ZAMBIA ENVIRONMENTAL MANAGEMENT AGENCY

NATIONAL GREENHOUSE GAS INVENTORY REPORT

BIENNIAL TRANSPARENCY REPORT

August 2025

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ACRONYMS

AD	Activity Data
AFOLU	Agriculture Forestry and Other Land Use
CCS	Carbon capture and storage
CO2 e	Carbon Dioxide equivalent
CSO	Civil Society Organisations
CSO	Central Statistics Office
EAF	Electric Arc Furnace
EF	Emission Factor
GDP	Gross domestic product
GEF	Global Environment Facility
GHG	National Greenhouse Gas
HFO	Residual Fuel Oil
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
LECB	Low Emissions Capacity Building Project
LPG	Liquefied Petroleum Gas
NDC	Nationally Determined Contribution
ODU	Oxidised During Use
PFC	Perfluorocarbons
QA/QC	Quality assurance and quality control
TNC	Third National Communication
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
ZEMA	Zambia Environmental Management Agency

ABBREVIATIONS FOR CHEMICAL COMPOUNDS

CH_4	Methane
N_2O	Nitrous oxide
CO_2	Carbon dioxide
CO	Carbon monoxide
NO_X	Nitrogen oxides
NMVOC	Non-methane volatile organic compound
NH_3	Ammonia
CFCs	Chlorofluorocarbons
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SF_6	Sulfur hexafluoride
CCl_4	Carbon tetrachloride
$C2F_6$	Hexafluoroethane
CF_4	Tetrafluoromethane

STANDARD EQUIVALENTS

1 tonne of oil equivalent (toe)	1 x 10^{10} calories
10^3 toe	41.868 TJ
1 short ton	0.9072 tonne
1 tonne	1.1023 short tons
1 tonne	1 megagram
1 kilo tonne	1 gigagram
1 mega tonne	1 tera gram
1 giga tonne	1 peta gram
1 kilogram	2.2046 lbs
1 hectare	104 m^2
1 calorie	4.1868 Joules

UNITS AND ABBREVIATIONS

Cubic	Metre m^3
Hectare	Ha
Gram	G
Tonne	T
Joule	J
Degree Celsius	℃
Calorie	Cal
Year	Yr
Capita	Cap
Gallon	Gal
Dry Matter	dm

PREFIXES AND MULTIPLICATION FACTORS

Multiplication Factor	Abbreviation	Prefix	Symbol
1 000 000 000 000 000	10^{15}	Peta	P
1 000 000 000 000	10^{12}	Tetra	T
1 000 000 000	10^{9}	Giga	G
1 000 000	10^{6}	Mega	M
1 000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	mm

EXECUTIVE SUMMARY

Background

The preparation of the national Greenhouse Gas inventory (GHG) forms a critical component of Zambia's commitment under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. Following the signing and ratification of the Paris Agreement in 2016, the Government of the Republic of Zambia (GRZ) submitted its Nationally Determined Contribution (NDC) outlining a strategic pathway towards a low carbon, climate resilient future, contributing to the global temperature goals of limiting warming to well below 2°C, while pursuing efforts to limit the increase to 1.5°C above pre-industrial levels.

Under the Enhanced Transparency Framework of the Paris Agreement, Parties are required to submit Biennial Transparency Reports (BTR) every two years detailing information on national GHG emission inventory, progress on emission reductions, adaptation efforts, support needed and received in the implementation of the Nationally Determined Contributions (NDCs).
This report represents Zambia's submission of the National Inventory component of its first Biennial Transparency Report (BTR1) and Fourth National Communication (NC4, providing estimates of GHG emissions and removals resulting from anthropogenic sources and sinks across key sectors.

Objectives
The objective of the National Greenhouse Gas Inventory (GHGi) is to quantify Zambia's greenhouse gas emissions and removals for the period 1990 to 2022, in line with the transparency requirements under Article 13 of the Paris Agreement. The Inventory was prepared in accordance with the Modalities, Procedures and Guidelines adopted under Decision18/CMA 1, utilizing the 2006 IPCC Guidelines for National Greenhouse Gas Inventories along with the 2019 Supplement, as encouraged. The Inventory covers key sectors, including Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry and Other Land Use (AFOLU); and Waste. It reports greenhouse gases emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) and Sulphur hexafluoride (SF6). In addition the inventory includes data on precursor gases such as carbon monoxide (CO), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), and Sulphur dioxide (SO_2) and ammonia (NH_3) estimated in accordance with the 2023 European Environment Agency (EMEP/EEA) air pollutant emission inventory guidebook. While these are GHG totals, they play important roles in atmospheric chemistry, air quality, and climate processes including ozone formation and aerosol interactions.

Institutional Arrangement

The National GHGi was prepared under the established institutional framework for the GHG Inventory management system which includes formal agreements or Memoranda of Understanding (MOUs) between the Zambia Environmental Management Agency and sector lead institutions. The MoOs outline roles and responsibilities for data provision, methodological consistency, and capacity building, thereby strengthening collaboration and accountability in line with the requirements of the Enhanced Transparency Framework under the Paris Agreement. The GHGi management system institutional arrangements consists the following:

- Ministry of Green Economy and Environment: Overall policy guidance and reporting to the UNFCCC.
- Zambia Environmental Management Agency (ZEMA): Overall inventory coordinating institution, data management and archiving.
- GHG sector lead institutions responsible for sector inventory preparation include:
- Energy -Department of Energy and Energy Regulation Board
- Industrial Processes and Product Use: Department of Commerce and Industry and Zambia, Zambia Compulsory Standard Agency, Ministry of Small and Medium Enterprises, Zambia Bureau of standards and Zambia Revenue Authority
- AFOLU-livestock- Ministry of Livestock and Fisheries and University of Zambia
- AFOLU-Aggregate sources of Emissions-Ministry of Agriculture, Zambia Agriculture Research Institute (ZARI), Forestry Department
- AFOLU-Forestry and Other Land Use Change-Forestry Department
- Waste: Ministry of Local Government and Rural Development

(i). Data providers serving under sector leads.

