NATIONAL GHG INVENTORIES DATA FLOW SYSTEM RESPONSIBILITIES AND ARCHITECTURE

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National GHG Inventories Data Flow System Responsibilities and Architecture

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A	Activity
AAS	Annual Abstract of Statistics
AFDB	African Development Bank
AFOLU	Agriculture, Forestry and Other Land Use
AGO	Automotive Fuel Oil
API	Application Programming Interface
AWACS	Airborne Warning and Control System
BTR	Biennial Transparency Report
CH_4	Methane
CL	Cropland
CL-CL	Cropland Remaining Cropland
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DCA	Data Collection Agreements
DF	Department of Forestry
DFA	Data Flow Architecture
DFS	Data Flow System
DISCOS	Distribution Companies
DOM	Dead Organic Matter
DPR	Department of Petroleum Resources
DWW	Domestic Waste water
ECN	Energy Commission of Nigeria
EF	Emission Factors
EIT	Economies in Transition
EPSRA	Electric Power Sector Reform Act
ERP	Enterprise Resource Planning
ETL	Extract Transform Load
FAO	Food and Agriculture Organization
FASO	Forestry Outlook Study for Africa
F-gases	Fluorinated Organic Compounds
FL	Forest Land
FL-FL	Forest Land remaining Forest Land
FLL	Flooded Land
FLL-FLL	Flooded Land remaining Flooded Land
FMAFS	Federal Ministry of Agriculture and Food Security
FMARD	Federal Ministry of Agriculture and Rural Development
FMENV	Federal Ministry of Environment
FMITI	Federal Ministry of Industry Trade and Investment
FMLD	Federal Ministry of Livestock Development
FORMECU	Forestry Management, Evaluation and Coordinating Unit
FRP	Fire Radiating Power
GDP	Gross Domestic Product
GENCOS	Generation Companies
GHG	Greenhouse Gas
GL	Grassland
GL-GL	Grassland remaining Grassland
HFCs	Hydro-fluorocarbons
HWP	Harvested Wood Products
IEA	International Energy Agency
IEPC	Indorama Eleme Petrochemical Company
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producers
IPPU	Industrial Processes and Products Use
IWW	Industrial Waste Water
LL-CL	Land Converted to Cropland
LL-FL	Land Converted to Forest Land
LL-FLL	Land Converted to Flooded Land
LL-GL	Land Converted to Grassland
LL-OL	Land Converted to Other Land
LL-SL	Land Converted to Settlements
LL-WL	Land Converted to Wetlands
LPFO	Low Power Fuel Oil
LPG	Liquified Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MAN	Manufacturers Association of Nigeria
MDAs	Ministries, Department and Agencies
MEMS	Microelectromechanical Systems
MSW	Municipal Solid Waste
N_2O	Nitrous Oxide
NADFS	National Activities Data Flow System
NADSS	New Activities Data Surveillance System
NASRDA	National Space Research and Development Agency
NBS	National Bureau of Statistics
NCC	Nigerian Coal Corporation
NCCC	National Council on Climate Change
NCS	Nigerian Custom Service
NDEPGI	National Database to Enhance the Preparation of GHG Inventories
NEFDFS	National Emission Factors Data Flow System
NEPA	National Electric Power Authority

NERC	National Electricity Regulatory Commission
NF_3	Nitrogen Trifluoride
NGEDS	National GHG Emissions Data System
NGHGI-MS	National GHG Inventory Management System
NIMO	National Inventory Management Office
NIPRART	National Inventory Planning, Reporting and Associated Research Team
NITL	National Inventory Team Leader
NMDPRA	Nigerian Midstream and Downstream Petroleum Regulatory Authority
NMVOC	Non-Methane Volatile Organic Compound
NNPC	Nigerian National Petroleum Company
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NSI	National Statistical Institutions
NSIPRT	National Sectoral Inventory Preparation and Reporting Teams
NUPRC	Nigerian Upstream Petroleum Regulatory Commission
O_3	Ozone
ODS	Ozone Depleting Substances
OL	Other Land
OLEDS	Organic Light Emitting Diodes
OL-OL	Other Land remaining Other Land
PFCs	Per-fluorocarbons
PL	Peatland
PPCP	Polypropylene Co-polymer
PPHP	Polypropylene Home Polymer
PV	Photovoltaic
QA/QC	Quality Assurance and Quality Control
RFO	Residual Fuel Oil
SF_6	Sulphur Hexafluoride
SL	Settlements
SL-SL	Settlements Remaining Settlements
SME	Small and Medium Enterprise
SO_2	Sulphur Dioxide
SWDS	Solid Waste Disposal Sites
SWMA	States Waste management Agencies
TCN	Transmission Company of Nigeria
TFT	Thin-Film Transistors
TRACCC	Transparency, reproducibility, Accuracy, Comparability, Consistency and Completeness
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WL	Wetland
WL-WL	Wetland remaining Wetland

POLICY MAKER'S SUMMARY

The National GHG Inventories Data Flow System Responsibilities and Architecture report is the follow-up to the National Greenhouse Gases Inventories Management System report both supported under the auspices of the Initiative for Climate Action Transparency (ICAT) Phase II project in Nigeria which was inaugurated in December 2024. The Activities of both projects anchor on the development of a national system that would support and enhance inventories management in Nigeria. The current report focuses specifically on defining the data flow system architecture and the responsibilities of each entity in the system which would make the implementation of the National Inventories Management System seamless and whose outputs would continue to improve in transparency, accuracy and other vital attributes defined by the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Accord over time. The primary aim is to ensure that there is an in-dept in-country understanding of the processes associated with the operational flow of data from sources to points of use for emissions compilation, reporting and other activities relevant to inventories to support informed decision-making, policy development and compliance with reporting requirements.

The report has an introduction which covers definitions of basic terms associated with Greenhouse Gases (GHG) inventories data flow system and architecture. The specific objectives and scope show the activities that would be undertaken in defining the data flow system and what outcome and outputs are expected. Two sets of data namely, Activities and Emission Factors data are the key ones required for national inventories. The IPCC 2006 Guidelines and 2019 Refinements to the earlier Guidelines provide the detailed break down of how to compute emissions by process and the detailed data required for such compilations. This formed the basis for the comprehensive identification of national Activities data and gaps to be filled in future inventories. An overview of the data needs show that there is a huge gap in funding for data collection, development of archival and retrieval systems to enhance data security as well as funding for other key activities that have to be bridged by both national and donor funds at a level that is higher than what is currently available.

This is further buttressed by the fact that in some sectors like Land Use, Land Use Change and Forestry (LULUCF) where current reports depict as the highest emitting sector for Nigeria has not had new surveillance data for close to two decades or more. It is also established that other key sectors such as Energy, Industrial Processes and Products use (IPPU), Agriculture and Waste, have marginal data that require substantial update to make the inventories produce the quality of results needed to address mitigation assessment. The need for new data especially for key sources such as Energy and LULUCF cannot be over emphasised to ensure that what is reported for Nigeria is accurate, transparent and is a reflection of the actual situation on ground.

The report has also provided the data flow system and architecture that cuts across a wide range of national institutions. These include the National Statistical Institutions that would be responsible for Activities data collection, research institutions that would provide emission factors data and other research support such as the development of data archival and retrieval systems to enhance data security and other computational tools to support inventories management. It would also include operational institutions that would be responsible for emissions compilation and reporting in line with international requirements. With regard to the operational institutions, it was proposed in the report on National GHG Inventory Management System that a National Inventory Technical Support Institution (NITSI) be appointed among national research institutions to provide technical support to the National Council on Climate Change (NCCC) to enhance operational efficiency that would enable inventories work within the National Inventory Cycle (NIC) and submit reports timely to meet national obligations. It was also proposed that National Sectoral Inventory Teams (NSITs) be appointed to work under the NITSI to undertake sectoral inventories and that both NITSI and NSITs should report to the National Inventory Management Office (NIMO) in NCCC. While it is expected that data collection could start for instance as a manual process, experience from other climes show the need to prepare for a systematic process that would enhance

automated data collection using technology over time. This and other operational activities would come with further funding needs that must be planned for and overcome.

An envelop of policies that would enhance the operationalisation of the proposed GHG inventory system responsibilities and architecture is also presented in this report. A timely adoption of this and the earlier report on the national inventory management system is expected to boost the activities of NCCC in the areas of GHG inventories and mitigation scenarios development towards attaining net-zero CO_2 emission at a date that would not stifle the economy but expand it to enhance sustainability. It is therefore imperative that NCCC is further strengthened to overcome all subsisting operational challenges to be able to present Nigeria with an inventory management system and data flow strategy in particular, as well as climate change management strategy in general to the level that would provide positive structural changes to buoy the economy through the development of knowledge-based products that could be used to mitigate climate change locally and for export.

EXECUTIVE SUMMARY

This report is a follow-up to the report titled "Federal Republic of Nigeria: Guidebook for National Greenhouse Gases Inventory Management System (NGHGI-MS)" under the auspices of the Initiative for Climate Action Transparency (ICAT) Phase II project in Nigeria. In 2023, the National Council on Climate Change (NCCC) sought assistance from ICAT for its Phase II support to Nigeria to develop and deliver an NGHGI-MS as part of the Phase II project entitled; "Climate Change Monitoring, Reporting and Verification (MRV)" whose core focus is to review and update sectoral guidelines and other associated activities in the UNFCCC's key emissions and mitigation sectors.

The current report titled National GHG Inventories Data Flow System Responsibilities and Architecture is meant to define the data flow system architecture and the responsibilities of each entity in the system. The primary aim of establishing this data flow system responsibilities and architecture is to ensure that there is an in-dept understanding of the systematic processes regarding the operational flow of data from sources to points of use for emissions compilation, reporting and other activities relevant to inventories to support informed decision-making, policy development and compliance with reporting requirements.

The report is divided into six (6) sections with each section addressing a specific issue. Section 1 is the general introduction and is focused on providing definitions of basic terms associated with Greenhouse gases (GHG) inventories data flow system and architecture.
Section 2 provides the statement of the problem, aim, specific objectives and scope of this report. This includes:

i. Planning and Scoping;
ii. Components of the National Data Flow System;
iii. Data Flow System Architecture; and
iv. Policy to drive the data Flow System.

Based on the above, the expected outcome and outputs envisaged in the report are presented.

Section 3 is a review of the types of data required for GHG inventories based on the breakdown of data provided for specific processes identified by the IPCC 2006 Guidelines and the 2019 Refinements across all sectors. The objective is to ensure that there is adequate understanding of the activities and emissions factors data across all processes contributing to GHG emissions. It also seeks to understand the gaps currently available in the national Activities data used for inventories so that measures to fill the gaps could be proposed. The Activities data and gap analysis are presented for each of the five (5) sectors namely Energy, Industrial Processes and Products Use (IPPU), Agriculture, Land Use, Land use Change and Forestry (LULUCF) and Wastes.

Section 4 presents the National GHG emissions data flow system which is divided into the following entities:

i. National Activities Data Flow System;
ii. National Emission Factors Data Flow System;
iii. National Databases;
iv. National Databases to Enhance the Preparation of GHG Inventories; and
v. National GHG Emission Data System.

Each entity is assigned specific role and responsibilities in the data flow system. As these entities reside in different institutions, the data flow architecture is presented in section 5 and provides a depiction of how data is expected to move from sources through the National Statistical Institutions (NSIs), institutions that would undertake new data surveillance to ensure that Activities data update become available at regular intervals as well as institutions that are to undertake research to provide modelling indicators that would be used to generate missing Activities data especially in informal sectors. It also identifies entities that would be responsible for emission factors research that would enable Nigeria migrate from inventories based on tier 1 approach alone to higher tiers. Finally, the data flow

system identifies entities that would develop the databases for archival and retrieval of all data as well as entities that would take responsibilities for emissions compilation and reporting.

The report ends with section 6 which presents the policies needed to make the data flow system and architecture work cohesively. The ultimate aim of the policy is to establish a robust and sustainable system for collecting and managing GHG data that provides a true and fair estimates of emissions that is in line with the Transparency, Reproducibility, Accuracy, Consistency, Comparability and Completeness (TRACCC) criteria.

The policy is based on the following pillars:

i. Policies to Guide National Activities Data Flow System;
ii. Policies to Guide Emission Factors Data Flow System;
iii. Policies to Guide the Development and Management of National GHG Inventories Databases; and
iv. Policies on GHG Inventories Data Flow System Safeguards and Security.

These pillars contain policy elements that not only address what would be done under the data flow system responsibilities and architecture and by whom but also how data would flow from one entity to the other within the system.

1. INTRODUCTION

1.1 BACKGROUND

The climate system comprises the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, forced or influenced by various external forcing mechanisms. These forcing mechanisms influence parameters on earth such as atmospheric temperature, relative humidity, cloud formation, rainfall and atmospheric pressure, among others. They collectively define the weather condition of a place if instantaneous conditions of these parameters are considered. They also reflect the climate of a place if average conditions of these parameters have been obtained diurnally, seasonally, annually and over other longer variability timescales over an averaging period of about 30 years. The sun or solar activity has for millions to billions of years been the key external forcing which has influenced the earth's climate system. In this sun-earth system, the climate system is known to observe variability whereby each of those parameters increase steadily from a certain minimum value at the beginning of the period of variability to a maximum value and then gradually reduces to the value at its starting point at the end of the period. This is called weather or climate variability. Life on earth has existed as we know it taking into account that living organisms have become used to a certain range of climate variability which they are accustomed to. Within this range of climate variability, living resources on land, freshwater and marine ecosystems continue to live sustainably without any threat.

Since the advent of the industrial revolution, human activities have been added to solar activity as additional external forcing to the earth's climate system. With added human activity as external forcing, the variability of the climate system no longer exists as it used to be. Hence, when a particular parameter like atmospheric temperature starts varying at the beginning of a specific cycle and reaches maximum, it is no longer able to return to the original value at the end of the cycle. With continuous inability to return to the original climate state at the end of several climate cycles, climate variability is now distorted to become climate change. Climate change as it is currently known is brought by human activities that emits certain gases into the atmosphere that disrupts the atmospheric energy balance, leading to global warming. Global warming disrupts the balance o those key climate parameters in such a way that their values continue to either increase or decrease steadily over time with consequences on life on earth.

Climate change constitutes long-term shifts in global temperatures and weather patterns primarily driven by human activities, specifically the burning of fossil fuels releasing what are termed greenhouse gases (see sub-section 1.2). There is overwhelming scientific consensus on the causes, impacts and the framework for addressing climate change based on the economic imperative and the need to protect human health, well-being and ecosystems from severe, irreversible damage.

The impetus for addressing climate change is rooted in several interconnected principles:

i. Overwhelming Scientific Consensus: The Intergovernmental Panel on Climate Change (IPCC) has observed that human influence is the main driver of warming observed since the mid-20th century.
ii. Minimizing Catastrophic Risk: Global agreements, such as the Paris Agreement, aim to limit global temperature rise to no more than 1.5°C to 2°C above pre-industrial levels to avoid the most severe and irreversible impacts.
iii. Protecting Human Health and Life: The World Health Organization (WHO) posits that climate change is one of the biggest threats to global health in the 21st century with strong capacity to cause illness and death from heat stress, infectious diseases and food/water scarcity, among others. Action is necessary to protect vulnerable populations who are disproportionately affected despite contributing the least to the problem.
iv. Economic Prudence: While climate action requires significant financial investment, the long-term cost of inaction in terms of disaster relief, health crises and economic losses is vastly more expensive.

v. Ethical and Intergenerational Responsibility: There is a moral and ethical obligation to ensure a "liveable climate" for current and future generations. Developing countries believe that those countries that are most responsible for historical emissions should have a greater duty to lead the transition to clean energy and provide financial assistance to them so that they could mitigate future climate change in their domains, respond and adapt to reduce impacts on future generations in their respective country.

1.2 WHAT CONSTITUTES EMISSION INVENTORIES

The Greenhouse Gas (GHG) emission inventory process is concerned with a systematic accounting of all GHGs responsible for disrupting the atmospheric energy balance leading to net trapping of heat in the atmosphere by gases that are transparent to incoming solar radiation from the sun to the earth but absorb the outgoing infrared radiation from the earth to the outer space leading to global warming. The gases responsible for absorbing the outgoing infrared radiation from reaching the outer space are generally called greenhouse gases and include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) hydro-fluorocarbons (HFCs), per-fluorocarbons (PFCs) and sulphur hexafluoride (SF6). There are also gases that are emitted into the atmosphere and are converted by atmospheric transformation processes to GHGs. These include carbon mono-oxide (CO), non-methane volatile organic compounds (NMVOC), oxides of nitrogen (NO_X) comprising nitric oxide (NO) and nitrogen dioxide (NO_2), and sulphur dioxide (SO_2), which leads to the formation of atmospheric particulate matter that results in net cooling of the atmosphere. These second set of gases are collectively known as GHG precursors.

The general procedure for GHG emission inventory is presented by Equation 1.1.

$$E_i = \Sigma_j \Sigma_k A_k * EF_{kj} \qquad \text{Equation 1.1}$$

where E_i is the emission of each GHG or precursor gas i, EF is the emission factor or emissions per unit of activity (A), j represents summation over identified processes/economic sectors contributing to the emission of each GHG or its precursor i; k represents the summation over specific processes or technology types within each major economic sector. In this regard, the total GHG or precursor gas emission may be obtained by summing each GHG or precursor across sectors and processes.

An inventory represents the process where emissions as represented in Equation 1.1 are estimated for all processes across all sectors and then summed for the entire geographical zone which the inventory is meant to cover. Such a process will be repeated for all other GHG/precursor gases under investigation. This implies that computation of the Equation will be undertaken many times before all GHGs, relevant processes and sectors are covered. In order to obtain solution to the Equation, leading to the preparation of an inventory, all processes leading to the emission of GHG or its precursor gas must be identified and quantified. For each identified process, the activity data (A) and emission factors (EF) data must be established.

There are key components of the GHG inventory as presented above. These include:

i. Definition of Boundary: For inventories at national or sub-national level, the national or sub-national boundaries define the geographical coverage for the inventory. For other inventories, the boundaries may be similarly defined.
ii. Specified Period: For national or sub-national inventories, typically averaging period is one calendar year.
iii. Quantified Gases: The quantifies gases may be listed if a particular inventory does not cover all GHGs and their precursors.
iv. Source Identification: The national inventory activities are undertaken based on the guidelines provided by IPCC. The sectors include Energy, Industrial Processes and Products Use (IPPU), Agriculture, Forestry and

Other Land Uses (AFOLU) and Waste. The AFOLU sector could be sub-divided into Agriculture, and Land Use, Land Use Change and Forestry (LULUCF).

1.3 TYPES OF DATA

Two sets of data are needed for emission inventories. These include Activities (A) data and Emission Factors (EF) data. The collection of these data in such a way as to minimize uncertainties constitutes one of the biggest challenges of emission inventory activities.

1.4 SOURCES OF DATA

Data for GHG inventories computation are generally divided into two parts, namely, activities and emission factors (EFs) data. The collection of these data is a key activity that determines the success or failure of the inventory activities. In order to successfully collect data, the primary sources of data and the intermediate sources known as secondary sources of data that collects data from primary sources must be known. Where data becomes incomplete, certain research methods may also be undertaken to statistically estimate relevant data based on invaluable national statistical data.

1.4.1 Sources of Activities Data

The key sources of national activities data include data from primary sources and data from secondary sources. The primary sources of data include all point, line and area sources that could be reached for data collection. Wherever data collection is not possible from primary sources then secondary sources may be approached for such data collection (see section 3).

1.4.2 Sources of Emission Factors Data

The various IPCC guidelines as well as IPCC EFs database constitutes an invaluable source of emission factors for most developing countries who are yet to undertake source testing to establish national EF values. Where national EF values are being measured, published and archived, then the national EF listings or database form the key sources of such data.

1.5 WHAT CONSTITUES DATA FLOW?

In a GHG inventory management system, Data Flow constitutes the entire lifecycle of emissions data from the point of initial generation to final reporting and archiving. The Data Flow process is therefore a structured, controlled process that ensures data integrity, correctness, completeness and consistency, guided by relevant standards. Based on sub-section 1.2 and 1.3 above, Data Flows into the inventory system through two key pathways:

i. Activities Data Flow System (DFS); and
ii. Emission Factors Data Flow System (DFS).

These combine to generate GHG and precursors emissions data which form the GHG emissions data sets. The details of these are presented in sections 4 and 5.

2. OBJECTIVES AND SCOPE OF THE REPORT

2.1 STATEMENT OF THE PROBLEM

There is currently no known Data Flow system that has been defined with an enumerated system and architecture to support emission inventory activities in Nigeria. The absence of a national GHG inventory Data Flow system and architecture present some challenges. Some of the key challenges include:

i. Inadequate capacity to determine specific data and how they flow from one point to the other;
ii. Lack of information on how to enforce consistent methods for data collection, calculation and reporting across different sources and time periods to ensure comparability;
iii. Non-availability of a structured system for handling large datasets, documents and calculations to ensure data integrity and accessibility for future use and verification.
iv. Non-availability of a system for automated or manual quality checks to identify and correct errors, inconsistencies and data gaps;
v. Lack of a system that can adapt to evolving regulatory environments, new data sources (e.g., IoT sensors) and technological advancements, among others; and
vi. Lack of clear roles and responsibilities of stakeholders and data providers to ensure efficient coordination and data flow within the system.

In general, these problems arise in countries where:

i. Data needed for inventories are often unavailable, incomplete or of low quality, leading to high uncertainty in emission estimates. Similarly, data providers may also be unwilling to share information without formal arrangements in place;
ii. There are no standardized system and methodology thereby leading to inventory data being inconsistent across different years or incomparable with other countries. In such cases, this would make it difficult to assess progress over time;
iii. There is absence of reliable data meaning that policymakers cannot accurately identify the most significant emission sources, target effective mitigation actions or assess whether existing policies are working as intended;
iv. There are no defined institutional arrangements, legal mandates and sufficient funding leading to problems such as understaffing, limited technical capacity and high reliance on external consultants for each report. This means capacity is built on an individual basis or small groups for specific projects rather than on a permanent institutional level. The Data Flow System (DFS) is meant to eliminate or minimize this problem;
v. There is no permanent system for data archiving and documentation leading to loss of historical data and methods, forcing inventory teams to rebuild their capacity and data sets for each new reporting cycle;
vi. There is absence of national DFS which often face problems with submitting regular reports such as Biennial Transparency Reports (BTR) to the UNFCCC under the Paris Agreement's Enhanced Transparency Framework; and
vii. There are no high-quality, transparent and consistent data which are essential for mobilizing climate finance and demonstrating the impact of mitigation actions to international partners and financing institutions.

The above constraints in general inhibits national capacity to track climate progress especially with regard to GHG inventory and mitigation options assessments, which ultimately hinders a nation's ability to put in place decisive policy to establish the roadmap towards net zero emissions, green economic growth, take effective steps to respond to climate change, meet international reporting obligations and manage climate risks.

2.2 AIM AND OBJECTIVES OF THE REPORT

The primary aim of establishing a GHG inventory DFS and DFA is to ensure that there is systematic, accurate and transparent flow of data from sources to the point of data use for emissions compilation, reporting and other activities relevant to inventories to support informed decision-making, policy development and compliance with reporting requirements.

The specific objectives are divided into two, the DFS objectives and the DFA objectives. The specific objectives of the DFS include to:

i. Systematically quantify GHG emissions from all relevant sources using consistent, standardized methodologies to reduce uncertainty in emission estimates;
ii. Provide policymakers, business leaders and other stakeholders with robust data that helps them identify all sources of emission, assess climate impact, manage risks and develop effective, cost-efficient climate policies and reduction strategies;
iii. Create a clear baseline against which progress toward voluntary or mandatory emission reduction targets can be measured and tracked over time;
iv. Meet national and international legal and regulatory obligations for GHG reporting in a structured and standardized manner;
v. Foster trust among internal and external stakeholders by ensuring data and methodologies are well-documented, verifiable and based on a clear audit trail;
vi. Enable organizations to identify opportunities for operational improvements such as energy efficiency measures and waste reduction, which can lead to cost savings and better management of GHG-related risks;
vii. Establish a sustainable system with clearly defined roles, responsibilities and documentation procedures that safeguards against data loss and ensures the inventory process can be maintained and improved upon even with staff turnover; and
viii. Provide reliable and verified data that serves as basis for participating in carbon markets, emissions trading programs or accessing green investment opportunities.

Similarly, the specific objectives of designing the DFA include:

i. Providing the data and information for evolving consistent methods for data collection, calculation and reporting across different sources and time periods to ensure comparability;
ii. Providing a structured system for handling large datasets, documents and calculations to ensure data integrity and accessibility for future use and verification;
iii. Incorporating automated or manual quality checks to identify and correct errors, inconsistencies and data gaps;
iv. Designing a system that can adapt to evolving regulatory environments, new data sources and technological advancements; and
v. Defining the roles and responsibilities of all stakeholders and data providers to ensure efficient coordination and data flow within the system.

2.3 SCOPE OF THE REPORT

Designing a GHG inventory DFS and architecture involve a structured, multi-stage process that ensures data flow pathway is understood and well managed. The scope of activities would be derived from the key tasks associated with GHG inventories. These centre around inventory planning, data management, calculation, quality assurance and reporting, guided by the fact that the transparency, reproducibility, accuracy, comparability, consistency and completeness (TRACCC) criteria is met. The scope of activities includes:

2.3.1 Planning and Scoping

i. Define Objectives: Determine the purpose of the inventory as this influences design decisions for data flow.
ii. Establish Boundaries:
    a. Organizational: Define the geographic boundary of the inventory, e.g. national, states or municipal areas, among others.
    b. Operational: Identify and categorize relevant emission sources including sectors of interest, indirect from purchased energy and other indirect value chain.
iii. Select Years for Inventory Trends: Choose years for inventory.
iv. Assign Roles and Responsibilities: Clearly define the inventory quality team, data providers, data analysts and management reviewers.

2.3.2 Establishing the Components of the National Data Flow System

This shall comprise:
i. Flow from Key Primary Activity Data Sources: Identify primary sources of data for preparing inventories in each of the sectors.
ii. Identifying Key Statistical Institutions and Responsibilities for Activity Data Collection on Sharing: Identify key statistical institutions and the scope of cross-cutting data they are to collect and deliver to inventory teams.
iii. Procedures for Indirect Activities Data Estimation: Develop methods for estimating activities data from secondary sources where primary data is poor.
iv. Establishing Emission Factors DFS: Identify the components of emission factors DFS across sectors.

2.3.3 Development of Data Flow System Architecture

i. Identify Data Requirements: For each emission source, determine the specific activity data needed.
ii. Develop Data Collection Procedures: Formalize the process for collecting data from its original source to the final system, including tools and frequency of collection.
iii. Design Data Management Systems:
    a. Establish systems to handle datasets, calculations and documents, ensuring flexibility and standardized output formats.
    b. Implement robust documentation and archiving procedures to maintain a clear audit trail.
    c. Integrate the GHG data flow with existing procurement, facilities and finance systems where possible.

2.4 EXPECTED OUTCOME AND OUTPUTS

The expected outcome and outputs of the report shall be as follows:

2.4.1 Expected Outcome

The systematic, accurate and transparent DFS for quantification of emissions to support informed decision-making, policy development and compliance with reporting requirements developed and in place.

2.4.2 Expected Outputs

The expected outputs shall be as follows:
i. Data and information for evolving consistent methods for data collection, calculation and reporting across different sources and time periods to ensure comparability provided;

ii. A structured system for handling large datasets, documents and calculations to ensure data integrity and accessibility for future use and verification provided;

iii. Automated or manual quality checks to identify and correct errors, inconsistencies and data gaps incorporated;

iv. A system that can adapt to evolving regulatory environments, new data sources and technological advancements designed; and

v. The roles and responsibilities of all stakeholders and data providers to ensure efficient coordination and data flow within the system defined.

3. DATA REQUIREMENTS FOR GHG INVENTORIES AND SUBSISTING GAPS

Based on Equation 1.1, a wide range of activities and emission factors data are required to support emission inventory activities. The template for activities and emission factors data is dependent on the IPCC guidelines used. The sub-sections below provide the data requirements based on the IPCC 2006 guidelines and software. The data requirements are presented on a sector-by-sector basis.

