Gas Flaring	Natural gas	kg/Mg	0.013

2.4.8. Emissions from the Energy Sector

Total aggregated emissions from the Energy sector increased from 116,057.44 Gg CO_2-eq in the year 2000 to 206,452.45 Gg CO_2-eq in 2016. Of the two main sources, Fuel Combustion Activities recorded an increase of 206% compared to a decline of 1% for Fugitive emissions during the period 2000 to 2016. Fuel Combustion Activities contributed 65.6% of total emissions of the Energy sector in 2016 with the remaining 34.4% originating from fugitive processes (Figure 2.6).

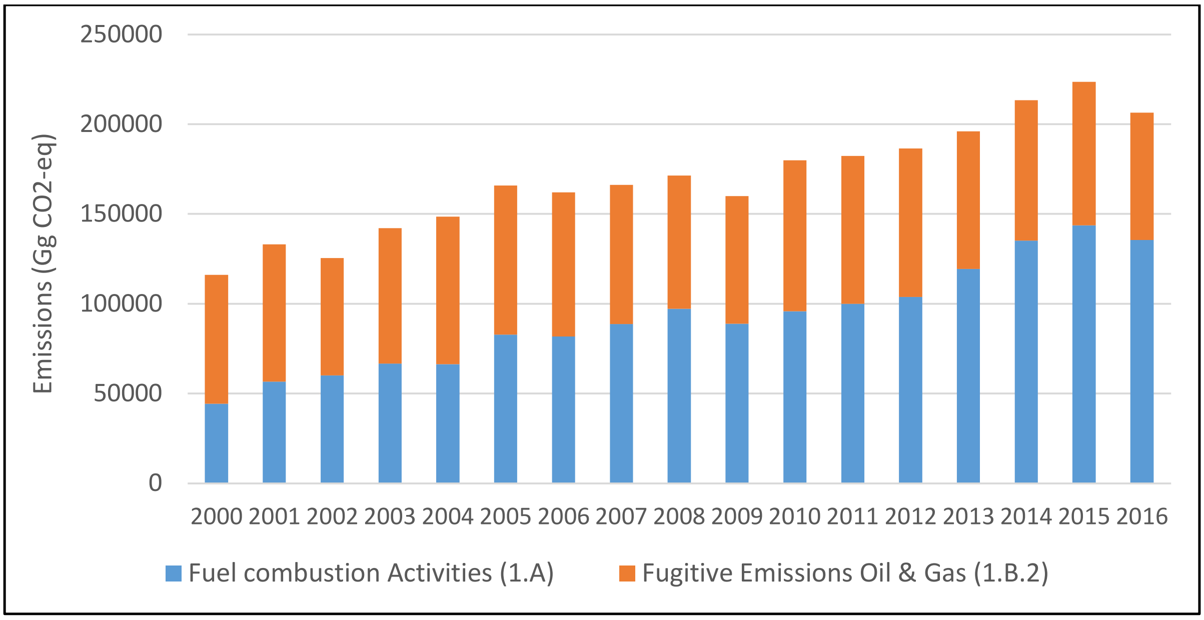


Figure 2.6 - Aggregated GHG emissions (Gg CO_2-eq) of the Energy Sector (2000-2016)

In 2016 within the Fuel Combustion sub-sector, Energy Industries was the highest contributor with 40.7% of total emissions followed by Transport (28.4%), Other Sectors (22.2%) and Manufacturing Industries &

Construction (8.7%). During the period 2000 to 2016, emissions increased by 539% for Energy Industries, 315% for Manufacturing Industries and Construction, 150% for Transport and 73% for Other Sectors (Table 2.22).

Table 2.22 - Aggregated emissions by category in the Energy Sector for period 2000 to 2016 (Gg CO_2-eq)

Year	Total Energy sector	Fuel combustion Activities (1.A)	Energy Industries (1.A.1)	Manufacturing Ind. & Constr. (1.A.2)	Transport (1.A.3)	Others sectors (1.A.4)	Fugitive Emissions Oil & Gas (1.B.2)
2000	116057.44	44298.80	8626.73	2835.32	15422.85	17413.90	71758.64
2001	133064.26	56576.83	11850.20	3656.99	19962.15	21107.50	76487.43
2002	125425.46	60030.34	14068.81	5565.73	23084.89	17310.91	65395.12
2003	142116.66	66635.99	13220.50	10228.85	22807.15	20379.49	75480.66
2004	148596.93	66357.97	17479.36	8793.34	19876.55	20208.71	82238.96
2005	165884.01	82874.30	27474.35	12188.05	21856.34	21355.56	83009.71
2006	162041.40	81727.39	29716.10	13630.40	18019.87	20361.01	80314.00
2007	166238.53	88645.70	34413.30	16186.33	18529.61	19516.46	77592.83
2008	171348.94	97168.52	37404.03	18492.43	19937.93	21334.13	74180.42
2009	159982.38	88870.80	37865.99	11129.38	19228.23	20647.20	71111.58
2010	179947.12	95840.65	38968.62	18698.04	19244.02	18929.98	84106.46
2011	182256.31	100041.16	41435.45	19283.41	19904.29	19418.01	82215.15
2012	186456.82	103773.97	44271.27	21071.76	19896.33	18534.60	82682.86
2013	196079.16	119444.02	37191.43	17088.76	33843.24	31320.59	76635.13
2014	213453.87	135142.42	44007.77	20450.55	37251.51	33432.59	78311.45
2015	223619.70	143701.77	53683.60	23845.51	33843.24	32329.42	79917.94
2016	206452.45	135496.35	55113.68	11765.68	38576.46	30040.53	70956.10

2.4.8.1. Emission Trends by Gas

Table 2.23 summarizes the emission trends by gas for the period 2000 to 2016. Carbon dioxide was the dominant gas in the energy sector with some 60% of total emissions in 2016. In the same year, CH_4 contributed (38%) and N_2O (2%). These emissions exclude CO_2 from Biomass burning for energy production. CO_2 emissions from Biomass are accounted for under the AFOLU sector and reported also under Memo Items for informative purposes.

In general, there was a steady increase in CO_2 emissions from 37,253.0 Gg in the year 2000, to an apex level of 133,225.1 Gg in 2015 which then declined to 124,021.6 Gg in 2016 (Table 2.23). The increase is of the order of 233% from the year 2000 to 2016.

CH_4 emissions followed the same pattern as CO_2 over the same time period, from 3653.8 Gg or 76,352.7 Gg CO_2-eq in 2000 to 3762.3 Gg or 79,007.3 Gg CO_2-eq in 2016 (Table 2.23) which represented a 1.3% increase in emissions.

Likewise, N_2O emissions increased by 40%, from 2,451.7 Gg CO_2-eq in 2000 to 3,423.6 Gg CO_2-eq in 2016(Table 2.23).

Table 2.23 - Absolute (Gg) and CO_2 equivalent (Gg CO_2-eq) GHG emissions by gas for the Energy Sector

Year	CH_4(Gg)	N_2O(Gg)	CO_2(Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)
2000	3635.8	7.9	37253.04	76352.73	2451.68
2001	3853.0	8.3	49592.85	80913.46	2557.95
2002	3373.4	8.5	51963.21	70842.12	2620.13
2003	3818.7	8.6	59250.29	80192.85	2673.52
2004	4120.4	8.6	59399.49	86527.68	2669.76
2005	4158.7	8.8	75818.62	87332.41	2732.98
2006	4048.9	8.8	74279.68	85026.87	2734.84
2007	3941.5	9.1	80653.61	82770.49	2814.42
2008	3800.1	9.2	88685.33	79801.16	2862.46
2009	3659.6	9.3	80258.01	76852.64	2871.73
2010	4248.4	9.4	87807.92	89216.37	2922.84
2011	4175.0	9.7	91585.16	87675.46	2995.69
2012	4215.9	9.9	94843.54	88533.92	3079.37
2013	3957.2	10.7	109675.18	83101.25	3302.72
2014	4052.6	10.8	125004.82	85103.63	3345.43
2015	4145.3	10.8	133225.06	87051.97	3342.67
2016	3762.3	11.0	124021.55	79007.25	3423.65

2.4.8.2. Emissions of direct GHGs, GHG precursors (NO_X, CO, NMVOCs) and SO_2

Emissions of all three precursors (Table 2.24) increased during the period 2000 to 2016, NO_X by 76% from 243.7 Gg to 429.0 Gg, CO by 34% from 6,870.4 Gg to 9,207.8 Gg (34%) and NMVOCs by 27% from 1,370.9 Gg to 1,734.9 Gg. SO_2 also increased, from 38.4 Gg to 59.4 Gg representing 55% more emissions in 2016 compared to the year 2000 (Table 2.24).

Table 2.24 - Emissions (Gg) of direct GHGs, its precursors and SO2 for the period 2000 to 2016

Year	NO_X	CO	NMVOCs	SO2
2000	243.7	6870.4	1370.9	38.4
2001	271.6	7138.1	1436.3	51.2
2002	282.9	7298.5	1421.6	49.7
2003	315.0	7375.5	1473.4	49.9
2004	282.8	7386.0	1491.0	43.8
2005	317.1	7483.3	1513.9	53.2
2006	289.8	7497.4	1497.7	44.6
2007	301.9	7528.6	1483.8	41.2
2008	319.6	7701.2	1506.0	48.4
2009	296.6	7810.4	1521.3	43.0
2010	307.4	7841.0	1562.2	46.1
2011	321.0	7924.2	1568.8	47.8
2012	329.5	8018.0	1582.2	48.2
2013	388.5	8708.1	1706.2	63.6
2014	416.0	8955.1	1734.5	63.5
2015	413.7	8967.0	1723.5	57.1
2016	429.0	9207.8	1734.9	59.4

2.4.8.3. Emissions by sub-category

Trend of emissions in the Energy Industries (1.A.1) sub-categories

The trend of emissions is given in Table 2.25. An increase in emissions is observed for 3 sub-categories and the quantum varied. The increase over the time period 2000 to 2016 is 538.9 % for the Energy Industries category while at sub-category level, it was 1692.4 % for electricity generation, 106.1 % for manufacture of solid fuels and 88.0 % for Other energy industries. A decrease of 26.3 % is recorded for petroleum refining.

Table 2.25 - Aggregated emissions (Gg CO_2-eq) in Energy Industries sub-categories for 2000 to 2016.

Year	1.A.1 Energy Industries	1.A.1.a.i Electricity Generation	1.A.1.b - Petroleum Refining	1.A.1.c.i - Manufacture of Solid Fuels	1.A.1.c.ii - Other Energy Industries
2000	8,626.73	2,516.81	1,343.22	277.83	4488.87
2001	11,850.20	3,892.16	2,273.64	300.86	5383.54
2002	14,068.81	7,232.34	2,394.52	326.07	4115.88
2003	13,220.50	7,639.57	1,437.66	351.47	3791.80
2004	17,479.36	11,798.79	1,204.74	380.65	4095.19
2005	27,474.35	19,874.56	2,372.90	410.15	4816.74
2006	29,716.10	23,788.52	1,090.72	440.35	4396.50
2007	34,413.30	28,728.01	738.18	566.26	4380.85
2008	37,404.03	3,1064.19	1,221.31	515.61	4602.92
2009	37,865.99	32,135.45	675.08	442.76	4612.70
2010	38,968.62	33,171.23	1,179.49	482.65	4135.25
2011	41,435.45	33,548.47	1,377.48	524.71	5984.79
2012	44,271.27	35,785.04	1,304.02	559.92	6622.29
2013	37,191.43	27,825.01	1,474.72	533.97	7357.73
2014	44,007.77	33,655.59	948.48	566.28	8837.43
2015	53,683.60	43,479.51	520.55	570.16	9113.38
2016	55,113.68	45,110.27	989.95	572.74	8440.72

Emissions from the Energy Industries category by gas for the year 2016 are presented in Table 2.26. The major contribution came from Electricity Generation activities with 81.9 % of total emissions of Energy Industries followed by 16.3 % from Manufacture of solid Fuels and Other Energy Industries (fuel use in the up-stream Oil & Gas Sector). Petroleum Refining was responsible for the remaining 1.8 %. CO_2 remained the principal GHG emitted for all activities of the Energy Industries category.

In absolute terms, CH_4 emissions amounted to 10.18 Gg while N_2O contributed 1.33 Gg only.

Table 2.26 - Absolute (Gg) and Aggregated (Gg CO_2-eq) emissions of direct GHGs for Energy Industries in 2016

Source category	CH_4 (Gg)	N_2O (Gg)	CO_2 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)
1.A.1 - Energy Industries	10.18	1.33	54,488.56	213.71	411.41
1.A.1.a - Main Activity Electricity and Heat Production	0.80	0.08	45,068.50	16.87	24.90

Source category	CH_4 (Gg)	N_2O (Gg)	CO_2 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)
1.A.1.a.i - Electricity Generation	0.80	0.08	45,068.50	16.87	24.90
1.A.1.b - Petroleum Refining	0.03	0.01	987.16	0.73	2.06
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	9.34	1.24	8,432.90	196.11	384.45
1.A.1.c.i - Manufacture of Solid Fuels	9.19	1.23	0.00	192.96	379.79
1.A.1.c.ii - Other Energy Industries	0.15	0.02	8,432.90	3.16	4.66

The indirect GHGs, and SO_2 for 2016 are given in Table 2.27. Electricity Generation was the highest emitter of NO_X, and CO with 64% and 48% contribution respectively while Manufacture of solid Fuels accounted for 47% of NMVOCs and Petroleum Refining 57% of SO_2.

Table 2.27 - Absolute emissions of indirect GHGs (Gg) for Energy Industries for 2016

Categories	NO_X	CO	NMVOCs	SO_2
1.A.1 - Energy Industries	111.30	64.98	4.75	8.32
1.A.1.a - Main Activity Electricity and Heat Production	71.50	31.33	2.09	0.23
1.A.1.a.i - Electricity Generation	71.50	31.33	2.09	0.23
1.A.1.b - Petroleum Refining	1.62	0.22	0.03	4.75
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	38.19	33.43	2.63	3.35
1.A.1.c.i - Manufacture of Solid Fuels	24.81	27.57	2.24	3.31
1.A.1.c.ii - Other Energy Industries	13.38	5.86	0.39	0.04

Manufacturing Industries and Construction (1.A.2)

Emissions from this category came from fuel combustion activities for auto production of electricity and heat in the Iron & Steel, Non-Ferrous Metals, Chemicals & Petrochemicals, Pulp, Paper & Print, Non-metallic Minerals, Transport Equipment, Machinery, Mining & Quarrying, Wood & Wood Products, Construction, and Textile & Leather industries. The estimates did not include non-energy use of fuel of these industries. Total aggregated emissions from this category increased steadily from 2,679.4 Gg CO_2-eq in year 2000, to peak at 23,615.3 Gg CO_2-eq in 2015 and then declined to 11,544.9 Gg CO_2-eq in 2016. This decline in emissions levels was a result of lower activity levels in this sector in 2016 which is reflected in the drop in natural gas consumption from 410,001.7 TJ in 2015 to 190,328.9 TJ in 2016 (Table 2.15). CO_2 is the dominant gas (Table 2.28) with 98.1% of total emissions of this category in 2016. CH_4 represented 0.6% and N_2O 1.2%. Further disaggregation of emissions of this category was not possible due to lack of relevant data for the respective subcategories. Emission estimates of NO_X, CO, NMVOCs in 2016 for the Manufacturing Industries and Construction category were 29.1 Gg, 70.1 Gg and 37.77 Gg respectively. SO_2 emissions stood at 2.9 Gg.

Table 2.28 - Trends in absolute (Gg) and aggregated (CO_2-eq) emissions of direct and indirect GHGs from Manufacturing Industries and Construction

Year	CO_2 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)	Total (Gg CO_2-eq)	CH_4 (Gg)	NO_X (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
2000	2679.43	53.42	102.48	2835.32	2.54	15.97	47.37	25.01	1.56
2001	3489.81	57.35	109.83	3656.99	2.73	17.50	50.97	27.02	1.62
2002	5382.18	62.99	120.56	5565.73	3.00	21.11	57.07	30.05	2.70
2003	10018.26	70.81	139.78	10228.85	3.37	51.62	64.46	33.61	5.03

Year	CO_2 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)	Total (Gg CO_2-eq)	CH_4 (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
2004	8576.50	74.06	142.77	8793.34	3.53	31.35	67.04	35.88	2.62
2005	11954.13	80.43	153.49	12188.05	3.83	32.32	73.27	39.83	2.27
2006	13378.41	86.62	165.37	13630.40	4.12	32.68	79.34	43.34	2.13
2007	15915.35	90.36	180.61	16186.33	4.30	35.71	83.46	45.74	2.47
2008	18185.58	101.98	204.86	18492.43	4.86	46.28	94.49	51.46	3.57
2009	10805.58	110.52	213.28	11129.38	5.26	36.05	100.83	53.86	3.49
2010	18353.62	118.02	226.41	18698.04	5.62	44.60	109.13	59.33	3.52
2011	18920.13	124.38	238.90	19283.41	5.92	46.98	114.84	62.44	3.58
2012	20695.40	128.81	247.55	21071.76	6.13	51.13	119.45	64.88	4.18
2013	16726.30	123.75	238.72	17088.76	5.89	48.04	114.01	61.38	4.27
2014	20221.05	79.04	150.47	20450.55	3.76	48.02	74.20	40.79	3.78
2015	23615.34	80.05	150.12	23845.51	3.81	43.64	75.84	42.54	2.88
2016	11544.87	76.08	144.73	11765.68	3.62	29.06	70.10	37.77	2.93

Transport (1.A.3)

Emission trends for the sub-categories are depicted in Table 2.29. The overall increase of 150.13% in the transport category fluctuates between the sub-categories. It varied from -33.15% for Railways and 209.39% for Water-Borne Navigation.

Table 2.29 - Aggregated emissions (Gg CO_2-eq) for sub-categories of the Transport Sector for 2000 to 2016

Year	1.A.3 - Transport	1.A.3.a - Civil Aviation	1.A.3.b - Road Transportation	1.A.3.c - Railways	1.A.3.d - Water-borne Navigation
2000	15422.85	42.62	14777.46	125.39	477.38
2001	19962.15	72.85	19100.75	129.82	658.73
2002	23084.89	79.45	22089.36	136.24	779.83
2003	22807.15	91.83	21809.50	129.64	776.19
2004	19876.55	78.57	19002.93	93.35	701.70
2005	21856.34	65.26	20919.64	115.39	756.05
2006	18019.87	65.89	17223.76	35.43	694.79
2007	18529.61	79.62	17697.36	29.74	722.88
2008	19937.93	93.52	19035.16	32.59	776.66
2009	19228.23	96.06	18348.89	24.28	759.00
2010	19244.02	47.65	18328.83	18.89	848.66
2011	19904.29	53.09	18935.67	21.00	894.53
2012	19896.33	76.02	18827.11	14.53	978.66
2013	33843.24	99.09	32369.27	60.80	1314.09
2014	37251.51	88.34	35651.11	69.14	1442.92
2015	33843.24	99.09	32369.27	60.80	1314.09
2016	38576.46	123.83	36891.85	83.82	1476.95

Emission trends by vehicle group for Road Transportation is given in Table 2.30. Cars are the highest emitters throughout the time series followed by Light Duty Trucks, Heavy Duty Trucks and Buses with Motorcycles contributing the least in 2016. The increase over the period 2000 to 2016 is 265.6% for Motorcycles, 257.5% for cars, 112.5 for Light Duty Trucks and 7.9 for Heavy Duty trucks and Buses.

Table 2.30 - Emission (Gg CO_2-eq) trends for direct gases for Road Transportation vehicle groups for 2000 to 2016

Year	1.A.3.b - Road Transportation	1.A.3.b.i - Cars	1.A.3.b.ii - Light-duty trucks	1.A.3.b.iii - Heavy-duty trucks and buses	1.A.3.b.iv - Motorcycles
2000	14777.46	6355.14	3248.00	4520.24	654.08
2001	19100.75	9441.45	3982.47	4695.71	981.13
2002	22089.36	11449.03	4512.77	4935.74	1191.82
2003	21809.50	11488.13	4422.91	4700.36	1198.11
2004	19002.93	10756.93	3722.59	3397.63	1125.78
2005	20919.64	11359.82	4182.06	4189.09	1188.67
2006	17223.76	10829.59	3183.68	2068.98	1141.50
2007	17697.36	11529.97	3200.56	1749.86	1216.97
2008	19035.16	12365.37	3448.85	1915.92	1305.02
2009	18348.89	12351.14	3248.82	1443.91	1305.02
2010	18328.83	14102.63	2235.93	1116.06	874.21
2011	18935.67	14823.06	2101.09	1231.64	779.87
2012	18827.11	15522.14	1756.54	859.76	688.68
2013	32369.27	20703.52	5921.99	3561.38	2182.38
2014	35651.11	22670.41	6545.39	4045.39	2389.92
2015	32369.27	20703.52	5921.99	3561.38	2182.38
2016	36891.85	22718.82	6903.40	4878.43	2391.21

Aggregated emissions by subcategory within the transport category for the year 2016 are given in Table 2.31. Road transportation emitted the major share of this category with 36,891.85 Gg CO_2-eq (95.6%) out of a total of 38,576.46 Gg CO_2-eq with cars responsible for 61.6% in this activity area. Domestic water borne Navigation followed with 1476.95 Gg CO_2-eq (3.8%), Domestic Aviation with 123.83 Gg CO_2-eq (0.3%) and Railways with 83.82 Gg CO_2-eq (0.2%). CO_2 with 37,771.44 Gg CO_2-eq made up for 97.9% of the total emissions of the direct GHGs. CH_4 represented 0.8% and N_2O 1.3% with emissions of 302.65 Gg CO_2-eq and 502.37 Gg CO_2-eq respectively.

In absolute terms the transport category emitted 14.41 Gg of CH_4 and 1.62 Gg of N_2O. The share of the different sub-categories followed the same trend as for aggregated emissions and is provided in Table 2.31.

Table 2.31 - GHG emissions (Gg CO_2-eq) for Transport category for 2016

Category	CH_4 (Gg)	N_2O (Gg)	CO_2 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)	Total (Gg CO_2-eq)
1.A.3 Transport	14.41	1.62	37771.44	302.65	502.37	38576.46
1.A.3.a - Civil Aviation	0.00	0.00	122.75	0.02	1.06	123.83
1.A.3.a.ii - Domestic Aviation	0.00	0.00	122.75	0.02	1.06	123.83
1.A.3.b - Road Transportation	14.26	1.55	36112.99	299.47	479.39	36891.85
1.A.3.b.i - Cars	10.47	1.03	22180.93	219.96	317.93	22718.82
1.A.3.b.ii - Light-duty trucks	2.37	0.32	6752.96	49.77	100.66	6903.40

Category	CH_4 (Gg)	N_2O (Gg)	CO_2 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)	Total (Gg CO_2-eq)
1.A.3.b.iii - Heavy-duty trucks and buses	0.30	0.09	4844.65	6.39	27.38	4878.43
1.A.3.b.iv - Motorcycles	1.11	0.11	2334.45	23.34	33.42	2391.21
1.A.3.c - Railways	0.00	0.03	74.78	0.09	8.95	83.82
1.A.3.d - Water-borne Navigation	0.15	0.04	1460.91	3.07	12.96	1476.95
1.A.3.d.ii - Domestic Water-borne Navigation	0.15	0.04	1460.91	3.07	12.96	1476.95

Emissions of the indirect GHGs and SO_2 by activity area within the Transport category are given in Table 2.32. Road Transportation was responsible for the highest share of emissions of all gases with 94% of NO_X, 84% of CO, 72% of NMVOCs and 1.2% of SO_2 emissions. Under the Road Transportation activity area, cars contributed most for NO_X and CO with 43% and 49% respectively. However, the contribution of cars to NMVOCs emissions under the Road Transportation activity area stood at a mere 4%, with motorcycles topping the list with 50%.

Table 2.32 - Emissions (Gg) of GHG precursors for Transport categories for year 2016

Category	NO_X	CO	NMVOCs	SO_2
1.A.3 - Transport	158.24	1482.44	274.78	9.63
1.A.3.a - Civil Aviation	0.40	0.08	0.00	0.04
1.A.3.a.ii - Domestic Aviation	0.40	0.08	0.00	0.04
1.A.3.b - Road Transportation	148.22	1242.54	198.87	0.12
1.A.3.b.i - Cars	63.33	606.44	71.98	0.07
1.A.3.b.ii - Light-duty trucks	29.82	240.60	23.57	0.02
1.A.3.b.iii - Heavy-duty trucks and buses	50.02	17.04	3.40	0.02
1.A.3.b.iv - Motorcycles	5.05	378.46	99.92	0.01
1.A.3.c - Railways	1.23	0.25	0.11	0.00
1.A.3.d - Water-borne Navigation	8.39	239.58	75.79	9.47
1.A.3.d.ii - Domestic Water-borne Navigation	8.39	239.58	75.79	9.47

Other Sectors (1.A.4)

Trends of aggregated emissions for the Other Sectors sub-categories are provided in Table 2.33. Emissions increased from the year 2000 to 2016 for all sub-categories except Stationary combustion where a decrease is noted over the same time period. Emissions increased by 486.81% for Commercial/Institutional, 60.56% for Residential, 27.12% for Agriculture/Forestry/Fishing and 52.73% for Off Road vehicles. The decrease was 15.69% for Stationary.

Table 2.33 - GHG emissions (Gg CO_2-eq) for direct gases in Other Sectors for 2000 to 2016

Year	1.A.4 - Other Sectors	1.A.4.a – Commercial / Institutional	1.A.4.b - Residential	1.A.4.c – Agriculture / Forestry / Fishing/Fish Farms	1.A.4.c.i - Stationary	1.A.4.c.ii - Off-road Vehicles and Other Machinery
2000	17413.90	491.87	16877.08	44.95	16.83	28.13
2001	21107.50	454.76	20592.16	60.58	31.46	29.12

Year	1.A.4 - Other Sectors	1.A.4.a – Commercial / Institutional	1.A.4.b - Residential	1.A.4.c – Agriculture / Forestry / Fishing/Fish Farms	1.A.4.c.i - Stationary	1.A.4.c.ii - Off-road Vehicles and Other Machinery
2002	17310.91	408.56	16868.84	33.51	2.95	30.56
2003	20379.49	387.40	19941.85	50.23	21.15	29.09
2004	20208.71	323.07	19843.20	42.44	21.52	20.92
2005	21355.56	1210.04	20098.22	47.30	21.42	25.88
2006	20361.01	1099.01	19229.55	32.45	14.29	18.16
2007	19516.46	1041.11	18451.86	23.50	8.25	15.25
2008	21334.13	1113.51	20188.82	31.79	15.10	16.69
2009	20647.20	923.60	19700.30	23.31	10.88	12.43
2010	18929.98	873.41	18036.58	19.98	10.31	9.67
2011	19418.01	959.99	18433.36	24.65	13.89	10.76
2012	18534.60	996.58	17520.82	17.19	9.73	7.46
2013	31320.59	2124.23	29124.12	72.25	41.08	31.17
2014	33432.59	2426.46	30926.22	79.91	44.48	35.43
2015	32329.42	2247.48	30009.69	72.25	41.08	31.17
2016	30040.53	2886.33	27097.06	57.14	14.19	42.96

Aggregated and absolute emissions for the Other Sectors category are given in Table 2.34. This category emitted a total of 30,040.53 Gg CO_2-eq in 2016. The highest share came from activities in the Residential sector with 90.2% of emissions. CO_2 led emissions for all three direct GHGs from this activity area, with 15,611.85 Gg CO_2-eq of CO_2, 12,084.74 Gg CO_2-eq of CH_4 and 2,886.33 Gg CO_2-eq of N_2O. Commercial / Institutional activities came next to Residential with emissions from Agriculture / Forestry / Fishing / Fish Farms being marginal at 0.2% of the total of this subcategory. In absolute terms also, the same order of contribution is observed for the sub-categories with Residential responsible for the major share of emissions for the three direct GHGs, namely 85% for CO_2, 96% for CH_4 and 96% for N_2O.

Table 2.34 – Absolute (Gg) and Aggregated GHG emissions (Gg CO_2-eq) for Other Sectors for 2016

Category	CH_4 (Gg)	N_2O (Gg)	CO_2 (Gg)	CH_4 (Gg CO_2-eq	N_2O (Gg CO_2-eq	Total (Gg CO_2-eq
1.A.4 - Other Sectors	575.46	7.56	15611.85	12084.74	2343.94	30040.53
1.A.4.a - Commercial/Institutional	22.45	0.28	2328.47	471.49	86.37	2886.33
1.A.4.b - Residential	553.00	7.28	13226.55	11613.09	2257.43	27097.06
1.A.4.c – Agriculture / Forestry / Fishing / Fish Farms	0.01	0.00	56.84	0.16	0.14	57.14
1.A.4.c.i - Stationary	0.00	0.00	14.11	0.04	0.04	14.19
1.A.4.c.ii - Off-road Vehicles and Other Machinery	0.01	0.00	42.73	0.12	0.11	42.96

The Residential sub-category again vastly dominated emissions of the GHG precursors which stood at 86% for NO_X, 99% for CO, 98% for NMVOCs and 90% for $_{SO2}$. The contribution from each sub-category is depicted in Table 2.35.

Table 2.35 - Emissions of GHG precursors (Gg) by sub-category for the Other Sectors category for 2016

Category	NO_X	CO	NMVOCs	SO_2
1.A.4 - Other Sectors	120.12	7547.08	1148.20	36.58
1.A.4.a - Commercial/Institutional	16.59	48.85	24.87	3.68
1.A.4.b - Residential	103.30	7498.16	1123.32	32.83
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	0.24	0.07	0.02	0.07
1.A.4.c.i - Stationary	0.06	0.02	0.00	0.02
1.A.4.c.ii - Off-road Vehicles and Other Machinery	0.18	0.05	0.01	0.05

Fugitive Emissions from Fuel (1.B.2) – Oil (1.B.2.a) and Natural Gas (1.B.2.b)

Trends of aggregated emissions for the Oil and Gas sub-categories under Fugitive emissions are given in Table 2.36. Emissions increased in the gas component but regressed in the oil one following the country's programme of flaring. The increase is by 84.80% in the natural gas segment accompanied by a reduction of 18.59% in the Oil sub-category

Table 2.36 - GHG emissions (Gg CO_2-eq) for direct gases in Fugitive Emissions from fuels Sector

Year	1.B.2 - Oil and Natural Gas	1.B.2.a - Oil	1.B.2.b - Natural Gas
2000	71758.64	59629.52	12129.12
2001	76487.43	62582.40	13905.03
2002	65395.12	52592.83	12802.30
2003	75480.66	61156.55	14324.12
2004	82238.96	65941.69	16297.28
2005	83009.71	66560.15	16449.56
2006	80314.00	62974.61	17339.39
2007	77592.83	58177.10	19415.73
2008	74180.42	55696.90	18483.52
2009	71111.58	56535.89	14575.70
2010	84106.46	64919.04	19187.42
2011	82215.15	62760.56	19454.59
2012	82682.86	61784.39	20898.47
2013	76635.13	57996.33	18638.80
2014	78311.45	57854.47	20456.99
2015	79917.94	56036.23	23881.71
2016	70956.10	48541.99	22414.11

Fugitive Emissions for the year 2016 are summarised in Table 2.37. Oil and Natural Gas activities were responsible for a total aggregated emissions of 70,956.10 Gg CO_2-eq, the Oil industry contributing 68.4% and the Gas industry 31.6% of this total respectively. The main contributor in the Oil industry was Production and Upgrading with 44,113.01 Gg CO_2-eq which represented 90.9% of this activity while Flaring and Venting emitted respectively 9.0 % and 0.05 %. On a GHG basis, CH_4 topped the emissions with 93.5% followed by CO_2 with 6.5% and N_2O with 0.03%.

Table 2.37 - Absolute (Gg) and aggregated (Gg CO_2-eq) of Fugitive Emissions of direct GHGs in 2016

Category	CH_4 (Gg)	N_2O (Gg)	CO_2 (Gg)	CH_4 (Gg CO_2-eq	N_2O (Gg CO_2-eq	Total (Gg CO_2-eq
1.B.2 - Oil and Natural Gas	3158.57	0.07	4604.83	66330.07	21.20	70956.10
1.B.2.a - Oil	2092.41	0.07	4580.30	43940.55	21.14	48541.99
1.B.2.a.i - Venting	1.10	0.00	0.23	23.16	0.00	23.39
1.B.2.a.ii - Flaring	2.66	0.07	4314.45	55.93	21.14	4391.52
1.B.2.a.iii - All Other	2088.64	0.00	265.62	43861.47	0.00	44127.09
1.B.2.a.iii.2 - Production and Upgrading	2087.99	0.00	265.26	43847.75	0.00	44113.01
1.B.2.a.iii.3 - Transport	0.58	0.00	0.36	12.08	0.00	12.44
1.B.2.a.iii.4 - Refining	0.08	0.00	0.00	1.64	0.00	1.64
1.B.2.a.iii.5 - Distribution of oil products	0.00	0.00	0.00	0.00	0.00	0.00
1.B.2.b - Natural Gas	1066.17	0.00	24.52	22389.52	0.07	22414.11
1.B.2.b.i - Venting	17.43	0.00	0.23	366.05	0.00	366.28
1.B.2.b.ii - Flaring	0.01	0.00	12.39	0.16	0.07	12.62
1.B.2.b.iii - All Other	1048.73	0.00	11.90	22023.31	0.00	22035.21
1.B.2.b.iii.2 - Production	958.95	0.00	7.63	20137.98	0.00	20145.61
1.B.2.b.iii.4 - Transmission and Storage	9.74	0.00	0.03	204.48	0.00	204.51
1.B.2.b.iii.5 - Distribution	80.04	0.00	4.25	1680.85	0.00	1685.09

Emissions of the GHG precursors and SO_2 are presented in Table 2.38. Natural gas operations were responsible for the major share of NO_X and CO compared to Oil segment while the latter emitted most of the NMVOC and SO2. Thee contribution varied between the sub-categories and according to gas. Flaring of natural gas contributed most of the NO_X and CO while Venting in the Oil industry was responsible for the significant share of NMVOCs. SO_2 emissions were estimated at 1.85 Gg and 0.09 Gg for Oil and Natural gas activities respectively.

Table 2.38 - Emissions (Gg) of GHG precursors by gas for Fugitive Emissions from Fuel category for 2016

Category	NO_X	CO	NMVOCs	SO_2
1.B.2 - Oil and Natural Gas	10.25	43.15	269.44	1.94
1.B.2.a - Oil	0.72	0.27	251.36	1.85
1.B.2.a.i - Venting	0.00	0.00	203.38	0.00
1.B.2.a.ii - Flaring	0.00	0.00	2.13	0.00
1.B.2.a.iii - All Other	0.72	0.27	45.84	1.85
1.B.2.a.iii.2 - Production and Upgrading	0.00	0.00	0.00	0.00
1.B.2.a.iii.3 - Transport	0.00	0.00	8.61	0.00
1.B.2.a.iii.4 - Refining	0.72	0.27	0.60	1.85
1.B.2.a.iii.5 - Distribution of oil products	0.00	0.00	36.64	0.00
1.B.2.b - Natural Gas	9.53	42.88	18.08	0.09
1.B.2.b.i - Venting	0.00	0.00	4.45	0.00
1.B.2.b.ii - Flaring	9.53	42.88	12.25	0.09

Category	NO_X	CO	NMVOCs	SO_2
1.B.2.b.iii - All Other	0.00	0.00	1.38	0.00
1.B.2.b.iii.2 - Production	0.00	0.00	0.06	0.00
1.B.2.b.iii.4 - Transmission and Storage	0.00	0.00	0.17	0.00
1.B.2.b.iii.5 - Distribution	0.00	0.00	1.16	0.00

Memo items

Emissions from fuels used for International aviation and international marine bunkers (IMB) are excluded from the nation's totals and reported as memo items. Emissions of CO_2, CH_4 and N_2O from the international bunkers (marine and aviation bunkers) increased from 501.67 Gg CO_2-eq in 2000 to 1,322.95 Gg CO_2-eq in 2016 (Table 2.39). In the year 2000, IMB contributed 85.9% of total emissions from International Bunkers, while the balance came from international aviation bunkers. On the other hand, in the year 2016, international aviation contributed 94.7% of the emissions of international bunkering with that of IMB being only 5.3% for that year.

In order to avoid double counting, CO_2 emissions from biomass combustion for energy production are also reported under the memo items and not included in the Energy sector emissions. They are estimated and reported in the AFOLU sector as part of emissions from Forest land sub-category (3.B.1.a). This includes CO_2 emissions from transformation of fuel wood to charcoal in energy industries, as well as CO_2 emissions from the use of biomass for energy purposes in the residential and commercial/institutional sectors. In the year 2000, CO_2 emissions from this activity amounted to 202,167 Gg CO_2, while in 2016, the total CO_2 emission from this activity was 256,091 Gg CO_2.

Table 2.39 - GHG emissions (Gg CO_2-eq) trend for International Bunkers and Biomass consumption for Energy Production

Year	Total International Bunkers	International Aviation Bunkers	International Marine Bunkers	CO_2 from biomass combustion for energy production
2000	501.67	430.93	70.74	202167.33
2001	807.36	736.62	70.74	204951.46
2002	874.03	803.29	70.74	207829.07
2003	999.19	928.45	70.74	210997.32
2004	865.02	794.28	70.74	214091.80
2005	730.60	659.86	70.74	217625.70
2006	736.92	666.18	70.74	221118.23
2007	875.79	805.06	70.74	227793.44
2008	1017.39	946.65	70.74	230030.52
2009	1040.61	969.87	70.74	231441.57
2010	552.51	481.77	70.74	236952.29
2011	607.53	536.80	70.74	242250.06
2012	840.21	769.47	70.74	249363.41
2013	1072.61	1001.87	70.74	249582.34
2014	963.92	893.18	70.74	249143.33
2015	1072.61	1001.87	70.74	252771.20

Year	Total International Bunkers	International Aviation Bunkers	International Marine Bunkers	CO_2 from biomass combustion for energy production
2016	1322.95	1252.21	70.74	256090.83

The GHG precursors and SO_2 were computed for International Aviation and Marine Bunkers and are presented in Table 2.40. NO_X was the main indirect GHG emitted followed by CO and NMVOCs.

Table 2.40 - Emissions (Gg) trends of GHG precursors for International Marine Bunker fuels

Year	NO_X	CO	NMVOCs	SO_2
2000	3.510	0.315	0.128	0.583
2001	4.740	0.420	0.176	0.680
2002	5.009	0.444	0.187	0.701
2003	5.512	0.487	0.206	0.740
2004	4.972	0.440	0.185	0.698
2005	4.432	0.394	0.164	0.655
2006	4.457	0.396	0.165	0.657
2007	5.016	0.444	0.187	0.701
2008	5.585	0.493	0.209	0.746
2009	5.679	0.501	0.213	0.753
2010	3.715	0.332	0.136	0.599
2011	3.936	0.351	0.145	0.617
2012	4.872	0.432	0.181	0.690
2013	5.808	0.512	0.218	0.763
2014	5.370	0.475	0.201	0.729
2015	5.808	0.512	0.218	0.763
2016	6.815	0.599	0.257	0.842

Under this category, the direct GHGs only were computed in 2016 for International Aviation Bunkering only (Table 2.41). Total aggregated emissions were 1241.3 Gg CO_2-eq with CO_2 contributing 99.13%, CH_4, 0.01% and N_2O, 0.86% in the year 2016.

Table 2.41 – Absolute (Gg) and aggregated (Gg CO_2-eq) of emissions from International Aviation Bunkers in 2016

Category	CO_2 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg CO_2-eq)	Total (Gg CO_2-eq)	CH_4 (Gg)	N_2O (Gg)
International Bunkers	1311.31	0.32	11.32	1322.95	1334.59	2668.87
1.A.3.a.i - International Aviation (International Bunkers) (1)	1241.27	0.18	10.76	1252.21	0.01	0.03
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	70.04	0.13	0.56	70.74	0.01	0.00

2.4.8.4. Comparison of the IPCC Tier 1 Reference and Sectoral Approaches

The Reference Approach (RA) is a top-down approach which used Nigeria’s total energy supply to calculate CO_2 emissions from fuel combustion rather than the IPCC source categories as obtained when adopting the

Sectoral Approach (SA) (bottom-up approach). It is good practice to compare emissions from these two approaches as significant differences may indicate possible inconsistencies with activity data, large statistical differences between energy supply and energy consumption, significant mass imbalances and the approximate net calorific value and carbon content values adopted, unrecorded consumption of fuels, high distribution losses and missing information on stock changes. A relatively small gap (5% or less) is typically expected between the two approaches.

The differences in energy consumption between the RA and SA approaches ranged from - -3.3% in 2000 to 8.9% in 2002 when the mass of all fuels is considered. In fact, the differences stemmed from liquid fuels only and stood at - 4.8% in 2000 and 14.6% in 2002 as the same data were used for the gaseous and solid fuels. These were due to high statistical differences between the supply and consumption of liquid fuels since transformation and distribution losses were not considered in both the RA and SA approaches due to lack of relevant data. Table 2.42 provides a comparison of the data adopted for computing emissions by the reference and sectoral approaches.

Table 2.42 - Energy consumption from Reference and Sectoral Approaches (Combustion Activities)

Year	Reference Approach (RA)				Sectoral Approach (SA)				RA/SA difference			
	Liquid (TJ)	Gaseous (TJ)	Solid (TJ)	Total (TJ)	Liquid (TJ)	Gaseous (TJ)	Solid (TJ)	Total (TJ)	Liquid (%)	Gaseous (%)	Solid (%)	Total (%)
2000	305414.9	155162.5	77.4	460654.8	320914	155163	77	476154	-4.8	0.0	0.0	-3.3
2001	448540.9	210235.3	77.4	658853.7	448236	210235	77	658548	0.1	0.0	0.0	0.0
2002	506400.7	277788.1	1109.4	785298.2	442038	277788	1109	720935	14.6	0.0	0.0	8.9
2003	510458.8	282880.5	593.4	793932.7	524291	282881	593	807765	-2.6	0.0	0.0	-1.7
2004	496503.9	401472	206.4	898182.3	432820	401472	206	834498	14.7	0.0	0.0	7.6
2005	519903.8	632894.2	206.4	1153004	479826	632894	206	1112927	8.4	0.0	0.0	3.6
2006	425183.8	728264	206.4	1153654	389450	728264	206	1117921	9.2	0.0	0.0	3.2
2007	373924.8	863216.4	593.4	1237735	379746	863216	593	1243555	-1.5	0.0	0.0	-0.5
2008	503762.1	928431.1	825.6	1433019	442835	928431	826	1372092	13.8	0.0	0.0	4.4
2009	427677.9	822819	877.2	1251374	407690	822819	877	1231386	4.9	0.0	0.0	1.6
2010	305416.6	974504.9	980.4	1280902	383116	974505	980	1358601	-20.3	0.0	0.0	-5.7
2011	315153.1	1021941	825.6	1337919	401838	1021941	826	1424604	-21.6	0.0	0.0	-6.1
2012	277759	1099725	1238.4	1378722	387250	1099725	1238	1488213	-28.3	0.0	0.0	-7.4
2013	786004.5	891235.9	1135.2	1678376	766997	891236	1135	1659368	2.5	0.0	0.0	1.1
2014	835378.4	1076735	1186.8	1913300	836561	1076735	1187	1914483	-0.1	0.0	0.0	-0.1
2015	723940.8	1346629	1241	2071811	743638	1346629	1241	2091508	-2.6	0.0	0.0	-0.9
2016	779411.1	1144008	1297.7	1924717	784388	1144008	1297	1929693	-0.6	0.0	0.0	-0.3

The differences in CO_2 emissions between RA and SA ranged from - 8.1 % in 2003 to 10.8% in 2002 (Table 2.43 and Figure 2.7). Negative values indicate that SA CO_2 emissions / fuel consumption is higher than RA CO_2 emissions/fuel consumption. Emissions from RA were generally higher, 11 years out of the 17 reviewed in this inventory, than emissions from SA. These results reflect the differences in the energy consumption reported in the previous paragraph and may be due to pipeline losses of liquid petroleum products during distribution which were not recorded in sufficient details for the inventory calculation in the national energy statistics in addition to the other explanations provided already.

Table 2.43 - Differences in CO_2 emissions between the Reference and Sectoral Approaches

Year	Reference Approach (RA)				Sectoral Approach (SA) (1.A)				RA / SA difference			
	Liquid	Gaseous	Solid	Total	Liquid	Gaseous	Solid	Total	Liquid	Gaseous	Solid	Total
	Emissions Gg CO_2								%			
2000	23329.8	8704.6	7.3	32042	22875	8704.6	7.3	31587	2.0	0.0	0.0	1.4
2001	33776.0	11794.2	7.3	45578	31844.1	11794.2	7.3	43646	6.1	0.0	0.0	4.4
2002	36350.2	15583.9	104.9	52039	31276.9	15583.9	104.9	46966	16.2	0.0	0.0	10.8
2003	36683.9	15869.6	56.1	52610	37513.8	15869.6	56.1	53440	-2.2	0.0	0.0	-1.6
2004	35168.9	22522.6	19.5	57711	30593	22522.6	19.5	53135	15.0	0.0	0.0	8.6
2005	37069.7	35505.4	19.5	72595	33973.7	35505.4	19.5	69499	9.1	0.0	0.0	4.5
2006	30024.5	40855.6	19.5	70900	27422.4	40855.6	19.5	68298	9.5	0.0	0.0	3.8
2007	26275.4	48426.4	56.1	74758	26640.5	48426.4	56.1	75123	-1.4	0.0	0.0	-0.5
2008	35708.1	52085.0	78.1	87871	31232.0	52085.0	78.1	83395	14.3	0.0	0.0	5.4
2009	30184.9	46160.0	83.0	76428	28653.0	46160.0	83	74896	5.3	0.0	0.0	2.0
2010	21689.5	54669.7	92.7	76452	26887.0	54669.7	92.7	81649	-19.3	0.0	0.0	-6.4
2011	22425.1	57330.9	78.1	79834	28220.0	57330.9	78.1	85629	-20.5	0.0	0.0	-6.8
2012	19919.8	61694.6	117.2	81732	27168.0	61694.6	117.2	88980	-26.7	0.0	0.0	-8.1
2013	55620.6	49998.3	107.4	105726	54071.5	49998.3	107.4	104177	2.9	0.0	0.0	1.5
2014	59069.5	60404.8	112.3	119587	59006.6	60404.8	112.3	119524	0.1	0.0	0.0	0.1
2015	50952.4	75545.9	117.4	126616	52248.0	75545.9	117.4	127911	-2.5	0.0	0.0	-1.0
2016	56720.2	64179.0	122.8	121022	55115.2	64179.0	122.7	119417	2.9	0.0	0.1	1.3

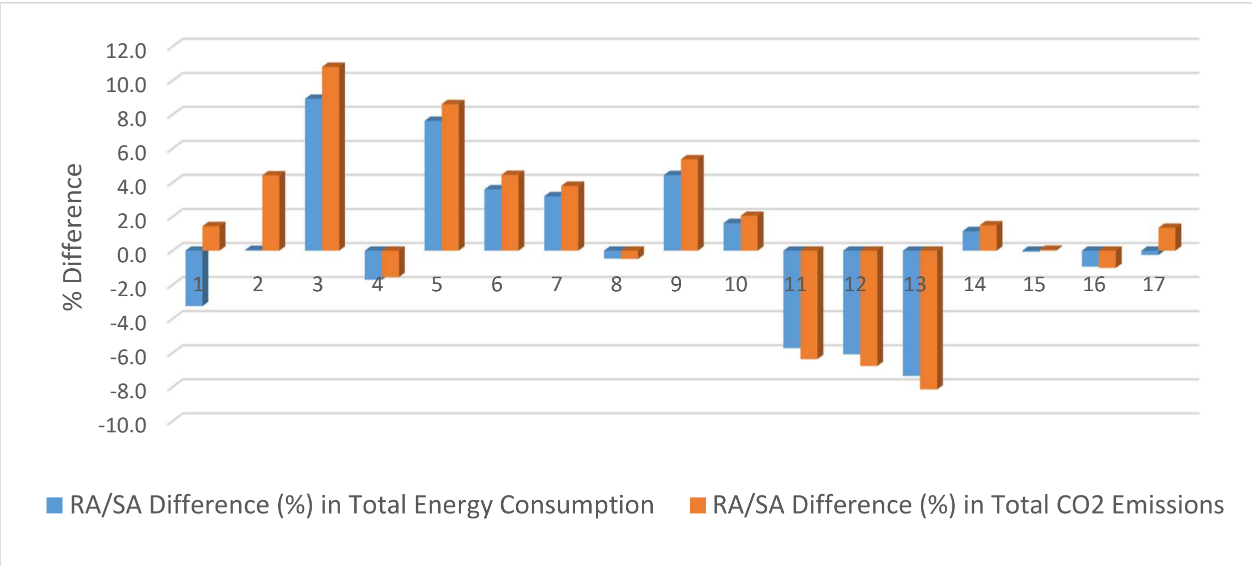


Figure 2.7 - Difference (%) between Reference and Sectoral Approaches in total energy consumption and CO_2 emissions (2000 – 2016)

2.5. Industrial Processes and Product Use

The IPPU sector comprises GHGs emitted as by-products during industrial processes for the manufacture of new products. Coverage of this sector has widened from the previous inventory when the cement industry of the mineral category only was covered to include activities in the metal and chemical categories in this inventory. Due to data challenges, emissions have not been estimated for some categories of this sector. Full details on the coverage of the IPPU sector is provided under completeness in this chapter.

- The categories and activity areas considered are:
- Mineral Industry - Cement Production
- Chemical Industry - Ammonia Production
- Metal Industry - Iron and Steel Production

2.5.1. Methodology

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3 (IPCC, 2007) were used for computing emissions in conjunction with the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2001). The decision tree in each source category was applied to determine the tier level to be adopted for computing the GHG emissions. Eventually, Tier 1 level was adopted due to data scarcity and the unavailability of national emission factors. Hence, IPCC default emission factors were adopted. Activity data for the IPPU categories covered in this inventory were obtained mainly from the National Bureau of Statistics (NBS) supplemented with those from the manufacturers of the products.

The formula used for computing emissions is

$$\text{Emissions} = \sum Aj * Efi$$

Where:

A = Activity is Production Process Input or output (tonnes/year); J = Industrial Activity
EF = Emission factor (t/kt) and i is GHG or precursor

2.5.2. Trend of national emissions

Total aggregated emissions for the IPPU sector, Table 2.44, ranged between 2,510.185 Gg CO_2-eq and 13,267.142 Gg CO_2-eq during the period 2000 to 2016 with an annual average of 7,844.193 Gg CO_2-eq. In 2016, the cement industry was responsible for 53.4% of the aggregated emissions followed by the iron and steel industry with 46.5%. The contribution of the ammonia industry was marginal.

Table 2.44 - Emissions (Gg CO_2-eq) by sub-category for the IPPU sector (2000 - 2016)

Year	Cement (CO_2)	Ammonia (CO_2)	Iron and Steel (CO_2)	Iron and steel (CH_4)	Total
2000	713.597	2.014	1,791.026	3.548	2,510.185
2001	714.464	2.014	1,791.026	3.548	2,511.053
2002	682.498	2.274	1,791.026	3.548	2,479.346
2003	652.839	1.657	5,227.132	10.356	5,891.983
2004	770.158	1.800	5,227.132	10.356	6,009.446
2005	938.888	1.617	5,227.132	10.356	6,177.993
2006	1,057.526	1.626	5,227.132	10.356	6,296.640

Year	Cement (CO_2)	Ammonia (CO_2)	Iron and Steel (CO_2)	Iron and steel (CH_4)	Total
2007	1,529.771	1.635	5,227.132	10.356	6,768.894
2008	2,117.359	1.644	5,227.132	10.356	7,356.491
2009	2,621.570	1.653	5,227.132	10.356	7,860.711
2010	3,328.455	1.663	4,904.280	9.716	8,244.113
2011	3,954.930	1.672	5,157.396	10.217	9,124.215
2012	5,408.575	1.681	5,410.512	10.719	10,831.487
2013	6,613.409	1.691	5,663.629	11.220	12,289.949
2014	6,534.317	1.700	5,916.745	11.722	12,464.484
2015	7,083.348	1.709	6,169.861	12.223	13,267.142
2016	7,083.348	1.709	6,169.861	12.223	13,267.142

Emissions by direct GHGs are given in Table 2.45. CO_2 emissions increased by more than 5.3 times from 2,506.637 Gg in the year 2000 to 13,254.918 Gg in 2016 and CH_4 increased 3.5 times from 3.548 Gg CO_2-eq to 12.223 Gg CO_2-eq over the same time period. Otherwise, CO_2 represented 99.99% of all GHG emissions of the IPPU sector in 2016, the remaining 0.01% being CH_4.

Table 2.45 - Trends of aggregated emissions (Gg CO_2-eq) of CO_2 and CH_4 (2000 – 2016)

Year	CO_2	CH_4	Total
2000	2,506.637	3.548	2,510.185
2001	2,507.504	3.548	2,511.053
2002	2,475.798	3.548	2,479.346
2003	5,881.628	10.356	5,891.983
2004	5,999.091	10.356	6,009.446
2005	6,167.637	10.356	6,177.993
2006	6,286.284	10.356	6,296.640
2007	6,758.538	10.356	6,768.894
2008	7,346.135	10.356	7,356.491
2009	7,850.356	10.356	7,860.711
2010	8,234.397	9.716	8,244.113
2011	9,113.998	10.217	9,124.215
2012	10,820.768	10.719	10,831.487
2013	12,278.729	11.220	12,289.949
2014	12,452.762	11.722	12,464.484
2015	13,254.918	12.223	13,267.142
2016	13,254.918	12.223	13,267.142

Regarding the GHG precursors CO, NO_X and NMVOCs, the emissions were insignificant during the period under review for the IPPU sector. NMVOCs increased from 0.25 Gg in 2000 to reach a value of 0.87 Gg in 2016 (Table 2.46).

Table 2.46 - Emissions of GHG precursors (Gg) of the IPPU sector (2000 - 2016)

Year	CO (Gg)	NO_x (Gg)	NMVOCs (Gg)
2000	0.00062	0.00006	0.25345
2001	0.00062	0.00006	0.25345
2002	0.00069	0.00007	0.25345
2003	0.00051	0.00005	0.73969
2004	0.00055	0.00006	0.73969
2005	0.00049	0.00005	0.73969
2006	0.00050	0.00005	0.73969
2007	0.00050	0.00005	0.73969
2008	0.00050	0.00005	0.73969
2009	0.00051	0.00005	0.73969
2010	0.00051	0.00005	0.69400
2011	0.00051	0.00005	0.72982
2012	0.00051	0.00005	0.76564
2013	0.00052	0.00005	0.80146
2014	0.00052	0.00005	0.83728
2015	0.00052	0.00005	0.87309
2016	0.00052	0.00005	0.87309

2.5.3. Mineral category (2A) – Cement production (2.A.1)

Lime is produced by the thermal decomposition of limestone, which is mainly calcium carbonate ($CaCO_3$). This process, also known as calcination (equation below), produces lime (CaO) and CO_2 as by-product.

$$CaCO_3 + Heat \leftrightarrow CaO + CO_2$$

The CaO then reacts with silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) as other raw materials to make the clinker minerals (chiefly calcium silicates). This product is finely ground and mixed with a small proportion of calcium sulphate [gypsum ($CaSO_4 \cdot 2H_2O$) or anhydrite ($CaSO_4$) to produce hydraulic (typically Portland) cement. CO_2 is the main GHG emitted during cement production and it is emitted during calcination. Based on the decision tree in the IPCC 2006 GL (V3_2_Ch2_p 2.9), Tier 1 methodology was used in the estimation of CO_2 due to data constraints.