Process of Inventory Preparation

The national GHG inventory preparation process was coordinated by the Zambia Environmental Management Agency, the designated national Inventory coordinating Agency in collaboration with the key Sector lead institutions under the GHG management system. The process began with the development of a roadmap outlining sector specific roles, methodologies based on 2006 IPPC guidelines, capacity building initiatives on the use of the IPPC 2006 guidelines and 2019 amendments, Emission Factor database and the 2006 IPPC Inventory software to ensure technical readiness. In addition, the process includes formalizing data sharing protocols and establishing timelines aligned with the reporting requirements under the UNFCCC and Paris Agreement.

Data collection was conducted for period of one year from October 2023 to November 2024 across a wide range of data providers, government agencies, private sector, civil Society and academia, data sorting and documentation. Sector teams documented source and sink category activity data and emission factors, methodological approaches and uncertainty estimates. This documentation was reviewed through a Quality Control (QC), Quality Assurance process to ensure completeness and accuracy before being input into the IPPC software to generate emission estimates.

All data, supporting documentation, and outputs were archived in the national GHG management system using tools and spreadsheets and the IPCC software. On completion of data documentation the respective sector compilers submitted the data documented for Quality Control (QC) to evaluate for completeness and accuracy.

Methodologies and used data sources

The methodology used to calculate source and sink category estimates was based on the IPCC 2006 Guidelines and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The 2006 IPCC Software and Emission Factor Database were used in preparing the inventory. Activity data used for the emissions estimates were obtained from the energy balance. Currently, the country does not have country specific emission factors for Energy, IPPU, and Waste sectors and for this reason, Tier 1 method and default emissions factors were used to estimate emissions for the said sectors. Tier 2 method was employed for the Land sub category under AFOLU while Tier 1 was used for the remaining. sub categories under AFOLU. For precursor emissions estimates, the emission factors were derived from the Emission Factor Database.

Trends in Greenhouse Gas Emissions

In 2022, Zambia's GHG emissions (without AFOLU) amounted to 18,410.3 Gg CO_2 equivalent (CO_2e). In comparison with the base year, 5,942.5 Gg CO_2e (1990), GHG emissions without AFOLU increased by 209.81%. The emissions increased steadily from 1990 to 2008 and continued to increase sharply from 2008 to 2022.

Zambia's total GHG emissions (with AFOLU) stood at 220462.1 Gg CO_2e in 2022, representing an increase of 121% against 99578.7 Gg in the 1990 base year. The GHG removals (sink) reduced by 2.6% from -164745.1 Gg CO2e in the current year (2022) to -160443.0 Gg CO2e in the base year (1990). The net GHG emissions indicate that Zambia was a net Sink for the period 1990 to 2006 and a net source from 2007 to 2022. In 2022, most of the GHG emissions existed as CO_2 (87%) followed by CH_4 at 11%, N_2O was 2% while HFC and SF6 were negligible. Contribution of SF6 and HFC to the emissions was negligible. SF6 has been largely negligible across all the years. The emissions of CO_2 increased from 88549.0 Gg CO_2e in the base year(1990) to 189215.2 Gg CO_2e in the current year (2022) representing a 113 % increase. In the same period, CH_4, N_2O, and HFCs increased from 9,437.3 Gg CO_2e, 633.2 Gg CO_2e, 0.2 Gg CO_2e and 0.2 Gg CO_2e in the base year 1990 to 23,296.7 Gg CO_2e, 3,561.6Gg CO_2e and 69.3Gg CO_2e in the current year 2022, respectively

In 2022, total CO_2 emissions from AFOLU sectors were primarily driven by three key activities: wood removal (timber harvesting), fuelwood extraction, and disturbances (wildfires, pest outbreaks, and natural land degradation).

In Zambia, the key precursor gases assessed in the current review include carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), nitrogen oxides (NOx), sulfur dioxide (SO_2), and ammonia (NH_3). Between 1990 and 2022, emissions of NMVOCs, NOx, SO_2, and NH_3 increased steadily, while CO emissions rose sharply. The Agriculture, Forestry, and Other Land Use (AFOLU) sector was the dominant source, contributing 62% of emissions, followed by the energy sector at 38%. Emissions from industrial processes and product use (IPPU) and the waste sector remained minimal. Figure 7 illustrates the sectoral trends in precursor gas emissions. As of 2022, CO accounted for the largest share of precursor gas emissions at 71%, followed by NOx (13%), NMVOCs (9%), and SO_2 (6%), with NH_3 contributing just 1%. Despite its small share, NH_3 emissions rose significantly 400% from 34 Gg in 1990 to 168 Gg in 2022. Similarly, CO emissions increased by approximately 400%, from 2,092 Gg to 10,467 Gg over the same period. NOx and NMVOCs also saw sharp increases of 313% and 399%, respectively

Key category analysis
According to Approach 1 Level Assessment the Key Categories were Forest land Remaining Forest land, Land Converted to Cropland, Land Converted to Settlements, Emissions from biomass burning, Enteric Fermentation, Manufacturing Industries and Construction - Liquid Fuels. In this assessment, for the year 2022 ten key categories were identified (six with both the level and trend assessment, two with the level assessment and two with the trend assessment). Most of the categories identified as key are from the AFOLU sector, which reflects the importance of this sector in the country's inventory.