3.1 ENERGY SECTOR

Emissions from the energy sector are emissions from activities associated with combustion of fuels as well as fugitives associated with fuel production, transport and storage, among others. Emissions from the non-energy uses of fuels are generally not included here, but reported under the Industrial Processes and Product Use (IPPU) sector. Where carbonates such as limestone or dolomite are consumed for environmental pollution control (e.g. for flue gas desulphurisation) these emissions are reported in the category of the energy sector where the carbonates are consumed. The categories of activities data and associated emission factors in the energy sector are presented in sub-sections 3.1.1 and 3.1.2 based on the IPCC 2006 guidelines.

3.1.1 Activities Data

The IPCC provides two main approaches for estimating CO_2 emissions from the energy sector: the Reference Approach (a top-down method) and the Detailed Energy Technologies Approach (a detailed bottom-up method). Countries use both to verify their emission estimates. The data requirements for the two approaches are presented in the sub-sections below.

3.1.1.1 Data for the Reference Approach

Based on the IPCC Reference approach, the determination of emissions of CO2 from the energy sector requires data on primary and secondary energy production, imports, exports, international bunker fuels and stock changes. The National Bureau of Statistics (NBS), Nigerian Upstream Petroleum Regulatory Commission (NUPRC) and Nigeria Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) have most of these data needed to support emission estimates based on the Reference Approach. Data for coal production are provided primarily by the Nigerian Coal Corporation as cited by NBS Annual Abstracts of Statistics (AAS) reports. Significant data gaps exist in the national database on the flow of liquid fuels into the economy. The most prominent of such gaps is the inconsistency in the data on fuel imports into the country, even though it is generally acknowledged by NUPRC and the Federal Government of Nigeria that before the Dangote refineries began operation, substantial fraction of the petroleum products consumption were imported. There is also no consistent documentation of the amount of fuel in stock and stock changes annually.

3.1.1.2 Data for Detailed Energy Technologies Approach

There are nine sub-categories of data required for emission inventories under the IPCC 2006 guidelines. The data requirements for them are presented in under the bullets below.

i. Energy Industries:

The Power Holding Company of Nigeria (PHCN), formerly National Electric Power Authority (NEPA) was through the Electric Power Sector Reform Act (EPSRA) of 2005 unbundled into (eighteen 18) successor companies, comprising six generation companies (GENCOS) eleven (11) distribution companies (DISCOS) and one (1) Transmission

Company of Nigeria (TCN), which remains wholly owned by the Federal Government of Nigeria. The functions of GENCOS, TCN and DISCOS are regulated by the National Electricity Regulatory Commission (NERC). The public electricity supply since the days of NEPA has always been supplemented by generation by auto-producers at residential, industrial and public sector areas. The independent power producers (IPP) have now joined the electricity generation team since 2001. The consumption of electricity from public power supply has until recently been published by both the NBS and the defunct Department of Petroleum Resources (DPR). Such data where available could be used for estimation of emissions from energy industries.

Energy industries comprise public electricity generating facilities. Natural gas is the major contributor to fossil fuel combustion by electric power generating stations nationally, with contributions from Residual Fuel Oil (RFO) and Automotive Fuel Oil (AGO)/Diesel. In trying to account for the annual consumption of natural gas, RFO and Diesel to public electricity consumption, it is observed that substantial gaps exist in the database prior to the establishment of both NUPRC and NMDPRA. Data for liquid fuels used are also relatively weak but there is promise for improved data if the NMDPRA becomes more effective than DPR in their data management and reporting.

From the gas accounting data reported by the different National Statistical Institutions (NSIs) including the National Bureau of Statistics (NBS), NUPRC and NMDPRA, there appears to be clarity that data for the detailed consumption of natural gas in the economy is weak. In reviewing the gas accounting data, it is evident that “gas sold”, are either going to industries or power plants. It is also evident that gas consumed in oil fields are used for electricity generation for oil field operations. The overlap in accounting for “gas sold” and “gas used” in the field needs to be clarified in future data to ensure that the bottleneck in gas accounting is removed. This will make it more effective to account for both gas and liquid fuel consumption by energy industries.

ii. Petroleum Refining:

Besides fuel consumption for electricity generation discussed in (i) above, there is also reasonable fossil fuel consumption on the petroleum refining process. The fuels consumption for refinery operations which include fuel gas, Liquified Petroleum Gas (LPG), Low Poor Fuel Oil (LPFO), coke, AGO and natural gas/LPG flared are expected to be reported annually by NMDPRA in their database. Where such data are lacking, NMDPRA has to include them in their future reporting to improve the quality of emission estimates for refining operations.

iii. Manufacturing Industries and Construction

Manufacturing industries consume fossil fuels for heat generation to support boiler operations as well as for on-site electricity generation. Nigerian National Petroleum Company (NNPC) and NBS which used to report these data are no longer doing so. Data for industrial energy consumption are currently sourced from a combination of sources including NNPC Statistical Bulletins, NMDPRA bulletins, NUPRC bulletins or annual reports and International Energy Agency (IEA) publications, among others. These could be used as mean values to estimate industrial consumption of natural gas and liquid fuels until more precise data becomes available. There is currently no data available for use in computing emissions from construction activities even though substantial activities are ongoing in the construction sector. There is therefore need for the National Council on Climate Change (NCCC) to come up with a strategy, policy or legislation that would compel Ministries, Departments and Agencies (MDAs) responsible for providing oversight for activities in the construction sector to commence developing a database for such information as part of their routine activities. Such activities could include but not limited to average fuel used by off-road construction equipment and generators at construction site, annual length of roads of specific categories constructed annually, the fuel consumption by off-road machineries and generators for the construction of each category of houses for residential, commercial and industrial use, and a number of each category of such houses constructed per year.

iv. Transport

The transport sector in Nigeria is dominated by road transport, supplemented by air, transport by inland water ways (national navigation) and now minimally by railway. Like most other downstream sector of the petroleum industry, no formal estimates of the fuel consumption in the transport sector are reported routinely by national data sources. The NBS has only consistently published the annual consumption of petroleum products in Nigeria, but transport sub-sector disaggregation is not available. Similarly, the average vehicle kilometres travelled by fleet type is also not yet available. This implies that sub-sector specific fuel consumption may have to be established through indirect or secondary modelling approaches. There is therefore need for NCCC to come up with a strategy, policy or legislation that would compel MDAs responsible for providing oversight for activities in the transport sector to commence developing a database for downstream petroleum products and other fuels consumption in the transport sector. Such a policy or legislation shall also identify MDAs that shall take responsibility for defining vehicle fleet and keeping records of annual fleet statistics for road transportation, rail transportation, civil aviation, military aviation, inland waterways, naval fleets in inland waterways and continental shelf, and ships that berth in Nigeria from international navigation. Where needed, fuel consumption for international and local aviation as well as for local and international navigation should respectively be separated. Other statistics such as vehicle kilometre travelled annually could also be estimated.

v. International Bunker Fuels

The consumption of diesel and fuel oil as marine bunker fuels has been provided in the NNPC statistics annually, except for some years. International bunker fuels consumption would be estimated from fuels consumed for international aviation and international navigation in (iv) above.

vi. Commercial and Institutional

There is currently no estimate of gasoline and diesel consumption by commercial and institutional establishments in national statistics data system of either NMDPRA or NBS. This kind of data are usually provided from field surveys across states and geopolitical zones.

vii. Residential

Energy consumption for the residential sector may be divided into two major segments, consumption for domestic cooking and lighting by lanterns, and consumption to support in-house electricity generation in the homes to supplement public electricity supply. For domestic cooking and lighting, household kerosene, LPG, coal, charcoal, fuel wood and other biomass-based fuels are the most dominant energy fuels in use, while for private electricity generation gasoline and diesel are the major fuels used.

The consumptions for domestic cooking and lighting by lanterns are usually obtained from the annual consumption of household kerosene and LPG in the NNPC Annual Reports under the assumption that all LPG is used for household cooking. Such an assumption needs to be verified by field survey or from sales of LPG by refineries to sources outside of residential households. The consumption of charcoal and fuel wood are usually extrapolated from the Food and Agriculture Organization (FAO) estimates. Coal consumption data has not been reported in recent times. However, with the low production of coal generally and without any known consumption in key formal sectors, the first assumption has been that all produced coal is consumed in the informal sector, and

reported under the residential sector. In arriving at the consumption of kerosene and LPG for residential sector, it is always assumed that use of kerosene outside of the residential sector is negligible, thus assigning the total national consumption to the residential sector for cooking and use by lanterns. It is recognized that industrial use of LPG is low, but not negligible. There is therefore need for NCCC to come up with a strategy, policy or legislation to compel refineries and/or NMDPRA to publish annual data for various consumers of LPG including the industrial sector. Similarly, the law should compel relevant MDAs such as Nigerian Coal Corporation (NCC) and Manufacturers Association of Nigeria (MAN) to report on coal consumption for sectors including residential, industrial and transportation sectors, among others.

The consumption of fuel wood and charcoal has continued to be based on the early data by FAO as reported by EMRD (1991). This is based on a per capita fuel wood and charcoal consumption of 0.5 t/cap/year and 0.2 t-charcoal/cap./year and projected for annual national population as available. There is need however for NCCC to support new field assessment nationally to estimate per capita fuel wood, charcoal and other biomass fuels in the residential sector.

The consumption of energy for private electricity generation in the households has been documented in earlier GHG inventory (Obioh and Adegbulugbe, 1997) based on data from World Bank (1993). These showed that 1.74% and 0.59% respectively of total national PMS and diesel consumptions were used for private electricity generation in the residential sector. There is need for new field surveys nationally to revise these estimates and to establish the numbers and categories of gasoline and diesel generation in use in households nationally.

viii. Agriculture, Forestry and Fishing

Like it is for other transportation sub-sectors, the consumption of fossil fuels by off-road vehicles, agricultural tractors and other off-road vehicles used for forest timber logging have not been reported. There is need for a combination of approach to estimate the fleet for these classes of vehicles as well as their fuel consumptions. There is therefore need for NCCC to come up with a strategy, policy or legislation to identify the competent authority such as the Federal Ministry of Agriculture to estimate the vehicle fleet while field surveys could be used to estimate fuel consumption for each fleet.

ix. Upstream Petroleum Sector Activities

The upstream petroleum sector activities are divided into two segments, upstream oil production and upstream gas production activities.

a. Upstream Oil Production Activities

This comprises activities such as crude oil exploration, production and upgrading, transport, refining and distribution. NNPC annual statistical bulletins now under the auspices of NUPRC has been publishing data on some of the upstream oil and gas statistics.

b. Upstream Gas Production Activities

This comprises activities related to natural gas production, venting and flaring in oil fields. NNPC annual statistical bulletins now under the auspices of NUPRC has been publishing data on some of the upstream oil and gas statistics, though there is need for improvements.

3.1.2 Emission Factors Data

The Country currently uses tier 1 emission factors data.

3.2 INDUSTRIAL PROCESSES AND PRODUCTS USE SECTOR

A variety of industrial activities produce GHGs, which are not related to energy production and consumption in the industrial sector. The emissions arise from the physical and chemical transformation of materials in the industrial process to greenhouse and precursor gases. IPCC (2019) indicates that Industrial Processes and Product Use (IPPU) cover GHG emissions occurring from industrial processes, from the use of GHGs in products, and from non-energy uses of fossil fuel carbon. EPA (2024) indicates that there are a wide-range of industrial processes that lead to the emission of GHG and precursor gases. Some of those processes relevant to the Nigerian economy include iron and steel production and metallurgical coke production, cement production, petrochemical production, ammonia production, lime production, other process uses of carbonates (including flue gas desulfurization, ceramics production, and soda ash consumption not associated with glass manufacturing). Others include nitric acid production, adipic acid production, urea consumption for non-agricultural purposes, aluminium production, HCFC 22 production, other fluorochemical production, glass production, soda ash production, ferroalloy production, lead production, and silicon carbide production and consumption. Similarly, GHGs that are used in manufacturing processes or by end-consumers include man-made compounds such as HFCs, PFCs, SF_6 and nitrogen trifluoride (NF_3).

In addition, GHGs often are used in products such as refrigerators, foams or aerosol cans. For example, HFCs are used as alternatives to ozone depleting substances (ODS) in various types of product applications. Similarly, SF_6 and N_2O are used in a number of products used in industry. The non-energy uses of fossil fuels encompass their uses as feedstock, reductants and as non-energy products in which their physical properties are used directly rather than combusted for energy purposes.

3.2.1 Activities Data

3.2.1.1 Industrial Mineral Products and Other Process Uses of Carbonates

There is sparse of data reporting the production of industrial mineral products in respect of cement, lime and glass production some of which production have been in place in Nigeria since the late 1950s. For other process uses of carbonates, there is also very little data available. The data so far available is for ceramics for which production of tiles was reported for a limited period by the NBS. In view of the limited data from NBS annual abstract of statistics, there is need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as Federal Ministry of Industry, Trade and Investment (FMITI), NBS and Nigeria Custom Services (NCS), among others to develop and provide the database associated with activities in the IPPU sector as listed in the paragraphs above.

3.2.1.2 Chemicals and Petrochemicals Production, and Non-Energy Products Use

Apart from ammonia production and known use of carbide and soda ash nationally, there is no information regarding the production of nitric acid, adipic acid, caprolactam, glyoxal and glyoxylic acid, and titanium dioxide production nationally. The petrochemicals consumed in the country include low- and high-density polyethylene, and polypropylene home polymer (PPHP) and polypropylene co-polymer (PPCP) products produced at Indorama Eleme Petrochemical Company (IEPC). There are however no annual production estimates available from NBS annual statistics. Similarly, the refineries are known to produce lubricants, paraffin wax and carbon black. The available NNPC annual statistical records do not clearly reflect all products in recent years with the exception of key

fuels, include long residues (LRS), heavy naphtha, waxy paraffines, waxy distillates and an agglomeration of other products listed in bulk as intermediate products. The non-energy products consumed include among others lubricants, paraffin wax and solvents.

Based on the records of some of these, there is limited data available from NBS, NUPRC and NMDPRA. There is therefore need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as FMITI, NCS, NBS and NMDPRA, among others to develop and provide the database associated with activities in this sub-sector of IPPU.

3.2.1.3 Metal Industry

The available data from the NBS and NNPC annual statistical publications indicate that iron and steel production had been on the decline based on either low-capacity utilization of the companies or outright shutdown of operations. Similar situation holds for the production of rolled products by the different steel rolling mills in the country. Very scanty data are available in respect of the production of wire rods and coils. There is need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as FMITI and NBS, among others to develop and provide the database associated with activities in this sub-sector of IPPU.

3.2.1.4 Other Industry

There are no national activity and recorded data in other industrial processes and industrial products consumptions listed in sub-section 3.2.1.1 outside those listed in sub-sections 3.2.1.2 to 3.2.1.3. Pulp and paper production data still remain scanty despite the demand nationally. There is therefore need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as FMITI and NBS, among others to develop and provide the database associated with activities in this sub-sector of IPPU.

The electronic industry manufacturing processes uses and emits fluorinated organic compounds (F-gases) that are radiatively active and N_2O. Some of the sectors include the manufacturing of semiconductor devices, microelectromechanical systems (MEMS), photovoltaic (PV) devices, and displays, which in turn consist of thin-film-transistors (TFTs) for displays and organic light emitting diodes (OLEDs).

The electronics industry mentioned above are nearly non-existent in Nigeria. However, it may be a good idea to undertake field studies among the growing tech hubs in Nigeria and solar PV panels manufacturing to know whether F-gases are being used and to what extent. If indeed F-gases are in use, then it would be necessary for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as FMITI and NBS, among others to develop and provide the database associated with activities in this sub-sector of IPPU.

3.2.1.5 Consumption of GHGs in Products Manufacture and Use

Identified applications in this source category include:

i. SF_6 and PFCs used in military applications, particularly SF_6 used in airborne radar systems, e.g., Airborne Warning and Control System (AWACS), and PFCs used as heat transfer fluids in high-powered electronic applications;
ii. SF_6 used in equipment in university and research particle accelerators;
iii. SF_6 used in equipment in industrial and medical particle accelerators;
iv. 'Adiabatic' applications utilising the low permeability through rubber of SF_6 and some PFCs, e.g., car tires and sport shoe soles;

v. SF_6 used in sound-proof windows;
vi. PFCs used as heat transfer fluids in commercial and consumer applications;
vii. PFCs used in cosmetics and in medical applications;
viii. Other uses e.g. gas-air tracer in research and leak detectors;
ix. PFCs and other fluorinated compounds in the manufacturing of textiles and waterproofing of electronic circuits.

Information on these activities which cuts across industries, universities and other research institutions are not available yet in the national data provided by FMITI, NBS and other data providers. A field survey would first be needed to establish where this F-gases are in use and annual consumptions where possible. There would also be need to have discussions on annual F-gases imports into the country with NCS. There would then be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as FMITI and NBS, among others to develop and provide the database associated with activities in this sub-sector of IPPU.

3.2.2 Emission Factors Data

The Country currently uses tier 1 emission factors data.

3.3 AGRICULTURE SECTOR

Emissions from agriculture which is a component of the Agriculture, Forestry and Other Land Use (AFOLU) sector comprise emissions from livestock enteric fermentation and from manure management. Sub-sections 3.3.1 and 3.3.2 provide information on the kinds of activities and emission factors data required to compile emissions

3.3.1 Activities Data

Some of the major activities and processes associated with the production of crops and livestock contribute directly or indirectly to GHG and precursor gases emissions globally. The agriculture components of the AFOLU activities include enteric fermentation and manure management. The rest are to be presented in sub-section 3.4 under Land Use, Land Use Change and Forestry (LULUCF).

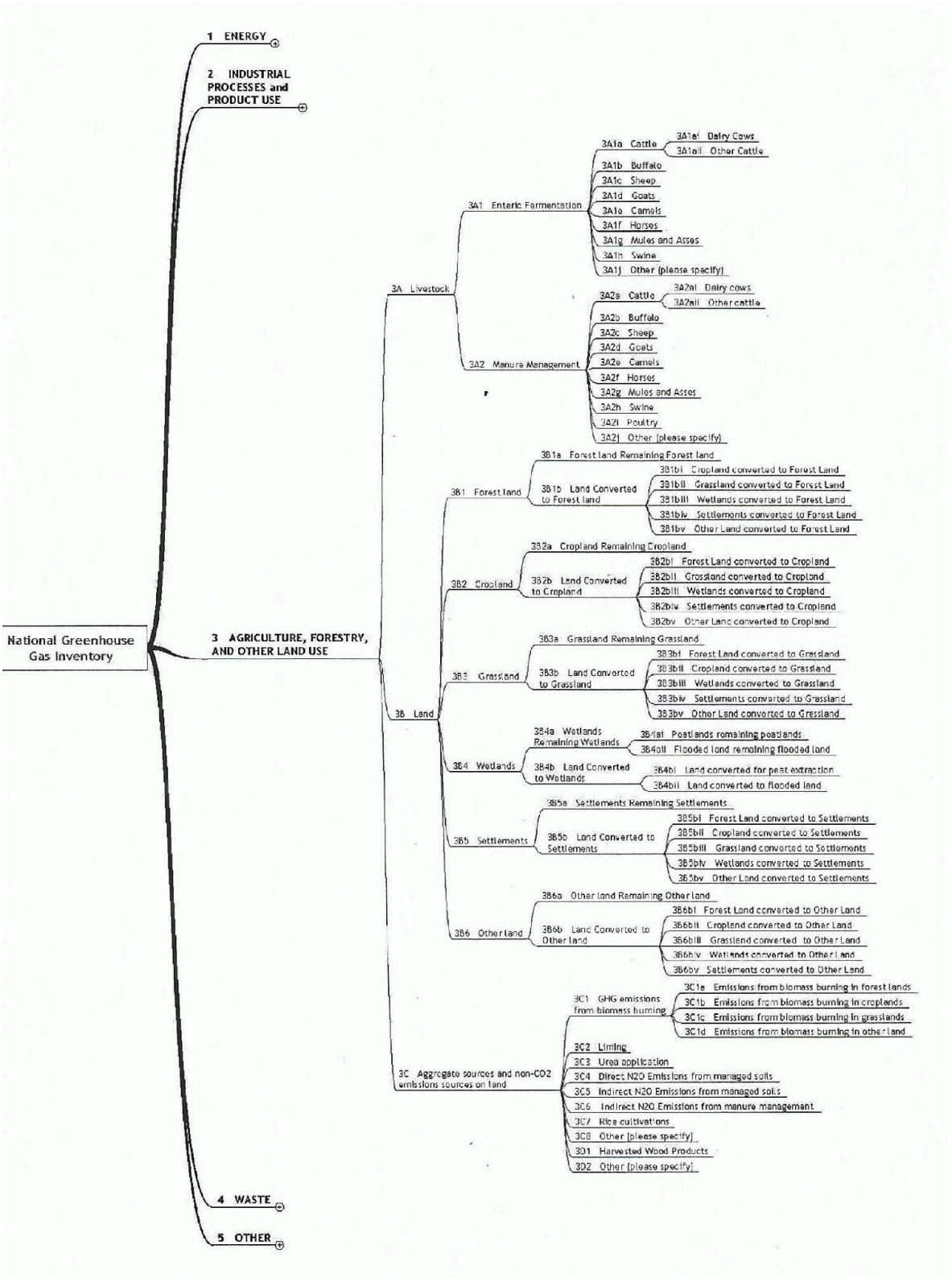

Figure 3.1: AFOLU ACTIVITY CATEGORIES AND STRUCTURE OF REPORTING (IPCC, 2006)

The activities data are being collected from these AFOLU processes in such a way that would ensure that emissions are not double-counted. These data would then be used with relevant emission factors to compute emissions.

3.3.1.1 Livestock Production: Enteric Fermentation

Data on livestock population in Nigeria has not been very consistent. Sometimes the NBS publishes this information from the data available from the Livestock Department of the Federal Ministry of Agriculture and Rural Development (FMARD). Where data gaps exist in the database, some extrapolations are usually made through simple estimates of annual growth or decline rates for the livestock species of interest. The livestock population presented in national statistics do not have the sub-details such as adults and juveniles; male and female; and lactating and non-lactating. New data are therefore needed through field survey to establish these details. There would then be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as Federal Ministry of Livestock Development (FMLD) and NBS, among others to develop and provide the database associated with activities in this sub-sector of agriculture annually.

3.3.1.2 Livestock Production: Manure Management

Emissions from manure management are dominated by those from cattle and swine. Most of the emissions are associated with confined animal management operations where manure is handled in liquid-based systems. There are no national data on manure generation per capita by cattle, swine and other livestock. Similarly, no information is available from FMARD as well as the new FMLD on the manure management technologies in use in Nigeria. Field survey will therefore be necessary to create national data on per-capita livestock waste generation and waste management technologies in use to improve current emission estimates. There would then be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as FMLD and NBS, among others to develop and provide the database associated with activities in this sub-sector of agriculture annually.

3.3.1.3 Field Burning of Crop Residues

Field burning of crop residues emits significant GHGs, primarily CO_2, CH_4 and N_2O to the atmosphere. Estimating GHG emissions from field burning of crop residues involves multiplying the total dry matter of biomass burned by specific emission factors (EFs) for gases like CH_4 and N_2O. Common methodologies include the IPCC Tier 1 approach based on crop statistics or satellite-based methods using Fire Radiative Power (FRP) to estimate burned area and biomass.

The core formula for calculating emissions (E) is:

$$E = A \times EF \quad \text{Equation 3.1}$$

Where A is the total amount of biomass burned (activity data) and EF is the emission factors.

Activity Data (A) is calculated as:

$$Dry\_Matter\_Burned = Crop\_Production \times Residue\_to\_Product\_Ratio \times Dry\_Matter\_Fraction \times Fraction\_Burned\_in\_Fiel$$

Equation 3.2

3.3.1.4 Liming

Liming is used to reduce soil acidity and improve plant growth in managed lands. The application of lime is mostly done in agricultural lands and managed forests. The addition of carbonates to soils either as lime (e.g., calcic limestone (CaCO3), or as dolomite (CaMg(CO3)2) is known to contribute to CO2 emissions into the atmosphere. As there is no record of the use of lime or dolomite within the statistical bulletins of the NBS, who collect annual data

from the Federal Ministry of Agriculture and Rural Development (FMARD) or the Federal Department of Forestry (FDF). While calcic limestone is mostly used in cement production, it appears that most of the dolomite mined locally are exported. This report estimates under its first approximation that liming is zero in both agriculture and forestry programmes in Nigeria unless new data exists to show otherwise.

3.3.1.5 Urea Applications

The application of urea to agricultural soils during fertilisation is known to be associated with a loss of CO_2 which was fixed in the industrial production process. Urea ($CO(NH_2)_2$) is converted into ammonium (NH_4+), hydroxyl ion (OH-) and bicarbonate (HCO_3-) in the presence of water and urease enzymes. The bicarbonate is then converted chemically into CO_2 and water. The production and export of urea in Nigeria, of which the difference could represent annual consumption has not been regularly reported. There would be need for the Federal Ministry of Agriculture to provide new data on urea consumption based on the difference between local production and export.

3.3.1.6 Rice Cultivation

The NBS publishes annual production of different crops in Nigeria. The basic data for rice cultivation and yield are usually derived from the different NBS Annual Abstracts of Statistics. The data on the speciation of area under rice into irrigated, upland and rain-fed species are derivable from IPCC (2006) and IPCC (2019) refinements defaults for Nigeria. These indicate the percentage of rice under irrigated, upland and rain-fed condition to be 16, 51 and 33 percent respectively. Of the 33% of total area of rice cultivated under rain-fed condition, the relative contribution of each state to rice production indicated that flood prone and drought prone fractions can also be estimated. From these, the trends in rice production under the different water regimes can be obtained.

3.3.2 Emission Factors Data

The Country currently uses tier 1 emission factors data.

3.4 LAND USE, LAND USE CHANGE AND FORESRY SECTOR

The processes underlying greenhouse gas emissions and removals, as well as the different forms of terrestrial carbon stocks, can occur across all types of land. It also recognizes that same practices influence both Agriculture (sub-section 3.3) and this sub-section focused on Land Use, Land Use Change and Forestry (LULUCF). The integrated approach is intended to improve consistency and completeness in the estimation and reporting of greenhouse gas emissions and removals. The IPCC (2019) refinement builds on this objective by providing updates to the guidance in terms of improved emission factors, new methodologies and examples for compilers to better understand the estimation of emissions and removals across the AFOLU sector. For activities data estimation in the LULUCF sector, these include:

i. Adoption of the six land-use categories used in GPG-LULUCF. These land categories are further sub-divided into land remaining in the same category and land converted from one category to another. The land-use categories are designed to enable inclusion of all managed land area within a country;
ii. Reporting on all emissions by sources and removals by sinks from managed lands, which are considered to be anthropogenic, while emissions and removals for unmanaged lands are not reported;
iii. Identification of additional reporting elements introduced to report all emissions and removals for managed lands;

iv. Introduction of generic methods for accounting of biomass, dead organic matter and soil carbon stock changes in all land-use categories as well as introduction of generic methods for greenhouse gas emissions from biomass burning that can be applied in all land-use categories;
v. Incorporating methods for non-CO_2 emissions from managed soils and biomass burning, and livestock population characterization and manure management systems from Agriculture;
vi. Description of alternative methods to estimate and report carbon stock changes associated with harvested wood products;
vii. Incorporation of key category analysis for land-use categories, carbon pools and CO_2 and non-CO_2 greenhouse gas emissions;
viii. Adherence to principles of mass balance in computing carbon stock changes;
ix. Identification of methods to enhance greater consistency in land area classification for selecting appropriate emission and stock change factors and activity data;
x. Incorporation of methods to estimate CO_2 and CH_4 emissions from flooded land.

The activities data needs for LULUCF sector are presented in the following sub-sections.

3.4.1 Activities Data

The ways and means of estimating activities data for the LULUCF sector are presented in the sub-sections below.