Activity Data on the production of cement for the period 2000 to 2015 were collected from the Cement Manufacturer's Association of Nigeria (CMAN) while for 2016 the same value as for 2015 was adopted as those for this year was not yet available. The data are presented in Table 2.47. For the period under review, there was no import or export of clinker.

Table 2.47 - Production of cement (10^3 tonnes) between 2000 and 2016

Year	2000	2001	2002	2003	2004	2005	2006	2007
Production	2,165	2,168	2,071	1,981	2,337	2,849	3,209	4,642

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Production	6,425	7,955	10,100	12,001	16,412	20,068	19,828	21,494	21,494

Source: Cement Manufacturer's Association of Nigeria

Emissions of CO_2 (Gg) from Cement Production for the period 2000-2016 are presented in Figure 2.8. The highest emissions of 7,083.345 Gg of CO_2 for the period under review was recorded in 2015 and 2016 and was generated from the production of 21,494,000 tonnes of cement. The lowest emissions of 652.839 Gg CO_2 occurred in 2003 from 1,981,000 tonnes of cement (CMAN, 2012).

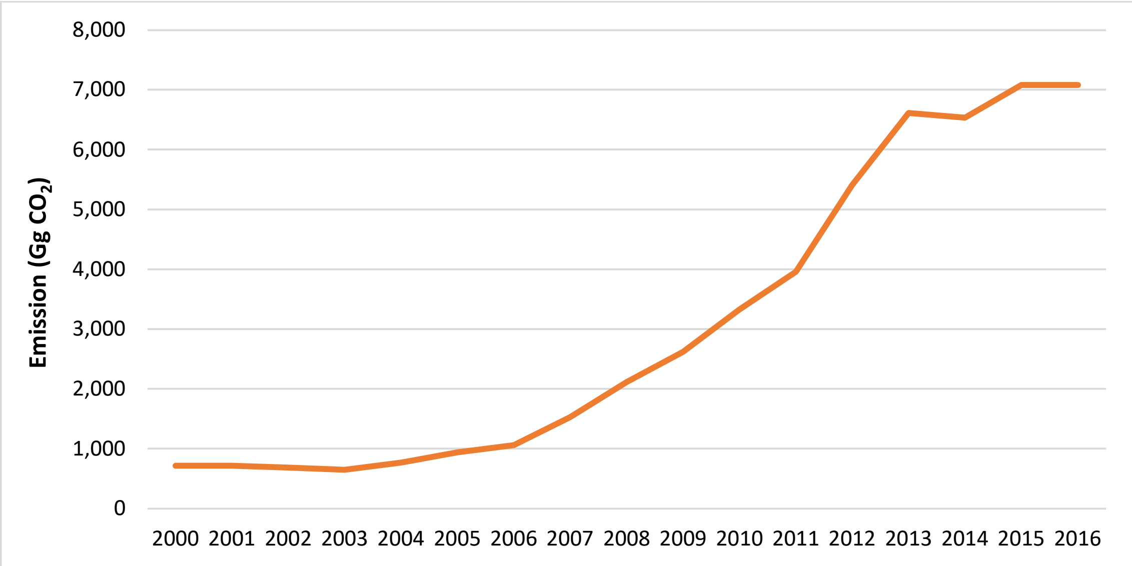


Figure 2.8 - CO_2 Emission (Gg) in Cement Production for the period 2000-2016

2.5.4. Chemical industry (2.B) - ammonia production (2.B.1)

Ammonia (NH_3) is produced by catalytic steam reforming of natural gas or other fuels. When natural gas (CH_4) is used as feedstock, nitrogen and hydrogen undergo chemical reaction in the ratio 1:3. CO_2 is the only direct GHG emitted during ammonia production The basic equations are:

Overall Reaction: $0.88\ CH_4 + 1.26\ Air + 1.24\ H_2O \rightarrow 0.88\ CO_2 + N_2 + 3H_2$

Ammonia Synthesis: $N_2 + 3H_2 \rightarrow 2NH_3$

Data obtained from the National Bureau of Statistics (NBS) on ammonia production was incomplete for the time series of this inventory as it only covered the period 2000 to 2008. It also contained several outliers. Statistical techniques, namely averaging and trending were used with the available data to produce a full timeseries from 2000 to 2016. Data on ammonia production used for estimating emissions are given in Table 2.48.

Table 2.48 - Production (tonnes) of Ammonia (2000-2016)

Year	2000	2001	2002	2003	2005	2005	2006	2007
Production	615.46	615.46	694.78	506.41	550.08	494.22	496.94	499.69

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Production	502.47	505.26	508.07	510.89	513.73	516.58	519.45	522.34	522.34

Source: National Bureau of Statistics for period 2000 to 2008

Based on the decision tree in the IPCC 2006 Guidelines (V3_3_Ch3_p 3.14) and due to lack of information on the quantity of feedstock fuel used for ammonia production, the Tier 1 methodology was adopted. In this method, it is recommended that the average value of fuel requirement stated in Table 3.1 of the 2006 IPCC Guidelines (IPCC, 2007); (42.5 GJ(NCV)/tonne NH_3) be used. The corresponding values of carbon content of fuel used for production and carbon oxidation factors of the fuel according to the Tier 1 method are 21kg/GJ and 1 respectively.

The general equation using Tier 1 method used to estimate the emissions associated with ammonia production is:

$$ECO_2 = AP * FR * CCF * COF * 44/12 - RC0_2$$

Where:

ECO_2 = Emission of CO_2 (kg)
AP = Ammonia production, tonnes
FR = Fuel requirement per unit of output (GJ/tonne NH_3 produced)
CCF = Carbon content of the fuel (kg C/GJ)
COF = Carbon oxidation factor of the fuel (fraction)
RCO_2 = CO_2 recovered for downstream use in urea production (kg)

The emissions of the precursor GHGs were calculated using methods prescribed by the EMEP/EEA air pollutant guidebook for Chemical Industry. A Tier 1 method was used to estimate emissions of CO and NO_X.

2.5.5. Emissions of direct and indirect GHGs (Gg) from ammonia production for 2000 to 2016

Emissions of CO_2 and the GHG precursors CO and NO_X emitted during the production of ammonia are presented in Table 2.49. The highest CO_2 emissions of 2.274 Gg CO_2 resulted from the production of 694 tonnes of NH_3 in 2002. The year with the least emissions was 2005 with 1.617 Gg of CO_2 emitted as a result of the production of 550 tonnes of ammonia only. The highest emissions of CO and NO_X were also associated with the year 2002 with emission of 0.00006 Gg and 0.00069 Gg respectively.

Table 2.49 - Emissions of CO_2, CO and NO_X (Gg) for NH_3 production (2000 -2016)

Year	CO_2	CO	NO_X
2000	2.014	0.00006	0.00062
2001	2.014	0.00006	0.00062
2002	2.274	0.00007	0.00069
2003	1.657	0.00005	0.00051
2004	1.800	0.00006	0.00055
2005	1.617	0.00005	0.00049
2006	1.626	0.00005	0.00050
2007	1.635	0.00005	0.00050
2008	1.644	0.00005	0.00050
2009	1.653	0.00005	0.00051
2010	1.663	0.00005	0.00051
2011	1.672	0.00005	0.00051
2012	1.681	0.00005	0.00051
2013	1.691	0.00005	0.00052

Year	CO_2	CO	NO_X
2014	1.700	0.00005	0.00052
2015	1.709	0.00005	0.00052
2016	1.709	0.00005	0.00052

2.5.6. Metal industry (2.C) - Iron and Steel production (2.C.1)

Activity Data on Iron and Steel production for the period 2000 to 2008, except for 2005 was provided by the NBS. The timeseries was amended and completed for missing years using statistical techniques, namely averaging and linear extrapolation to obtain a full set of data for the period 2000 to 2016. GHG emissions from Iron and Steel production were estimated out using the data presented in Table 2.50.

Table 2.50 - Production of Iron and Steel (tonnes) (2000-2016)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Production	1,689,647	1,689,647	1,689,647	4,931,257	4,931,257	4,931,257	4,931,257	4,931,257	4,931,257

Year	2009	2010	2011	2012	2013	2014	2015	2016
Production	4,931,257	4,626,679	4,865,468	5,104,257	5,343,046	5,581,835	5,820,624	5,820,624

Source: National Bureau of Statistics (2000-2004 and 2006-2008)

Three GHGs (CO_2, CH_4 and N_2O) are emitted during Iron and Steel production but only CO_2 and CH_4 were computed as there are no EF in the IPCC 2006 GL. The EMEP/EEA air pollutant emission inventory guidebook could not be used as alternative method since the technology adopted in the manufacturing process was not known. Based on the decision tree of the IPCC 2006 Guidelines (V3_4_Ch4_p 4.20), a Tier 1 approach was used due to lack of plant specific data. The Global Average Factor of 1.06 based on 65% BOF, 30% EAF and 5% OHF) was used to estimate the CO_2 emissions from steelmaking. The equation is

$$\mathbf{E_{CO_2} = EF * AM_{I\,\&\,S}}$$

Where:

ECO_2 = Emission of CO_2 (Gg)
EF = Emission factor (tonne CO_2/tonnes produced)
AM = Amount of iron and steel produced (tonnes)

The 2006 IPPC guidelines recommend a default emission factor of 0.1 for coke production when adopting Tier 1 estimation method. This emission factor is used in the estimation of CH_4 emissions.

The estimation of NMVOC was carried out using the Tier 1 method provided in the 2016 EMEP/EEA air pollutant emission inventory guidebook. The 2016 EMEP/EEA air pollutant emission inventory guidebook recommended default emission factor of 150g/mg for NMVOC for Iron and Steel production was used. The general equation presented below was used to estimate NMVOC emissions in Iron and Steel production:

$$\text{E pollutant} = \text{AR production} * \text{EF pollutant}$$

Where:

E pollutant = Emission of NMVOC
AR production = Amount of iron and steel produced yearly in tonnes

EF pollutant = Emission factor for NMVOC

CO_2 emissions (Table 2.51) varied between 6,169.861 Gg from production of 5,820,624 tonnes of Iron and Steel in 2015 and 2016 and 1791.026 Gg CO_2 from production of 1,689,647 tonnes in the year 2000. Emissions increased by 44% during the period 2000 to 2016.

CH_4 emissions increased from 0.169 Gg CH_4, equivalent to 3.548 Gg CO_2-eq. in 2000 to 0.582 Gg equivalent to 12.223 Gg CO_2-eq in 2016. NMVOC emissions increased from 0.253 Gg in the year 2000 to 0.873 in the year 2016.

Table 2.51 - Emissions of CO_2 and CH_4 from Iron and Steel production (2000 – 2016)

Year	CO_2 (Gg)	CH_4 (Gg)	CH_4 (Gg CO_2-eq)	NMVOCs (Gg)
2000	1,791.026	0.169	3.548	0.253
2001	1,791.026	0.169	3.548	0.253
2002	1,791.026	0.169	3.548	0.253
2003	5,227.132	0.493	10.356	0.740
2004	5,227.132	0.493	10.356	0.740
2005	5,227.132	0.493	10.356	0.740
2006	5,227.132	0.493	10.356	0.740
2007	5,227.132	0.493	10.356	0.740
2008	5,227.132	0.493	10.356	0.740
2009	5,227.132	0.493	10.356	0.740
2010	4,904.280	0.463	9.716	0.694
2011	5,157.396	0.487	10.217	0.730
2012	5,410.512	0.510	10.719	0.766
2013	5,663.629	0.534	11.220	0.801
2014	5,916.745	0.558	11.722	0.837
2015	6,169.861	0.582	12.223	0.873
2016	6,169.861	0.582	12.223	0.873

2.6. Agriculture, Forestry and Other Land Use (AFOLU)

Based on the last inventory, activities in the AFOLU sector are among the highest contributors to emissions of greenhouse gases in Nigeria, which makes it a key category.

The AFOLU sector comprises four subcategories:

- Livestock (3.A)
- Land (3.B)
- Aggregated sources and non-CO_2 emissions from land (3.C)
- Other (3.D)

For this inventory, only livestock (3.A) was fully covered while biomass burning in grassland and crop land as well as use of synthetic fertilizers and rice cultivation were the ones covered for Aggregated sources and non-CO_2 emissions from land (3.C) subcategories. For land (3.B), emissions from changes within Forest land only were estimated. Under Other (3.D), removals for harvested wood products (HWP) only were estimated.

2.6.1. Data sources and methodology

The data needed for this inventory were sourced from different relevant national and international institutions as presented in Table 2.48.

Table 2.52 - Data and data sources

Category	Sub-category	Data Type	Data Source	Principal Data Provider
Livestock	Enteric Fermentation Manure Management	Animal population (Cattle, goats, sheep, asses and mules, camels, swine, horses and poultry)	FAOSTAT	FAO
Land	Forest Land	Forest area	USGS 2016 Report FRA 2015 NBS report	USGS FAO NBS
		Climate zone and soil classification	IPCC GL	IPCC
		Biomass estimate for 5 IPCC pools (above-ground biomass, below-ground biomass, deadwood, herb, litter and soil	IPCC GL	IPCC
		Harvested Wood Products	FAOSTAT	FAO
		Wood/Fuel wood removal	FAOSTAT	FAO
Aggregated and non-CO_2 emission on land	Biomass burning	Actual mass of savanna and crop residues burnt	FAOSTAT	FAO
	Direct N_2O emission from managed soil	Synthetic fertilizer consumption	FAOSTAT	FAO
	Indirect N_2O emission from managed soil	Crop land area	FAOSTAT	FAO
	Indirect emissions from manure management	Animal population (Cattle, goats, sheep, asses and mules, camels, swine, horses and poultry)	FAOSTAT	FAO
	Rice cultivation	Area of land under rice	FAOSTAT	FAO

Source: http://faostat.fao.org/ (Accessed December 2018)

2.6.2. Filling of Data Gaps

Gaps identified in the inventory were filled using appropriate IPCC methodologies. The specific method employed in filling the gaps was selected based on the nature and type of gaps. Data from FAOSTAT was analysed and outliers were replaced using statistical techniques such as averages and trending.

2.6.3. Methodology

Tier 1 was adopted for the estimation of emissions/removals in the AFOLU sector as there were no reliable country-specific data. Activity data here refers to the intensity, level or quantity of activity that led to emissions/removals of GHGs while emission factor represents the rate at which a particular GHG is emitted or removed as a result of use of, change of and level of intensity/frequency of use/number of activity will generate/remove GHGs under certain defined conditions. Therefore, the product of activity data and emission factor gives the total GHG emission for a particular activity. The equation is as follows:

$$E = AD * EF$$

Where

E = Emission
AD = Activity Data
EF = Emission factor

Extrapolation and interpolation techniques were used in line with IPCC good practice guidance (GPG) to generate missing data and replace outliers in the time series. In cases where there were no data, expert judgment was applied, and the assumption was documented. (Protocol description)

2.6.4. Emission trends in the AFOLU sector

Emissions and removals by category of the AFOLU sector are given in Table 2.53. Total emissions were 371,022 Gg CO_2-eq in 2016 with a removal of 4,288 Gg CO_2-eq under HWP to give net emissions of 366,734 Gg CO_2-eq which is the highest emissions for the entire period under consideration. Compared to the year 2000 emissions, 295,444 Gg CO_2-eq, those of 2016 represented an increase of about 25.6%. The highest emitter of the AFOLU sector is the Land category, Forestland remaining Forestland which is the only activity area computed in this inventory, with 84.0% of total emissions. Aggregated sources and non-CO_2 emission source on land followed with 8.1% and Livestock with 7.9%. HWP removed 1.2 % of total emissions.

Net emissions increased from 289,476 Gg CO_2-eq in the year 2000 to 366,734 Gg CO_2-eq in 2016, an increase of 26.7%. Emissions from Land (Forestland remaining Forestland) represented about 85.0% of 2016 net emissions of 366,734 Gg CO_2-eq. Livestock and Aggregated sources and non-CO_2 source on land contributed 8.0 % and 8.2 % of net emissions respectively.

Table 2.53 - Emissions and removals (Gg CO_2-eq) by source categories of the AFOLU sector

Year	Total emissions	Livestock (3A)	Land (3B)	Aggregated sources and non-CO_2 emission source on land (3C)	Other (3D) (HWP)	Net emissions
2000	295,444	19,420	255,877	20,147	-5,968	289,476
2001	300,107	20,170	259,019	20,917	-5,827	294,280
2002	303,829	20,444	262,265	21,121	-5,680	298,149
2003	307,643	20,614	265,615	21,414	-5,697	301,947
2004	312,451	21,324	269,072	22,055	-5,642	306,809
2005	317,716	21,721	272,645	23,351	-5,403	312,313
2006	322,145	22,099	275,836	24,211	-5,272	316,874
2007	325,262	22,477	279,119	23,667	-5,330	319,932
2008	329,228	22,854	282,501	23,872	-5,131	324,097
2009	332,231	23,261	285,978	22,992	-4,959	327,272
2010	338,420	23,703	289,554	25,163	-4,808	333,612
2011	345,869	26,901	292,853	26,115	-5,475	340,394
2012	351,820	27,367	296,236	28,218	-4,187	347,633
2013	356,618	27,774	299,705	29,139	-5,090	351,528
2014	363,140	28,308	305,150	29,681	-5,402	357,737
2015	366,668	28,746	308,796	29,127	-4,792	361,876
2016	371,022	29,241	311,609	30,173	-4,288	366,734

Aggregated emissions by gas for the AFOLU sector is presented in Table 2.54. Emissions increased over the time series for all 3 gases, namely by 21.8% for CO_2, 47.2% for CH_4 and 54.5% for N_2O. In 2016, CO_2 contributed 311,609 Gg, CH_4 34,439 Gg CO_2-eq and N_2O 24,974 Gg CO_2-eq. CO_2 remained as the main gas emitted over the entire period 2000-2016 with about 85.3% of total annual emissions followed by CH_4 with about 8.5% and N_2O with about 6.2% on average for that period.

Table 2.54 - Emissions by gas (Gg CO_2-eq) for the AFOLU sector (2000 – 2016)

Year	CO_2	CH_4	N_2O	Total
2000	255,877	23,398	16,168	295,444
2001	259,019	23,852	17,235	300,107
2002	262,265	24,281	17,284	303,829
2003	265,615	24,556	17,473	307,643
2004	269,072	25,482	17,897	312,451
2005	272,645	26,180	18,892	317,716
2006	275,836	27,057	19,252	322,145
2007	279,119	26,771	19,372	325,262
2008	282,501	26,957	19,770	329,228
2009	285,978	26,071	20,182	332,231
2010	289,554	27,844	21,022	338,420
2011	292,853	30,554	22,462	345,869
2012	296,236	32,344	23,240	351,820
2013	299,705	32,908	24,005	356,618
2014	305,150	33,761	24,228	363,140
2015	308,796	34,265	23,608	366,668
2016	311,609	34,439	24,974	371,022

Emissions of the precursor gas NO_X increased by 58.3%, from 0.122 Gg in 2000 to 0.193 in 2016. Emissions of CO more than doubled from the year 2000 to the year 2016 with 5.912 Gg (Table 2.55).

Table 2.55 - Emissions and removals (Gg) by precursor gas for the AFOLU sector (2000-2016)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
NO_X emissions	0.122	0.128	0.142	0.15	0.149	0.161	0.158	0.18	0.181
CO emissions	2.811	2.884	3.679	3.868	3.882	4.127	4.165	5.062	5.367

Year	2009	2010	2011	2012	2013	2014	2015	2016
NO_X emissions	0.171	0.126	0.218	0.151	0.115	0.173	0.189	0.193
CO emissions	5.236	3.598	4.829	4.666	4.243	5.569	5.8	5.912

2.6.4.1. Livestock (3.A)

Emissions from livestock are generated through enteric fermentation and management of manure from domestic animals such as cattle, sheep, goats, horses, swine, donkeys (asses and mules), camels and poultry. Significant amounts of CH_4 are produced by herbivores during the normal digestive process as microorganisms break down carbohydrates into simpler molecules for absorption. CH_4 is produced as a by-product. Ruminant animals such as cattle generate the most methane while non-ruminant animals such as swine generate minimal amounts. It was estimated that there exist no dairy cattle activity solely for milk production in Nigeria as the vast majority of the herd is owned by pastoral Fulani (Dr Obadina, 1999) farmers. This tribe sells most of the domestic milk consumed in Nigeria.

CH_4 and N_2O are the two direct GHGs emitted during handling and storage of livestock manure. The magnitude of emissions depends on the quantity of manure handled, its characteristics, and the manure management system. Generally, poorly aerated manure management systems generate more CH_4 than well-aerated systems. The manure management systems assigned in this inventory are paddock, range and pasture (PRP) and solid storage. All the animals listed for enteric fermentation plus poultry were considered for estimating emissions for manure management.

Total emissions from livestock increased from 19,420 Gg CO_2-eq in 2000 to 29,241 Gg CO_2-eq in 2016 which represented an increase of 50.6%. Enteric fermentation contributed of 89.9% of the total emissions from livestock on average when considering the 17 years results and manure management added the remaining 10.1% (Table 2.56).

Table 2.56 - Emissions (Gg CO_2-eq) from livestock

Year	Enteric fermentation	Manure management	Total
2000	17505	1915	19,420
2001	18111	2059	20,170
2002	18352	2091	20,444
2003	18566	2049	20,614
2004	19145	2180	21,324
2005	19493	2227	21,721
2006	19809	2290	22,099
2007	20131	2346	22,477
2008	20453	2402	22,854
2009	20796	2465	23,261
2010	21172	2531	23,703
2011	24186	2715	26,901
2012	24583	2783	27,367
2013	24986	2788	27,774
2014	25472	2837	28,308
2015	25859	2887	28,746
2016	26300	2940	29,241

Enteric Fermentation (3.A.1)

Emissions from enteric fermentation were calculated using IPCC Tier 1 methodology and default emission factors. This was done by multiplying the individual animal population with the default emission factor of the respective animal type for the specific activity. Activity data used for computing the emissions for both enteric fermentation and manure management are provided in Table 2.57.

Table 2.57 - Categorization of Livestock Population (2000 – 2016)

Year	Livestock category									
	Other cattle	Goat	Sheep	Horses	Asses	Camel	Swine (Breeding)	Swine (Market)	Poultry (broilers)	Poultry (layers)
2000	15,118,300	42,500,000	26,000,000	204,000	1,000,000	80,000	504,762	4,542,862	26,200,000	87,000,000
2001	15,133,400	45,260,400	28,692,600	205,000	1,000,000	100,000	524,954	4,724,586	28,620,000	96,000,000
2002	15,148,600	46,400,000	29,400,000	205,000	1,000,000	120,000	611,182	5,500,642	33,125,000	98,000,000
2003	15,163,700	47,551,700	30,086,400	205,000	1,000,000	140,000	567,790	5,110,110	36,680,000	101,000,000
2004	15,700,000	48,700,000	30,800,000	204,550	1,050,000	160,000	591,000	5,319,000	39,500,000	104,000,000
2005	15,875,266	49,959,000	31,547,900	203,533	1,050,000	180,000	614,122	5,527,098	40,700,000	110,000,000
2006	16,013,382	51,208,220	32,305,000	161,032	1,080,000	200,000	638,687	5,748,181	43,400,000	115,000,000
2007	16,152,700	52,488,200	33,080,400	147,602	1,060,000	220,000	664,234	5,978,106	45,127,000	121,000,000
2008	16,293,200	53,800,400	33,874,300	104,413	1,065,000	240,000	690,803	6,217,227	47,434,000	127,000,000
2009	16,434,978	55,145,440	34,687,264	102,729	1,065,000	260,000	718,436	6,465,920	48,156,000	135,000,000
2010	16,577,962	56,524,076	35,519,760	101,509	1,200,000	277,727	747,173	6,724,557	56,313,000	136,000,000
2011	19,041,270	67,292,536	38,376,024	101,611	1,220,000	278,005	628,245	5,654,208	9,893,000	139,000,000
2012	19,206,928	68,974,848	39,335,424	101,713	1,250,000	278,283	653,375	5,880,376	19,254,000	140,000,000
2013	19,374,029	70,699,218	40,318,809	101,715	1,265,000	278,561	679,510	6,115,591	22,922,630	111,916,370
2014	19,753,249	71,958,213	41,284,022	101,862	1,270,000	279,215	699,199	6,292,790	23,330,800	113,909,200
2015	20,184,763	72,527,691	41,632,158	102,147	1,279,443	279,534	736,822	6,631,394	34,272,870	108,022,130
2016	20,560,933	73,879,561	42,091,042	102,356	1,295,593	279,802	748,863	6,739,768	36,989,990	111,413,890

Source: FAOSTAT

In 2016, total emissions from enteric fermentation were 26,300 Gg CO_2-eq, making up for about 90% of the total livestock emissions for that year. This was 50.2% higher than emissions of the year 2000. In 2016, cattle contributed 50.9% of the total emissions by enteric fermentation, closely followed by goats (29.5%) and sheep (16.8%). Camels, mules, swine and horses made up for the remaining 2.8% (Table 2.58).

Table 2.58 - Emissions (Gg CO_2-eq) from enteric fermentation by animal type

Year	Cattle	Sheep	Goat	Camels	Horses	Mules and Asses	Swine	Total
2000	9,842	2,730	4,463	77	77	210	106	17,505
2001	9,852	3,013	4,752	97	77	210	110	18,111
2002	9,862	3,087	4,872	116	77	210	128	18,352
2003	9,872	3,159	4,993	135	77	210	119	18,566
2004	10,221	3,234	5,114	155	77	221	124	19,145
2005	10,335	3,313	5,246	174	77	221	129	19,493
2006	10,425	3,392	5,377	193	61	227	134	19,809
2007	10,515	3,473	5,511	213	56	223	139	20,131
2008	10,607	3,557	5,649	232	39	224	145	20,453
2009	10,699	3,642	5,790	251	39	224	151	20,796
2010	10,792	3,730	5,935	268	38	252	157	21,172
2011	12,396	4,029	7,066	269	38	256	132	24,186
2012	12,504	4,130	7,242	269	38	263	137	24,583
2013	12,612	4,235	7,423	269	38	266	143	24,986
2014	12,859	4,335	7,556	270	39	267	147	25,472
2015	13,140	4,371	7,615	270	39	269	155	25,859
2016	13,385	4,420	7,757	270	39	272	157	26,300

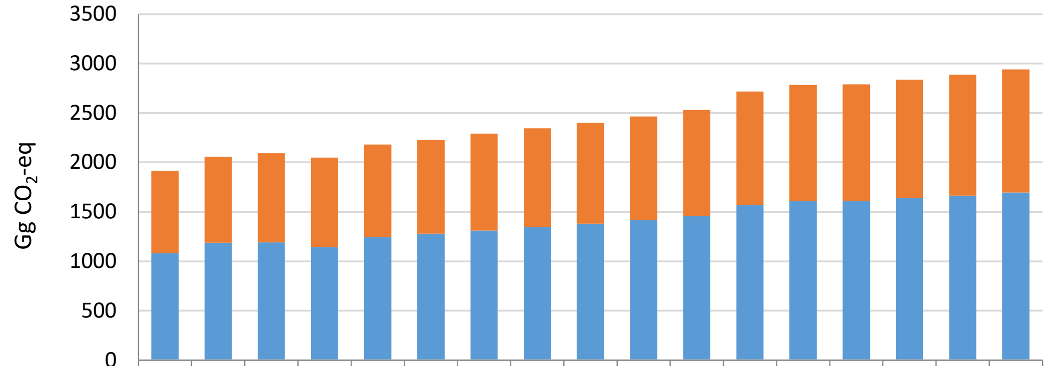
Manure Management (3.A.2)

Emissions from manure management were calculated using IPCC Tier 1 methodology and default emission factors. This was done by multiplying the individual animal population with the default emission factor of the respective animal type according to manure management system. The fraction of manure treated under the different manure management systems for each livestock species is given in Table 2.59.

Table 2.59 - Manure management systems (MMS) applied

Livestock	Manure Management Systems (MMS)		
	PRP	Solid storage	Poultry with litter
Cattle	90%	10%	0%
Sheep	70%	30%	0%
Goats	70%	30%	0%
Camels	90%	10%	0%
Horses	70%	30%	0%
Mules	70%	30%	0%
Swine (market)	60%	40%	0%
Swine (breeding)	60%	40%	0%
Poultry	0%	0%	100%

Total aggregated emissions increased from 1,915 Gg CO_2-eq in 2000 to 2,940 Gg CO_2-eq in 2016 representing an increase of 53.6% (Figure 2.9). In 2016, N_2O contributed about 57.7% of the total aggregated emissions from manure management and methane the remaining 42.3%. In 2016, emissions from cattle made up for about 21.5% of the total emissions from manure management. The contributions of the other animal types were sheep (18.5%), goats (39.1%), swine (9.1%) and poultry (9.0%). Camels, horses and mules made up the remaining 2.8%.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Methane	834	870	901	905	935	948	979	1001	1023	1047	1075	1146	1172	1177	1198	1223	1245
Nitrous Oxide	1081	1189	1190	1144	1245	1279	1311	1345	1379	1418	1456	1569	1611	1611	1638	1664	1695

Figure 2.9 - Methane and nitrous oxide emissions from manure management

Emissions by animal type for manure management is given in Table 2.60. The highest emission was from Goats throughout the timeseries under consideration and it stood at 1151 Gg CO_2-eq in 2016 which represented 39.1% of total emissions from this subcategory.

Table 2.60 - Emissions (Gg CO_2-eq) by animal type for manure management systems

Year	Cattle	Sheep	Goat	Camels	Horses	Mules and Asses	Swine	Poultry	Total
2000	464	336	662	5	23	41	180	203	1,915
2001	464	371	705	6	23	41	187	260	2,059
2002	465	380	723	8	23	41	218	233	2,091
2003	465	389	741	9	23	41	202	178	2,049
2004	482	398	759	10	23	43	210	253	2,180
2005	487	408	778	11	14	43	219	267	2,227
2006	491	418	798	13	18	44	227	280	2,290
2007	496	428	818	14	17	44	237	294	2,346
2008	500	438	838	15	12	44	246	308	2,402
2009	504	449	859	16	12	44	256	325	2,465
2010	509	460	881	17	12	49	266	337	2,531
2011	584	496	1,049	17	12	50	224	283	2,715
2012	589	509	1,075	17	12	51	233	297	2,783
2013	595	522	1,102	17	12	52	242	247	2,788
2014	606	534	1,121	17	12	52	248	246	2,837

Year	Cattle	Sheep	Goat	Camels	Horses	Mules and Asses	Swine	Poultry	Total
2015	619	539	1,130	18	12	53	262	254	2,887
2016	631	545	1,151	18	12	53	267	264	2,940

Land (3B)

CO_2 is emitted from human induced modification of landscapes leading to land use changes. The land use change is the result of conversion of land categories amongst the various IPCC land classes, namely (a) Forest land (FL), (b) Crop land, (c) Grassland, (d) Wetlands, (e) Settlements and (f) Other land. Due to data constraints, only activities within FL have been assessed and emissions estimated. However, in this inventory, data on land use changes were not available and thus emissions stemming from this activity has not been computed.

On the basis of available data from different sources, a land matrix with areas of the different land categories has been constructed with no movement between them. The total area of the country was balanced with corrections made to the Other land category. Information obtained from USGS (2016) together with other sources including FRA (2015), FAO Aquastat and NBS were used to validate the different areas adopted for the period 2000 to 2016. The information is summarized in Table 2.61. The default soil type Low Activity Clay and climate Tropical moist short dry season since these were considered as being most appropriate to represent the country.

Two categories of forestland were considered, forestland and other wooded land. The areas of land classified in the USGS 2016 report and FRA 2015 were reassigned to fall within the six different IPCC land classes. The area of forestland declined during the timeseries on account of deforestation and wood removals for both merchantable wood and wood fuel.

Cropland was assumed to fall under three subclasses: Cropland Annual for annual crops, Cropland perennial for perennial crops such as coffee, rubber, palm, tea, etc. and rice paddy. Annual cropland relates to rainfed crops produced during part of the year and thereafter used for production of fodder and grazing during the remaining part of the same year. Cultivation of rice paddy is mainly done in wetlands but due to scarcity of information and confirmation of the different areas involved, for this inventory they have been considered as a separate entity as per the 2006 IPCC Guidelines.

There is a mix of permanent grazing land and grassland and these have been summed as area of the Grassland land class.

With the rapidly increasing population of Nigeria, an important change in the area of settlement has been identified, but it has not been possible to track from which land category they originated over the time period under consideration.

Table 2.61 - Area (ha) of the different land categories in Nigeria from 2000 to 2016

Year	Forestland	Cropland Annual	Cropland perennial	Rice paddy	Grassland	Wetland	Settlements	Other land	Area of country
2000	15,796,400	29,029,000	188,800	2,199,000	39,310,800	3,387,600	1,205,200	1,260,100	92,376,900
2001	15,681,908	29,756,138	188,277	2,117,000	38,734,185	3,382,585	1,256,708	1,260,100	92,376,900

2002	15,567,415	30,333,277	187,754	2,185,000	38,157,569	3,377,569	1,308,215	1,260,100	92,376,900
2003	15,452,923	30,953,415	187,231	2,210,000	37,580,954	3,372,554	1,359,723	1,260,100	92,376,900
2004	15,338,431	31,460,554	186,708	2,348,000	37,004,338	3,367,538	1,411,231	1,260,100	92,376,900
2005	15,223,938	31,959,692	186,185	2,494,000	36,427,723	3,362,523	1,462,738	1,260,100	92,376,900
2006	15,109,446	32,373,831	185,662	2,725,000	35,851,108	3,357,508	1,514,246	1,260,100	92,376,900
2007	14,994,954	33,292,969	185,138	2,451,000	35,274,492	3,352,492	1,565,754	1,260,100	92,376,900
2008	14,880,462	34,007,108	184,615	2,382,000	34,697,877	3,347,477	1,617,262	1,260,100	92,376,900
2009	14,765,969	35,197,366	184,092	1,836,880	34,121,262	3,342,462	1,668,769	1,260,100	92,376,900
2010	14,651,477	35,246,755	183,569	2,432,630	33,544,646	3,337,446	1,720,277	1,260,100	92,376,900
2011	14,536,985	36,055,113	183,046	2,269,410	32,968,031	3,332,431	1,771,785	1,260,100	92,376,900
2012	14,422,492	36,105,847	182,523	2,863,815	32,391,415	3,327,415	1,823,292	1,260,100	92,376,900
2013	14,308,000	36,683,400	182,000	2,931,400	31,814,800	3,322,400	1,874,800	1,260,100	92,376,900
2014	14,193,508	37,178,015	181,477	3,081,923	31,238,185	3,317,385	1,926,308	1,260,100	92,376,900
2015	14,079,015	37,783,515	180,954	3,121,562	30,661,569	3,312,369	1,977,815	1,260,100	92,376,900
2016	13,964,523	38,554,521	180,431	2,995,694	30,084,954	3,307,354	2,029,323	1,260,100	92,376,900

Wood removals 2000 – 2016

Data for wood removal was available from FAOSTAT. As the data covers different types of wood removed, these were regrouped for calculating the activity data for round wood and fuel wood removal in forestland (Table 2.62).

Table 2.62 - Forest land areas and wood removal

Year	Wood removals	
	Round Wood (m3)	Fuel wood (m3)
2000	33,454,229	59,348,652
2001	34,030,721	59,697,552
2002	34,622,300	60,064,328
2003	35,229,350	60,449,216
2004	35,852,286	60,852,440
2005	36,493,514	61,274,260
2006	37,079,479	61,629,309
2007	37,679,286	62,000,000
2008	38,292,857	62,388,600
2009	38,920,807	62,793,234
2010	39,563,493	63,214,728
2011	40,154,021	63,599,551
2012	40,756,943	63,999,115
2013	41,372,514	64,413,551
2014	42,605,007	64,843,002
2015	43,246,679	65,287,615
2016	43,771,007	65,583,432

Source: FAOSTAT

Carbon stock factors in different land representations

Default stock factors were used in the different land classes except for forestland where a weighted average based on the area of woodland and forestland were adopted. Different values assigned from the IPPC guidelines, were used to calculate a single value for this land class for the country, as follows:

- Above ground biomass (tdm/ha) = 144.14
- Above ground biomass growth (tdm/ha/yr) = 1.02
- Ratio above to below ground = 0.26
- BCEF (Wood Removal) = 1.44

The estimated CO_2 emissions from land (FL) increased from 255,887 Gg CO_2 in 2000 to reach 311,609 Gg CO_2 in 2016 (Figure 2.10). CO_2 emissions from land contributed about 85.4 % of the total emissions in the AFOLU sector on average as the only source of emissions. Though forestland is a natural sink of CO_2, the situation at the national level is not so, as emissions exceeded removals. A general increase in net CO_2 emissions is observed, due to deforestation and increased wood removals in the existing areas.

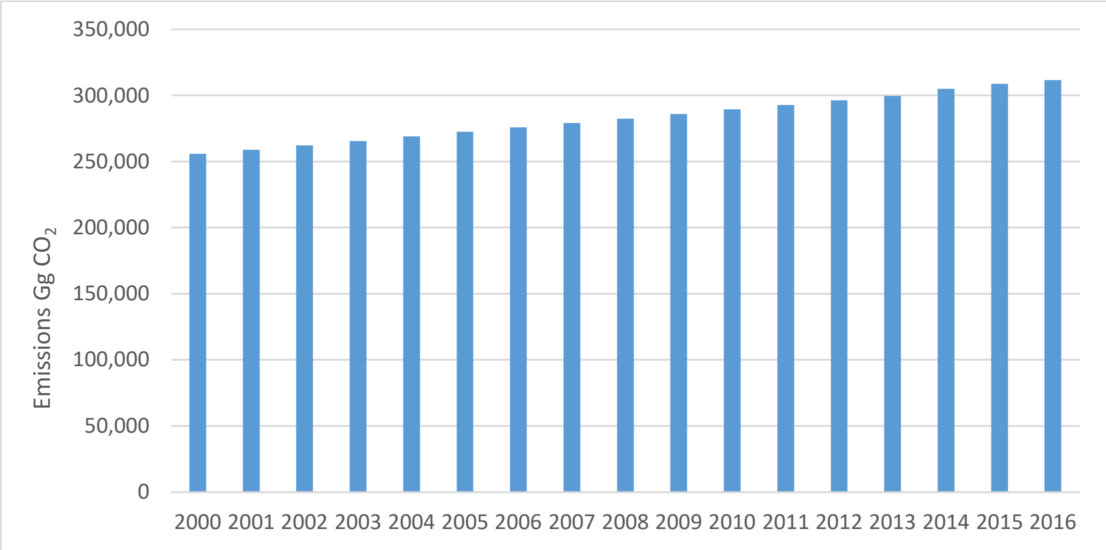


Figure 2.10 - Emission trend in forest land

2.6.4.2. Aggregated sources and non-CO_2 emissions from land (3.C)

Non-CO_2 gases are emitted in this category through biomass burning, direct and indirect emissions of N_2O from managed soils, indirect emissions of N_2O from manure management and CH_4 emissions from rice cultivation. Activity data used for estimating the emissions for all these activities were obtained from the FAOSTAT database and provided in Table 2.63. Crop residues from maize, wheat and rice are considered burnt as a source of fuel and are thus accounted for in the Energy sector for non-CO_2 gases.

Table 2.63 - Synthetic N-fertilisers used, crop residues burned, and rice cultivated areas (2000 - 2016)

Year	N fertilisers	Crop residues burned	Rice
	Amount (kg N)	Sugar cane (kg dm)	Area (ha)
2000	145,017,450	15,600,000	2,199,000
2001	150,476,550	14,950,000	2,117,000
2002	125,131,000	26,000,000	2,185,000
2003	167,778,000	27,300,000	2,210,000
2004	116,343,000	27,950,000	2,348,000
2005	213,221,000	28,600,000	2,494,000
2006	216,854,000	30,550,000	2,725,000

Year	N fertilisers	Crop residues burned	Rice
	Amount (kg N)	Sugar cane (kg dm)	Area (ha)
2007	183,231,150	40,950,000	2,451,000
2008	188,690,250	46,729,000	2,382,000
2009	194,149,350	47,489,000	1,836,880
2010	263,151,000	29,692,000	2,432,630
2011	138,428,000	38,953,000	2,269,410
2012	192,598,730	42,645,000	2,863,815
2013	269,528,610	46,119,000	2,931,400
2014	238,827,890	53,217,000	3,081,923
2015	172,445,230	52,490,000	3,121,562
2016	232,363,050	53,681,000	2,995,694

Source: FAOSTAT

The method used for estimating emissions for these sub-categories is as recommended in the 2006 IPCC guidelines using default emission and stock factors.

In 2016, the total aggregated emissions amounted to 30,173 Gg CO_2-eq, representing 8.1% of the total emissions of the AFOLU sector for that year (Table 2.64). Compared to the year 2000 (20,147 Gg CO_2-eq), total emissions increased by 49.8 %. Direct and indirect emissions of N_2O from managed soils added to indirect emissions from manure management contributed about 77.1% of the overall emissions from this category in 2016 while rice cultivation contributed about 22.8 %. The contribution from savannah and crop residues burning was insignificant at 0.01%. Emissions from sub-categories evolved from 2000 to 2016 at varying degrees with 54.3% increase from Agricultural soils, 36.2% increase for Rice Cultivation and a 3-fold increase for crop residue burning. Savannah burning on the other hand decreased by 29.5 % during the same period.

Table 2.64 - Aggregated sources and non-CO_2 emissions (Gg CO_2-eq from land

Year	Rice Cultivation	Agricultural soils	Savanna burning	Crop residues burning	Total
2000	5,057	15,086	2.4	1.2	20,147
2001	4,869	16,045	2.6	1.2	20,917
2002	5,025	16,091	2.4	2.0	21,121
2003	5,083	16,327	2.5	2.1	21,414
2004	5,400	16,650	2.3	2.2	22,055
2005	5,736	17,610	2.6	2.2	23,351
2006	6,267	17,939	2.4	2.4	24,211
2007	5,637	18,025	2.3	3.2	23,667
2008	5,478	18,389	1.9	3.7	23,872
2009	4,225	18,762	1.5	3.7	22,992
2010	5,595	19,564	1.5	2.3	25,163
2011	5,219	20,891	1.3	3.5	26,115
2012	6,586	21,627	1.3	3.3	28,218
2013	6,742	22,392	1.1	3.6	29,139
2014	7,088	22,588	1.2	4.2	29,681
2015	7,179	21,942	1.7	4.1	29,127
2016	6,890	23,277	1.7	4.2	30,173

Emissions of precursor gases from this category is given in Table 2.62. These gases were emitted from savannah burning and burning of crop residues. NO_X emissions increased by 58.3 % from 0.122 Gg in year 2000 to reach 0.193 in 2016. CO emissions more than doubled, increasing from 2.811 Gg to 5.912 Gg from 2000 to 2016.

Table 2.65 - Emissions of precursor gases (Gg) from Aggregate sources and non-CO_2 emissions from Land

Year	NO_X	CO
2000	0.122	2.811
2001	0.128	2.884
2002	0.142	3.679
2003	0.150	3.868
2004	0.149	3.882
2005	0.161	4.127
2006	0.158	4.165
2007	0.180	5.062
2008	0.181	5.367
2009	0.171	5.236
2010	0.126	3.598
2011	0.218	4.829
2012	0.151	4.666
2013	0.115	4.243
2014	0.173	5.569
2015	0.189	5.800
2016	0.193	5.912

2.6.4.3. Direct and indirect emission of N_2O from managed soils (3.C.4 and 3.C.5)

Direct N_2O emissions from managed soils, the major share of this category, increased from 11,309 Gg CO_2-eq in 2000 to 17,324 Gg CO_2-eq in 2016 (Figure 2.11). Indirect emissions reached 5,953 Gg CO_2-eq in 2016 representing an increase of 57.6% from 2000.

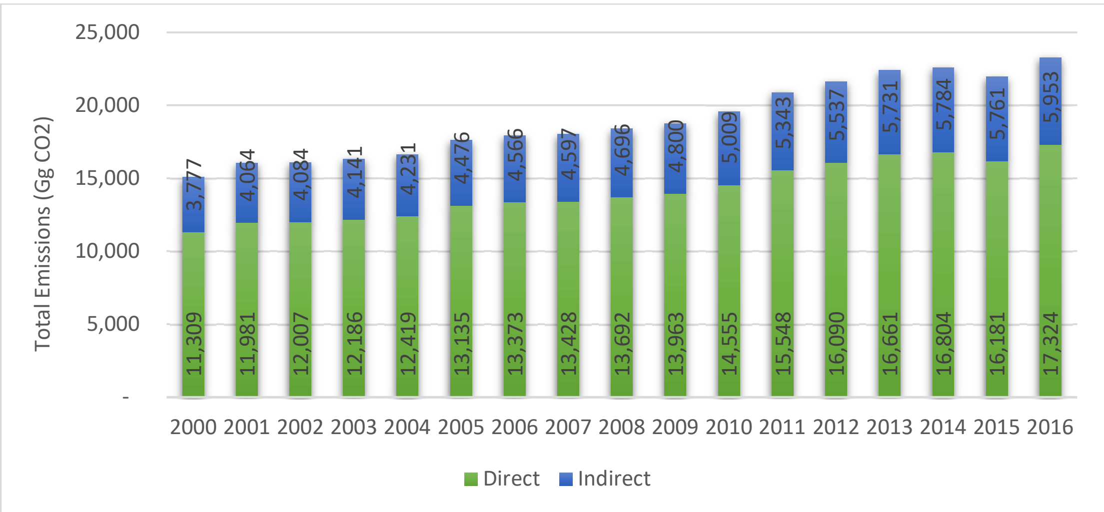


Figure 2.11 - Emission trends by direct and indirect emissions of N_2O from soil management

2.6.4.4. Rice cultivation (3.C.7)

The IPCC Tier 1 methodology with default emission factors was used for estimating emissions from rice cultivation. Activity data for area under rice was those used for generating the land matrix. Defaults EFs were used for management practices.

CH_4 emissions from rice cultivation varied over the time series with a peak of 7,179 Gg CO_2-eq in 2015. The lowest emissions of 4,225 Gg CO_2-eq were recorded in 2009 and attributed to the lowest area cultivated among all the years under review. Emissions from rice cultivation constituted about 25.1 % of the total emissions from Aggregated sources and non-CO_2 emission from land (3.C) in 2000 and about 22.8 % in 2016. Figure 2.13 illustrates the trend of emissions from rice cultivation.

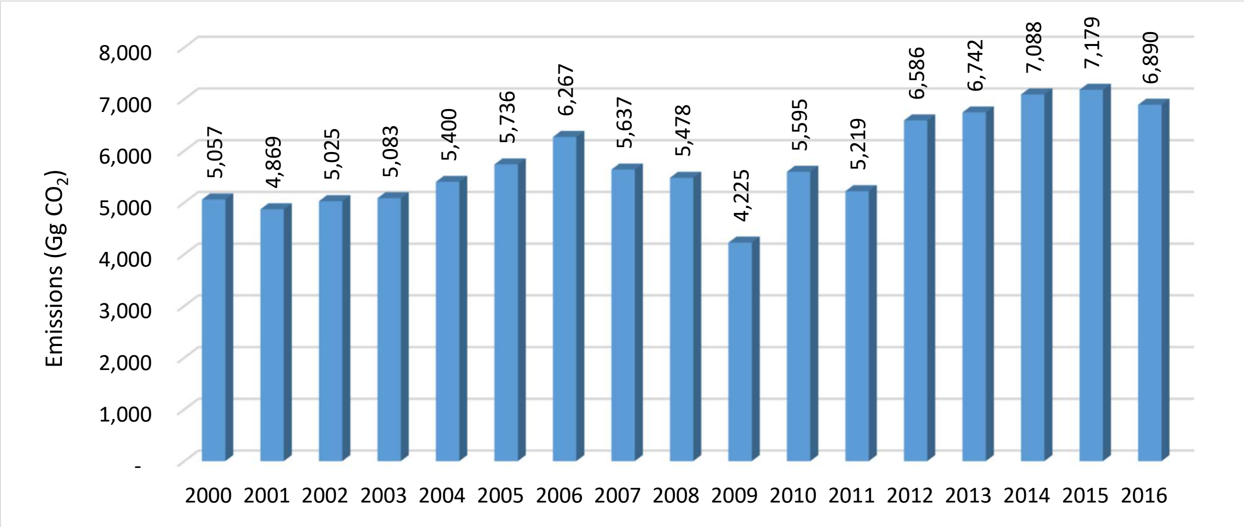


Figure 2.12 - Emission trends in rice cultivation

2.6.4.5. Other (3.D) – Harvested Wood Products (3.D.1)

Merchantable wood harvested from Forest Land remain as wood products for differing lengths of time after their transformation. This constitutes a carbon reservoir. HWP includes all wood (including bark) that leaves harvest sites. Slash and other material left at harvest sites were regarded as dead organic matter. The time during which carbon is held in products varies according to the product and its uses. For example, fuel wood and mill residue may be burned in the year of harvest; many types of paper are likely to have a useful life of less than 5 years which may include recycling of paper; and sawn wood or panels used in buildings may be held for decades to over 100 years.

All the data on production, imports and exports of round-wood, sawn wood, wood based panels, paper and paper board, wood pulp and recycled paper, industrial round-wood, chip and particles, wood charcoal and wood residues were obtained from FAOSTAT database (http://faostat.fao.org/). Most data were available since 1960 but there existed some gaps. All data from 1961 from the FAO time series were used and categorized in their required field for calculations. The data from FAOSTAT was summarized according to the classification given in Table 2.66.

Table 2.66 - Reclassification of information available from FAOSTAT

FAOSTAT Classification	Reclassification for inventory
Wood fuel, coniferous	Roundwood
Wood fuel, non-coniferous	Roundwood
Industrial roundwood, non-coniferous tropical (export/import)	Industrial roundwood
Sawnlogs and veneer logs, non-coniferous	Sawnwood
Other industrial roundwood, non-coniferous (production)	Other Industrial Roundwood
Wood charcoal	Wood charcoal
Wood residues	Wood residues
Sawnwood, coniferous	Sawnwood
Sawnwood, non-coniferous all	Sawnwood
Veneer sheets	Wood-based panels
Plywood	Wood-based panels
Particle board and OSB (1961-1994)	Wood-based panels
Other fibreboard	Wood-based panels
Fibreboard, compressed (1961-1994)	Wood-based panels
Semi-chemical wood pulp	Wood Pulp (1875)+ recycled paper
Chemical wood pulp	Wood Pulp (1875)+ recycled paper
Chemical wood pulp, sulphate, unbleached	Wood Pulp (1875)+ recycled paper
Chemical wood pulp, sulphate, bleached	Wood Pulp (1875)+ recycled paper
Chemical wood pulp, sulphite, bleached	Wood Pulp (1875)+ recycled paper
Recovered paper	Wood Pulp (1875)+ recycled paper
Newsprint	Paper+Paperboard
Printing and writing papers	Paper+Paperboard
Other paper and paperboard	Paper+Paperboard
Wrapping and packaging paper and paperboard	Paper+Paperboard
Other paper and paperboard n.e.s. (not elsewhere specified)	Paper+Paperboard

Only data for roundwood export had to be amended as the increase in export values exceeded the concurrent increase in production. Thus, the average of export data for the other years of the timeseries plus a nominal increase of 100,000 m^3 based on increase in production was adopted as AD for 2014 to 2016. The activity data used for the estimation are provided in Tables 2.67 and 2.68.