Recalculations
Recalculations were made for the years 1990 to 2022 for all the sectors, as a result of the change of Global Warming Potential from AR2 used in the BUR to AR5. For livestock, country specific emission factors for enteric fermentation and manure management for Dairy Cows and Other cattle also necessitated the recalculations. In addition, improved data sets on forest areas affected by disturbances were used. In the BUR emissions estimate, it was assumed that 20% of forests were affected by disturbances, however, in the BTR more accurate and much lower values were used. It is for this reason that emissions reported in the BTR are significantly lower than those contained in the BUR

Conclusion
Overall emissions results indicate Zambia was a net sink from 1990 to 2006 and transitioned to a source in 2007 with the later years also remaining a net source. It was observed that the sink capacity has been observed to be reducing over the years while the source also continued

to increase. AFOLU sector has been the major source of emissions over the years, followed by Energy, Industrial Processes and Product Use and Waste. Emissions from Waste, Energy and IPPU are increasingly becoming significant. Carbon dioxide remains the most dominant gas among the GHGs emitted in Zambia, followed by methane and nitrous oxide. Other gases are HFC and SF6 from refrigeration and electrical equipment, respectively.

1.0 INTRODUCTION

1.1 Background and Objectives

The preparation of the national Greenhouse Gas inventory (GHG) forms a critical component of Zambia's commitment under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. Following the signing and ratification of the Paris Agreement in 2016, the Government of the Republic of Zambia (GRZ) submitted its Nationally Determined Contribution (NDC) outlining a strategic pathway towards a low carbon, climate resilient future, contributing to the global temperature goals of limiting warming to well below 2°C, while pursuing efforts to limit the increase to 1.5°C above pre-industrial levels.

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1.2 NATIONAL CIRCUMSTANCES

This section provides an update of the changing national circumstances that are relevant to climate change in Zambia. It also highlights the country's socio-economic development perspectives and priorities including policy, legal framework and institutional arrangement relevant to climate change.

1.2.1 Economy profile

In the early 1990s, the Zambian government made a move towards a privatized and open market economy. This helped to transform the Zambian economy and achieved an average Gross Domestic Product (GDP) growth of more than 6 percent in the period of 2005 to 2013. For the years 2011, 2012 and 2013 the real GDP was 6.8, 7.3 and 6.4 percent respectively, with annual inflation rate of 8.7 for 2011, 6.6 for 2012 and 7.1 percent for 2013 (Table 2.4). The GDP remained relatively stable in the years 2016, 2017 and 2018 with growth rates between 3 and 4 percent and an inflation rate was between 6 and 8 percent (ZAMSTATS, 2019 and Ministry of Finance, 2019). The economy was expected to grow between 4 and 5 percent from 2019 to 2021 (Medium Term Expenditure Framework, 2018). In 2022, Zambia's real GDP growth was 5.2% and grew steadily to 5.8% in 2023, primarily driven by wholesale and retail trade, agriculture and mining. On the other hand, the 2022 GDP growth represents a decline from the previous year's performance which stood at 6.2%. The Bank of Zambia also attributes increase in inflation especially in 2015 and 2016, to the increase in the cost of supply of selected food items, general increase in transportation costs due to changes in fuel prices and depreciation of the Kwacha against major currencies (BOZ, 2019).

1.2.2 Population

The population in Zambia in 1990 was 7,383,097 with the rural population at 4,477,814 and urban population at 2,905,283 respectively. Between 2010 and 2022, the country experienced an average annual population growth rate of 3.4%. [1]The survey reported 3,861,557 households, with an average household size of 5.1 persons. Zambia's population stood at 19,610,769 as of September 2022, representing a 49.8% increase compared to the population in 2010 (ZAMSTATS, 2022). The population is projected to continue growing at an average rate of 2.7% per annum while the total population is expected to double in the next 25 years. In 2022, the proportion of the population living in rural areas accounted for 60% as compared to the urban population which stood at 40%. The population density for Zambia increased from 17.3 persons per square kilometer in 2010 to 27.1 in 2022. The population and projections up to 2035 are shown in Table 1.

[1] Energy Sector Report, 2023: Energy Regulation Board (ERB)

Table 1:Population Size by Rural/Urban, Zambia 1990-2022

	Population				
Rural/Urban	1990	2000	2010	2022	% change
Zambia	7,383,097	9,885,591	13,092,666	19,610,769	49.8
Rural	4,477,814	6,458,729	7,919,216	11,766,461	48.6
Urban	2,905,283	3,426,862	5,173,450	7,844,308	51.6

Sources: Censuses of Population and Housing, 1990, 2000, 2010 and 2022

1.2.3 Energy

Zambia is predominantly dependent on hydro-power, taking up over 80% of the country's installed capacity, as a source of electricity. In 2022, the country's total installed capacity was 3,777.3 MW, with 3,164.14 MW being hydro, 300 MW from coal-fired power plant, 110 MW from Heavy Fuel Oils (HFO), 84.80 MW from diesel and 89.38 MW from on-grid solar PV[2]. The daily peak demand for electricity increased from 1,700 MW in 1990 to 2,300 MW in 2022. Zambia's total national electricity generation capacity for both on-grid and off-grid systems increased to 3,871 MW in 2024, up from 3,811 MW in 2023[3].