3.4.1.1 Land Uses and Land Use Conversions

3.4.1.1.1 Land Use Categories

The land-use categories that are to be used to report emissions for LULUCF for which activities data would be needed include:

i. Forest Land (FL): This includes all land with woody vegetation consistent with thresholds used to define Forest Land by competent national authorities such as the Department of Forestry of the Federal Ministry of Environment. It also includes systems with a vegetation structure that currently fall below, but in-situ could potentially reach the threshold values used by Nigeria to define its Forest Land category.
ii. Cropland (CL): This includes cropped land, including rice fields and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category.
iii. Grassland (GL): This includes rangelands and pasture land that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and shrubs that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and Silvi-pastoral systems, consistent with national definitions.
iv. Wetlands (WL): This includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions. Wetlands are generally managed under the Ramsar Convention on Wetlands. The Convention signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. (See section 3.7 of the IPCC (2006) Guidelines document).
v. Settlements (SL) This includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories consistent with national definitions.

vi. Other Land (OL): In Nigeria, this category includes bare soil, rock and all land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available. In order to improve transparency and where data is available, other lands could be further categorized to include unmanaged lands by the above land-use categories. These could include Unmanaged Forest Land, Unmanaged Grassland and Unmanaged Wetlands.

3.4.1.1.2 Trends in Land Use and Land Cover Mapping in Nigeria

Nigeria has over the years undertaken a number of land-use and land-cover mappings to establish trends. These include the 1978/79 and 1993/95 full grid land cover mappings undertaken by the Forestry Management, Evaluation and Coordinating Unit (FORMECU) of the defunct Federal Department of Forestry in 1996 as well as the recently mappings of FAO and the Forestry Outlook Study for Africa (FASO) with projections up to the year 2020, a programme that is jointly funded under the auspices of the FAO, the World Bank and the African Development Bank (AFDB). Both recent reports used the FORMECU (1995) data as the base year with projections to 2016 and 2020 respectively. While the bulk of these current estimates of GHG emissions from AFOLU are based on FAO (2020), the data from FASO (2020) were used to fill some gaps and to enable projections to the year 2020. There is information that the National Space Research and development Agency (NASRDA) is currently updating data on LULUCF beyond the year 2020. These body of knowledge however lacked ground truthing data to validate above ground and below ground biomass stocks as well as soil carbon stocks across the different land use categories. This information is needed to quantify activities data in the LULUCF sector.

There would then be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as the Department of Forestry (DF) of Federal Ministry of Environment (FMENV), NBS and NASRDA, among others, to develop and provide the database associated with activities including the land areas and biomass stocks under each land use category as stipulated in sub-section 3.4.1.1.1 in this sub-sector of LULUCF annually.

3.4.1.1.3 Land Use Conversions

The IPCC (2006 and 2019) guidance documents require estimation of land-use conversions that lead to land use transition from one category to the other, to allow for carbon stock changes, emission and removal factor estimates which are associated with lands before and after a transition. Field validation of the projects undertaken between 1996 and the current period could also have been able to quantify forest conversion to other land use categories and similarly for cropland, grassland, wetland, settlements conversion to other land use categories, among others. The acronyms below are recommended for use as the nomenclature for the land uses/land cover and land-use conversions in future reports. They include:
FL-FL = Forest Land Remaining Forest Land;
CL-CL = Cropland Remaining Cropland
GL-GL = Grassland Remaining Grassland
WL-WL = Wetlands Remaining Wetlands
SL-SL = Settlements Remaining Settlements
OL-OL = Other Land Remaining Other Land
LL-FL = Land Converted to Forest Land, where LL could be CL, GL, WL, SL or OL
LL-CL = Land Converted to Cropland, where LL could be FL, GL, WL, SL or OL
LL-GL = Land Converted to Grassland, where LL could be FL, CL, WL, SL or OL
LL-WL = Land Converted to Wetlands, where LL could be FL, CL, GL, SL or OL
LL-SL = Land Converted to Settlements, where LL could be FL, CL, GL, WL or OL
LL-OL = Land Converted to Other Land, where LL could be FL, CL, GL, WL or SL

There would then be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as the DF of FMENV, NBS and NASRDA, among others, to develop and provide the database associated with activities including the land areas and biomass stocks conversion from one land use category to the other as stipulated in sub-section 3.4.1.1.1 in this sub-sector of LULUCF annually.

Methods to estimate greenhouse gas emissions and removals in the AFOLU Sector can be divided into two broad categories: 1) methods that can be applied in a similar way for any of the types of land use; and 2) methods that only apply to a single land use or that are applied to aggregate data on a national-level, without specifying land use. This section discusses the generic land uses under category 1.

3.4.1.1.3.1 Forest Land Remaining Forest Land

Changes in carbon stock for Forest Land Remaining Forest Land (FL-FL) are derivable from the forest land area remaining as forest land and carbon stock changes derivable from five carbon pools. These include:

i. Above-ground biomass;
ii. Below-ground biomass;
iii. Dead wood;
iv. Litter; and
v. Soil organic matter.

It also includes estimation of emissions of non-CO_2 gases.

3.4.1.1.3.2 Land Converted to Forest Land

Annual stock changes due to human activities, which occur on lands converted to Forest Land (LL-FL) from different land-uses through:

i. Afforestation: promotion of natural re-growth, establishment of plantations on non-forest lands or previously unmanaged Forest land, lands of settlements and industrial sites, abandonment of croplands, pastures or other managed lands, which re-grow to forest;
ii. Reforestation: promotion of natural re-growth, establishment of plantations on non-forest lands or previously unmanaged Forest land, lands of settlements and industrial sites, abandonment of croplands, pastures or other managed lands, which re-grow to forest; and
iii. Abandoned Lands.

While land conversion may result in an initial loss of carbon due to changes in biomass, dead organic matter, and soil carbon, natural regeneration or plantation practices lead to carbon uptake which is affected by changes in the area of plantations and their biomass stock

3.4.1.1.3.3 Cropland Remaining Cropland

These are croplands that have not undergone any land use conversion for a period of at least 20 years as a default period. The annual GHG emissions and removals from Cropland Remaining Cropland (CL-CL) include estimates of:

i. Land area that has remained Cropland over the default period;
ii. Annual change in carbon stocks from all carbon pools and sources for Cropland Remaining Cropland; and
iii. Annual emission of non-CO_2 gases from all pools and sources.

The changes in carbon stocks in Cropland Remaining Cropland may be estimated using Equation 3.3.

$$\Delta C_{CL-CL} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$$ Equation 3.3

Where:

ΔC_{CL-CL} = carbon stock changes for cropland remaining as cropland.

Subscripts denote the following carbon pools:

AB = above-ground biomass

BB = below-ground biomass

DW = deadwood

LI = litter

SO = soils

HWP = harvested wood products

3.4.1.1.3.4 Land Converted to Cropland

Conversion to Cropland is a leading contributor to land-use change from tropical deforestation and other activities meant to enhance food security. Estimation of annual GHG emissions and removals from Land Converted to Cropland (LL-CL) includes the following:

i. Total land areas converted to Cropland;

ii. Annual change in carbon stocks from all carbon pools and sources:
   a. Biomass (above-ground and below-ground biomass);
   b. Dead organic matter (dead wood and litter);
   c. Soils (soil organic matter);

iii. Estimates of non-CO_2 gases (CH_4, CO, N_2O, NO_x) from burning of above-ground biomass and dead organic matter

3.4.1.1.3.5 Grassland Remaining Grassland

This includes managed pastures which have always been under grassland vegetation and pasture use or other land categories converted to grassland more than 20 years ago. Estimating GHG emission for Grassland Remaining Grassland (GL-GL) involves an estimation of:

i Total land area that has remained Grassland over the default period;

ii Annual change in carbon stock from all carbon pools and sources:
   a. Above-ground biomass;
   b. Below-ground biomass;
   c. Dead wood;
   d. Litter;
   e. Soil organic matter;

iii Emissions of non-CO_2 gases.

The sources of emissions and removals of GHG in this category include Grassland management and changes in management. The changes in carbon stocks in Grassland Remaining Grassland may be estimated using Equation 3.4.

$$\Delta C_{GL-GL} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$$ Equation 3.4

Where:

ΔC_{GL-GL} = carbon stock changes for grassland remaining grassland.

Subscripts denote the following carbon pools:

AB = above-ground biomass
BB = below-ground biomass
DW = deadwood
LI = litter
SO = soils
HWP = harvested wood products

3.4.1.1.3.6 Land Converted to Grassland

This includes Forest Land or other land-use categories converted to Grassland within the last 20 years as default. Quantifying GHG emissions for this land-use category Land Converted to Grassland (LL-GL) involves estimation of:

i. Total land areas converted to Grassland from other land use classes;
ii. Annual change in carbon stock from all carbon pools and sources:
    a. Above-ground biomass;
    b. Below-ground biomass
    c. Dead wood
    d. Litter;
    e. Soil organic matter;
iii. Emissions of non-CO_2 gases.

The key sources of emissions and removals of GHGs in this category are mainly land-use change and management. The carbon implications of the conversion from other land uses to Grassland is not as clear as those for conversion to Cropland.

3.4.1.1.3.7 Wetlands Remaining Wetlands

This includes areas associated with peat extraction (Peatland) and land that is covered or saturated by water permently or intermittently (Flooded Land) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. A Peatland is a Wetland ecosystem where waterlogged conditions slow plant decomposition, causing organic matter (peat) to build up over time, making them massive carbon sinks, storing more carbon than all forests combined. These diverse landscapes, including bogs (rain-fed) and fens (groundwater-fed), support unique biodiversity, regulate water and provide climate regulation, but are highly vulnerable to drainage, releasing huge amounts of greenhouse gases. Wetlands Remaining Wetlands (WL-WL) are therefore divided into two:

i Peatlands Remaining Peatlands: This covers emissions from Peatlands (PL) undergoing active peat extraction. International Peat Society (2004) indicates that the use of peat is widely distributed: about half is used for energy; the remainder for horticultural, landscape, industrial waste water treatment and other purposes. The available information indicates that while peatlands are present in Nigeria (especially the Niger Delta region), their primary vulnerability relates to oil and gas exploration activities and land conversion for agriculture, rather than large-scale, documented commercial peat extraction for fuel or horticulture, as seen in other countries. Techniques for peat extraction from peat deposits are similar and all on-site sources of GHG emissions should be reported under this category regardless of the end-use of peat. Emissions from the off-site energy use of peat are reported in the Energy Sector. Estimating CO_2 emissions from lands undergoing peat extraction has two basic elements: on-site emissions from peat deposits during the extraction phase and off-site emissions from the horticultural use of peat which are estimated using Equation 3.5. Peat extraction starts with vegetation clearing, which prevents further carbon sequestration, so only CO_2 emissions are considered.

$$CO_{2_{WW_{peat}}} = \left(CO_2 - C_{WW_{peat_{off_{site}}}} + CO_2 - C_{WW_{peat_{on_{site}}}} \right) \cdot \left(\frac{44}{12} \right)$$ Equation 3.5

Where:

$CO_{2_{WW_{peat}}}$ = CO_2 emissions from land undergoing peat extraction, Gg CO_2 yr^1

$CO_2 - C_{WW_{peat_{off_{site}}}}$ = off-site CO_2–C emissions from peat removed for horticultural use, Gg C yr^{-1}

$CO_2 - C_{WW_{peat_{on_{site}}}}$ = on-site CO_2–C emissions from drained peat deposits,

Gg C yr^{-1}

Off-site CO_2–C emissions are associated to the horticultural use of peat extracted and removed. Off-site emissions from peat used for energy are to be reported in the Energy Sector. Regardless of the end-use of peat, the choice of method, emission factors and activity data for estimating the onsite emissions can be the same, so long as the data are disaggregated for type of peat, which is closely associated with nutrient level and climate zone.

ii Flooded Land Remaining Flooded Land: According to IPCC (2019) the initial flooding of land can cause elevated CO_2 emissions as inundated soil and biomass decay. After this initial phase, typically lasting 20 years or less, the CO_2 emitted from Flooded Land (FLL) is largely derived from carbon input from the catchment, which is estimated as emissions from other managed land categories, and not addressed in this category to avoid double-counting of emissions (i.e., IPCC (2019) Volume 4 Chapter 4 Forest Land, Chapter 5 Cropland, Chapter 6 Grassland, Chapter 8 Settlements and the 2013 Wetlands Supplement). Therefore, no methodologies (Choice of Methods, Emission Factors or Activity Data) are provided to estimate total CO_2 emissions for Flooded Land Remaining Flooded Land (FLL-FLL).

3.4.1.1.3.8 Land Converted to Wetlands

i Land Being Converted for Peat Extraction: Under a Tier 1 approach, the activity data do not distinguish between peatlands under peat extraction (Peatlands Remaining Peatlands), and those being converted for peat extraction. Section 7.2.1 of IPCC (2006) provides the methodological guidance for Peatlands Remaining Peatlands which is the same as Land Being Converted to Peat Extraction under the IPCC tier 1 approach, the subsisting approach used by Nigeria in its inventory.

ii Land Converted to Flooded Land: Conversion of land to Flooded Land is a disturbance that affects all five terrestrial carbon pools in the area impounded (above-ground biomass, below-ground biomass, litter, dead wood and soil organic matter; see 2006 IPCC Guidelines (Volume 4 Chapter 2, Fig. 2.1). Apart from the total land areas converted to Flooded Land, the 2006 IPCC Guidelines and 2013 Wetlands Supplement as well as Chapter 2 of the IPCC (2019) AFOLU sector, give guidance on how to estimate the five carbon pools in the land to be flooded and guidance is provided in Chapter 12 for estimating harvested wood products (HWP). Chapter 7 of IPCC (2019) AFOLU sector gives guidance on emissions related to land use conversion and the subsequent emissions. The changes in carbon stocks in Land Converted to Flooded Land (LL-FLL) may be estimated using Equation 3.6.

$$\Delta C_{LL-FLL} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$$ Equation 3.6

Where:

ΔC_{LL-FLL} = carbon stock changes for land converted to flooded land.

Subscripts denote the following carbon pools:

AB = above-ground biomass

BB = below-ground biomass

DW = deadwood

LI = litter

SO = soils

HWP = harvested wood products

3.4.1.1.3.9 Settlement Remaining Settlement

This refers to all classes of urban formations that have been in use as settlements (e.g., areas that are functionally or administratively associated with public or private land in cities, villages or other settlement types), since the last time data were collected. Emissions and removals of CO_2 in this category are estimated by:

i Land areas for Settlements Remaining Settlements (SL-SL) since last data collection/mapping;

ii Sub-categories of changes in carbon stocks in biomass, dead organic matter and soils, as summarized in Equation 3.7.

$$\Delta C_{SL-SL} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP} \quad \text{Equation 3.7}$$

Where:

ΔC_{SL-SL} = carbon stock changes for settlements converted to settlements.

Subscripts denote the following carbon pools:

AB = above-ground biomass

BB = below-ground biomass

DW = deadwood

LI = litter

SO = soils

HWP = harvested wood products

The biomass pool in settlements comprise woody and herbaceous components. For woody biomass, carbon stock change is calculated as the difference between biomass increment and biomass loss due to management activities. For herbaceous biomass in Settlements Remaining Settlements, the carbon stock change in biomass may be assumed to be zero. The dead organic matter pool in settlements contains dead wood and litter from both woody and herbaceous components. For the woody vegetation, changes in this pool can be quantified as production of coarse and fine litter from woody plants. For herbaceous vegetation, annual production of dead organic matter is estimated as the accumulation of thatch plus production of herbaceous material such as garden waste and yard trimmings. Greenhouse gas emissions associated with Waste Sector are estimated in IPCC (2006) Volume 5 (Waste) and therefore the methods in IPCC (2006) Chapter 8 describe only those components of annual production that can reasonably be expected to stay on-site. Soil carbon pools vary with time depending on the balance between carbon inputs from plant litter and other forms of organic matter and carbon outputs resulting from decomposition, erosion and leaching. Where large portions of lands are in cities and town or where there are high rates of settlements expansion, estimating the impact of settlement management on soil carbon storage becomes important. For mineral soils, the impact of settlement land use and management on soil carbon stocks may be estimated based on differences in storage among settlement cover classes relative to a reference condition, such as native lands. Armentano (1986) indicates that although organic soils are less commonly used for settlements, carbon is emitted from these soils if they are drained for development due to enhanced decomposition, similar to

the effect of drainage for agricultural purposes. Peat may also be harvested from organic soils during settlement development which will also generate emissions to the atmosphere.

3.4.1.1.3.10 Land Converted to Settlement

Land Converted to Settlements (LL-SL) occurs due to expansion of urban area, construction of transportation infrastructure and other reasons/purposes. Urban extent has been increasing globally over the last three decades (Seto et al. 2011). Land Converted to Settlements in Nigeria is rapidly increasing due to urbanization, population growth and economic pressures. This is significantly reducing agricultural land and natural covers like forests with major impacts on planning, leading to expansions around cities and transport routes, often with informal development and regulatory gaps. In areas that are primarily rural, even if land uses are not changing quickly, land devoted to residential uses can occupy a significant portion of the landscape. Conversion of Forest Land, Cropland, Grassland and Wetlands to Settlements has strong impacts on carbon stocks and fluxes (Imhoff et al., 2000; Milesi et al., 2003). Estimation of annual greenhouse gas emissions and removals from Land Converted to Settlements includes the following:

i Land areas converted to settlements since the last data collection/mapping;

ii Estimates of annual change in carbon stocks from all carbon pools and sources:
   a. Biomass (above-ground and below-ground biomass);
   b. Dead organic matter (dead wood and litter);
   c. Soils (soil organic matter); and

iii Estimates of non-CO2 gases (CH_4, CO, N_2O, NO_x) from burning of above-ground biomass and dead organic matter.

3.4.1.1.3.11 Other Land Remaining Other Land

Emissions and removals on Land Converted to Other Land class are estimated using the methods described below, which also cover land remaining Other Land after conversion. All areas of Other Land Remaining Other Land are included in the land-use change matrix as described in IPCC (2006) Volume 4 Chapter 3 as a check on the overall area. Emissions from land converted to bare soil as a result of development of settlements are to be included in the Settlements land-use category.

3.4.1.1.3.12 Land Converted to Other Land

Land can be converted to Other Land for a number of reasons. For instance, it could be as a result of deforestation with subsequent severe degradation, release of carbon stocks and associated emissions. Figure 3.2 provides the decision tree which can be used to identify the appropriate tier-level for Land Converted to Other Land. The fundamental equation for estimating change in carbon stocks associated with land-use conversions are summarized in Equation 3.8 and 3.9. This can be applied to estimate change in carbon stocks in Forest Land, Cropland, Grassland, Wetlands and Settlements converted to Other Land. Extensions to the method are provided for the subsequent treatment of these land areas following the transition period to the Other Land category.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L \qquad \text{Equation 3.8}$$

Where:

ΔC_B= annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1}

ΔC_G= annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr^{-1}

$\Delta C_{CONVERSION}$ = initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1}

ΔC_{L}= annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category in tonnes C yr^{-1}

$$\Delta C_{CONVERSION} = \sum_{i}\{(B_{AFTER_i} - B_{BEFORE_i}) \blacksquare \Delta A_{TO_{OTHERS_i}}\} \blacksquare CF \qquad \text{Equation 3.9}$$

Where:

$\Delta C_{CONVERSION}$ = initial change in biomass carbon stocks on land converted to another land category, tonnes C yr-1

B_{AFTER_i} = biomass stocks on land type i immediately after the conversion, tonnes dry matter ha^{-1}

B_{BEFORE_i} = biomass stocks on land type i before the conversion, tonnes dry matter ha-1

$\Delta A_{TO_{OTHERS_i}}$ = area of land use i converted to another land-use category in a certain year, ha yr^{-1}

CF = carbon fraction of dry matter, tonne C (tonnes dry matter)$^{-1}$

i = type of land use converted to another land-use category

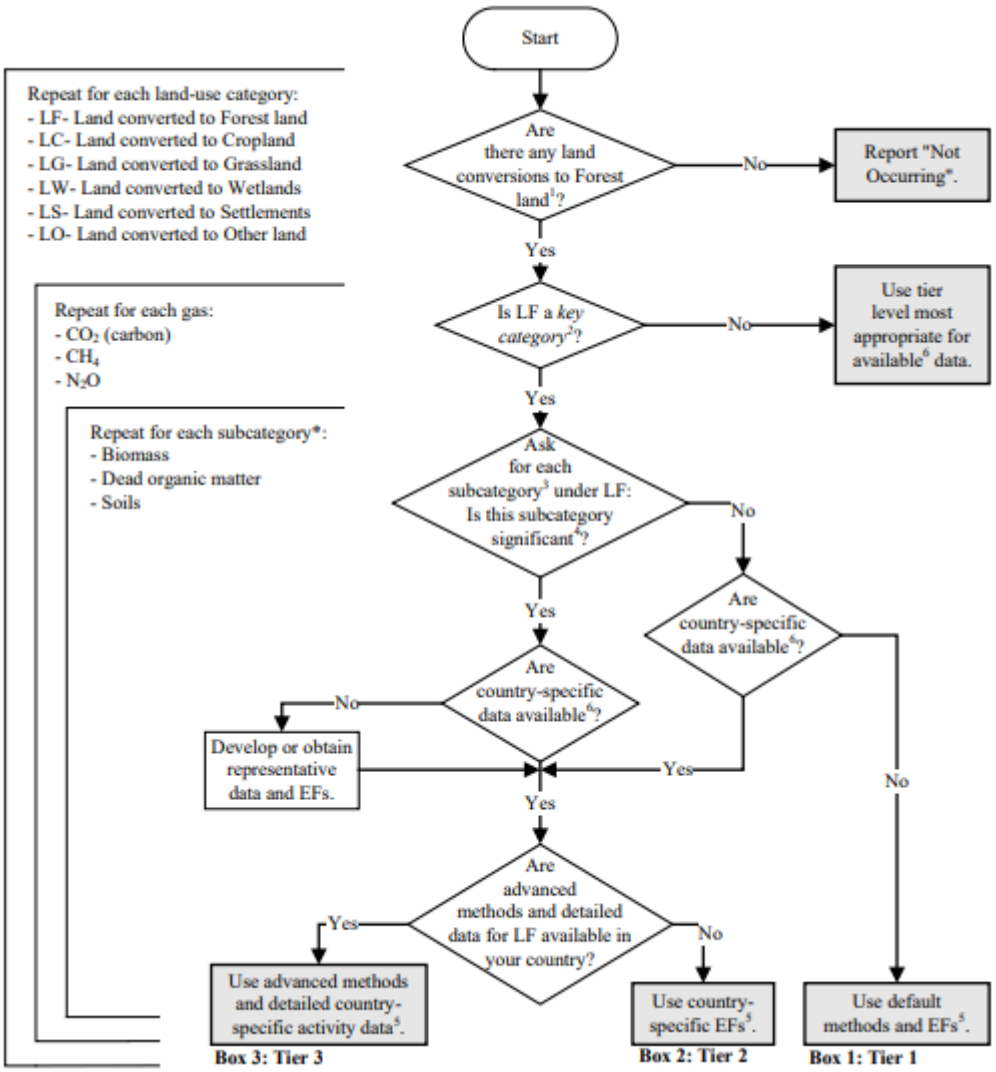

Figure 3.2: Decision tree for identification of appropriate Tier level for Land Converted to Other Land

There would then be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as the DF of FMENV, NBS and NASRDA, among others, to develop and provide the database associated with activities including the land areas and biomass stocks conversion from one land use category to the other as stipulated in the above sub-sections in this sub-sector of LULUCF annually.

3.4.1.2 Generic Methodologies Applicable to Multiple Land Use Categories

Chapter 2 of IPCC (2019) Volume 4 report provides that emissions and removals of CO_2 within the LULUCF are generally estimated on the basis of changes in ecosystem carbon stocks, comprising above-ground and below-ground biomass, dead organic matter and soil organic matter. As shown in Equation 3.10, net losses in total ecosystem carbon stocks are used to estimate CO_2 emissions to the atmosphere and net gains in total ecosystem carbon stocks are used to estimate removal of CO_2 from the atmosphere. The net CO2 emissions is then given as:

$$Net CO_2 emissions\ to\ the\ atmosphere = Gross\ CO_2 emissions - Gross\ CO_2 uptake \quad \text{Equation 3.10}$$

From above and below ground biomass in T CO_2-C.

Inter-pool transfers may be taken into account where appropriate. Changes in carbon stocks may be estimated by direct inventory methods or by process models. Each of the carbon stocks or pools can occur in any of land-use categories, hence general attributes of the methods that apply to any land-use category are described here. In particular cases, losses in carbon stocks or pools are also associated with emissions of non-CO_2 gases. It is good practice to check for complete coverage of CO_2 and non-CO_2 emissions due to losses in carbon stocks or pools to avoid omissions or double counting.

3.4.1.2.1 Change in Above-ground and Below-ground Biomass Carbon Stocks

Plant biomass constitutes a significant carbon stock in many ecosystems. Biomass is present in both above-ground and below-ground parts of annual and perennial plants. Biomass associated with annual and perennial herbaceous plants is relatively ephemeral, i.e., it decays and regenerates annually or every few years. So, emissions from decay are balanced by removals due to re-growth making overall net carbon stocks in biomass stable in the long term. Thus, the methods focus on stock changes in biomass associated with woody plants and trees, which can accumulate large amounts of carbon over their lifespan. Carbon stock change in biomass on Forest Land is an important sub-category in Nigeria because of substantial fluxes owing to management and harvest, natural disturbances, natural mortality and forest regrowth. In addition, land-use conversions from Forest Land to other land uses often result in substantial loss of carbon from the biomass pool. Trees and woody plants can occur in any of the six land-use categories although biomass stocks are however largest on Forest Land. For inventory purposes, changes in carbon stock in biomass are estimated for (i) land remaining in the same land-use category and (ii) land converted to a new land-use category. The reporting convention is that all emissions and removals associated with a land-use change are reported in the new land-use category. The net CO_2 emissions is provided for in Equation 3.11 above, which may be reduced to

$$Net CO_2 emissions\ to\ the\ atmosphere = A\left(\rho_{BE} - \rho_{BU}\right) \blacksquare C_B \blacksquare \frac{44}{12} \quad \text{Equation 3.11}$$

From above and below ground biomass in T CO_2-C.

Where:

A = land area associated with the biomass stock changes

ρ_{BE}=density of biomass emitted per unit area

ρ_{BU}= density of biomass sequestered per unit area

C_B= carbon content of the biomass

The above assumes that carbon content for the biomass emitted is the same as carbon content for the biomass sequestered.

3.4.1.2.2 Change in Carbon Stocks in Dead Organic Matter

Dead organic matter (DOM) comprises dead wood and litter. Estimating the carbon dynamics of dead organic matter pools allows for increased accuracy in the reporting of where and when carbon emissions and removals occur. For example, only some of the carbon contained in biomass killed during a biomass burning is emitted into the atmosphere in the year of the fire. Most of the biomass is added to dead wood, litter and soil pools from where the carbon will be emitted over years to decades, as the dead organic matter decomposes. Decay rates differ greatly between regions, ranging from high in warm and moist environments to low in cold and dry environments. Although the carbon dynamics of dead organic matter pools are well understood qualitatively, countries may find it difficult to obtain actual data with national coverage on dead organic matter stocks and their dynamics. In forest ecosystems, DOM pools tend to be largest following stand-replacing disturbances due to the addition of residual above-ground and below-ground biomass. In the years after the disturbance, DOM pools decline as carbon loss through decay exceeds the rate of carbon addition through litterfall, mortality and biomass turnover. Later in stand development, DOM pools increase again. Representing these dynamics requires separate estimation of age-dependent inputs and outputs associated with stand dynamics and disturbance-related inputs and losses. These more complex estimation procedures require higher Tier methods.

3.4.1.2.3 Change in Carbon Stocks in Soil

Although both organic and inorganic forms of carbon are found in soils, land use and management typically has a larger impact on organic carbon stocks. Consequently, the methods provided in this sub-section focus mostly on soil organic carbon. Overall, the influence of land use and management on soil organic carbon is dramatically different in a mineral versus an organic soil type. Generally, organic soils have a minimum of 12 percent organic carbon by mass, and develop under poorly drained conditions of wetlands (Brady & Weil 1999). All other soils are classified as mineral soil types, and typically have relatively low amounts of organic matter, occurring under moderate to well drained conditions and predominate in most ecosystems except wetlands.

There would be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as the DF of FMENV, NBS and NASRDA, among others, to develop and provide the database associated with activities including the land areas and biomass stocks conversion from one land use category to the other as stipulated in the above sub-sections in this sub-sector of LULUCF annually. In particular, the framework should make provisions for research into the methods that could be used to estimate stock changes in DOM, mineral and organic soils respectively.