Table 2.67 - Activity data for HWP

Year	Roundwood (m^3)			Sawnwood (m^3)			Wood-based panels (m^3)			Paper+Paperboard (t)			Wood Pulp (1875)+ recycled paper (t)		
	Production	Import	Export	Production	Import	Export	Production	Import	Export	Production	Import	Export	Production	Import	Export
1961	36,237,496	0	0	1,596,000	0	794,900	20,000	10,300	18,000	0	20,300	0	0	0	
1962	36,526,920	0	0	1,379,000	0	651,100	26,000	10,200	23,000	0	20,500	0	0	0	
1963	36,818,660	0	0	6,284,000	6,400	743,800	30,000	9,900	21,000	0	28,600	0	0	0	
1964	37,112,728	0	0	1,639,000	2,200	859,500	34,000	10,600	22,000	0	34,600	0	0	0	
1965	37,409,148	0	0	1,660,000	1,700	667,000	31,000	10,550	24,000	0	51,900	0	0	0	
1966	37,707,936	0	0	1,736,000	100	634,600	25,000	7,407	21,000	0	56,000	200	0	0	
1967	38,009,104	0	0	1,699,000	0	385,200	23,000	6,433	14,900	0	51,700	400	0	0	
1968	38,312,684	0	0	1,507,000	0	372,900	24,000	3,559	16,800	0	55,400	400	0	1,700	
1969	38,618,684	0	0	1,756,000	0	418,700	28,000	7,770	12,100	0	74,400	0	0	2,700	
1970	38,927,132	0	0	1,966,000	0	266,100	23,000	13,019	21,000	0	118,700	0	0	6,400	
1971	38,456,528	0	0	1,966,000	0	248,800	46,800	13,019	20,500	0	146,500	0	0	6,400	
1972	39,120,820	0	0	1,966,000	0	227,600	50,900	13,019	20,500	0	114,500	0	0	6,400	
1973	39,079,844	0	0	2,415,201	0	362,300	60,800	15,768	17,000	0	131,700	0	0	4,300	
1974	38,684,456	0	0	1,957,101	4,600	281,900	72,600	13,546	29,600	0	167,600	0	0	6,700	
1975	39,881,944	0	0	3,144,000	3,000	105,300	65,500	35,825	1,000	0	156,700	0	0	11,800	
1976	39,727,676	0	0	3,144,000	3,500	28,300	67,700	52,900	0	0	224,800	0	0	12,200	
1977	39,919,640	0	0	3,144,000	17,700	11,100	67,700	129,000	0	0	210,700	0	0	5,100	
1978	41,526,896	0	0	5,384,000	0	11,100	88,100	119,500	0	0	224,300	0	5,000	5,100	
1979	41,664,504	0	0	5,968,000	0	11,100	102,400	118,200	0	0	204,500	0	3,000	5,100	
1980	42,150,384	0	0	7,756,000	0	11,100	94,000	168,500	0	24,000	175,300	0	3,000	4,700	
1981	44,266,220	0	0	9,163,000	2,400	26,700	149,000	157,500	0	22,000	403,500	0	3,000	4,700	
1982	45,324,120	0	0	8,272,000	700	102,400	147,000	129,500	0	20,000	287,800	0	3,000	4,700	
1983	47,251,696	0	0	7,448,000	1,600	51,500	144,000	117,000	0	18,000	287,400	0	3,000	5,100	
1984	48,402,404	0	0	7,790,000	1,700	60,900	144,000	23,100	0	32,000	188,800	0	6,000	3,200	
1985	48,040,816	0	0	8,867,000	1,100	60,400	104,000	23,100	0	80,000	180,800	0	30,800	3,200	
1986	49,243,784	0	0	8,301,000	1,100	60,400	102,000	23,100	0	102,000	94,600	0	36,600	3,200	
1987	50,822,432	0	0	8,595,000	1,100	17,200	102,000	6,000	0	76,000	32,500	0	37,600	3,200	
1988	50,645,764	0	0	8,595,000	173	16,482	102,000	11,798	0	82,000	116,811	0	38,600	2,100	

Year	Roundwood (m^3)			Sawnwood (m^3)			Wood-based panels (m^3)			Paper+Paperboard (t)			Wood Pulp (1875)+ recycled paper (t)		
	Production	Import	Export	Production	Import	Export	Production	Import	Export	Production	Import	Export	Production	Import	Export
1989	50,786,024	0	0	8,595,000	68	11,288	102,000	3,234	0	61,000	63,273	0	18,600	2,100	0
1990	50,916,960	0	0	8,713,000	225	29,074	102,000	3,308	0	55,000	99,757	0	18,600	4,200	0
1991	51,733,968	0	0	8,703,000	225	29,074	105,000	3,308	0	37,000	99,757	0	18,600	0	0
1992	52,854,280	0	0	8,699,000	536	41,366	112,000	19,328	159	29,000	170,771	29,369	18,600	4,155	0
1993	54,030,624	0	0	8,695,000	200	35,280	105,000	9,055	371	7,000	156,646	19	18,600	7,832	0
1994	55,524,128	0	0	8,517,000	273	46,819	103,000	4,579	892	6,000	161,388	19	18,600	4,127	0
1995	56,765,876	0	0	8,340,000	255	14,443	100,000	12,855	189	8,500	102,152	19	18,600	6,741	0
1996	57,672,528	0	0	8,378,000	500	25,300	98,000	19,920	372	41,000	85,000	19	18,600	6,908	0
1997	58,661,088	0	266	8,800,000	2,862	46,010	95,000	11,925	260	37,000	130,793	19	32,000	6,764	650
1998	58,456,792	0	266	9,100,000	400	60,600	95,000	11,925	260	37,000	237,982	0	45,000	6,764	650
1999	58,912,676	0	1,060	9,100,000	1,300	50,000	95,000	89,100	0	37,000	288,131	0	45,000	23,900	0
2000	59,387,652	0	1,060	9,100,000	900	54,000	95,000	49,300	0	37,000	354,200	4,800	45,000	19,500	0
2001	59,736,552	0	1,060	9,100,000	1,300	38,300	95,000	73,800	300	37,000	359,900	4,800	45,000	17,900	0
2002	60,103,328	0	1,060	9,100,000	2,220	38,300	95,000	76,139	78	37,000	375,900	4,800	45,000	17,900	0
2003	60,488,216	0	1,060	9,100,000	998	21,779	95,000	54,299	83	37,000	509,541	4,800	45,000	17,900	0
2004	60,891,440	0	1,060	9,100,000	1,616	20,710	95,000	42,302	96	37,000	623,395	4,800	45,000	18,100	0
2005	61,313,260	0	1,060	9,102,000	335	39,916	96,000	42,450	125	37,000	623,395	4,800	45,000	18,100	0
2006	61,668,309	0	1,060	9,102,000	680	26,365	96,000	80,415	76	37,000	623,395	4,800	45,000	18,100	0
2007	62,039,000	0	1,060	9,102,000	122	24,057	97,000	126,232	81	37,000	745,552	4,800	45,000	18,100	0
2008	62,427,600	434	1,883	9,102,000	2,918	15,677	97,000	114,059	2,795	37,000	743,411	1,923	45,000	71,966	5,319
2009	62,832,234	434	1,883	9,102,000	2,751	7,561	97,000	94,930	2,616	37,000	747,857	538	45,000	44,763	3,683
2010	63,253,728	434	28	9,102,000	2,399	11,192	97,000	141,654	76	37,000	712,454	405	45,000	70,329	4,266
2011	63,638,551	434	28	9,102,000	4,600	5,616	97,000	269,453	310	37,000	1,174,432	1,097	45,000	51,629	2,992
2012	64,038,115	165	74	9,102,000	5,959	7,666	97,000	200,152	247	37,000	521,650	547	45,000	34,861	12,522
2013	64,452,551	28	74	9,102,000	10,132	7,226	97,000	337,390	104	37,000	1,042,507	660	57,000	41,088	23,414
2014	64,865,002	919	297	9,602,000	10,287	8,586	97,000	285,581	286	37,000	1,085,913	2,347	57,000	68,017	10,914
2015	65,309,615	919	407	9,602,000	985	16,061	97,000	303,659	378	37,000	801,892	3,836	57,000	69,836	7,680
2016	65,605,432	919	371	9,602,000	3,139	30,364	97,000	260,121	883	37,000	627,383	2,005	57,000	129,909	3,171

Table 2.68 - Activity data for HWP

	Industrial roundwood (m^3)			Chips and particles (m^3)		Wood charcoal (t)			Wood residues (m^3)	
	Production	Import	Export	Import	Export	Production	Import	Export	Import	Export
1961	1,095,000	400	200	0	0	771,261	0	0	0	0
1962	1,128,000	900	0	0	0	794,540	0	0	0	0
1963	1,185,000	0	6,700	0	0	818,523	0	0	0	0
1964	1,235,000	0	8,400	0	0	843,229	0	0	0	0
1965	1,239,000	0	3,900	0	0	868,680	0	0	0	0
1966	1,583,000	0	0	0	0	894,900	0	0	0	0
1967	1,626,000	0	0	0	0	921,912	0	0	0	0
1968	1,675,000	0	0	0	0	949,739	0	0	0	0
1969	1,722,000	0	0	0	0	978,405	0	0	0	0
1970	1,762,000	0	600	0	0	1,007,937	0	0	0	0
1971	1,805,000	0	0	0	0	1,014,300	0	0	0	0
1972	1,850,000	0	0	0	0	1,055,688	0	0	0	0
1973	1,898,000	0	4,500	0	0	1,076,642	0	0	0	0
1974	1,863,000	0	6,900	0	0	1,087,104	0	0	0	0
1975	1,914,000	0	1,900	0	0	1,149,970	0	0	0	0
1976	1,968,000	0	0	0	0	1,168,026	0	0	0	0
1977	2,025,000	0	0	0	0	1,198,482	0	0	0	0
1978	2,089,000	0	0	0	0	1,279,394	0	0	0	0
1979	2,151,000	0	0	0	0	1,311,257	0	0	0	0
1980	2,279,000	0	0	0	0	1,357,001	0	0	0	0
1981	2,279,000	0	0	0	0	1,469,004	0	0	0	0
1982	2,279,000	0	0	0	0	1,545,258	0	0	0	0
1983	2,279,000	0	0	0	0	1,658,896	0	0	0	0
1984	2,279,000	0	0	0	0	1,745,863	0	0	0	0
1985	2,279,000	0	0	0	0	1,773,315	0	0	0	0
1986	2,279,000	0	0	0	0	1,867,006	0	0	0	0
1987	2,279,000	0	0	0	0	1,980,778	0	0	0	0
1988	2,279,000	0	0	0	0	2,020,427	0	0	0	0

	Industrial roundwood (m^3)			Chips and particles (m^3)		Wood charcoal (t)			Wood residues (m^3)	
	Production	Import	Export	Import	Export	Production	Import	Export	Import	Export
1989	2,279,000	0		0	0	2,075,513	0	0	0	0
1990	2,279,000	0	7,678	0	0	2,131,778	0	0	0	0
1991	2,279,000	658	19,875	0	0	2,210,445	0	0	0	0
1992	2,279,000	0	4,193	0	309	2,314,797	41	8,234		
1993	2,279,000	0	999	0	0	2,420,873		11,843	0	970
1994	2,279,000	1,950	3,210	0	0	2,542,902	21	11,492	0	53
1995	2,279,000	1,950	11,292	0	0	2,646,794	21	1,394	0	53
1996	2,279,000	1,950	11,239	0	0	2,763,475	21	16,800	0	53
1997	2,279,000	1,950	11,376	0	0	2,872,535	22	16,858	0	31
1998	2,279,000	500	10,947	0	0	2,922,971	22	16,000	0	0
1999	2,279,000	0	7,300	0	0	3,006,209	200	11,700	0	0
2000	2,279,000	0	7,300	0	0	3,085,072	0	28,000	0	0
2001	2,279,000	500	3,800	0	0	3,165,781	0	22,298	0	0
2002	2,279,000	288	2,000	0	0	3,248,602	0	17,019	0	0
2003	2,279,000	64	2,119	0	0	3,333,589	0	26,010	0	0
2004	2,279,000	500	40,000	0	0	3,420,800	0	42,096	0	0
2005	2,279,000	723	38,255	0	0	3,510,292	0	52,306	0	0
2006	2,279,000	60	32,420	0	0	3,592,327	0	71,332	0	0
2007	2,279,000	742	69,868	0	0	3,676,300	0	90,971	0	0
2008	2,279,000	1,365	64,506	0	512	3,762,200	136	24,312	5,498	0
2009	2,279,000	630	58,348	0	104	3,850,113	9	87,858	122	0
2010	2,279,000	54	109,950	0	1	3,940,089	24	88,345	25	2
2011	2,279,000	1,491	106,268	0	1	4,022,763	16	126,201	25	15
2012	2,279,000	116	108,226	6,409	1	4,107,172	88	132,278	206	1,000
2013	2,279,000	810	127,673	1,246	150	4,193,352	193	156,999	33	2,000
2014	2,400,000	2,144	213,029	1,246	150	4,281,341	346	140,486	1	2,000
2015	2,400,000	1,009	213,029	1,246	5	4,371,175	213	171,148	1	56
2016	2,400,000	58	213,029	1,246	1	4,444,581	138	194,145	1	5

Source: - FAOSTAT visited on 12/03/2019

HWPs were a sink of CO_2 which fluctuated during the period 2000 and 2016. The evolution of removals through HWP is given in Figure 2.14. There was an overall tendency for removals to decrease between 2000 and 2016 from -5958 to -4288 Gg CO_2.

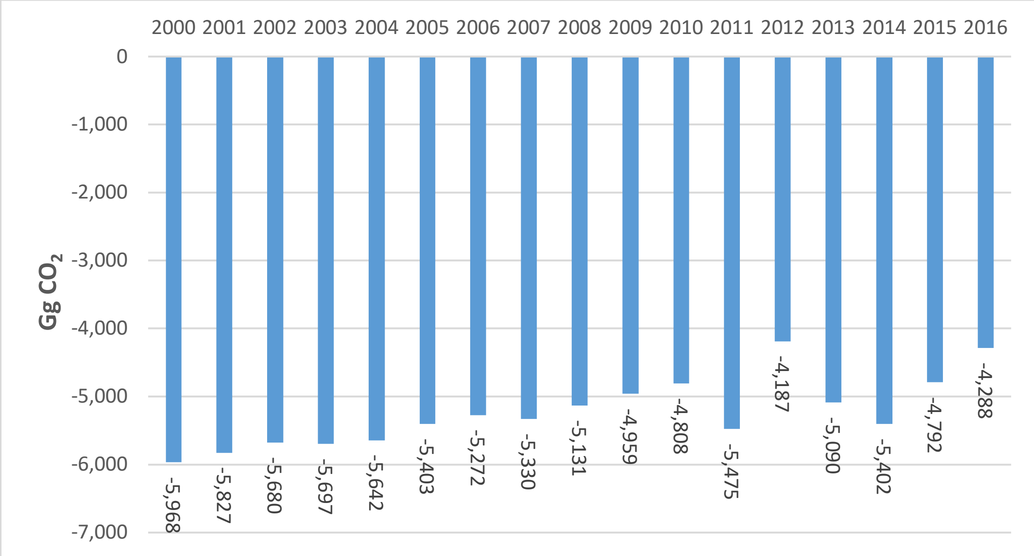


Figure 2.13 - CO_2 removed and stored in harvested wood products

2.7. Waste

2.7.1. Overview

Waste in Nigeria comprises of solid and liquid wastes. These wastes can be further divided into domestic and industrial wastes as listed below:

- Solid waste: Municipal solid waste and industrial solid waste
- Wastewater: Domestic wastewater and industrial wastewater.

Daily anthropogenic activities produce wastes consisting of different materials, including plastics, wood, paper, food remains, etc, which must be dealt with in safe manners to prevent environmental pollution and degradation which can cause waste related diseases.

Currently in Nigeria, waste is often disposed in very inefficient ways. Nigeria does not currently have engineered landfills where proper techniques are used to reduce potential contamination of water tables via leachate or where methane can be captured and possibly used for captive energy or flared. Solid waste is mostly disposed of at unmanaged land fill sites. Some of the dump sites are subject to minimal management even if they are not the engineered landfill sites required for proper storage of municipal waste. On the other hand, liquid waste is disposed of into open sewers, septic tanks, sea, rivers, lakes and latrines.

GHG emissions from the Waste sector result largely from disposal of solid wastes through landfilling, dumping, incineration, open burning and treatment of domestic and industrial liquid wastes. The emissions, from solid waste are CH_4 from disposal sites and predominantly CO_2 from open burning of waste. Wastewater can also be a source of methane (CH_4) when treated or disposed of anaerobically as well as of nitrous oxide (N_2O) emissions. Key factors that affect emissions generation are population growth, rural-urban drift and improper management of waste both at its source of generation and its final fate.

The IPCC 2006 Guidelines divide the Waste sector into the following source categories: Solid Waste Disposal (4A), Biological Treatment of solid waste (4B), Incineration and Open Burning (4C) and Wastewater Treatment and Discharge (4D). Each source category is further divided into sub-categories that take into account different waste attributes, management practices and approaches.

Analysis of solid waste disposal led to the choice of 2 categories for computing emissions of the Waste sector in Nigeria. These are Unmanaged Waste Disposal and Open Burning.

2.7.2. Solid Waste Disposal (4.A)

Anaerobic decomposition of MSW high in carbon content, emits mainly CH_4 while aerobic treatment and open burning or incineration yields mostly CO_2. In Nigeria, there are no engineered or sanitary landfills. Thus, municipal solid wastes either find their way into managed dump sites where compaction and sand filling of waste occurs or unmanaged ones where non-segregated waste is often heaped and occasionally the waste is burned to reduce the volume and health hazards. The latter constitutes most dump sites. Solid waste disposal activities are further categorized into: Managed Waste Disposal Sites (4.A.), Unmanaged Waste Disposal Sites (4.A.2) and Uncategorized Waste Disposal Sites (4.A.3).

2.7.2.1. Unmanaged Waste Disposal Sites (4.A.2)

The available data on the quantity of municipal solid waste (MSW) generated in major cities in Nigeria were utilized together with key socioeconomic data to estimate waste generation during the study period for the national inventory of solid waste. This data and characterisation of MSW using the estimation protocol specified by the IPCC for the unmanaged waste disposal sites were utilized to estimate GHG emissions from MSW in Nigeria.

2.7.2.2. Open Burning (4.C.2)

Emissions of CO_2 and CH_4 emanate from open burning of municipal solid wastes which is presently practised in Nigeria due to the inability to collect all waste generated, especially in the rural areas, insufficient resources in the urban areas and the inexistence of managed engineered landfill sites.

2.7.3. Wastewater Treatment and Discharge (4D)

Wastewater treatment is divided into Domestic wastewater treatment and discharge (4.D1), and Industrial wastewater treatment and discharge (4.D2). Both situations are encountered in the country. However, due to lack of activity data, Industrial Wastewater Treatment and Discharge subcategory has not been covered in this inventory. Domestic wastewater in Nigeria is yet to be treated efficiently in reticulated networks on the municipal scale and often ends up in septic tanks and latrines while a portion is also discharged through closed sewers/channels and into rivers, lakes and the sea.

2.7.4. Methodology

The decision tree of the IPCC 2006 Guidelines was used to choose the most appropriate method for computing emissions of this sector. There is a paucity of data on specificity and management of waste, such as annual information on the amount and composition of waste generated, the specifics of waste management practices in both the rural and urban areas of the country, the waste generation rate in the industry and other relevant data. This resulted in the adoption of Tier 1 methodology.

Under this Tier 1 methodology waste emission is computed by the formula:

$$E = AD * EF$$

Where:

E = emissions (tonne CO_2-eq)

AD is the activity data (population and waste generation rate)

EF is emission factor (tonne CO_2-eq/tonne waste)

2.7.5. Activity data

Solid Waste Disposal (4.A) - Unmanaged Waste Disposal Sites (4.A.2)

Data used in the estimation of GHG emissions from solid waste handling include: national and state population figures; waste generation rate per capita; solid waste stream characteristics; etc. Sources of these data included the National Bureau of Statistics (NBS), National Population Commission (NPC) for urban and rural population fraction, Central Bank of Nigeria for GDP, Energy Commission of Nigeria (ECN), the Department of Climate Change (DCC) of the Federal Ministry of Environment, Literature, published statistics in national reports and Waste Management Authorities such as the Lagos Waste Management Authority (LAWMA), amongst others. Factors used in the calculation of the GHG contribution from the waste sector include dry matter content, fraction of carbon in dry matter, fraction of fossil carbon and oxidation factor. The information provided in Table 2.69 were adopted for generating activity data for computing emissions from solid waste. The following assumptions were also adopted for computing emissions in the Waste sector:

- Default values for methane generation rate constant k, degradable organic content and other variables are based on default values for a tropical wet climate country in the West Africa region available in the software.
- 100% of collected waste ends up in unmanaged shallow dumps less than 5m deep.
- Waste generation data for the country are based on the urban waste amount for the state capitals and urban areas for the year 2005.
- The waste generation rate is constant for the entire time series.
- Waste generated by 30% of the rural fraction of the population and 55% of the urban are collected and sent to the dump sites. This represented between 40.66 to 43.09 % from 2000 to 2016 being sent to solid waste disposal sites on average for the country.
- AD for Solid Waste for the period 1990 to 1999 was generated using the trending technique for the % of waste disposed in Solid Waste Disposal Sites (SWDS) in order to capture decomposition happening from solid waste disposed of prior to the year 2000, the starting point of the time series of this inventory
- Per capita waste generation rate is set at a constant value of 119.02 kg/annum

Table 2.69 - MSW generated and treatment data for the period 2000-2016

Year	Population ($x10^3$)	Urban fraction of Population	Rural fraction of Population	Total MSW [Gg]	% sent to SWDS	Total MSW sent to unmanaged dumpsites [Gg]
2000	122,880	0.4262	0.5738	14,625.178	40.7	5,946.6
2001	126,010	0.4325	0.5675	14,997.710	40.8	6,119.1
2002	129,250	0.4398	0.5602	15,383.335	41.0	6,307.2
2003	132,580	0.4471	0.5529	15,779.672	41.2	6,501.2
2004	136,030	0.4544	0.5456	16,190.291	41.3	6,686.6
2005	139,610	0.4617	0.5383	16,616.382	41.5	6,895.8
2006	143,320	0.4690	0.5310	17,057.946	41.7	7,113.2
2007	147,150	0.4763	0.5237	17,513.793	41.9	7,338.3

Year	Population (x10^3)	Urban fraction of Population	Rural fraction of Population	Total MSW [Gg]	% sent to SWDS	Total MSW sent to unmanaged dumpsites [Gg]
2008	151,120	0.4836	0.5164	17,986.302	42.1	7,572.2
2009	155,210	0.4909	0.5091	18,473.094	42.3	7,814.1
2010	159,420	0.4982	0.5018	18,974.168	42.5	8,064.0
2011	163,770	0.5055	0.4945	19,491.905	42.6	8,303.6
2012	168,240	0.5128	0.4872	20,023.925	42.8	8,570.2
2013	172,820	0.5201	0.4799	20,566.656	43.0	8,843.7
2014	177,480,	0.5274	0.4726	21,123.670	43.2	9,125.4
2015	182,200	0.5347	0.4653	21,685.444	43.7	9,476.5
2016	187,050	0.5420	0.4580	22,262.691	43.9	9,773.3

Another set of assumptions was used to generate industrial waste. These are provided below, and the activity data generated from industrial activities is depicted in Table 2.70.

70% of the industrial solid waste makes its way to the unmanaged dump sites with about 30% unaccounted for due to collection inefficiencies.

Industrial waste generation rate is assumed to be 1/5 of per capita municipal waste sent to disposal site.

Industrial solid waste has the same final fate as MSW.

Table 2.70 - Industrial solid waste generated (2000-2016)

Year	GDP [million]	Waste Generation Rate [Gg/ US$ m GDP/yr]	Total Industrial Waste [Gg]	Total waste sent to SWDS [Gg]
2000	15,002.94	0.0966	1449.28	1014.50
2001	15,663.56	0.0948	1484.91	1039.43
2002	16,259.03	0.0937	1523.47	1066.43
2003	17,938.43	0.0871	1562.43	1093.71
2004	23,992.22	0.0668	1602.68	1121.88
2005	24,819.54	0.0663	1645.54	1151.87
2006	26,855.63	0.0629	1689.22	1182.45
2007	28,688.61	0.0605	1735.66	1214.96
2008	30,491.87	0.0580	1768.53	1237.97
2009	32,607.23	0.0560	1826.00	1278.20
2010	35,123.86	0.0535	1879.13	1315.39
2011	36,877.58	0.0524	1932.39	1352.67
2012	38,457.90	0.0516	1984.43	1389.10
2013	40,533.63	0.0503	2038.84	1427.19
2014	43,089.89	0.0486	2094.17	1465.92
2015	44,229.31	0.0486	2149.54	1504.68
2016	46,440.78	0.0475	2206.40	1544.48

2.7.5.1. Incineration and Open Burning (4.C) - Open Burning of Waste (4.C.2)

The decision tree of the IPCC 2006 GL (Vol 5 Ch5 p5.9) guided the choice of method for estimating emissions from Open Burning. The Tier 1 approach was adopted due to scarcity of activity data and lack of country specific emission factors. Activity data for Open Burning was generated from available information and based on the following assumptions.

30% of the urban fraction of the population and 40% of the rural fraction of the population engage in open burning of waste.

Fraction of waste burned relative to the amount of waste treated is assumed to be 0.6 for all years. This is based on the example in the 2006 IPCC guideline Chapter Volume 5, Chapter 5 - Incineration and Open Burning of Waste.

Required information, namely population, fraction of urban and rural population, total MSW generated and the fraction burned are captured in Table 2.71.

Table 2.71 - Annual open burning at solid waste disposal sites (fraction of population burning waste) 2000-2016

Year	Population (x103)	Urban Fraction of Population	Rural Fraction of population	MSW Waste (Gg/year)	Fraction of population burning waste Pfrac	Amt of waste open burned (Gg/yr)
2000	122,880	0.43	0.5738	14,625.178	0.359	3,135.43
2001	126,010	0.43	0.5675	14,997.710	0.356	3,209.90
2002	129,250	0.44	0.5602	153,83.335	0.356	3,285.05
2003	132,580	0.45	0.5529	15,779.672	0.356	3,363.06
2004	136,030	0.45	0.5456	16,190.291	0.353	3,443.78
2005	139,610	0.47	0.5383	16,616.382	0.356	3,526.44
2006	143,320	0.47	0.5310	17,057.946	0.353	3,612.99
2007	147,150	0.48	0.5237	17,513.793	0.353	3,702.18
2008	151,120	0.48	0.5164	17,986.302	0.351	3,793.43
2009	155,210	0.49	0.5091	18,473.094	0.351	3,888.34
2010	159,420	0.50	0.5018	18,974.168	0.351	3,985.85
2011	163,770	0.51	0.4945	19,491.905	0.351	4,086.42
2012	168,240	0.51	0.4872	20,023.925	0.348	4,188.35
2013	172,820	0.52	0.4799	20,566.656	0.348	4,293.73
2014	177,480	0.53	0.4726	21,123.670	0.348	4,400.64
2015	182,200	0.53	0.4653	21,685.444	0.345	4,507.27
2016	187,050	0.53	0.4583	22,262.690	0.345	4,627.25

2.7.5.2. Wastewater Handling (4.D) - Domestic Wastewater Treatment and Discharge (4.D.1)

Domestic wastewater releases CH_4 when organic components in the wastewater anaerobically biodegrade while it releases N_2O as an intermediate product when nitrogen components in wastewater undergo nitrification (an aerobic process) and denitrification (an anaerobic process). Production of CH_4 associated with wastewater depends primarily on the quantity of degradable organic matter in the wastewater, the temperature, and the type of treatment system. It is important to note that wastewater in closed underground sewers is not believed to be a significant source of CH_4.

The decision tree of the IPCC 2006 Guidelines (Vol5-Ch6-p6.10) guided the estimation of GHG emissions from this subcategory. Domestic wastewater in the software is allocated as three categories of population based on income: rural, urban low and urban high. The degree of adoption and fraction of population income are applied to generate the organically degradable material in wastewater. Activity data generated based on the assumptions listed below and used in the computation of emissions from wastewater are presented in Table 2.72.

Domestic wastewater is not efficiently treated in wastewater treatment plants.

Latrines in Nigeria are mostly communal and ground water table are often higher than latrine. This is consistent with the wet climate assumed for the country.

Treatment methods selected were sea, river and lake discharge, stagnant sewer, latrine (wet climate) and septic system.

Table 2.72 - Average organically degradable material in domestic wastewater (Kg BOD/Yr)

Year	Population (x103)	Average protein content in diet (kg /person/year)	Organically degradable material in domestic wastewater (TOW) (kg)
2000	122,880	58	1,659,494,400.00
2001	126,010	58	1,701,765,050.00
2002	129,250	58	1,745,521,250.00
2003	132,580	59	1,790,492,900.00
2004	136,030	60	1,837,085,150.00
2005	139,610	62	1,885,433,050.00
2006	143,320	62	1,935,536,600.00
2007	147,150	62	1,987,260,750.00
2008	151,120	63	2,040,875,600.00
2009	155,210	64	2,096,111,050.00
2010	159,420	66	2,152,967,100.00
2011	163,770	66	2,211,713,850.00
2012	168,240	66	2,272,081,200.00
2013	172,820	67	2,333,934,100.00
2014	177,480	68	2,396,867,400.00
2015	182,200	70	2,460,611,000.00
2016	187,050	70	2,526,110,250.00

Adoption rate of different types of waste treatment method provided for Nigeria in Table 6.5 of 2006 IPCC Guidelines Volume 5 Chapter 6 were used for all years in the time series. Table 2.73 summarizes the information used for calculations.

Table 2.73 - Use rate of different types of wastewater treatment across Nigeria

Region	Septic tank	Latrine	Other	Sewer	None
Rural	0.02	0.28	0.04	0.10	0.56
Urban High income	0.32	0.31	0.00	0.37	0.00
Urban low income	0.17	0.24	0.05	0.34	0.20

The computation of emissions is based on the available degradable organic component in the wastewater, TOW, which is multiplied by the emission factor according to treatment type. The emissions factors adopted, based on the maximum methane producing capacity and methane correction factor for each treatment type, are presented in Table 2.74.

Table 2.74 - Emission factor for domestic wastewater calculations

Type of Treatment /discharge	Maximum Methane producing capacity-BO [kg CH_4/kg BOD]	Methane correction factor for each treatment system - MCFj	Emission Factor [kg CH_4/kg BOD]
Stagnant sewer	0.6	0.5	0.30
Latrine, wet climate	0.6	0.7	0.42
Septic System	0.6	0.5	0.30
Sea, river and lakes	0.6	0.1	0.06

2.7.6. Emissions

2.7.6.1. Emissions by source category

The annual emissions from the Waste sector for the years 2000 to 2016 are presented in Table 2.75. Total aggregated emissions for the Waste sector was 23,330.275 Gg CO_2-eq in 2016 compared with 13,894.041 Gg CO_2-eq in 2000. This represents a 67.92% increase over the emissions of the year 2000.

Table 2.75 - Aggregated emissions (Gg CO_2-eq) of the waste sector

Year	SWDS	Open Burning	Wastewater	Total
2000	1,344.577	559.741	11,989.722	13,894.041
2001	1,477.823	573.035	12,295.124	14,345.983
2002	1,601.875	586.451	12,611.260	14,799.586
2003	1,718.725	600.378	13,007.220	15,326.323
2004	1,828.928	614.787	13,418.587	15,862.303
2005	1,935.118	629.544	13,921.356	16,486.017
2006	2,038.419	644.994	14,291.302	16,974.716
2007	2,139.635	660.918	14,673.215	17,473.768
2008	2,239.600	677.208	15,150.066	18,066.875
2009	2,338.204	694.152	15,643.267	18,675.623
2010	2,437.119	711.558	16,238.436	19,387.113
2011	2,535.260	729.513	16,681.525	19,946.298
2012	2,634.429	747.709	17,136.836	20,518.974
2013	2,734.641	766.522	17,695.960	21,197.123
2014	2,836.173	785.607	18,268.226	21,890.007
2015	2,943.072	804.643	18,949.327	22,697.042
2016	3,050.473	826.061	19,453.741	23,330.275

In 2016, emissions from Wastewater handling represented 83.4% (19453.741 Gg CO_2-eq) of total Waste sector emissions followed by the SWDS category with 13.1% (3050.473 Gg CO_2-eq) and the remaining 3.5 % (826.061 Gg CO_2-eq) came from open burning (Figure 2.14). From 2014 to 2016, the highest increase in emissions occurred under SWDS with 7.6 % followed by 6.5% in Wastewater handling and 5.2% from Open Burning.

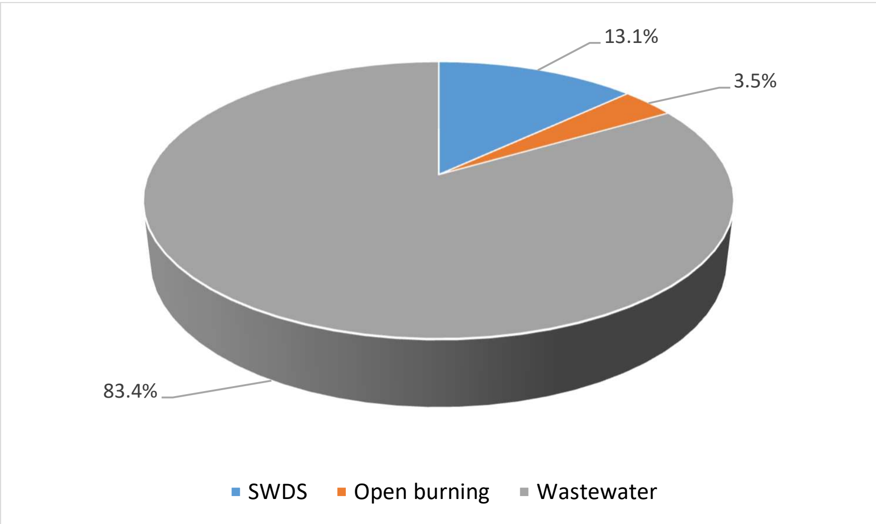


Figure 2.14 - Contribution (%) by source category in emissions of the Waste sector in 2016

2.7.6.2. Emissions by Gases

Emissions by gas for the Waste sector are given in Table 2.76. In 2016, the emissions were 71.797 Gg of CO_2, 767.599 Gg of CH_4 and 23.029 Gg of N_2O compared with 48.65 Gg, 473.486 Gg and 12.588 Gg respectively for these three GHGs in 2000. N_2O recorded the highest increase of 82.95% when comparing emissions of 2016 over those of the year 2000. Methane emissions increased by 62.12 % while CO_2 increased by 47.58% over the same period.

Table 2.76 - Aggregated and absolute emissions by gas (2000 to 2016)

Year	CO_2	CH_4		N_2O		Total
	(Gg)	(Gg)	(Gg CO_2-eq)	(Gg)	(Gg CO_2-eq)	(Gg CO_2-eq)
2000	48.650	473.486	9,943.211	2.588	3,902.180	13,894.041
2001	49.805	490.226	10,294.744	12.908	4,001.433	14,345.983
2002	50.971	506.881	10,644.491	13.239	4,104.123	14,799.586
2003	52.182	523.496	10,993.411	13.809	4,280.730	15,326.323
2004	53.434	540.192	11,344.032	14.403	4,464.836	15,862.303
2005	54.717	557.121	11,699.549	15.264	4,731.751	16,486.017
2006	56.060	574.350	12,061.353	15.669	4,857.303	16,974.716
2007	57.444	591.877	12,429.412	16.087	4,986.912	17,473.768
2008	58.860	609.800	12,805.810	16.781	5,202.205	18,066.875
2009	60.332	628.063	13,189.325	17.503	5,425.965	18,675.623
2010	61.845	646.737	13,581.484	18.528	5,743.784	19,387.113
2011	63.406	665.838	13,982.598	19.033	5,900.294	19,946.298
2012	64.987	685.376	14,392.903	19.552	6,061.084	20,518.974
2013	66.622	705.335	14,812.038	20.382	6,318.463	21,197.123
2014	68.281	725.620	15,238.020	21.238	6,583.706	21,890.007
2015	69.935	746.349	15,673.319	22.432	6,953.787	22,697.042
2016	71.797	767.599	16,119.588	23.029	7,138.891	23,330.275

When taking into consideration the GWP of CH_4 and N_2O, the aggregated emissions of 2016 were 16,119.588 Gg CO_2-eq and 7138.891 Gg CO_2-eq respectively. In 2016, and on the same basis of equivalence, CH_4 topped the emissions with 69.09 % followed by N_2O with 30.60% and CO_2 with 0.31% of total aggregated emissions.

Emissions of the precursor gases are given in Table 2.77. NO_X emissions increased from 9.971 Gg in year 2000 to reach 14.715 Gg in 2016 while CO increased from 175.051 Gg to 258.339 Gg during the same period. Emissions of SO2 reached 0.509 Gg in 2016 representing an increase of 47.58 % over the year 2000. There was an increase of 59.43 % in NMVOC emissions from year 2000 to 2016, from 13.133 Gg to 20.938 Gg.

Table 2.77 - Emissions by gas of precursors for the period 2000 to 2016

Year	NO_X	CO	SO2	NMVOC
2000	9.971	175.051	0.345	13.133
2001	10.207	179.209	0.353	13.494
2002	10.446	183.404	0.361	13.880
2003	10.695	187.760	0.370	14.278
2004	10.951	192.266	0.379	14.667
2005	11.214	196.881	0.388	15.095
2006	11.489	201.713	0.397	15.541
2007	11.773	206.693	0.407	16.001

Year	NO_X	CO	SO2	NMVOC
2008	12.063	211.787	0.417	16.479
2009	12.365	217.086	0.428	16.973
2010	12.675	222.530	0.438	17.482
2011	12.995	228.145	0.450	17.980
2012	13.319	233.836	0.461	18.521
2013	13.654	239.719	0.472	19.078
2014	13.994	245.688	0.484	19.648
2015	14.333	251.641	0.496	20.327
2016	14.715	258.339	0.509	20.938

2.7.6.3. Solid Waste Disposal Systems

Solid waste amounts for the component not estimated to be burned will decay based on its carbon content. It also considers the carbon stored in harvested wood products which can be discarded as part of the waste which may emit stored CO_2 during decomposition. GHG emissions for direct and indirect GHGs from SWDS (2000-2016) is presented in absolute and aggregated values in Table 2.78. Methane emissions increased from 64.027 Gg or 1,344.577 Gg CO_2-eq in 2000 to reach 145.261 Gg or 3,050.473 Gg CO_2-eq in 2016. The latter represented an increase of 1,705.896 Gg CO_2-eq over the emissions of the year 2000. Emissions of NMVOC from this source category increased by 64.34 % over the time series, from 9.277 Gg in the year 2000 to reach 15.246 Gg in 2016.

Table 2.78 - Emissions of CH_4 from solid waste disposal systems (2000-2016)

Year	CH_4 (Gg)	CH_4 (Gg CO_2 eq)	NMVOC (Gg)
2000	64.027	1,344.577	9.277
2001	70.373	1,477.823	9.546
2002	76.280	1,601.875	9.839
2003	81.844	1,718.725	10.142
2004	87.092	1,828.928	10.431
2005	92.148	1,935.118	10.757
2006	97.068	2,038.419	11.097
2007	101.887	2,139.635	11.448
2008	106.648	2,239.600	11.813
2009	111.343	2,338.204	12.190
2010	116.053	2,437.119	12.580
2011	120.727	2,535.260	12.954
2012	125.449	2,634.429	13.370
2013	130.221	2,734.641	13.796
2014	135.056	2,836.173	14.236
2015	140.146	2,943.072	14.783
2016	145.261	3,050.473	15.246

2.7.6.4. Open burning of Waste

Emissions from open burning, consisting of CO_2, CH_4 and N_2O are given in absolute and aggregated values in Table 2.79. Emissions in the year 2000 were 48.650 Gg of CO_2, 20.380 Gg or 427.987 Gg CO_2-eq CH_4 and 0.268 Gg or 83.105 Gg CO_2-eq of N_2O. The emissions from 2016 are 71.797 Gg of CO_2, 30.077 Gg CH_4 or 631.619 Gg CO_2-eq and 0.396 Gg or 122.645 Gg CO_2-eq N_2O. All three GHGs increased by about 47.58% over the period 2000 to 2016. On a comparable basis in CO_2-eq, CH_4 was the major GHG emitted with 76.46%. N_2O and CO_2 emissions represented 14.85 % and 8.69 % respectively.

Table 2.79 - Emissions from open burning (2000-2016)

Year	CO_2 (Gg)	CH_4 (Gg)	CH_4 (Gg CO_2eq)	N_2O (Gg)	N_2O (Gg CO_2-eq)
2000	48.650	20.380	427.987	0.268	83.105
2001	49.805	20.864	438.151	0.274	85.078
2002	50.971	21.353	448.410	0.281	87.070
2003	52.182	21.860	459.058	0.288	89.138
2004	53.434	22.385	470.076	0.294	91.277
2005	54.717	22.922	481.359	0.302	93.468
2006	56.060	23.484	493.173	0.309	95.762
2007	57.444	24.064	505.348	0.317	98.126
2008	58.860	24.657	517.804	0.324	100.545
2009	60.332	25.274	530.759	0.332	103.061
2010	61.845	25.908	544.068	0.341	105.645
2011	63.406	26.562	557.797	0.349	108.311
2012	64.987	27.224	571.710	0.358	111.012
2013	66.622	27.909	586.094	0.367	113.805
2014	68.281	28.604	600.687	0.376	116.639
2015	69.935	29.297	615.242	0.385	119.465
2016	71.797	30.077	631.619	0.396	122.645

Open burning also results in emissions of precursor gases which are depicted in Table 2.80. The method adopted for estimation is based on information from the EMEP/EEA Air Pollution Guidebook 2016, Open Burning of Waste. Emissions for the year 2016 were 14.715 Gg of NO_X, 258.339 Gg of CO, 0.509 Gg of SO_2, and 5.692 Gg of NMVOC. The values for the precursor gases in 2000 were 9.971 Gg of NO_X, 175.051 Gg of CO, 0.345 Gg of SO_2, and 3.857 Gg of NMVOC. The growth in emissions from 2000 to 2016 for these precursor gases is by 47.58 % for all four gases, due to the increase in population over the time series.

Table 2.80 - Precursor gases from open burning (Gg)

Year	NO_X	CO	SO_2	NMVOC
2000	9.971	175.051	0.345	3.857
2001	10.207	179.209	0.353	3.948
2002	10.446	183.404	0.361	4.041
2003	10.695	187.760	0.370	4.137
2004	10.951	192.266	0.379	4.236
2005	11.214	196.881	0.388	4.338
2006	11.489	201.713	0.397	4.444
2007	11.773	206.693	0.407	4.554
2008	12.063	211.787	0.417	4.666
2009	12.365	217.086	0.428	4.783
2010	12.675	222.530	0.438	4.903
2011	12.995	228.145	0.450	5.026
2012	13.319	233.836	0.461	5.152
2013	13.654	239.719	0.472	5.281
2014	13.994	245.688	0.484	5.413
2015	14.333	251.641	0.496	5.544
2016	14.715	258.339	0.509	5.692

2.7.6.5. Domestic Wastewater

The annual absolute (Gg) and aggregated (Gg CO_2-eq) emissions of direct GHGs and NMVOC from Domestic Wastewater (2000-2016) are presented in Table 2.81. Domestic Wastewater in Nigeria generated more emissions as CH_4 (63.93%) than N_2O (36.07%) when compared in CO_2-eq in 2016. Emissions for CH_4 in 2000 were 389.078 Gg which translates to 8170.647 Gg CO_2-eq and for N_2O, 12.320 Gg or 3819.075 Gg CO_2-eq. The values for 2016 are 592.262 Gg CH_4 or 12437.496 Gg CO_2-eq and 22.633 Gg or 7016.246 Gg CO_2-eq of N_2O. The increase over the review period is 83.7% for N_2O and 52.2% for CH_4. NMVOC emissions from this sub-category increased from 0.00003 Gg in year 2000 to reach 0.00005 Gg in 2016.

Table 2.81 - Emissions from the Domestic Wastewater sub-category (2000-2016)

Year	CH_4 (Gg)	CH_4 (Gg CO_2-eq)	N_2O (Gg)	N_2O (Gg CO_2-eq)	Total (Gg CO_2-eq)	NMVOC (Gg)
2000	389.078	8170.647	12.320	3819.075	11989.722	0.00003
2001	398.989	8378.770	12.633	3916.355	12295.124	0.00004
2002	409.248	8594.207	12.958	4017.053	12611.260	0.00004
2003	419.792	8815.628	13.521	4191.592	13007.220	0.00004
2004	430.716	9045.028	14.108	4373.559	13418.587	0.00004
2005	442.051	9283.073	14.962	4638.283	13921.356	0.00004
2006	453.798	9529.762	15.360	4761.541	14291.302	0.00004
2007	465.925	9784.429	15.770	4888.785	14673.215	0.00004
2008	478.496	10048.406	16.457	5101.660	15150.066	0.00004
2009	491.446	10320.362	17.171	5322.905	15643.267	0.00004
2010	504.776	10600.297	18.188	5638.139	16238.436	0.00004
2011	518.550	10889.541	18.684	5791.983	16681.525	0.00005
2012	532.703	11186.764	19.194	5950.072	17136.836	0.00005
2013	547.205	11491.302	20.015	6204.658	17695.960	0.00005
2014	561.960	11801.159	20.862	6467.067	18268.226	0.00005
2015	576.905	12115.005	22.046	6834.322	18949.327	0.00005
2016	592.262	12437.496	22.633	7016.246	19453.741	0.00005

Table 2.82 - Uncertainty

2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO_2 equivalent)	Year T emissions or removals (Gg CO_2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Inventory trend in national emissions for year t increase with respect to base year (% of base year)	Uncertainty introduced into the trend in total national emissions (%)
1 - Energy									
1.A.1 - Energy Industries - Gaseous Fuels	CO_2	6999.192968	53501.39863	7.071067812	9.899494937	12.16552506	0.206864898	764.3938219	0.477517855
1.A.1 - Energy Industries - Gaseous Fuels	CH_4	2.620018758	20.02726152	7.071067812	106.0660172	106.3014581	2.21318E-06	764.3938219	3.529E-06
1.A.1 - Energy Industries - Gaseous Fuels	N_2O	3.867646738	29.56405272	7.071067812	420.021428	420.0809446	7.53163E-05	764.3938219	0.000119427
1.A.1 - Energy Industries - Liquid Fuels	CO_2	1339.882211	987.1591408	5	7	8.602325267	9.58893E-05	73.6750688	0.000220635
1.A.1 - Energy Industries - Liquid Fuels	CH_4	0.900078526	0.726688704	5	75	75.16648189	3.96743E-09	80.736145	4.01102E-09
1.A.1 - Energy Industries - Liquid Fuels	N_2O	2.432748073	2.060859106	5	297	297.0420846	4.98306E-07	84.71321501	3.92559E-07
1.A.1 - Energy Industries - Biomass	CO_2	16640.33305	34303.21366	5	7	8.602325267	0.115788441	206.1449945	0.166555161
1.A.1 - Energy Industries - Biomass	CH_4	93.60187341	192.9555768	5	75	75.16648189	0.000279722	206.1449945	6.19965E-05
1.A.1 - Energy Industries - Biomass	N_2O	184.2322588	379.7855798	5	297	297.0420846	0.016922978	206.1449945	0.003494936
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CO_2	966.6817917	744.705261	5	7	8.602325267	5.45713E-05	77.03726991	0.000115903
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.791201187	0.59247909	5	75	75.16648189	2.63729E-09	74.88349357	3.73679E-09
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	N_2O	2.332364205	1.72063113	5	297	297.0420846	3.47356E-07	73.77197465	5.21111E-07
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CO_2	7.32204	122.7173904	5	7	8.602325267	1.48186E-06	1676	3.52111E-06
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CH_4	0.016254	0.27241704	5	75	75.16648189	5.57546E-10	1676	9.09565E-10
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	N_2O	0.035991	0.60320916	5	297	297.0420846	4.26909E-08	1676	6.92498E-08
1.A.2 - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	1705.424853	10677.44961	5	7	8.602325267	0.011218393	626.0873699	0.023283516
1.A.2 - Manufacturing Industries and Construction - Gaseous Fuels	CH_4	0.63839433	3.99690627	5	75	75.16648189	1.20022E-07	626.0873699	1.41552E-07
1.A.2 - Manufacturing Industries and Construction - Gaseous Fuels	N_2O	0.94239163	5.90019497	5	297	297.0420846	4.08444E-06	626.0873699	4.77166E-06
1.A.2 - Manufacturing Industries and Construction - Biomass	CO_2	8940.72081	12325.70763	5	7	8.602325267	0.014949247	137.8603347	0.019471613
1.A.2 - Manufacturing Industries and Construction - Biomass	CH_4	51.96915342	71.21825027	5	75	75.16648189	3.81061E-05	137.0394659	6.62649E-07
1.A.2 - Manufacturing Industries and Construction - Biomass	N_2O	99.16686553	136.5083163	5	297	297.0420846	0.002186342	137.655169	2.69983E-06
1.A.3.a - Civil Aviation - Liquid Fuels	CO_2	469.4069001	1364.021159	7.071067812	7.071067812	10	0.000103441	290.5839599	0.000224399
1.A.3.a - Civil Aviation - Liquid Fuels	CH_4	0.06893388	0.2003108	7.071067812	818.9852161	819.0157411	1.49639E-08	290.5839599	7.79393E-09
1.A.3.a - Civil Aviation - Liquid Fuels	N_2O	4.070381511	11.82787578	7.071067812	7.071067812	10	7.77792E-09	290.5839599	1.6873E-08
1.A.3.b - Road Transportation - Liquid Fuels	CO_2	14518.0197	36112.99486	10	7	12.20655562	0.028060974	248.7460109	0.069165982
1.A.3.b - Road Transportation - Liquid Fuels	CH_4	87.03362148	299.4677822	10	19.24	21.68357904	8.041E-06	344.0828695	1.06158E-05
1.A.3.b - Road Transportation - Liquid Fuels	N_2O	172.4071218	479.3888583	10	24	26	2.54111E-05	278.0562968	2.69075E-05
1.A.3.c - Railways - Liquid Fuels	CO_2	111.870993	74.782461	5	1.5	5.220153254	2.02642E-07	66.84705212	7.5414E-07

2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO_2 equivalent)	Year T emissions or removals (Gg CO_2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Inventory trend in national emissions for year t increase with respect to base year (% of base year)	Uncertainty introduced into the trend in total national emissions (%)
1.A.3.c - Railways - Liquid Fuels	CH_4	0.13157297	0.087952652	5	250	250.049995	6.43155E-10	66.84705212	1.43836E-09
1.A.3.c - Railways - Liquid Fuels	N_2O	13.38526618	8.94765586	5	125	125.09996	1.66608E-06	66.84705212	3.72928E-06
1.A.3.d - Water-borne Navigation - Liquid Fuels	CO_2	542.2855751	1530.957374	11.18033989	4.242640687	11.95826074	9.72032E-05	282.3157104	0.0002885
1.A.3.d - Water-borne Navigation - Liquid Fuels	CH_4	1.117941396	3.206985222	11.18033989	70.71067812	71.58910532	3.17876E-08	286.8652358	1.98725E-08
1.A.3.d - Water-borne Navigation - Liquid Fuels	N_2O	4.715126976	13.52606012	11.18033989	127.2792206	127.7693234	1.8195E-06	286.8652358	1.09712E-06
1.A.4 - Other Sectors - Liquid Fuels	CO_2	5423.614624	15611.85385	10	12.61942946	16.10124219	0.017747886	287.8496156	0.026686422
1.A.4 - Other Sectors - Liquid Fuels	CH_4	15.93556391	44.93662593	10	87.13520758	87.70715136	5.07133E-06	281.9895561	1.94732E-06
1.A.4 - Other Sectors - Liquid Fuels	N_2O	13.97898632	38.71448324	10	156.3457706	156.6652482	1.20917E-05	276.9477153	4.14553E-06
1.A.4 - Other Sectors - Biomass	CO_2	176586.2713	209461.913	7.071067812	9.899494937	12.16552506	3.960503921	118.617326	5.296058836
1.A.4 - Other Sectors - Biomass	CH_4	10032.15426	12039.80387	7.071067812	70.71067812	71.06335202	0.450557036	120.0121485	0.038246539
1.A.4 - Other Sectors - Biomass	N_2O	1928.217403	2305.222996	7.071067812	127.2792206	127.4754878	0.053530626	119.5520273	0.003269439
1.B.2.a - Oil	CO_2	5626.139785	4580.303225	10	163.936007	164.2407209	0.139850347	81.41111667	0.135950807
1.B.2.a - Oil	CH_4	53977.4171	43940.5509	10	163.9359631	164.2406771	3.05659E-05	81.40543446	2.33669E-05
1.B.2.a - Oil	N_2O	25.96307383	21.13597939	10	612.8825336	612.9641099	0.000213856	81.40784691	0.00020523
1.B.2.b - Natural Gas	CO_2	40.39792684	24.52228299	10	325.9601203	326.1134772	2.65341E-06	60.70183525	1.89695E-05
1.B.2.b - Natural Gas	CH_4	12088.53188	22389.52279	10	325.9601203	326.1134772	0.238935898	185.2129192	0.216208419
1.B.2.b - Natural Gas	N_2O	0.193748218	0.068576108	10	500	500.09999	1.56348E-09	35.39444563	2.57411E-08
2 - Industrial Processes and Product Use									
2.A.1 - Cement production	CO_2	713.5970244	7083.3477	10	5	11.18033989	0.008339711	992.6257338	0.028099958
2.B.1 - Ammonia Production	CO_2	2.01409285	1.70935765	5	0	5	9.71337E-11	84.86985344	3.74475E-10
2.C.1 - Iron and Steel Production	CO_2	1791.02582	6169.86144	10	25	26.92582404	0.03669887	344.4875764	0.041246822
2.C.1 - Iron and Steel Production	CH_4	3.5482587	12.2233104	10	25	26.92582404	1.44039E-07	344.4875764	1.61894E-07
3 - Agriculture, Forestry, and Other Land Use									
3.A.1 - Enteric Fermentation	CH_4	17504.9054	26300.39578	56.56854249	78.74007874	96.95359715	0.328679275	150.2458606	0.391608685
3.A.2 - Manure Management	N_2O	1081.10359	1695.187971	60	90	108.1665383	0.001512959	156.8016226	0.001438573
3.A.2 - Manure Management	CH_4	833.731164	1245.271794	60	90	108.1665383	0.000635421	149.3613107	0.000464559
3.B.1.a - Forest land Remaining Forest land	CO_2	255877.2289	311608.6447	20	10	22.36067977	64.55841639	121.7805297	199.5955944
3.C.1 - Emissions from biomass burning	CH_4	1.907150791	3.766442135	28.28427125	14.14213562	31.6227766	6.51093E-09	197.4905263	1.9896E-08
3.C.1 - Emissions from biomass burning	N_2O	1.716848458	2.137677964	28.28427125	14.14213562	31.6227766	1.53151E-09	124.5117445	3.62656E-09
3.C.4 - Direct N_2O Emissions from managed soils	N_2O	11308.70101	17323.67601	20	20	28.28427125	0.319252246	153.1889117	0.61809816
3.C.5 - Indirect N_2O Emissions from managed soils	N_2O	3520.831021	5585.715255	20	20	28.28427125	0.03319032	158.647638	0.064477193

2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO_2 equivalent)	Year T emissions or removals (Gg CO_2 equivalent)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Inventory trend in national emissions for year t increase with respect to base year (% of base year)	Uncertainty introduced into the trend in total national emissions (%)
3.C.6 - Indirect N_2O Emissions from manure management	N_2O	256.1024312	367.758866	20	10	22.36067977	8.99208E-05	143.5983502	0.000277372
3.C.7 - Rice cultivations	CH_4	5057.326564	6889.587468	20	1.5	20.05617112	0.025389045	136.2298317	0.097333789
3.D.1 - Harvested Wood Products	CO_2	-5967.538367	-4288.204679	0	0	0	0	0	0
4 - Waste									
4.A - Solid Waste Disposal	CH_4	1344.577355	3050.472521	60	60	84.85281374	0.089090337	226.8722219	0.184661016
4.C - Incineration and Open Burning of Waste	CO_2	48.64987347	71.79710214	200	40	203.9607805	0.000285148	147.5792166	0.001057112
4.C - Incineration and Open Burning of Waste	CH_4	427.9865462	631.619192	200	100	223.6067977	0.026524335	147.5792166	0.081842285
4.C - Incineration and Open Burning of Waste	N_2O	83.10464035	122.6451772	200	100	223.6067977	0.00100008	147.5792166	0.003085802
4.D - Wastewater Treatment and Discharge	CH_4	8170.6468	12437.4958	35	40	53.15072906	0.581096441	152.2216797	0.976348381
4.D - Wastewater Treatment and Discharge	N_2O	3819.075291	7016.2455	35	500	501.223503	16.44509087	183.7158203	2.19120943
5 - Other									
							Uncertainty in total inventory: 9.366		Trend uncertainty: 14.517

3. Mitigation Assessment

3.1. Introduction

As per Article 4, paragraphs 1, 3 and 7, Article 10, paragraph 2 (a) , and Article 12, paragraphs 1, 5 and 7, of the Convention, Parties are committed to provide in their national communications "*A general description of steps taken or envisaged by the non-Annex I Party to implement the Convention*". The information provided in this national communication is to enable Nigeria to meet this commitment, be in line with various COP decisions and ensure that the Conference of the Parties (COP) has enough information to carry out its responsibility for assessing the implementation of the Convention by Parties.

This chapter provides information on options and actions taken by the country and aiming at reducing current and future GHG emissions stemming from socio-economic activities, without compromising opportunities for sustainable development. A robust mitigation strategy demands for a good understanding of the historical and base period GHG emissions in each of the sectors of the economy, as the starting point for gathering information about actions already taken and planned in the country. As presented in Chapter 2 of this TNC, Nigeria's GHG intensity, emissions per capita, is presently going down after peaking in 2005 while the GDP emissions index is regressing slowly since the year 2001. The net national GHG emissions, including removals in 2016 has been estimated to be about 609,800 Gg-CO_2 -eq. The share of GHG emissions in the four IPCC sectors, Energy, AFOLU, IPPU and Waste as depicted in Figure 2.4 of chapter 2 showed that AFOLU dominated national emissions with some 60% followed by the Energy sector with a contribution of about 34%, while the remaining two sectors IPPU and Waste had a combined contribution of about 6%. During the inventory period 2000 to 2016, total aggregated emissions of the direct GHGs increased by 45%, accounted for by 53% from CO_2, 18% from CH_4 and 58% from N_2O. Emissions of the GHG precursor NO_X progressed by 85%, CO by 39%, NMVOC by 31% while SO_2 increased by 64%.