Zambia diversified its energy mix by adding electricity produced from fossil fuel-fired thermal power plants, i.e. from HFO (starting in 2013) and coal (starting in 2016) to the national grid. During the period under review, Zambia imported and refined crude oil into petroleum products (i.e., petrol, diesel, kerosene, liquefied petroleum gas, bitumen and other products). The country's annual consumption of petroleum products steadily increased from about 384,360 MT in 1990 to 1,549,270 MT in 2022. A total of 15,366,370 MT of crude oil was refined from 1990 to 2021, with the minimum being 16,850 MT in 2000 and the maximum of 701,330 MT in 2014 at the INDENI refinery plant located in Ndola District on the Copperbelt Province of Zambia. In the petroleum sub-sector, national consumption of petroleum products continued to rise with the total national consumption of petroleum products reaching 1,627,405.87MT in 2023 from 1,549,274.44MT in 2022. Kerosene recorded the highest growth rate at 370.4 percent followed by Jet A-1 at 41.7 percent and LPG at 13.3 percent.

1.2.4 Livestock

Cattle production in Zambia is characterized by rearing of 'Dairy cattle' and 'Other cattle', produced through commercial, emerging and extensive/traditional production systems. The majority of farmers

[2] esr2023.pdf
[3] https://www.moe.gov.zm/?page_id=2198

involved in livestock production do it only at sustenance level with limited or no mechanization to assure production efficiency.

There was a 10.65 percent decline in the total livestock emissions between 2000 and 2005. Therefore, the numbers of buffalo that were being held in captivity were relatively fewer, about 503 to 935 for 2005 and 2010, respectively. There was an increase in cattle population from 1,748,856 in 2011 to 2,109,231 in 2016. The population of dairy cattle increased from 874,268 in 2011 to 1,279,734 in 2012 due to an increase in the number of entities investing in the dairy value chain. Small ruminants animals equally recorded an increase in population from 1,855,366 in 2011 to 2,632,277 in 2016 which translates into 30%[4] increase in population. The sheep population has generally been lower than the goat population for all the years under consideration. The sheep population was generally less than one hundred thousand from 1990 to 2005. The layer birds population has been on the upward swing since 2017 (1,744,188) to 2022 (2,217,434). The egg production sales have recorded an increase in the demand for eggs for consumption and other culinary activities. A trend of increasing livestock population country wide from 2011 to 2013, There was a drop in the pig population in 2014 due to an outbreak of African Swine Fever which led to massive mortalities and slaughter of pigs. Lusaka and southern provinces were the most affected. The pig population was steady at just over seven hundred thousand heads for the period 2009 to 2015. The annual population of horses was generally less than three hundred and fifty heads from 1990 until 1998(GRZ, 2022)[5].

1.2.5 Forestry

The trend in wood removals indicates that the highest removals occurred in woodland (semi-evergreen) and pine plantations, while the least wood removals was observed in dry deciduous forests, moist evergreen forests, and eucalyptus plantations. Additionally, there was a marked increase in the harvesting of commercial species. This surge, particularly between 2016 and 2022, was driven by growing demand for timber in both domestic and export markets. Fuelwood removals exhibited a steady upward trend from 1990 to 2010, followed by a decline between 2010 and 2015. Charcoal is the dominant household energy source in urban Zambia. Over 75% of peri-urban and urban households rely on charcoal for cooking, regardless of income level. At the national level, 49.3% of households gather firewood as their primary cooking energy source. Despite its relatively high cost in urban areas, charcoal remains a culturally preferred fuel due to its accessibility. This high demand drives rapid growth in charcoal production, particularly in rural areas, resulting in the over-exploitation of Zambia's biodiverse forests. Charcoal production is responsible for nearly 25% of deforestation and forest degradation[6], posing significant environmental threats.

[4] Central Statistics Office
[5] Ministry of Fisheries and Livestock
[6] USAID, Alternatives to Charcoal

1.2.6 Crop production

Maize production from 1990 to 1994 dropped from 1.1 million metric tons to 1 million, and further to 737,000 in 1995, but rose to 800,000MT by 1999. This increased to 850,000 in 2000 and rose to 1.2 million MT. Then again to 866,000MT in 2005, but to 1.8 million MT by 2009.2010 some remarkable million thereafter to 2.6 million, and 2 million productions rose to 3 million MT, but dropped to 2.6 million MT, and then 2 million from 2015 to 2019. This coincided with the droughts and declines continued in the 2020 to 2022 periods.

1.3 Institutional Arrangements

The Green Economy and Climate Change Act, no 18 of 2024 stipulates that the Department of Green Economy and Climate Change shall establish and maintain the Greenhouse Gas Inventory Management System which shall serve as a central depository for data and information on greenhouse gases. The Minister may, by notice in the Gazette, designate the Zambia Environmental Management Agency to manage the Greenhouse Gas Inventory Management System. In line with the Green Economy and Climate Change Act, no 18 of 2024, the established institutional arrangements for GHGi management system consist of the following and included Memoranda of Understanding between ZEMA and sector lead institutions:

a) Ministry of Green Economy and Environment: Overall policy guidance and reporting to the UNFCCC.
b) Zambia Environmental Management Agency (ZEMA): Overall BTR and National Communications coordinating institution.
c) GHG sector lead institutions responsible for sector inventory preparation include:

- ❖ Energy – Ministry responsible for Energy Industrial Processes and Product Use: Ministry responsible for Commerce, Trade and Industry, Ministry responsible for Small and Medium Enterprises,
- ❖ AFOLU-livestock- Ministry responsible for Fisheries and Livestock
- ❖ AFOLU-Aggregate sources of Emissions-Ministry responsible for Agriculture, AFOLU-Forestry and Other Land Use Change-Forestry Department
- ❖ Waste: Ministry responsible for Local Government and Rural Development