3.4.1.3 Non-CO_2 Emissions

In addition to CO_2 emissions from the LULUCF sector, non-CO_2 GHG and precursor gases are also emitted. These include CH_4, N_2O, CO, NO_x and NMVOC emitted from sources such as fire, biomass burning or soils. A generic approach to estimating GHG emissions from fire (both CO_2 and non-CO_2 gases) is described in the sub-sections below. In order to avoid omissions and double counting, it is good practice to check for complete coverage of CO_2 and non-CO_2 emissions due to losses in carbon stocks and pools.

Emissions from fire include not only CO_2, but also other GHGs and their precursors that originate from incomplete combustion. Non-CO_2 GHG emissions from fire in savannas and burning of crop residues were addressed along with emissions from Forest Land and Grassland conversion in the IPCC (1996) Guidelines and GPG (2000). The

methodology used differed by vegetation type and fires in Forest Land were not included. The GPG-LULUCF document however addressed CO_2 and non-CO_2 emissions from fires particularly in the chapter covering Forest Land. In the Cropland and Grassland chapters, only non-CO_2 emissions were considered by first assuming that the CO_2 emissions would be counterbalanced by CO_2 removals from the subsequent regrowth of the vegetation within one year. This assumption implies maintenance of soil fertility, an assumption which countries may ignore if they have evidence of fertility decline due to fire. There is generally a lack of synchrony (non-equivalence of CO_2 emissions and removals in the year of reporting) in Forest Land.

Fire is treated as a disturbance that affects not only the biomass (in particular above-ground) but also the dead organic matter (litter and dead wood). The term `biomass burning` is widely used and is retained in this report but acknowledging that fuel components other than live biomass are often very significant, especially in forest systems. For Cropland and Grassland having little woody vegetation, reference is usually made to biomass burning, since biomass is the main pool affected by the fire.

The following steps are used to estimate emissions resulting from fires in Forest Land, Cropland and Grassland (IPCC (2019)):

i Coverage of reporting: With the exception of CO_2 from Grassland, CO_2 and non- CO_2 emissions need to be reported for all fires on managed lands. Where there is a land use change, any GHG emission from fire should be reported under the new land-use category. Emissions from wildfires (and escaped prescribed fires) that occur on unmanaged lands do not need to be reported unless they are associated with land use change.

ii Fire as a Management Tool: GHG emissions from the area burnt are reported and if the fire affects unmanaged land, GHG emissions should also be reported if the fire is followed by a land-use change.

iii Equivalence of CO_2 Emissions and Removals: CO_2 net emissions should be reported where the CO_2 emissions and removals for the biomass pool are not equivalent in the inventory year. For Grassland biomass burning and burning of agriculture residues, the assumption of equivalence is generally reasonable. However, woody vegetation may also burn in these land categories and GHG emissions from those sources are best reported using a higher Tier method. In Nigeria, pastoralists and farmers often burn savanna vegetation, including forest fringes to clear land for crops and stimulate fresh grass growth for livestock, a practice that significantly contributes to land degradation, deforestation, soil erosion, biodiversity loss and desertification, especially in northern savanna regions. The burning of high Forest land for grazing is not well reported in the south. For Forest Land, synchrony is unlikely if significant woody biomass is killed and the net emissions should be reported. Examples include: clearing of native forest and conversion to agriculture and/or plantations and wildfires in Forest Land.

iv Fuels Available for Combustion: In addition to land area exposed to fire, factors that reduce the amount of fuels available for combustion are to be accounted for. A mass balance approach should be adopted to account for residues to avoid underestimation or double counting.

v Annual Reporting: despite the large inherent spatial and temporal variability of fire, land areas and approximate biomass exposed to fire are to be reported annually.

The paragraphs below provide a comprehensive approach for estimating carbon stock changes and non-CO_2 emissions resulting from fire in the Forest Land and non-CO_2 emissions in the Cropland and Grassland. Non-CO_2 emissions are addressed for the following five types of burning: (1) grassland burning which includes perennial woody shrubland and savanna burning; (2) agricultural residues burning; (3) burning of litter, understory and harvest residues in Forest Land; (4) burning following forest clearing and conversion to agriculture; and (5) other types of burning including those resulting from wildfires. Direct emissions of CO_2 are also addressed for items (3) and (4) and (5). Since estimating emissions in these different categories have many elements in common, this

section provides a generic approach to estimate CO_2 and non-CO_2 emissions from fire to avoid repetition in specific land-use sections that address emissions from fire in this document.

Prescribed burning of savannas is included under the Grassland biomass burning section (IPCC (2019) Volume 4, Chapter 6, Grassland, Section 6.3.4). It is important to avoid double counting when estimating GHG emissions from savannas that have a vegetation physiognomy characteristic of Forest Land as may be the case for some sections of derived savanna zones in Nigeria.

In addition to the GHG emissions from combustion, fires may lead to the formation of an inert carbon stock (charcoal or char). Post-fire residues comprise unburned and partially burnt components as well as a small amount of char that due to its chemical nature is highly resistant to decomposition. The knowledge of the rates of char formation under contrasting burning conditions and subsequent turnover rates is currently limited (Forbes et al., 2006; Preston and Schmidt, 2006) to allow development of a reliable methodology for inventory purposes and hence is not included in this document.

There would then be need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as the DF of FMENV, NBS, NASRDA and relevant research institutions, among others, to develop and provide the database associated with activities including the land areas and biomass stocks in the different land use categories exposed to fire annually.

3.4.1.3.1 Method Description

This sub-section identifies a three-tiered approach to address CO_2 and non-CO_2 GHG emissions from fire. The choice of Tier is made following the steps in the decision tree presented in Figure 3.3. Under the Tier 1 approach, the formulation presented in Equation 3.8 can be applied to estimate CO_2 and non-CO_2 emissions from fire, using the default data provided in chapter 2 and the relevant land-use sections of IPCC (2019) Volume 4. Higher Tiers involve a more refined application of the same Equation 3.12.

$$L_{fire} = A \blacksquare M_B \blacksquare C_f \blacksquare G_{ef} \blacksquare 10^{-3} \qquad \text{Equation 3.12}$$

Where:

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG.

A = area burnt, ha

M_B = mass of fuel available for combustion, tonnes ha^{-1}. This includes biomass, ground litter and dead wood. When Tier 1 methods are used then litter and dead wood pools are assumed zero, except where there is a land-use change.

C_f = combustion factor, dimensionless.

G_{ef} = emission factor, g kg-1 dry matter burnt.

Note. Where data for M_B and C_f are not available, a default value for the amount of fuel actually burnt (the product of M_B and C_f) can be used under Tier 1 methodology.

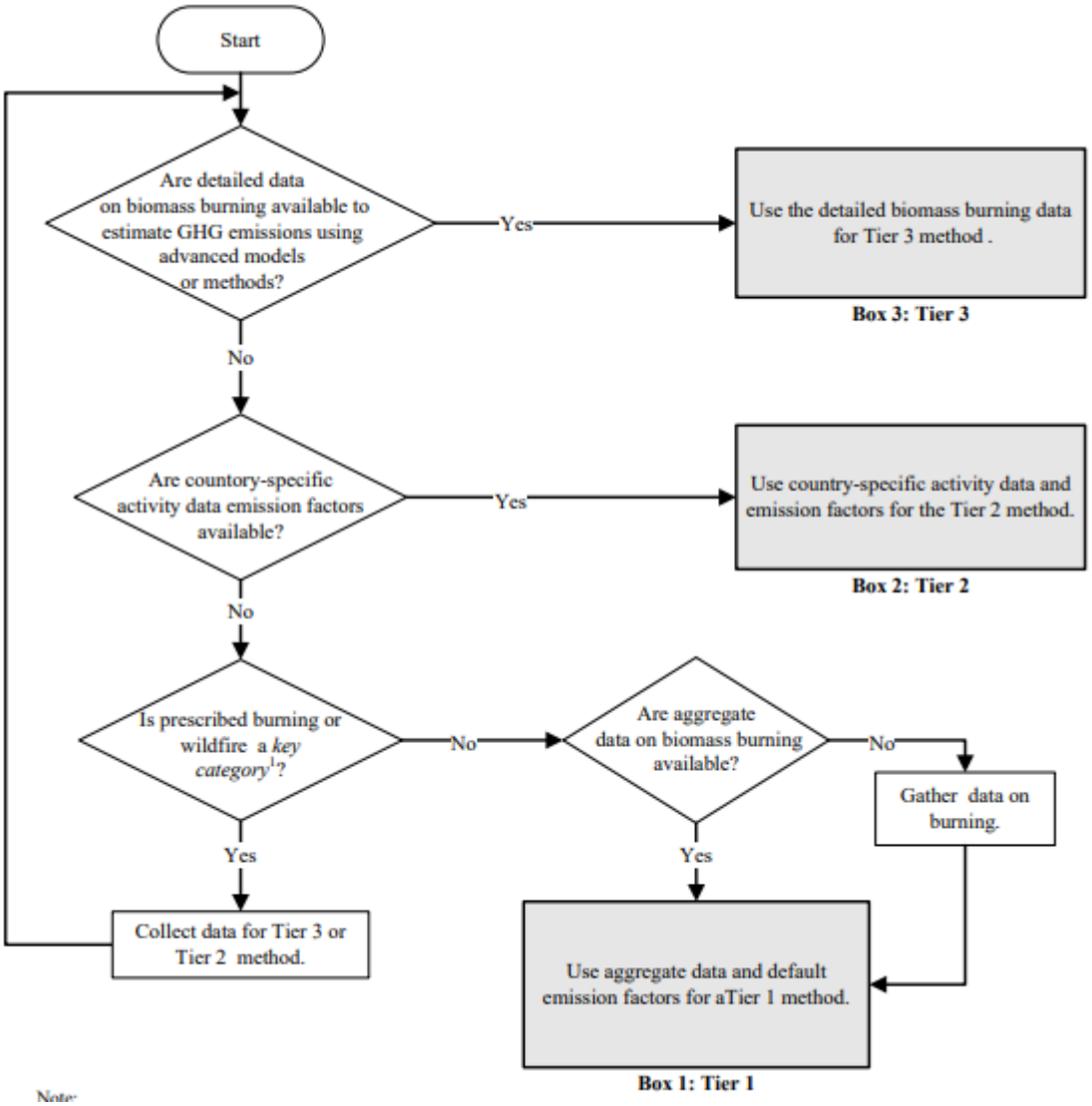

Figure 3.3: Generic Decision Tree for Identification of Appropriate Tier to Estimate GHG Emissions from Fire in a Land Use Category

Since Tier 1 methodology adopts a simplified approach to estimating the dead organic matter pool, certain assumptions must be made when estimating net GHG emissions from fire in those systems where dead organic matter can be a major component of the fuel burnt. Emissions of CO_2 from dead organic matter are assumed to be zero in forests that are burnt but not killed by fire. If the fire is of sufficient intensity to kill a portion of the forest stand, under Tier 1 methodology, the carbon contained in the killed biomass is assumed to be immediately released to the atmosphere. This Tier 1 simplification may result in an overestimation of actual emissions in the year of the fire if the amount of biomass carbon killed by the fire is greater than the amount of dead wood and litter carbon consumed by the fire.

Non-CO_2 GHG emissions are estimated for all fire situations. Under Tier 1, non-CO_2 emissions are best estimated using the land area burnt, estimate of fuel load per unit land area and emission factors associated with the fuels in sub-section 3.4.2.1.2. For forests where fire contributes to emissions such as forest reserves in the northern part of the country, a complete methodology for estimating emissions from fire in those forest sub-sectors will be undertaken. For Forest Land converted to other land uses, organic matter burnt is derived from both newly felled

vegetation and existing dead organic matter, and CO_2 emissions should be reported. In this situation, estimates of total fuel consumed can be used to estimate emissions of CO_2 and non-GHG using Equation 3.10.

The amount of fuel that can be burnt is given by the area burnt and the density of fuel present on that area. The fuel density can include biomass, dead wood and litter, which vary as a function of the type, age and condition of the vegetation. The type of fire also affects the amount of fuel available for combustion. For example, fuel available for low-intensity ground fires in forests will be largely restricted to litter and dead organic matter on the surface, while a higher-intensity 'crown fire' can also consume substantial amounts of tree biomass.

The combustion factor is a measure of the proportion of the fuel that is actually combusted, which varies as a function of the size and architecture of the fuel load, the moisture content of the fuel and the type of fire. Finally, the emission factor gives the amount of a particular greenhouse gas emitted per unit of dry matter combusted which can vary as a function of the carbon content of the biomass and the completeness of combustion. For species with high nitrogen concentrations, NO_x and N_2O emissions from fire can vary as a function of the nitrogen content of the fuel. A comprehensive review of emission factors was conducted by Andreae and Merlet (2001) and is summarised in Table 3.2. Tier 2 methods employ the same general approach as Tier 1 but make use of more refined country-derived emission factors and/or more refined estimates of fuel densities and combustion factors than those provided in the default tables. Tier 3 methods are more comprehensive and include considerations of the dynamics of fuels (biomass and dead organic matter).

There would be a strong need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as the DF of FMENV, NBS, NASRDA and relevant research institutions, among others, to develop and provide the database associated with activities including the land areas and biomass stocks that would be needed to compute emissions for tier 1 to tier 3 respectively.

3.4.1.4 Emissions from Harvested Wood Products

Harvested Wood Products (HWP) includes all wood material, including bark that leaves harvest sites. Any wood material including slash that are left at harvest site constitute dead organic matter and not HWP. HWPs are a carbon reservoir and retain carbon for different timescales depending on the product. Fuelwood for instance, may be burned within the year of harvest while carbon stored in paper may be held up to 5 years. Similarly, sawn wood or wood panels used in buildings and other such products may be held between a few decades and a few hundreds of years. Also, some HWPs that are discarded in solid waste disposal sites (SWDS) may remain there for long periods of time depending on the vicinity. Carbon in HWPs are oxidized with time and annual emissions associated with such oxidation may be less or more than the total harvested in the specific year of interest. However, UNFCCC secretariat (2003) estimates that carbon stored in HWP are increasing globally with time.

The IPCC (1996) default assumption was that inputs to the HWP reservoir equals outputs. Since the only significant output is oxidation, this means that the amount of oxidation equals the harvest, where the oxidation includes oxidation of some of the wood harvested in the current year and oxidation of some of the HWP placed in use in prior years.

IPCC (2006) provides method for estimating release of carbon which may also be counted as methane emissions in the Waste Sector. This indicates that there is possibility for double counting which may be corrected by subtracting the carbon emitted in the methane emissions from HWP in landfill from the carbon emissions estimated in this sub-section.

IPCC (2006) with refinements in IPCC (2019) indicates that in order to make estimates of the HWP Contribution for the various approaches, there is a generic set of annual variables that can be used to make the estimates. Using estimates of such annual variables, the HWP Contribution can be estimated for any of the currently proposed approaches. While not all of the data are required for every approach, the complete set would allow any of the proposed approaches to be adopted. These HWP Variables are:

i. Annual change in carbon stock in HWP, including HWP stocks from domestic harvest and imports (Gg of carbon per year);
ii. Annual change in carbon stock in HWP made from wood harvested in-country including annual change in carbon stock in HWP exported to other countries (Gg of carbon per year);
iii. Annual imports of all types of wood and paper material (Gg of carbon per year);
iv. Annual exports of all types of wood and paper material (Gg of carbon per year); and
v. Annual harvest for wood products in-country (Gg of carbon per year).

The specific methods for estimating these variables are provided by both IPCC (2006) and IPCC (2019) in the following tiers:

i. Tier 1: First Order Decay Method;
ii. Tier 2: Method using National-specific Data; and
iii. Tier 3: National-specific Methods

There would be a strong need for NCCC to come up with a strategy, policy or legislation that would compel MDAs such as the DF of FMENV, NBS, NASRDA and relevant research institutions, among others, to develop and provide datasets for HWPs as provided above as well as in the detailed methodology for tiers 1, 2 and 3.

3.4.2 Emission Factors Data

3.4.2.1 Emission Factors from Land Uses and Land Use Conversions

3.4.2.1.1 Emission Factors from Biomass Stock Changes

3.4.2.1.1.1 Change in Above-ground and Below-ground Biomass Stocks

CO_2 emission factors from above-ground and below-ground biomass are estimated from Equation 3.9 divided by the land area to obtain Equation 3.13 which is the emission factor per unit land area.

$$NetCO_2 emissions\ to\ the\ atmosphere = \left(\rho_{BE} - \rho_{BU}\right) \blacksquare C_B \blacksquare \frac{44}{12} \qquad \text{Equation 3.13}$$

From above and below ground biomass in T CO_2-C.

Where:

ρ_{BE}=density of biomass emitted per unit area

ρ_{BU}= density of biomass sequestered per unit area

C_B= carbon content of the biomass

3.4.2.1.1.2 Change in Carbon Stocks in Dead Organic Matter

The information for emission factors is still lean. National research team are expected to provide this information.

3.4.2.1.1.3 Change in Carbon Stocks in Soil

Tier 1 emission factors are based on land areas that are stratified by climate regions and default soils types as shown in Table 3.1. The emission factors for tiers 2 and 3 may need to be developed by national research teams.

Table 3.1: Emission Factors for Drained Organic Soils in Managed Forests

Emission Factors for Drained Organic Soils in Managed Forests		
Climate	**Emission factors (tonnes C ha^{-1} yr^{-1})**	
	Values	**Ranges**
Tropical	1.3	0.82-3.82
Temperature	0.68	0.41-1.91
Boreal	0.16	0.08-1.09

3.4.2.1.2 Emission Factors from Fire

Combustion factors and emission factors for dry matter burnt are presented for various burning regimes in Tables 3.2 and 3.3.

Table 3.2: Combustion Factor Values (Proportion of Pre-Fire Fuel Biomass Consumed) for Fires in a Range of Vegetation Types

Vegetation type	**Subcategory**	**Mean**	**SD**	**References**
Primary tropical forest (slash and burn)	Primary tropical forest	0.32	0.12	7, 8, 15, 56, 66, 3, 16, 53, 17, 45,
	Primary open tropical forest	0.45	0.09	21
	Primary tropical moist forest	0.50	0.03	37, 73
	Primary tropical dry forest	-	-	66
All primary tropical forests		**0.36**	**0.13**	
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3- 5 yrs)	0.46	-	61
	Intermediate secondary tropical forest (6-10 yrs)	0.67	0.21	61, 35
	Advanced secondary tropical forest (14-17 yrs)	0.50	0.10	61, 73
All secondary tropical forests		**0.55**	**0.06**	56, 66, 34, 30
All tertiary tropical forest		**0.59**	**-**	66, 30
Boreal forest	Wildfire (general)	0.40	0.06	33
	Crown fire	0.43	0.21	66, 41, 64, 63
	surface fire	0.15	0.08	64, 63
	Post logging slash burn	0.33	0.13	49, 40, 18
	Land clearing fire	0.59	-	67
All boreal forest		**0.34**	**0.17**	45, 47
	Wildfire	-	-	
	Prescribed fire – (surface)	0.61	0.11	72, 54, 60, 9

Eucalyptus forests	Post logging slash burn	0.68	0.14	25, 58, 46
	Felled and burned (land-clearing fire)	0.49	-	62
All Eucalyptus forests		**0.63**	**0.13**	
Other temperate forests	Post logging slash burn	0.62	0.12	55, 19, 27, 14
	Felled and burned (land-clearing fire)	0.51	-	53, 24, 71
All "other" temperate forests		**0.45**	**0.16**	53, 56
Shrublands	Shrubland (general)	0.95	-	44
	Calluna heath	0.71	0.30	26, 56, 39
	Fynbos	0.61	0.16	70, 44
All shrublands		**0.72**	**0.25**	
Savanna woodlands (early dry season burns)*	Savanna woodland	0.22	-	28
	Savanna parkland	0.73	-	57
	Other savanna woodlands	0.37	0.19	22, 29
All savanna woodlands (early dry season burns)		**0.40**	**0.22**	
Savanna woodlands (mid/late dry season burns)*	Savanna woodland	0.72	-	66, 57
	Savanna parkland	0.82	0.07	57, 6, 51
	Tropical savanna	0.73	0.04	52, 73, 66, 12
	Other savanna woodlands	0.68	0.19	22, 29, 44, 31, 57
All savanna woodlands (mid/late dry season burns)*		**0.74**	**0.14**	
Savanna Grasslands/ Pastures (early dry season burns)*	Tropical/sub-tropical grassland	0.74	-	28
	Grassland	-	-	48
All savanna grasslands (early dry season burns)*		**0.74**	**-**	
Savanna Grasslands/ Pastures (mid/late dry season burns)*	Tropical/sub-tropical grassland	0.92	0.11	44, 73, 66, 12, 57
	Tropical pasture˜	0.35	0.21	4, 23, 38, 66
	Savanna	0.86	0.12	53, 5, 56, 42, 50, 6, 45, 13, 44, 65, 66
All savanna grasslands (mid/late dry season burns)*		**0.77**	**0.26**	
Other vegetation types	Peatland	0.50	-	20, 44
	Tropical Wetlands	0.70	-	44
	Wheat residues	0.90	-	see Note b
	Maize residues	0.80	-	see Note b

Agricultural residues (Post-harvest field burning)	Rice residues	0.80	-	see Note b
	Sugarcane a	0.80	-	see Note b
	Other Crops	0.85	-	see Note b
* Surface layer combustion only; ~ Derived from slashed tropical forest (includes unburned woody material); [a] For sugarcane, data refer to burning before harvest of the crop; [b] Expert assessment by authors.				

Table 3.3: Emission Factors (G Kg-1 Dry Matter Burnt) for Various Types of Burning. Values are Means ± Sd and are based on the Comprehensive Review by Andreae and Merlet (2001)

Category	CO2	CO	CH4	N2O	NOX
Savanna and grassland	1613 ± 95	65 ± 20	2.3 ± 0.9	0.21 ± 0.10	3.9 ± 2.4
Agricultural residues	1515 ± 177	92 ± 84	2.7	0.07	2.5 ± 1.0
Tropical forest	1580 ± 90	104 ± 20	6.8 ± 2.0	0.20	1.6 ± 0.7
Extra tropical forest	1569 ± 131	107 ± 37	4.7 ± 1.9	0.26 ±0.07	3.0 ± 1.4
Biofuel burning	1550 ± 95	78 ± 31	6.1 ± 2.2	0.06	1.1 ± 0.6
Note: The "extra tropical forest' category includes all other forest types. Note: For combustion of non-woody biomass in Grassland and Cropland, CO2 emissions do not need to be estimated and reported, because it is assumed that annual CO2 removals (through growth) and emissions (whether by decay or fire) by biomass are in balance (see earlier discussion on synchrony in Section 2.4.					

3.4.2.2 Emission Factors from Harvested Wood Products

Please check IPCC (2006 and 2019) for appropriate tiers 1 to 3 emission factors.

3.5 WASTE SECTOR

3.5.1 Activities Data

The waste sector covers issues ranging from waste generation, composition and management. The collection of data on waste generation, composition and management for solid waste and wastewaters, and their methods of disposal and treatment, each of which lead to emissions are the subject of this sub-Section. The structure of processes and activity categories that lead to GHG emissions from wastes are presented in Figure 3.4

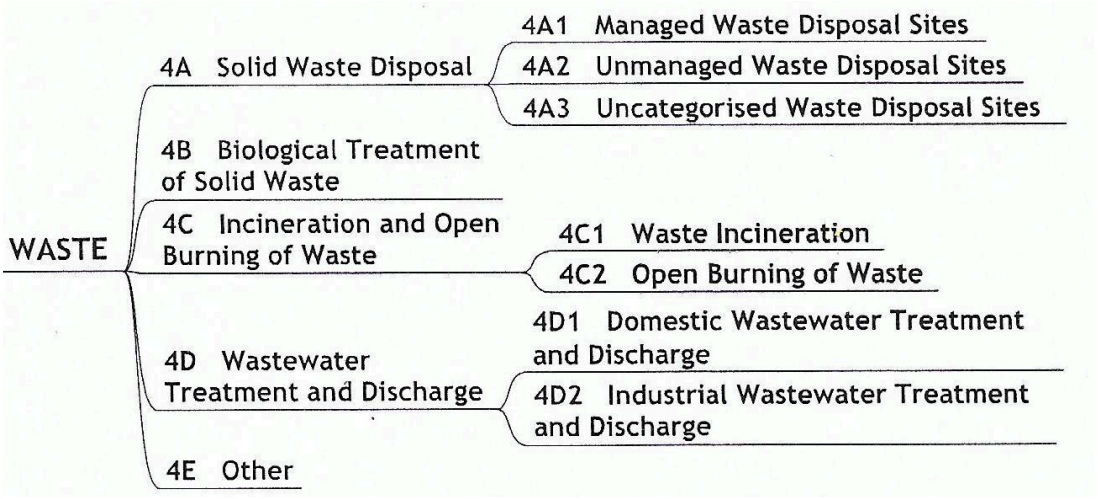

Figure 3.4: Process and Activity Structure for GHG Emissions in the Waste Sector

These processes and activities may be summarized as:

i. Solid Waste Disposal
   a. Managed Waste Disposal Sites
   b. Unmanaged Waste Disposal Sites
   c. Uncategorized Waste Disposal Sites

ii. Biological Treatment of Solid Waste
   a. Municipal Solid Waste
   b. Industrial Waste
   c. Anaerobic Digestion at Biogas Facilities

iii. Incineration and Open Burning of Waste
   a. Waste Incineration
   b. Open Burning of Wastes

iv. Wastewater Treatment and Discharge
   a. Domestic Wastewater Treatment and Discharge
   b. Industrial Wastewater Treatment and Discharge

3.5.1.1 Solid Waste Generation and Composition

The sources range from municipal infrastructure to industrial. Municipal Solid Waste (MSW) generation for urban areas in Nigeria have assessed for at least 13 state capital cities in Nigeria combining the mean data for Ogwueleka (2009) and Abila and Kantola (2015) out of a total of 15 cities assessed gave a mean per capita generation of 0.57 kg/cap/day. For rural areas, the data from Ehard (2015) is adopted at 0.29 kg/cap/day.
The waste generation per capita could be used in conjunction with the national population data to estimate gross waste generation per category per year. There is generally scarcity of data on solid waste generation from industries that are of organic origin. National data are needed in this sub-sector as a critical data for improving the quality of emissions from rest.

The typical bulk composition of MSW in Nigerian cities derived from a combination of literature data are presented in Table 4.41. Similarly, the typical composition of industrial and non-hazardous solid wastes is presented in Table 4.42. The general composition of these wastes included all types of recyclable wastes such as plastic, paper and glass, scraped metal, boxes and wood, rubber and textile wastes, but were generally found by Mallak et al (2016) to be dominated by iron (31%), plastic (24.54%), paper (25%), and other wastes (19.46%) in Thailand. New research data are needed to update these tables and provide annual information on such data.

Table 3.4: Mean Components of MSW Based on Ogwueleka (2009) And Harrir et al (2015)

City	Organic Wastes	Paper	Plastic	Glass (%)	Metal	Textile /Leather	Inert /Others	Total (%)
Makurdi	52.20	12.30	8.20	3.60	7.10	2.50	14.00	99.90
Abuja	58.50	8.00	11.10	4.80	3.10	1.45[1]	0.20	87.15
Maiduguri	25.80	7.50	18.10	4.30	9.20	3.90	31.30	100.10
Kano	43.00	17.00	4.00	2.00	5.00	7.00	22.00	100.00
Onitsha	30.35	23.10	9.20	9.20	6.20	6.20	15.40	99.65
Nsukka	56.00	13.80	8.40	2.50	6.80	3.10	9.40	100.00
Ibadan	76.00	6.60	4.00	0.60	2.50	1.40	8.90	100.00
Lagos	56.00	14.00	4.00	3.00	3.50	4.00	19.00	103.50
Mean	49.73	12.79	8.38	3.75	5.43	3.69	15.03	98.79

Table 3.5: Typical Composition of Industrial Solid Waste by Industry Type

S/N	Industry Type	Typical Solid Waste Composition
1	Electrical and Electronic	Plastic, Paper, steel, glass, scrap metal, box and wood
2	Non-Metallic and Minerals	Glass, wood, paper, metal, box
3	Basic Metal	Metal (iron, copper, aluminium), box, glass, paper and plastic
4	Food and Beverage	Paper, box and plastic
5	Medical Device	Box, glass and plastic
6	Textile and Apparel	Textile, paper
7	Chemical	Metal, glass, wood, paper, plastic and box
8	Wood	Wood, paper
9	Labelling and Packaging	Plastic, paper
10	Rubber	Metal, glass, wood, paper, plastic and box
11	Machinery and Equipment	Metal, paper

3.5.1.2 Apportionment of Solid Waste to Various Disposal and Management Categories

Most solid wastes generated in communities end up in managed and unmanaged Solid Waste Disposal Sites (SWDS). Understanding the waste generation rate, composition and other relevant waste data that are useful in planning wastes generated from community, gives general hints and guidance regarding data collection for solid waste management. There are no reliable national or state data available regarding the fraction of the MSW that are deployed to SWDS and other waste management processes such as biological treatment, waste incineration and open burning.