3.2. National Development Plans and Policies on Climate Change Mitigation

Mitigation is guided by the National Climate Change Policy Response and Strategy (NCCPRS) which was adopted in 2012 to better frame and implement the GHG reduction options. The goal of the NCCPRS is to foster low-carbon high economic growth and build a climate resilient society, through the following main objectives:

- Implement mitigation to promote low carbon sustainable high economic growth.
- Enhance national capacity to adapt to climate change.
- Increase public awareness.
- Involve the private sector to address CC challenges.
- Strengthen national institutions and mechanisms for a suitable and functional CC governance framework.

Within the framework of this strategy, several policies have been developed and the main ones are given below.

3.2.1. The National Energy Policy

3.2.1.1. Framework for sustainable energy development

The framework for sustainable energy development to provide clean, affordable, adequate and reliable energy with the participation of the private sector.

Objectives

- Ensure development of the nation's energy resources, diversification of energy options, national energy security and efficient energy delivery with an optimal energy mix.
- Guarantee an adequate, reliable and sustainable energy supply at appropriate costs for the various sectors of economic development.
- Ensure comprehensive, integrated and well-informed energy sector plans and programmes for effective development.
- Promote R&D in, and adoption of, sustainable low carbon and clean energy technologies to mitigate CC and environmental pollution.
- Promote efficiency, and best practices for conservation and carbon management in the energy supply chain; and
- Ensure effective coordination of energy planning, programmes and policy implementation.

The Sustainable Energy for All (SE4ALL) Action Agenda

The key objectives of the SE4ALL initiative globally are:

- Ensuring universal access to modern energy services.
- Doubling the global rate of improvement in energy efficiency; and
- Doubling the share of renewable energy in the global energy mix by 2030 compared to 2010.

National Renewable Energy and Energy Efficiency Policy

NREEEP seeks to achieve a renewable electricity target of 16% by 2030 as opposed to the current 1.3%.

Objectives

- Produce guidelines on all key components of energy efficiency by 2020.
- Ensure reduction in transmission/ distribution losses from 30-40% to under 10% by 2020.
- Enactment of all relevant legislation for policy implementation by 2020.
- Attain a 40% of electricity consumption by 2030 through replacement of old and inefficient appliances with energy efficient ones.
- Replace all incandescent bulbs with LEDs and other energy saving ones by 2025; and
- Reduce by 2025 energy related GHG emissions by 15% of 2013 levels.

The Renewable Energy Master Plan (REMP)

REMP aims to articulate a roadmap for national development through the accelerated development and exploitation of renewable energy to increase the supply of the latter from 13% of total electricity generation in 2015 to 23% in 2025 and 36% by 2030.

Nigeria Feed-in Tariff for Renewable Energy Sourced Electricity

An optimal economic instrument for hydro schemes not exceeding 30MW, all biomass cogeneration power plants, solar and wind-based power plants, irrespective of their sizes.

UN-REDD Programme

This programme aims at consolidating the countries' efforts to reduce emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks.

Solid Waste Program Interventions of the Federal Ministry of Environment

The programme has the following objectives:

- Construct Integrated Waste Management Facilities in 11 states.
- Establish several waste recycling interventions.
- Improve Solid and Medical Waste Disposal interventions across the country.

Natural Gas Flare-out Policy

The approved National Gas Policy has as agenda to phase out flaring for utilization in the country and is also working on a National Gas Flaring Prohibition Bill.

Its plans for creating the gas market include the following:

Upgrading and amending its Infrastructure Blueprint of the Gas Master Plan within the context of the Gas Resource Management Plan that it will develop.

- Develop an industry consultation mechanism to assist in feasible targets for the industry.
- Mandate the requirement of a gas field development plan for new associated gas fields.
- Take measures to improve the whole supply chain.
- Identify and develop clusters and industrial parks that will utilize processed gas for various energy-intensive activities. This has the added impact of reducing demand for current inefficient fuels such as diesel.
- Consider regulations to allow for open access to gas gathering pipelines, etc.

With regards to disincentives, the Nigerian Government is considering the following:

- Take measures that include shutting down of production plants operating at uneconomic fields.
- A new sliding scale penalty for existing brown fields.
- Take measures to increase the current gas flaring penalty to a more appropriate punitive level.
- Consider a sliding scale penalty for existing brown fields.

3.3. Methods

3.3.1. Choice of economic sectors for mitigation assessment

The choice of the right method is crucial when undertaking a mitigation assessment to ascertain that it is robust and representative of the national context to the maximum to allow for concrete actions to be taken by the decision-makers. Additionally, resources are most of the time a limiting factor which demands for some prioritisation in the assessment. However, mitigating GHGs should also encompass other benefits in line with the Sustainable Development Goals. The assessment should also rest on sound basic principles, namely a good quality inventory for use as baseline and the most reliable projections of socio-economic factors determining the country's future growth and development, which are the driving factors for GHG emissions.

For this assessment, emissions from the latest inventory, the best that has been produced with available data and information, and presented in Chapter 2 of this report, has been used. The KCA for the level assessment for the year 2016 and the trend assessment for the period 2000-2016 have been used to guide the prioritisation exercise and choice of activities offering the highest potential for mitigation. However, some of the activities have not been addressed in this assessment either because of their nature within the national circumstances without affecting the well-being of significant segments of the population such as Livestock and Waste-water Treatment and Discharge. A summary of the KCA is provided in Table 3.1 with the details of the two assessments given on pages 56 and 57 of this report.

Table 3.1 - Summary of Key Categories for level (2016) and trend (2000 to 2016) assessments

Number	IPCC category code	IPCC category	GHG	Identification criteria	Comment
1	3.B.1.a	Forest land Remaining Forest land	CO_2	L1, T1	Quantitative
2	1.A.1	Energy Industries - Gaseous Fuels	CO_2	L1, T1	Quantitative
3	1.B.2.a	Oil	CH_4	L1, T1	Quantitative
4	1.A.3.b	Road Transportation	CO_2	L1, T1	Quantitative
5	3.A.1	Enteric Fermentation	CH_4	L1	Quantitative
6	1.B.2.b	Natural Gas	CH_4	L1, T1	Quantitative
7	3.C.4	Direct N_2O Emissions from managed soils	N_2O	L1	Quantitative
8	1.A.4	Other Sectors - Liquid Fuels	CO_2	L1, T1	Quantitative
9	4.D	Wastewater Treatment and Discharge	CH_4	L1	Quantitative
10	1.A.4	Other Sectors - Biomass	CH_4	L1, T1	Quantitative
11	1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	L1, T1	Quantitative
12	2.A.1	Cement production	CO_2	L1, T1	Quantitative
13	4.D	Wastewater Treatment and Discharge	N_2O	L1, T1	Quantitative
14	3.C.7	Rice cultivations	CH_4	L1	Quantitative
15	2.C.1	Iron and Steel Production	CO_2	L1, T1	Quantitative
		Oil	CO_2	L1, T1	Quantitative

Notation keys: L = key category according to level assessment; T = key category according to trend assessment; The Approach used to identify the key category is included as L1, L2, T1 or T2.

Equations from an analytical tool, the Long Range Energy Alternatives Planning (LEAP) model was utilized to quantitatively study the inherent characteristics of activities within the energy sector and their GHG emissions for the business as usual scenario (when the pathway for energy consumption is maintained) and a pathway that is characterized by deliberate policies of utilizing low carbon technologies in the energy and other pertinent GHG emission sectors within the Nigerian economy. The base year adopted for the assessment is the latest results from 2016 from this inventory.

3.3.2. Approach

Nigeria, like many other developing countries, is currently undergoing industrialization in order to address its developmental challenges. This industrialization process will lead to increased economic growth and increased welfare of its citizens. The increased empowerment will result in an increase in energy utilization which is presently low on a per capita basis. The increased energy utilization has GHG implications which we aim to analyse within their integration in national strategies and policies. We analysed national development plans and policies and modelled how the current anthropogenic GHG emissions as determined in the GHG inventory, will change into the future as a result of national development plans and implementation of Programmes and Measures (PaMs).

3.3.2.1. Modelling Approach

The LEAP model was utilized as the analytical framework for assessing low-carbon development opportunities that can be implemented as mitigation activities in the various sectors of the Nigerian economy. The modelling involved a comprehensive national-level representation of: energy resource extraction; transportation of primary energy resources to processing centres; processing of primary energy resources to secondary energy forms; and the final conversion of secondary energy to useful energy at the end-use level. We have used LEAP10 equations to analyse scenarios of energy production and utilization in the different sectors of Nigeria's economy, as well as activities in the Forest sector (AFOLU), over the assessment period (2016 – 2035) and the emission reduction implications of PaMs implemented in these sectors.

3.3.2.2. Business as Usual and Low Carbon Scenarios

A key approach in the use of LEAP equations is the development of Business as Usual (BaU) and Low Carbon Development (LCD) scenarios. The quantitative and qualitative meaning of the BaU and the LCD scenarios are provided below:

(a) The BaU Scenario – For each sector of the economy, the ongoing and projected activities are the drivers of GHG emissions. For example, thermal power generation involves the combustion of fossil fuels, where the oxidation of the carbon and nitrogen in the fuel can result in the production of GHGs which are emitted at the point of the activity. BaU scenario for this activity is the projected pathway of power generation in that sector based on historical trends and economic development indicators. The existing generation types and their GHG emissions pathway can be considered as the BaU for that sector.

(b) The LCD Scenario – From the selected base year through in the period of the study (2016 – 2035), deliberate (PaMs) can be implemented to promote GHG emission reductions in different sectors of the economy. Therefore, in the LCD pathway, LCD technologies are deliberately introduced into each sector of the economy. During these years, autonomous implementation of PaMs NOT primarily targeted at GHG emissions reduction, but which have this potential reduction benefits are also considered as part of the LCD scenario.

Therefore, using the concepts discussed above, the starting point of our analysis for the study of GHG mitigation opportunities for Nigeria begins with the development of the BaU and LCD scenarios for each of the targeted sectors of the country's economy.

3.3.2.3. Development of the BAU and LCD Scenarios

The BAU and LCD scenarios were developed based on national information and data available in policy documents and more detailed sectoral plans. Socio-economic scenarios were developed based on growth in population and GDP primarily to project the increase in energy utilization. Variables such as the growth in population and income were held constant between both scenarios to allow for a fair comparison between the two scenarios. The BAU scenario is a forward looking scenario for the period 2016-2035 and has been used to analyse the transformation sectors (electricity generation, oil refining, etc), the energy demand of the household, industrial, commercial and transport sectors, as well as emissions growth in the non-energy sector (Forestry in this case) that are likely to evolve when existing policy conditions are

---

10Long Range Energy Alternatives Planning – a tool developed by the Stockholm Environment Institute, Boston, USA maintained during the assessment period. The emissions of this BaU scenario are then compared with the ones developed for the LCD scenario to evaluate mitigation potential at different 5 years' time horizons.

The LCD scenario integrates low carbon programmes in the activities of the sectors of the country's economy over the study time period. In this scenario, a less carbon intensive and more sustainable development pathway is simulated. The implications of the penetration of the low carbon technologies on emissions of GHGs over the same time period as for the BaU scenario were evaluated. A comparative analysis of the GHG emissions of these two scenarios is utilized to establish the possible GHG emission reduction that can be achieved in the Nigerian economy as development needs are met.

3.3.2.4. Socio-economic scenarios

Emission projections for both the BaU and LCD scenarios are based on key parameters which include, the national GDP and its sectoral value added, national GDP growth rate, national population (Total, Urban and Rural) and population growth rate. These key parameters are drivers of the economy and national development plans provide for the projected changes in the future. As adopted for the INDC, a 5% annual growth of the Nigerian economy and a national population increase of 2.6% per annum were used throughout the assessment period 2016-2035. However due to the international agenda on climate change under the Convention and the fact that Nigeria's oil and gas production varied without ever reaching the maximum potential, a lower progression of 2.5% annually has been adopted instead of the 5% of GDP applied for other socio-economic sectors. We used the Sector Value Added statistics to disaggregate the GDP growth by sector and subsector contributions to cover the key sectors and subsectors being assessed. The assumptions adopted for the key parameters are provided in Table 3.2.

Table 3.2 - Assumptions for Key Parameters adopted for the BaU and LCD Scenarios

Key Parameter	Assumption
Study Base Year	2016
Base Year Emissions	609,800 Gg-CO_2-eq
Global Warming Potential Used	The IPCC Second Assessment Report (SAR)
Gases Covered	CO_2, N_2O, CH_4
Base Year Population	187.05 Million people
Average Household size	5 Persons per household
Annual Population Growth rate	2.6%
Base year GDP	404.7 Billion US$
Sectoral Value Added	Agriculture -- 21.2% Manufacturing & Construction - 12.2% Electricity Generation - 0.5% Oil & Gas/Refining - 5.6% Commercial/Institutional - 60.6%
Annual GDP Growth Rate	5%
National Grid Electricity Access	Increase from 40% in 2010 to 90% by 2035 (SE4ALL report)[11]
Implementation Period	2017-2035

[11] Federal Republic of Nigeria, "Sustainable Energy for ALL (SE4ALL) Agenda", Adopted by Inter-ministerial Committee on Renewable Energy and Energy Efficiency (ICREEE), July 2016.

3.3.3. Description of the BaU scenario

Based on the assumptions for the key parameters provided in Table 3.2 above and other information such as available national resources, the factors entering in the assessment by sector follow.

3.3.3.1. The Energy Sector

Nigeria is endowed with appreciable resources of fossil energy, which include: Oil, Natural Gas, Coal, and Lignite. Nigeria is also richly blessed with renewable resources of which Solar, Hydro, Wind and Biomass are the most abundant. Nigeria's renewable energy resources, however, remain largely untapped as the nation economy is mainly dependent on oil and gas for commercial energy supply. Table 3.3 gives the potential of these energy resources.

Table 3.3 - Nigeria's Energy Resources Potentials

Resources	Proven Reserves	Units	Comment
Crude Oil	37	Billion bbls	Production as at 2010: 0.896 Billion bbls Domestic utilization (2010): 0.164 Billion bbls
Natural Gas	187	Trillion Cubic Feet	Production as at 2010: 2.392 Tcf 24.3% gas flared
Coal	2.7	Billion Tonnes	Negligible domestic utilization
Tar Sands	31	Billion bbls of Oil Eq.	0.224 million tonnes domestic utilization
Large Hydro Power Potential	11,250	MW	1900 MW exploited
Small Hydro Power Potential	3,500	MW	64.2 MW exploited
Solar	4.0 - 6.5	Kwh/m^2/day	15 MW dispersed solar PV installations
Wind	2 to 4	m/sec at 10m height mainland	Electronic WIS available; 10 MW wind farm in Kastina in progress
MSW	18.5	Million tonnes	2005 estimated production
Fuel Wood	43.4	Million tonnes/year	estimated fuelwood consumption
Animal Waste	245	Million tonnes assorted animal wastes	2001 value
Agricultural Residues	91.4	Million tonnes / year	yearly production estimate
Energy Crops	28.2	Hectares of arable land	8.5% cultivated

Source: NNPC, 2015; ECN, Renewable Energy Master Plan (2012)

The GHG inventory estimates provided in Chapter 2 of this report for the time series 2000-2016 shows that Energy (exploitation and use) is one of the major contributing sectors with respect to Nigeria's total national emissions. The Energy sector GHG emitting important categories include natural gas consumption in the Energy Industries (Power generation and upstream oil and gas energy use); fuel use in Road Transportation; the combustion of liquid fuels and biomass in the Residential, and Commercial and Institutional activities; gas flaring and venting in the important Oil & Gas industry and emissions from the combustion of natural gas for heat and electricity power generation during Manufacturing and Construction activities.

Electricity Generation (1.A.1.a.i)

There are two types of generation plants supplying electricity to the Nigerian grid: hydro and thermal power plants, which produce electricity from natural gas. Pertinent characteristics of the grid electricity production system in Nigeria are presented in Table 3.4.

The installed capacity in the grid as at December 2016 was 12,500 MW. The plant average MW availability stood at 6,700 MW. The thermal stations average power availability contribution was 5,648 MW while Hydro Stations average availability was 1,052 MW.

Table 3.4 - Installed and available capacity (2016) of existing Generation plants (MW) by type

Power Plant Type	Total Installed Capacity	Total Available Capacity
Steam Turbines	1848	991.6
Open Cycle Gas Turbines	6749	3,618.0
Closed Cycle Gas Turbine	1936	1,038.5
Large Hydro Plants	1967	1,051.9

In 2016, about 29,205 GWh of electricity was generated by active electricity generating plants in the country. With about 16% transmission and distribution losses, and 3.6% used by the generation plants, 80.4% was available for distribution through the grid to service the economic sectors. Electricity consumption in the Residential Sector of the Nigerian Economy from the central National Grid represented about 50.1% of total grid electricity distributed to all end users in that year. Supply from onsite (off-grid) power generating facilities (AGO and PMS fired) also complemented grid supplies in that year. As at 2016, about 52% of the entire households in Nigeria were connected to the grid. One objective of the national electrification plan is to increase grid access from this current level to at least 90% by 2030. Likewise, considering national population and GDP growth, energy demand is projected to rise to 59,000 GWh by 2020, 92,000 GWh by 2025, 145,000 GWh by 2030 and 246, 147 GWh by 2035. (Nigeria Electricity and Gas Improvement Project: Transmission Expansion Plan, 2017)

To meet this projected electricity demand, Government targets a peak generation capacity of 14,444 MW in 2020, 28,200 MW in 2025, 38,900 MW in 2030 and 45,500 MW by 2035 (Nigeria Electricity and Gas Improvement Project: Transmission Expansion Plan, 2017). A variable electricity generation systems analysis was conducted to accommodate these planned capacities for the BaU scenario and assuming the following:

- Current installed power generation plants as at 2016 (Table 3.4) will continue to contribute to meeting the country's electricity demand during the study period. Beyond 2016, some of the very old capacities (older than 50 years) will be retired; those not up to 50 years will be refurbished back to their commissioning capacities over a period of 5 years from 2016 and kept in service for the study period.
- In order to meet the deficit in electricity demand, new power generation plants will be built and commissioned starting as from 2018. This will include LHPs, SHPs, SCGT, and CCGT, maintaining their percentage contribution to the total energy mix as in the base year 2016 (Figure 3.1).
- The quantity of natural gas reported as feedstock sent to main activity electricity production plants compared to the quantity of electricity generation reported for the same year (2016), implies an overall average generation efficiency of 11.1% for the thermal plants in 2016. Therefore, for both scenarios, we assume that a gradual improvement of generating efficiency of the power plants through maintenance works, will result in a 33% efficiency of the power plants by 2033.

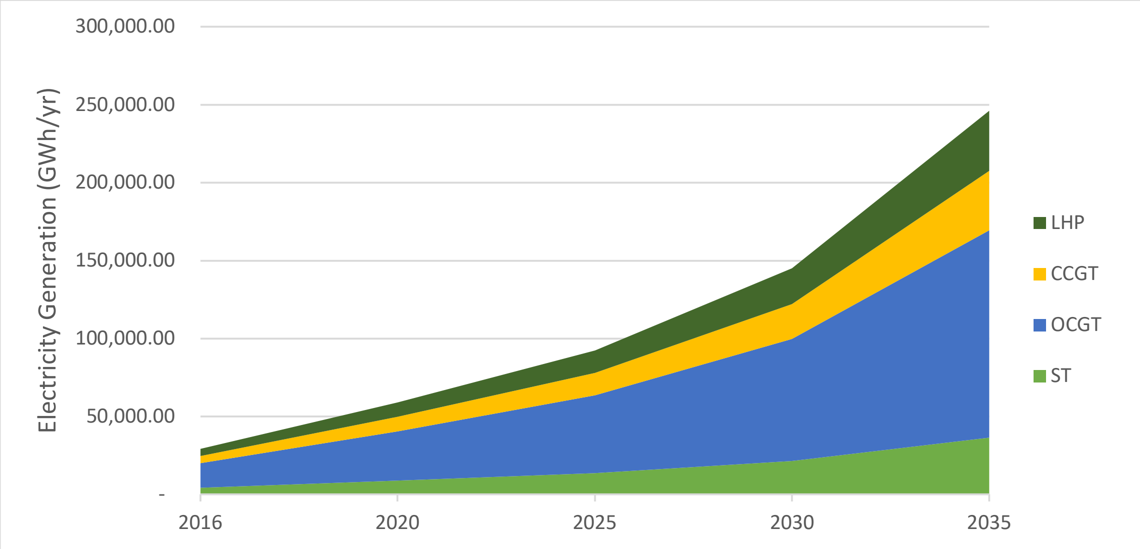


Figure 3.1 - Planned Electricity Generation by Power Plant Type (GWh/yr)

Petroleum Refining (1.A.1.b)

There are currently five refineries in Nigeria, of which four plants are owned by the Nigerian Government through the Nigerian National Petroleum Corporation (NNPC), while the fifth is owned and operated by Niger Delta Petroleum Resources (NDPR). Apart from the single fully-fledged petrochemical plant, two of the refining plants, Kaduna Refining and Petrochemical Company (KRPC) and Warri Refining and Petrochemical Company (WRPC), have petrochemical complexes that utilize their refinery intermediates to produce petrochemical precursors. Total combined capacity of these refineries stands at 445,000 barrels per stream day.

Due to the low capacity utilization and periodic stoppages of the local refineries, Nigeria has relied heavily on importation of finished petroleum products to meet her energy needs. Table 3.5 shows the historical capacity utilization of domestic refineries.

It is assumed that under both the BaU and LCD scenarios, maintenance works will be carried out on the refineries to improve capacity utilization to 50% by 2035.

Table 3.5 - Domestic Refining Capacity Utilization (%) for the period 2011 to 2016

Year/Refineries	2011	2012	2013	2014	2015	2016
Overall Refineries	18.27%	22.98%	25.03%	4.90%	4.90%	13.90%

Source: NNPC ABS, 2016

Manufacture of Solid Fuels (Charcoal Production) (1.A.1.c.i)

Fuelwood is used as feedstock for charcoal production, which is primarily used as a cooking fuel in the residential sector. Under both BaU and LCD scenarios, consumption of fuelwood for charcoal production is projected to grow linearly with demand for charcoal across sectors.

Other Energy Industries (Natural Gas Use for Upstream Oil & Gas Processes) (1.A.1.c.ii)

In the oil & gas sector, natural gas is utilized for own-use electricity and heat generation during upstream production and processing activities. In the base year as well as in historical years, about 5% of the total natural gas production is used as fuel for these purposes. This amounts to a final energy intensity of 0.072 KTOE/KTOE of total natural gas produced. This baseline value formed the basis of projections and did not change under the BaU and LCD scenarios.

Manufacturing Industries & Construction (1.A.2)

Key energy end-use characteristics in the Industrial sector include:

- Grid electricity for motive power (50% of total supply), lighting (30% of total supply) and other appliances (20%);
- Natural gas for own-use electricity generation (about 60% of total supply) and process heat generation (40%);
- Residual Fuel Oil (RFO), Charcoal, LPG, Fuelwood, Coal and Other primary solid biomass, for process heat generation (100% of total supply); and
- Gas/Diesel Oil for own-use electricity generation (100% of total supply).

The technology adopted for modelling industrial steam generation is assumed to be stand-alone steam generators under the BaU scenario. Furthermore, it is assumed that little effort is made to improve efficiency of electricity use under the BaU scenario. Generally, energy use projection in this sector is based on sectoral GDP growth.

Domestic Aviation (1.A.3.a.ii)

In the base year, total fuel use for domestic aviation amounted to 40.9 KTOE. Energy use projection in this sector was based on sectoral GDP growth for both BaU and LCD scenarios.

Road Transportation (1.A.3.b)

Activity data for the road transport category is based on the transport analysis reported by Cervigni et. al, 2013 in "Low-Carbon Development: Opportunities for Nigeria".

In the Road Transport sub-category, BaU assumptions used for the projection of emissions was according to the parameters provided in Table 3.6.

Table 3.6 - Baseline Road and Rail Transport Data and assumptions

Sector	Activity Level	Subsector	Share of Passenger-km (2016)	% of vehicles using each Fuel Type (2016)		BAU
				Gasoline	Diesel	
Road Passenger Transport	552,800 Million Passenger-km	Cars	31.1	98%	2%	This scenario continues through the study period. Total Passenger-km growth is driven by national population.
		Motorcycles	5.1	100	--	
		Light Duty Trucks (including light passenger commercial buses)	54.8	75%	25%	
		Heavy Duty Buses	9.0	50%	50%	
Freight Transport	69,351 Million Tonne-km	Heavy Duty Trucks	99.85% (of freight tonne-km)	--	100%	Total freight-km, continues to grow with national GDP.
		Rail	0.15% (of freight tonne-km)	--	100%	

Domestic Water-borne Navigation (1.A.3.d.ii)

During the base year, total fuel use (Gas/Diesel oil) for domestic water-borne navigation amounted to 59.3 KTOE. Energy use projection in this sector was based on sectoral GDP growth.

Commercial/Institutional (1.A.4.a)

Key energy end-use classifications for this sector are as follows:

- Grid electricity for lighting (30% of total supply), cooling (28% of total supply), cooking (10% of total supply) and other appliances (32%);
- Gas/Diesel Oil for own-use electricity generation (100% of total supply); and
- Total traditional cooking fuel in the commercial/institutional sector amounted to 1,763.6 KTOE in the base year. This comprises LPG (which made up 2.7% of total), Fuelwood (which made up 69.7% of total) and Charcoal (which made up 27.6% of total).

Under the BaU scenario, energy demand projection is based on sectoral GDP growth, with little effort to improve energy efficiency. It is also assumed that the % contribution of diesel generators to total electricity supply in this sector, as well as % contribution of different fuel types to the cooking fuel mix maintains the base year status.

Residential (1.A.4.b)

The residential sector is the largest consumer of energy in Nigeria. Electricity, charcoal, and fuelwood are the leading energy forms historically consumed in this sector. This sector is considered as having an appreciable potential for energy savings, given its relative quantity of energy consumption as well as the poor vintage of energy consuming equipment. This promotes inefficient use of the final energy supply. Key characteristics of final energy consumption in the sector are presented below:

- Grid electricity for lighting (37% of total supply), cooling (28% of total supply), cooking (10% of total supply) and other appliances (25%). It is expected that households connected to the grid will increase from 19 million in 2016 to about 55 million in 2035. Considering this, electricity demand has been projected to rise to about 99,149 GWh by 2035, from the 2016 supply of 11,764 GWh.
- Gasoline for own-use electricity generation (100% of total supply)
- Gas/Diesel Oil for own-use electricity generation (100% of total supply)
- For cooking, most households use more than one type of fuel. In the base year, 20% of the households used LPG for cooking, while 74.1% used fuelwood, 2% Charcoal, 22.9% kerosene and 1% vegetal wastes. The situation whereby the total percentage of the cooking fuel share exceeds 100% results from the fact that most households in the residential sector uses a mix of cooking fuel and this is modelled as % saturation.

Under the BaU scenario, energy demand is projected based on national population growth and increase in GDP per capita, with little effort to improve energy efficiency. It is also assumed that the % contribution of different fuel types to the total energy mix maintains the base year shares.

Agriculture/Forestry/Fishing/Fish Farms (1.A.4.c)

Key energy end-use characteristics for this category are as follows:

- Grid electricity for lighting (30% of total supply), cooling (28% of total supply), cooking (10% of total supply) and other appliances (32%); and
- Gas/Diesel Oil to power off-road vehicles and other machinery (100% of total supply), kerosene and electricity for diverse uses.

Under the BaU scenario, the projection for energy demand is based on sectoral GDP growth.

Fugitive Emissions- Oil and Natural Gas (1.B.2)

The BaU Scenario during the assessment period for Gas Flaring Rates can be summarized as follows: Flaring of Associated Natural Gas (AG) will continue in the oil and gas sector at the observed 2016 rate of 11.3% per annum throughout the study period. In the same vein, the rate of venting will equally continue throughout the assessment period.

Given these assumptions, it has been estimated that the total energy utilization of the whole economy (excluding exports and including fuels used as feedstocks) in the BaU Scenario will grow from 54.48 Million TOE in 2016 to about 118.50 Million TOE in 2035, which represents an average yearly growth rate of about 6.2%.

3.3.3.2. Industrial Processes and Product Use (IPPU)

Total base-year emissions for the IPPU sector amounted to 0.0003 tonnes CO_2-eq/US$ (sectoral GDP). Emissions projections under both BaU and LCD scenarios are based on sectoral GDP.

3.3.3.3. The AFOLU Sector

Net emissions from the AFOLU sector totalled 366,730 Gg-CO_2-eq in 2016 and covered the following IPCC categories.

- Forest Land (3.B.1)
- Aggregate Sources and non-CO_2 emissions sources on land (3.C)
- Harvested Wood Products (3.D.1)

Nigeria's forests, which currently extend over 13.96 million hectares, have been rapidly declining over the past decades. The current deforestation rate is estimated at 110,000 ha per annum while the annual wood removal rate stands at 0.5% per annum (calculated averages from FAO historical data). These rates are expected to continue under the baseline scenario. Emissions from other sub-categories are expected to grow with sectoral GDP.

3.3.3.4. Waste

Total base-year emissions for the Waste sector amounted to 0.12 tonnes CO_2-eq/capita. Emissions projections under both BaU and LCD scenarios are based on national population growth.

3.3.4. National GHG Emissions under the BaU Scenario

Under the BaU scenario, national GHG emissions from the different IPCC Sectors are expected to grow from about 609,836.74 Gg CO_2-eq in 2016 to about 966,673.69 Gg CO_2-eq by the year 2035. This translated to an emission increase of about 58.5% within the period under review (Table 3.7). The small difference in the total national emissions of the baseline year from the results of the GHG inventory due to rounding of data between the 2006 IPCC software and the worksheets used for simulating the LEAP equations.

Table 3.7 - GHG Emissions under the BaU Scenario for years 2016, 2020, 2025, 2030 and 2035

Sector	2016	2020	2025	2030	2035
				Gg CO_2 eq	
National emissions	**609836.74**	**683237.73**	**764873.56**	**843200.01**	**966673.69**
Total Energy sector	206505.42	253892.54	297515.94	330387.31	398993.17
Fuel combustion activities	135549.32	175557.04	210423.64	234190.61	293621.37
Energy Industries	55113.65	84514.78	103852.51	109054.29	146207.11
Electricity Generation	45110.26	72050.32	87762.99	88536.41	120237.08

Sector	2016	2020	2025	2030	2035
				Gg CO_2 eq	
Petroleum Refining	989.93	1533.64	2213.27	2892.91	3572.55
Manufacture of Solid Fuels (Charcoal Production)	572.74	671.08	781.92	912.93	1068.20
Other Energy Industries (Upstream Natural Gas Use)	8440.72	10259.75	13094.33	16712.05	21329.28
Manufacturing Industries and Construction	11767.59	14303.58	18255.40	23299.03	29736.12
Transport	38627.86	43557.98	50698.41	59125.31	69097.88
Domestic Aviation	123.85	150.54	192.13	245.21	312.96
Road Transportation	36943.27	41510.34	48085.05	55789.93	64841.00
Railway	83.80	101.86	130.01	165.92	211.77
Domestic Water-borne Navigation	1476.94	1795.23	2291.22	2924.25	3732.16
Other Sectors	30040.22	33180.70	37617.32	42711.98	48580.26
Commercial/Institutional	2886.24	3508.24	4477.50	5714.55	7293.38
Residential	27096.87	29603.04	33051.22	36884.34	41142.56
Agriculture/Forestry/Fishing/Fish Farms	57.11	69.42	88.60	113.08	144.32
Fugitive Emissions (Oil & Natural Gas)	70956.1	78335.5	87092.3	96196.7	105371.8
IPPU	13267.14	16126.29	20581.69	26268.03	33525.41
AFOLU	366733.9	387306.02	417229.13	452854.35	495740.19
Livestock (Enteric Fermentation & Manure Management)	29240.86	35542.44	45362.16	57894.89	73890.19
Land	311608.64	319463.16	329544.38	339818.02	350319.69
Aggregate sources and non-CO_2 emissions sources on land	30172.64	36675.03	46807.67	59739.77	76244.76
Other (HWP)	-4288.20	-4374.61	-4485.08	-4598.33	-4714.45
Waste	23330.28	25912.88	29546.80	33690.32	38414.92

3.3.5. Low Carbon Development scenarios

3.3.5.1. Nigeria's Low Carbon Energy Pathway

In the LCD scenario, the Nigerian economy is also expected to grow at about 5% per year with a population growth rate of about 2.6% per year. However, it is expected that the LCD scenario will be characterized by penetration of LCD technologies at both the demand and supply sides in numerous sectors of the economy. The LCD scenario comprises several components that have been assessed individually and collectively. They are summarized as follows:

3.3.5.2. The Energy Sector

Electricity Generation (1.A.1.a.i)

Penetration of Renewable Energy: For the main activity power generation, a higher penetration of renewable energy sources is assumed under the LCD scenario in lieu of non-renewable energy sources. According to Nigeria's development plans (Nigeria's SE4ALL, 2016; National Renewable Energy Master Plan), penetration of renewable energy into grid-based power production is expected to rise steadily, from its 2016 level of 15.7% to 41.5% (including hydro plants) by 2035 as presented in Table 3.8. SHPs and Solar Power are expected to penetrate the grid as from 2018, when the FGN commissions some ongoing projects, while wind energy is assumed to penetrate the grid in modules as from the year 2020. The resulting contribution by the planned installations in the electricity generation mix is shown in Figure 3.22.

Table 3.8 - Contributions of renewable energy in the electricity generation fuel mix

Power Plant Type	Percentage Penetration					
	2016	2018	2020	2025	2030	2035
Gas -fired Power Plants (ST, OCGT, CCGT)	84.3%	83.0%	80.3%	73.0%	65.8%	58.5%
Hydro (LHP, SHP)	15.7%	15.9%	16.4%	17.6%	18.8%	20.0%
Solar (PV & Solar Thermal	0.0%	1.1%	3.2%	8.4%	13.7%	19.0%
Wind Energy	0.0%	0.0%	0.2%	0.9%	1.7%	2.5%

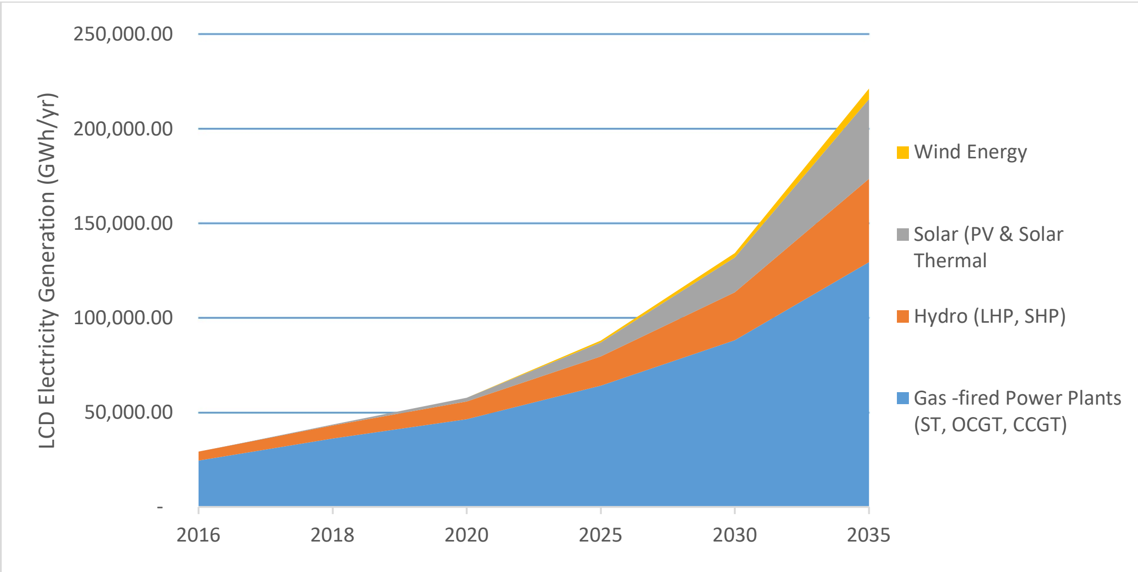


Figure 3.2 - LCD Fuel mix for Power Generation (GWh/yr)

Cross-sectoral Energy Efficiency Measures: Improving energy efficiency is important for many countries, as it has the potential to reduce fuel consumption, improve energy security, and reduce costs. While in many cases, energy-efficiency measures are cost-effective, upfront costs of measures can be an important challenge. In the short-term, it is usually more expensive to purchase efficient equipment than to keep older equipment operating. Nigeria's National Renewable Energy and Energy Efficiency Policy (NREEEP) as well as Nigeria's INDC, aim to achieve energy efficiency of 2% per year reaching 38% by 2035. The LCD scenario includes an assessment of an economy-wide energy-efficiency programme covering all sectors of the economy. For this scenario component, adopting energy-efficiency measures is assumed to result in a reduction of the final energy supply to each end-use sector. For this study, we have conservatively simulated the penetration of energy efficient bulbs, replacing the baseline incandescent bulbs across sectors in Nigeria. Table 3.9 shows total energy savings achievable by implementing this LCD option.

Table 3.9 - Total Energy Savings (GWh/yr) Achievable by Implementing Penetration of Energy Saving Bulbs

2016	2020	2025	2030	2035
-	1,257.89	4,432.46	10,819.98	24,927.48

Manufacturing Industries & Construction (1.A.2)

Combined Heat and Power (CHP) Program: For this category, the LCD option that was modelled is the program of aggressive introduction of CHP facilities in the Nigerian industrial sector. This will involve the gradual replacement of steam production of stand-alone steam boilers fired by fuel oil by CHP plants for the whole industrial sector. It is assumed that the status quo ante for industrial steam production is continued between 2016 -2019, in standalone boilers with an average efficiency of 55%. A sector CHP program backed up by tax incentives (full deduction of investment in CHP in taxation) in the sector is introduced as from the year 2020 such that by 2035, 60% of all steam generation in the industrial sector is generated by CHP plants

The implication of this assumption is that natural gas fired CHP plants, operating with a heat generation efficiency of 50%, will also generate onsite power with an electricity generation efficiency of 25%. This onsite power will replace part, or all the onsite off-grid power generated in the BaU scenario in the industrial sector in those years.

Road Transportation (1.A.3.b)

BRT Transport Program: Under the road transportation sub-category, it is assumed that BRT transport will displace a substantial fraction of cars, motorcycles, Light passenger and Heavy-Duty passenger buses used in the BaU scenario. The resulting share of the different classes of vehicles is provided in Table 3.10.

Table 3.10 – Evolution of share of vehicle classes and passenger-km from BaU scenario in 2016 to the LCD scenario in 2035

Sector	Activity Level	Subsector	Share of Passenger-km (2016)	Share of Passenger-km (2035)	% of vehicles using each Fuel Type	
					Gasoline	Diesel
Road Passenger Transport (Million Passenger-km)	552,800 (2016) 910,282.6 (2035)	Cars	31.1%	26.43%	98%	2%
		Motorcycles	5.1%	4.07%	100	0
		Light Duty Trucks (including light passenger commercial buses)	54.8%	38.36%	75%	25%
		Heavy Duty Buses	9.0%	9.02%	50%	50%
		BRT Buses	0	22.12%	0	100%
Freight Transport (Million Tonne-km)	69,351(2016) 174,984.4 (2035)	Heavy Duty Trucks	99.85% (of freight tonne-km)	99.85% (of freight tonne-km)	--	100%
		Rail	0.15% (of freight tonne-km)	0.15% (of freight tonne-km)	--	100%

3.3.5.3. Other Sectors

Penetration of rooftop solar PVs for off-grid generation: When modelling the penetration of solar PVs in the residential and commercial sectors, a conservative total installed capacity of 3 GW by 2035 was adopted as opposed to the highly ambitious 13 GW described in the INDC. This LCD option is expected to displace part of the diesel and gasoline own-use power generation considered in the BaU scenario. A contribution of about 2,365 GWh/yr and 1577 GWh/yr to the residential and commercial sectors respectively by the year 2035 is forecasted.

Cooking Fuels switch: During the period 2016 – 2019, it is expected that the cooking fuels mix maintains the BaU scenario in both the Residential and Commercial/Institutional sectors due to the combination of LPG shortages, its increasing prices and the cooking equipment in use. However, as from the year 2020, it is projected that the implementation of national energy policies such as expanding the capacity of the NLNG to meet domestic demand for LPG, the provision of incentives to domestic consumers to use or switch to gas, and other programmes such as the integrated 3kg LPG solution with burner by Oando[12] will accelerate the penetration of LPG cooking stoves in the urban zones. This will result in a complete shift from the use of solid fuels in these areas to the use of LPG stoves by 2035. This scenario is summarized in Table 3.11. The total exceeding 100% under the Residential sector is double counting of some households which uses more than one fuel type which is difficult to segregate.

Table 3.11 - Mix and share of cooking fuels by 2035 for the Residential and Commercial/Institutional Sectors

	Residential Sector		Commercial/Institutional	
Fuel	Baseline Energy Mix	LCD Cooking fuel mix by 2035	Baseline Energy Mix	LCD Cooking fuel mix by 2035
LPG	20.0%	32.9%	2.7%	47.7%
Wood	74.1%	39.1%	69.7%	24.7%
Efficient Wood Cookstoves	0.1%	35.1%	-	-
Charcoal	2.0%	2.0%	27.6%	27.6%
Kerosene	22.9%	10.0%	`	`
Vegetal Waste	1.0%	1.0%	`	`

Efficient Fuelwood Cookstoves Program: During the period 2016 to 2035, it is expected that the ongoing penetration of improved cooking stoves, which has already been launched by ICES, will continue from its 2016 remain, attaining a 35.1% share of the total cooking fuels mix in the Residential sector (Table 3.11);

These efficient cookstoves have been reported to have an average efficiency of 45%[13] compared to the efficiency of the traditional 3-stone cook-stoves which range from 5-10%.

Fugitive Emissions- Oil and Natural Gas (1.B.2)

Gas Flare-out: The LCD scenario projects that by 2035, gas flaring will be eliminated, and all associated gas produced from Nigerian oil fields will be used either in the domestic economy or exported through the LNG route and by pipeline. To achieve this, we have assumed that the legislative arm of the Nigerian Government will sort out the political riddle surrounding the Petroleum Industry Bill (PIB) by the end of the 2017/2018 Legislative years. As a result, funds for the development of the Nigerian Gas Master Plan (GMP) will be appropriated by 2018/2019 and the infrastructure needed for the GMP will be commissioned on or before the end of the year 2019. This means that associated gases will only be flared when there are system upsets.

[12] Global Alliance for Clean Cookstoves: Nigeria Market Assessment-Sector Mapping, 2011

[13] Programme design document form for small-scale CDM Programmes of Activities (PoA), 2014.

3.3.5.4. Energy demand under the BaU and LCD scenarios in the Energy sector

Implementing all the energy saving LCD options, total energy demand, including electricity, for the economy is projected to decrease to 2,730.3 Million TOE in 2035 from the 3,054.5 Million TOE forecasted in the BaU scenario. This represent a reduction of about 11% in energy consumption across sectors by 2035 (Figure 3.).

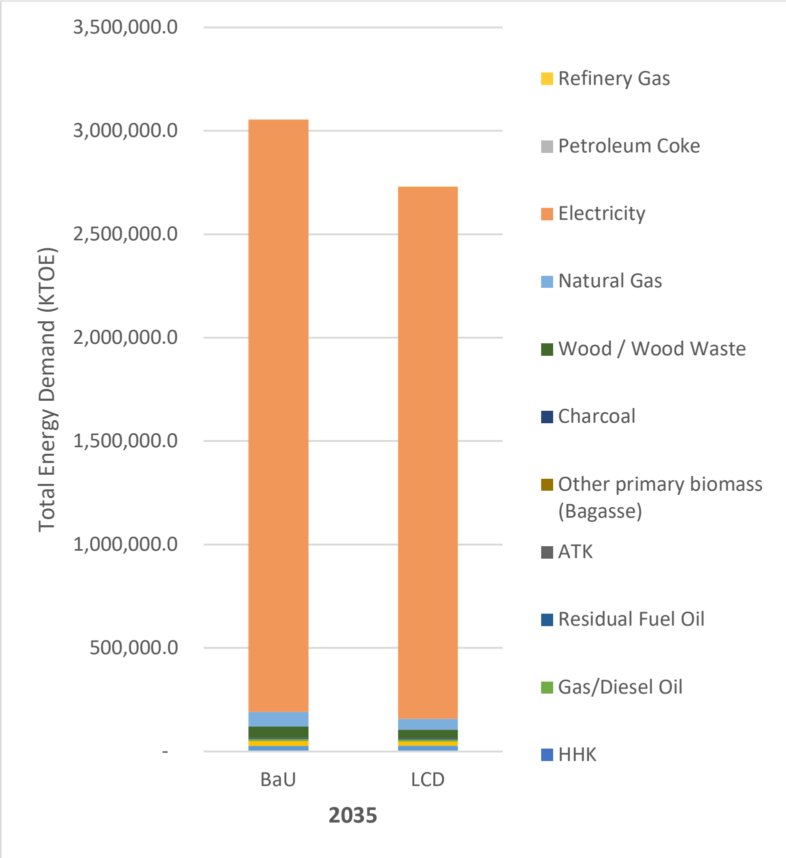


Figure 3.3 - Projected Final Energy Demand (KTOE) by Fuel Type for the LCD and BaU scenarios in 2035

3.3.5.5. AFOLU

Forest Management (Afforestation and Reforestation)

The Federal Government of Nigeria, reinforced by pioneering efforts from Cross River State, began to engage in REDD+ activities in 2009 and signed an agreement with the UN-REDD programme in August 2012.

Reducing Emissions from Deforestation and Forest Degradation (REDD+) is an international effort to create a financial value for the carbon stored in forests by offering incentives for developing countries to reduce emissions from forested lands and investing in low-carbon paths for sustainable development. REDD+ goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

In February 2015, Nigeria's REDD+ Readiness Programme was extended through 2016, following two years of stakeholder approach to achieve REDD+ readiness in Nigeria, based on the following;

The development of institutional and technical capacities at Federal level

Consolidating four key UNFCCC requirements for REDD readiness on a pilot basis in Cross River State: the four Warsaw Framework elements of Strategy, Safeguards Information System, Forest Monitoring System, and Forest Reference Levels for carbon.

Nigeria's REDD+ "readiness" programme entails the participatory development of a national strategy. The UNREDD funding of the Nigeria REDD+ programme developed a strategy for Cross River State as a pilot state, and the National strategy framework. Cross River State REDD+ Strategy is meant to serve as a model for other states in the country. The proposed strategy will comprise policy reforms, investment priorities, and a related REDD+ implementation framework, with due monitoring and safeguard systems, as required under the UNFCCC. The REDD+ strategy intends to enhance the value of forest resources and to incentivize sustainable forest management through a multi-stakeholder approach and a green development perspective.

The government has received grant support from the Forest Carbon Partnership Facility (FCPF) of the World Bank to further implement REDD+ readiness activities in two additional states (namely Ondo and Nasarawa). Nigeria's preparation for the expansion of REDD+ mechanism to these two additional states started with an R-PP (REDD+ Readiness Preparation Programme) preparation phase. National REDD+ strategy aims at addressing the direct drivers of deforestation and forest degradation which are expected to serve as the basis for further dialogue during the REDD+ strategy formulation. The strategy options and the eventual formulation of the REDD+ strategy document requires further analytical work, consensus building, prioritization and operationalization. A number of existing policies, plans, laws and regulations which are REDD+ related, also provide inputs for the development of a national REDD+ strategy.

With support from the FCPF/WB, Nigeria is currently designing a transformational, socially and environmentally viable national strategy with issues and options drawn from sub-national Ondo and Nasarawa States as well as Cross River State as pilots in the UNREDD readiness supported funding, building upon what has been achieved so far in Cross River State and at Federal level. The issue of reducing emissions from deforestation and forest degradation, as compared to a reference level is the focus. This national REDD+ strategy is expected to meet international standards and form a sound basis for mobilizing investment and results that are based on the phases of REDD+, namely

(a) Biomass Pool and Supply Management
(b) Forest Protection
(c) Reforestation

In addition to the REDD+ programme, additional efforts by state and non-state actors to combat deforestation exist in Nigeria and include the following:

The Planting of 5,000 trees in 5 villages in Nigeria Campaign: this project was a reforestation and mixed-cropping program carried out by the Tropical Research and Conservation Centre, a non-profit organization in Akwa Ibom State. Funding was through public donations. (http://www.tropicalconservationcentre.org);

The Planting Trees and Seeds of Hope in Nigeria: this project is an agroforestry program carried out by Bernadette Strebel World Peace (http://bsworldpeace.org/) and funded by public donations. So far, more than 150,000 trees have been planted in a plantation of 400 hectares in Edo State, and the target is to reach 1,000,000 trees in this location.

The Lagos State Annual Tree Planting Campaign: the tree planting campaign was launched in 2008 and is coordinated by the Lagos Parks and Gardens Agency (LASPARK). The campaign boasts of about 6.2 million trees planted since the inception of the campaign (http://moelagos.gov.ng/agencies/lagos-state-parks-and-garden-agency-laspark/).

The Great Green Wall Programme: this programme commenced in 2013 and is coordinated by the National Agency for the Great Green Wall (https://ggwnigeria.gov.ng). The primary focus of this programme is to combat desertification in affected states in Northern Nigeria. The programme involves among others, the establishment of a Green wall or shelterbelt from the Kebbi State in Northwest to Borno State in Northeast. Activities comprise Sensitization and Awareness campaigns; Afforestation and Forestry-related Programmes; Promotion of alternative livelihoods; Popularization of Alternative and Improved Sources of Rural energy etc. In 2013 alone, 235 ha of fruit trees were established in 92 community orchards. In 2016, 372 ha of woodlot and 335 ha of community orchards were established among many other related projects.

Considering the progress and targets of the above mentioned activities and other efforts in the country on reforestation and on combating deforestation, we have modelled a scenario of increasing the total forest cover in Nigeria from the base-year level of 13,964,523 ha in 2016 by 150,000 ha annually to offset the 114,492 ha of annual deforestation. This will increase the total land area of Forest land in the country to 14,639,169 ha by 2035.

3.3.5.6. Summary of LCD interventions

A summary of the key LCD interventions that were included in this mitigation analysis is presented in Table 3.12.

Table 3.12 – Summary of LCD opportunities assessed

S/N	LCD Opportunity	Sector	Gases	Timeline	Comments
1.	Penetration of Renewable Energy to the Electricity Grid.	Energy Sector- Electricity Generation	CO_2, CH_4, N_2O	2018-2035	• Grid scale RE power plants will be implemented to supply electricity to the grid to achieve 41.5% penetration by 2035 • 15.7% contribution in 2016 to 20% by 2035 (for Hydro power both LHPs and SHPs) • 19% contribution to total grid electricity generation by 2035 for Solar PV and thermal plants • 2.5% contribution to total grid electricity generation by 2035 for Wind energy.
2.	Energy Efficiency Measures	Cross-sectoral (Electricity Generation, Residential, Commercial / Institutional, Manufacturing Industries and Construction)	CO_2, CH_4, N_2O	Ongoing	• The specific electrical energy efficiency modelled for this study is penetration of energy efficient bulbs to displace existing incandescent bulbs. According to the (I)NDC and NNREEEAP, a 2% per annum improvement of energy efficiency was modelled to achieve 38% by 2035.
3.	Combined Heat and Power (CHP) Program	Manufacturing Industries and Construction	CO_2, CH_4, N_2O	2020-2035	• This program will target a 60% replacement of existing fuel oil-fired stand-alone steam boilers in the industries with natural gas-fired CHPs. • This onsite power will replace part, or all the onsite power generated in the BaU in the

S/N	LCD Opportunity	Sector	Gases	Timeline	Comments
					industrial sector in those years that is used to generate off grid electricity in industry in the BaU in those years.
4.	BRT Transport Program	Road Transportation	CO_2, CH_4, N_2O	Ongoing	• Under the road transport sub-category, it is assumed that BRT transport will displace fractions of cars, motorcycles, Light passenger and Heavy-Duty passenger buses used in the Baseline scenario, resulting in a 22.1% contribution to total passenger km by 2035.
5.	Penetration of Rooftop Solar PVs for Off-grid power generation.	Other Sectors (Residential and Commercial / Institutional sectors)	CO_2, CH_4, N_2O	Ongoing	• This will include the adoption of: RE power supplying cluster of off-grid consumers. RE considered will include solar power farms and rooftop solar PVs achieving a total installed capacity of 3 GW by 2035. This will displace part of existing diesel and gasoline generators in the residential and commercial sectors.
6.	Cooking fuels switch	Other Sectors (Residential and Commercial / Institutional sectors)	CO_2, CH_4, N_2O	2020-2035	• This will be an offshoot of an aggressive program to increase the penetration of the use of LPG in homes and commercial centres. This will increase the share of households using LPG stoves from 20% in 2016 to 32.9% in 2035. Likewise, projections for the commercial sector targets increasing the share of LPG in the cooking fuels mix from 2.7% in 2016 to 47.7% by 2035.
7.	Efficient Fuelwood Cookstoves Program	Residential Sector	CO_2, CH_4, N_2O	Ongoing	• This will involve the continuation of the improved efficiency fuelwood cooking stoves e.g. SAVE 40 to replace the traditional cooking stoves (three stones stoves) especially in the rural areas. This targets a 35.1% of households using efficient fuelwood stoves in place of the traditional 3-stone cook stoves.
8.	Elimination of Flaring of Associated Gas in the Nigerian Oil and Gas Sectors	Fugitive Emissions (Oil & Gas Sector)	CO_2, CH_4, N_2O	Ongoing	• Flaring of AG will be comprehensively reduced if not eliminated from the 2016 level of ~ 11% to close to 0%
12.	Forest Management (Afforestation and Reforestation Programmes)	AFOLU (Forestry Department)	CO_2	Ongoing	• Nigeria's Economic Transformation Agenda14, LCD option targets increasing the forest cover from 15% of total land area in 2016 to 25% by 2035, but the modelled option represents only about 1% unless deforestation is halted completely

14 Nigeria's Vision 2020 Economic Transformation Blueprint, 2010.

3.4. GHG Emissions under the LCD Scenario

With the implementation of the LCD opportunities listed in Table 3.12 and based on the LEAP simulations, it is expected that in 2035, GHG emissions will decrease from the BaU level of 966,674 Gg CO_2-eq to an LCD level of about 796,658 Gg CO_2-eq. An 18% GHG emissions reduction will be achieved when all the LCD interventions are completed.

3.4.1. Energy

3.4.1.1. Fuel Combustion activities

Implementation of the LCD options in the Fuel Combustion activities will result in a reduction of 329.8 Million TOE in the year 2035 under the LCD scenario compared to BaU. This represents a reduction of 12.6 % of the BaU scenario projected for the year 2035, attributed to the higher energy efficiency. The highest potential rests with the Residential sector with a decrease of 172.9 Million TOE over the assessment period 2016-2035. The other categories are less important contributors as depicted in Table 3.133 and 3.4.