Data providers served under sector leads as shown in figure 1

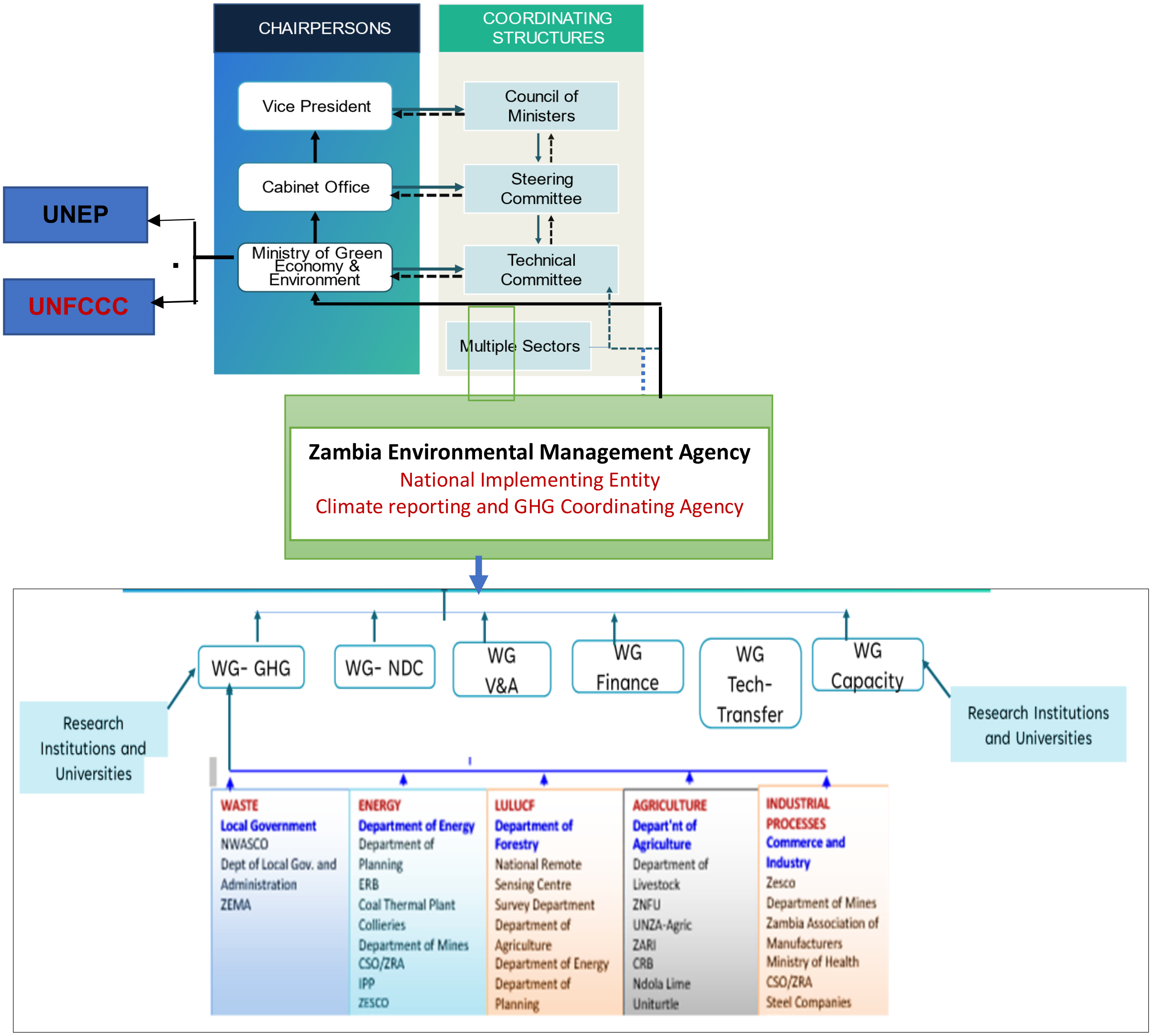


Figure 1 Institutional arrangements for preparing the Biennial Transparency Reports and National Communication

1.4 Inventory Planning and Management

The process to prepare the GHG inventory involved a series of structured steps to ensure Transparency, Accuracy, Consistency, Completeness and Comparability (TACCC). The steps include; Planning for inventory data collection from various data providers (i.e., government institutions, private sector, Civil Society Organizations (CSO) and academia). The data collected was sorted, categorized and documented. The data documentation process involved provision of source and sink category information (classification of emission sources and removals based on the IPCC 2006 sectoral approach) , methodological choices and description (justification for the selection of estimation methods based on IPCC tiers 1,2,or 3 depending on the availability of data and sectoral requirements), listing of activity data (compilation of statistical and measured data essential for emissions estimations), identification of emission factors (use of default emission factors from the IPCC emission factor database or country specific values where applicable) and uncertainty estimates (evaluation of data reliability, potential source of error and recommendations for reducing uncertainties).

Additional information and recommendations for future improvements were also documented. On completion of data documentation, the respective sector compilers submitted the data documented for Quality Control (QC) to evaluate for completeness and accuracy. After QC of all activity data and emission factors, they were input into the IPCC software to generate GHG estimates. All data and documentation were archived in the GHG Management System. The tools used in the inventory preparation process included spreadsheets, IPCC 2006 Guidelines, IPCC Software. Figure 2 illustrates the GHGi preparation process. The inventory preparation commenced in October 2023 and was completed in March 2025.

Figure 2: GHGi preparation process

1.5 Scope, Methodologies and Data Parameters

1.5.1 Gases

The greenhouse gases covered in the Inventory included; Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydro fluorocarbons (HFCs) and Sulphur hexafluoride (SF_6). The objective of the GHGi was to determine Zambia's emission levels for 1990 to 2022 using the updated 2006 IPCC Guidelines.