[1] Based on Olaide and Dias (2020)

There would be a strong need for NCCC to come up with a strategy, policy or legislation that would compel the State's Ministries of Environment and State's Waste Management Agencies, which ever exists in each State to create data collection templates that would make provision for data that are mandatory for emission estimations from the solid waste sector. Such templates would then be used for providing data needed for inventories by SMEs/SWMAs as well as by research institutions providing research data on emissions from each category of waste.

3.5.1.3 Wastewater Generation, Treatment and Discharge

The first step in establishing emissions from wastewater is to estimate the quantum of generation from domestic and industrial sources. This requires the characterization of wastewater according to the generation as well as the percentages flowing to different treatment systems (aerobic and anaerobic) and the percentage of untreated wastewater. This generation of Domestic Waste Water (DWW) have so far been estimated based on per capita DWW available in literature for Non-annex I (NAI) countries using tier 1 approach for emission estimates. Similarly, the parameters that are associated with Industrial Waste Water (IWW) generation in Table 4.47 are normally used to estimate IWW values in industrial sub-sectors with reported data on industrial productions.

Table 4. 47: Industrial Parameters Useful in the Estimate of Wastewater and Sludge Emission Factors

Industry	Industry Sub-Sector	Degradable Organic Component	Wastewater Produced	Fraction of DOC Removed as Sludge
		(kg COD/m^3-IWW)	(m^3/Tonne-Product)	(Fraction)
Iron and Steel		2	0.1	0.3
Non-ferrous metals				
Fertiliser		25	0.3	0.3
Food & Beverage	Canneries			
	Beer	17	5	0.3
	Wine			
	Meatpacking	3	0.014	0.3
	Dairy products			
	Sugar	15	98	0.3
	Fish Processing			
	Oil & grease			
	Coffee			
	Soft drinks	17	5	0.3
Paper & Pulp	Paper			
	Pulp	10	58	0.3
	Other			
Petroleum Refining & Petrochemicals		5	0.4	

There would be a strong need for NCCC to come up with a strategy, policy or legislation that would compel the States Ministries of Environment (SMEs) and States Waste Management Agencies (SWMA), which ever exists in each State to create data collection templates that would make provision for data that are mandatory for emission estimations from the waste water sector. Such templates would then be used for providing data needed for inventories by SMEs/SWMAs as well as by research institutions providing research data on emissions from each category of waste.

3.5.2 Emission Factors Data

The Country currently uses tier 1 emission factors data.

4. THE NATIONAL GHG EMISSIONS DATA FLOW SYSTEM

Responsibilities for data flow in national GHG inventories are distributed among several institutions. These are discussed in the sub-sections below.

4.1 THE CONCEPT OF DATA FLOW SYSTEM AND PURPOSE

4.1.1 The DFS Concept

A GHG inventory Data Flow System (DFS) is a structured system of institutions, operational procedures and tools required to enhance logical flow and used to support systematic movement of information or data from source to where it is needed for emissions compilation, archiving and other processes to improve the quality of inventories. The system becomes essential if such inventories are expected to align with the TRACCC criteria, as per the core principles established by the GHG Protocol and the IPCC Guidelines.

The DFS is the operational "how" of tracking emissions, encompassing the procedural and step-by-step methodology often focusing on the logic and sequence of data movement. The key elements include:

A. Focus:
Operational, procedural and logical flow.

B. Key Characteristics:

i. Logical View: Defines what steps happen.
ii. Human-Centric: Involves departments, teams and data providers such as National Statistical Institutions (NSIs).
iii. Focus on Sequence: Clearly defined schedules and workplans for annual reporting.

C. Components:

i. Data Collection Procedures: This provides the standardized processes designed by the entity (nation, states, municipalities etc.) for gathering the necessary activity data from source systems.
ii. Data Management Systems: This provides the tools and databases used to handle the datasets, perform calculations and archive all relevant documentation and assumptions.
iii. Quality Assurance and Quality Control: This provides the procedures to verify data integrity, identify errors and ensure continuous improvement of the inventory process.
iv. Reporting and Archiving: This provides the formal processes for compiling the final data into standardized reporting tables and written reports for internal use or submission to external bodies such as the UNFCCC.
v. Institutional Arrangements: This defines the roles, responsibilities and formal agreements between the various data providers and the coordinating institution to ensure reliable and recurring data access.

The detailed Components of the Data Flow System (DFS) for enhanced Greenhouse Gas (GHG) inventory management are presented in Sections 4.2 to 4.4.

4.1.2 Purpose and Benefits

The primary goal of a DFS is to:

i. Assess the existing institutions available for getting data from primary sources to the institutions that are responsible for emission computation, data management, quality assurance and quality control, and reporting, among others.
ii. Identify gaps that are to be filled with new institutions needed to support data flow for purposes of achieving (i) above.
iii. Identify gaps in data that are yet to be collect and to provide needed framework for collecting such new data to improve the quality of inventories under (i) and (ii) above.

4.2 NATIONAL ACTIVITIES DATA FLOW SYSTEM

The sources of activities data are presented below. They comprise:

i. The National Statistical Institutions which are responsible for collecting activities data from the formal sector of the economy and making them available to the data flow system for transmission to the institution(s) responsible for inventory compilation. These are presented on a sector-by-sector basis.
ii. Setting up an Integrated Surveillance System to Support Routine Update of New Activities Data.
iii. The use of modelling indicators to establish missing activities data.

4.2.1 National Statistical Institutions Responsible for Data Flow

4.2.1.1 Energy Sector

Data for the Energy Sector data comprises those for the reference approach as well as data for the detailed energy sector approach. The following are the institutions identified with responsibilities for data flow in the sector:

4.2.1.1.1 The Nigerian Upstream Petroleum Regulatory Commission

The Nigerian Upstream Petroleum Regulatory Commission (NUPRC) has the statutory responsibility of ensuring compliance to petroleum laws, regulations and guidelines in the Upstream Oil and Gas Sector, while carrying out the following functions, among others:

i. Supervising all Upstream Petroleum operations being carried out under licences and leases in the country;
ii. Maintaining records on upstream petroleum operations, particularly on matters relating to petroleum reserves, production/exports, licences and leases;
iii. Maintain and administer the National Data Repository (NDR) in the upstream oil and gas sector;
iv. maintain a Nigerian petroleum industry data bank comprising of materials, information and data acquired by, or submitted to, the Commission in the exercise of its statutory and regulatory functions; and
v. establish special laboratories to provide data storage and testing, quality assurance and certification for upstream petroleum operations.

As the administrator of the National Data Repository (NDR) in the upstream oil and gas sector, NUPRC is responsible for collecting upstream oil and gas data from the Nigerian National Petroleum Company (NNPC) Ltd and respective oil companies, through their Joint Venture (JV) partnerships with NNPC. Upon data collection, these data are then processed and archived in the NDR and used to provide data services to the public, whenever such data are needed.

NUPRC currently has data that is useful in supporting GHG inventory activities. These data include production, transportation, storage of crude oil and natural gas, as well as data on specific activity such as gas flaring, and data provided to the refineries, among other institutions, for use in their operations. These data would generally cover

some of the those required in the reference approach as well as in the detailed upstream petroleum sector production and consumption in sun-section 3.1.1. A few data may still be lacking. There may therefore be need for NCCC to liaise with NUPRC to define their detailed data needs across the entire energy sector, which NUPRC could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC.

4.2.1.1.2 The Nigerian Midstream and Downstream Petroleum Regulatory Authority

The Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) has the statutory responsibility of ensuring compliance to petroleum laws, regulations and guidelines in the Midstream and Downstream Oil and Gas Sectors, while carrying out the following functions, among others:

i. Regulate and monitor technical and commercial midstream and downstream petroleum operations in Nigeria;
ii. Establish laboratories to provide data storage and testing, quality assurance and certification of crude oil, natural gas and petroleum products and regulate the activities of third-party laboratories used in midstream and downstream petroleum operations;
iii. Keep and classify records, data and reports as may be prescribed in regulations or guidelines; and
iv. Develop, maintain and publish a database of midstream and downstream petroleum operations.

As the administrator of the national database for the midstream and downstream oil and gas sector, NMDPRA is responsible for collecting mid- and downstream oil and gas data from the Nigerian National Petroleum Company (NNPC) Ltd and respective oil companies, through their Joint Venture (JV) partnerships with NNPC as well as from refineries, petroleum products imports and exports, transportation to depots and filling stations, as well as data on depot and filling station sales to local entities, among others. Upon data collection, these data are then processed and archived in the NMDPRA database and used to provide data services to the public, whenever such data are needed.

NMDPRA currently has data that is useful in supporting GHG inventory activities. These data include production, transportation, storage of crude oil and natural gas in the mid- and downstream level, as well as data provided by the refineries, pipelines and depots, and filling stations among other entities. These data would generally cover some of the those required in the reference approach as well as in the detailed mid- and downstream petroleum sector production and consumption in Section 3.1.1. A wide range of data needed for GHG inventory may still be lacking. There is therefore need for NCCC to liaise with NMDPRA to define their detailed data needs across the entire energy sector, which NMDPRA could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC.

4.2.1.1.3 The Nigerian Coal Corporation

The Nigerian Coal Cooperation (NCC) has the statutory responsibility of exploiting coal resources and promoting activities such as coal mining, processing, exports and domestic consumption, while carrying out the following functions, among others:

i. To work and win the coal in the mines of coal transferred to the Corporation as well as in other deposits as may from time to time be made available under licence issued by the Minister;
ii. To make supplies of coal available of such qualities and sizes, in such quantities and at such prices, as may seem to them best calculated to further the public interest;
iii. To carry out research and experimental work in matters connected with the functions of the Corporation; and

iv. To carry on all such activities as it may appear to the Corporation to be requisite, advantageous, or convenient for them to carryon for or in connection with the discharge of their duties.

As the primary exploiter and licensee in the sector, NCC undoubtedly has records of its operations and related activities, hence, development of database on production processing, exports, transportation and consumption among others is part of their routine activities. These data would generally cover some of the those required in the reference approach as well as in the detailed energy sector approach in Section 3.1.1. Some of these data, especially coal consumption in residential, transportation (railway) and in industries are not published routinely. It is recognised that steps are being taken by the national assembly which could repeal the current Act and replace the NCC with a new entity. Whatever, the case may be, NCCC will need to work with whoever is the subsisting institution in the coal mining and production sector. There is therefore need for NCCC to liaise with NCC (or its successor-in-title) to define their detailed data needs across the energy sector, which NCC could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC.

4.2.1.1.4 The Energy Commission of Nigeria

The Energy Commission of Nigeria (ECN) is the apex government organization empowered with the statutory responsibility to carry out overall energy sector planning and policy implementation, while carrying out the following functions, among others:

i. Serving as a centre for gathering and dissemination of information relating to national policy in the field of energy development;
ii. Serving as a centre for solving any inter-related technical problems that may arise in the implementation of any policy relating to the field of energy;
iii. Collating, analysing and publishing information relating to the field of energy from all sources, where such information is relevant to the discharge of its functions under the ECN Act;
iv. Monitoring the performance of the energy sector in the execution of government policies on energy; and
v. Carry out such other activities as are conducive to the discharge of its functions under the Act.

As seen above, ECN is responsible for collecting all energy-sector-related data from the industry players, households, public and private sector establishments. Upon data collection, these data are then processed and archived in the ECN database by the ECN Energy Information System Department and used to provide data services to the public, whenever such data are needed.

ECN currently has a wide range of energy-sector-related data including energy masterplan database for the Federal Republic. These data would generally cover some of the those required in the reference approach as well as in the detailed energy sector approach in Section 3.1.1. A number of data may still be lacking. There may therefore be need for NCCC to liaise with ECN to define their detailed data needs across the entire energy sector, which ECN could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Such range of data would include:

i. Data on annual fuel consumption, fuel consumption per vehicle kilometre travelled (VKT) and other fuel consumption indicators by vehicle fleet, as defined by the Federal Ministry of Transportation and other national agencies responsible for transportation;
ii. Data on types and sizes of generators used for alternative electricity generation in (a) public sector; (b) commercial sector; (c) industrial sector; and (d) residential sector; and volume of diesel and gasoline consumed annually by generators of each size range;
iii. Annual fuel wood, charcoal, coal, solar photovoltaic, solar photothermal and other emerging fuels such as biogas, sawdust, cow dung consumption in the residential, commercial and industrial sectors;

iv. Annual consumption of fuels including light pour fuel oil (LPFO), diesel/automative fuel oil (AGO) and natural gas consumption by electricity generating plants as well as total electricity generated per plant by fuel type in million-kilowatt hours.
v. Annual coal consumption in the transportation sector (railway);
vi. Annual data on filling station dispensing units, their associated dispensing technologies, and fuel dispensed by filling stations; and
vii. Any other relevant information considered important for GHG inventory by the NCCC, as may be defined later.

4.2.1.1.5 The Federal Ministry of Power

The Federal Ministry of Power (FMP) is the policy-making arm of the Federal Government responsible for the provision of electricity in the country, with the core mandate to ensure a reliable, safe, and sustainable electricity supply. In discharging this responsibility, the Ministry performs the following functions, among others:

i Formulating and updating national electricity policies and implementation plans to harmonize the use of diverse fuel sources for stable power generation;
ii Creating an enabling environment for a decentralized electricity market, allowing State Governments and private investors to license and manage their own power systems;
iii Supervising the Rural Electrification Fund to drive the expansion of electricity infrastructure to unserved and underserved rural communities; and
iv Collecting, processing, and disseminating technical and commercial data on grid performance, generation capacity, and consumer metering to support sector-wide planning.

The FMP, primarily through its Planning, Research & Statistics department, is mandated to collect data across the entire electricity value chain (generation, transmission, and distribution) for policy formulation and performance monitoring. A crucial target is the full deployment of the Supervisory Control and Data Acquisition (SCADA) system for automated, real-time grid monitoring, fault detection and digital control. Once collected, data is archived in the National Energy Data Bank to provide accurate data services to the public, among other functions.

FMP currently has data that is useful in supporting GHG inventory activities. These include data on categories of turbines used for electricity generation by fuel, by technology and by generation capacity, as well as data on annual fuel consumption by type of fuel per category of turbines, among others. These data would generally cover some of those required in the detailed energy sector approach in Section 3.1.1. A few data are still lacking. There is therefore need for NCCC to liaise with FMP to define their detailed data needs across the power generation sector, which FMP could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC.

4.2.1.1.6 The Federal Ministry of Transportation

The Federal Ministry of Transportation (FMoT) has the core mandate to ensure a fast, safe, efficient, affordable, convenient, integrated, and inter-modal transport system that supports the nation's socio-economic development, while carrying out the following functions, among others:

i. Developing short, medium, and long-term national transport plans and policies, coordinating research, and reviewing feasibility studies for projects;
ii. Managing the National Transport Databank (NTDB) to collect, process, and disseminate statistics on all transport modes, covering network, terminals, flows, and impacts;
iii. Conducting applied research, serving as a Transport Intelligence Centre, and providing advisory functions; and

iv. Liaising with state governments, federal agencies (like the National Bureau of Statistics), and international partners for data sharing and project implementation.

The FMoT, primarily through its Planning, Research & Statistics (PRS) department and the Nigerian Institute of Transport Technology (NITT), has a mandate for collecting data across all modes (road, rail, water, air) for policy, planning, and performance monitoring, focusing on improving efficiency, safety, and sustainability, with a key goal being the establishment of a unified National Transport Data Bank (NTDB). Upon data collection, these data are then processed and archived in the NTDB and used, among other things, to provide data services to the public, whenever such data are needed.

FMoT currently has data that is useful in supporting GHG inventory activities. These data include vehicle information by fleet and by technology, across all transportation modes as well as the contribution of each transport mode to the inter-modal transportation data. These data would generally cover some of the those required in the energy sector approach in Section 3.1.1. A few data are still lacking. There is therefore need for NCCC to liaise with FMoT to define their detailed data needs across the entire energy sector, which FMoT could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Such data could among others, include:

i. Defining the vehicle fleet by fuel, technology and vehicle weight for each transportation mode in such a manner that each vehicle can only belong to one fleet category. The transportation modes shall include road, rail, air, inland waterways and maritime transportation. Where possible, the aviation, inland waterways and marine transportation shall be further subdivided into civil and military transportation systems, where military transportation data could be provided with adequate provision for confidentiality to protect national security; and
ii. Annual fuel consumption by vehicle fleet in each transport mode as defined above.

4.2.1.1.7 The Federal Ministry of Agriculture and Food Security

The full mandate of the Federal Ministry of Agriculture and Food Security (FMAFS) is presented in Section 4.2.1.3.2. The Ministry currently has data that is useful in supporting GHG inventory activities in the energy sector, but these data do not appear to be currently available in the format required. There is therefore need for NCCC to liaise with FMAFS to define their detailed data needs across the crop production sector relevant to energy consumption, which FMAFS could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Such data could include:

i. Defining the off-road vehicle fleet that are used to support agriculture;
ii. Annual fuel consumption per fleet category (gasoline, diesel, others);
iii. Non-mobile sources of fuel consumption (generators, farm equipment, etc.) in the sector (gasoline, diesel, others).

4.2.1.1.8 The Federal Ministry of Aviation and Aerospace Development

The Federal Ministry of Aviation and Aerospace Development (FMAD) is directly responsible for the overall development of the aviation sector in the country, while carrying out the following functions, among others:

i. Developing and managing government programs for the entire aviation and aerospace sector.
ii. Ensuring that all aviation activities align with the International Civil Aviation Organization (ICAO) and World Meteorological Organization (WMO) standards.
iii. Supervising key parastatals including the Nigerian Civil Aviation Authority (NCAA), Federal Airport Authority of Nigeria (FAAN), Nigerian Airspace Management Agency (NAMA), Nigerian Meteorological Agency (NiMet), and the Nigerian Safety Investigation Bureau (NSIB).

iv. to collect, process, and analyse comprehensive data, including safety performance metrics via the Safety Data Collection and Processing System (SDCPS), economic statistics and passenger manifests for revenue oversight, real-time weather information through NiMet, and Advanced Cargo Information (ACI) for security—all of which are managed through the Electronic Content Management System (ECMS).

FMAD has a mandate to collect data, including safety reports, flight data analysis, and advanced cargo information (ACI) systems, among other things. Upon data collection, these data are then processed and archived in the ECMS and used, among other things, to provide data services to the public, whenever such data are needed.

FMAD currently has data that is useful in supporting GHG inventory activities. These data include aircraft fleet data for domestic and international aviation, annual fuel consumption by fleet for domestic and international aviation, annual fuel consumption for airport logistics and electricity generation, among others. These data would generally cover some of the those required in the detailed energy sector approach in Section 3.1.1. Not all these data are currently available from the National Bureau of Statistics (NBS) and national statistical institutions. There is therefore need for NCCC to liaise with FMAD to define their detailed data needs across the entire energy sector, which FMAD could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Among these, critical data are:

i. Definition of aircraft fleet for civil aviation in the domestic and international routes by aircraft technology and aircraft size in such a way that every aircraft can be classified into only one fleet category;
ii. Annual numbers of aircraft per fleet for domestic and international aviation;
iii. Fuel consumption (diesel and gasoline) per fleet for domestic and international aviation;
iv. Fuel consumption (diesel and gasoline) for airport logistics, for domestic and international aviation, excluding power generation; and
v. Fuel consumption (diesel, other) for power generation at airports.

4.2.1.1.9 Nigerian Port Authority

The Nigerian Ports Authority (NPA) is the statutory body mandated to manage, develop, and operate Nigeria's ports and harbours, ensuring safe and navigable waterways while maintaining the overall security of maritime operations. In discharging this responsibility, the NPA performs the following functions:

i. Developing, owning, and operating ports and harbours, including conducting hydrographic surveys and providing essential towage, mooring, and pilotage services to ensure safe and navigable channels;
ii. Collecting, processing, and analysing port statistics (including vessel turnaround times, cargo throughput, and berth occupancy rates) to monitor operational efficiency and facilitate national trade planning;
iii. Administering land and water within port limits and monitoring concession agreements with private terminal operators to ensure compliance with international safety, environmental, and performance standards; and
iv. Planning and maintaining port operational infrastructure while enforcing regulations and bylaws to ensure a secure and customer-friendly environment as well mitigating marine pollution risks.

The NPA is mandated to collect data across all maritime operations to facilitate trade and monitor port efficiency. This data collection covers vessel traffic, cargo volumes, and terminal performance to ensure transparency and accountability within the port system. Upon collection, these data are processed and archived to provide essential maritime statistics to the public, inform federal trade policies, and support the National Single Window initiative for streamlined cargo clearance and improved global trade connectivity.

NPA currently has data that is useful in supporting GHG inventory activities. These data include information on maritime vessel fleet and fuel consumed by such fleet. These data would generally cover some of those required in

the detailed energy sector approach in Section 3.1.1. Not all these data are currently available from the National Bureau of Statistics (NBS) and other national statistical institutions. There is therefore need for NCCC to liaise with NPA to define their detailed data needs across the maritime transport sector, which NPA could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Among these, critical data include:

i. Definition of marine vehicle fleet by fuel, technology and weight in the maritime sector;
ii. Other fuel consuming stationary and off-road mobile facilities in the ports sector by fuel type;
iii. Provision of statistics for the annual entry and exit of marine vehicle fleet into the Nigerian ports;
iv. Annual fuel consumption by type per marine fleet category;
v. Annual fuel consumption by stationary and off-road mobile facilities in the ports sector for (a) electricity generation; (b) for any other services including.

4.2.1.1.10 National Inland Waterways Authority

The National Inland Waterways Authority (NIWA) is the statutory body mandated to manage, regulate, and develop Nigeria's inland waterways, ensuring a safe and efficient alternative mode of transportation for the evacuation of economic goods and persons. In discharging this responsibility, NIWA performs the following functions:

i. Developing, owning, and maintaining inland river ports, jetties, and dockyards, including undertaking capital and maintenance dredging and providing essential navigational aids like buoys and lights to ensure all-year-round channel navigability;
ii. Collecting, processing, and publishing navigational and hydrological data (including river flow measurements, bathymetric mapping, and water discharge rates) to produce river charts, maps, and hydrological yearbooks for informed maritime decision-making, among others;
iii. Administering the right-of-way of declared federal waterways and managing the registration and licensing of all inland watercraft, shipyard operators, and private waterway piers to ensure compliance with safety and environmental standards; and
iv. Planning and regulating water transportation infrastructure while enforcing the Waterways Transportation Code and maritime safety bylaws to mitigate risks such as marine pollution and waterways obstruction by aquatic weeds.

NIWA is mandated to collect data across all inland maritime operations to facilitate trade and monitor waterway efficiency. This data collection covers vessel registration, river flow characteristics, and sedimentological studies. Upon collection, the data are processed and archived to provide essential maritime statistics to the public and support the National Single Window initiative, among other things.

NIWA currently has data that is useful in supporting GHG inventory activities. These data include information on watercraft vessel fleet and associated fuel consumption by fleet. These data would generally cover some of those required in the detailed energy sector approach in Section 3.1.1. Not all these data are currently available to the public. There is therefore need for NCCC to liaise with NIWA to define their detailed data needs across the inland waterways transport sector, which NIWA could then provide, when requested, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. These data could, among others, include:

i. Defining the watercraft transportation fleet by fuel, technology and weight;
ii. Other infrastructure associated with fuel consumption at inland river ports, jetties, and dockyards;
iii. Annual fuel consumption of watercraft, by fuel type per fleet category;
iv. Annual fuel consumption at stationary inland waterway facilities such as inland river ports, dockyards and jetties.

4.2.1.1.11 The Ministry of Defence

The Ministry of Defence (MOD) is the arm of the Federal Government responsible for the administration of the Nigerian Armed Forces, with the core mandate to maintain a modern, professional, and combat-ready military to protect Nigeria's territorial integrity and ensure national security. In discharging this responsibility, the Ministry performs the following functions, among others:

i. Formulating and implementing national defence policies and implementation plans to ensure the operational readiness, training, and welfare of the Nigerian Armed Forces;
ii. Overseeing the procurement of military hardware and fostering domestic defence production through the Defence Industries Corporation of Nigeria (DICON) to enhance national self-reliance in defence requirements;
iii. Coordinating internal security operations and international peacekeeping commitments to maintain national stability and fulfil international security obligations; and
iv. Collecting, processing, and analysing strategic defence data, including personnel nominal rolls, equipment inventories, and security intelligence, to support evidence-based defence planning and resource allocation.

The MOD, primarily through its Planning, Research & Statistics department, is mandated to collect data across all defence operations to evaluate national security threats and monitor military readiness. A crucial component of this mandate is the Electronic Content Management System (ECMS), implemented as of December 31, 2025, which ensures a secure, fully digitalized environment for real-time data handling and personnel management. Once processed, this defence data is used for national security planning, policy formulation and implementation.

Some of the MOD data are useful in supporting GHG inventory activities. However, in view of the nature of military operations, the Ministry does not generally share its data with the public. A persuasive and reassuring approach is needed by NCCC to liaise with MOD in providing the key data that could be used for GHG inventory. MOD would be comfortable to release such data in confidence to NCCC using codes that do not reveal the strategic technologies associated with them, except for fuel consumption and emission factors, where available. There would therefore be need for a Memorandum of Agreement/Understanding (MOA/MOU) between the MOD and NCCC that spells out the data requirements of NCCC for GHG inventory with the assurance in the MOA/MOU that the reported inventory shall use codes that protects such information from public access to sensitive military technologies and information that could compromise national security. The NCCC will also need to provide assurance of the confidentiality of all data released to them by the MOD. Such data could among others, include:

i. Annual vehicle fleet for Army, Navy and Airforce operations, and the corresponding fuel consumption per fleet; and
ii. Military stationary sources, and annual fuel consumption per source category.

4.2.1.2 Industrial Processes and Products Use (IPPU) Sector

The NSIs that support activities data collection in the IPPU Sector, are presented in the subsections below.

4.2.1.2.1 Federal Ministry of Industry, Trade and Investment

The Federal Ministry of Industry, Trade and Investment (FMITI) is the government body responsible for creating an enabling environment for industrialization, trade expansion, and investment attraction to drive Nigeria's economic diversification. Its core mandate is to foster a sustainable and inclusive economy by supporting local businesses and integrating Nigeria into the global market. In discharging this responsibility, the Ministry performs the following functions, among others:

i. Formulating and implementing industrial policies to strengthen Nigeria's manufacturing base, promote innovation, and drive value addition across key sectors such as solid minerals and the creative economy;
ii. Facilitating domestic and foreign direct investment by modernizing regulatory regimes, streamlining licensing procedures, and establishing sub-national one-stop investment centres to restore investor confidence;
iii. Promoting regional and global trade through the leadership and implementation of the African Continental Free Trade Area (AfCFTA) and the negotiation of preferential trade agreements to enhance market access for Nigerian exporters; and
iv. Collecting, processing, and analysing industrial and trade statistics to monitor sectoral performance, track investment flows, and inform evidence-based national economic planning.

The FMITI, primarily through its Planning, Research & Statistics department, is mandated to collect and manage data across the industry and trade value chains for performance monitoring and policy formulation. Once collected, these data are archived to provide accurate market insights to the public, support the National Single Window initiative for streamlined trade facilitation, and track the delivery of priority investment projects.

FMITI currently has industrial production data that is useful in supporting GHG inventory activities, but most of these are not readily made available. There is therefore need for NCCC to liaise with FMITI to define their detailed data needs across the entire energy sector, which FMITI could then provide, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC.