Table 3.13 - Energy Demand in 2035 (BaU and LCD Scenarios)

Sector	BaU	LCD
	Energy Demand Million TOE	
Energy Industries	175.96	156.78
Electricity Generation	154.04	134.85
Petroleum Refining	1.17	1.17
Manufacture of Solid Fuels (Charcoal Production)	11.72	11.72
Other Energy Industries (Upstream Natural Gas Use)	9.04	9.04
Manufacturing Industries and Construction	608.21	534.62
Transport	23.14	21.41
Other Sectors	1,801.83	1,566.53
Commercial/Institutional	549.48	487.06
Residential	1,224.68	1,051.80
Agriculture/Forestry/Fishing/Fish Farms	27.67	27.67

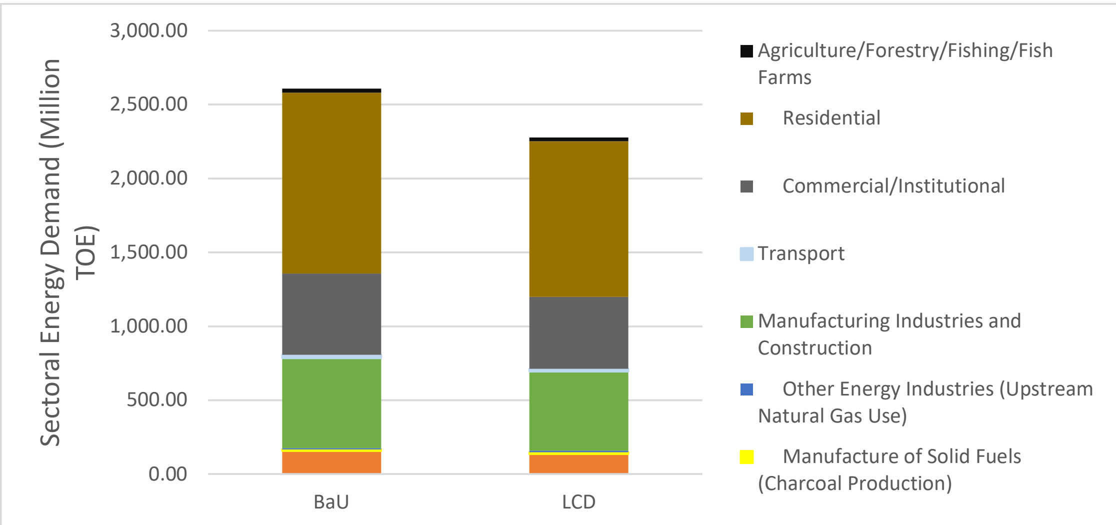


Figure 3.4 - Energy Demand for Fuel Combustion Industries in 2035 (BaU and LCD Scenarios)

Table 3.14 and Figure 3.5 present the penetration of renewable energy sources in the generation of electricity in the year 2035 for the BaU and LCD scenarios. There is a marked regression from 207,503 GWh under the BaU to 129,413 under the LCD scenario. This difference is replaced by cleaner energy sources, namely Solar, Hydro and Wind. Concurrently, Nigeria intends introducing EE measures and reduction of losses on the grid that explains the lower generation to meet the demands under the BaU scenario.

Table 3.14 - Electricity Generation (GWh) under the BaU and LCD Scenarios in 2035

Energy Type	Power Generation by 2035	
	BaU	LCD
Gas-fired plants (ST, OCGT, CCGT)	207,501.92	129,413.42
Hydro plants (LHPs % SHPs)	38,645.08	44,243.90
Solar (PV & Solar Thermal)	-	42,031.71
Wind Energy	-	5,530.49
Total	246,147.00	221,219.52

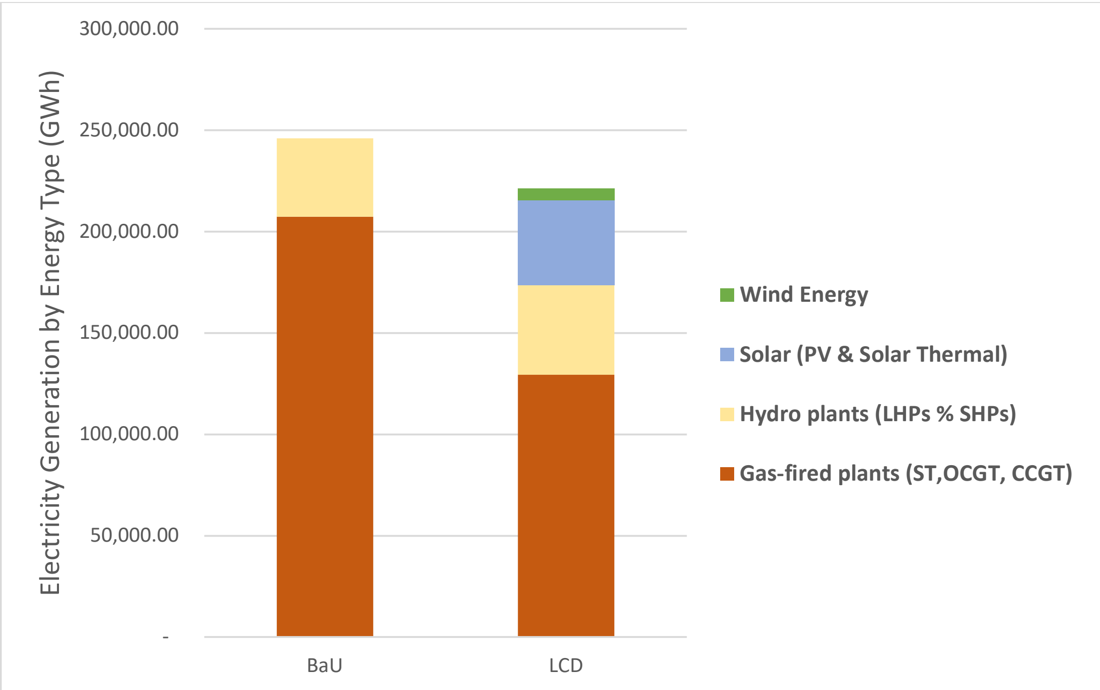


Figure 3.5 - Electricity Generation by energy type under the BaU and LCD Scenarios in 2035

3.4.1.2. Fugitive Emissions

The action will consist of eliminating flaring totally in the Oil and Gas industry by capturing all associated gases and producing LPG for use in the Nigerian economy and export. This is an important feature as it is planned to switch fuel by replacing fuelwood with this LPG which will preserve carbon stocks by preventing deforestation and forest degradation.

3.4.2. AFOLU

Deforestation and forest degradation are major problems in the country and to contain these unsustainable practices, it is imperative to slow this down through appropriate measures. The mitigation options assessed to reduce fuelwood consumption are fuel switching though the replacement of fuelwood by LPG and improving the efficiency of utilisation through the adoption of improved stoves. These have been assessed under the energy sector. Additionally, as per the policy of the country, reforestation/afforestation has been on the agenda and this will continue in the future. Without being too ambitious and taking into consideration the national context added to the difficulties of implementing successful reforestation/afforestation, it is projected to plant 150,000 ha of forest annually throughout the study period to offset the 110,000 ha estimated as being deforested annually for a net increase in area of forest by 40,000 ha annually. This will increase the carbon stocks and mitigate climate change.

3.5. Emission reduction potential of the mitigation options

The mitigation potential at national level and by sector and category is presented in Table 3.15. The potential amounts to 170, 016.5 Gg CO_2-eq in 2035, representing a decrease of 18% on the BaU scenario emissions. The highest saving is from the Land sector followed by the Energy sector. The negative value obtained for Commercial/Institutional is explained by the intervention fuel switch from fuelwood to LPG with the CO_2 accounted for under Land rather than under the energy sector as per the IPCC guidelines. Only the methane and nitrous oxide has been accounted for under the energy sector.

Table 3.15 - Mitigation potential of the interventions by sector and category in 2035

Sector and Category	Mitigation potential (Gg CO_2 eq)
National	**170,016.51**
Energy	60,002.18
Fuel Combustion	53,426.80
Energy Industries	45,248.40
Electricity Generation	45,248.40
Manufacturing Industries and Construction	405.30
Transport	4,897.90
Road Transportation	4,897.80
Other Sectors	2,875.20
Commercial/Institutional	-3,196.80
Residential	6,072.00
Fugitive Emissions (Oil & Natural Gas)	6,575.38
AFOLU	110,014.33
Land	110,014.33

3.6. Description of Action Plans for Mitigation in the Energy Sector

This LEAP model was used in the evaluation of the mitigation potential of the low carbon interventions that can be pursued in the Nigerian national economy. Despite the sparseness and low reliability of data available (nationally and from international sources), the modelling team carefully reviewed them and ensured an acceptable level of consistency. Given the non-availability of appropriate cost data on the micro-mitigation interventions covered in the assessment within the Nigerian economy during the study period, the study team decided not to include the cost implications of the GHG emissions reduction potentials in this report. A useful list of LCD opportunities that can be targeted as mitigation actions that can be potentially developed, implemented and possibly funded using national resources as projects for which Nigeria will need international assistance to develop have been identified. The list of LCD opportunities is presented in Table 3.16.

Table 3.16 - LCD Opportunities in Nigeria and their Possible sources of funding

S/N	LCD Opportunity	Comments: General and Probable Funding Type
1.	Economic Sector-Wide Energy Efficiency Improvement: - End Use Electric Energy Efficiency - End Use Non-Electric Energy Efficiency Improvement	- Will cover: residential, industrial, commercial and transportation sectors; - Energy efficiency (EE) measures are noted to be characterized worldwide by many barriers, especially in developing countries. A recent report15 characterized the EE projects in Nigeria will break even in the worst case over project lifetimes. Given the uncertainties and the usual inability to raise financing for EE projects, we conclude that EE projects will fall under the category of LCD projects for which international funding will be sought.
2.	Elimination of flaring of AG	- Although cost/tCO_2-eq of this intervention has been reported as negative in a past report, we are of opinion that the coverage of the flare reduction intervention in that report must not have been as robust compared to the findings of more recent ones. - Even with the realization of historical reluctance of upstream Nigerian Oil and Gas operators and the Nigerian Government to fund an aggressive gas flare-out program and the marginal impact of regulations to catalyse more aggressive gas flaring reduction, we conclude that the gas flare-out program should be funded jointly between the Nigerian government in joint venture with partners of the oil and gas industry.
3.	Increased Penetration of Renewable Power to Grid and Off-grid Generation	- There are indications that one or 2 renewable power projects, already approved by the Nigerian power sector regulator (NERC) has progressed in the development cycle. There are also more than 10 projects to both grid and off- grid that were recently approved through PPAs by the government bulk purchasing company (NBET) for implementation. Given these developments, we conclude that a mixed financing mode can be successfully organized for these LCD opportunities. This also includes sole private sector financing of some of these projects (grid and off-grid) as LCD projects.
4.	Displacement of stand-alone boilers with CHP in the Industrial Sector	It is assumed that these concern mostly private sector enterprises who will fund these low carbon interventions. In order to catalyse these private sector investments, we have assumed that the Federal Government of Nigeria, will introduce incentives such as tax deductions on investments in CHP; zero custom duties on CHP and allied equipment by 2020. This will incentivize the private sector to invest and hence, allow the penetration of CHP in the sector. A key policy instrument that must also be put in place will be the sale of excess power from the CHP after meeting the producer's demand for power (e.g. as embedded generation, encouraging power tariffs for the excess power that will be injected to the grid). The funding of these interventions will therefore primarily be recognized as a national funding.
5.	Displacement of light duty passenger vehicles by BRT	This will be a follow-up introduction of BRT to major cities in Nigeria, following the successful implementation in Lagos starting with Abuja. Starting from 2020, BRT will be introduced to cities such as: Abuja; Kaduna; Kano; Port Harcourt; Ibadan; etc. It is expected that the Federal Government of Nigeria will seek Bilateral Funding for this program.
6.	Displacement of traditional wood fuelled cookstoves by more efficient wood	In this LCD Scenario, starting from 2020, the Nigerian Government will introduce a program in all the zones of the country to replace traditional three stone wood fuel cooking stoves with about 5% energy efficiency, with

15 Ricardo Energy and Environment, "Intended Nationally Determined Contributions for Nigeria, Consultant's Draft submitted to the FGN, FMEnv by Ricardo Energy and Environment, September 14, 2015.

S/N	LCD Opportunity	Comments: General and Probable Funding Type
	cookstoves in rural and peri-urban households	more efficient designs that are now available internationally, including SAVE 40 design that was introduced in N. Nigeria through a CDM project initiative. It is envisaged that this program, which must adopt learning curves from similar ongoing and past programs, will be introduced in Nigeria in 2020 and allowed to gradually penetrate through the study period. This is an initiative that can attract international bilateral and multilateral funding, which must be supported by some seed funds from the Federal Government of Nigeria.
7.	Shift from use of fuelwood, charcoal and biomass stoves in the urban areas to LPG stoves	The Federal Government of Nigeria is aggressively pursuing the program to increase the domestic utilization of its natural gas resources through the LPG route. Towards this end all oil and gas companies in Nigeria must provide its plan for domestic utilization of natural gas as part of its renewal of operating license. A key component of this program is the need to have in place an LPG domestic utilization program before the export of LPG produced from Natural gas and in domestic refineries can be exported (e.g. LPG produced from gas processing plants and LNG plants in the country). We have assumed in this study that the penetration of LPG in urban and semi-urban households still burning fuelwood as cooking fuels will be targeted for this substitution with LPG. This program, which will cover: increased domestic production of LPG; introduction of comprehensive LPG cylinder availability and quality assurance and control; and incentives to shift, will be introduces as from the year 2020 and gradually expanded throughout the study period. Funding for this program will come partly from the Federal Government of Nigeria and from international bilateral and multilateral funding cooperation.
8.	Afforestation and Reforestation Program	This target will be achieved through efforts by the Forestry Department Federal Ministry of Environment, Nigeria's Great Green Wall Programme, National Forest Policy, strengthening the implementation of the Nigeria's Community-Based Natural Resource Management Programme (CBNRMP), and Nigeria's REDD+ Programme. Some financial sources identified for this LCD opportunity include, the FGN and FCPF/WB

3.7. Implemented and / or Firmly Planned Low Carbon Activities in Nigeria including CDM Projects and Program of Activities

The Federal government has taken measures to mitigate the GHG emissions from its various sectors with heavy emphasis on the energy sector. These mitigation activities include government initiatives as well as intergovernmental initiatives such as the Clean Development Mechanism (CDM) projects and Programme of Activities projects in the country.

The Clean Development mechanism is a cooperative mechanism established under the Kyoto Protocol. Under this mechanism, industrialized countries can implement emission reduction projects in developing countries and receive credit for emission reductions that can count towards their national reduction targets16. Eligible projects include end-use energy efficiency improvements, fuel switching, industrial processes, etc.

16 UNEP. Introduction to the Clean Development Mechanism

Programme of Activities (POA) is a framework which defines how a policy/measure leads to GHG emission removal that are additional to a CDM (Silva Vintura, 2013). It consists of individual component project activities which are unrestricted that can be implemented in multiple locations.

The detailed list of CDMs and PoAs are available in the First Biennial Update Report (https://unfccc.int/documents/66114).

3.8. Financing Climate Change Mitigation

Nigeria has taken measures to identify various financing channels for the climate change mitigation opportunities modelled in LEAP in line with government policies. In its preparation of its Market Readiness for NAMA, various options including multilateral, bilateral and funding from the private sector were identified as financing options. Some of the sources of climate funding with whom Nigeria has worked or is working with as well as new potential partners are provided below.

3.8.1. Multilateral Climate Finance Funds

- The Green Climate Fund (GCF)
- The Emerging Africa Infrastructure Fund (EAIF)
- Adaptation Fund established under the Kyoto Protocol
- The ASAP, a multi-donor grant co-financing program, launched by the International Fund for Agriculture and Development (IFAD);
- The Clean Technology Fund (CTF) is one of four key programs under the Climate Investment Funds (CIFs)
- The Forest Carbon Partnership Facility (FCPF) operating under the World Bank Programme
- The Global Climate Change Alliance + (GCCA+) established by the European Union (EU)
- The Global Energy Efficiency and Renewable Energy Fund (GEEREF), a Public-Private Partnership (PPP) designed to maximize the private finance leveraged through public funds, funded by the European Commission and managed by the European Investment Bank.

3.8.2. Bilateral Climate Finance Funds

- The Global Climate Partnership Fund (GCPF), a public-private partnership investment fund based in Luxembourg
- The International Climate Fund (ICF) operational under the UK government
- Norway's International Climate and Forest Initiative (NICFI)
- The International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)
- The NAMA Facility of the UK Department of Energy and Climate Change (DECC) and the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

3.8.3. Private Climate Finance Funds

- Ariya Capital Sub-Saharan Africa Cleantech Fund (ARIYA)
- Emerging Africa Infrastructure Fund (EAIF), a Public Private Partnership of the Private Infrastructure Development Group (PIDG)
- Energy Access Ventures (EAV); a partnership including Schneider Electric, the European Investment Bank (EIB), the UK government-owned development finance institution – the CDC Group, Investment and Support Fund for Businesses in Africa (FISEA), the OPEC Fund for International Development (OFID), and the French Facility for Global Environment (FFEM)

3.9. Mitigation projects areas

- Reinforce, expand and implement programmes to build and maintain wastewater and solid waste management facilities.
- Encourage States to pilot the "Cool Communities" programme by building on and expanding tree planting activities, promoting appropriate architecture for cool housing and workspaces and promoting designs to reduce heat island effect in urban areas.
- Implement a programme of revitalization of green spaces and shade. The programme could also include providing financial incentives for trees and shade on private property.
- Integrate climate change concerns into implementation of the current energy master plan, including climate change impacts on future energy demands caused by excessive heat.
- Develop policies that promote development/use of decentralized renewable energy resources.
- Update standards for construction and maintenance of energy infrastructure to include an additional protective margin for the expected risks associated with climate change.
- Develop and promote renewable energy for rural uses to reduce pressure on forests and watersheds by encouraging use of more energy efficient wood stoves and solar cookers in rural areas, offering financial co-benefits through the Clean Development Mechanism programme.

4. Vulnerability and Adaptation

4.1. Introduction and General Overview

Weather is the changes we see and feel daily while climate change is the changes in weather on a longer term. Climate varies with seasons. Climate change occurs when long-term weather patterns are altered. For example, a region in the country that is known to have over 200 rainy days in a year, may experience a higher number of dry days, with associated droughts instead. Such alterations of the normal climate may be due to natural occurrences (e.g. changes in earth distance from the sun, changes in ocean, volcanic eruptions etc.). It is, however, now scientifically established that such alterations may also be the result of human activities (anthropogenic), which is causing the earth's atmosphere to warm more quickly than usual.

4.2. General Overview of Vulnerability and Approach for Adaptation

Nigeria is no exception to the global fact that climate change is on and will stay for a substantial period. A study, carried out by Akpodiogagaa (2010), presented a general overview of climate change in Nigeria. Mean annual and monthly temperatures and rainfall data were collected from the Nigerian Meteorological Agency and some States' airports for a period of 105 years (1901-2005). The analysis showed that temperature increased by 1.1 °C over these 105 years while rainfall decreased by 81 mm. Desert encroachment, coastal inundations, drying up of surface water bodies and a shift in crops cultivated over time were also noticed. The declining rainfall worsened as from the early 1970s, and this pattern has continued to-date. The period of drastic rainfall decline corresponds with that of sharp temperature rise. Odjugo (2005, 2007) observed that the number of rain days dropped by 53% in north-eastern Nigeria and by 14% in the Niger-Delta coastal areas. These studies also showed that, while the areas experiencing double rainfall maxima are shifting southward, the short dry season (August break) is being experienced earlier in July as opposed to its normal occurrence in August prior to the 1970s. These major disruptions in climatic patterns in Nigeria are supporting evidences of a changing climate.

The latest projections detailed in this chapter forecast increases in temperature within the range 1.48°C to 3.48°C coupled with an increase of 9 to 45.8% in annual rainfall. It is also expected that climate extremes such as floods and droughts will increase in frequency and severity. These events along with the projected changes will exacerbate the already fragile balances of socio-economic sectors such as Agriculture, Water Resources and Energy as well as natural ecosystems, namely Forests and Wetlands. Thus, climate change, which is presently a major environmental challenge will remain so in the short and medium term with potential serious impacts staying even in the longer term. The main reason for this is that there is hardly any sector of the country's economy that is not vulnerable to its impacts. These include among others, rising sea levels, increased frequencies of extreme events, higher temperatures, changes in the onset and retreat of the rainy seasons. These disturbances will affect the whole population and their welfare with the highest impacts anticipated to be borne by the economically more vulnerable groups as well as women.

In this chapter, we present a discussion of how human societies, with emphasis on Nigeria, will have to effectively devise ways and means to adapt to climate variability and change by altering their lifestyles, agricultural practices, settlement arrangements and other critical aspects of their economies and livelihoods. It is now an increasingly globally accepted norm that climate change is principally a major problem caused by human activities, leading to several direct and indirect impacts. These climatic changes have resulted in a wide-range of impacts including increase in heat-related mortality, dehydration, spread of infectious diseases, malnutrition, damage to public infrastructure, migration of both man and animals among others.

Nigeria like other countries of the world has witnessed negative climate change impacts such as:

(a) The gradual drying up of Lake Chad that started about 25 years ago. Lake Chad sited in the north-eastern region of the country with the Southern part of it in Nigeria and spanning areas of Borno and Yobe states has virtually dried up in the latter regions. It is worth noting that Lake Chad which four decades ago covered an area of over 40,000 km^2, has presently been reduced to a mere 1,300 km^2.

(b) The rapid encroachment by the Sahara Desert that has been observed over the last few decades has also been attributed as arising out of the negative impact of climate change, especially the rising temperature (M. Idris, 2011). As a result of observed desert encroachment in this area of Nigeria, farmlands became barren and surrounding villages were deserted by inhabitants who had to escape the advancing desertification and migrate to other regions, namely from the northeast part towards the greener plateau and middle belt regions (M. Idris, 2011), in search of more fertile land.

(c) Growing desertification forced thousands of Fulani herdsmen to move to the south and middle belt leading to clashes with crop farmers. This culminated in the death of hundreds according to reports of residents and activists. Nigeria's Guinea Savannah region has not been spared either. Logging, resulting from the dependence on firewood for cooking, has stripped a greater part of this area of its vegetation cover (M. Idris, 2011).

(d) The situation is similar in the south where the forest around Oyo has long been converted to grassland (M. Idris, 2011).

(e) The south eastern part of the country has been struck by a different ill. Here, gulley-erosion has devastated many settlement areas and farmlands, leading to poverty among local populations (M. Idris, 2011).

(f) Just as desertification is devastating vast areas of the north, rising sea levels are threatening Nigeria's coastal regions. Although a source of oil wealth, the Niger Delta's low-lying terrain and various interconnected waterways make it extremely vulnerable to flooding.

(g) Other disastrous consequences of climate change are being witnessed in the country, especially in the southern regions. These take the form of massive floods for example, such as the one experienced in 2012 which claimed the lives of 363 people, displaced more that 1.2 million others and affected 30 out of the 36 states of the country. The country was again affected by floods in 2015 (53 deaths, 100,000 displaced) and 2016 (38 deaths, 92,000 displaced).

Nigeria has been experiencing adverse climatic conditions with negative impacts on the welfare of millions of people. It has been observed that persistent droughts and flooding, exacerbated by off season rains and dry spells, have sent the traditional predictive approach of the metrics of growing seasons out of orbit. This is very serious for a country dependent on rainfed agriculture for food security. The result is reduced water availability to service agricultural needs, hydro power generation and other uses. Climate change has been fingered in many scientific publications as the main cause of all these (M. Idris, 2011). According to the same author, most of the countries in Africa, including Nigeria, will be worst hit by the effects of climate change.

The dominant role of agriculture in the economy of African countries, including Nigeria, makes it obvious that climate change and variability can cause devastating socio-economic consequences in such countries. Policies to curb climate change by reducing the consumption of fossil fuels like oil, gas or coal can have significant economic impacts on the producers and suppliers of these fuels. Climate change impacts are starting to be taken seriously in Nigeria as a real problem that must be frontally tackled. The notable increasing incidences of certain diseases in the country, the declining agricultural productivity, and the more frequent heat waves in many parts of the country have been attributed to the effects of climate change. There is glaring evidence that climate change is not only happening, but also changing our lives. People in the coastal areas who used to depend on fishing have seen their livelihoods negatively impacted by the rising sea level.

The current global estimate of sea level rise is 0.2 m and it is projected to increase to 1 m by the year 2100 (Hengeveld et al., 2002; Hengeveld et al., 2005). This implies that the inundated area of 3,400 km^2 in the coastal regions of Nigeria with the present 0.2 m sea level rise will increase and attain 18,400 km^2 under the projected 1 m scenario (NEST, 2003). Coastal settlements like Bonny, Forcados, Lagos, Port Harcourt, Warri and Calabar that are less than 10 m above sea level will be seriously threatened by a 1 m sea level rise. Additionally, the country's coastal zone and low-lying islands in the Gulf of Guinea are vulnerable to sea level rise. An estimated 27 to 53 million people in the country may need to be relocated with a 0.5 m increase in sea level. Nigeria's coastal and marine areas are also home to the country's economically important petroleum and fisheries industries.

Vulnerability to climate change has been defined as the degree to which a system (natural or human) is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001). Africa is very vulnerable to short-term climatic variability principally, because it has a weak financial base with which to cope with these changes (World Bank, 1998).

Nigeria is prone to a variety of climate-induced hazards, including floods, storms, ocean surges, droughts, pest plagues, air and water pollution, and wildfires which have caused extensive losses to livelihoods and property, compromised development, and claimed many lives (BNRCC, 2011). Changes in climate may increase the frequency and intensity of extreme events in Nigeria. Vulnerabilities vary broadly across the country. Most vulnerable is the north-eastern region followed by the north-west while the south-west is the least vulnerable followed by the south-east (Adesina and Odekunle, 2011). This implies that effective adaptation needs are very variable and not the same across the country. Thus, detailed analyses by region, based on the critical key parameters are needed in order to adequately respond to the specific regional adaptation needs (Adesina and Odekunle, 2011). In the north-east, the issue of water stress is most determinant. The development of two major earth dams - Tiga and Challawa along the Komodogu-Yobe basin in the last two decades or so have been a challenge. The erstwhile invaluable ecological system of the Nguru-Hadejia, the wetlands, which had attracted the International Union for Conservation of Nature (IUCN), have been impaired by the reduced flow of water into it (Dami, 2008).

Changes in climate may alter Nigeria's major ecological zones. Agricultural ecosystems, freshwater and coastal resources, forests, and biodiversity are all susceptible to the impacts of climate change. Impacts include increases in soil erosion, flooding, desertification, and salt-water intrusion. Furthermore, Nigeria's transportation infrastructure, which is inadequate for current needs, will be further degraded by extreme weather, negatively impacting industry and commerce while putting greater stress on the economy.

The lack of explicit integration of livelihood adaptation to climate change and of the broader development issues, which are most evident in the Nigerian system and in Africa in general, are drawing national and global attention. This concern prompted the Nigerian National Assembly to pass a bill to create a National Climate Change Commission in 2010. The core responsibility of the commission is to facilitate coordination and support for the multi-level and cross-sectoral adaptation responses. Although measures are being taken globally to reduce greenhouse gas emissions, which will probably reduce the rate and magnitude of climate change, it is unlikely that the reduction of emissions will be at the required pace to stabilize climate. Therefore, adaptation will be necessary (IPCC, 1990).

Having realized the need to adapt to their changing environment, Nigerians are already adapting to climate change in various ways. However, due to the urgency of the threat and because of the power of inertia, which makes people slow and reluctant to change, Nigeria cannot afford to solely depend on individuals and communities to take these steps on their own, as and when they deem fit. Rather, the country needs a regime of guided change with full government support. This can only be achieved through a strong and visionary national leadership. That is why developing an enhanced leadership is a vital aspect of climate change adaptation in the country. This leadership must be provided by public sector entities at the Federal, State and Local Governments' level through their institutions; the organized private sector; and civil society organizations (CSOs), including non-governmental and community-based organizations.

4.3. Historical climate and projections

4.3.1. Methodology for Constructing Climate Change Scenarios

The multi-model ensembles dynamic downscaling analysis method using 11 Global Circulation Models (GCMs) presented in Table 4.1 has been used in developing future climate change scenarios for Nigeria. All the 11 models applied in this analysis are the 5th Phase GCM models of the Coupled Model Inter-comparison Project (CMIP5) models used in the development of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The GCM output data used in the analysis have been developed by WorldClim (Hijmans et al., 2005*),* which include baseline and projected temperature and precipitation data sets.

Table 4.1 - Ensemble Global Circulation Models Used to Generate Climate Change Scenarios

No.	GCM Model	Description/Institution
1.	BCC CSM1.1	Beijing Climate Centre Climate System Model, China
2.	CCSM4	The Community Climate System Model (CCSM) of the University Corporation for Atmospheric Research, USA
3.	GISS-E2-R	NASA Goddard Institute for Space Sciences (GISS) coupled general circulation model (CGCM), USA
4.	HadGEM2-AO	Hadley Global Environment Model 2 - Atmosphere (Met Office Hadley Centre climate prediction model), UK
5.	HadGEM2-CC	Hadley Global Environment Model 2 - Carbon Cycle (Met Office Hadley Centre climate prediction model), UK
6.	HadGEM2-ES	Hadley Global Environment Model 2 - Earth System (Met Office Hadley Centre climate prediction model), UK
7.	INMCM4	Russian Institute for Numerical Mathematics Climate Model Version 4, Russia.
8.	IPSL-CM5A- LR	Institute Pierre Simon Laplace (IPSL)'s Earth System Model, France.
9.	MPI-ESM-LR	Max Planck Institute for Meteorology, Germany.
10.	MRI-CGCM3	Meteorological Research Institute-Earth System Model Version 3, Japan.
11.	NorESM1-M	The Norwegian Earth System Model, Norway

The WorldClim global dataset is produced from the processed observation of a global network of stations. In the case of Nigeria, the spatial dataset is produced, based on the national meteorological stations, which are then interpolated at different grid-resolutions at national level. WorldClim has four types of downscaled spatial resolutions (expressed as minutes or seconds of a degree of longitude and latitude) such as 10 minutes, 5 minutes, 2.5 minutes and 30 seconds, the latter being the highest spatial resolution. The data used for this analysis is the downscaled IPPC5 (CMIP5) data at 30 seconds (~1 km resolution) spatial resolution. The downscaling assumes that the change in climate is relatively stable over space with high spatial autocorrelation. The data used in the analysis constitutes the baseline for the years 1960-1990 and projections for the 2050 (average for 2041-2060) and 2070 (average for 2061-2080) time horizons. As the GCMs do not accurately predict the current climate in all places, calibration of the models has been performed on observed data. The dynamic downscaling of precipitation and temperature data used in this study is for a grid resolution of 50 km, which when mapped over the country, constitutes a total of 38 grid points, which are adopted from the global climate simulations produced at the *National Center for Atmospheric Research* (NCAR) by the Community Climate System Model (CCSM4) for the AR5.

The emissions scenarios considered in the analysis is the third generation Representative Concentration Pathways (RCP) used in AR5 (Moss, R. et al., 2011). The two RCPs adopted for the analysis are RCP8.5 (high emissions scenario) and RCP4.5 (intermediate/medium emissions scenario).

4.3.2. Validation of Climate Model Performance

The model performance was validated by comparing the locally derived observed baseline climate (Figure 4.1a) with the modelled historical baseline climate (Figure 4.1b) derived from the global data set of WolrdClim. As shown in the figures, the modelled data surprisingly simulated well the observed climate both in pattern and magnitude. Moreover, the observed spatial baseline (1961-1990) mean monthly precipitation and spatial baseline (1960-1990) mean annual rainfall derived from the global data set (WorldClim) of the *ensemble* data output are highly correlated with a coefficient of 99.68% (Figure 4.2).

The locally derived observed baseline mean annual rainfall and the model spatial baseline mean annual rainfalls of Nigeria share the following common characteristics:

- Mean annual rainfall generally decreases from south to north.
- The high mean annual precipitation at the central part of Nigeria with a circular shape is perfectly simulated.
- The lowest rainfall is observed in the north-eastern part of Nigeria.
- The highest precipitation is observed in the southern part of Nigeria; and
- The amount of rainfall in both cases is highly correlated (99.68%) in which the historical observed data are less than 10% the simulated precipitation.

(a) Historical Observed **(b) Historical Surrface Precipitation Simulated**

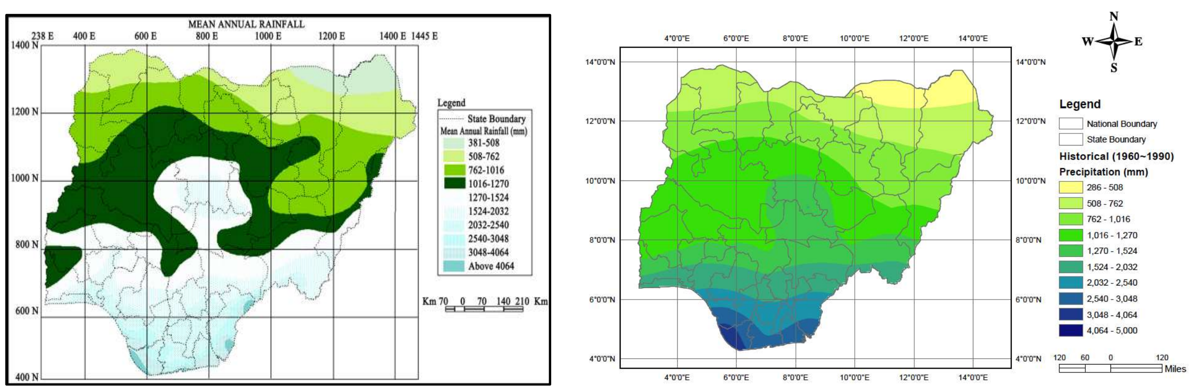


Figure 4.1 - Historical Observed Mean Annual Precipitation for the period 1960-1990 (a) and Modelled Spatial Baseline Mean Annual Precipitation (1961-1990) developed from the Global Data Set of WorldClim (b)

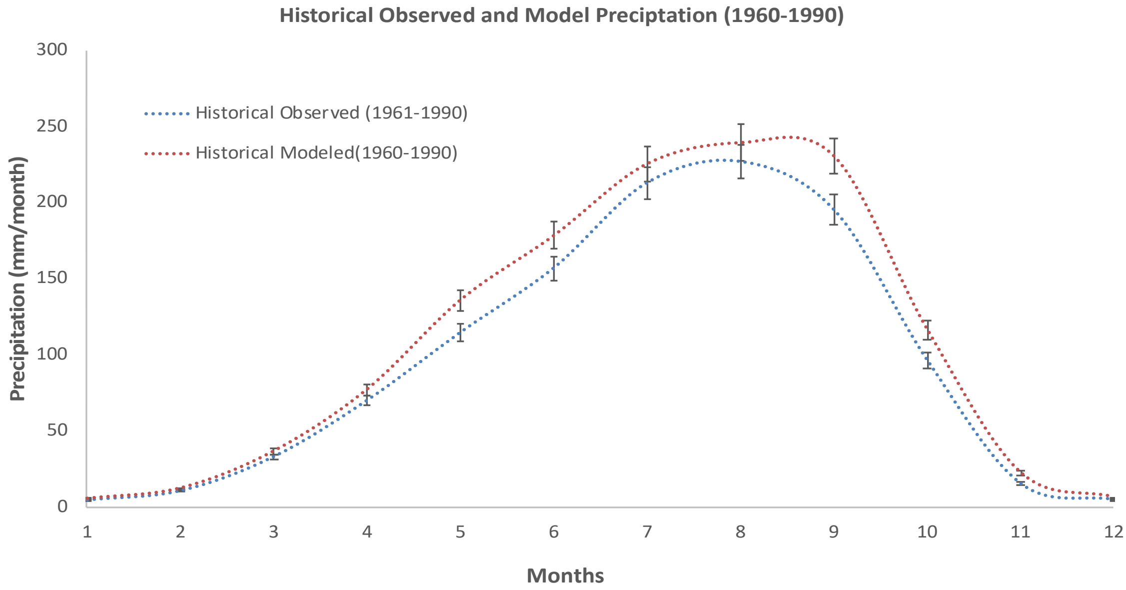


Figure 4.2 - Historical Observed Spatial Baseline (1961-1990) Mean Monthly Rainfall and Spatial Baseline (1960-1990) Mean Monthly Rainfall Derived from Global WorldClim Data Set

Similar to the performance of observed and modelled historical mean monthly rainfall data (Figure 4.2, the performance of observed and modelled historical mean monthly temperatures is shown in Figure 4.3. The results of the correlation analysis show that the historical and global (WorldClim) data sets of the *ensemble mean* annual temperature outputs are highly correlated with a coefficient of about 70%.

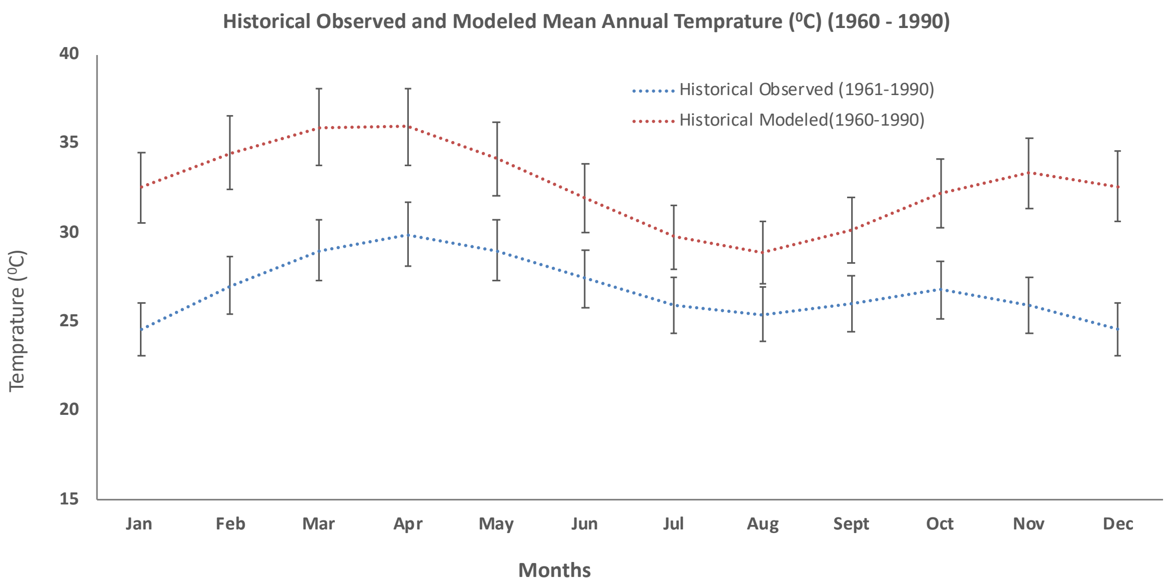


Figure 4.3 - Historical observed spatial baseline (1961-1990) mean monthly temperature and spatial baseline (1960 – 1990) mean monthly temperature derived from Global WorldClim

Unlike precipitation, temperature does not have a spatial pattern. Though there is no spatial historical mean annual temperature, the locally derived observed baseline mean annual temperature (World Bank Climate Knowledge Portal) and the modelled spatial baseline mean annual temperature (WorldClim) of Nigeria share the following common characteristics:

- Mean annual temperature generally increase from south to north.
- North-western and north eastern parts of Nigeria have the highest temperature records, and
- The historical modelled and observed data are well correlated at about 70%.

The observed and modelled historical precipitation and temperature performance indicate that the use of future projections using the GCM models is acceptable to undertake vulnerability and adaptation analysis in the future. As a result, future climate projections have been conducted to determine Nigeria's future temperature and precipitation. Though this study does not cover vulnerability analysis for each sector based on future projections, the outcome of these projections could be used for any vulnerability and adaptation analysis, whenever deemed.

4.4. Mean Precipitation Projections

The spatial mean annual precipitation of the baseline (1960-1990) and for time horizons of 2050 (mean 2041-2060) and 2070 (mean 2061-2080) for the emission scenarios RCP4.5 and RCP8.5, are shown in Figure 4.4. Both RCP 4.5 and RCP8.5 predict that there is likely to be a variable increase in precipitation up to the year 2070 in all parts of Nigeria. The likely annual increase in precipitation is given in Figure 4.5 for the agro-ecological zones depicted in Figure 1.9.The Sahel savannah is projected to have the highest increase of around 30% under both RCPs for the 2050 time step followed by the Sudan savanna with about 10% while the remaining zones are at less than 5%. The projections follow the same trend for the 2070 time horizon, with higher increases under RCP8.5 and even a 45% peak for the Sahel savanna.

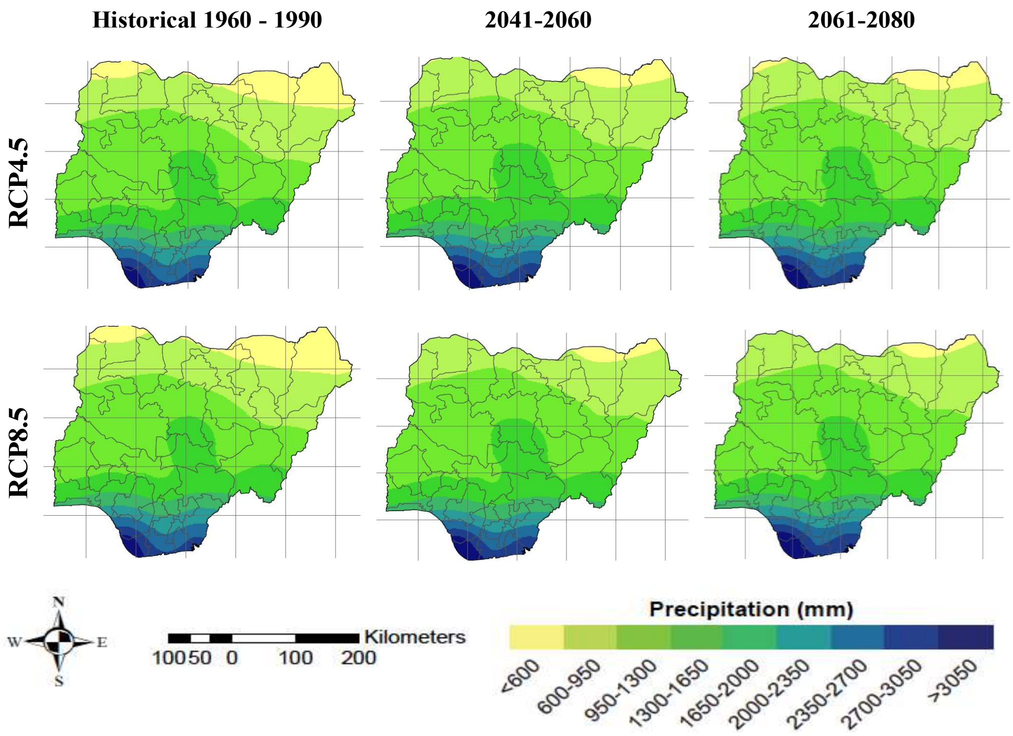
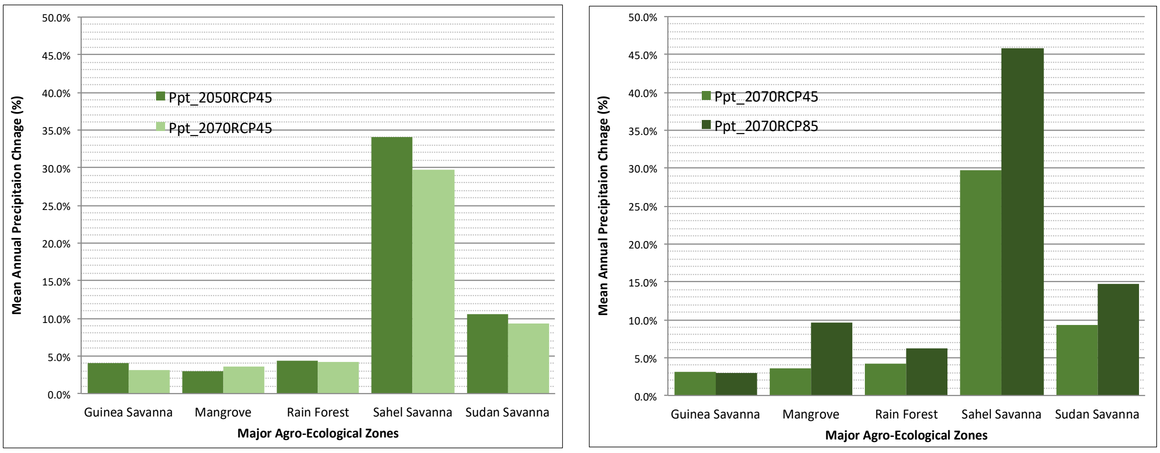


Figure 4.4 - Historical (1960-1990) and projected mean annual precipitation (mm) over Nigeria for 2050 and 2070 time horizons for RCP 4.5 and 8.5

As shown in Figure 4.4, in terms of an aggregated mean annual precipitation, the southern part of the country is expected to have a bigger area that could get more than 3000 mm/year. On the other hand, the northern part of Nigeria, the Sahel and Sudan savannas could experience an increase of 29% to 45.8%

and 9% to 14.2%, respectively. Though the Sahel savanna could experience the highest percentage increase, this could be insignificant when considering the annual mean precipitation, which ranges from 286 mm/year to about 400 mm/year maximum historically over this zone.



(a) RCP4.5 (b) RCP8.5

Figure 4.5 - Mean Annual Precipitation Change Compared to Historical Mean Annual Precipitation By Agro-Ecological Zones at RCP4.5 and RCP8.5

4.5. Mean Temperature Projections

The spatial mean temperature increases for time steps 2050 and 2070 for both emission scenarios RCP4.5 and RCP8.5 compared to the baseline (1960-1990) are shown in Figure 4.6. Under the RCP4.5 for 2050 and 2070, the temperature increase could range from a low of 1.48°C to 1.78°C to a high of 3.08°C to 3.48°C compared to the baseline (Table 4.2). On average, the temperature increase is projected to vary between 1.95 to 2.31°C under the RCP4.5 scenario increasing to the range 3.15 to 3.54°C for the RCP8.5 one across the country. The lower increase in the southern part of the country gains in magnitude northward. Under the RCP8.5 scenario for 2050 and 2070, the low range temperature increase is from +2.41°C to +2.68°C and the highest ranges from +4.25°C to +4.63°C compared to the baseline. Under RCP8.5 almost all parts of Nigeria could experience an increase of a minimum of 2°C and a maximum of 4°C or higher, with the highest increase being felt in the northern parts of the country.

Table 4.2 - Annual temperature changes for time series of 2050 and 2070 at RCP 4.5 and RCP8.5 compared to the historical baseline of 1960-1990.

Annual Temperature Change	Projected Temperature Increase Compared to 1960-1990			
	RCP 4.5		RCP 8.5	
	2050	2070	2050	2070
Low Temperature Change	+1.48	+1.78	+2.41	+2.68
Average Temperature Change	+1.95	+2.31	+3.15	+3.54
High Temperature Change	+3.08	+3.48	+4.25	+4.63

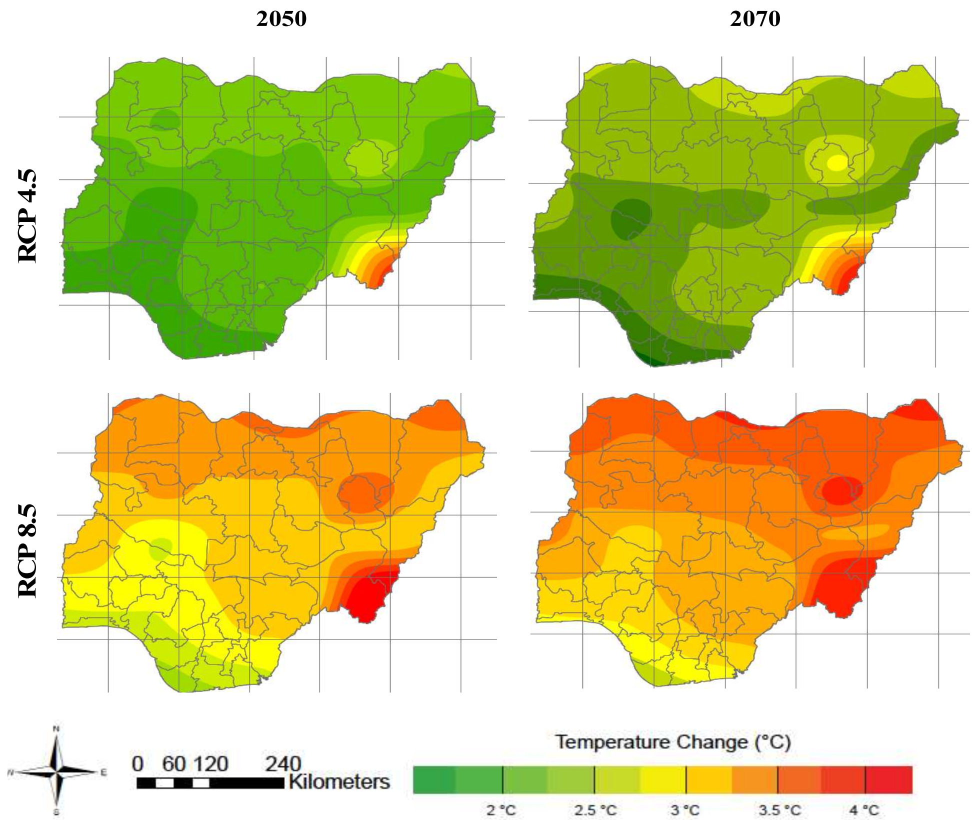


Figure 4.6 - Mean annual temperature changes for time series of 2050 and 2070 at RCP4.5 and RCP8.5 compared to the historical baseline of 1960-1990.

4.6. Uncertainty

The interpolated climate change surface temperatures and precipitation used in the analyses contain some level of uncertainty mainly due to geographic variations. Hijmans et al. (2005) quantified uncertainty arising from the input data and the interpolation by mapping weather station density, elevation bias in the weather stations, and elevation variation within grid cells and through data partitioning and cross validation. WorldClim have used two-degrees grid cells in order to have many stations in most cells so that the results could become regionally coherent and not dominated by outliers. As a result, compared to previous global climatology, the WorldClim climate data has the following advantages:

- The data are at a higher spatial resolution (400 times greater or more).
- More weather stations records were used.
- Improved elevation data were used; and
- More information about spatial patterns of uncertainty in the data is available.

However, it should be noted that the overall low density of available weather stations, especially in Nigeria, does not capture all variations that may occur at a resolution of 1 km, notably in mountainous areas. Thus, for in-depth future sectoral vulnerability and adaptation studies, these gaps and other shortcomings need to be addressed.

In the context of the Coupled Model Inter-comparison Project (CMIP) such as CMIP3 (Meehl et al., 2007) and CMIP5 (Taylor et al., 2012) within IPCC's World Climate Research Programme (WCRP) for standard experimental protocol for studying the output of coupled atmosphere-ocean GCMs, climate variability in

West Africa has been extensively studied. Though progress is promising, the results are not yet satisfactory (Sultan and Gaetani, 2016). Both CMIP exercises show low confidence in the simulation of the observed West Africa Monsoon (WAM), variability (amplitude, phases, and trends), and thus sizeable uncertainties affect projections in the twenty-first century, the example being a shift from dry to wet conditions in the Sahel (Biasutti, 2013). Although coupled models generally well reproduce the relationship between the regional atmospheric circulation and the monsoonal precipitation during both the twentieth and the twenty-first centuries, the same models show discrepancies in future projections (Biasutti et al., 2009). Thus, climate change studies, especially in the northern part of Nigeria, should incorporate future projections of the West African climate that includes monsoonal precipitation.

4.7. Climate Change Impact Assessment on Agriculture

4.7.1. Overview

The Nigerian agricultural activities are rain-fed, thus making it highly susceptible to climate variability and change. About 70% of Nigeria's population are engaged directly and indirectly in various agricultural activities, namely crop production, livestock rearing and fisheries. The five major crops considered as the priority staple food commodities under the Nigeria's Agriculture Transformation Agenda (ATA) include cassava, maize, millet, sorghum, rice, and sorghum. The climate vulnerability assessment focuses on these crops and is based on several studies.

In recent years, several studies have been conducted on climate change impacts on Agriculture in West Africa in general and Nigeria in particular. These studies have used various crop models and assessed the impact of climate change on yields of numerous crops. In this report, we are providing climate change impacts on crop yield, based on the most recent developments and studies. The case study conducted by the World Bank (Cervigni et al. 2013) is considered quite extensively in this assessment.

4.7.2. Crop Modelling for Crop Yield Analysis

As indicated in Table 4.3, several studies have used different crop modelling approaches and the response of the crop to climate change is subject to uncertainties that can arise from several sources (Challinor et al., 2009). Using the climate projections derived from the Global Circulation Models (GCMs) such as the coupled model atmosphere-ocean-sea-ice based on the climate model (CMCC-MED), Geophysical Fluid Dynamics Laboratory (GFDL), Institute of Atmospheric Physics (IAP), Model for Interdisciplinary Research on Climate (MIROC), and National Center for Atmospheric Research (NCAR), the World Bank has determined climate change impacts on agriculture for the 30-years climatic periods centred on 2020 (2006-35) and 2050 (2036-65). The baseline period is 1976 - 2005 (centred on 1990). The researchers have run the crop models at a reference atmospheric concentration of CO_2 (380 ppm) and future projected increases in CO_2 atmospheric concentration, from 380 to 582 ppm under the A1B scenario, to determine how the crop yield varies under different scenarios. Although the model calibration/validation is made for only a few Nigerian states, the climate impact is assessed for all Nigerian areas where each crop is grown whenever the higher resolution of the RCM makes this possible.