The report also covers precursor gases for sector to include; energy, Industrial Processes and Product use, Agriculture Forestry and Other Land Use (AFOLU) and Waste. The precursor emissions were prepared in accordance with the European Environment Agency EMEP/EEA air pollutant emission inventory guidebook 2023. Although they are not included in global warming potential-weighted greenhouse gas emission totals, emissions of carbon monoxide (CO), oxides of nitrogen (NOx), non-methane volatile organic compounds (NMVOCs), and sulphur dioxide (SO2) are reported in greenhouse gas inventories. Carbon monoxide (CO), Nitrogen oxides (NOx) and NMVOC in the presence of sunlight contribute to the formation of the greenhouse gas ozone (O3) in the troposphere and are therefore often called 'ozone precursors'. Furthermore, NOx emission plays an important role in the earth's nitrogen cycle. Sulphur Dioxide emissions lead to formation of sulphate particles, which also play a role in climate change. Ammonia (NH3) is an aerosol precursor, but is less important for aerosol formation than SO2.

1.5.3 Compilation

The National Greenhouse Gas Inventory (GHGi) was prepared in compliance with the modalities, procedures and guidelines (MPGs) established under the Enhanced Transparency Framework (ETF) for action and support as referenced in Article 13 of the Paris Agreement (Decision 18/CMA.1) "It follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the subsequent 2019 refinements. The GHGi quantifies and reports emission sources and removals for the period 1990-2022 across four key sectors:

- Energy
- Industrial Processes and Product Use
- Agriculture Forestry and Other Land Use (AFOLU)
- Waste.

The 2006 IPCC Software and Emission Factor Database were used in preparing the inventory. Activity data used for the GHG emissions estimates for the energy sector were obtained from the energy balance. Currently, the country does not have country specific emission factors for Energy, IPPU, and Waste sectors and for this reason, Tier 1 method and default emissions factors were used to estimate emissions for the said sectors.. Tier 2 method was employed for the Land sub category under AFOLU while Tier 2 was used for livestock(cattle only) and Tier 1 for other animals and Aggregate Sources and Non-CO2 Emissions Sources on Land. For precursor emissions estimates, the emission factors were derived from the Emission Factor Database.

The precursor emissions were prepared in accordance with the European Environment Agency EMEP/EEA air pollutant emission inventory guidebook 2023. Although they are not included in global warming potential-weighted greenhouse gas emission totals, emissions of carbon monoxide (CO), oxides of nitrogen (NOx), non-methane volatile organic compounds (NMVOCs), and Sulphur dioxide (SO2) are reported in greenhouse gas inventories. Carbon monoxide (CO), Nitrogen oxides (NOx) and NMVOC in the presence of sunlight contribute to the formation of the greenhouse gas ozone (O3) in the troposphere and are therefore often called ‘ozone precursors. Furthermore, NOx emission plays an important role in the earth's nitrogen cycle. Sulphur Dioxide emissions led to formation of sulphate particles, which also play a role in climate change. Ammonia (NH3) is an aerosol precursor, but is less important for aerosol formation than SO2. Detailed methodologies are provided in the sectoral analysis.

1.5.4 Reporting years.

The reporting years for this inventory is from 1990 to 2022.

1.5.5 Uncertainties

Energy

The Uncertainty analysis for the year 2022 for the Energy sector was estimated using approach 1 and computed using the IPCC 2006 software. Generally, uncertainty for activity data from energy is ± 5%. Detailed uncertainty values are provided in Annex I. Base year for uncertainty assessment was 1990.

IPPU

The Uncertainty Analysis (UA) for the year 2022 for IPPU sector was estimated using approach 1 and computed using the IPCC 2006 software and is provided in Annex II . Uncertainty arose from the quantity of cement and lime produced. Slight differences were observed between data from the Zambia Revenue Authority, ZAMSTATs, and from manufacturers. As regards nitric acid and ammonia production data was obtained from factory records with uncertainty of ±2%. Data on steel production was obtained from ZRA and ZAMSTAT database whose uncertainty was about ±5%. Data on lubricants were obtained from the Ministry of Energy database. Uncertainty for data on SF6 in electrical equipment was ±2% obtained from nameplate capacity from electricity utility companies.

The database for ZRA and ZAMSTAT does not record numbers of refrigeration and air conditioning units by type. Only the mass of refrigeration and air conditioning units by type is recorded for tax purposes. Thus, the data captured in the ZRA database is not suitable for inventory preparation. For this reason the inventory preparation team devised a methodology to deduce the charge contained in the units by utilising the mass and number of units imported and correlating with standards charge content in the units. This approach gives room for significant estimations of the numbers and it is for this reason that the uncertainty was set at ±50. The emissions factors in the UA were calculated using the 2006 IPCC Software. The AD was calculated from confidence levels from source data providers, including ZAMSTAT and industries. Where applicable, expert judgment was utilised to account for gaps in confidence level in the data.

AFOLU

The Uncertainty Analysis (UA) for the year 2010 for AFOLU sector was estimated using approach 1 and computed using the IPCC 2006 software and is provided in Annex I 3.11. Data for estimating emissions in the Land category was obtained from the ILUA data with uncertainty of ±5%. All the population data for Dairy, other cattle, Buffalo, Sheep, Goat, Swine and poultry were sourced from Central Statistical office (CSO).

Waste

The Uncertainty Analysis (UA) for the year 2010 for Waste sector was estimated using approach 1 and computed using the IPCC 2006 software and is provided in Table 6.4. Data for estimating emissions in the Waste sector was estimated from population, GDP, and other factors to include waste characterization. It was for this reason that the uncertainty was estimated to be ±50%. For wastewater activity data was obtained from installed capacities, thus the uncertainty were estimated at ±30%.