4.2.1.2.2 Manufacturer's Association of Nigeria

The Manufacturers Association of Nigeria (MAN) is a national industrial association that serves as the representative voice for nearly 2,000 companies across the private and public industrial sectors. Its core mandate is to promote the interests of manufacturers by fostering a business-friendly environment, deepening advocacy with government actors, and driving industrial competition for national economic growth. In discharging this responsibility, the Association performs the following functions, among others:

i. Advocating for favourable industrial and economic policies to stabilize the operating environment;
ii. Promoting "Made-in-Nigeria" products and enhancing the export capacity of local firms through the MAN Export Group to maximize opportunities under the African Continental Free Trade Area (AfCFTA);
iii. Facilitating technical capacity building and research through the MAN Resource Centre (MRC) to encourage the adoption of smart factory technologies; and
iv. Liaising with government and regulatory bodies to harmonize taxes, improve infrastructure in industrial hubs, and ensure consistent policy implementation to restore investor confidence.

MAN is mandated to conduct extensive research and collect industrial data to inform its advocacy and support national economic planning. This data collection is primarily executed through its research and statistical functions, which produce the half-yearly Economic Review covering key indicators such as capacity utilization, local raw material sourcing, and employment trends. Once processed, this data is used to advise the Federal Government on industrial policy, guide the Raw Materials Research and Development Council (RMRDC), and provide members with critical market intelligence to enhance global competitiveness.

MAN has some data that may be useful in supporting the estimation of GHG emissions. Examples of such data include annual production of certain industrial products. However, these data do not appear to be publicly available. It would therefore be useful if NCCC could liaise with MAN to ensure that these data are made available annually for emission inventory activities; through a Memorandum of Agreement/Understanding (MOA/MOU) that

is acceptable to both parties. The MOA/MOU should spell out the data that are needed by NCCC to support its operations. These among others include

i. Data on industrial solid mineral products, iron and steel production, aluminium production; etc.
ii. Data on electrical and electronics equipment production; and
iii. Data on manufacture of compressors of air conditioners, refrigerators, fire extinguishers, rigid and flexible foams as well as products in aerosol spray cans.

4.2.1.2.3 National Bureau of Statistics

The full mandate of the National Bureau of Statistics (NBS) is presented in sub-section 4.2.1.6.1. The Bureau, being involved in cross-sectoral activities data collection and publication, already has a wide range of data that could support national GHG emission inventories. However, these data are lacking in certain areas where industrial process and products use are concerned. It would therefore be necessary for NCCC liaise and sign a Memorandum of Agreement/Understanding (MOA/MOU) with NBS to make data available to it in formats that are needed for inventories.

4.2.1.2.4 Nigeria Customs Service

The full mandate of the Nigeria Customs Service (NCS) is presented in Section 4.2.1.6.2. The NCS, being the regulator of imports and exports of goods into the country through its major gateways – land, air and sea ports is the custodian of data that may be useful in estimating GHG emissions in the IPPU Sector. This is especially so for data on imported products that contribute to the emissions of F-Gases. It is therefore important that NCCC liaises with and enters a Memorandum of Agreement/Understanding (MOA/MOU) with NCS to provide such data available to it in formats that are needed for inventories. Some of these include data on imports of F-Gases that are used in manufacturing processes or by end-users, including man-made compounds such as:

i. Hydrofluorocarbons (HFCs);
ii. Perfluorocarbons (PFCs);
iii. Sulphur hexafluoride (SF_6);
iv. Nitrogen trifluoride (NF_3);
v. HFCs used as alternatives to ozone depleting substances (ODS) in various types of product applications; and
vi. N_2O.

4.2.1.2.5 The Power Sector

The mandate of the Federal Ministry of Power has been presented in sub-section 4.2.1.1.5 including its role in coordinating data archival and information sharing to the public on activities in the power sector. The power sector is responsible for electricity generation at the national and state levels. The key activities of the power sector re hosted by a number of companies at the federal level which include electricity generating Companies (GENCOs), Transmission Company of Nigeria (TCN) and electricity Distribution Companies (DISCOs). At the state level, there are also generating and distributing companies. This sector of the economy is known to be associated with the consumption of F-Gases which contribute to greenhouse effect. It is therefore important that NCCC liaises with and enters a Memorandum of Agreement/Understanding (MOA/MOU) with the Ministry of Power and the above companies to provide data available to it in formats that are needed for inventories. Some of these include data on consumption of F-Gases that are used in the electricity sector by each of the above companies, including man-made compounds such as:

a. Hydrofluorocarbons (HFCs);
b. Perfluorocarbons (PFCs);
c. Sulphur hexafluoride (SF_6);
d. Nitrogen trifluoride (NF_3);

e. HFCs used as alternatives to ozone depleting substances (ODS) in various types of product applications; and
f. N_2O.

4.2.1.2.6 Research Centres, Nuclear Medicine and Radiotherapy Facilities

Sulphur hexafluoride (SF6) is routine used in certain research centres in Nigeria. A typical example is the Centre for Energy Research and Development (CERD) at the Obafemi Awolowo University (OAU), Ile-Ife where a 1.7 Mega electron Volts (MeV) two-stage tandem accelerator has been in operation since 2005. In recent years, Federal and State Governments have setup a number of nuclear medicine and radiotherapy centres across the nation. These facilities all consume SF6 and other F-Gases for their superior dielectric, electrical insulation and arc-quenching properties. While these gases are crucial in enabling the compact design of these facilities, they also end up in the atmosphere as highly potent greenhouse gases. It is therefore important that NCCC liaises with and enters a Memorandum of Agreement/Understanding (MOA/MOU) with the relevant research centres and medical facilities to provide data available to it in formats that are needed for GHG inventories.

4.2.1.2.7 Consumption of F-Gases for Maintenance and Recharging of Refrigerators, Air Conditioners and Firefighting Equipment

The use of refrigerators, air conditioners and firefighting equipment is increasing in both urban and rural areas of Nigeria. It is estimated that national ownership of refrigerators and air conditioners stand at 22% and 20% of the population respectively. These together with the use of firefighting equipment continues to rely strongly on availability and use of F-Gases to keep the facilities functional. However, these gases continue to escape from the equipment into the atmosphere through leak modules or during routine maintenance. The gases have to be replaced through regular recharge. The leak modules and routine maintenance therefore release these gases into the atmosphere with consequences on global warming. Research and/or field studies need to be carried out on the frequencies and quantities of the F-Gases being replaced annually.

In view of the fact that these recharge services are carried out under the informal economic sector, there is no specific institution that can provide such data. Despite this, the National Bureau of Statistics (NBS) stands out as a key NSI that is familiar with data collection at the grassroot, semi-formal and informal sector levels. The NCCC is therefore encouraged to liaise with and sign a Memorandum of Agreement/Understanding (MOA/MOU) with the NBS to undertake data collection that can be used to report activities associated with annual consumption of F-Gases in the above areas. NCCC shall within that MOA/MOU provide templates for data collection in formats that are needed for GHG inventories.

4.2.1.3 Agriculture Sector

The NSIs that collect data for livestock development include are presented in the subsections below.

4.2.1.3.1 The Federal Ministry of Livestock Development

The Federal Ministry of Livestock Development (FMLD) is the policy-making arm of the Federal Government established in July 2024 to transform Nigeria's livestock sector into a globally competitive and sustainable industry. Its core mandate is to enhance livestock productivity, ensure food security, and mitigate conflicts between farmers and herders through modernized pastoral management. In discharging this responsibility, the Ministry performs the following functions, among others:

i. Formulating and implementing national livestock policies and programs to increase the productivity and resilience of ruminant and monogastric systems while fostering climate-smart production practices;

ii. Strengthening animal health systems by coordinating disease surveillance, implementing nationwide pest control, and overseeing the eradication of transboundary animal diseases;
iii. Promoting ranching and pastoral resource development through the sustainable management of grazing reserves and the establishment of pilot ranches to improve land use and reduce communal tensions; and
iv. Creating enabling environments for private-sector investment across the livestock value chain, including the development of meat processing plants and dairy infrastructure to reduce reliance on animal protein imports.

The FMLD, primarily through its Planning, Research & Statistics (PRS) department, is mandated to collect and harmonize national livestock data to replace the previously fragmented records with an evidence-based reporting framework. A critical priority is the full implementation of the Livestock Identification and Traceability System (LITS), to facilitate the digital mapping of livestock assets and movement. In December 2025, the Ministry commenced the deployment of its first cohort of Livestock Data Collection Officers to the 36 states to standardize data pipelines for animal health, market dynamics, and production gaps. Upon data collection and processing, this data is integrated into a unified national database to inform the National Livestock Master Plan (NLMP), ensuring that sector-wide decisions are driven by accurate, real-time statistics.

The FMLD already has data that is useful in estimating GHG emissions form livestock and manure management, however, this data has a wide range of gaps. There is therefore need for NCCC to liaise with FMLD to define their detailed data needs across the entire livestock sector, which FMLD could then provide, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC.

4.32.1.3.2 The Federal Ministry of Agriculture and Food Security

The Federal Ministry of Agriculture and Food Security (FMAFS) has the core mandate to ensure national food and nutrition security through the sustainable development of crop and fisheries value chains, while driving economic diversification and rural prosperity. To achieve this, the Ministry performs the following functions, among others:
i Developing short, medium, and long-term national agricultural plans and policies, coordinating sector-wide research, and reviewing feasibility studies for agro-industrial projects;
ii Coordinating the collection, processing and dissemination of comprehensive agricultural statistics, including crop yields, livestock populations and market prices, to support evidence-based planning and national food security assessments;
iii Overseeing the Strategic Food Reserve to stabilize market prices, manage seasonal fluctuations and provide emergency food interventions during periods of national crisis or natural disasters; and
iv Regulating and implementing national programs for the prevention and control of migratory pests and transboundary animal diseases, while enforcing quality standards for agricultural inputs and export commodities.

The FMAFS, primarily through its Planning, Policy Coordination & Statistics (PPCS) department and its specialized research institutes, has a mandate for collecting data across all sub-sectors (crops, livestock, fisheries and forestry) for policy formulation and performance monitoring. Upon collection, this data is processed and used to provide critical data services to the public, inform the National Agricultural Sample Survey (NASS) and guide government interventions in the Agriculture and Food Security sector.

The Ministry currently has data that is useful in supporting GHG inventory activities in the LULUCF sector, especially data on land-use change associated with cropland as well as data on crop residues production. But these data do not appear to be currently adequate in the format required for inventories. There is therefore need for NCCC to liaise with FMAFS to define their detailed data needs across the LULUCF sector, which FMAFS could then provide in

the required format under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Such data could include:

i. Data on field burning of crop residues including land areas burnt, annual crop production, residue to product ratio, dry matter fraction, fraction burned in field and burning efficiency;
ii. Data on liming of soils including annual dolomite production and export, as well as dolomite consumption for liming in Nigeria;
iii. Data on urea applications to agricultural soils including annual urea production, export and soil application; and
iv. Data on rice cultivation including land areas of rice cultivated under permanent flooding, intermittent flooding, rainfed, as well as organic amendment and soil types.

4.32.1.4 Land Use, Land Use Change and Forestry (LULUCF) Sector

The NSIs that support activities data collection in the LULUCF Sector are presented in the subsections below.

4.32.1.4.2 The Department of Forestry, Federal Ministry of Environment

The Department of Forestry (DoF) is the specialized technical arm of the Federal Ministry of Environment responsible for the sustainable management, conservation, and protection of Nigeria's forest resources. Its core mandate is to ensure the perpetual availability of forest goods and services while maintaining ecological balance and addressing the challenges of climate change. In discharging this responsibility, the Department performs the following functions, among others:

i. Formulating and reviewing national forest policies and legislation to regulate timber extraction, forest conservation, and the protection of endangered flora and fauna;
ii. Coordinating large-scale afforestation and reforestation programs project to combat desertification, land degradation and anthropogenic-induced land-use change;
iii. Managing forest reserves and national parks in collaboration with state governments to prevent illegal logging, poaching, and encroachment, thereby preserving Nigeria's biodiversity; and
iv. Collecting, processing, and analysing forestry statistics related to forest cover, carbon sequestration rates, and timber trade to support international reporting and national climate action plans.

The Department, through its Forestry Information and Data Management unit, is mandated to collect data across all forest ecosystems to monitor deforestation rates, biomass inventory and land-use change. Furthermore, the Department oversees the collection of field data for the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) program to quantify carbon credits and forest-based emission reductions. Once processed, this data is integrated into the National Environmental Data Bank and shared with the National Bureau of Statistics (NBS) to inform Nigeria's Nationally Determined Contributions (NDCs) under the Paris Agreement and guide sustainable investment in the green economy.

Although the DoF already has certain data on forest inventories and land-use change, there is no certainty that such data are adequate to support comprehensive GHG inventories in the LULUCF Sector. There is therefore need for NCCC to liaise with the DoF to define their detailed data needs across the entire LULUCF sector, which the DoF could then provide, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Some of the new data needs would include:

i. data on annual Land Use Change areas across all the land-use change sectors, including change from one land-use type to the other;
ii. data on above- and below-ground biomass, including above- and below ground biomass annual growth rates;

iii. data on dead organic matter and annual decay rates, soil carbon, biomass carbon and nitrogen content, among others;
iv. data on forest and savannah areas burnt across each of the land-use types including information on dead organic matter arising from burning; and
v. data on annual harvested wood products, and their carbon and nitrogen content, among others.

4.32.1.4.3 The Forestry Research Institute of Nigeria, Ibadan

The Forestry Research Institute of Nigeria (FRIN) is the federal parastatal under the Ministry of Environment mandated to conduct high-impact research into all aspects of forestry, wildlife management, and environmental conservation. Its core mission is to provide the scientific evidence and technological innovations necessary for the sustainable management of Nigeria's forest resources and the mitigation of climate change. In discharging this responsibility, the Institute performs the following functions, among others:

i. Conducting fundamental and applied research into silviculture, forest biology, and wood properties to improve timber quality and accelerate the growth rates of indigenous and exotic tree species;
ii. Developing sustainable agroforestry models and land-use systems to enhance food security while promoting the reclamation of degraded lands and the stabilization of ecosystems;
iii. Managing the National Herbarium and Arboretum to preserve Nigeria's botanical diversity and providing specialized training through its colleges of forestry to build technical manpower for the sector; and
iv. Generating and disseminating scientific data on forest genetic resources, carbon stocks, and pest outbreaks to guide policymakers and industrial stakeholders in forest-based investments.

FRIN is mandated to maintain a centralized forestry research database to track the health and productivity of Nigeria's forest estates. This data collection covers seed germination rates, biodiversity indices, and the socio-economic impact of forest-dependent communities. Once processed, this data is archived and published in the Nigerian Journal of Forestry and shared with the Department of Forestry to inform the national carbon credit framework and support Nigeria's compliance with the Global Biodiversity Framework. FRIN already has data that is useful in estimating GHG emissions in the LULUCF sector, however, there is no assurance as to the adequacy of such data. There is therefore need for NCCC to liaise with FRIN to define their detailed data needs across the entire LULUCF sector under a Memorandum of Agreement/Understanding (MOA/MOU).

4.32.1.4.4 The Federal Ministry of Agriculture and Food Security

The information on the mandates of FMAFS has been presented in sub-section 4.2.1.3.2. A number of data is also needed from FMAFS to enhance emissions compilation from LULUCF. These include:

i. Annual conversion of forest land, grassland, wetland, settlements and other lands to croplands and vice versa;
ii. Above- and below-ground biomass including annual biomass growth rates, carbon and nitrogen content;
iii. Soil carbon and nitrogen contents, among others;
iv. Annual harvested wood products from cropland, among others;
v. Annual data on crop residue generation from croplands; and
vi. Annual cultivation of different varieties of rice.

4.32.1.4.5 The Federal Ministry of Housing and Urban Development

The Federal Ministry of Housing and Urban Development (FMHUD) is the policy-making arm of the Federal Government responsible for facilitating the provision of adequate and affordable housing, with the core mandate to drive sustainable urban development and ensure habitat dignity for all Nigerians. In discharging this responsibility, the Ministry performs the following functions, among others:

i. Formulating and implementing national housing and urban development policies to harmonize land administration, promote affordable homeownership, and accelerate urban renewal nationwide;
ii. Regulating and coordinating the activities of the housing sector, including the supervision of federal housing agencies to ensure compliance with national building standards and urban planning regulation; and
iii. Collecting, processing, and analysing housing market data related to housing demand, construction costs, and urban growth patterns to support planning and investment.

The FMHUD, primarily through its Planning, Research & Statistics (PRS) department, is mandated to collect data across the entire housing and urban development value chain to ensure accurate planning and effective resource allocation. Furthermore, the Ministry has adopted an Electronic Content Management (ECM) System to digitalize records and improve the transparency of land and property transactions. Once collected, this data is used to inform the National Housing Data Initiative, guide private sector investments, and ensure the equitable distribution of housing projects.

FMHUD is expected to have data that is useful in estimating GHG emissions, especially data on the urban development component of settlements. However, this data does not appear to be available in the national data systems. There is therefore need for NCCC to liaise with FMHUD to define their detailed data needs across the entire LULUCF sector, which FMHUD could then provide, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC. Some of the critical data required would include:

i. Data on annual conversion of forestland, cropland, grassland, wetlands and other lands to settlements in general, and to urban areas, in particular.
ii. Data on above- and below-ground biomass densities in urban areas, as well as their growth rates, among others.

4.32.1.4.6 The National Space Research and Development Agency

The National Space Research and Development Agency (NASRDA) is the primary regulatory and research parastatal under the Federal Ministry of Innovation, Science, and Technology responsible for the development and application of Space science and Technology in Nigeria. Its core mandate is to pursue the attainment of space capabilities as an essential tool for socio-economic development and the enhancement of the quality of life for Nigerians. In discharging this responsibility, the Agency performs the following functions, among others:

i. Developing and operationalizing indigenous satellite technology for diverse applications, including Earth observation, telecommunications, and global navigation;
ii. Implementing a formal licensing and regulatory regime for all entities conducting space-related activities, including upstream, midstream, and downstream space operations within Nigeria;
iii. Collaborating with security and investigative agencies, such as the EFCC, to deploy geospatial intelligence and satellite-based surveillance for asset tracking and combating crimes like illegal mining; and
iv. Serving as the sole repository of all satellite data over Nigeria's territory, ensuring that all collaborations and consultations in space-related data matters are coordinated centrally.

NASRDA, primarily through its Planning, Research and Statistics (PRS) Department, is mandated to provide data-driven insights for strategic decision-making and policy formulation. Once collected, high-resolution satellite imagery and geospatial data are archived and utilized to support national projects.

NASRDA already has data that is useful in estimating GHG emissions in the LULUCF sector, however, this data may have a wide range of gaps and may also not have the data continuity that could be used to establish land-use change trends. There is therefore need for NCCC to liaise with NASRDA to define their detailed data needs across

the LULUCF sector, which NASRDA then provide, under a Memorandum of Agreement/Understanding (MOA/MOU) between it and NCCC.

4.32.1.5 Waste Sector

The Waste Sector is one of the sectors where activities are undertaken mainly at the state level. There is therefore, no Federal institution directly responsible for waste management. However, the NBS is strategically positioned to obtained secondary data from all states waste management institutions and present that aggregated national data.

4.32.1.5.2 National Bureau of Statistics

The full mandate of the NBS is presented in sub-section 4.2.1.6.1. The Bureau, being involved in cross-sectoral activities data collection and publication, already has a wide range of data that could support national GHG emission inventories. Data on waste management could additionally be collected from responsible states institutions. NCCC is expected to sign an MOA with NBS for such data collection which would include:

i. Data on solid waste management including municipal and industrial solid waste in the format required for emissions computation; and
ii. Data on liquid waste management in the format required for emissions computation.

4.32.1.5.3 States Waste Management Institutions

Nearly all the states have either a Ministry of Environment or a Waste Management Agency that takes responsibility for all waste management in the state. There is therefore need for NCCC to liaise with the state ministry responsible for waste management through the State Climate Change Focal Institution (SCCFI) to define their detailed data needs across the LULUCF sector, under a Memorandum of Agreement/Understanding (MOA/MOU) by each State. The areas of data needs include:

i. Annual weight of waste generated per waste category (organic and inorganic solid and liquid waste respectively);
ii. Carbon, nitrogen and other components of solid waste as well as the biochemical oxygen demand of liquid waste generated per state;
iii. Volumes of solid waste managed, by landfill, by open dump sites, incineration and compost, among others; and
iv. Technologies used in solid and liquid waste management, among other information.

4.32.1.6 Cross-Sectoral Data Collection

There are a few NSIs whose data collection responsibilities cuts across multiple sectors. These are presented in the subsections below.

4.32.1.6.2 The National Bureau of Statistics (NBS)

The NBS is the central hub of the National Statistical System in Nigeria, with the core mandate to coordinate the production of official statistics for all tiers of government and serve as the primary source of data for national development and planning. In discharging this responsibility, the Bureau performs the following functions, among others:

i. Coordinating the National Statistical System to ensure high standards, uniformity, and avoid duplication in the collection, analysis, and publication of statistical information;
ii. Conducting national censuses and surveys to generate and monitor national socio-economic indices;

iii. Collecting and analysing macroeconomic data, such as Gross Domestic Product (GDP), Consumer Price Index (CPI), and foreign trade statistics, to monitor national economic performance; and
iv. Maintaining a comprehensive National Data Bank by integrating datasets from various Ministries, Departments, and Agencies (MDAs) to provide a single point of data for policymaking.

Because the NBS serves as the primary custodian of data in the country, generally, it has, through its specialized departments and state offices, been collecting data which cuts across all the GHG sectors (Energy, IPPU, Agriculture, LULUCF, and Waste) to support national reporting. Once collected, this data is processed and archived to provide critical statistics to the public and international organizations. However, although NBS has some data that could be used to support emissions computations, this data is not well captured in the format required for emission inventories. There is therefore need for the NCCC to liaise with the NBS to define its data needs and refine data collection templates for activities data across all sectors, through a Memorandum of Agreement/Understanding (MOA/MOU).

4.32.1.6.3 The Nigerian Customs Service (NCS)

The Nigeria Customs Service (NCS) is the statutory body mandated to collect and account for import and export duties, facilitate international trade, and protect Nigeria's borders against the smuggling of prohibited goods. In discharging this responsibility, the Service performs the following functions, among others:

i. Collecting and accounting for revenue from customs and excise duties, fees, and levies, while implementing fiscal policies that drive national economic growth;
ii. Facilitating legitimate trade by simplifying and harmonizing customs procedures through the Nigeria Integrated Customs Information System (NICIS II) and the National Single Window;
iii. Enforcing trade compliance and border security to prevent the entry of illegal goods, including hazardous waste and restricted chemical substances that impact national safety and the environment; and
iv. Collecting and processing trade statistics on the volume, value, and classification of all goods entering and leaving the country to monitor trade patterns and inform national economic strategy.

The NCS is mandated to collect comprehensive trade data that cuts across multiple sectors, particularly the Energy, IPPU and Agriculture sectors. This data collection covers the importation of petroleum products, industrial chemicals, fluorinated gases, synthetic greenhouse gases (such as HFCs), nitrogenous fertilizers, and machinery, providing a primary source for tracking national consumption levels. Upon collection, the data is used to provide critical trade statistics to the government and the public. The NCS therefore currently holds data that is useful for GHG inventory activities. However, some of these data, especially those published by NBS, do not appear to be currently adequate and in the format required for inventories. There is therefore a need for the NCCC to liaise directly with the NCS to define their detailed data needs across the sectors, under a Memorandum of Agreement/Understanding (MOA/MOU).

4.32.2 Setting up an Integrated Surveillance System to Support Routine Update of New Activities Data

The Agriculture, Forestry and Other Land Use (AFOLU) sector is a key sector where activities data updates are required to be undertaken regularly through an integrated surveillance system, if such data is to remain correct. Putting in place such an integrated monitoring system is essential for routine updating of activities data to improve the accuracy of GHG inventories. The required robust system is to integrate remote sensing technologies with on-the-ground surveys to track land-use changes, such as deforestation, fire, and soil degradation, providing data that aligns with the TRACC criteria.

The key components of such a Data Surveillance System include:

i. Integrated Monitoring Technologies: Utilizing a combination of Satellite Land Monitoring Systems (SLMS) for broad landscape-level monitoring and drones for high-resolution localized data.
ii. Remote Sensing and AI: Implementing Artificial Intelligence (AI) based interpretations of satellite imagery (e.g., from Sentinel, Landsat, or NOAA satellites) to map, monitor, and update land use and land-use change in real-time, such as tracking vegetation change (through the Normalized Difference Vegetation Index (NDVI)] and deforestation.
iii. Ground-Based Verification: Deploying in-situ, field-based measurements (forest inventories, soil sampling etc.) to verify and calibrate remote sensing data.
iv. Data Management Framework: Using standardized platforms to ensure data is, transparently documented, and compliant with international guidelines.

NASRDA already has the SLMS which could be used in combination with other tools to provide regular surveillance, to obtain data locally, instead of continuing to rely on international data sources. NCCC is encouraged to liaise with and reach agreement with NASRDA and other relevant institutions including the DoF, FRIN, FMAFS, and FMHUD for satellite and other categories of data to be provided and analysed for use in establishing land use and land use change related issues for Nigeria. Once such a system is in place, it will enable five-yearly updates of surveillance data for which annual land use change data could be established.

4.32.3 Use of Modelling Indicators to Establish Missing Activities Data

Although the NSIs are providing and are expected to continue to provide a wide range of range of data for GHG inventories, these are mostly from the formal sector of the economy. The informal sector poses a specific challenge, because data from this sector are not documented directly by any institution. In some cases, research institutions do surveys to establish activities data in some of the sectors, but these are mainly data in localized communities which may not be used nationally, except such studies are done across a wide range of communities nationwide that could be used to extrapolate national information.

Modelling indicators for Activities Data in GHG inventories are the specific physical or economic metrics that could be used to estimate activities data through research when direct primary data, such as fuel consumption, are unavailable or difficult to collect. Modelling indicators such as per capita gasoline consumption for household power generation, when multiplied by the population, can be used to estimate the total fuel consumption by private generators in households. Another example is the per capita municipal liquid waste generation or solid waste generation, could also be used to establish the volume of solid and liquid municipal waste, by multiplying the per capita waste consumption by the population.

Literature review for modelling indicators in countries that have the same socio-economic setting as Nigeria will be done and the modelling indicators sourced would be used to estimate activities data in Nigeria. Similarly, modelling indicators established for states could be used to establish activities data at national level; based either on population or other socio-economic indices. The essence of this activity is to be able to do gap-filling for activities data especially in the informal sector where direct estimation of activities data remains difficult. Once such indicators are established, they would be used to do gap filling for missing activities data across the GHG inventory sectors.

4.33 NATIONAL EMISSION FACTORS DATA FLOW SYSTEM

The sources of emission factors data are presented below. They comprise:

i. Developing literature-based emissions factors database for interim use;

ii. Emission factors modelling; and
iii. Developing a national emission factors measurement system.

4.33.1 Developing Literature-Based Emission Factors Listing/Database for Interim Use

Developing a literature-based emission factor database for interim national use is a strategic, cost-effective approach to improve GHG inventory accuracy before full, country-specific measurements can be finalized. This process involves compiling data from peer-reviewed literature, IPCC default values, and regional reports into a structured, documented, and searchable format.

A desk within the National GHGI-MS has been assigned in Section 5 to develop and provide the implementation framework for the interim literature-based emissions factors database. NCCC shall consider options and frameworks for facilitating the development of this interim database. This shall form the interim emission factors for use in national inventories until national emission factors are developed from both modelling and measurements (Sections 4.3.2 and 4.3.3).

4.33.1.3 Approaches for Developing the Database

In developing the Interim database, the following approach will be followed:

i. Identification of Priority Sectors and Processes: this would focus on key emission sources by sector, where literature-based values can significantly improve upon default Tier 1 values.
ii. Literature Search Strategy: this would search academic journals, National Inventory Reports (NIRs) from comparable countries, and international databases (e.g., IPCC EFDB, FAOSTAT).
iii. Database Structure: this shall follow a spreadsheet or SQL database that includes:
    a. Source Data: Emission factor value, unit, gas (CO2, CH4, N2O).
    b. Context: Activity description, technology type, geographical region, climate, soil type.
    c. Documentation: Technical reference, author, year of publication, link to the source and quality of EF data, if available.
iv. Evaluation & Interim Selection: this would critically evaluate whether the literature values reflect the national circumstances in Nigeria (e.g., livestock systems, fuel types).