Table 4.3 - Crop models used for climate impact analysis of crop yield in West Africa and Nigeria

Crop model	Area	Crop	References
Empirical	Nigeria	18 food crops and maize, sorghum, cotton, rice, and cassava	Ajetomobi et al., 2015
GLAM	Nigeria	Maize, rice, cowpea, and groundnut	Matthew et al. 2015
DSSAT-CSM	Nigeria	Cassava, maize, millet, rice, sorghum	Cervigni et al. 2013

Crop model	Area	Crop	References
EPIC	Nigeria	Cassava, maize, millet, rice, sorghum	Adejuwon, 2006
CERES – maize	West Africa	Maize	Jones and Thornton, 2003
CERES – maize	West Africa	Maize	Jones and Thornton, 2003
CERES – maize + Empirical	Niger, Nigeria, Mali, Guinea, Ivory	CERES – maize + Empirical	Niger, Nigeria, Mali, Guinea, Ivory
Empirical	West Africa	Cassava, groundnut, maize, millet, rice, sorghum, wheat, yams	Empirical
LPJmL	West Africa	Global	Müller et al., 2010
Empirical + BLS	West Africa	Global	Parry et al., 2004
Empirical	West Africa	Cassava, groundnut, maize, millet, sorghum	Schlenker and Lobell, 2010
SARRA-H + APSIM	West Africa	Sorghum (two cultivars)	Sultan et al., 2014
ORCHIDEE	West Africa	C4 crop	Berg et al., 2013
GLAM	West Africa	Groundnut	Parkes et al., 2015

4.7.3. Crop Yield Analysis

Predicting the potential impacts of climate change on crop yields requires simulating how various crops respond to future climate conditions such as warmer temperatures, more frequent extreme temperatures, possible changes in rainfall patterns and amounts, and seasonal spatial and temporal distributions. Ajetomobi et al. (2015) examined the effects of climate change on 18 food crops in Nigeria, including the five major crops that constitute priority staple food commodities under the nation's ATA action plan. The results indicate a clear level of variation in crops' production and risk response to extreme weather across states. While an increase in total annual rainfall could have a beneficial effect on the productivity of cassava and ginger, the productivity of yam, maize, tomato, and melon is threatened by an increase in total annual rainfall.

On the other hand, extreme temperatures have a negative association with cassava and sweet potato yields (Ajetomobi et al., 2015). This is consistent with several other studies (Lobell et al. 2008 and Lobell and Burke 2010), which indicated that temperature change is likely to be the major driver of yield shocks, rather than precipitation. Thus, while rainfall variability could explain the year-to-year yield variation, there is widespread appreciation of the fact that a strong signal of temperature increase above the historical range, consistent across climate models, is likely to be the main driver of yield change, particularly when indications relating to precipitation change are less clear. Thus, agricultural productivity could also drop when above normal hot days are experienced, even under irrigated conditions (Hawkins, 2012).

Extreme temperatures increase the risk of crop failure in onion and okra, two major vegetable crops. While the effect on yield will vary according to region and crop, it is expected that climate change will very likely affect agricultural production. The results of the analysis indicate that the productivity of more than half of Nigeria's staple crops is threatened by an increase in total annual rainfall (Ajetomobi et al., 2015). While extreme temperature showed positive association for crops predominantly grown in northern Nigeria such as millet, onion, and melon, extreme temperatures have a negative association with about two-thirds of Nigeria's staple crops. The state-level analysis shows that extreme temperatures are an important limiting factor for crop grown in more than 25% of the states of Nigeria, the worst affected states located in the North. The results further show that increased temperatures affect not only the mean yield, but also increases the risk for crop failures in several states with the most affected crop being maize. The results of the ensemble model for the mean annual temperature change for the time horizons 2050 and 2070 at RCP 4.5 and RCP8.5 compared to the baseline 1960-1990 indicate an increase in this parameter everywhere in the country (Figure 4.6).

Climate impact on agriculture varies considerably by agro-ecological subzone (AESZ) and crop type. The World Bank study (Cervigni et al. 2013) indicated that in 2020 (Figure 4.7), negative median values are predicted for all crops and in the longer term (2050) (Figure 4.8), lower yields are predicted. The outlook for yam, millet and cassava is uncertain, particularly in 2020, when the median from the climate models indicates the possibility of mild yield increases (3–6% or less). In 2050, the consensus of models is clearer, with 70% pointing to lower yields.

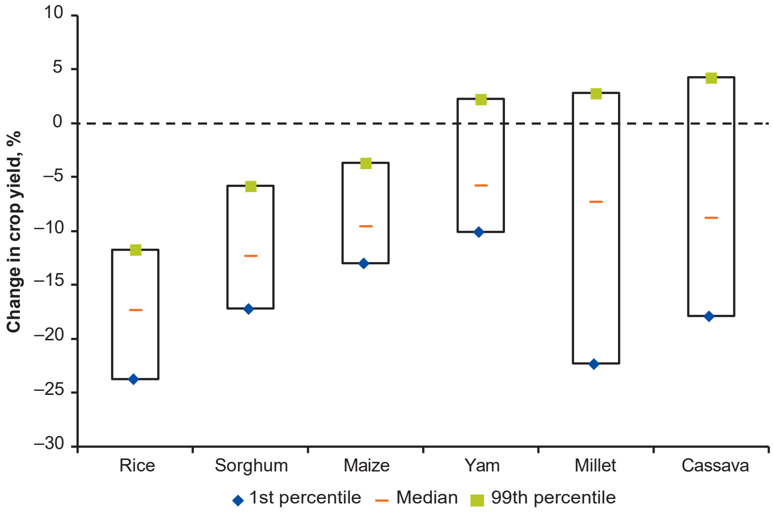


Figure 4.7 - Aggregate percent change in crop yields, 2020

Note: For each crop, yield changes are aggregated across agro-ecological subzones and weighted by using base year share in crop production

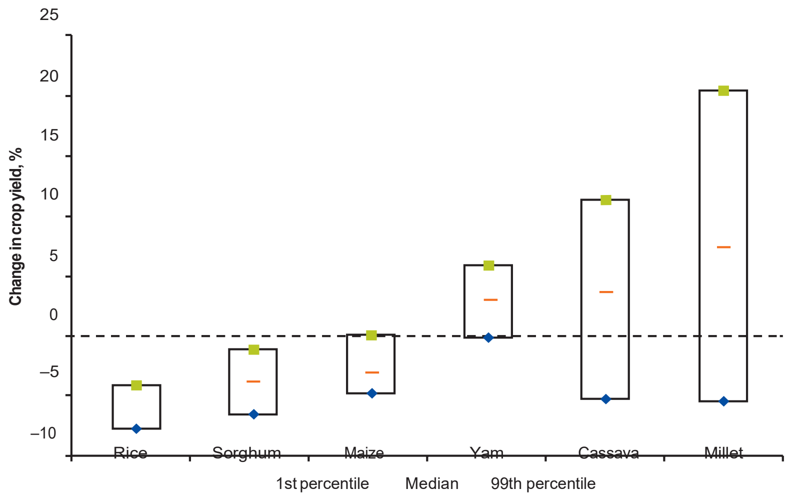


Figure 4.8 - Aggregate percent change in crop yields, 2050

Note: For each crop, yield changes are aggregated across agro-ecological subzones and weighted by using base year share in crop production).

Changes in rice yields for 2020 and 2050 are presented in Figure 4.9. It is clearly seen how rice yields are seriously affected in the longer term. The aggregated impact on a variety of crops' yield in the AESZ is provided in Figure 4.10 and Figure 4.11 for 2020 and 2050, respectively. According to the results of the model, in the Northern AESZs significant yield declines close to 20% in 2020 and 40% in 2050 are expected. There is also more uncertainty, with yield increases obtained with the more optimistic models, up by 20 % in 2020 and almost 10 % in 2050. Despite the significant spatial variability, by 2050 the aggregated yield decline is pronounced in the northern part of Nigeria.

The results of the modelling exercise indicate that:

- Reductions projected for sorghum, millet, maize, and rice in 2020 are probable in all AESZs except AESZ 10, where the uncertainty is very high, and AESZs 1 and 2, where increases are projected.
- Rice seems particularly vulnerable in the north, with longer-term reduction in yields of 20–30% or more (Figure 4.9), and
- By 2050, the probability of lower yields in all cereals in all AESZs is very high except for millet in AESZ 2 and maize in AESZs 4 and 10, where projections are clouded by uncertainty.

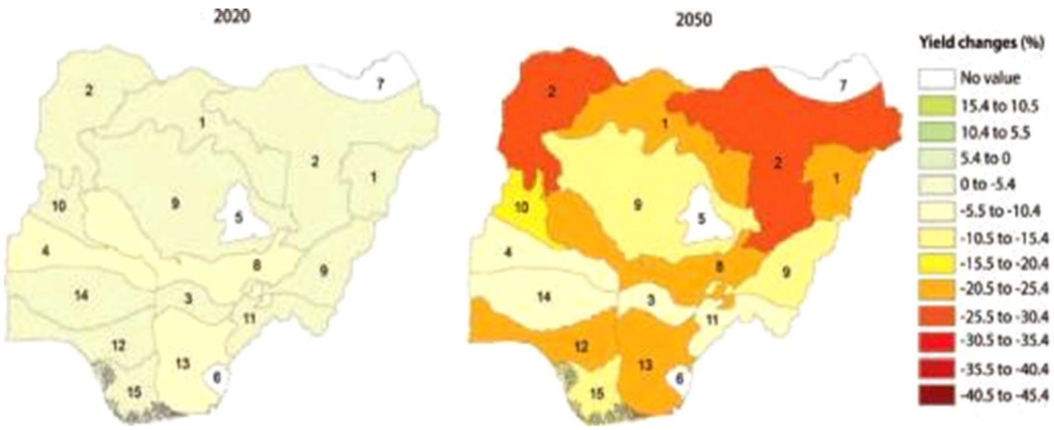


Figure 4.9 - Changes in rice Yields (intermediate model) – 2020

Source: Cervigni et al. 2013.

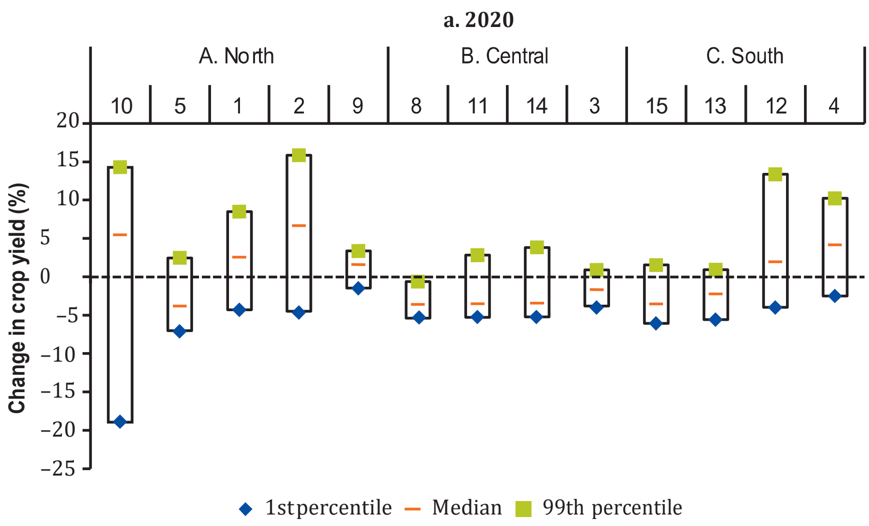


Figure 4.10 - Aggregate % change in crop yields by AESZ in 2020 (Cervigni et al. 2013)

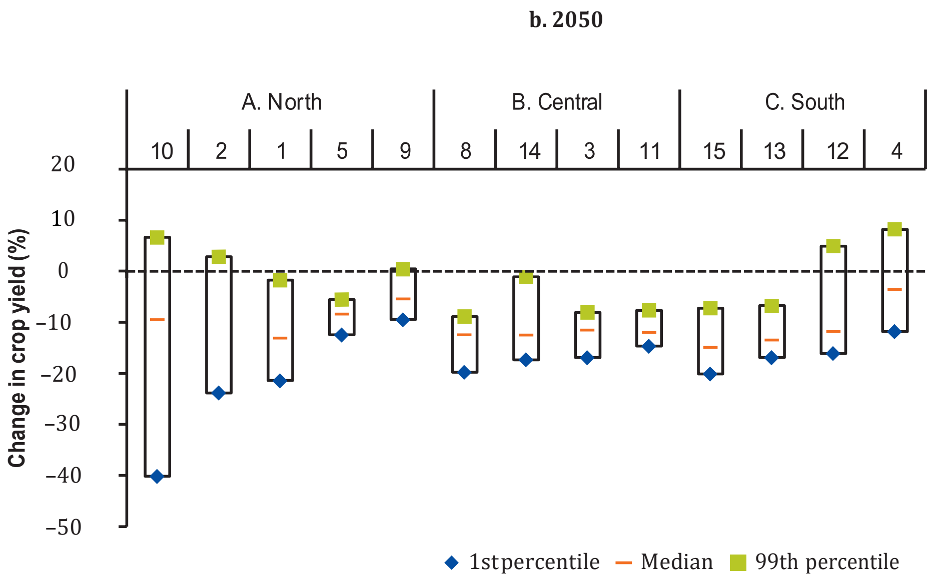


Figure 4.11 - Aggregate % change in crop yields by AESZ in 2050 (Source: Cervigni et al. 2013).

In conclusion, it is evident that temperature and precipitation variability will affect the agriculture sector, especially the priority staple food commodities. As indicated above, while an increase in total annual rainfall could have a beneficial effect on the productivity of some crops such as cassava and ginger, the productivity of yam, maize, tomato, and melon could be threatened by an increase in total annual rainfall. Thus, this differentiated impact on different crops need to be considered in any adaptation planning strategy. On the other hand, extreme temperatures have a negative association with cassava and sweet potato yields. As the annual maximum temperature increases in 2050 and 2070 under both scenarios could range from +3.08°C to +4.63°C, the negative impact on cassava and sweet potato productivity could be evident. Specifically, given the importance of cassava in the Nigerian food basket and an increase in recent years in the number of days with temperatures above 34°C, cassava yields could further be exacerbated due to extreme temperature events. The projected temperature increase could reduce agricultural productivity and this needs to be addressed to ensure the resilience of agricultural production.

4.7.4. Impacts of Climate Change on crop production

Crop production in Nigeria has experienced and is experiencing many hazards related to climate change. Climate change impacts are associated with a range of climatic variables such as temperature, rainfall, and extreme events. Also important are the country's social, cultural, geographical and economic backgrounds which determine the resilience of communities dealing with climate change impacts. While climate change is driving aridity and desertification in northern Nigeria, it is increasing flooding and erosion (gully, sheet and coastal / beach) in the middle belt and southern regions, especially in the coastal and rainforest ecological zone (Uyique and Agho, 2007).

Flooding and erosion have increasingly been reported as a major climate change hazard by almost all communities in these zones. Flooding and erosion lead to crop failure by removing topsoil, making soil more acidic and washing away or submerging crops. Flooding is a climate change hazard related to a more irregular rainfall pattern which can give rise to a single or series of rain events of high intensity and duration leading to very high total rainfall amounts over a short period of time (Adelekan, 2009). Other climate change hazards include landslides, severe windstorms, excessive heat, drought and late and variable onset of the rainy season. Another climate change hazard relates to the trend of rising temperatures, reported to be increasing in Nigeria since 1901 (Odjugo, 2010). Temperature increase was gradual until the late 1960s, with more rapid increases occurring since the 1970s, a trend which has continued to the present. Sea-level rise, resulting from climate change, is affecting crop production in coastal areas. The Nigerian Environmental Study / Action Team (NEST, 2004), reported that sea- level rise and repeated ocean surges is leading to increased coastal erosion and associated intrusion of sea water into surface water and groundwater resources. Exacerbating the problem is the fact that many coastal ecosystems are degraded due to the loss of mangrove forests which, when present, provide a protective function in reducing the impact of salt water on inland cropping areas. Farmers in the coastal and rainforest ecological zones face a range of impacts from climate change hazards, contributing to a loss of livelihoods. Climate change impacts can include: decline in crop yields resulting in reduced marketable surpluses; irregular fruiting of cocoa; total failure of some crops; increase in pests and diseases; soil degradation and loss of farm land due to flooding and erosion; reduction in bush foods such as bush mango (*Irvingia gabonensis*) and getup africana also known as Okazi, Afang or eru; and post-harvest losses of farm products due to bad and extreme weather events.

A serious hazard of climate change that directly impacts agriculture in the Savanna and Sahel ecological regions is increased variation in the amount, geographic distribution and timing of rainfall. Traditionally, planning and timing of farming operations are tied to the onset and duration of rainfall, particularly the first rainfall events of the wet season. In the past, farmers in these ecological regions have indicated that the period of initial rainfall onset usually occurred during the month of March with rainfall continuing until November. Recent observations report a delayed onset of rainfall until May or June and a cessation of rainfall in October. The impacts can include a loss of planting material, reduction in grain yield, reduction in animal feed and fodder, and at times complete crop failure due to cessation of rain (BNARDA, 1992; NAERLS, 2004). Due to extreme levels of poverty, poor levels of infrastructure and heavy dependence on rainfed agriculture, communities in the Sahel and Savannah ecological regions are extremely vulnerable to climate change impacts and have limited ability to adapt. In the Savannah and Sahel the impacts of climate change include: lower rainfall, higher temperature and evaporation; more frequent drought spells leading to source water shortage; changes in the onset of the rainy season changing planting dates and the length of the growing season of annual crops; increased fungal outbreaks and insect inter-relation due to changes in temperature and humidity; decrease in the available areas that can be cultivated and decline in yields; increased risk of food shortage and famine; increased potential of malaria transmission and the related reduction in available labour to work on farms; increased movement of pastoralists to more humid southern areas in search of fodder and water; lower quality and quantity of grazing lands; increased desertification of arable lands; increased rural to urban migration leading to a reduction of available farm labour and loss of soil fertility.

4.7.5. Adaptation strategies

1. Provision of accurate and timely weather forecasting

A major factor responsible for poor crop performances and low harvest is the inadequacy of weather forecasting which is crucial for improving farming activities. This would require developing human capacity and appropriate infrastructure for weather forecasting and information sharing. The Central Climate Forecasting Office (CFO) of the Nigerian Meteorological Agency (NIMET) is responsible for short-term and extended range weather forecast in Nigeria. The option is of very high priority in every part of the country.

2. Adoption of drought-tolerant and early maturing crop varieties

This strategy is relevant in every part of the country where water stress may be the limiting factor or soil productivity has declined. Switching to new crops will become crucial in many locations for farmers to have rewarding harvests. This practice is by no means a new phenomenon. The adoption of cassava for example, derived from realization that it offered better returns on soils of lower fertility than many other crops. Cassava is also tolerant to drought.

3. Diversifying livelihoods to improve income

Diversity in livelihood affects the incidence and depth of poverty. Thus, vulnerability can be reduced by enhancing livelihoods diversity. In this respect, crop farmers can combine farming with raising livestock like chickens, rabbits, grass cutters, pigs and goats in an integrated manner to enhance their income. Diversifying livelihood requires guided decision-making and, NGOs, research institutes as well as the various communities, have key roles to play in identifying what is best for the individual to combine with his primary engagement to improve his socio-economic status. The option is of very high priority and is low cost.

4. Increasing and upgrading crop storage facilities

Nigeria has poor post-harvest storage facilities. Consequently, significant amounts of harvested products, particularly vegetables and fruits are wasted. This cannot continue under a less favourable climatic regime. Also, there is a need to raise the standard of local storage facilities to meet international ones for food banking to enhance food security. Currently, Nigeria is far from meeting the target. Indigenous adaptation strategies for various crops need to be identified and further developed for adoption. Additionally, improved methods enabling more significant areas to be harvested should be identified and encouraged.

5. Control of pests, insect and birds

In agricultural history, pests have been real threats to harvest. Their impacts could be more severe as climate changes. For pests attacking crop plants on the farm, early detection of breeding sites is critical in controlling the pests before the swarms begin to move. The option is currently being practiced in some parts of Nigeria and should be encouraged elsewhere in the country. Pests damage crops at different stages of development such as at harvest, during transportation and storage. This leads to 5 - 40% crop losses yearly and has serious effects on the food security of the increasing population. The different methods of pest control currently being used are cultural, biological, indigenous knowledge systems, use of resistant varieties, use of plant extracts, use of pheromones and the minimal use of chemicals within an integrated pest management system.

6. Growing more cover crops like potatoes and melon to protect soil from erosion

Planting cover crops primarily help to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife. This strategy is of low cost. Cover cropping also helps prevent soil from washing away during rains. Erosion of the humus layer and topsoil from a home garden greatly reduces crop growth and yield at harvest. Cover cropping is also a long-term weed control technique for the home garden. Cover crops are more efficient in controlling both weeds and soil erosion, and they also improve the structure and nutrient content of the soil.

7. Enhancing agricultural extension services

Agricultural extension officers have significant roles to play in improving farm productivity. They are trained to link farmers with scientist working on how to improve farm operations They also help farmers to deal with difficulties that they may have in the field. In adapting to climate variability and change, this category of professionals would need to be further trained and empowered to function more effectively. For instance, it would be more relevant for them to provide weather information based on local and indigenous knowledge and information about adaptive mechanisms that are working elsewhere.

8. Irrigation

Irrigated agriculture needs further expansion as it ensures double cropping within a year for several of the stable food crops whose importation contributes most in depleting the country's foreign reserves. This is concentrated in the North where billions of Naira have been sunk on dams. Presently, small earth dams have been discovered as being more adaptable to the farmers needs and State governments are currently commissioning many of these dams. Expected investments in this area would boast agricultural productivity. This adaptation strategy has been adopted in part of south western Nigeria (Plate 5.1). This is a project where the changing climate has affected the timeline and caused a delay in its operations. Hence the need for the above irrigation strategy.

Plate 5.1 - An Adaptation strategy on Rubber Budded Stumps

9. Flood control

Following heavy rains, all the rivers of Nigeria swell above their normal flow levels. After spilling over their banks during the rainy season, they flood the surrounding fields, damage the cultivated lands, buildings and life. Floods have become uncontrollable and are taking their toll. These above normal downpours are attributed to climate change. Hundreds of people die, and properties are destroyed by the heavy floods.

10. Drainage

The low-lying and swampy coastal areas of the country need drainage and protection from salt-water intrusion. Inland, especially in the southern parts of the country where the pressure of population on land is most acute, substantial areas of arable land become waterlogged and remain so for a long period during the rainy season. The problem of urban and rural drainage which is worsening because of anthropogenic pressure, is drawing more attention from the authorities.

11. Improving transportation between rural areas and urban centres

Part of the problem of food insecurity in the country is due to inadequate transportation infrastructures which hangs the wellbeing of the farmers on the goodwill of roving middlemen. Farmers are forced to part with their product at give-away prices to traders who have the wherewithal to transport the products to the urban markets. Sometimes, perishable farm products, particularly vegetables, are lost because they cannot be transported to the markets on time. Improving transportation facilities is thus a very relevant measure that should be considered.

4.8. **Livestock**

4.8.1. Vulnerability of the livestock sector

Livestock production accounts for one third of Nigeria's agricultural GDP, providing income, employment, food, farm energy, manure, fuel and transport (Nuru, 1986). Pastoral herding is a major occupation of the people in the Sahel and parts of the savanna regions of Nigeria. Approximately 75% of all the livestock in Nigeria are in the northern region (World Bank, 1992). The livestock species are cattle, goat, sheep, camel, local poultry. Other non-livestock animals are donkey, horse, and wildlife. The feeding sources are natural rangelands, tree forage, and crop residues. Because of the low annual availability of feed, animals are kept partly under a transhumant system in which they are moved shortly before the dry season to the more humid southern areas for grazing and drinking. The livestock sub-sector is affected by climate change and other environmental hazards within all ecological regions of Nigeria. The climate change hazards affecting livestock in Nigeria include late onset of rains, higher than normal temperatures, flooding, salt-water intrusion and windstorms. The late onset of the rainy season causes a lack of available water for livestock and reduces forage production. Higher than normal temperatures lead to poor livestock health which reduces their market value, thereby reducing the farmers' income. Flooding leads to loss of livestock, destruction of livestock enclosures and outbreak of diseases. Windstorms impact fodder crops. Salt-water intrusion leads to decline in livestock production as quality of fodder becomes poor due to saltwater (Scholes, 1990, 1993). This sub-sector is vulnerable to climate change hazards because livestock farmers in Nigeria are dependent on the availability of water for the provision of sufficient quantity of quality fodder from rangelands and for drinking water for the animals. The high levels of poverty among livestock farmers and the lack of economic alternatives for farmers and their household members combine to enhance the vulnerability of the livestock sub-sector. The main economic impact of climate change on livestock production is the loss of income that sustains pastoral livelihoods. Men are predominantly involved in livestock production. Therefore, they have greater vulnerability to climate change impacts. However, women are also affected because of their role in marketing milk products and indirectly through loss of family income from livestock. Despite the low adaptive capacity of livestock farmers to the impacts of climate change, historically they have developed strategies to cope with and adapt to a region characterized by a variable climate. Communities dependent on livestock have over time faced harsh changes in environmental conditions and are therefore aware of the need to adopt different strategies to cope and adapt. These strategies include the use of forage obtained from hedgerows and compound farms, use of herbs to treat diseases, migration of male and female youth to cities in search of jobs, drilling boreholes and water harvesting (e.g. from zinc roofs). The livestock sub-sector is particularly susceptible to climate change due to the extent that livestock depend on water for survival. Shortage of rainfall, late onset of rains and rising temperature in the Sahel and Savanna will result in declining livestock productivity and production as well as increased incidence of diseases. In the rainforest and coastal zones, flooding and erosion will displace livestock farmers, destroy their assets and increase disease infestation on livestock farms. This trend will ultimately reduce animal protein supply in the country as much as the livestock production is a major source in Nigeria.

4.8.2. **Adaptation of the livestock sector**

1. Intensive livestock keeping

Intensive farming refers to animal husbandry, namely the keeping of livestock such as cattle, poultry, and fish at higher stocking densities than is usually the case with other forms of animal rearing. This is a practice typical to industrial farming in agribusinesses. Keeping livestock in confinement instead of free range (extensive) will help farmers adapt to climate change impacts like disease infestation. Government, the private sector, and NGOs can support livestock farmers adapt to climate change by providing soft loans needed to initiate intensive livestock production.

2. Planting trees near livestock houses and on pastureland

This strategy will help farmers adapt to severe windstorms which are responsible for destruction of livestock houses and forage land.

3. Greater support for insurance

Government should increase support for the Nigerian Agricultural Insurance Scheme and farmers should register with the scheme. This will make farmers resilient and enable them to replace their stocks in the event of death of livestock due to flood, diseases and lack of water.

4. Developing improved livestock breeds

Government and NGOs are the bodies saddled with the responsibilities of supporting and enhancing livestock breeders to develop disease resistant races. They are currently working very hard to ensure this option is well disseminated in the country.

5. Institutionalize Early Warning Systems

This will increase livestock farmers' ability to prepare and respond to climate-related drought, flooding and disease impacts by being aware of the treats well in advance of the event.

6. Provision of potable water for livestock

Providing enough water of good quality is essential for appropriate livestock husbandry. Water makes up 80% of the blood, regulates body temperature and is vital for organ functions such as digestion, waste removal and the absorption of nutrients. Understanding daily livestock watering needs is key when designing a system for provision of drinking water to livestock. Construction of dams, boreholes and wells are recommended to cater for the water needs of livestock, especially during the dry spells. The provision of drinking water for livestock is the sole responsibility of government agencies such as the ministry of water resources.

7. Construction of embankment (dikes)

This will help to reduce flooding caused by high rainfall events that can result in death of livestock.

8. Culling animals

Maintaining a manageable herd size according to carrying capacity of the pasturelands helps in avoiding death during climate extremes while eliminating diseased animals early will help reduce and control disease propagation.

9. Vaccination of livestock and cross border diseases surveillance

Vaccination can help reduce disease transmission and propagation, especially for migrating animals. Nigeria historically has used vaccination to control major transboundary animal diseases such as Rinderpest and CBPP through JP15 and JP28, Newcastle, and Infectious Bursal Disease both in livestock and poultry. Vaccination was also used to control resurgence of Rinderpest in Nigeria in the 1980s. This option is of high importance and it is still being used in some parts of the country.

10. Encourage rainwater harvesting practices:

Rainwater harvesting (RWH) is a method of inducing, collecting, storing and conserving local surface runoff water for agricultural production. RWH system has been designed using local materials in the Otukpa community, Benue State, Nigeria (Onoja et al, 2010) and is a practice of most households in this community. This option will help farmers adapt to shortage of water during dry spells and improve availability of forage on rangelands.

4.9. Vulnerability and Adaptation of the Water Resources sector

4.9.1. Overview

With the substantial yearly rainfall, large surface bodies of water, rivers, streams and lakes, as well as plentiful reserves of underground water, Nigeria is endowed with abundant natural water resources whose extent and distribution have not been fully assessed. The annual mean rainfall distribution ranges from about 4,000 mm at the coast to practically zero at the northern border with an average annual average of 1,200 mm for the country. Over 80% of the precipitation in the country falls within the six wet months, April to September. A sizeable amount of the rainwater is lost by percolation to underground flows. The bulk of the rain, however, flows as runoff into rivers, streams and lakes. There are over 200 dams and water reservoirs all over the country, most of which are in the northern regions. The reason for having many such dams and reservoirs in the North is due to the pattern of rainfall which makes it mandatory for water harvesting for irrigation purposes. Surface water bodies occupy over 20 million hectares, storing water in excess of about 30 billion m^3.

River Niger, the third largest river in Africa, spans over the greater part of Nigeria with River Benue dividing the country into three geographical regions. Other rivers such as Cross River, Imo, Sokoto, Ogun, Anambra and Kaduna along with several streams, channels, lakes and ponds, complete the network of surface water resources of the country. Within Nigeria and over the part of the basin extending south of the Sahel zone, an increase in the occurrence of extreme weather events has been documented. A greater number of torrential rainfall events and storms have been experienced (Odjugo, 2009). The major part of the Niger Basin that falls outside of the Sahelian zone is in the humid tropical zone of southern Nigeria, a region already facing high temperatures and high levels of precipitation (Goulden and Few, 2011). The vulnerability of the water resources sector summarizes the major impacts on the sector and assesses its exposure based on the ensemble model results obtained for the RCP4.5 and RCP8.5 scenarios that have been described earlier in this chapter.

4.9.2. Impacts

While climate models differ, projections used in this assessment suggest that Nigeria will generally experience an increase in both rainfall and temperature (Podesta and Ogden, 2008). This is consistent with the more recent results of the ensemble model outputs of the 5th Phase GCM models of the Coupled Model Inter-comparison Project (CMIP5) models used in the development of the AR5, as well as to an increase in the frequency and intensity of extreme weather events such as floods and droughts. For example, in the last few years, the southern states have witnessed more and harsher torrential rains and windstorms than in the past forty years, with up to a 20% increase in recorded volumes of torrential rains across various states, many of them recording up to 4064 mm of rainfall annually (USIP, 2011). On the other hand, the northern arid parts of Nigeria are facing more heat and some parts, like the northern Sahel area, are getting less rain, below 250 mm a year already, representing about 25% less than 30 years ago (USIP, 2011). However, though the results project an increase in rainfall, the associated temperature increases will lead to higher evapotranspiration, thus negating any effective precipitation increase, consequently leading to droughts. As discussed below, this phenomenon could lead to dry water risks. Using the ArcSWAT Soil and Water Assessment Tool (SWAT) model in consultation with local experts, especially in electing input data to support the hydrological analysis, the World Bank conducted a climate impact analysis on water resources in Nigeria (Cervigni et al. 2013). In the study, data from some 893 sub-basins, including their reach and falling inside the boundaries of the country were extracted (Figure 4.12). The precipitation and temperature stations, discharge stations and Nigerian rivers are provided in

Figure 4.13.

Figure 4.12 - Hydrological Areas of Nigeria by rivers (left) and sub-basins (right)

Source: ArcSWAT

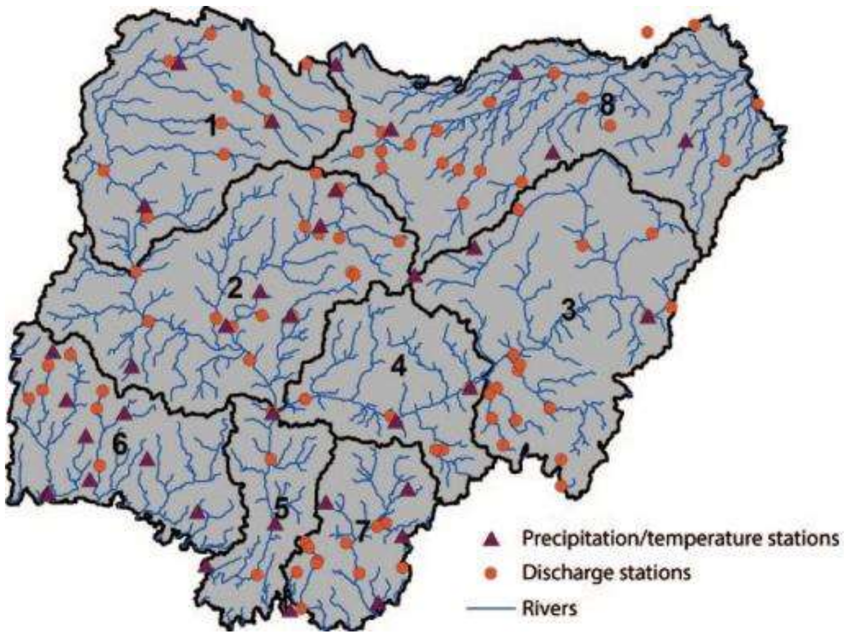
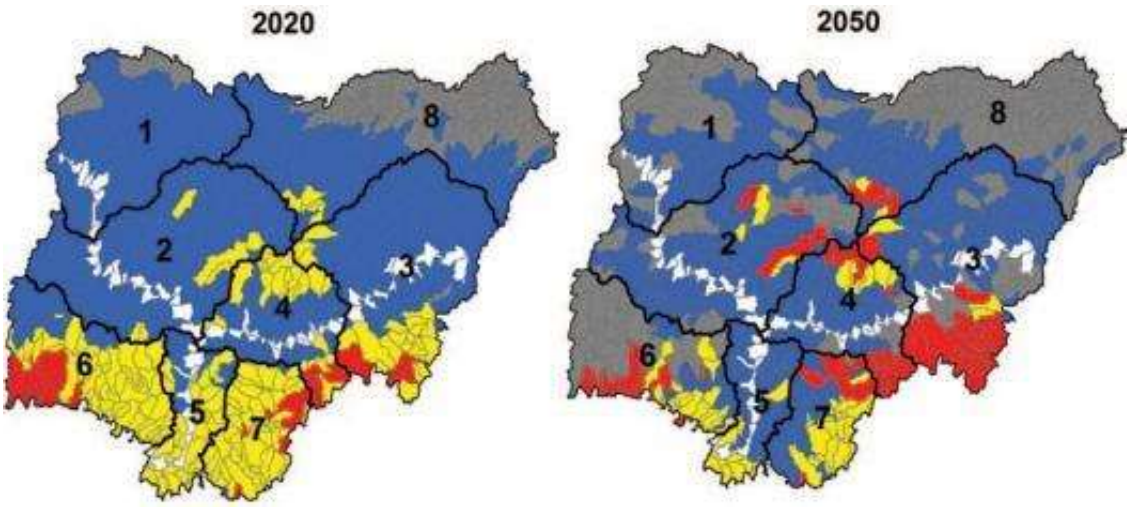


Figure 4.13 - Measurementstationsforrainfall - temperatureandDischarge(JICAmasterplan)inthe hydrographic network

Source: Cervigni et al. 2013 (Note: Numbers refer to hydrological areas. JICA = Japan International Cooperation Agency)

According to the results of the study, by 2020, about 62% of the country is expected to be wetter, 4% drier, and 23% stable (Figure 4.14). Similarly, by 2050, it is expected that significant parts of the country could face wetter or drier conditions while 11% of the projections are uncertain. The distribution of classes of risks for Water Flows for 2020 and 2050 indicated as Dry Risk areas and integrating the projected mean annual temperature increase for the 2050 and 2070 time horizons for the RCP4.5 and RCP8.5 scenarios are presented in Figure 4.14. In both maps, the South Eastern tip of Nigeria and smaller areas of the south west and centre, especially by 2050 are observed to be subject to the Dry Risk. Substantial areas also are projected to suffer the Wet Risk, meaning that this could also result in negative impacts on activities such as agriculture and health with potentially higher occurrences of floods.



		1st Percentile	
		< -15%	> -15%
99th Percentile	<15%	Dry Risk	Stable
	>15%	Uncertain	Wet Risk

Figure 4.14 - Distribution of classes of risk for Water Flows, 2020 and 2050 compared to 1990

Source: Cervigni et al. (2013) (Note: Distribution of classes of risk for water resources in 2020 (left) and 2050 (right) compared to 1990. Small units are sub-basins; numbers indicate hydrological areas. White areas are adjacent to the Niger and Benue main river stem and not part of the analyses)

Despite the abundant water resources that Nigeria is endowed with, the country suffers from access to a regular supply of good quality water for domestic use. A recent report by UNICEF indicates that over 57 million Nigerians do not have access to potable water. This water shortage and lack of access leave no choice to this segment of the population than to harvest and use water of poorer quality. This in turn have health consequences, namely incidences of diarrhoea and other diseases such as cholera, typhoid fever, salmonellosis, other gastrointestinal disorders and dysentery.

There is a consensus view that adverse environmental changes that are evident in all parts of the country are driven more by human activities such as, damming of the rivers, water diversions aid water withdrawals, land-use changes through engineering constructions, deforestation and agriculture in Nigeria rather than by climate change. Global climate may, however, be the primary cause for system function and service changes in areas such as the coastal zones where sea level rise could salinize the coastal freshwater resources through salt-water intrusion in Lagos, Delta areas, Port Harcourt and Calabar amongst others.

Statistical analysis of climate data suggests that the frequencies of extreme weather events, which are already rampant in Nigeria, are likely to increase because of the projected changes in precipitation amounts and intensities. Water managers are expected to come up with strategies to cope with both drought and floods that have been recurrent features in both the North and South of the country. Semi-arid tropical lands are characterized by long dry seasons, low and unpredictable rainfall and poor soils.

Drought has adverse impacts on the environment, water quality and water availability, water supply system, hydropower generation, navigation, vegetation cover, dilution capacity of the rivers, groundwater balances, and deposition of sediments in lakes and reservoirs in Nigeria. Falenmakr et al. (1990) emphasized that droughts and famines should not be regarded as disasters but as normal processes. Agricultural drought occurs when the available moisture in the root zone falls below 30% of the water holding capacity of the soil and this condition is projected to be experienced more frequently in the future.

Flooding takes place when the river channels are unable to contain the discharge. In Nigeria, floods are caused by climatological and human-induced factors. Some of these are: Heavy and intensive rains, coastal storm surges, estuarine interactions, failure of dam and other control works, excessive release from drains and control works as experienced recently in Adamawa State, blockage of drainage and river channels such as in Ogunpa in Ibadan and Onitsha. Floods are likely to intensify following heavier more intense rainfall because of basin, network, and channel characteristics remaining stable and the variable component not able to cope with the additional water flow. Improper land-use practices can accentuate devastation by floods. There is hardly any forest left in the catchment areas of the rivers. It is well known that forests possess a high infiltration capacity and transmissibility. The infiltration capacity of forests is 2-3 times greater than open fields while surface runoff may be as little as one-tenth of that of the open fields. There is hardly any protective vegetation on the banks of the rivers Niger and Benue. Crops are grown right to the edges of the rivers, even on the slopes of riverbanks. Thus, the combination of absence of forest cover, inappropriate farming practices and allocation of land for residential building (Akpaka forest Reserve at Onitsha) on flood plains intensifies the floods. Urban forestry is being projected in the built environment as a mitigation action to the numerous flood disasters.

Extreme flooding conditions have been experienced recently and has caused serious havoc to life and property worth millions, especially in the northern region and coastal plains adjacent to rivers and the ocean. The flood hazard itself cannot be prevented, but through a better understanding of the areas which are prone to this hazard and the conditions and processes which could culminate in the loss of lives and damage to property, it is possible to minimize these through preparedness for appropriate action.

4.9.3. Adaptation Policies and Strategies

4.9.3.1. Adaptation policies

The Ministry of Water Resources is responsible for ensuring efficient and effective management of the nation's water resources in an equitable and sustainable manner. The Ministry is responsible for the storage of bulk water reserves through construction of small, medium and large dams across the country. Water supply and sanitation improvement through intervention programmes are being carried out nationwide as well as extension of irrigation facilities to boost food security.

For the period under review, in 2014, the Ministry produced the National Water Resources Masterplan (NWRM) and in 2015, the National Water Policy was published. The National Irrigation Policy was also reviewed in 2015 with support from the FAO.

Furthermore, the Nigeria Hydrological Services Agency, a parastatal body under the Ministry of Water Resources, ensured the publication of Annual Flood Outlook (AFO) as an early warning tool for the population to serve as a guide on widespread annual flooding in the country.

As a way towards effective adaptation in the sector, the Ministry has launched the Partnership for Expanded Water, Sanitation and Hygiene (PEWASH), an initiative for improved water supply and sanitation nationwide in partnership with all stakeholders.

Presently, the Ministry is working towards ensuring deployment of solar power systems to support water supply and irrigation facilities, and application of water efficient systems for sustainable water development.

In addition to the above and realizing the need for effective information dissemination to the population at grassroots level on adaptation mechanisms for combating the negative impacts of climate change, the Ministry has commenced the following:

- Establishment of Climate Desks at the River Basin Development Authority (RBDA) headquarters, and support for effective operations and information dissemination at basin levels; and
- Advocacy visits on climate change to each RBDA and local communities in each catchment area - that is, mainstreaming climate change to the Basin Authorities to promote climate resilient water management.

The advocacy visit on climate change to communities is designed to disseminate climate change information to the grassroots and villages downstream of water infrastructures. This is done to enhance information and knowledge sharing on climate change issues. It also aims at keeping abreast with the latest technologies and advances in the field of climate change. Between 2016 to 2018, training workshops were held at Sokoto (Sokoto Rima RBDA), Abeokuta (Ogun Oshun RBDA), Ilorin (Lower Niger RBDA), Calabar (Cross Rivers RBDA), Makurdi (Lower Benue RBDA), Benin (Benin Owena RBDA), Imo (Anambra–Imo RBDA) and Minna (Upper Niger RBDA) states.

- In order to address the issue of paucity of climate change data for Water Resources management in Nigeria, the Ministry has commenced an initiative tagged *"The Development of a Climate Change Information Guide for each Hydrological Area"* designed to gather information on impact of climate change on water resources management for each hydrological area as well as suggestions on suitable adaptation mechanisms. It also aims at developing resilient strategies for each vulnerable community as well as downscale global climate data for each catchment area. Eastern Littoral (Anambra-Imo), Niger North (Sokoto Rima) and Western Littoral (Ogun Oshun) have been completed. The next catchment under study is Hydrological Area II, otherwise known as Niger Central.

4.9.3.2. Adaptation strategies

Improved management of water resources

The demand for potable water is growing sharply as a result of the population increase and higher standards of living in addition to demands for industrialization. Nigeria is committed and dedicated to meet Sustainable Development Goal 6, namely "*Ensuring universal access to safe and affordable drinking water for all by 2030*". This will require investment in adequate infrastructure while protecting and restoring water-related ecosystems such as forests, mountains, wetlands and rivers to mitigate water scarcity. Strategies and plans of action to adapt to climate change is through an integrated approach to land and water management to develop effective resilience to the projected impacts of climate change in the water resources sector. A wide range of adaptation options are already being applied and they need to be further amplified. Some of these options require intensive research in water resources management and development.

Adaptation in the water resources sector are geared towards meeting the targets of SDG 6 on clean water and sanitation. The Federal Government is developing and implementing programmes with the following objective:

- Improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials into waterways, reducing the proportion of untreated wastewater and substantially increasing recycling and safe reuse of wastewater at the national level.
- Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and reduce the number of people suffering from water scarcity.
- Implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.
- Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
- Expand international cooperation through capacity building support in water-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies; and
- Support and strengthen the participation of local communities in improving water management.

Federal and State Governments' agencies are independently undertaking various activities on water resources development and utilization (Orjiakor, 2000). Recently, the private sector has increased its financing and technical involvement. The principal Federal agencies involved are: Federal Ministry of Water Resources (FMWR), River Basin Development Authorities (RBDAs) Federal Ministry of Transport, Federal Ministry of Aviation (FMA), hydro power generation companies and mining companies including those extracting oil. The 36 State governments have created their own agencies that complete water resources development. These agencies include the State Ministries of Works and Housing, and of Agriculture, State water boards, and Rural Electrification boards. Most water resources development activities undertaken by the Federal Government besides power production are carried out through the eleven RBDAs under the direct surveillance and coordination of the Federal Ministry of Water Resources. The Ministry often directly undertakes water resources development to adapt to climate change impacts though such activities as erosion and flood control, development of underground water resources and other hydrological activities. For effective control, the Ministry is organized in five main sections or sub-departments: Water Resources and Irrigation, Hydrology and Hydrogeology, Dams, Water Supply and Sanitation.

Water resources management aims to increase the reliability of water-related services and improve the management of hydrologic extremes such as floods and droughts. It should be a self-adapting endeavour, whereby the management system responds and adjusts to various challenges, such as climate variability, water availability, shifts in water uses and demands, demographic changes along with technological innovations and institutional requirements (Stakhiv, 1998). Additionally, water resources management is being increasingly called upon to address water-related environmental issues, such as aquatic ecosystems, wetlands, endangered species and waterborne diseases. Water resources management is as much concerned with the efficient operation of the physical structures such as reservoirs, irrigation infrastructure as with institutional structures (such as regulatory measures, behavioural changes and water conservation). By the application of such management techniques, it is possible to bring down the total freshwater withdrawals in Nigeria. Unfortunately, developing countries like Nigeria are ill equipped to undertake adaptive management systems, for the simple reason that they generally do not have either the physical structures or institutional capacity needed for this purpose.

Improved exploitation of groundwater

The importance of groundwater in the water resources management framework arises from the following considerations. The quality of groundwater is generally superior to that of surface water. Unlike surface water, groundwater hardly suffers any evaporation losses, and groundwater is the main source of potable water for domestic purposes in many countries of the world.

Besides the efforts made by governments and corporate organizations, the contributions of NGOs, educational institutions as well as communal efforts in advancing community-based adaptation in areas ravaged by drought, notably the North East and the North West, deserve mention. A typical example is the water harvesting project embarked upon by the University of Maiduguri (UNIMAID) in Tosha community in Borno State (BNRCC, 2011). Water is one of the most critical resources that determines the severity of climate change impacts in the Sahel. The erratic short duration rainfall often comes in heavy downpours and wastefully drains off into natural depressions, infiltrating into the sandy soil while the remaining evaporates in the dry air. During the initial stages of engaging the community of Tosha, the community expressed a strong desire to revive some of their six dried oases to harvest underground water for uses such as dry season irrigation, livestock drinking and domestic consumption. The UNIMAID project team responded to this community-identified need to revive the productivity of the oases by facilitating the implementation of the adaptation option of harvesting their underground water for irrigation, livestock consumption (Plate 5.2), and domestic use through the provision of boreholes and water pumps in two oases.

Plate 5.2 - Water harvesting borehole at Tosha

4.10. Vulnerability and Adaptation of the Health sector

4.10.1. Overview

The IPCC Third Assessment Report projected that changes in extreme weather events, namely a higher number of hot days and heat waves; more intense precipitation events and floods; and increased risks of drought could aggravate health problems that already represent a major burden to vulnerable communities.

4.10.2. **Impacts and Vulnerability**

Impacts of climate change on health can prove to be very detrimental to the population and the economy with higher order effects on the social fabric and the society. Though there is no national level extensive assessment of the impact of climate change on health in Nigeria, the few studies conducted to-date indicate that climate-induced hazards on health are evident. For example, Tunde et al., 2013, indicated a relationship between climate and the major causes of mortality in Ilorin (South Western Nigeria) in the rainy season. There is evidence that some vector-borne diseases like malaria, fever and dengue transmission are highest during the months of heavy rainfall and high humidity (More, 1992). Moreover, heavy rainfall events, which are common in Nigeria, can also carry terrestrial micro-biological agents into drinking water sources, which could eventually lead to outbreaks of cryptosporidiosis, giardiasis, amoebiasis, typhoid and other infections (Lisle, 1995; Rose, 2000). Typhoid is mostly triggered by high temperatures and increased humidity. Two case studies providing information on malaria and climate change from the Ilorin (South Western Nigeria) and Port Harcourt (Southern Nigeria) regions, and meningitis and climate change in the northern region of the country are presented further in this chapter.

Climate change has the potential to cause havoc to humans through serious impacts on their health in many ways, notably, from the direct effects of resulting hazards such as heat waves, windstorms, drought, wildfires, floods and storms. These changes alter infectious disease patterns, disrupt agricultural and other supportive ecosystems, thus, affecting the socio-economic activities and well-being of people. The impacts are felt strongly among people residing in places prone to impacts of climate change such as the densely populated urban areas. The recent flooding recorded between July and September 2017 in some parts of Lagos, Benue and Bayelsa states, affected many business activities and led to temporary loss of accommodation and sources of livelihood. These events also accelerated the spread of both vector and water borne diseases. The impacts of climate change on human health poses a high risk of some diseases reaching the epidemic stage for the inhabitants of the affected areas.

Climate change has direct and indirect effects on human health. Some of the direct effects include a higher incidence in temperature related illnesses and deaths, increase in mortality and morbidity due to intense heat waves over longer durations coupled with higher humidity. Indirect effects of climate change on health may arise from malnutrition due to reduced food production and availability, spread of infectious diseases and environmental pollution. These impacts are expected to be more pronounced among the more vulnerable segments of the population such as the urban poor, rural and the elderly people.

Considering the peculiarities of Nigeria, there are different adaptation strategies geared to reduce the impact of climate change in the health sector. Some of these strategies and others that take cognizance of the geographical location of the country are presented below.

4.10.3. Malaria and Climate Change

In Nigeria malaria is a major public health problem since it accounts for more cases of deaths than in any other country in the world. *Plasmodium falciparum,* which is commonly found in Nigeria, is the most dangerous malaria parasite (NIMET, 2017). The process of mosquito birth and bites are directly related to rainfall, temperature and humidity that give rise to differences in rate of disease transmission and incidence.

Malaria is a health risk factor for 97% of the population and there is an estimated 100 million cases resulting in over 300,000 deaths per year (USEN, 2011). One of the key challenges faced by the country is that an estimated 65% of the population lives in poverty, which translates into a low adaptive capacity for malaria prevention and treatment.

Several recent case studies have been conducted to look at the correlation between climate change and malaria incidences in Nigeria. Results from the two case studies of Ilorin and Port Harcourt follow (Figure 4.15). Regarding the impact of climate variables on human health in Ilorin, Nigeria (Tunde et al., 2013), the researchers found that there is a good positive correlation between minimum temperature and typhoid (0.844), maximum temperature and malaria (0.794), maximum temperature and typhoid (0.793), sunshine and typhoid (0.667) and sunshine and malaria (0.630). However, maximum temperature (0.794), and to a lesser extent sunshine duration (0.630) and rainfall (-0.692) seem to be the two main climatic variables that induce malaria. One strange fact is the negative correlation between rainfall and malaria incidence and this could be explained by the fact that the southern part of Nigeria receives more than 3,000 mm of annual rainfall and this is the cut-off point whereby further increases in amount do not have any more detrimental effect. Though some climate variables certainly affect human health in the study area, there are other factors that have contributory additive roles in the higher incidence and prevalence of these diseases. The two most prominent ones are socio-economic status and management of stagnant water amongst others which were not assessed in the studies. The increase in temperature coupled with availability of water are clear factors responsible for the spread of malaria. As both these variables are projected to increase under the RCP 4.5 and RCP 8.5 scenarios, the spread and hence, incidence of malaria is also expected to increase and need to be addressed concurrently along with the other contributing factors like poverty and management of stagnant water.

Figure 4.15 - Ilorin, Kwara State and Port Harcourt, Niger Delta, Malaria Case Study Areas

Similar to the Ilorin's study, Tunde et al., (2013) and Weli and Efe (2015) also examined the effect of climate on the occurrence of malaria in Port Harcourt, Niger Delta. The study used 65 years of weather data covering the period 1950 to 2014 and medical records of the number of malaria cases from the University of Port Harcourt Teaching Hospitals (UPTH), the Braithwaite Memorial Hospital (BMH) and private hospitals in Port Harcourt and neighbouring areas for the same period of time. The study revealed an annual rainfall of 2,375 mm with an increase of 1,581 mm from 1950 to 2014. The results of the ensemble model indicate that in 2050 and 2070, under both the RCP4.5 and RCP8.5 scenarios, the Southern tip of Nigeria, where Port Harcourt is located, could get an annual mean precipitation of more than 3,000 mm/year (Figure 4.16). This indicates the high potential for the spread and increased incidence of malaria in the southern parts of Nigeria and other areas with high rainfall and/or stagnant water.

The study (Weli and Efe, 2015) also showed an urban warming of 3˚C from 1950 to 2014, and a mean temperature of 27.2˚C in Port Harcourt. The results of the multiple regressions revealed that the prevalence of malaria is significantly related to the increase in rainfall and temperature. Specifically, there is a double-maxima for malaria cases, with 1006 cases in July and 1540 cases in September, these two months coinciding with the double monthly rainfall maxima. Malaria incidences correlate at about 65% with the monthly rainfall record. As in the case of Ilorin, there are other non-climatic factors that need to be addressed to enhance the adaptive capacity to climate induced malaria. This points out to the fact that non-climatic factors which are more controllable should be considered to enhance adaptation, namely poverty eradication.

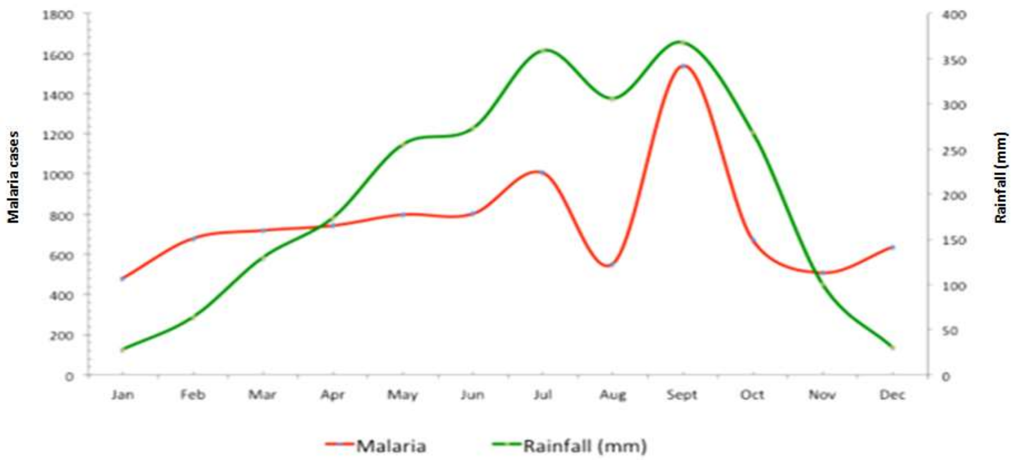


Figure 4.16 – Monthly Rainfall and malaria incidence in Port Harcourt, Niger Delta, Nigeria wrong axes

The country level ensemble model results under both scenarios RCP4.5 and RCP8.5 indicated that during the rainy season (June, July and August), the mean annual temperature is well above 27°C (Figure 4.17).