1.5.6 Time-Series Consistency and Recalculations

Recalculations were made for the years 1990 to 2022 for all the sectors, as a result of the change of Global Warming Potential from Second Assessment Report (AR2) to Fifth Assessment Report (AR5). For livestock, country specific emission factors for enteric fermentation and manure management for Dairy Cows and Other cattle also necessitated the recalculations. The Livestock Sector Study "Assessment of Heads, Sex and Age of different Cattle Categories were undertaken under the Supporting Preparedness for Article 6 Cooperation Program (SPAR6C). The SPAR6C program was funded by the German Federal Ministry for Economic Affairs and Climate Action through the International Climate Initiative (IKI) and led globally by Global Green Growth Institute. In addition, improved data sets on forest areas affected by disturbances resulting from fires were used. Provided in Table 2 and figure 3 is a comparison of emissions between BUR and BTR after recalculation.

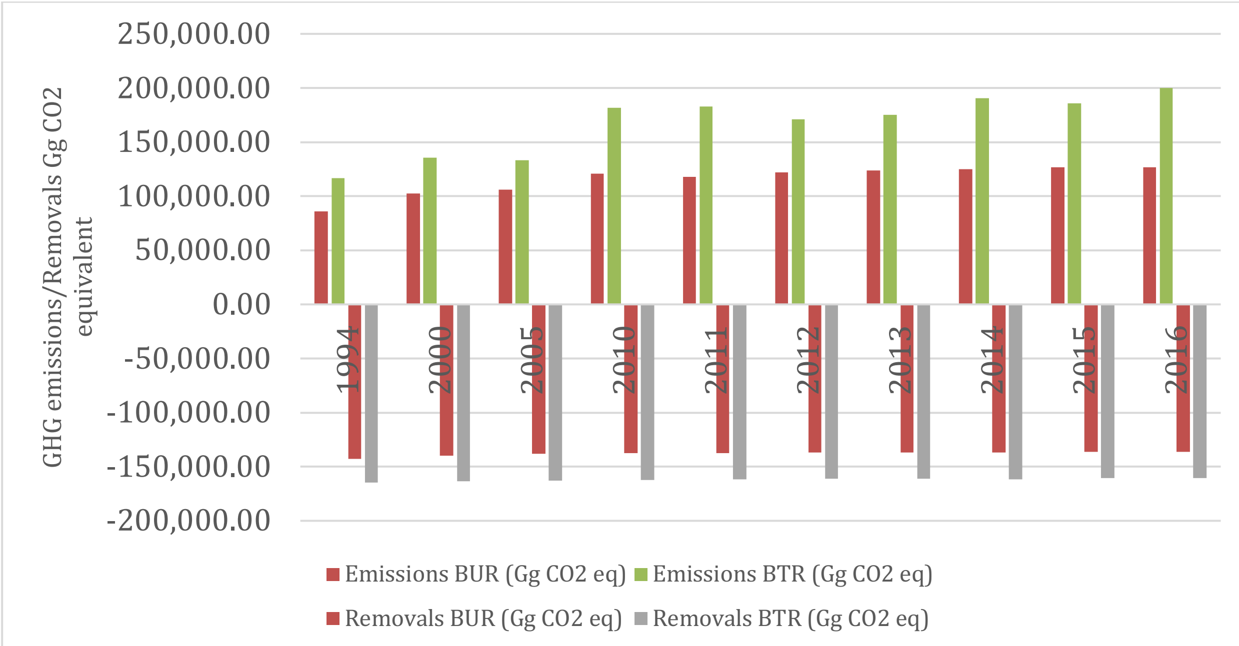


Figure 3: *Comparison of BUR and BTR emissions after recalculations*

Table 2: Comparison of BUR and BTR emissions after recalculations

Year	Emissions		Difference		Removals		Difference	
	BUR (Gg CO2 eq)	BTR (Gg CO2 eq)	Gg CO2 eq	(%)	BUR (Gg CO2 eq)	BTR (Gg CO2 eq)	(Gg CO2 eq)	(%)
1994	86,063.20	117,907.33	31,844.13	37.0	-142,929.20	-164,652.27	21,723.07	-15.2
2000	102,236.80	139927.8	37,691.00	36.9	-139,624.20	-163,476.75	23,852.55	-17.1
2005	105,938.40	156,700.00	50,761.60	47.9	-138,259.00	-162,841.04	24,582.04	-17.8
2010	120,604.70	185,957.44	65,352.74	54.2	-137,322.90	-162,184.54	24,861.64	-18.1
2011	117,654.00	187,688.70	70,034.70	59.5	-137,213.60	-161,887.02	24,673.42	-18
2012	121,775.50	176,618.58	54,843.08	45.0	-137,020.90	-161,045.35	24,024.45	-17.5
2013	123,881.50	181,092.57	57,211.07	46.2	-136,828.20	-160,900.51	24,072.31	-17.6
2014	125,047.30	195,444.00	70,396.70	56.3	-136,635.50	-161,451.68	24,816.18	-18.2
2015	126,425.70	192,055.28	65,629.58	51.9	-136,442.80	-160,609.02	24,166.22	-17.7
2016	126,758.30	205,958.27	79,199.97	62.5	-136,266.80	-160,414.17	24,147.37	-17.7

The emissions for the entire timeline were recalculated due to change in Global Warming Potential from AR2 to AR5.

1.5.7 Quality Assurance and Quality Control

Quality control was conducted at three levels of the inventory process as follows:

a) Pre-inventory preparation : This involved cross checking the activity data collected from various data providers , compilation and cleaning of the data by the sectoral technical working group prior to inventory compilation.
b) inventory preparation: This involved checking and verification of activity data and emissions factors and ensuring correct entry of figures in the software.
c) Post inventory preparation : This involved checking and verification of activity data, emission factors, and results of emissions in the report and common reporting tables.