4.33.1.4 Key Components of the Database

The key components of the interim Database include:

i. Background Documentation: Each emission factor must be accompanied by its technical reference for future validation.
ii. Applicability Indicators: Notes on why a specific emission factor is considered appropriate should be included.
iii. Uncertainty Assessment: The uncertainty range provided in the literature should be documented to assist with national uncertainty analysis.

4.33.1.5 Best Practices for Data Collection

The following are the best practices to be observed in data collection:

i. Prioritize regional or local data and search for studies from countries with similar ecological zones, agricultural practices, or industrial technologies, and other national circumstances.
ii. Clearly document the assumptions made when adopting a literature value, particularly regarding technology, abatement techniques, and operating conditions.

iii. Use the IPCC Emission Factor Database (EFDB) as the primary resource for validated emission factors, subject to (i) and (ii) above.
iv. Perform quality assurance and quality control (QA/QC) procedure to verify unit conversions, accuracy of the source, and applicability to the national context.

4.33.1.6 Framework for Interim Implementation

Interim implementation should follow the following framework:
i. Transparency: The methodology report must explain that these factors are derived from literature to be transparent with reviewers.
ii. Evolution: The database should be designed to be updated as new national science emerges, evolving from a literature-based repository to a fully, nationally-derived database.

This approach allows countries to shift from Tier 1 methods to higher-tier methods, thereby improving the accuracy of GHG inventories without the immediate high cost of extensive, long-term direct measurements.

4.33.2 Emission Factors Modelling

GHG emission factors modelling is a mathematical modelling process of determining representative coefficients that convert human activity into a volume of emissions through the related activities data. Modelling provides the framework for estimating emission factors mathematically, without relying on expensive measurement systems. The mathematical framework follows from the IPCC 2006 Guidelines (and 2019 refinements) for Tiers 1, 2 and 3 emission estimates, which provide a structured approach to data collection, calculation, and reporting on a process-by-process basis.

A desk within the National GHGI-MS has been assigned in Section 5 to develop and provide the implementation framework for the emissions factors modelling activity. NCCC shall consider options and frameworks for facilitating the development of this modelling framework. The output of the modelling framework shall be used as the first segment of the final national emission factors database together with those that would arise from measurements (See Section 4.3.3).

4.33.2.3 Developing the Modelling Framework

Developing a national framework for Emission Factors Modelling involves establishing a systematic process to estimate GHG emissions across various economic sectors mathematically. The framework allows for different levels of complexity based on national data availability:
i. Tier 1 (Default): Uses international default emission factors from the IPCC-EFDB, suitable for countries starting their inventory.
ii. Tier 2 (Country-Specific): Incorporates emission factors derived from national statistics, local research, and scientific literature to reflect country-specific conditions.
iii. Tier 3 (High-Resolution): Employs complex, often facility-specific models or direct continuous measurement systems for the most accurate data.

4.33.2.4 Modelling Principles

Effective modelling must adhere to the TRACC criteria based on the principles below:
i. Quality Control (QA/QC): All methodologies, assumptions, and uncertainties must be documented from the outset to maintain reliability.

ii. Sectoral Structure: Data will be organized on a sector-by-sector basis according to the GHG emission sectors.
iii. Data Archiving: Rigorous records of original raw data and the steps used to process it into emission factors computation formats must be maintained.

4.33.3 National Emission Factors Measurement System

4.33.3.3 What Constitutes the Measurement System

Establishing national emission factors across each sector of the economy requires Non-Annex 1 Parties to the UNFCCC to transition from depending exclusively on Tier 1 emission factors, as has been the case with Nigeria, to the use of higher tier emission factors. In order to achieve this, the following pathways shall be used:

i. direct measurement;
ii. mass balance/stoichiometry; and
iii. modelling (See Section 4.3.2).

A desk within the National GHGI-MS has been assigned in Section 5 to develop and provide the implementation framework for the emissions factors measurement system. NCCC shall consider options and frameworks for facilitating the development of this measurement systems under the institutional.

4.33.3.4 Approaches Measurement

4.33.3.4.2 The Direct Measurement Pathway

This is the most accurate but resource-intensive pathway. It involves physical sensors capturing actual gas concentrations through the following:

i. Source Testing: Periodic sampling of emissions from specific industrial stacks or mobile sources exhaust (vehicle fleet across the different transport modes – roads, rails, inland waterways, civil aviation and other) under local conditions.
ii. Remote Sensing: Using satellite data or airborne sensors to measure fugitive and other emissions in the Energy, IPPU, LULUCF and Waste sectors.

4.33.3.4.3 The Mass Balance Pathway

This is used when emissions are a direct result of chemical transformations rather than just combustion as exemplified in the IPPU sector. The following form the mass balance measurement pathway:

i. Input Analysis: For industries like steel or aluminium, the emission factors are derived by tracking the carbon that enters the process minus what is stored in the final product, all divided by the factory throughput.
ii. Fuel Characterization: Laboratories would test domestic fuel samples to create a Carbon & other vital elements (such as nitrogen) Profile, for greater accuracy than global averages.

4.33.3.5 Typical Measurement Pathways

The following table summarizes typical examples of pathways that could used to develop national emission factors across all GHG sectors:

Table 4.1: Typical Measurements Pathway

Sector	Primary Measurement Pathway	Technical Execution
Energy	Stoichiometry & Chemical Analysis	Analysing the carbon content and net calorific value of domestic fuels (coal, natural gas) at refineries or ports to calculate the theoretical CO_2 release.
IPPU	Mass Balance & Direct Measurement	Measuring the difference between raw material input and finished product output (e.g., limestone in cement) or using Continuous Emission Monitoring Systems (CEMS) in smokestacks.
Agriculture	Empirical Field Research (Modelling)	Using flux chambers in soil to measure $N2O$ or respiration chambers on livestock to measure enteric methane (CH_4) based on local feed types.
Waste	Sampling & Decay Modelling	Conducting waste characterization studies to determine the degradable organic carbon (DOC) content of local landfills and measuring methane recovery rates.

4.34 NATIONAL DATABASES TO ENHANCE THE PREPARATION OF GHG INVENTORIES

The role of databases in emission inventories among others include:

i. Data Storage and Retrieval: Databases serve as the central repository for all emission inventory data, including information on greenhouse and precursor gases, emission sources, activity levels and emission factors. Such organized storage allows for easy access and retrieval of data as needed;

ii. Data Compilation and Aggregation: Databases facilitate the collection and aggregation of data from various sources, such as industry reports, statistical data and monitoring data. This allows for a comprehensive overview of emissions from different sectors and locations;

iii. Data Analysis and Modelling: Databases enable the analysis of emission data to identify trends, patterns and key sources. This information is among what is needed for developing effective atmospheric concentrations models and predicting the impact of various mitigation measures;

iv. Reporting and Compliance: Databases are used to generate reports and provide data for regulatory compliance, ensuring that organizations can meet reporting requirements and track their progress towards emission reduction goals; and

v. Collaboration and Data Sharing: Databases are useful in facilitating collaboration and data sharing among different stakeholders, including businesses, regulatory agencies and research organizations. This can improve the quality and consistency of emission data.

Research on database development is therefore sine qua none for any systematic GHG inventories management. The research programmes would among others include the following categories of databases:

i. Emission Factors Information System (EFIS); and

ii. Sectoral Activities Data and Modelling Indicators System (SAMIS)

iii. Socio-Economic Data System (SEDS).

For each of the above, data systems would have an associated Query, Import and Export function. If and when these are developed, they shall become a valuable asset to the inventory management programme in the future.

The activities associated with the development of national databases to enhance the preparation of GHG inventories are to be undertaken. The sub-activities are:

i. National database for modelling indicators;

ii. National activities database; and
iii. National emission factors database.

4.34.1 National Database for Modelling Indicators

The national database for modelling indicators would be developed as part of the activities in sub-section 4.2.3. as the research activities under the sub-section progresses. The database would provide searchable modelling indicators retrieval system that would enhance the work of gap-filling missing activities data in sub-section 4.2.1. The institutional arrangement is discussed in section 5.

4.34.2 National Activities Database

The national activities database would be developed to support the archival and retrieval of activities data produced from the activities in sub-section 4.2. as the research activities under the sub-section progresses. The database would provide searchable activities data to support emissions compilation activities. The institutional arrangement is contained in section 5.

4.34.3 National Emission Factors Database

The development of GHG emission factors database is an important step in any organized inventories management. This is because such a database plays crucial roles in emission inventories management. It provides searchable emission factors data retrieval system that would enhance the work of emission compilers. The data to support the development of this database would be obtained from activities undertaken in sub-sections 4.3.1 to 4.3.3 while the institutional arrangement is provided in section 5.

4.35 NATIONAL GHG EMISSIONS DATA SYSTEM

A National GHG emissions data system (NGEDS) is needed to report anthropogenic GHG emissions and removals based on data obtained from NADFS, NEFDFS and the associated databases discussed in sub-section 4.3 and used to compile GHG emissions across sectors. The NGEDS is needed to report emissions that would meet the Enhanced Transparency Framework (ETF) of the Paris Agreement, which requires biannual reporting to track progress against Nationally Determined Contributions (NDCs).

Among the key components is the NGEDS Data Quality Management, which includes QA/QC procedures, Key source analysis and Trends analysis, among others. All of which ensure that reported Data meets the TRACC criteria of both UNFCCC and IPCC.

The NGEDS shall be a searchable data archival and retrieval system, which allows national inventory compilers to archive new data, and users to retrieve data whenever such data is needed. A desk within the National GHGI-MS has been assigned in Section 5 to develop and provide the implementation framework for the NGEDS. NCCC shall consider options and frameworks for facilitating the development of the NGEDS. A modelling framework shall be established, whose output shall provide the NGEDS structure and modelling system. Once this is achieved, the implementation phase of the NGEDS shall commence at the appropriate desk of the NGHGI-MS.

5. THE NATIONAL GHG EMISSIONS DATA FLOW ARCHITECTURE AND SYSTEM RESPONSIBILITIES

5.32 THE CONCEPT OF DATA FLOW ARCHITECTURE AND PURPOSE

5.32.1 Data Flow Architecture

The key difference between a DFS as provided for in section 4 and a Data Flow Architecture (DFA) is in their scope. While the DFS refers to the operational processes and procedures, the DFA refers to the cross-institutional structural design and technical infrastructure that enables those processes to function. Hence, while the DFS focuses on how data moves through the inventory process (inputs, calculations, archiving, reporting, etc.), the DFA defines for instance which sub-institution is concerned with data collection, storage, transformation and exchange, as well as the structural design and infrastructure available across the institutions to support the activities of DFS. The bullets below explain how the DFA operates.

The DFA is considered the technical "where" (institutional) and "what" (structural design and infrastructure) outlining who has responsibilities for specific activities and hosting software, databases, integration points and physical storage mechanisms for the DFS. It also provides the focus for the DFA with elements such as structural, technical and physical design (Database → Application Programming Interface (API) → Frontend), among other issues. This report provides an overview of the components of the DFA in sub-section 5.2 and the entities responsible for managing the specific activities under NCCC as the apex institution for GHG inventories is presented in sub-section 5.3. Similarly, the details of the technical design and infrastructure under the DFA is provided in sub-section 5.4.

The underlying system architecture for managing this data flow often includes:

i. Modular Framework: To accommodate evolving reporting requirements.
ii. Custom Emission Factor Libraries: To align with recognized, up-to-date sources.
iii. Source Tracking Tools: To maintain traceability across all emission scopes.
iv. Data Management Protocols: For version control and QA/QC.
v. Software and Tools: Ranging from simple spreadsheets to advanced platforms that integrate GIS data, machine learning or process simulations to generate robust inventory data.

This systematic architecture ensures that the inventory meets the TRACCC criteria.

5.32.2 The Purpose

The purpose of the DFA is to provide the interlinkages between the institutions responsible for DFS and how they can host the network of infrastructure needed to work together seamlessly to provide emission inventory reports that is in line with the TRACC criteria.

5.33 OVERVIEW OF THE NATIONAL GHG INVENTORY DATA FLOW ARCHITECTURE

The DFA is derived from activities that define the DFS as presented in section 4. These activities may be spread across a number of institutions associated with the inventory management system defined in section 5 of Obioh (2026). The DFA is first defined in terms of the institution hosting the sub-systems under the DFS. This is summarized in Figure 5.1 under the following headings.

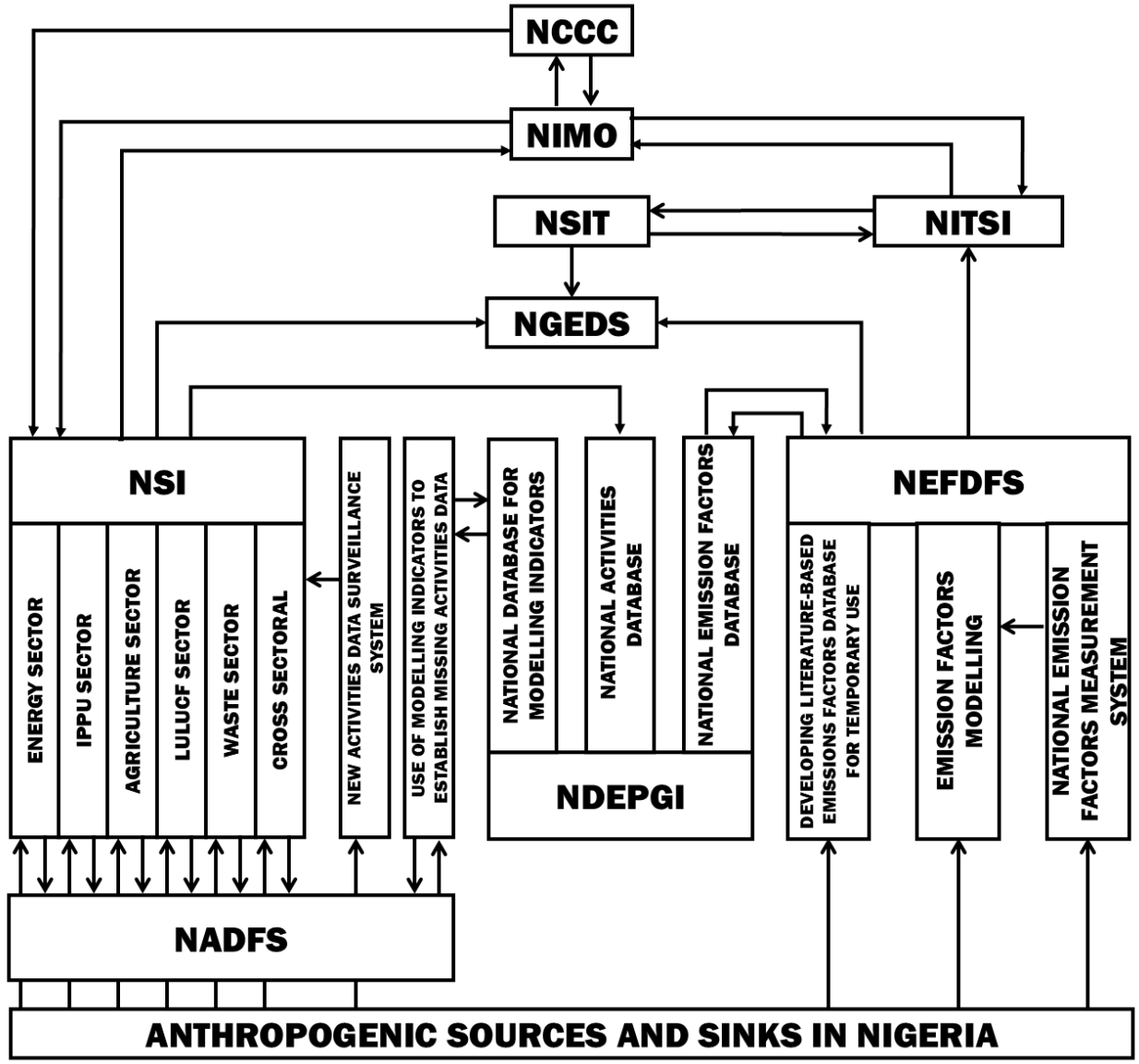

Figure 5.1: Overview of the Data Flow Architecture for National GHG Inventories in Nigeria

The anthropogenic sources and sinks of GHGs and their precursors form the pool that activities and emission factors data commences their flow into the different institutions associated with the National GHG Inventory Management System (NGHGI-MS). This pool is divided into sources in the Energy, IPPU, Agriculture, LULUCF and Watse sectors respectively from which all GHGs are either emitted into or sequestered from the atmosphere.

Activities data from anthropogenic sources and sinks are primarily collected by the NSIs that work in tandem with NCCC to collect GHG inventories data. NSIs form part of the National Activities Data Flow System (NADFS) alongside with the modelling indicators for estimating missing activities data as well as new activities data surveillance system. Activities data collected by NSIs are transmitted through the National Inventory Management Office (NIMO) to the National Sectoral Inventory Preparation and Reporting Teams (NSIPRT). Where activities data are inadequate, appropriate modelling indicators may be used to estimate missing data. Similarly, programmes shall also be put in place by NCCC that will undertake new activities data surveillance and bring such surveillance data into the data pool with time to ensure continuity in data and data representativeness over time. The modelling indicators and activities data surveillance shall be anchored under a programme officer in NIMO with technical

support provided by the National Inventory Planning, Reporting and Associated Research Team (NIPRART) headed by the National Inventory Team Leader (NITL) Technical.

With each activity data, there shall be a corresponding emission factors data that shall form the basis for emissions calculations. The National Emission Factors Data Flow System (NEFDFS) is designed to provide emission factors data through literature review, national emission factors measurement as well as national emission factors modelling. These shall be undertaken under a programme officer in NIMO with technical support provided by NIPRART.

The next element of the DFA defines the National Database to Enhance the Preparation of GHG Inventories (NDEPGI). This shall comprise software and databases for:

i. National Database for Modelling Indicators;
ii. Activities Database; and
iii. Emission Factors Database.

These activities shall be anchored by a programme officer in NIMO with technical support provided by NIPRART.

There shall be as part of the DFS the National GHG Emissions Data System (NGEDS). This shall host all emission calculated annually from all sector and shall be used for reporting emissions after due QC/QA, archiving and other processes needed to enhance the quality of emissions data. It shall be hosted by a programme officer under NIMO with technical support provided by NIPRART.

5.34 DATA FLOW ARCHITECTURE AND INSTITUTIONAL RESPONSIBILITIES

A GHG inventory DFA represents the structured, institutionalized process for collecting, calculating and reporting emissions. It ensures that data use for the inventory is in compliance with the TRACCC criteria. Therefoe, it is the role of the DFA to provide clear roles and responsibilities for various stakeholders involved in data flow for the inventory process. The responsibilities of various stakeholders involved in the NGHGI-MS are presented in summary in the sub-sections below.

5.34.1 Institutions Associated with Anthropogenic Sources and Sinks

Anthropogenic sources and sinks in Nigeria which form the pool of sources contributing to anthropogenic emissions from human activities that lead to global warming may be categorized broadly as

i. Sources and sinks in the formal economic sector, and
ii. Sources and sinks in the informal economic sector.

The formal economic sector comprises registered, regulated and taxed businesses and activities that contribute directly to the country's Gross Domestic Product (GDP). For this set of anthropogenic sources, their operators are usually known and they are expected to comply with regulatory provisions guiding their businesses. One of these provisions is provision of data to specific NSIs that are responsible for developing databases for the country. Depending on which NSIs covers their operations, it is mandatory for them to make their data available to such NSIs for onward archiving and release to the public when requested. Hence, data flow in the formal economic sector starts with the management of these businesses who must submit their data regularly for use in strategic planning and other relevant activities.

The informal economic sector comprises unregistered, untaxed and unregulated economic activities that operate outside legal, social or public authority oversight, and accounts for over half of global employment and up to 90% in some developing nations, including street vending, agriculture and artisanal services. The informal sector in Nigeria is a massive component of the economy, estimated to account for over 50% of the GDP with some estimates

ranging from 55% to over 60% and roughly 92% of all employment. The informal sector like the formal sector counterpart contributes to GHG emissions. However, unlike the formal sector which is registered and regulated, this sector is unregistered and unregulated. Access to data in the informal sector can be daunting. Such data only become available through various field researches undertaken by researchers to unravel data in specific areas of interest. Where such data are undertaken for GHG inventories, then they form the basis for providing data to NSIs, NGOs and community development organizations, among others. In some cases, government set up state institutions to obtain data from such sector. An example is the household survey which the Energy Commission of Nigeria (ECN) undertakes routinely and waste generation and management which State's Waste Management Agencies also develop data on their operations.

5.34.2 National Activities Data Flow System

The National Activities Data Flow System (NADFS) shall be responsible for activities data collection from the formal and informal sectors of the anthropogenic sources and sinks pool and making such data available for emissions computation through the relevant institution undertaking emissions calculations. It has three components, namely:

i. NSIs which shall be responsible for the collection of activities data from the formal sector of the anthropogenic sources and sinks pool;
ii. New Activities Data Surveillance System (NADSS); and
iii. Use of modelling indicators to establish missing activities data.

As indicated in sub-section 4.2.1, the NSIs are already established statutorily and are collecting data for various uses nationally. To ensure that such data are more beneficial to the national GHG inventories programme than they are currently, NCCC shall sign Data Collection Agreements (DCA) with each of them specifying the details of data required that would meet the demands of inventories. Such data shall then be annually provided to NCCC through NIMO for sharing with sectoral inventory teams for use in inventories compilation. Where NCCC data needs as envisioned in each DCA appears to exceed the financial capability of such NSI in going for more data, NCCC may wish to explore options to augment the financing of such additional data collection from Federal Government and others including the development partners through various projects until the NSIs are able to seek additional statutory funding to support their activities.

There is need for putting in place a New Activities Data Surveillance System (NADSS) especially in the AFOLU sub-sector of the inventory. This is to ensure that gaps for new activities data collection are bridged. For instance, the NADSS when fully setup shall be responsible for undertaking land use change surveillance that covers the entire federation and with support ground truthing activities that allows establishment of activities data and in some cases emission factors to support new inventory activities. NCCC shall work in collaboration with the DF of FMENV, Federal Ministry of Agriculture and Food Security (FMAFS) and NASRDA to establish the NADSS. Universities and research institutions shall work as part of the teams under the NADSS to provide ground truthing information in their areas of competence. Once established, the NADSS shall require funding to support its activities routinely. NCCC shall explore options in collaboration with Federal Government through its board to open up additional funding for the activities of NADSS to ensure that they operate seamlessly to discharge their responsibilities. This will ultimately bridge the current data gaps in the AFOLU sector and reduce dependence on international data as is the case already.

The use of modelling indicators to establish missing activities data shall be undertaken as needed across all inventory sectors. This shall use information available in the modelling indicators database that would be hosted by a programme officer in NIMO with technical support from NIPRART. NIPRART shall as part of its responsibilities be the national institution to develop the national database for modelling indicators and to provide terms for its use.

5.34.3 National Emission Factors Data Flow System

The National Emission Factors Data Flow System (NEFDFS) shall be responsible for emission factors data collection across all the sectors from the formal and informal sectors of the anthropogenic sources and sinks pool and making such data available for emissions computation through the relevant institution undertaking emissions calculations (NIMO, NIPRART and NSIPRT). It has three components, namely:

i. Developing literature-based emission factors listing/database for temporary use;
ii. Emission factors modelling; and
iii. National emission factors measurement system.

The development of literature-based emission factors listing/database shall be undertaken as part of the initial activities of the NEFDFS to ensure availability of emission factors from literature whose processes have the same operational circumstances as those in Nigeria. Most of such literature-based emission factors data shall obviously be derived from the IPCC sources without excluding those not listed in the IPCC database but whose process operational circumstances are similar to similar processes in Nigeria. Such literature-based emission factors listing/database shall be available for use temporarily until EF measurements/modelling are undertaken nationally. The technical guidelines for the use of such emission factors shall be provided by NIPRART through the relevant programme office in NIMO.

Emission factors modelling shall be undertaken by various researchers and research teams in Nigeria. This modelling shall align with the relevant IPCC guidelines for estimating emissions in each sector. NIPRART shall provide the guidelines for admitting such modelled emission factors into the national emission factors listing/database. The guidelines shall be published by the relevant programme office in NIMO.

Besides the modelling of emission factors, various source testing activities shall be undertaken to measure emission factors across all inventory sectors and bring such new factors into the national emission factors pool. Through funding provided for research in section 8 of Obioh (2025), such measurements shall be done routinely by academic institutions with requisite capacity for emission factors measurement. NIPRART shall provide the modalities for admitting new emission factors into the national emission factors listing/database which shall be published by the relevant programme officer in NIMO. Once national emission factors are admitted through measurement/modelling, they shall be used by NIPRART to create the national emission factors database under the National Database to Enhance Preparation of GHG Inventories (NDEPGI) subsystem. The emission factors database shall be used by the compiling teams to support emission calculations alongside the respective activities data.

5.34.4 National Database to Enhance Preparation of GHG Inventories

The National Database to Enhance Preparation of GHG Inventories (NDEPGI) shall be responsible for providing the databases for developing and putting in place the databases to enhance the preparation of GHG inventories. It has three components, namely:

i. National database for modelling indicators;
ii. National activities database; and
iii. National emission factors database.

The national database for modelling indicators shall be responsible for developing and putting in place the modelling indicators database for estimating missing activities data in the formal and informal sectors of the economy across the key inventory sectors. Such indicators could for instance include how to estimate MSW in a community based on per capita MSW generation per year in such community using the population of the community. Similar indicators exist for various activities data estimation across all sectors and must be established from research. Scientists from universities and other research institutions shall play crucial role in research to evolve such modelling indicators data. NIPRART shall use such data to develop the database that become accessible

to teams using modelling indicators to estimate activities data in various sectors. Once developed, the NADSS team responsible for using modelling indicators to bridge data gaps shall use the database to support their activities.

The national activities database is required as the database that provides all activities data for emissions calculations. The database shall combine activities data provided by the NSIs and those provided from modelling indicators. NIPRART shall be responsible for developing the national activities database for use by NSIPRTs in inventory compilations. Once developed, NSIPRTs shall then use the database for their inventories compilation activities.

The national emission factors database shall be developed by NIPRART combining the sources of emission factors provided in sub-sections 4.3 and 5.3.3. This shall be used by NSIPRT for emission compilations as needed.

5.34.5 National GHG Emissions Data System

The National GHG Emissions Data System (NGEDS) shall be developed by NIPRART and made available to the inventory management system for reporting and other activities. The data system shall be compiled based on the emission calculations undertaken using the IPCC (2006) and IPCC (2019) guidelines with the supporting software or other relevant tools. The NGEDS could be made publicly available or through restricted access to allow information sharing with stakeholders on emissions by sources and removals by sinks for each sector annually. NIPRART shall provide the guidelines for access to the database and acknowledgement of NCCC's proprietary to it.

5.35 STRUCTURAL DESIGN AND TECHNICAL INFRASTRUCTURE IN SUPPORT OF THE DFA

Beneath the institutional framework hosting the DFA, there is subsisting infrastructure that supports operations of each institution identified in the DFA in sub-section 5.3 above. Over time, the need for more infrastructure will arise naturally and the need to have a design of technical system architecture that would be networked across institutions to improve data flow in the DFS will become necessary. The objective of this sub-section of the DFA is to design and develop such technical infrastructure that would support improved data flow across all institutions in the inventory management system associated with efficient data flow. However, this objective cannot be achieved immediately and is left as part of future activities of the report. Future versions of this report shall therefore integrate and expand on the technical design of infrastructure, software, databases, integration points and physical storage mechanisms, among others that would be used to support the DFA activities seamlessly across the institutional framework. Some of the technical design features could among others include:

i. Focus: Structural, technical and physical design (Database → API → Frontend).
ii. Components: Enterprise Resource Planning (ERP) systems, databases, data warehouses, API connections and software tools for data ingestion.
iii. Key Characteristics:
    a. Physical View: Specifies the actual devices, software and databases.
    b. System-Centric: Focuses on integration, API connections and data pipelines.
    c. Focus on Structure: Data Lake vs. Data warehouse, Extract Transform Load (ETL) processes.