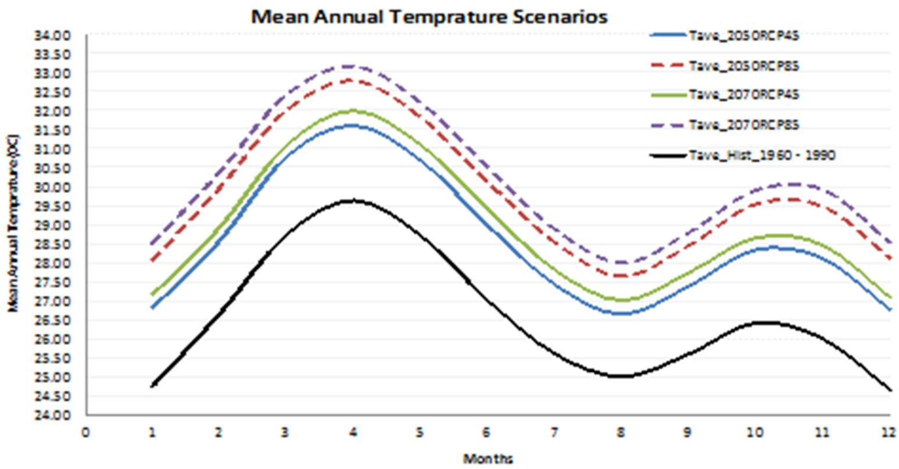


Figure 4.17 - National level mean annual projection under RCP 4.5 and RCP 8.5 Scenarios

In the Niger Delta region, the temperature under both scenarios is expected to be more than 27°C, with the possibility of a mean annual temperature of about 29°C during the rainy season. The projected temperature increase is higher than that obtained from the historical records. It is recognised that at low temperatures a small increase in temperature can greatly increase the risk of malaria transmission (Bradley, 1993) and that a high increase (8°C) at higher temperatures in excess of a certain threshold can be lethal to the vector. However, in the case of Nigeria, the highest projected temperature increases under the RCP8.5 scenario is 4.63°C for the 2050-time horizon. Unfortunately, the increase will be gradual, thus enabling the vector also to adapt. Under such circumstances, it is highly recommended that adaptation to cope with increased prevalence and higher incidences of malaria be considered as a priority (Christiansen-Jucht, C et al. Parasites & Vectors 2014, 7:489. http://www.parasitesandvectors.com/content/7/1/489).

4.10.4. Adaptation against Malaria

The most effective preventive method is through the control of the mosquito vector. This can be achieved in several ways. Control refers to various methods adopted to reduce malaria by reducing the level of transmission by mosquitoes. For individual protection, the most effective method is through the use of repellents. Insecticide-treated mosquito nets (ITNs) and indoor residual spraying (IRS) have also been demonstrated to be highly effective in preventing malaria incidence in regions where it is endemic or common. Prompt treatment of confirmed cases with various therapies can also reduce transmission.

Mosquito nets help to keep them away from people and reduce infection rates and transmission. Nets are not a perfect barrier and are often treated with an insecticide geared to be fatal to the mosquito before it has time to find its way past the net to bite the person. Insecticide-treated nets are estimated doubly more effective than untreated nets and offer more than 70% protection compared with no nets. The insecticide usually used to impregnate nets are from the pyrethroids family, a class of insecticides with low toxicity to humans. Maximum effectiveness is when they are used from dusk to dawn.

Indoor residual treatment consists of the spraying of insecticides on the walls of the dwelling. Most mosquitoes rest on a nearby surface after ingestion to digest their bloodmeal. So, if the walls of homes are coated with insecticides, the resting mosquitoes will be killed before they can bite another person and transfer the malaria parasite.

Other preventive methods adopted to reduce mosquito bites and halt the spread of the disease is by controlling breeding of the mosquitoes. Efforts are deployed to eliminate breeding sites and reduce the mosquito larva population by decreasing the availability of stagnant water where adult lay their eggs and larva develop, or by adding chemicals to reduce their development. Mosquito repellent devices are now commonly used by people inside the house. They are used to vaporise insecticide at a low level but enough to kill the mosquitoes or repel them. They are quite effective in mosquito prone areas when used again between dusk and dawn.

4.10.5. Other methods

Education and awareness of communities to buy in their participation are meaningful strategies to promote control measures and have been successfully used to reduce the incidence of malaria in some countries. Early detection of the disease can enhance its treatment to prevent it from becoming fatal. Education can also be adopted to inform communities of the importance of preventing access to areas of stagnant, still water, such as water tanks, empty bottles and worn out tyres that are ideal breeding grounds for the mosquito vector. This reduces the risk of transmission and eventual incidence within communities. This usually works well in areas with large population in a confined space such as in towns and villages where transmission would be most likely.

4.10.6. Meningitis

Meningitis is one of the major health problems common in Nigeria that could be exacerbated by climate change. Meningitis usually occurs when hot dry conditions are experienced, especially in the arid areas such as the Sahel. In the north west of Nigeria especially, the meningitis season peaks during February to April, the months that are warmest and driest (Abdussalam et al., 2014). Records from the World Health Organization (WHO) archives indicate that over 35% of reported meningitis cases in Africa between 1996 and 2010 came from Nigeria, with 95% of these occurring in the northern part of the country. Meningitis annual incidences, especially in the heavily populated parts of North Western Nigeria ranged from 18 to 200 per 100,000 people based on 2000 to 2011 data. Abdussalam et al. (2014) (https://doi.org/10.1175/WCAS-D-13-00068.1) assessed the impact of climate change on meningitis risk in northwest Nigeria with selected cities of Kano, Sokoto, and Gusau using the modelling approach. These results indicate that meningitis cases in northwest Nigeria may increase in the future, primarily as a result of warmer temperatures. The ensemble model outputs (Figure 4.6) indicate an increase of temperature in the study area. Under RCP4.5 the mean annual temperature could increase by 2.25˚C and 2.5˚C by 2050 and 2070, respectively and under RCP8.5 by 3.25˚C and 3.75˚C by 2050 and 2070 respectively, compared to 1960-1990.

The results suggest future temperature increases due to climate change have the potential to significantly increase meningitis cases in both the early (2020 - 2035) and late (2060 - 2075) twenty-first century, and for the seasonal onset of meningitis to begin about a month earlier on average by late century, in October rather than November. It is expected that the annual incidence may increase by 47% ±8%, 64% ±_9%, and 99% ± 12% for the RCP 2.6, 6.0, and 8.5 scenarios, respectively, in 2060 - 2075 with respect to 1990 - 2005. The results suggest that meningitis cases in northwest Nigeria may increase in the future, primarily as a result of warmer temperatures. This indicates the future potential threat posed by climate change that could result in an increase of the number of cases of meningitis if the current prevention and treatment strategies, land use patterns, and lifestyles do not evolve for the communities to adapt in the future.

4.10.7. Adaptation to meningitis

4.10.7.1. Vaccination/Early detection/Early warning system

Mass vaccination against the 4 groups of pathogens can be very effective even if it is somewhat expensive. This could be coupled with early detection and an early warning system through the monitoring and forecasting of weather conditions conducive to the spread of the disease to make the action more efficient while reducing costs and burden on the society.

4.10.7.2. Behavioural change

Lifestyle to reduce exposure

Bacterial and viral meningitis are contagious, and both can be transmitted through droplets of respiratory secretions during close contact such as kissing, sneezing or coughing on someone. Viral meningitis is typically caused by enteroviruses, and is most commonly spread through faecal contamination. The risk of infection and hence, incidence, can be reduced by changing the behaviour of the communities to avoid transmission.

4.10.7.3. Other Adaptation avenues for meningitis

1. Strengthening Research on Impacts of Climate Change on Human Health

The goal of this strategy is to enable the health experts to acquire adequate knowledge on the impacts of climate change on the health of people living in the areas predicted to be affected. This knowledge will enable health workers to identify appropriate actions that can be taken as precautionary measures and drugs that are effective in the treatment of diseases. The Federal Ministry of Health has drawn up a plan to improve research on climate change and health. However, the various reforms put forward by the Federal Government to address the wide-ranging issues of the health sector should be implemented at the state and local government levels concurrently for better results.

2. Improve Weather Prediction/Forecasting Technology and Training of Health Workers

Extreme weather events, namely floods, droughts and heat waves, resulting from climate change that are already being felt and will increase in frequency and severity in the future. The Federal Ministry of health has the following preparedness strategies for meningitis:

- Designated coordination committees at all levels.
- Epidemiology and surveillance (including data management) activities.
- Steps for implementing a risk communication strategy including social mobilization.
- Operational actions at each expected phase of the epidemic.
- Laboratory confirmation: specimen collection, handling, transportation and processing including on-site processing.
- Case treatment (antibiotics) and care.
- Immunization strategies.
- Capacity building including required training, sensitization meetings and simulation exercises
- Logistics including supply lists.
- Enhanced surveillance during epidemics.
- Operational research and the documentation of the response.
- Risk communication.
- Monitoring/evaluation.

Therefore, relevant Government institutions such as NIMET should be more proactive in disseminating information about the forecasted heavy rainfall, intense heat and drought events to the people. NIMET personnel should be fully equipped with modern technology and undergo training so that they may be able to record accurate extensive weather data for developing weather forecasts and early warnings. Special attention should be given to ecological zones in Nigeria by deploying enough funds to acquire modern weather monitoring tools. In addition, the Nigerian Medical Association should patron capacity building of health workers at the Federal, State and Local Government levels. As part of its contribution towards effective service delivery, the Federal Ministry of Health is already working towards signing a Memorandum of Understanding with NIMET for climate information and training of public health officers. The ministry is also creating awareness through Information Education and Communication (IEC) materials posted on the web sites of the Federal Ministry of Health (FMOH) and WHO on climate change, air pollution and heat waves. As part of its capacity building activities, the FMOH has a programme on Industrial Training through attachments to FMOH on climate change and health for students from tertiary institutions.

These health officials should be empowered to design a strategy which can be utilized to distribute drugs to villages especially in areas devoid of any form of development. The capacity building should cover the ability to disseminate preventive and precautionary information in different local languages using appropriate public address systems.

3. Improvement of Water Management Strategies

Increased rainfall resulting from climate change will lead to water pollution and contamination. This usually results in a higher incidence of water borne diseases such as cholera, dysentery, typhoid fever, diarrhoea and filariasis among others. Effective actions designed to adapt to impact of climate change on water resources will reduce the incidence of water borne diseases significantly. Some of the adaptation measures on water management include investments in desalination technology, increased grey water treatment for reuse, rainwater harvesting for everyday human uses other than drinking, and flood control mechanisms to protect water resources from pollution and contamination from overflowing rivers. Adaptation efforts should also focus on how infrastructure can be upgraded to simultaneously manage water for hydropower and human consumption to further scale up the environmental and economic development of communities.

4. Capacity Building and Awareness

Virtually all the communities and people living in Nigeria are affected by the impacts of climate change. However, because of geographical location and characteristics such as age, gender, the surrounding environment, availability of natural resources for food, cultural activities and income, some groups of people have higher level of health risk in Nigeria. People living in these areas should be educated on the impact of climate change on health. An integral part of such training should include how to detect the impending health hazard and precautionary measures to be undertaken to adapt to the impact of climate change on their health. This proactive strategy will significantly reduce loss of lives. FMOH as part of its contribution towards actions to adapt to impacts of climate change has already mapped out a programme that will strengthen health system in order to adapt to climate change. Hence, the FMOH has established State desk offices for climate change and health in most of the 36 State ministries of health and FCT. It also has a plan to establish national country task team for climate change and health. Public education using country profile on climate change and health on FMOH and WHO websites is also part of the awareness programme currently in place by the ministry. With this programme, there will be adequate climate change awareness in all the states of the federation.

4.11. Impacts and vulnerability of Infrastructure

4.11.1. Flood Risk on Infrastructure

Nigeria's economic infrastructure in the social environmental (education, health and housing), productive (agriculture, manufacture, commerce and oil industry), infrastructure (water and sanitation, electricity and transport) and cross-sectoral (environment) are at risk mainly due to flooding. Flooding is one of the major events that have become more frequent, causing widespread damage in Nigeria. Historical spatial and temporal distribution of significant floods in Nigeria is provided in Figure 4.18. The people who live in the riverine and coastal settlement areas are exposed to flooding.

For example, the 2012's flood is characterized as the worst in more than 40 years (NASA, 2012). The NASA's Terra satellite captured images of the confluence of the Niger and Benue Rivers on October 20, 2008 and October 13, 2012, which clearly show flooding of huge areas in the 2012's image (NASA, 2012) (disasters. 8). During the flooding both rivers had burst their banks, engulfing the small lakes and ponds. South of Idah, the Niger River ballooned into a sprawling temporary lake. In the Niger Delta, land use change and poor land use planning have worsened the impact of flood disasters.

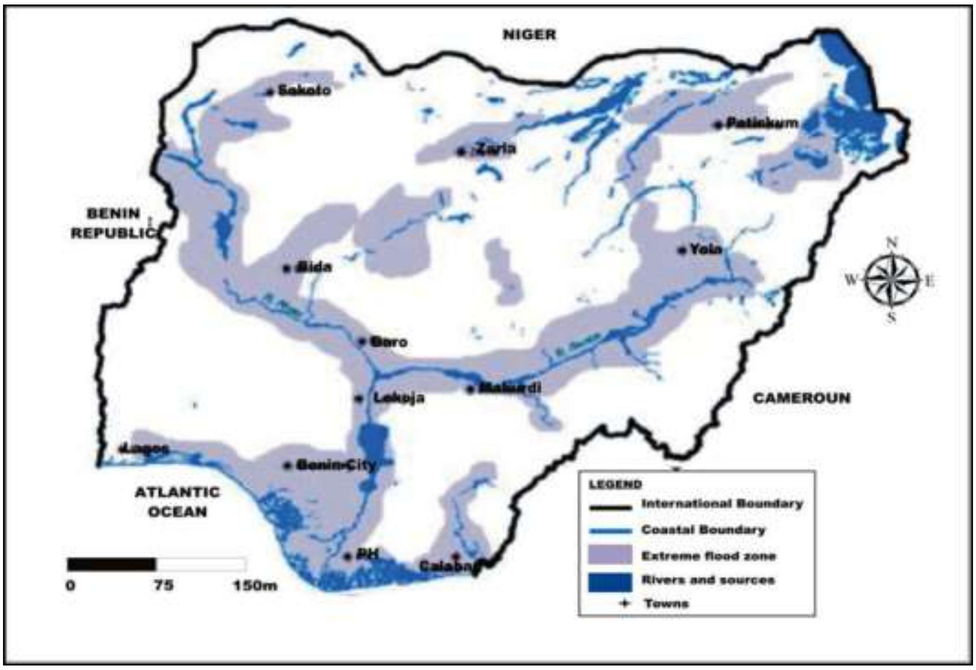


Figure 4.18 - Spatial distribution of areas affected by extreme floods in Nigeria between 2000 and 2012

Source: Federal Ministry of Environment (2012), Adopted from Nkwunonwo, 2016.

4.11.2. Exposed Population

Using the moderate resolution imaging Spectroradiometer (MODIS) data of NASA Terra satellite and geospatial methodology for detecting and extracting the flood risk areas, Nkeki et al. (2013) attempted to assess the spatial impact of the October 2012 flooding of the Niger-Benue basin's surrounding areas. The people who live in the riverine and coastal settlement areas are exposed to flooding. Based on the October 2012 flooding, Table 4.4 shows that the population at risk in Nigeria amounts to a total of about 23 million.

In the flood risk analysis for the Niger-Benue-Basin, Nkeki et al. (2013) found out that very high population concentrated areas are exposed to high flood risk magnitude including Yenegoa (Bayelsa state), Aguata, Nnewi South, and Ogbaru (Anambra state). For example, in Yenegoa there are 302,782 people estimated to be exposed to high flood risk along the Niger-Benue basin in Niger Delta area with 630 km^2 of land susceptible to flooding This area is characterized as high population concentration located in a floodplain.

The city of Lagos is one of the world's mega cities, which is also exposed to flooding. The city is one in the top 20 countries ranked in terms of population exposed to coastal flooding in the 2070s (Nicholls et al., 2007). Currently, about 357,000 people are exposed and by 2070 about 3.2 million people could be at risk due to flooding.

Table 4.4 - Summary of the flood risk analysis by magnitude

Magnitude	Area at Risk (km^2)	Population at Risk
High	31,216	5,909,455
Medium	28,138	5,128,254
Low	110,099	12,072,950
Total	169,453	23,110,659

Source: Nkeki et al. (2013)

4.11.3. Damage and Loss

The Federal Government of Nigeria has conducted extensive post-disaster risk assessments (FGN, 2013). According to the studies, the total value of destroyed physical and durable assets caused by the 2012 floods in the most affected states of Nigeria has been estimated at about ₦1.48 trillion (Nigerian Naira) (Table 4.5) equivalent to US$9.5 billion (FGN, 2013). The summary of damage and losses on Nigeria's critical infrastructures such as education, health, housing, agriculture, manufacture, commerce, oil industry, water and sanitation, electricity, transport and environment by the 2012 floods in Nigeria's most affected states is provided in Table 4.5 with the total damage of about ₦2.6 trillion, or US$16.9 billion. The highest damage has occurred on housing.

Table 4.5 - Summary of Damage and Losses Caused by the 2012 Floods in Nigeria's Most Affected States

Sector	Subsector	Damage	Disaster Effects, million Naira Losses	Total
Social	Education	82,134.60	15,211.20	97,345.80
	Health	18,204.80	9,476.80	7,681.70
	Housing	1,155,959.90	48,869.90	204,829.70
		1,256,299.30	**73,557.90**	**1,329,857.20**
Productive	Agriculture	101,008.20	380,520.80	481,528.90
	Manufacture	21,795.20	74,425.00	96,220.20
	Commerce	18,693.10	357,124.20	375,817.30
	Oil industry	6,500.00	225,000.00	231,500.00
		147,996.50	**1,037,070.00**	**1,185,066.50**
Infrastructure	Water and Sanitation	12,902.20	--	12,902.20
	Electricity	329	8,013.60	8,342.60
	Transport	40,788.40	--	40,788.40
		54,019.60	**8,013.60**	**62,033.20**
Cross-Sectoral	Environment	23,840.20	17,167.00	41,007.20
Total		**1,482,155.60**	**1,135,808.50**	**2,617,964.00**

Source: FGN, 2013. Estimates of the Assessment Team based on official information

As indicated in the climate projections, the results of the high-resolution (30 seconds i.e. ~ 1 km) multi-model ensembles dynamic downscaling analysis of 11 Global Circulation Models (GCMs) of the 5th Phase Coupled Model Inter-comparison project (CMIP5), results indicate an increase in mean annual precipitation for the time series 2050 (2041-2060) and 2070 (2061-2080) for both emission scenarios RCP 4.5 and RCP 8.5 compared to the baseline (1960-1990). Though an in-depth projected flood risk analysis is warranted, the overall picture based on historical and the projected increase of precipitation indicates that Nigeria is exposed to flood risks due to more severe wet seasons.

4.11.4. Adapting Buildings to reduce the Impacts of Climate Change

One of the fundamental functions of building is to protect people from bad weather. When this function is altered by agents of climate, people are susceptible to adverse condition which eventually result in deterioration of health. Apart from this, on-site electricity generation emitted greenhouse gasses, which are injurious to people living in the house, also contribute to global warming. Construction of climate resilient buildings reduces the impact of climate change. This can be achieved by using modern building materials to construct the elements of the building such as using strong roof materials that can withstand heavy winds and storm. The FMOH, as part of its strategies to adapt to climate change, already has a programme that promotes the use of renewable energy for heating and lighting purposes to reduce the impacts of the noxious gases associated with combustion of biomass by households.

4.12. **The Oil sector**

The vulnerability of the oil sector to climate change is potentially high in Nigeria (FME, 2014). Most of the known oil reserves and current oil exploitations in the country are in the coastal region which is experiencing increased flooding associated with climate change. It is expected, with high level of certainty, that coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion due to relative sea level rise (IPCC, 2014 [Chap 5]). This will greatly limit oil production by the large damages to existing oil infrastructures including settlements. This will remain a challenge for Nigeria even as governments make effort to diversify the economy. Figure 4.19 depicts a good example of the impacts of coastal flooding in Nigeria.

Figure 4.19 - Coastal Flooding in a part of Nigeria

4.12.1. Adaptation Strategies

Adaptation strategies for human settlements and physical infrastructures require knowledge of the particular climate vulnerability and the economic, institutional and socio-economic characteristics of the settlement area. In the Nigerian context, some of the adaptation strategies that can be adopted are discussed below.

Proper town and country planning

One of the negative impacts of rural-urban migration is the indiscriminate construction of buildings. Due to the increase in the demand for accommodation, there is building construction in any available land areas. This exposes the buildings, including the residents, to floods and heat waves from overheating of poorly planned construction. Government should reinforce the norms in relation to the impacts of climate change and empower Planning Authorities to regularly verify and inspect buildings under construction to ensure that properties are not developed against planning regulations. In addition, a Planning Enforcement Agency should be created with the mandate to demolish property that are not within the prescribed norms to allow for adaptation to climate change.

4.13. Transportation

4.13.1. Vulnerability of the Sector

An efficient transport sector facilitates economic growth and development of a country. Transportation includes road, rail, air and maritime transport. The effectiveness of any type of transport depends to a large extent on the condition of existing infrastructures. Some of the transport infrastructures in Nigeria include roads network, railways, ports, waterways and airports. Well-functioning transportation infrastructure increases efficiency and reduces cost of moving goods and people and save many man-hours on daily basis. However, transportation infrastructures are impacted by climate change. Highway roads soften and expand due to temperature rise. This can degenerate into potholes and subject bridge joints to stress. In case of floods, traffic is disrupted, construction work delayed and in extreme cases, the entire pavement, culverts and bridges are washed away. Similarly, rail tracks expand due to high temperature while constant and severe heat waves damage rail tracks. Sea level rise, storm surges and flooding damage port infrastructures and disrupts port operations.

4.13.2. Adaptation Strategies

The quality of transportation planning and management determine the effectiveness of the system and its contribution to the country's economic growth. An integral part of management and planning rests on well-articulated actions to adapt to impacts of climate change in the transport sector. Some actions that can be taken to adapt to the impacts of climate change in the transport sector are hereby presented.

1. Develop alternatives to road transportation

Road transport is the most utilized means of transportation in Nigeria. Different vehicles convey people and goods across the country. Concentration on road transportation subject road infrastructures to enormous stress. This is the reason for the deterioration of significant parts of the road network in Nigeria. Construction of railways and procurement of modern and efficient trains will reduce the pressure on road infrastructure. Provision of modern trains with capacity to convey many passengers and large loads of goods to different parts of the country will reduce the pressure on the use of bus, cars and lorries. Another alternative is the water transport which can be promoted by navigating inland rivers in places like Lagos

2. Expansion of major highways

It is undisputed that road transport is the most patronized transport means in Nigeria. All the major highways in Nigeria are under stress daily due to the pressure from very heavy vehicular traffic. A good adaptation action in this case is the expansion of busy highways in Nigeria. The roads should also be maintained periodically. In addition, appropriate drainage systems should be constructed and maintained periodically to reduce flooding of highways.

3. Improvement of road maintenance

The deterioration of major highways is due to inadequate maintenance. Relevant government agencies such as the Federal Ministry of Works, Power and Housing (FMWPH), Federal Emergency Road Maintenance Agency (FERMA) and Public Works Department (PWD) should develop a maintenance policy. This policy should stipulate a maintenance schedule for major highways including the type of materials to be used during the maintenance work.

4.14. Forests and Biodiversity

4.14.1. Vulnerability of forests

Climate change will potentially increase the incidence of pests and diseases that decimate forest trees. This in turn can lead to species extinction in the various ecosystems of Nigeria, as it has already been the case for Iroko and oil bean in the southeast; various mahogany species in southwest; the baobab and the locust bean in the northwest and gum Arabic in the northeast (NEST, 2008b). It is ecologically significant to restore the vegetation cover of the country especially the tropical forest and woodlands because of the huge impacts on the environment and socio-economic activities.

Most of the forest products are consumed directly by the households collecting them. The direct use values of forests come from harvesting of fuelwood and poles for construction of houses and fences, mostly concerning rural households and the consumption of other forest products for craft production, food, medicine and cosmetics. Although there are no quantitative estimates for the country, forest use can contribute significantly to GDP.

In accordance with the study by Reid et al. (2007) the areas with broadleaf woodlands in the southern part of the country are not likely to experience losses due to climate change. Indeed, the potential to use forest products could increase in this area. However, in the more arid zone of the north, potential benefits from climate change might be offset by increases in tree damage from fire.

Forest resources in Nigeria have undergone changes from both natural and human-induced activities. Global climate change is a new challenge as it is having a significant negative impact on this natural resource and weakening its capacity to provide critical ecological resources and services.

The direct and indirect climate change hazards that affect the forest ecosystem include:

(a) Land use change and deforestation.
(b) Drought.
(c) Flooding of low-lying landscapes.
(d) Erosion.
(e) Sea level rise.
(f) Changes in precipitation.
(g) Warmer temperatures; and
(h) Greater intensity and frequency of wildfires.

A discussion of these climate change hazards in the forestry sub-sector is provided below. Forest lands are reportedly being decimated in Nigeria at the rate of 350,000 to 400,000 hectares annually (FME, 2006) even if this is considered unrealistic as at this rate there should no longer exits any forest in the country. However, the lower rate of some 150,000 ha conversion of forests to other land uses such as settlements and agriculture annually is not sustainable in Nigeria. In addition, the loss of forest land is one of the drivers of climate change (IPCC, 2007; Johnston and Williamson, 2007). As land productivity declines, the needs of people can only be met by utilizing and potentially degrading larger areas of forest land to meet their basic needs for timber, fuelwood, and medicine or for occupation.

4.14.2. Drought and Desertification

Most climatic and environmental changes that occur today are manifestations of man's inadvertent modifications of the climate based on his livelihood strategies. Climatic variation in Nigeria is physically evident in drought and desertification, especially in the northernmost states. The former also affects the social and economic structure and framework, and by implication, the survival of the affected population of animals and humans. Desertification affects the people's livelihoods and the people affect desertification. Poverty is a key indicator of desertification. Also, there appears to be a very strong connection between desertification and the pattern of communal clashes in Nigeria. The immediate triggers of agricultural decline and high food prices are traceable to desertification, and the results are manifested in massive migration from rural to urban areas and the struggle and clashes over available land resources such as farmland, grazing land, settlement areas, water, minerals, forests, etc. Massive rural-urban migration results in widespread breakdown of urban infrastructure, crime and the emergence of urban slums, ghettos and squatter settlements. This portrays the social dimensions of desertification.

In Nigeria, drought is a recurring event, particularly in many northern states where there may be longer than normal dry seasons, reduced annual rainfall and a lowering of the groundwater table. States most affected by drought include Sokoto, Kebbi, Taraba, Niger, Kano, Kaduna, Adamawa, Yobe, Jigawa, Borno, Zamfara and Bauchi (NBSAP, 2008). The Federal and States governments currently have programmes that mobilize human and economic resources to combat desertification in drought-prone areas of Nigeria. Drought is often the final blow to government forest reserves in the northern part of Nigeria (over 42,000 km^2 of land). These lands are already degraded by encroachment and poor management, resulting in the loss of some of the only remaining areas of forest cover that provides the habitat for native plant and animal species (FME, 2006). A very significant proportion of Nigeria's remaining forest resources is present as lowland forests, freshwater swamp forests and mangrove forests, typically located in low lying and wetland areas of Nigeria (Ayodele, 1992; FME, 2006). These forests are now more frequently flooded for a longer period each year as a result of more extreme rainfall events. There have been reports of changing forest structure and function, changes in species distribution, inhibited soil biological activity and suppression of root development as a result of flooding of forest ecosystems (Locatelli et al., 2008). Therefore, the impact of flooding on forests is emerging as a significant climate change adaptation and management challenge to forests in Nigeria due to the changing pattern of rainfall and sea level rise.

4.14.3. Adaptation strategies

- Afforesting with suitable indigenous and exotic species. This strategy is applicable nationwide i.e. including the desert threatened environment of the north and the swamps of the coastal areas.
- The second category of options relate to controlling access to the forest. It also involves controlling wildlife population particularly in fragile ecosystems. Access control involves physical fencing and legislation.
- The third approach is socio re-engineering which is to assist local people in developing positive attitudes towards forest resources and their management when communities are made to own the forests and are encouraged to have the right attitude when exploiting the ecosystems. Bush burning and inconsiderate felling of trees can be significantly reduced. The cost is low for an approach of high relevance.

4.14.4. Other adaptation options in the Forestry sector are:

- Provide extension services to CSOs, communities and the private sector to help establish and restore community and private natural forest, plantation and nurseries.
- Strengthen the implementation of the community-based natural forest resources management programme. The department of Forestry of the Federal Ministry of Agriculture and Rural Development is responsible for the full implementation of this option.

- Develop and maintain a frequent forest inventory system to facilitate monitoring of forest status and initiate a research programme on a range of climate related topics, including long term impacts of climate shifts on closed forest.

4.15. Wetlands

4.15.1. Vulnerability of Wetlands

Wetlands are water bodies in the terrestrial or semi-terrestrial ecosystem characterized with low drainage, organic soils, and usually typical plant species. Wetlands are very important and valuable components of the terrestrial ecosystem. There are different wetlands in the world and Nigeria owns one of the internationally recognized wetlands which was the first registered as a Ramsar site. In Nigeria, the Hadejia-Nguru wetlands is a wide expanse of floodplain wetlands, which is situated in the North-East. It is located in the Sudanosahelian zone, which is between the Sudan Savanna in the south and the Sahel in the north. Some of the activities carried out on the Hadejia-Nguru wetlands include fishing, agriculture and tourism. There are different challenges facing wetlands globally, some of which are pollution, over intensification of agriculture activities, industrialization and urbanization. Some of the challenges in wetlands are due to insufficient monitoring and lack of sustainability measures and awareness of the inhabitants. The promulgation of legislations and establishment of thrusts could empower individuals and corporate organisations to intervene and help meeting the challenges.

4.15.2. Adaptation Strategies

The changing state of wetlands requires urgent responses and the following strategies could be adopted.

1. Provide frequent artificial flooding downstream of earth dams.

Wetlands are degrading because of the decrease in floodwater downslope of earth dams. For instance, the famous Hadejia-Nigeria wetland complex is being impacted by reduced seasonal flooding due to water storage upstream. One option is to release water for artificial flooding downstream from time to time. This will concurrently provide a solution to the incessant flooding that is being experienced in that area.

2. Switch to short-lived hardy crops

As soil water level drops in many wetlands, switching to short-lived hardy crops could be an excellent option that the farmer can consider. The option is suitable across the country. Its cost is low once the variant of crops to be grown are identified. The responsible agencies are research institutes, extension workers and the community.

3. Management and regulation of water flows

Wherever feasible, recharging wetlands with alternative sources of water should be attempted. This can be achieved by building more small reservoirs or mining water from boreholes located around the wetlands. The option is good, but the cost is high. Responsible agencies are river basin authorities, NGOs and the communities.

4.16. Tourism

4.16.1. Vulnerability

Developing countries such as Nigeria are said to be more vulnerable to the effects of climate change with little capacity to adapt due to low level of awareness, insufficient human and financial resources as well as institutional and technological capability, (Okoli and Ewah, 2004). For tourism, climate change is not a remote event, but a phenomenon that already affects the sector and certain destinations, mountain regions and coastal destinations among others. This is due to the adverse impacts of climate change reflecting the many species of plants and animals rapidly becoming extinct, the decreasing tree density and floristic richness, the disruption and reduction of the fruiting intensity of some trees and the changes in the migratory patterns of birds and other animals.

Results of research conducted by Ijeoma and Aiyeloja (2009) on the impact of climate change in Jos Plateau state, Nigeria, have revealed that climate change can destabilize ecosystems, reduce tourism patronage, cause shifts in tourist destinations, death and migration of wild life species, flooding of eco-destinations that disrupts the scheduling of events like sighting of games and fixed dates for cultural events. It has been observed that climate change has resulted in changed rainfall patterns which has contributed to increase damage to roads across the country. Heavy downpours have created large potholes on many roads. The poor state of the roads can cause a shift in tourist destination and participation.

4.16.2. Adaptation strategies

Mass tree planting to conserve the natural environment

Tree planting creates an ecosystem providing habitat and food for birds and other animals while embellishing the landscape. This could attract more tourists and promote ecotourism. The Federal Environmental Protection Agency is responsible for tree planting, a high priority, across the country.

Producing and promoting environmentally friendly products

This option will help in achieving sustainable tourism development and make Nigeria a preferred tourism destination. The Department of Domestic and Eco-Tourism Promotion and Control has the responsibility of making this option a reality.

Tourists and the local resident's participation in environment friendly tourism activities

The effective participation of tourists and residents in environmentally friendly tourism will ensure their maximum involvement in tourism as a support for conservation of the natural environment.

4.17. Other adaptation issues

4.17.1. Vulnerable Groups and the Gender issue

Certain socio-economic and demographic groups exhibit particular vulnerability in the face of climate change. These include women and female heads of household, children and the elderly, the chronically sick and indigenous people.

Aguilar (2008) observed that women in developing societies are more vulnerable to environmental change because they are very often socially excluded and lack equal access to resources, culture and mobility. An analysis in 141 countries showed that gender differences in deaths from natural disasters are directly linked to women's lack of economic and social rights (Neumayer and Pluemper, 2007). In the specific context of Nigeria, women are more vulnerable to the effects of climate change than men because they constitute the majority of the country's poor and are more dependent for their livelihood on natural resources that are threatened by climate change.

Access to housing is inadequate and urban service delivery of facilities such as water, electricity, sewage and waste disposal represent severe problems. Women in a typical rural setting in Nigeria compared to their male counterparts are reported to have limited technical skills required to acquire employment or generate income. Additionally, they have limited access to capital, productive land, knowledge and services. These factors decrease resilience and adaptive capacities of men and women differently (Angula and Menjolo, 2014).

Children, the elderly and chronically sick people also typically exhibit high levels of vulnerability. This arises from their physiological sensitivity: for example, children are most sensitive to cholera and diarrhoea exposure and the compromised immune system of people living with HIV/AIDS can increase their sensitivity to other diseases, such as tuberculosis and heat stress. They also typically have a low adaptive capacity through high levels of dependence on others for their survival, including their food security, mobility, and access to information. Another angle is added to the vulnerability of women to climate change impacts when they happen to be family heads.

4.17.1.1. Adaptation Strategies

Zumba Case Study (Agwu and Okhimamhe, 2009)

To cope with the changing climate, women in Zumba community in Niger State have resorted to the use of maize or guinea corn stalk after harvesting for cooking in the absence of fuel wood. Though the consequential smoking arising from this exercise affects the aroma and taste of the food, there is also need to keep the fire kindled throughout the cooking duration to avoid smoking. This prevents the woman from attending to other activities or as an alternative, the task is assigned to the girl child (the automatic choice for a helper). In addition, even though the Zumba community is close to the Shiroro dam, drinking water is increasingly becoming scarce. To cope, the women must either purchase a drum of water from the tankers owned by Power Holding Company of Nigeria Limited (PHCN) or queue up for hours to fetch water from the only functional borehole in the community. This borehole is used on a rotational basis, that is, each woman is allocated a particular time (like an informal timetable) to fetch water, and if her supply gets exhausted before her next allocated slot, she has to find an alternative. This could be to purchase from or exchange with another woman. For other household usage of water, they have two options: a stream for use in the rainy season as it dries up during the dry season and a pond containing harvested rainwater for use in the dry season. These are not enough for the community. The problem is further compounded by the fact that there are no dug-out wells in the village.

4.17.1.2. Capacity Building on Climate Change Risks and Opportunities

Climate change experts should organize training for decision makers of industries and capacitate staff on the concept of climate change, its negative impacts on industrial activities and opportunities such as the Green Climate Fund. This training will enable industries to be proactive in addressing impacts of climate change in their organization. Also, the industries can come together under an association to apply for grant or loan under the Green Climate Fund to execute sustainable projects.

4.17.1.3. Incorporate Climate Change into on-going Business Planning.

Creating a climate change department in the industrial sector is a very good tool to adapt to impacts of climate change in the sector. This department will formulate policy which will be used to adapt to impacts of climate change. In this way, each industry will develop its climate change policy to address any issue resulting from climate change

4.17.1.4. Promote Market Emerging Opportunities from Climate Change

Many business opportunities abound in Nigeria within the context of adaptation to climate change. Different professionals such as the Engineers, Bankers, Insurance Brokers etc. can be fully engaged in climate change related projects. Government agency like the Federal Ministry of Information should work closely with climate change experts to educate all the economy sectors in the country on their relevance to climate change

5. Other Information Considered Relevant to the Achievement of the Objective of the Convention

5.1. Introduction

This chapter looks at the mélange of interconnected phenomena which have implications on the mitigation of, and adaptation to impacts of climate change in Nigeria. These include factors such as technology needs and transfer, education, training and public awareness, research and systematic observation, information and networking and gender amongst others. It also adds value with project proposals for climate change adaptation and mitigation. These items are treated on a stand-alone basis or collectively whenever they are closely linked.

5.2. Science, Technology and Innovation

Developing countermeasures to address the cause and impacts of climate change in Nigeria is a strategy that can only be achieved with the rolling out of appropriately engineered and technological mitigation and adaptation strategies. Research and development; improved knowledge on climate change concepts; and access to technology via technology transfer or any other means will enhance capacity to mitigate and adapt. This section provides an overview of technology transfer, the set of processes involving the deployment of knowledge, experiences and equipment for tackling climate change effectively. The speed at which information on climate change experienced in different parts of the world and learning from such experiences can be useful for disseminating early warning signs that can be shared on mobile devices. This is a simple example of the relevance of the discussion of technology transfer as a cross-cutting issue.

5.2.1. Technology Transfer for Climate Change Mitigation and Adaptation

The world of technology has undergone tremendous advances which has successfully improved our lifestyle and work environment over time. These advances in technology nurture new concepts that give birth to efficient innovative strategies and designs, which have since extended to combating climate change. New technologies are required to slow down the rate of GHG emissions. However, the level of access to or need for all technologies available to combat climate change varies from country to country due to a myriad of factors. An example is that the ramifications of climate change vary between countries and continents. As such, the strategies applied to some countries may not necessarily work in others. Another reason is the uncertainty of the projected impacts of climate change at any given period. The correlation between technology transfer and economic growth has also been established (Barton, 2008).

5.2.1.1. The Nature of Technology Transfer

It has been reported that apart from reducing emissions, technological innovations do help also in adaptation to climate change. Thus, the adoption and transmission of technology between and among nations and non-state actors is very critical in responding to the impacts of climate change.

Technology transfer has been recognized globally for its critical role in responding to the challenges of climate change. This is emphasized in Article 4.5 of the UNFCCC which states that: "*The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention.*"

There are different modes of technology transfer. These include:

(i) The transfer of skills and expertise in the areas of licensing or assistance with the purchase of proprietary knowledge, provision of technical and manual skills training; scientific and academic training; training and technical advice and assistance.
(ii) Access to scientific and technical information and data, namely blueprints; publications and reports; manuals; designs and operating instructions among others.
(iii) Transfer of ability to adapt and improve the technology such as establishment of research and development facilities in the country in which the technology will be transferred.
(iv) Creation of joint Research and Development (R&D) projects; and
(v) Transfer of physical capital and goods, including specialized equipment; goods embodying or incorporating the relevant technology or idea (Shabalala, 2014).

5.2.1.2. Technology transfer within the Nigerian context

The Federal Ministry of Science and Technology (FMST) has the mandate for dealing with technology related issues in Nigeria. The vision of the FMST is '*to make Nigeria one of the renowned nations in the world in the science and technology field*'. The mission of FMST is to facilitate the development and deployment of science and technological tools to enhance the pace of socio-economic development of the country. The interrelated components of the mandate of the FMST have implications for climate change and vice-versa. These include the formulation, monitoring and review of the National Policy on Science, Technology and Innovation to attain the macro-economic and social objectives of the policy direction of government as it relates to science and technology; the acquisition and application of Science, Technology and Innovation to increase agricultural and livestock productivity; increasing energy reliance through sustainable R&D in nuclear, renewable and alternative energy sources for peaceful and developmental purposes; promotion of wealth creation through support to key industrial and manufacturing sectors; and the creation of a technology infrastructure and knowledge base to facilitate its wide application for development. Other areas needing technology transfer are related to the application of natural medicine resources and technologies for the development of the health sector; the acquisition and application of Space Science and Technology as a key driver of economic development; and ensuring the adoption of R&D results in the Nigerian economy through the promotion of indigenous research capacity to facilitate country-relevant technology transfer.

In this era of emerging technologies worldwide where countries are beginning to co-operate on solving cross-border issues on climate change, Nigeria created the National Office for Technology Acquisition and Promotion (NOTAP). This agency provides an enabling environment for actual and potential researchers and investors to initiate strategies that could assist Nigeria in achieving her vision on science and technology. Technology transfer is one of the emerging issues where Nigeria requires support for the effective implementation of initiatives towards meeting the targets of the SDGs. The needs are primarily in the areas of data production and information collection on performance (Federal Government of Nigeria (2017).

5.2.1.3. National Office for Technology Acquisition and Promotion (NOTAP)

NOTAP is the agency of the Federal Ministry of Science and Technology with the responsibility for nurturing national talents by harnessing the potential for ideas, inventions, innovations and creative works towards technological advancement and global competitiveness. NOTAP creates an enabling environment and initiates strategies to protect all stakeholders, researchers and investors alike, and their creative works. Thus, the Agency undertakes activities that can lead to the realization of its vision, mission and objectives. These include:

- Evaluation/Registration of Technology Transfer Agreements (new, renewal and extension agreements).

- Promotion of Intellectual Property Rights.
- Technology Advisory and Support Services.
- Commercialization of R&D /Inventions.
- Research Industry Linkage.
- Maintenance of a Compendium of R&D activities in the country; and
- Production and Publication of Industrial Project Profiles on SMEs.

Some of the achievements of NOTAP so far include:

- The development of technology transfer agreements.
- Intellectual Property Rights awareness.
- Creation of a Patent Information and Documentation Centre (PIDC).
- The establishment of thirty-nine (39) Intellectual Property Technology Transfer Offices (IPTTOs) in Universities, Polytechnics and Research Institutions, to:
    - Promote interaction and strengthen the linkage between University/Research Institutions and Industries.
    - Develop a robust intellectual Property Right portfolio through patenting, copyright, technology licensing.
    - Support the Institution's initiative in developing patent culture; and
    - Set in motion the formal system of incentives and reward that encourages individual researcher to involve in partnerships (See www.notap.gov.ng).

It is expected that, with the enhanced capacity of NOTAP and continued government support, the Agency will be the multi-purpose vehicle of government for the efficient and effective transfer of technology beneficial to deal with climate change in the future. This would go a long way in attracting foreign technologies and investments, in addition to the development of indigenous technologies.

5.2.2. Encumbrances to technology transfer in Nigeria

Some of the identified challenges and barriers to technology transfer in Nigeria are:

Inadequate awareness on available technologies

Sometimes there is a disconnect between state and non-state actors on what is available and what is not. This communication gap between the two sectors makes it difficult for the country to achieve the proper balance in technology transfer.

Low capacity

Inadequate capacity and the required skill necessary to effectively manage technology transfer.

Poor Perception of Commercial Applications

Most of the citizens are not aware of the value and right application of the available technologies.

Intellectual Property Rights

The rights associated with innovative technology can prove detrimental to the climate change cause because some companies may choose not to disclose the information.

Understanding the Innovation Process

Lack of understanding of the complexity of the innovation process can lead to incorrect analysis when determining some basic information concerning appropriate technology related to climate change.

Funding

Not all institutions, organizations and agencies serving the purpose of combating climate change have the available funding to make this happen. This, in turn, would steer the country in the direction of low productivity.

Tariffs

Tariff rates have the potential to increase the cost of technology transfer, thus creating an unfavourable environment for an effective process.

Bureaucratic Barriers

Bureaucratic processes associated with technology transfer can be challenging. Concerns about conflict of interest, legal concerns and other factors can cause a significant delay and legal expense to the customer at the receiving end of the technology transfer, which can cause partnership pull out of negotiations.

The failure of companies to follow the due process in adaptation of foreign technology within the transfer agreements, makes Nigeria lose over ₦30 billion to unsuccessful technology transfer annually. If not well addressed, some of these barriers have the potential to create a negative effect on technology transfer.

The two most critical factors are discussed further below:

5.2.2.1. Intellectual property right (IPR)

Intellectual Property Right (IPR) is a set of rights associated with creations of the human mind. Essentially, by the creation of a programme or product, an individual or group indirectly create an intellectual property which can be licensed or sold. The establishment of the World Intellectual Property Organization (WIPO) is an important milestone in the history of humankind that recognizes the legitimate rights of the creators on their work (UNESCO, 2015). IPR is an instrument that plays a major role in climate change because it creates an environment for a smoother process in technology transfer between intellectual property owners and final consumers. It seems that intellectual property rights are not a major issue with regards to technology transfer in Nigeria. This is due to the activities of NOTAP as described in 5.2.1.3., born out of the realization of the need to strike a balance between the rights of inventors and creators to protection, and the rights of users of technology. However, the agency is encouraged to undertake research on the advantages and disadvantages of IPRs in developed and developing nations to underscore its role in the transfer of technology that supports mitigation and adaptation actions. This can further the understanding of how IPRs can be both an incentive and obstacle to technology transfer.

5.2.2.2. Tariffs and trade barriers

A tariff is a tax or duty imposed on a product when it crosses national boundaries. An example is tax imposed on imported and exported goods. When dealing with technology transfer related to the transfer of physical goods across countries, a tariff cannot be avoided. However, the tariff imposed for some goods acquired may discourage the buyer, and thus the transfer of the particular technology. It is imperative therefore to have a deeper understanding of this as it will assist in our negotiations for climate change technology transfer. To determine this, a basic knowledge of tariffs and how it applies in international trade is critical. A predictive model can be created based on the data generated from research to determine a range of values for tariff rates which can be tested against actual values for errors to update the mode.

5.2.3. Critical sectors needing technology transfer

Technology transfer is of relevance to all sectors in Nigeria but the level of importance varies from one sector to another. The strategic sectors can appropriate the technologies provided from these transfers and implement them to combat climate change.

A potential list of sectors having a more urgent need for technology transfer include, but are not limited to the following:

Healthcare

The relationship has been established between healthcare activities and GHG emissions worldwide. In the United States of America and the EU countries for instance, this accounts for between 3 – 8% of emissions (WHO, 2015). It is expected that this would be much higher in Nigeria where there is limited electricity access and hospitals and clinics are heavily reliant on diesel generators. Therefore, availability of appropriate technology to ensure low carbon energy will ensure resilience as well as mitigation. Additionally, the technology transfer will help in the prevention and treatment of diseases and illnesses associated with the effects of climate change.

Weather Forecasting

Availability of up-to-date modern weather forecasting technology allows for a more efficient and accurate monitoring of the changes in different weather-related variables over time, which enables a better understanding of the patterns of climate change. Up to date equipment is also very helpful for medium and long-range weather forecasting for prevention of the negative impacts of climate change on economic activities. They also strongly support risk management.

Agriculture

The complex presentation of the two-way relationship of climate change and agriculture in a developing country like Nigeria cannot be glossed over. It has been established that agriculture is both a victim of, and a contributor to climate change. Nigeria depends heavily on rainfed agriculture, which makes the activities in the sector directly dependent on and affected by climatic conditions. Conversely, agriculture affects the climate through GHG emissions such as carbon dioxide, methane and nitrous oxide. According to reports, agriculture currently contributes about 14 % to GHG emissions (6.8 Gt of CO_2) annually all around the world. However, it has also been documented that agriculture has the potential to mitigate between 5.5 – 6 Gt of CO_2 per annum, especially in developing countries, through the widespread adoption of mitigation and adaptation actions. The transfer of appropriate technology would enhance these actions.

Energy

Globally, about 4.3 million premature deaths are recorded annually from cardiovascular and respiratory diseases as a result of household air pollution (WHO, 2015). The use of solid fuels such as wood and charcoal contributes to such diseases as ischaemic heart disease, lung cancer, stroke, childhood pneumonia, coronary artery disease, and so on. It is therefore essential to source technologies that reduce black carbon and support the development of cleaner energy sources and lower emission transition fuels.

Transportation

The transport sector has one of the largest energy demands and by implication, is one of the largest contributor of GHG emissions around the world. Available data show that 14% of global GHG emissions is attributed to the transport sector (WHO, 2015). Technology transfer is therefore required to develop climate-smart technologies to improve the transportation infrastructure. Adoption of the latest cleaner vehicles is warranted to reduce emissions and the health risks associated with it.

Manufacturing, Industry and Commerce

This sector induces climate change as it depends on climate-sensitive resources. For instance, offshore oil and gas operations; construction; transportation operations, tourism and recreation, road infrastructure, energy production and transmission, thermal power generation contribute to and suffer from changing climatic conditions. It is therefore essential that this vital sector of the economy benefits from climate-resilient technologies that help mitigate the impact of climate change on the sector and vice-versa, as well as engender adaptation plans.

5.3. Education, Training, and Public Awareness

The level of public awareness is a causative factor for vulnerability and poor adaptation to impacts, as well as mitigation of climate change. It has been established over time that the level of awareness of the climate change phenomenon is still low in Nigeria as with other developing nations. Citizens are mostly not aware of changing climatic patterns and their consequences. They also have little appreciation of their contribution and vulnerability to climate change impacts. As presently designed, national educational curricula across the education sector are not yet ready to provide education to the tune required to fill that gap and prepare the population. As well, significant segments of the population are not aware enough of climate change and their role to minimize the impacts and be resilient. Thus, a significant majority do not have required knowledge and information on mitigation and adaptation measures. For instance, there is empirical data from studies around the country showing that farmers have low knowledge of the contribution of agriculture to GHG emissions and consequently to climate change. They did not also possess adequate knowledge of human and technological investments to address the impacts. As such, most farming and conservation practices still aggravate ecosystems' vulnerability (Dimelu et al., 2014). Furthermore, it is essential to develop an integrated information framework that highlights local and global environmental challenges to critical stakeholders responsible for policy decision-making to facilitate timely response to the impacts of climate change while contributing in their daily life to mitigation of climate change.

Education plays a major role in addressing climate-change related challenges. An increase in climate-literacy amongst the population, especially among young people, fosters a change of attitude and behaviour whilst mitigating and adapting to the impacts and consequences of climate change. Increasing knowledge and raising public awareness to engender climate-friendly attitudes, resources and measures to reduce vulnerability and increase resilience are very critical to facilitating effective climate change mitigation and adaptation strategies.

The Ministry of Information and the National Orientation Agency design and undertake public awareness campaigns in English and local languages on the radio, national television, and print media. The Department of Climate Change located in the Federal Ministry of Environment also undertakes public awareness programmes and supports local and international training of relevant stakeholders. Civil society organizations such as the Nigerian Red Cross Society (NRCS), the Nigeria Environmental Study/Action Team (NEST), Nigerian Conservation Foundation (NCF), play active roles in raising local awareness; encouraging community members to undertake practical climate change adaptation actions; assisting with the interpretation of early warning information for appropriate and timely action.

As articulated in policy documents such as the National Strategic Plan of Action; Climate Change Policy Response and Strategy; Nigeria's INDC; National Policy on Environment 2016, among others, the following are some of the proposals by the national government for educating, training and improving public awareness of the nation on climate change:

- Provision of evidence-based information for continuous implementation of a sustained public awareness and education programme on climate change risks, adaptation options, and opportunities.
- Dissemination of information on climate change in all its ramifications by traditional and new media via print and electronic channels. This will include programming on state as well as community radio and TV stations in English and local languages, publishing climate information in newspapers, on social media platforms, etc.
- Provision of support for development of skills-based curriculum at all levels of the education system. This is aimed at empowering young people to be aware of the threats of climate change and be equipped with effective response strategies. This would involve the integration of climate change issues language, social studies, geography, science and technology and environmental studies, among others.
- Investment in school-based programmes and projects aimed at helping children and students better respond to the threats posed by climate change.
- Encouraging universities to address climate change mitigation and adaptation in academic programmes and in operations.
- Organizing training for teachers on techniques for teaching climate change mitigation and adaptation at all levels of education; and
- Undertaking mobilization and outreach activities to improve awareness of climate change mitigation and adaptation.

5.4. Research and Systematic Observation

Various academic institutions, research centres as well as agencies have the responsibility for conducting relevant research and observations on climate change mitigation and adaptation including disaster reduction and management to complement local indigenous knowledge for early warning capacities. These include the University of Ibadan; Ahmadu Bello University in Zaria; Obafemi Awolowo University, Ile-Ife; Federal University of Technology, Akure; and the National Centre for Arid Zone Studies, Maiduguri. Other institutions include the National Oil Spill Detection and Response Agency (NOSDRA); National Space Research and Development Agency (NASRDA); University Linkage Centre for Climate Change, Minna and National Centre for Remote Sensing, Jos, among others.

Civil Society organisations and networks such as the Environmental Rights Action (ERA); CEE-Hope; West Africa Civil Society Network; Friends of the Earth (FoE); Women Environmental Programme (WEP) and Nigerian Environmental Study/Action Team (NEST) also contribute to mapping vulnerabilities, enhancing capacity; advocating political will and commitment; adapting the way we live; adopting climate-smart technologies; ensuring water and food security; and developing effective response mechanisms for tackling climate change.

It is important to note that these state and non-state actors often work independently of one another instead of working collectively to ensure that Nigerians can deal with issues of vulnerability, mitigation and adaptation of climate change in an integrated manner. Thus, more effort should be put into fostering collaboration between and among stakeholders having similar objectives.

5.5. The Gender and Social Inclusion Dimensions of Climate Change

The vulnerability of any segment of the population to climate change depends largely on some inter-related factors, which determine the extent of exposure to climate change; sensitivity to its impacts and the capacity for adapting to these changes (Yila et al., 2014). These factors include gender; economic, social and political status; access to and control over resources and so forth.

Gender is the ensemble of an individual's life's experience in any given society as determined by his or her sex. It simply means how being male or female shapes a person's realities, namely what is valued, what is appropriate, what is allowed, what is available and what is expected. This varies from one community to another, stemming from cultural, legal, socioeconomic and religious constructs of that society. Consequently, the different roles and responsibilities as well as needs, access to opportunities and resources as well as the contribution of men and women in social and political lives are determined by their societies. These different roles and responsibilities also present opportunities for introducing productive alternatives into their different surroundings and within the development efforts of those societies.

As with other patriarchal societies, Nigerian women and men are conditioned to interact with the environment in different ways based on their needs, deriving from their pre-determined social roles and responsibilities. They are also affected by the impacts of climate change in different ways, with women more disproportionately affected. Closely linked to gender is social inclusion, defined as "the process of improving the terms of participation in society for people who are disadvantaged on the basis of age, sex, disability, race, ethnicity, origin, religion, or economic or other status, through enhanced opportunities, access to resources, voice and respect for rights" (United Nations, 2016). It aims to address issues of unequal power relations by seeking to make all groups of people within a society feel valued and important. Poverty, prejudices and discrimination are major drivers of exclusion. Therefore, social, political and economic inequalities are closely linked to gender as they limit women's capacity for coping with climate change impacts. Thus, gender is a major factor to consider when analysing vulnerability to the impacts of climate change as well as the adaptive capacity and the ability to mitigate those impacts.

5.5.1. Gender Issues in Vulnerability and Adaptation

According to UNDP (2007), "gender inequalities intersect with climate risks and vulnerabilities. Women's historic disadvantage such as their limited access to resources, restricted rights and a muted voice in shaping decisions, make them highly vulnerable to climate change. The nature of that vulnerability varies widely, cautioning against generalization. But climate change is likely to magnify existing patterns of gender disadvantage."

In both urban and rural settings around the country, vulnerabilities to climate change are influenced by the culturally assigned roles of both sexes in the society. Discriminatory cultural and socio-economic factors influence Nigerian women's gendered experiences significantly and make them more vulnerable to poverty. As a result of this, they make up a large proportion of about 69% of the country's poor people with a high level of susceptibility to climate change impacts. Nigerian women have lower incomes; lower decision-making power; limited or total lack of control over assets and resources including credit among other indices for measuring poverty. Furthermore, due to societal constructs, the support for the education of women is at a low, thus resulting in a population of women that are left with no option or opportunities to find medium to high-income jobs. Similarly, more men than women have access to agricultural extension services.

Environmental degradation exacerbates poverty and vice-versa. As is the case elsewhere, poor people in Nigeria depend mostly on the environment, especially the ecosystem services, for their sustenance and livelihood. Social and economic inequality make women more economically disadvantaged than men. Unequal household division of labour places the carer and nurturer burdens firmly on the shoulders of women. In situations of food crisis, women are saddled with dealing with under-nutrition and the attendant risk of diseases which has implications for women's already heavy workload. To function in this capacity, women undertake actions that degrade the environment, such as using GHG emitting resources such as fuelwood for household energy needs like cooking, lighting and other productive activities to cope with energy poverty, thereby contributing to deforestation. For instance, in the face of natural disasters, women's gendered roles as caregivers, coupled with their responsibilities for the very young and the very old as well as their task of generating solutions to food insecurity, deriving from socioeconomic instability engineered by natural disasters, make them resort to alternatives that vitiate the environment, even though they suffer more from the impacts of climate change. For example, 97% of female respondents in a recent study reported the use of biomass related energy types especially fuelwood. Only 3% have and use kerosene stoves as an alternative energy type. The dependence on the use of biomass related energy are attributed to: (1) availability- 43%; (2) combustibility - 29%; (3) affordability - 16%; (4) efficiency – 6%; and (5) other reasons - 5%.

Women are more susceptible to natural disasters like floods and droughts among other impacts of climate change. Data from a recent study in Anambra State in the South-East geopolitical zone put the vulnerability index for women at 0.62 while that of men was at 0.32, placing the women at a higher vulnerability to flooding. The study observed that gender-based vulnerability to climate change was higher in farm households in Onitsha, a more urban area compared to Awka and Anambra towns. The report further explains the reasoning behind this, "as urban agriculture is practiced by the poor" (Enete et al., 2016).

It is important to note however, that women are literally in the front lines when it comes to climate change. They contribute to national efforts to mitigate and adapt to climate change through hands-on intervention or as campaigners or researchers. This also presents an opportunity to involve them actively in the implementation of solutions. However, as with all spheres of life, Nigerian women are not sufficiently integrated when key decisions relating to climate change mitigation and adaptation are taken.

5.5.2. Gendered responses for mitigation and adaptation plans

There are plausible gendered approaches to adapting to the effects of climate change. These solutions revolve around creating a support system that constantly keeps people in the sphere of climate change events. Some of the adaptation strategies include: adapting agricultural practices: switching to other crops, animals or other cropping systems; saving food, seeds and animals; changing diets and food habits; water-saving practices, including rainwater harvesting; use of traditional medicines and application of other preventive or alternative methods; reducing impact on local forests, reforestation efforts among others (NEST, 2011). In addition, there are capacity building initiatives aimed at bridging the gender gap by empowering young women in the areas of energy management, green energy sources, climate change awareness and building of solar panels. It is anticipated that they will become advocates of renewable energy and future leaders in the energy sector.

The policy statements listed in the box below provide the response of the Nigerian government as contained in the National Policy on the Environment of 2016 for the promotion of a gender-responsive approach to the significant impacts of climate change on vulnerable groups.

Nigerian government National Policy on the Environment (2016)

Policy Statements

The government will:

1) Ensure gender is always mainstreamed into environmental concerns.
2) Promote review of related environmental policies and acts to include gender concerns.
3) Provide incentives for environmental programmes and initiatives that target under-represented gender and other vulnerable groups.
4) Facilitate full participation of women, men, girls and boys and other vulnerable groups in the decision-making processes in environmental governance and management.
5) Ensure the participation of women and other vulnerable groups across all sections of society in environmental trainings, public awareness and sensitization campaigns.
6) Continue to support the implementation of the country's gender policy.

5.6. Environmental Security and Climate Change

Environmental security is a critical component of human security that is fast gaining ground as a field of interest. The seven established indicators for environmental security are:

1. The proportion of the population using an improved drinking water source.
2. The proportion of population using an improved sanitation facility.
3. The proportion of land covered by forests.
4. Total annual rainfall.
5. Total amount of gas flared.
6. CO_2 emissions; and
7. Number of internally displaced persons due to disasters.

As noted by UNDP in its 2016 National Human Development Report for Nigeria, extreme volatility in energy and food prices, water and food supply crises, rising greenhouse gas emissions, severe income disparity, terrorism, and chronic fiscal imbalances are some of the most serious development challenges in the world today, and they are all environment-related, whether directly or indirectly. In Nigeria and elsewhere, these factors contribute significantly to poverty and conflict-induced migration which increases competition for resources due to scarcity and unsuitability of land and water to produce food and fuel, in addition to human settlement. These effects of environmental insecurity are triggers for adverse climate change (UNDP 1994).

The Environmental Performance Index (EPI) of 2014 ranked Nigeria 134 out of 178 countries. To improve the poor status of environmental security, the Nigerian government has integrated the environmental dimensions of the Sustainable Development Goals (SDGs) into its 2017 National Economic Recovery and Growth Plan (ERGP), with the objectives of;

- Promoting sustainable management of natural resources.
- Addressing severe land degradation and desertification issues.
- Attracting financing for projects on sustainable development.
- Reducing gas flaring by 2 % points a year so that it is eliminated by 2020; and
- Installing an additional 3,000 MW of solar systems over the next four years

5.7. Mainstreaming Strategies for Climate Change Mitigation and Adaptation

Given the significance of the effects of climate change to all facets of life, it is essential to integrate the phenomenon as a cross-cutting issue into national development plans. In Nigeria, it is essential to put in place extensive adaptation and mitigation measures in order to reduce vulnerability and reduce GHG emissions. Apart from the focused policy documents on climate change such as the National Climate Change Policy and Response Strategy, the National Adaptation Strategy and Plan of Action (NASPA), additional efforts are required to mainstream climate change into all sectors of the national development. The Economic Recovery and Growth Plan 2017 – 2020 addresses issues of climate change in relation to environmental sustainability. The policy objectives and key activities within the single strategy "Take targeted action to address environmental priorities are detailed in Table 5.1.

Table 5.1 - Objectives and activities for environmental protection

Policy Objectives	Key activities
• Promote sustainable management of natural resources • Address severe land degradation and desertification. • Attract financing for sustainable development projects. • Reduce gas flaring by 2 percentage points a year so that it is eliminated by 2020. • Install 3,000 MW of solar systems over the next 4 years. • Increase the number of households transiting from kerosene to cooking gas (LPG) to 20 per cent by 2020. • Increase the number of households switching from kerosene lanterns to solar lamps by 20 per cent by 2020.	• Implement projects under the Great Green Wall initiative to address land degradation and desertification, and support communities adapt to climate change (e.g., plant trees) • Implement environmental initiatives in the Niger Delta region (e.g., continue the Ogoni Land clean-up and reduce gas flaring) • Raise a Green Bond to finance environmental projects • Establish one forest plantation in each state • Rehabilitate all forest reserves and national parks to enhance eco-tourism • Establish a functional database on drought and desertification • Encourage and promote the development of green growth initiatives

Integrating climate change mitigation and adaptation concerns into planning underscores the need for urgent action to address medium to long term impacts of climate change because:

- Many actions that will strengthen longer-term climate resilience will also help reduce vulnerability to current climate swings.
- Investment decisions that will soon be made about long-lived, and expensive infrastructure, such as irrigation or hydropower, will determine how resilient these investments will be to the harsher climate of the future; and
- Building the knowledge, capacity, institutions, and policies needed to deal with the climate of the future takes time (Federal Government of Nigeria, 2013).

In view of the enormity of the climate change challenges, Nigeria would still need support to enable a coherent and strategic approach to be taken for greater effectiveness.

5.8. Climate Finance

It has been established that funding of mitigation and adaptation measures to cope with the challenges engineered by climate change has not received enough attention over the years. With the understanding that climate change is undeniably one of the most critical challenges of the 21st Century, climate finance is very critical to protecting the environment and addressing the impacts of climate change. As noted in the 2016 National Policy on the Environment, despite Nigeria's strong predisposition to severe negative impacts of climate change due to its fragile economy, weak resilience and low adaptive capacity, the country has so far been able to access only US$77.2 million of climate funds from global flows to implement climate change adaptation and mitigation initiatives and projects, compared to South Africa's US$600.1 million (www.climatefundsupdate.org).

It is crucial that Nigeria funds actions that will drive adaptation and mitigation plans in order to ensure climate-resilient economic growth; overcome energy deficiency; and facilitate the restoration of environmental health. According to the Minister of State for Environment, Ibrahim Jibril in his presentation of Nigeria's progress report on the climate change goal under the SDGs at the UN in September 2017, Nigeria will require an estimated US$10 billion annually to meet her INDC ambition under the Climate Change Accord. This means that about US$142 billion is required for adaptation and mitigation actions to meet the 2035 target. A fundamental re-orientation of financial flows within the economy is expedient for the delivery of Nigeria's INDC in the future.

To fast-track implementation of climate-smart initiatives, the government instituted the first sovereign green bond in Nigeria and indeed in Africa in the third quarter of 2017 as one of the strategies for raising funds for implementing climate change initiatives. A collaborative project between the Federal Ministries of Environment and Finance, leveraging on relationships with relevant partners, the pilot issue of ₦12.384 billion out of a total of ₦150 billion in total (about US$400 million).

Concerted efforts have been made since 2015 to fund the implementation of the recommendation of the UN Environment Programme report of 2011 to ensure the environmental clean-up of the Niger Delta region starting with Ogoniland. Similarly, the Ministry of Budget and Planning has incorporated efforts to realise all the seventeen (17) Sustainable Development Goals (SDGs) into the national budgetary framework, starting from 2017. This is necessary for the linkages between the global development goals and the Economic Recovery and Growth Plan of the government.

Furthermore, there is a plan to establish a national funding entity known as the National Strategic Climate Change Trust Fund (NSCCTF) with non-refundable contribution from bilateral and multilateral donors, to act as a catalyst for implementing financing mechanisms for climate change adaptation and mitigation initiatives. The Fund, through the Bank of Industry (BoI) will coordinate Nigeria's climate change financing.

It is expected that the level of funding for climate change received by Nigeria will improve considerably in the years ahead to trigger efficient and effective adaptation and mitigation actions in the short to medium term (www.climatechange.gov.ng).

5.9. Capacity Building for Early Warning Systems to Mitigate Climate Change Consequences

Having effective early warning systems for coping with climate change risks are essential for the protection of all that make up the environment, minimize death, damage and displacement, while at the same time limiting the economic impact significantly. Available reports show that most developing nations do not have effective early warning systems. A significant proportion (over 80%) only has a basic early warning system while some do not have any system at all (CREWS Initiative, 2015).

It has been documented that there is no systematic and automated process for developing and disseminating information on early warning signs for natural disasters in Nigeria. Presently, multiple agencies are trying to set up early warning systems. NiMET, the first meteorological agency in Africa to be ISO 9001 certified in 2015, provides weather forecasts and seasonal rainfall predictions, which inform early warning alerts for climate-related disaster threats across the country. The density of observation is sparse as NiMET has only 54 network stations. The agency is however working towards increasing the spread of observation stations across the country to one AWS per 100 square kilometres in line with World Meteorological Organization guidelines. The West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) donated 10 Automatic Weather Stations (AWS) to NiMET in 2017 in furtherance of this resolve.

The National Emergency Management Agency (NEMA) on the other hand has engaged in establishing an early warning system for epidemics. However, there is no effective system for specific natural disasters, which trigger or are triggered by climate change, neither are there systematic nor clear standard operating procedures or dissemination of alerts to communities most at risk (Federal Government of Nigeria, 2013).

The enormous impact of climate change on the environment and the economy cannot be overemphasized. Given the critical role of early warning systems, improving capacity for early warning systems among major stakeholders in Nigeria is of essence. It is therefore imperative to build capacity in that area to help the people recognise and express signs of impending flood, drought, coastal erosion, desertification, as well as the implications of risky environmental practices.

5.10. Potential areas for project development

Initiate research to establish the linkages of climate change factors in poverty, insurgencies and conflict-induced migration.

Develop a Monitoring, Evaluation and Learning (MEL) framework to assess the ability of policies and measures to increase resilience, facilitate social inclusion, improve livelihood security, and reduce emissions.

6. References

Abubakar, I. U. (2013). Recurrence of Drought in Nigeria: Causes, Effects and Mitigation. *International Journal of Agriculture and Food Science Technology, IV*(3), 169-180.

CIA. (2019). *Africa :: Nigeria — The World Factbook - Central Intelligence Agency*. Retrieved March 12, 2019, from Central Intelligence Agency: https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html

DCC. (2017). *Department of Climate Change*. Retrieved from Department of Climate Change Federal Ministry of Environment: http://climatechange.gov.ng/about-us/department-of-climate-change/

Downie, D. (2017). *Growing the Agriculture Sector in Nigeria.* CSIS. Washington, DC: Center for Strategic & International Studies.

EnviroNews Nigeria. (2019, February 04). *Lagos community at mercy of Atlantic Ocean (in photos) - EnviroNews Nigeria* -. Retrieved from EnviroNews Nigeria: https://www.environewsnigeria.com/lagos-community-at-mercy-of-atlantic-ocean-in-photos/

Emodi EE (2013). Drought and Dsertification as they affect Nigerian Environment. J. Environ. Manage. Saf. 4(1): 45-54

FAO. (2016). *AQUASTAT database Database Query Results*. Retrieved March 12, 2019, from Food and Agriculture Organisation of the United Nations: http://www.fao.org/nr/water/aquastat/data/query/results.html?regionQuery=false&showCodes=true&yearRange.fromYear=1960&yearRange.toYear=2015&varGrpIds=4150,4151,4154,4155,4156,4157,4158,4159,4160,4161,4162,4164,4165,4166,4167,4168,4169,4170,4171,4172,4173,

FAO. (2018). *FAOSTAT*. Retrieved March 12, 2019, from Food and Agriculture Organisation of the United Nations: http://www.fao.org/faostat/en/#data/QA

Federal Government of Nigeria. (2016). *Economy*. Retrieved July 18, 2017, from Federal Republic of Nigeria: http://www.nigeria.gov.ng/index.php/2016-04-06-08-38-30/economy

Federal Government of Nigeria. (2017). Retrieved June 15, 2017, from Federal Republic of Nigeria: http://www.nigeria.gov.ng/

Federal Government of Nigeria. (2017). *Federal Republic of Nigeria*. Retrieved June 15, 2017, from http://www.nigeria.gov.ng/

IDPM. (2014, February 04). *WS6-Nigeria_EN.pdf.* Retrieved from Integrated Droight Management Programme: http://www.droughtmanagement.info/wp-content/uploads/2016/10/WS6-Nigeria_EN.pdf

IPCC. (2007). *Climate Change 2007:Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson eds.* Cambridge UK: Cambridge University Press.

Keay, R. W. (1989). *Trees of Nigeria.* Oxford: Clarendon Press.

Mathews, M. P. (2002). *Nigeria: Current Issues and Historical Background.* New York: Nova Publishers.

National Population Commission of Nigeria. (2017). *NIGERIA'S POPULATION NOW 182 MILLION*. Retrieved July 08, 2017, from National Population Commission of Nigeria: http://www.population.gov.ng/

NBS. (2016). *Nigerian Gross Domestic Product Report Q4 2016.* National Bureau of Statistics, Nigeria. Abuja, Nigeria: NBS.

NBS. (2017). *Annual Abstract of Statistics 2016 (Vols 1 & 2).* National Bureau of Statistics, Nigeria. Abuja, Nigeria: NBS.

NBS. (2018). *Demographic Statistics Bulletin 2017.* National Bureau of Statistics, Nigeria. Abuja, Nigeria: NBS.

Nigeria. Federal Ministry of Environment. (2014). *Nigeria's second National Communication under the United Nations Framework Convention on Climate Change.* Abuja: Federal Ministry of Environment.

Nigeria. FMoH. (2010). *National Strategic Health Development Plan (NSHDP) 2010 - 2015.*

Nkwunonwo, U. C. (2016). A Review of Flooding and Flood Risk Reduction in Nigeria. *Global Journal of HUMAN-SOCIAL SCIENCE: Geography, Geo-Sciences, Environmental Science & Disaster Management, Volume 16* (Issue 2 Version 1.0), 23-42.

NPC. (2017, May 14). *NIGERIA'S POPULATION NOW 182 million-NPC*. Retrieved from National Population Commission: http://population.gov.ng/nigerias-population-now-182-million-npc/

NRGI. (2016). *Country Strategy Note Nigeria.* Retrieved from Learn more at www.resourcegovernance.org

Obioha, E. (2009). Climate Variability, Environment Change and Food Security Nexus in Nigeria. *J Hum Ecol, 26(2)*, 107-121.

OEC. (n.d.). *OEC - Nigeria (NGA) Exports, Imports, and Trade Partners*. Retrieved January 09, 2019, from OEC: . https://atlas.media.mit.edu/en/profile/country/nga/

OEC. (2018). OEC: (OEC - Nigeria (NGA) Exports, Imports, and Trade Partners). Retrieved January 09, 2019, from https://atlas.media.mit.edu/en/profile/country/nga/

Emodi EE (2013). Drought and Dsertification as they affect Nigerian Environment. J. Environ. Manage. Saf. 4(1): 45-54

Olagunju, T. .. (2015, July). Drought, desertification and the Nigerian environment:A review. *Journal of Ecology and the Natural Environment, Vol. 7*(7), 196-209. Retrieved from http://www.academicjournals.org/JENE

Vanguard. (2016, November 10). *Nigeria's population now 182 million NPC*. Retrieved from Vanguard: https://www.vanguardngr.com

WHO. (2015). *World Health Statistics 2015.* Luxembourg.

World Bank. (2018 a). *Data for Nigeria, Lower middle income | Data*. Retrieved January 08, 2019, from The World Bank: https://data.worldbank.org/?locations=NG-XN

World Bank. (2018b). *Nigeria Overview*. Retrieved January 08, 2019, from The World Bank: https:// www.worldbank.org/en/country/nigeria/overview

World Bank. (2018c). *Nigeria Data*. Retrieved January 21, 2019, from The World Bank: https://data.worldbank.org/country/nigeria

Annex 1 – Summary and Sectoral tables of estimate of emissions from the IPCC 2016 software

Table A.1 - Short Summary Table (Inventory Year: 2016)

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)					Emissions (Gg)			
Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
Total National Emissions and Removals	444668.708	6170.385	114.636	0	0	0	0	0	428.59	9231.248	1745.358	57.877
1 - Energy	124021.5523	3762.25	11.044	0	0	0	0	0	413.682	8966.997	1723.547	57.368
1.A - Fuel Combustion Activities	119416.7268	603.6751	10.9756						403.017	8920.051	1427.387	56.614
1.B - Fugitive emissions from fuels	4604.825508	3158.575	0.0684						10.665	46.946	296.16	0.754
1.C - Carbon dioxide Transport and Storage	0								0	0	0	0
2 - Industrial Processes and Product Use	13254.9185	0.582062	0	0	0	0	0	0	0.00052	0.000052	0.873	0
2.A - Mineral Industry	7083.3477	0	0						0	0	0	0
2.B - Chemical Industry	1.70935765	0	0	0	0	0	0	0	0.00052	0.000052	0	0
2.C - Metal Industry	6169.86144	0.582062	0	0	0	0	0	0	0	0	0.873	0
2.D - Non-Energy Products from Fuels and Solvent Use	0	0	0						0	0	0	0
2.E - Electronics Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.F - Product Uses as Substitutes for Ozone Depleting Substances				0	0			0	0	0	0	0
2.G - Other Product Manufacture and Use	0	0	0	0	0	0	0	0	0	0	0	0
2.H - Other	0	0	0						0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	307320.4401	1639.953	80.5628	0	0	0	0	0	0.19251	5.911646	0	0
3.A - Livestock		1311.698	5.46835						0	0	0	0
3.B - Land	311608.6447		0						0	0	0	0
3.C - Aggregate sources and non-CO_2 emissions sources on land	0	328.2549	75.0945						0.19251	5.911646	0	0
3.D - Other	-4288.204679	0	0						0	0	0	0
4 - Waste	71.79710214	767.5994	23.0287	0	0	0	0	0	14.7146	258.3392	20.93791	0.509
4.A - Solid Waste Disposal		145.2606							0	0	15.24635	0
4.B - Biological Treatment of Solid Waste		0	0						0	0	0	0

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)				Emissions (Gg)				
Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
4.C - Incineration and Open Burning of Waste	71.79710214	30.0771	0.39563						14.7146	258.3392	5.69151	0.509
4.D - Wastewater Treatment and Discharge		592.2617	22.6331						0	0	0.00005	0
4.E - Other (please specify)	0	0	0						0	0	0	0
5 - Other	0	0	0	0	0	0	0	0	0	0	0	0
5.A - Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3			0						0	0	0	0
5.B - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items (5)												
International Bunkers	1311.312933	0.015015	0.03653	0	0	0	0	0	6.8151	0.5988	0.2573	0.8417
1.A.3.a.i - International Aviation (International Bunkers) (1)	1241.269029	0.00868	0.03472						5.0388	0.433	0.1968	0.3937
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	70.043904	0.006335	0.00181						1.7763	0.1658	0.0605	0.448
1.A.5.c - Multilateral Operations (1)(2)	0	0	0	0	0	0	0	0	0	0	0	0

Table A.2 - Summary Table (Inventory Year: 2016)

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)					Emissions (Gg)			
Categories	**Net CO_2 (1)(2)**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**Other halogenated gases with CO_2 equivalent conversion factors (3)**	**Other halogenated gases without CO_2 equivalent conversion factors (4)**	**NOx**	**CO**	**NMVOCs**	**SO_2**
Total National Emissions and Removals	444668.708	6170.385	114.636	0	0	0	0	0	428.59	9231.248	1745.358	57.877
1 - Energy	124021.5523	3762.25	11.044	0	0	0	0	0	413.682	8966.997	1723.547	57.368
1.A - Fuel Combustion Activities	119416.7268	603.6751	10.9756	0	0	0	0	0	403.017	8920.051	1427.387	56.614
1.A.1 - Energy Industries	54488.55777	10.17664	1.32713						108.913	64.08	4.679	6.164
1.A.2 - Manufacturing Industries and Construction	11544.87226	3.62286	0.46688						43.64	75.838	42.536	2.877
1.A.3 - Transport	37771.44292	14.4118	1.62054						132.163	1350.23	250.068	8.8502
1.A.4 - Other Sectors	15611.85385	575.4638	7.56109						118.301	7429.903	1130.104	38.723
1.A.5 - Non-Specified	0	0	0						0	0	0	0
1.B - Fugitive emissions from fuels	4604.825508	3158.575	0.0684	0	0	0	0	0	10.665	46.946	296.16	0.754
1.B.1 - Solid Fuels	0	0	0						0	0	0	0
1.B.2 - Oil and Natural Gas	4604.825508	3158.575	0.0684						10.665	46.946	296.16	0.754
1.B.3 - Other emissions from Energy Production	0	0	0						0	0	0	0
1.C - Carbon dioxide Transport and Storage	0	0	0	0	0	0	0	0	0	0	0	0
1.C.1 - Transport of CO_2	0								0	0	0	0
1.C.2 - Injection and Storage	0								0	0	0	0
1.C.3 - Other	0								0	0	0	0
2 - Industrial Processes and Product Use	13254.9185	0.582062	0	0	0	0	0	0	0.00052	0.000052	0.873	0
2.A - Mineral Industry	7083.3477	0	0	0	0	0	0	0	0	0	0	0
2.A.1 - Cement production	7083.3477								0	0	0	0
2.A.2 - Lime production	0								0	0	0	0
2.A.3 - Glass Production	0								0	0	0	0
2.A.4 - Other Process Uses of Carbonates	0								0	0	0	0
2.A.5 - Other (please specify)	0	0	0						0	0	0	0
2.B - Chemical Industry	1.70935765	0	0	0	0	0	0	0	0.00052	0.000052	0	0
2.B.1 - Ammonia Production	1.70935765								0.00052	0.000052	0	0
2.B.2 - Nitric Acid Production			0						0	0	0	0
2.B.3 - Adipic Acid Production			0						0	0	0	0

Categories	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)					Emissions (Gg)			
	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO_2
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			0						0	0	0	0
2.B.5 - Carbide Production	0	0							0	0	0	0
2.B.6 - Titanium Dioxide Production	0								0	0	0	0
2.B.7 - Soda Ash Production	0								0	0	0	0
2.B.8 - Petrochemical and Carbon Black Production	0	0							0	0	0	0
2.B.9 - Fluorochemical Production				0	0	0	0	0	0	0	0	0
2.B.10 - Other (Please specify)	0	0	0	0	0	0	0	0	0	0	0	0
2.C - Metal Industry	6169.86144	0.582062	0	0	0	0	0	0	0	0	0.873	0
2.C.1 - Iron and Steel Production	6169.86144	0.582062							0	0	0.873	0
2.C.2 - Ferroalloys Production	0	0							0	0	0	0
2.C.3 - Aluminium production	0				0			0	0	0	0	0
2.C.4 - Magnesium production	0					0		0	0	0	0	0
2.C.5 - Lead Production	0								0	0	0	0
2.C.6 - Zinc Production	0								0	0	0	0
2.C.7 - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0
2.D - Non-Energy Products from Fuels and Solvent Use	0	0	0	0	0	0	0	0	0	0	0	0
2.D.1 - Lubricant Use	0								0	0	0	0
2.D.2 - Paraffin Wax Use	0								0	0	0	0
2.D.3 - Solvent Use									0	0	0	0
2.D.4 - Other (please specify)	0	0	0						0	0	0	0
2.E - Electronics Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.E.1 - Integrated Circuit or Semiconductor				0	0	0	0	0	0	0	0	0
2.E.2 - TFT Flat Panel Display					0	0	0	0	0	0	0	0
2.E.3 - Photovoltaics					0			0	0	0	0	0
2.E.4 - Heat Transfer Fluid					0			0	0	0	0	0
2.E.5 - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	0	0	0	0	0	0	0	0	0
2.F.1 - Refrigeration and Air Conditioning				0				0	0	0	0	0

Categories	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)				Emissions (Gg)				
	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
2.F.2 - Foam Blowing Agents				0				0	0	0	0	0
2.F.3 - Fire Protection				0	0			0	0	0	0	0
2.F.4 - Aerosols				0				0	0	0	0	0
2.F.5 - Solvents				0	0			0	0	0	0	0
2.F.6 - Other Applications (please specify)				0	0			0	0	0	0	0
2.G - Other Product Manufacture and Use	0	0	0	0	0	0	0	0	0	0	0	0
2.G.1 - Electrical Equipment					0	0		0	0	0	0	0
2.G.2 - SF_6 and PFCs from Other Product Uses					0	0		0	0	0	0	0
2.G.3 - N_2O from Product Uses			0						0	0	0	0
2.G.4 - Other (Please specify)	0	0	0	0	0	0	0	0	0	0	0	0
2.H - Other	0	0	0	0	0	0	0	0	0	0	0	0
2.H.1 - Pulp and Paper Industry	0	0							0	0	0	0
2.H.2 - Food and Beverages Industry	0	0							0	0	0	0
2.H.3 - Other (please specify)	0	0	0						0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	307320.4401	1639.953	80.5628	0	0	0	0	0	0.19251	5.911646	0	0
3.A - Livestock	0	1311.698	5.46835	0	0	0	0	0	0	0	0	0
3.A.1 - Enteric Fermentation		1252.4							0	0	0	0
3.A.2 - Manure Management		59.29866	5.46835						0	0	0	0
3.B - Land	311608.6447	0	0	0	0	0	0	0	0	0	0	0
3.B.1 - Forest land	311608.6447								0	0	0	0
3.B.2 - Cropland	0								0	0	0	0
3.B.3 - Grassland	0								0	0	0	0
3.B.4 - Wetlands	0		0						0	0	0	0
3.B.5 - Settlements	0								0	0	0	0
3.B.6 - Other Land	0								0	0	0	0
3.C - Aggregate sources and non-CO_2 emissions sources on land	0	328.2549	75.0945	0	0	0	0	0	0.19251	5.911646	0	0
3.C.1 - Emissions from biomass burning		0.179354	0.0069						0.19251	5.911646	0	0
3.C.2 - Liming	0								0	0	0	0
3.C.3 - Urea application	0								0	0	0	0

	Emissions (Gg)			Emissions CO_2 Equivalents (Gg)					Emissions (Gg)			
Categories	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
3.C.4 - Direct N_2O Emissions from managed soils			55.8828						0	0	0	0
3.C.5 - Indirect N_2O Emissions from managed soils			18.0184						0	0	0	0
3.C.6 - Indirect N_2O Emissions from manure management			1.18632						0	0	0	0
3.C.7 - Rice cultivations		328.0756							0	0	0	0
3.C.8 - Other (please specify)		0	0						0	0	0	0
3.D - Other	-4288.204679	0	0	0	0	0	0	0	0	0	0	0
3.D.1 - Harvested Wood Products	-4288.204679								0	0	0	0
3.D.2 - Other (please specify)	0	0	0						0	0	0	0
4 - Waste	71.79710214	767.5994	23.0287	0	0	0	0	0	14.7146	258.3392	20.93791	0.509
4.A - Solid Waste Disposal	0	145.2606	0	0	0	0	0	0	0	0	15.24635	0
4.B - Biological Treatment of Solid Waste	0	0	0	0	0	0	0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	71.79710214	30.0771	0.39563	0	0	0	0	0	14.7146	258.3392	5.69151	0.509
4.D - Wastewater Treatment and Discharge	0	592.2617	22.6331	0	0	0	0	0	0	0	0.00005	0
4.E - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0
5 - Other	0	0	0	0	0	0	0	0	0	0	0	0
5.A - Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3	0	0	0	0	0	0	0	0	0	0	0	0
5.B - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0
Memo Items (5)												
International Bunkers	1311.312933	0.015015	0.03653	0	0	0	0	0	6.8151	0.5988	0.2573	0.8417
1.A.3.a.i - International Aviation (International Bunkers) (1)	1241.269029	0.00868	0.03472						5.0388	0.433	0.1968	0.3937
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	70.043904	0.006335	0.00181						1.7763	0.1658	0.0605	0.448
1.A.5.c - Multilateral Operations (1)(2)	0	0	0	0	0	0	0	0	0	0	0	0

Table A.3 - Energy Sectoral Table (Inventory Year: 2016)

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1 - Energy	124021.552	3762.25	11.044	413.682	8966.997	1723.547	57.368
1.A - Fuel Combustion Activities	119416.727	603.6751	10.976	403.017	8920.051	1427.387	56.614
1.A.1 - Energy Industries	54488.5578	10.17664	1.3271	108.913	64.08	4.679	6.164
1.A.1.a - Main Activity Electricity and Heat Production	45068.496	0.80336	0.0803	68.914	30.198	2.013	0.218
1.A.1.a.i - Electricity Generation	45068.496	0.80336	0.0803	68.914	30.198	2.013	0.218
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				0	0	0	0
1.A.1.a.iii - Heat Plants				0	0	0	0
1.A.1.b - Petroleum Refining	987.159141	0.034604	0.0066	0.858	0.111	0.015	2.607
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	8432.90263	9.33868	1.2401	39.141	33.771	2.651	3.339
1.A.1.c.i - Manufacture of Solid Fuels		9.188361	1.2251	24.697	27.441	2.229	3.293
1.A.1.c.ii - Other Energy Industries	8432.90263	0.150319	0.015	14.444	6.33	0.422	0.046
1.A.2 - Manufacturing Industries and Construction	11544.8723	3.62286	0.4669	43.64	75.838	42.536	2.877
1.A.2.a - Iron and Steel				0	0	0	0
1.A.2.b - Non-Ferrous Metals				0	0	0	0
1.A.2.c - Chemicals				0	0	0	0
1.A.2.d - Pulp, Paper and Print				0	0	0	0
1.A.2.e - Food Processing, Beverages and Tobacco				0	0	0	0
1.A.2.f - Non-Metallic Minerals				0	0	0	0
1.A.2.g - Transport Equipment				0	0	0	0
1.A.2.h - Machinery				0	0	0	0
1.A.2.i - Mining (excluding fuels) and Quarrying				0	0	0	0
1.A.2.j - Wood and wood products				0	0	0	0
1.A.2.k - Construction				0	0	0	0
1.A.2.l - Textile and Leather				0	0	0	0
1.A.2.m - Non-specified Industry				43.64	75.838	42.536	2.877
1.A.3 - Transport	37771.4429	14.4118	1.6205	132.163	1350.23	250.068	8.8502
1.A.3.a - Civil Aviation	122.75213	0.000858	0.0034	0.321	0.062	0.003	0.311
1.A.3.a.i - International Aviation (International Bunkers) (1)							
1.A.3.a.ii - Domestic Aviation	122.75213	0.000858	0.0034	0.321	0.062	0.003	0.311
1.A.3.b - Road Transportation	36112.9949	14.26037	1.5464	124.128	1131.324	180.812	0.103
1.A.3.b.i - Cars	22180.932	10.47426	1.0256	57.663	553.667	65.709	0.066
1.A.3.b.i.1 - Passenger cars with 3-way catalysts				57.663	553.667	65.709	0.066
1.A.3.b.i.2 - Passenger cars without 3-way catalysts				0	0	0	0
1.A.3.b.ii - Light-duty trucks	6752.96319	2.370046	0.3247	25.478	218.807	21.339	0.019
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts				25.478	218.807	21.339	0.019
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts				0	0	0	0
1.A.3.b.iii - Heavy-duty trucks and buses	4844.64855	0.30442	0.0883	36.379	13.446	2.573	0.011
1.A.3.b.iv - Motorcycles	2334.4511	1.111643	0.1078	4.608	345.404	91.191	0.007
1.A.3.b.v - Evaporative emissions from vehicles				0	0	0	0
1.A.3.b.vi - Urea-based catalysts	0			0	0	0	0
1.A.3.c - Railways	74.782461	0.004188	0.0289	0.892	0.182	0.08	0.0002
1.A.3.d - Water-borne Navigation	1460.91347	0.146379	0.0418	6.822	218.662	69.173	8.436
1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.3.d.ii - Domestic Water-borne Navigation	1460.91347	0.146379	0.0418	6.822	218.662	69.173	8.436
1.A.3.e - Other Transportation				0	0	0	0
1.A.3.e.i - Pipeline Transport				0	0	0	0
1.A.3.e.ii - Off-road				0	0	0	0
1.A.4 - Other Sectors	15611.8538	575.4638	7.5611	118.301	7429.903	1130.104	38.723
1.A.4.a - Commercial/Institutional	2328.46754	22.45201	0.2786	14.01	47.784	24.538	2.909

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1.A.4.b - Residential	13226.5495	553.0041	7.282	103.989	7382.027	1105.547	35.722
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	56.8367886	0.007729	0.0005	0.302	0.092	0.019	0.092
1.A.4.c.i - Stationary	14.1085056	0.001962	0.0001	0.174	0.053	0.011	0.053
1.A.4.c.ii - Off-road Vehicles and Other Machinery	42.728283	0.005766	0.0003	0.128	0.039	0.008	0.039
1.A.4.c.iii - Fishing (mobile combustion)				0	0	0	0
1.A.5 - Non-Specified				0	0	0	0
1.A.5.a - Stationary				0	0	0	0
1.A.5.b - Mobile				0	0	0	0
1.A.5.b.i - Mobile (aviation component)				0	0	0	0
1.A.5.b.ii - Mobile (water-borne component)				0	0	0	0
1.A.5.b.iii - Mobile (Other)				0	0	0	0
1.A.5.c - Multilateral Operations (1)(2)							
1.B - Fugitive emissions from fuels	4604.82551	3158.575	0.0684	10.665	46.946	296.16	0.754
1.B.1 - Solid Fuels	0	0		0	0	0	0
1.B.1.a - Coal mining and handling	0	0		0	0	0	0
1.B.1.a.i - Underground mines	0	0		0	0	0	0
1.B.1.a.i.1 - Mining	0	0		0	0	0	0
1.B.1.a.i.2 - Post-mining seam gas emissions	0	0		0	0	0	0
1.B.1.a.i.3 - Abandoned underground mines				0	0	0	0
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO_2	0	0		0	0	0	0
1.B.1.a.ii - Surface mines	0	0		0	0	0	0
1.B.1.a.ii.1 - Mining	0	0		0	0	0	0
1.B.1.a.ii.2 - Post-mining seam gas emissions	0	0		0	0	0	0
1.B.1.b - Uncontrolled combustion and burning coal dumps				0	0	0	0
1.B.1.c - Solid fuel transformation				0	0	0	0
1.B.2 - Oil and Natural Gas	4604.82551	3158.575	0.0684	10.665	46.946	296.16	0.754
1.B.2.a - Oil	4580.30322	2092.407	0.0682	0.254	0.095	276.294	0.657
1.B.2.a.i - Venting	0.22904848	1.102683		0	0	233.661	0
1.B.2.a.ii - Flaring	4314.45169	2.663242	0.0682	0	0	2.46	0
1.B.2.a.iii - All Other	265.622489	2088.641	2E-06	0.254	0.095	40.173	0.657
1.B.2.a.iii.1 - Exploration	0	0		0	0	0	0
1.B.2.a.iii.2 - Production and Upgrading	265.2597	2087.988	0	0	0	0	0
1.B.2.a.iii.3 - Transport	0.36278854	0.57526	2E-06	0	0	7.834	0
1.B.2.a.iii.4 - Refining	0	0.078		0.254	0.095	0.212	0.657
1.B.2.a.iii.5 - Distribution of oil products	0	0		0	0	32.127	0
1.B.2.a.iii.6 - Other				0	0	0	0
1.B.2.b - Natural Gas	24.522283	1066.168	0.0002	10.411	46.851	19.866	0.097
1.B.2.b.i - Venting	0.23122761	17.431		0	0	4.82	0
1.B.2.b.ii - Flaring	12.387942	0.007787	0.0002	10.411	46.851	13.386	0.097
1.B.2.b.iii - All Other	11.9031134	1048.729	0	0	0	1.66	0
1.B.2.b.iii.1 - Exploration	0	0		0	0	0	0
1.B.2.b.iii.2 - Production	7.63070385	958.9513		0	0	0.061	0
1.B.2.b.iii.3 - Processing				0	0	0	0
1.B.2.b.iii.4 - Transmission and Storage	0.0258255	9.737294		0	0	0.403	0
1.B.2.b.iii.5 - Distribution	4.24658403	80.04033		0	0	1.196	0
1.B.2.b.iii.6 - Other				0	0	0	0
1.B.3 - Other emissions from Energy Production				0	0	0	0
1.C - Carbon dioxide Transport and Storage	0			0	0	0	0
1.C.1 - Transport of CO_2	0			0	0	0	0
1.C.1.a - Pipelines	0			0	0	0	0
1.C.1.b - Ships	0			0	0	0	0
1.C.1.c - Other (please specify)	0			0	0	0	0
1.C.2 - Injection and Storage	0			0	0	0	0

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1.C.2.a - Injection	0			0	0	0	0
1.C.2.b - Storage	0			0	0	0	0
1.C.3 - Other	0			0	0	0	0

	Emissions (Gg)						
Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
Memo Items (3)							
International Bunkers	1311.31293	0.015015	0.0365	6.8151	0.5988	0.2573	0.8417
1.A.3.a.i - International Aviation (International Bunkers) (1)	1241.26903	0.00868	0.0347	5.0388	0.433	0.1968	0.3937
1.A.3.d.i - International water-borne navigation (International bunkers) (1)	70.043904	0.006335	0.0018	1.7763	0.1658	0.0605	0.448
1.A.5.c - Multilateral Operations (1)(2)				0	0	0	0
Information Items							
CO_2 from Biomass Combustion for Energy Production	256090.834						

Table A.4 - IPPU Sectoral Table (Inventory Year: 2016)

Categories	(Gg)			CO_2 Equivalents (Gg)					(Gg)			
	Net CO_2 (1)(2)	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	NO_x	CO	NMVOCs	SO_2
2 - Industrial Processes and Product Use	13254.918	0.5820624	0	0	0	0	0	0	0.00052	0.000052	0.873	0
2.A - Mineral Industry	7083.3477	0	0	0	0	0	0	0	0	0	0	0
2.A.1 - Cement production	7083.3477								0	0	0	0
2.A.2 - Lime production	0								0	0	0	0
2.A.3 - Glass Production	0								0	0	0	0
2.A.4 - Other Process Uses of Carbonates	0	0	0	0	0	0	0	0	0	0	0	0
2.A.4.a - Ceramics	0								0	0	0	0
2.A.4.b - Other Uses of Soda Ash	0								0	0	0	0
2.A.4.c - Non-Metallurgical Magnesia Production	0								0	0	0	0
2.A.4.d - Other (please specify) (3)	0								0	0	0	0
2.A.5 - Other (please specify) (3)									0	0	0	0
2.B - Chemical Industry	1.7093577	0	0	0	0	0	0	0	0.00052	0.000052	0	0
2.B.1 - Ammonia Production	1.7093577								0.00052	0.000052	0	0
2.B.2 - Nitric Acid Production			0						0	0	0	0
2.B.3 - Adipic Acid Production			0						0	0	0	0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			0						0	0	0	0
2.B.5 - Carbide Production	0	0							0	0	0	0
2.B.6 - Titanium Dioxide Production	0								0	0	0	0
2.B.7 - Soda Ash Production	0								0	0	0	0
2.B.8 - Petrochemical and Carbon Black Production	0	0	0	0	0	0	0	0	0	0	0	0
2.B.8.a - Methanol	0	0							0	0	0	0
2.B.8.b - Ethylene	0	0							0	0	0	0
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer	0	0							0	0	0	0
2.B.8.d - Ethylene Oxide	0	0							0	0	0	0
2.B.8.e - Acrylonitrile	0	0							0	0	0	0
2.B.8.f - Carbon Black	0	0							0	0	0	0
2.B.9 - Fluorochemical Production	0	0	0	0	0	0	0	0	0	0	0	0
2.B.9.a - By-product emissions (4)				0					0	0	0	0
2.B.9.b - Fugitive Emissions (4)									0	0	0	0
2.B.10 - Other (Please specify) (3)									0	0	0	0
2.C - Metal Industry	6169.8614	0.5820624	0	0	0	0	0	0	0	0	0.873	0
2.C.1 - Iron and Steel Production	6169.8614	0.5820624							0	0	0.873	0
2.C.2 - Ferroalloys Production	0	0							0	0	0	0

	(Gg)			CO_2 Equivalents (Gg)					(Gg)			
Categories	**Net CO_2 (1)(2)**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**Other halogenated gases with CO_2 equivalent conversion factors (3)**	**Other halogenated gases without CO_2 equivalent conversion factors (4)**	**NO_x**	**CO**	**NMVOCs**	**SO_2**
2.C.3 - Aluminium production	0				0				0	0	0	0
2.C.4 - Magnesium production (5)	0					0			0	0	0	0
2.C.5 - Lead Production	0								0	0	0	0
2.C.6 - Zinc Production	0								0	0	0	0
2.C.7 - Other (please specify) (3)									0	0	0	0
2.D - Non-Energy Products from Fuels and Solvent Use (6)	0	0	0	0	0	0	0	0	0	0	0	0
2.D.1 - Lubricant Use	0								0	0	0	0
2.D.2 - Paraffin Wax Use	0								0	0	0	0
2.D.3 - Solvent Use (7)									0	0	0	0
2.D.4 - Other (please specify) (3), (8)									0	0	0	0
2.E - Electronics Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.E.1 - Integrated Circuit or Semiconductor (9)				0	0	0		0	0	0	0	0
2.E.2 - TFT Flat Panel Display (9)					0	0		0	0	0	0	0
2.E.3 - Photovoltaics (9)					0				0	0	0	0
2.E.4 - Heat Transfer Fluid (10)					0				0	0	0	0
2.E.5 - Other (please specify) (3)									0	0	0	0
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	0	0	0	0	0	0	0	0	0
2.F.1 - Refrigeration and Air Conditioning	0	0	0	0	0	0	0	0	0	0	0	0
2.F.1.a - Refrigeration and Stationary Air Conditioning				0					0	0	0	0
2.F.1.b - Mobile Air Conditioning				0					0	0	0	0
2.F.2 - Foam Blowing Agents				0				0	0	0	0	0
2.F.3 - Fire Protection				0	0				0	0	0	0
2.F.4 - Aerosols				0				0	0	0	0	0
2.F.5 - Solvents				0	0			0	0	0	0	0
2.F.6 - Other Applications (please specify) (3)				0	0			0	0	0	0	0
2.G - Other Product Manufacture and Use	0	0	0	0	0	0	0	0	0	0	0	0
2.G.1 - Electrical Equipment	0	0	0	0	0	0	0	0	0	0	0	0
2.G.1.a - Manufacture of Electrical Equipment					0	0			0	0	0	0
2.G.1.b - Use of Electrical Equipment					0	0			0	0	0	0
2.G.1.c - Disposal of Electrical Equipment					0	0			0	0	0	0
2.G.2 - SF_6 and PFCs from Other Product Uses	0	0	0	0	0	0	0	0	0	0	0	0
2.G.2.a - Military Applications					0	0			0	0	0	0
2.G.2.b - Accelerators					0	0			0	0	0	0
2.G.2.c - Other (please specify) (3)					0	0			0	0	0	0

	(Gg)			CO₂ Equivalents (Gg)					(Gg)			
Categories	**Net CO_2 (1)(2)**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**	**Other halogenated gases with CO_2 equivalent conversion factors (3)**	**Other halogenated gases without CO_2 equivalent conversion factors (4)**	**NO_x**	**CO**	**NMVOCs**	**SO_2**
2.G.3 - N_2O from Product Uses	0	0	0	0	0	0	0	0	0	0	0	0
2.G.3.a - Medical Applications			0						0	0	0	0
2.G.3.b - Propellant for pressure and aerosol products			0						0	0	0	0
2.G.3.c - Other (Please specify) (3)			0						0	0	0	0
2.G.4 - Other (Please specify) (3)									0	0	0	0
2.H - Other	0	0	0	0	0	0	0	0	0	0	0	0
2.H.1 - Pulp and Paper Industry									0	0	0	0
2.H.2 - Food and Beverages Industry									0	0	0	0
2.H.3 - Other (please specify) (3)									0	0	0	0

Table A.5 - AFOLU Sectoral Table (Inventory Year: 2016)

Categories	(Gg)					
	Net CO_2 emissions / removals	Emissions				
		CH_4	N_2O	NO_x	CO	NMVOCs
3 - Agriculture, Forestry, and Other Land Use	307320.4401	1639.953404	80.56282508	0.192509657	5.911645948	0
3.A - Livestock	0	1311.698456	5.468348294	0	0	0
3.A.1 - Enteric Fermentation	0	1252.399799	0	0	0	0
3.A.1.a - Cattle	0	637.388923	0	0	0	0
3.A.1.a.i - Dairy Cows		0		0	0	0
3.A.1.a.ii - Other Cattle		637.388923		0	0	0
3.A.1.b - Buffalo		0		0	0	0
3.A.1.c - Sheep		210.45521		0	0	0
3.A.1.d - Goats		369.397805		0	0	0
3.A.1.e - Camels		12.870892		0	0	0
3.A.1.f - Horses		1.842408		0	0	0
3.A.1.g - Mules and Asses		12.95593		0	0	0
3.A.1.h - Swine		7.488631		0	0	0
3.A.1.j - Other (please specify)		0		0	0	0
3.A.2 - Manure Management (1)	0	59.29865685	5.468348294	0	0	0
3.A.2.a - Cattle	0	20.560933	0.642668457	0	0	0
3.A.2.a.i - Dairy cows		0	0	0	0	0
3.A.2.a.ii - Other cattle		20.560933	0.642668457	0	0	0
3.A.2.b - Buffalo		0	0	0	0	0
3.A.2.c - Sheep		8.4182084	1.186348646	0	0	0
3.A.2.d - Goats		16.25350342	2.61243141	0	0	0
3.A.2.e - Camels		0.71629312	0.008009878	0	0	0
3.A.2.f - Horses		0.22415964	0.022495914	0	0	0
3.A.2.g - Mules and Asses		1.5547116	0.066657427	0	0	0
3.A.2.h - Swine		7.488631	0.35310513	0	0	0
3.A.2.i - Poultry		4.08221667	0.576631433	0	0	0
3.A.2.j - Other (please specify)		0	0	0	0	0
3.B - Land	311608.6447	0	0	0	0	0
3.B.1 - Forest land	311608.6447	0	0	0	0	0
3.B.1.a - Forest land Remaining Forest land	311608.6447			0	0	0
3.B.1.b - Land Converted to Forest land	0	0	0	0	0	0
3.B.1.b.i - Cropland converted to Forest Land	0			0	0	0
3.B.1.b.ii - Grassland converted to Forest Land	0			0	0	0
3.B.1.b.iii - Wetlands converted to Forest Land	0			0	0	0
3.B.1.b.iv - Settlements converted to Forest Land	0			0	0	0
3.B.1.b.v - Other Land converted to Forest Land	0			0	0	0
3.B.2 - Cropland	0	0	0	0	0	0
3.B.2.a - Cropland Remaining Cropland	0			0	0	0
3.B.2.b - Land Converted to Cropland	0	0	0	0	0	0
3.B.2.b.i - Forest Land converted to Cropland	0			0	0	0
3.B.2.b.ii - Grassland converted to Cropland	0			0	0	0
3.B.2.b.iii - Wetlands converted to Cropland	0			0	0	0
3.B.2.b.iv - Settlements converted to Cropland	0			0	0	0
3.B.2.b.v - Other Land converted to Cropland	0			0	0	0
3.B.3 - Grassland	0	0	0	0	0	0

Categories	(Gg)					
	Net CO_2 emissions / removals	Emissions				
		CH_4	N_2O	NO_x	CO	NMVOCs
3.B.3.a - Grassland Remaining Grassland	0			0	0	0
3.B.3.b - Land Converted to Grassland	0	0	0	0	0	0
3.B.3.b.i - Forest Land converted to Grassland	0			0	0	0
3.B.3.b.ii - Cropland converted to Grassland	0			0	0	0
3.B.3.b.iii - Wetlands converted to Grassland	0			0	0	0
3.B.3.b.iv - Settlements converted to Grassland	0			0	0	0
3.B.3.b.v - Other Land converted to Grassland	0			0	0	0
3.B.4 - Wetlands	0	0	0	0	0	0
3.B.4.a - Wetlands Remaining Wetlands	0	0	0	0	0	0
3.B.4.a.i - Peatlands remaining peatlands	0		0	0	0	0
3.B.4.a.ii - Flooded land remaining flooded land				0	0	0
3.B.4.b - Land Converted to Wetlands	0	0	0	0	0	0
3.B.4.b.i - Land converted for peat extraction			0	0	0	0
3.B.4.b.ii - Land converted to flooded land	0			0	0	0
3.B.4.b.iii - Land converted to other wetlands				0	0	0
3.B.5 - Settlements	0	0	0	0	0	0
3.B.5.a - Settlements Remaining Settlements	0			0	0	0
3.B.5.b - Land Converted to Settlements	0	0	0	0	0	0
3.B.5.b.i - Forest Land converted to Settlements	0			0	0	0
3.B.5.b.ii - Cropland converted to Settlements	0			0	0	0
3.B.5.b.iii - Grassland converted to Settlements	0			0	0	0
3.B.5.b.iv - Wetlands converted to Settlements	0			0	0	0
3.B.5.b.v - Other Land converted to Settlements	0			0	0	0
3.B.6 - Other Land	0	0	0	0	0	0
3.B.6.a - Other land Remaining Other land				0	0	0
3.B.6.b - Land Converted to Other land	0	0	0	0	0	0
3.B.6.b.i - Forest Land converted to Other Land	0			0	0	0
3.B.6.b.ii - Cropland converted to Other Land	0			0	0	0
3.B.6.b.iii - Grassland converted to Other Land	0			0	0	0
3.B.6.b.iv - Wetlands converted to Other Land	0			0	0	0
3.B.6.b.v - Settlements converted to Other Land	0			0	0	0
3.C - Aggregate sources and non-CO_2 emissions sources on land (2)	0	328.2549481	75.09447679	0.192509657	5.911645948	0
3.C.1 - Emissions from biomass burning	0	0.179354387	0.006895735	0.192509657	5.911645948	0
3.C.1.a - Biomass burning in forest lands		0	0	0	0	0
3.C.1.b - Biomass burning in croplands		0.1450035	0.00375935	0.1342625	4.94086	0
3.C.1.c - Biomass burning in grasslands		0.034350887	0.003136385	0.058247157	0.970785948	0
3.C.1.d - Biomass burning in all other land		0	0	0	0	0
3.C.2 - Liming	0			0	0	0

Categories	(Gg)					
	Net CO_2 emissions / removals	Emissions				
		CH_4	N_2O	NO_x	CO	NMVOCs
3.C.3 - Urea application	0			0	0	0
3.C.4 - Direct N_2O Emissions from managed soils (3)			55.88282582	0	0	0
3.C.5 - Indirect N_2O Emissions from managed soils			18.01843631	0	0	0
3.C.6 - Indirect N_2O Emissions from manure management			1.186318923	0	0	0
3.C.7 - Rice cultivations		328.0755937		0	0	0
3.C.8 - Other (please specify)				0	0	0
3.D - Other	-4288.204679	0	0	0	0	0
3.D.1 - Harvested Wood Products	-4288.204679			0	0	0
3.D.2 - Other (please specify)				0	0	0

Table A.6 - Waste Sectoral Table (Inventory Year: 2016)

Categories	Emissions [Gg]						
	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
4 - Waste	71.7971021	767.599405	23.0286796	14.71464	258.33919	20.93791	0.509
4.A - Solid Waste Disposal	0	145.260596	0	0	0	15.24635	0
4.A.1 - Managed Waste Disposal Sites				0	0	0	0
4.A.2 - Unmanaged Waste Disposal Sites				0	0	15.24635	0
4.A.3 - Uncategorised Waste Disposal Sites				0	0	0	0
4.B - Biological Treatment of Solid Waste		0	0	0	0	0	0
4.C - Incineration and Open Burning of Waste	71.7971021	30.0771044	0.3956296	14.71464	258.33919	5.69151	0.509
4.C.1 - Waste Incineration	0	0	0	0	0	0	0
4.C.2 - Open Burning of Waste	71.7971021	30.0771044	0.3956296	14.71464	258.33919	5.69151	0.509
4.D - Wastewater Treatment and Discharge	0	592.261705	22.63305	0	0	0.00005	0
4.D.1 - Domestic Wastewater Treatment and Discharge		592.261705	22.63305	0	0	0.00005	0
4.D.2 - Industrial Wastewater Treatment and Discharge		0		0	0	0	0
4.E - Other (please specify)				0	0	0	0