The key difference between a database, a data warehouse and a data lake is that a database stores the current data required to power an application, a data warehouse stores current and historical data from one or more systems in a predefined and fixed schema, which allows analysts and data scientists to easily analyse the data while a data lake stores current and historical data from one or more systems in its raw form, which allows analysts and data scientists to easily analyse the data.

The key objective of this segment of DFA that is structural design and technical infrastructure in support of the DFA is to ensure that the DFA grows in quality and capacity to improve data flow and make the inventories more efficient with time. As this is achieved, the gap between where Nigeria is currently and where Economies in Transition (EIT) and developed economies are, would gradually be breached in the GHG inventory sector.

6. THE NATIONAL GHG EMISSIONS DATA FLOW AND SECURITY POLICY

6.32 OVERVIEW

6.32.1 Why Policy is Necessary

A GHG inventory data flow and data security policy is needed to guide how data would be moved from sources to points of use for emissions compilation, archival and retrieval in the system while ensuring the accuracy, completeness, reliability and safeguard for data considered sensitive. A formal data flow policy is crucial for establishing a standardized, transparent and defensible process for emissions tracking. Key reasons include:

i. Accuracy and Consistency: It defines clear procedures for data collection, calculation and reporting, ensuring consistency over time and across different reporting teams or facilities. This minimizes errors and facilitates year-to-year comparisons.
ii. Compliance and Credibility: Standardized data flow ensures the inventory meets the requirements of reporting standards by UNFCCC and the Paris Accord especially with regard to the Enhanced Transparency Framework (ETF) and Biennial Transparency Reporting (BTR).
iii. Completeness: The policy helps identify all relevant emission sources within the boundary of the entity (nation, states, municipalities, etc.), reducing the risk of omitting any anthropogenic sources within the geographical entity of interest.
iv. Auditability: A well-documented data flow creates a clear "audit trail," making the inventory process more transparent and verifiable by reviewers during the QC/QA process.
v. Efficiency: It streamlines the data gathering process, clarifying roles and responsibilities and where possible provides the template for automating data gathering and processing to minimise time and effort required to compile the inventory.

GHG inventory data, particularly at the operational level, may be highly sensitive and needs protection. Key reasons for a data security policy include:

i. The Need to Protect Proprietary Data: Detailed data on energy consumption, production processes and supply chain logistics could reveal competitive business information or operational vulnerabilities. A data security policy minimises the rate at which sensitive information would fall into competitors' hands.
ii. The Need to Maintain Data Integrity: Security measures (like access controls and encryption) ensure that only authorized personnel can input or modify data, preventing intentional or accidental manipulation that could compromise the integrity of the entire inventory output.
iii. The Need to Prevent Misuse and Misrepresentation: A data security policy helps prevent unauthorized access that could lead to data being misrepresented in public reports which could result in reputational damage or legal issues.
iv. The Need to Ensure Confidentiality: For organizations that collect data from suppliers or other third parties, a data security policy ensures that confidentiality agreements are upheld, protecting sensitive partner data.

6.32.2 Aim and Objectives

The ultimate aim of the policy is to establish a robust and sustainable system for collecting and managing GHG data that provides a true and fair estimates of emissions that is inline with the TRACCC criteria.

The specific objectives of a data flow policy could be categorized into two sets viz:

i. Data Flow and Management Objectives:

a. Systematic Data Collection: Establish clear procedures and institutional arrangements, including formal agreements with data providers to ensure timely and consistent collection of all necessary activity and emission factors data.
b. Quality Assurance/Quality Control: Integrate rigorous QA/QC procedures, such as cross-checking data and reviewing documentation to identify and correct errors, inconsistencies or gaps in the data.
c. Standardized Calculation and Archiving: Mandate the use of consistent, internationally recognized methodologies and emission factors for emissions calculation and ensure all data, documentation and calculations are properly archived for future reference and verification.
d. Continuous Improvement: Provide a framework for regular review and update of data collection methods, processes and methodologies to enhance the overall quality and efficiency of inventories with time.

ii. Security and Accountability Objectives:
a. Data Integrity and Confidentiality: Develop policies to protect sensitive or proprietary data from unauthorized access, use or disclosure while still meeting the TRACCC criteria for reporting.
b. Role Definition and Access Control: Clearly define the roles and responsibilities of all personnel involved in the inventory process and implement access controls to ensure that only authorized persons can access, modify or verify specific data sets.
c. Audit Trail and Verification Readiness: Maintain a clear and complete audit trail for all data inputs, changes and assumptions to facilitate independent review during QA/QC processes.
d. Compliance and Risk Management: Ensure that the entire data flow process complies with relevant national and international reporting standards to improve the quality of inventories that would support mitigation scenarios analyses.

6.32.3 Scope of the Policy

Data flow and security policy seek to establish a robust, transparent and verifiable framework for the entire data lifecycle, ensuring the accuracy, consistency and security of all GHG emission data within defined organizational and geographical boundaries. The current version of the Policy is presented in sub-sections 6.2 to 6.5 below. Future versions would be updated as the need arises.

6.33 POLICIES TO GUIDE THE NATIONAL ACTIVITIES DATA FLOW SYSTEM

National GHG Inventories Data Flow System Policies are designed to ensure that the collection, management and reporting of emissions relevant data meet the standards of the UNFCCC and Paris Accord's TRACCC Criteria. Other key elements include policies on legal arrangement for data sharing, management and operations. These Policies are presented in the sub-sections below.

6.33.1 Policies to Guide the Activities of National Statistical Institutions

The following policies shall guide the activities of NSIs:

i. National institutions with mandates for Activities Data collection in general shall be identified and recognised by NCCC as NSIs to provide Activities Data to the inventory process at national and sub-national levels;
ii. NSIs shall be divided into two namely a) Primary Activities Data Providers (PADP) shall be institutions with mandates for data in their operations, sub-sectors or sectors and b) Secondary Activities Data Providers (SADP) which shall be institutions whose mandates are not specific to any sector or sub-sector but general in

nature and could be coopted to collect data that would fill gaps in any sector of interest where PADP data are inadequate;

iii. NCCC shall develop a register of accredited NSIs and the areas which each shall provide Activities Data across the different inventory sectors. Such a register shall also specify which NSI is a PADP or SADP in each sector;

iv. NCCC shall provide details of its annual data requirements, specificity and date such data should be made available by each NSI;

v. NCCC shall enter into Memorandum of Agreement (MOA) with NSIs which shall contain clauses that stipulate the roles and responsibilities of each party in the MOA; and

vi. NIMO shall be the coordinating arm of the NCCC to liaise with NSIs for the Activities Data collection as well as provide the mechanism and technologies for such data collection and sharing;

vii. Activities data transferred to NIMO by NSIs shall be processed with technical support from NITSI to ensure that data for the same emission relevant processes are not repeated. In doing so, data from PADPs are given priority over data from SADP; and

viii. Processed inventory data shall be transferred to NSITs by NIMO for emissions compilation, recalculations where needed, report preparation and other related activities in their respective sectors.

6.33.2 Policies on Programme to Update New Activities Data

The following policies shall guide the programme to update new Activities Data:

i. NCCC shall work collaboratively with the relevant national institutions listed in sub-sections 4.2.1.3 to 4.2.1.5 to put in place the framework for an integrated surveillance system for routine update of Activities Data in Agriculture, LULUCF and Waste sectors. The surveillance system is to integrate relevant technologies such as remote sensing with on-the-ground surveys to track land-use changes and other relevant ground data to improve the accuracy of GHG inventories that would align with the TRACC criteria;

ii. The surveillance system shall seek to update Activities Data at least once every Five (5) to Ten (10) years;

iii. NIMO shall play the coordinating role in bringing the stakeholder institutions together to work out the modalities for setting up and managing the surveillance system for improved systematic Activities Data collection in future. In doing so, NIMO shall set aside a minimum of 30% of the funding allocated to inventories research annually in sub-section 4.3.18 of Obioh (2026) as its contribution to the fund required by the Partnership for the surveillance system operation and ground truthing activities to appraise new Activities data;

iv. The new Activities data collected by the Partnership shall among others be transferred to NIMO and other Partners to ensure that Activities database in the relevant sectors are updated regularly with technical support from NITSI; and

v. The updated Activities database in the relevant sectors shall be used by NSITs for emissions compilation, recalculations where needed, report preparation and other related activities.

6.33.3 Policies on Development of Modelling Indicators

The following policies shall guide the development and use of modelling indicators to enhance gap-filling for missing Activities Data across sectors:

i. In view of the fact that the informal sector poses a specific challenge because data from this sector are not documented directly by any NSI, NIMO as the Coordinating arm of NCCC shall setup and manage a programme for development and use of modelling indicators to estimate missing Activities Data across all sectors;

ii. NIMO shall set aside a minimum of 5% of the research funds for GHG inventories proposed in section 4.3.18 of Obioh (2026) as funding for modelling indicators programme; and

iii. The modelling indicators programme shall support individual researchers or teams to undertake research that would link Activities data with certain socio-economic variables to establish the basis for modelling specific Activities data at national or sub-national levels using the Small Grant Programme (SGP) in section 8.7.1.1 (i) and 8.7.1.2 (i) respectively of Obioh (2026);

iv. Beneficiaries of the grants for modelling indicators research shall publish their results in peer-reviewed national journals and monographs and share such publications with NIMO who shall work in partnership with NITSI to use such data to update the modelling indicators database; and

v. The modelling indicators database shall be used by NSITs for emissions compilation, recalculations where needed, report preparation and other related activities.

6.34 POLICIES TO GUIDE THE NATIONAL EMISSION FACTORS DATA FLOW SYSTEM

Establishing a national emission factors data flow system for Nigeria is expected to integrate the development of National GHG emission factors to systematically phase out IPCC default and other literature emission factors from national inventories and produce national database that would support future inventories. The key policy pillars include:

i. Literature review to establish emission factors that have been measured or modelled elsewhere for processes that use technologies comparable with those in use in Nigeria;

ii. Review of IPCC Guidelines to model emission factors using national data for such processes;

iii. Measurements of the national emission factors in point, line and area sources; and

iv. Any other relevant pillar that might emerge in the cost of implementing this, Policy.

The policies below shall guide the specific pillars of the national emission factors data flow system.

6.34.1 Policies to Appraise Literature-Derived Emission Factors

The following policies shall guide the appraisal and use of literature-derived emission factors (EFs) across sectors:

i. Literature-based GHG EFs shall be used only when nationally derived data for a specific process is unavailable;

ii. Such EF values shall be obtained mainly from peer-reviewed publications. Where the values are obtained from non-peer-reviewed publications, they shall be given a ranking of 4 or 5 depending on whether they are from a developing or advanced economy;

iii. In appraising Literature-based EFs, priority shall be given to those derived from economies that are nearly at par with the level of development in Nigeria. Where EFs from such countries are difficult to obtain, data from more advanced economies may be admitted and ranked for use in Nigeria on a scale between 1 and 5 where, 1 is highest and 5 is the least quality EF. The quality of EF values shall be assigned 1 when they are from economies that are comparable to that of Nigeria and assigned 2 to 5 when from economies that steadily deviate from that of Nigeria towards advanced technologies;

iv. Literature-based EF values especially those with lowest ranks shall be changed as soon as national EF values are derived or EF values with higher rankings are obtained from literature;

v. EF values shall be obtained from the IPCC and other international EF databases where regional data are unavailable and appropriately ranked as in 3 above;

vi. Literature-based EF values shall not be used where uncertainties associated with the estimates are not provided in the publications;

vii. Beneficiaries of grants involved in review of literature-based emission factors for use in Nigeria shall publish their results in peer-reviewed national journals and monographs and share such publications with NIMO who shall work in partnership with NITSI to use such data to prepare or update national literature emission factors listings; and

viii. The updated national literature emission factors listings shall be used by NSITs for emissions compilation and recalculations where needed, report preparation and other related activities.

6.34.2 Policies to Enhance National Emission Factors Development

The following policies shall enhance the development and use of national EFs across all sectors:

i. NIMO as the Coordinating arm of NCCC shall design, develop and implement a programme for EF values measurements and modelling for which research institutions shall be the foot-soldiers to bring up national EF values;
ii. The Programme in one above shall include measurements of the national EF values in stacks, vehicle tail-pipes and for area sources based on measurement and reporting protocols provided in the National Air Quality Standards (2014) by National Environmental Standards and Regulations Enforcement Agency (NESREA);
iii. National EF values modelling shall be based on the application of IPCC 2006 Guidelines, 2019 Refinements and their subsequent versions to estimate EF values using national data for process modelling across all sectors;
iv. Beneficiaries of the grants for national emission factors research shall publish their results in peer-reviewed national journals and monographs and share such publications with NIMO who shall work in partnership with NITSI to use such data to update the modelling indicators database; and
v. The emission factors database shall be used by NSITs for emissions compilation, recalculations where needed, report preparation and other related activities.

6.34.3 Other Relevant Policies on Use of Emission Factors

The following policies shall enhance the development and use of national EF values across all sectors:

i. NIMO shall set aside a minimum of 40% of the research funds for GHG inventories as proposed in section 4.3.18 of Obioh (2026) as funding for EFs development programme; and
ii. The EFs programme shall support individual researchers or teams to undertake research to develop national EF values at national or sub-national levels using the Small, Medium and Large Grant Programmes in section 8.7.1.1 and 8.7.1.2 respectively of Obioh (2026).

6.35 POLICIES TO GUIDE THE DEVELOPMNENT AND MANAGEMENT OF NATIONAL GHG INVENTORY DATABASES

As part of measures to improve the quality of national GHG inventories, parties to the UNFCCC are expected to develop policies to guide the development of databases to enhance transparency in emissions compilation, reporting and verification. This is to ensure that data is not only collected but managed in a way that is credible, actionable and in line with the TRACCC criteria of the UNFCCC and the Paris Accord. An Inventory Management Plan is required to provide the framework for managing the databases. This Policy provides the components of the databases, QA/QC, measures to improve the quality of the databases. The key pillars of this Policy are presented in the sub-sections below.

6.35.1 Policies on Development of National Database for Modelling Indicators

The following policies shall guide the development and management of the national database to support the archival and retrieval of relevant data on modelling indicators research:

i. NIMO as the Coordinating arm of NCCC for modelling indicators research, shall work collaboratively with the National Inventory Technical Support Institution (NITSI) to design and develop the database for modelling indicators;
ii. NITSI shall be responsible for designing the architecture and components of the modelling indicators database. In doing so, NITSI shall obtain data on published modelling indicators available to NIMO and elsewhere to design, test run and operate the database;
iii. NIMO shall host the database in its operational phase while NITSI continues to provide technical support for trouble shooting, maintenance and and updates; and
iv. The National Sectoral Inventory Teams (NSITs) shall with the approval of NIMO be provided adequate access by NITSI to ensure that they are able to retrieve modelling indicators data from their respective sectors for inventories compilation and reporting in line with the inventories preparation instructions contained in the Manual of Procedures (MOP) for each National Inventory Cycle (NIC) in sub-section 6.2.1.9 of Obioh (2026).

6.35.2 Policies on Development of National Activities Database

The following policies shall guide the development and management of the national Activities database to support the archival and retrieval of relevant Activities data for emissions compilation:

i. NIMO as the Coordinating arm of NCCC for the development and management of the national Activities database, shall work collaboratively with NITSI to design and develop the national Activities database;
ii. NITSI shall be responsible for designing the architecture and components of the national Activities database. In doing so, NITSI shall obtain Activities data provided by NSIs and modelling indicators research teams as published;
iii. NIMO shall host the database in its operational phase while NITSI continues to provide technical support for trouble shooting, maintenance and updates; and
iv. NSITs shall with the approval of NIMO be provided adequate access by NITSI to ensure that they are able to retrieve data from their respective sectors for inventories compilation and reporting in line with the inventories preparation instructions contained in the MOP for each NIC in sub-section 6.2.1.9 of Obioh (2026).

6.35.3 Policies on Development of National Emission Factors Database

The following policies shall guide the development and management of the national EF-database to support the archival and retrieval of relevant EF-data:

i. NIMO as the Coordinating arm of NCCC for national EF research, shall work collaboratively with NITSI to design and develop the national EF-database;
ii. NITSI shall be responsible for designing the architecture and components of the EF-database. In doing so, NITSI shall obtain data on published national EF values available to NIMO and elsewhere to design, test run and operate the database;
iii. NIMO shall host the database in its operational phase while NITSI continues to provide technical support for trouble shooting, maintenance and updates; and
iv. NSITs shall with the approval of NIMO be provided adequate access by NITSI to ensure that they are able to retrieve national EF data from their respective sectors for inventories compilation and reporting in line with the inventories preparation instructions contained in the MOP for each NIC in sub-section 6.2.1.9 of Obioh (2026).

6.35.4 Policies on Development and Management of National Emissions Database

The following policies shall guide the development and management of the national emissions database to support the archival and retrieval of relevant national emissions data:

i. NIMO as the Coordinating arm of NCCC for national emissions compilation, shall work collaboratively with NITSI to design and develop the national emissions database;
ii. NITSI shall be responsible for designing the architecture and components of the emissions database. In doing so, it shall obtain compiled national emissions data available to NIMO to design, test run and operate the database;
iii. NIMO shall host the database in its operational phase while NITSI continues to provide technical support for trouble shooting, maintenance and updates;
iv. NSITs shall with the approval of NIMO be provided adequate access by NITSI to ensure that they are able to retrieve relevant data including modelling indicators, Activities data and EF values from their respective sectors for inventories compilation and reporting in line with the inventories preparation instructions contained in the MOP for each NIC in sub-section 6.2.1.9 of Obioh (2026); and
v. NSIT shall after emissions compilation report their respective sectoral data to NITSI for use as inputs to the national emissions database.

6.36 POLICIES ON GHG INVENTORIES DATA FLOW SYSTEM SAFEGUARDS AND SECURITY

GHG inventories data flow system requires policies that balance public transparency with the protection of sensitive information through institutional arrangements, specialized software tools and adequate confidentiality protocols. A robust GHG inventories management system is expected to be anchored on processes that ensure steady flow of data among its teams and stakeholders without safeguards and security breaches. Security breaches are incidents that compromise the system's integrity, physical assets or data while Safguards are the preventative measures ensuring accuracy and legal use of all data. Security policies address the protection of sensitive information during data collection, processing, emissions compilation and reporting as well as data platforms within the inventory system. The following are the policies for addressing safeguards and security in the national GHG inventory system;

i. As the technical support arm of NIMO, NITSI shall take the lead in designing architecture that would prevent breaches in safeguards and security of the national inventory system in its operational phase;
ii. NITSI shall provide technical advice and obtain approval of NIMO on the levels of security and accessibility that each database in sub-section 6.4 would require to operate without safeguards and security breaches;
iii. NSITs shall in all their inventories ensure material balance in Activities data and compiled emissions for each process across the different tiers of government as provided in sub-section 4.3.2 of Obioh (2026);
iv. NIMO as the curator of all data shall put place surveillance systems(s) to track unauthorised entry into computing facilities hosting inventories databases; and
v. When the design of technical system architecture and technologies are in place across selected or all institutions in the inventory management system, NIMO working with technical support from NITSI shall provide the design for preventing data compromise and security breaches as data are shared among the institutions and stakeholders in the DFS.

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8. GLOSSARY

Accuracy	This is a relative measure of the exactness of an emission/removal estimate. Estimates should be "accurate" in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as practicable.
Area Sources	Sources that fall outside the point and line source categories are defined as area sources. Area sources can refer to sources over an administrative area or grid, which do not meet the definition of point or line sources.
CO_2e	Means carbon dioxide equivalent emissions. It combines the climate-warming potential of different greenhouse gases into a single metric representing the emissions of all greenhouse gases estimated in the report, expressed as the equivalent amount of CO_2 that is emitted by the combined greenhouse gases.
Comparability	Estimates of emissions and removals reported in inventories should be comparable among Parties and between national teams which means that appropriate recommended source categories, methodologies, definitions and units for activity data and emissions factors are used and that the instructions in the latest IPCC Guidelines and IPCC Good Practice Guidance documents are followed.
Completeness	An inventory shall cover all sources and sinks in the full geographical area covered by the inventory (National, State, Municipality etc.), and all greenhouse and precursor gases included in the latest IPCC Guidelines for National Greenhouse Gas Inventories, in addition to other existing relevant source/sink categories which may be specific to the individual Parties to the UNFCCC (and therefore may not be included in the IPCC Guidelines).
Consistency	All inventories shall be internally consistent, which means that same methodologies and assumptions shall be used for all years and that emission estimates or removals from distinct sources that rely on the same type of information and assumptions shall be deduced from the same data sets.
Criteria Air Pollutants	These are traditional air pollutants (primary or secondary) associated with point, line and area sources and usually used in establishing the air quality criteria of urban and rural areas. The Federal Ministry of Environment is yet to specify what constitutes CAPs in Nigeria. However, the following listing is recommended based on experiences elsewhere: Particulate matter (PM), including the total suspended particulate (TSP), as well as respirable fractions: PM_{10}, $PM_{2.5}$, and PM_1; Carbon monoxide (CO); Volatile Organic Compounds (VOC); Nitrogen dioxide (NO_2); Sulphur Dioxide (SO_2); and Ozone (O_3).
Data Flow	Data Flow constitutes the entire lifecycle of emissions data from the point of initial generation to final reporting and archiving.

Data Flow Architecture	Refers to the cross-institutional structural design and technical infrastructure that enables the operational processes in the data flow system to function seamlessly.
Data Flow System	This is a structured system of institutions, operational procedures and tools required to enhance logical flow and used to support systematic movement of information or data from source to where it is needed for emissions compilation, archiving and other processes to meet the TRACCC criteria.
Emission Inventories	The process for establishing emissions from sources using standardized methods for any locality, state or country for the purposes of establishing trends and contribution by sector in an economy, managing risks associated with the emissions, identifying reduction opportunities, participating in voluntary or mandatory emissions management programmes, participating in emissions trading markets, and achieving recognition for early voluntary action.
Emissions from Sources	The mass of each array of compounds emitted from sources based on their associated emission rate (emissions per unit time) multiplied by time or based on the emission factor (emissions per activity) multiplied by the associated activities data (throughput x time) of the source. Emissions for GHGs would be established for CO_2, CH_4, N_2O, etc.
Excess Air	In undertaking stack emission measurements, the standard is to ensure that the plume has an oxygen content of 3% or that the emissions are reported at the standard plume-oxygen concentration of 3%.
F-Gases	Fluorinated greenhouse gases or F-gases, are a group of man-made, synthetic gases containing fluorine. They comprise Hydro-fluorocarbons (HFCs), Per-fluorocarbons (PFCs), Sulphur Hexafluoride (SF_6) and Nitrogen Trifluoride (NF_3). They are powerful greenhouse gases that contribute to greenhouse effect with global warming potentials (GWPs) much higher than that of carbon dioxide, and widely used in various applications including refrigeration, air conditioning, and other industrial processes.
GHG Precursors	Precursor gases are those primary air pollutants which do not directly induce global warming, but are involved in certain atmospheric reactions that lead to the formation of secondary substances that are radiatively active and affecting the atmospheric energy balance. Examples include: CO, SO_2, NO_x, VOC and PM.
Greenhouse Gases	Greenhouse gases are gases in the atmosphere emitted from natural, anthropogenic (human related) sources and from atmospheric photochemical reactions that leads to the modification of the atmospheric energy balance leading to greenhouse effect or global warming and subsequently to the modification of climate indices at global, regional or local scales beyond their established normal ranges of variabilities. They include Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O),

	Water vapour, Ozone, Hydro-fluorocarbons (HFCs), Per-fluorocarbons (PFCs), Sulphur Hexafluoride (SF_6), and Nitrogen Trifluoride (NF_3). However, where consideration is given only to anthropogenic sources, water vapour is usually not included because its concentration in the atmosphere is not known to be affected by human activities.
Line Sources	Emissions from transportation systems usually maintaining curvilinear trajectories such as roads, rivers, railways, and seaways and/or nodes such as parking lots, ports and airports. They generally comprise all the highways, urban extra-urban roads and all the main ports and airports are included.
NOx	This means oxides of nitrogen, a group of reactive gases primarily consisting of nitric oxide (NO) and nitrogen dioxide (NO2), formed during combustion processes.
Point Sources	Fixed or stationary sources whose total annual emissions are above a pre-defined threshold as follows: CO_2≥500 tonnes/year; CO≥250tonnes/year; methane≥50tonnes/year; and other precursor gases≥20tonnes/year, measured under standard stack emission measurement conditions.
Primary Activities Data Providers	These are the original sources or entities that collect raw Activities data directly in a specific sector or sub-sector. They are the institutions with the primary mandate to collect such data.
Reproducibility	An inventory report that meets the transparency requirement shall be so written with adequate details and assumptions that other teams can use such a report to reproduce the calculations and reach the same outcome and outputs for each source as well as for all GHG and precursor gases emissions.
Secondary Activities Data Providers	Are institutions that aggregate existing Activity data from primary data providers for general public interest or information.
Secretariat	This means the Secretariat of the National Council on Climate Change, Federal Republic of Nigeria. It is the management and administrative organ of the Council headed by the Director General and CEO who reports to the board.
Sinks	The process, activity or mechanism that removes GHGs, aerosols, or their precursors from the atmosphere.
Source Profile	The admixture or the concentrations of the array of compounds, pollutants or GHGs measured in the plume or stack of any source that is emitting substances into the atmosphere.
Sources	Refer to the activities and processes that release or emit greenhouse or precursor gases into the atmosphere, contributing to the greenhouse effect and global warming.
Transparency	The inventory should be reported in such a way that the activity data, methods and emission factors used as well as the underlying assumptions, emission calculations and how all data were archived are clearly documented so that users of the inventory can evaluate such information and have clear and unambiguous understanding of the inventory report. This also means that the use of confidential data should be kept to a minimum.

9. ANNEX

ABOVE-GROUND BIOMASS IN NATURAL FORESTS (TONNES D.M. HA-1)							
Domain	Ecological zone 1	Continent	Status/condition2	Above-ground biomass [tonnes d.m. ha-1]	Uncertainty	Uncertainty type	References
Tropical	Tropical Rainforest	Africa	Primary	404.2	120.4	SD	1-12
			Secondary >20 years	212.9	143.1	SD	5-7, 11, 13-16
			Secondary ≤20 years	52.8	35.6	SD	9-11, 14, 15, 17
		North and South America	Primary	307.1	104.9	SD	3, 4, 9, 10, 18-21
			Secondary >20 years	206.4	80.4	SD	9, 10, 22-28
			Secondary ≤20 years	75.7	34.5	SD	9, 10, 14, 22, 23, 28-32
		Asia	Primary	413.1	128.5	SD	3, 4, 9, 10, 33-35
			Secondary >20 years	131.6	20.7	SD	9, 10, 36, 37
			Secondary ≤20 years	45.6	20.6	SD	9, 10, 37-39
	Tropical moist deciduous forest	Africa	Primary	236.6	104.7	SD	1, 2, 16
			Secondary >20 years	72.8	36.4	SD	9, 10, 16, 40-47
			Secondary ≤20 years				
		North and South America	Primary	187.3	94.0	SD	3, 4, 9, 10, 18-21
			Secondary >20 years	131.0	54.2	SD	9, 10, 22-26
			Secondary ≤20 years	55.7	28.7	SD	9, 10, 22, 23, 25, 26
		Asia	Primary				
			Secondary >20 years	67.7	93.4	SD	9, 10, 35, 48-50
			Secondary ≤20 years				

	Tropical dry forest	Africa	Primary				
			Secondary >20 years	69.6	47.5	SD	1, 2, 43, 44, 51-53
			Secondary ≤20 years				
		North and South America	Primary	127.5	72.6	SD	18-21
			Secondary >20 years	118.9	81.3	SD	9, 10, 22, 23, 54
			Secondary ≤20 years	32.2	24.2	SD	9, 10, 22, 23, 54, 55
		Asia	Primary				
			Secondary >20 years	184.6	144.5	SD	9, 10, 35, 48, 56
			Secondary ≤20 years				
	Tropical Shrublands	Africa	Primary				
			Secondary >20 years	48.4	45.8	SD	44, 57, 58
			Secondary ≤20 years				
		North and South America	Primary				
			Secondary >20 years	71.5	46.4	SD	59
			Secondary ≤20 years				
		Asia	Primary				
			Secondary >20 years	38.3	33.0	SD	59
			Secondary ≤20 years				