Provided below are sectoral quality control measures

Energy

Activity data used in estimating GHG emissions from the energy sector came from the energy balance reports. To confirm and verify data, data from sources such as Energy Regulation Board, Oil Marketing Companies, Indeni oil refinery, Maamba Collieries, Railway Companies, Central Statistics Office and Zambia Revenue Authority were collected and compared. Efforts were made to check and verify the data from all sources to ensure good quality data was utilized in the inventory preparation for the energy sector.

IPPU

Activity data used in estimating GHG emissions from the IPPU was obtained from industries (Lubricants), CSO, Zambia Revenue Authority. Efforts were made to compare data from various sources and compile the most suitable data sets for use in emissions estimates. Efforts were made to check and verify the data from all sources to ensure good quality data was utilised in the inventory preparation from the IPPU sector.

AFOLU

Activity data used in estimating GHG emissions from the AFOLU was obtained from Forest Department (ILUA II data set), CSO, Zambia Revenue Authority. Efforts were made to compare data from various sources and compile the most suitable data sets for use in emissions estimates. Effort were made to check and verify the data from all sources to ensure good quality data was utilised in the inventory preparation from the AFOLU sector.

Waste

The data used for estimating emissions for solid waste disposal, incineration and open burning of waste were based on population, GDP and per capita waste generation. Data on population and per capita waste generation was obtained from Central Statistical Office (CSO). Whilst part of the GDP data was obtained from CSO, the other data came from World Economy Report and the World Bank data base. Data on wastewater treatment and discharge were based on installed capacities. Default values for Biochemical Oxygen Demand (BOD) generation per capita were used.

1.6 Key Category Analysis

Key Category Analysis (KCA) was undertaken using approach 1, for both level and trend assessment, consistent with the IPCC guidelines. key categories are identified using a pre-determined cumulative emissions threshold. key categories are those that sum to 95% of the total level when summed together in descending order of magnitude. According to Approach 1 Level Assessment, the Key Categories were Forestland Remaining Forest land, Forestland Land Converted to Grassland, Forestland Land Converted to Cropland, Enteric Fermentation, Energy Industries - Solid Fuels, Land Converted to Forest land, Road Transportation - Liquid Fuels, Lime production, Burning, and Other Sectors - Biomass solid (Table 3). Detailed results of KCA are provided in Annex II.

Table 3 Summary of key category analysis for inventory year 2022

IPCC Category code	IPCC Category	Greenhouse gas	Criteria
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO2)	T1, L1
3.B.3.b	Land Converted to Grassland	CARBON DIOXIDE (CO2)	T1, L1
3.B.2.b	Land Converted to Cropland	CARBON DIOXIDE (CO2)	T1, L1
3.A.1	Enteric Fermentation	METHANE (CH4)	T1, L1
1.A.1	Energy Industries - Solid Fuels	CARBON DIOXIDE (CO2)	T1, L1
3.B.1.b	Land Converted to Forest land	CARBON DIOXIDE (CO2)	T1
1.A.3.b	Road Transportation - Liquid Fuels	CARBON DIOXIDE (CO2)	T1, L1
2.A.2	Lime production	CARBON DIOXIDE (CO2)	T1
3.C.1	Burning	NITROUS OXIDE (N2O)	T1,
3.C.1	Burning	METHANE (CH4)	T1, L1
1.A.4	Other Sectors - Biomass - solid	METHANE (CH4)	T1
1.B.1.c	Fuel transformation	METHANE (CH4)	L1

The notation keys: L = key category according to level assessment; T = key category according to trend assessment;

1.6 Assessment of Completeness and Improvement Plan

The GHG emission inventory includes calculation of emissions from all relevant sources where data was available and are occurring in Zambia in accordance with the IPCC 2006 Guidelines. Completeness assessment was undertaken and appropriate notation provided in Table 4.

Table 4 General completeness of the inventory

Sector	Category	Status	Challenges /gaps to achieve completeness
Energy	1.C – Carbon dioxide Transport and Storage	Not Occurring (NO)	The current assessment did not include activities under 1.C, due to non-prevalence and/ or lack of activity data.
	I.A.3d Water Borne Navigation	Not estimated	Lack of activity data
IPPU	2.B Chemical Industry	Not Estimated	No emissions occurred in this category for the years 2005 to 2013 and 2015 and 2020 due to discontinuity in the production of ammonia and nitric acid in Zambia
IPPU	2.D - Non-energy use of fuels and solvents includes lubricants, paraffin wax and solvents	Not Estimated	Emissions from solvents and paraffin wax are not estimated due to a lack of activity data
IPPU	2.E Electronics industry	Not Estimated	No activity occurred under this category in Zambia from 1994 to 2016 and hence, emissions estimates were not calculated
IPPU	1.A.2 – Manufacturing industries and construction	Not Estimated	The Chemical Industry; activity data is insufficient from the current data sources. Other areas that need improvement in data collection are Textile and leather/ Paper and pulp, Food and Beverage, Wood and wood products. The activity

			data obtained from the ZRA and CSO for many of these sectors is not consistent across the years. There is therefore need harmonise data from these two sources.
			• Limited activity data in fuel used as feedstock and lubricant consumption records. • Inconsistent/insufficient activity data. It was observed that non-ferrous metals present an inconsistent fuel *use* (majorly coal) reporting from the current data sources. Industry facilities produce ferro-alloys through integrated unit operations; it is difficult for data sources like CSO to keep a measure of exact production statistics of ferro-alloys. • Industry specific information lies mainly within the individual manufacturing units. An annual Survey of manufacturing Industries, can be used as a prime source of information for the GHG estimations in the IPPU sector.
AFOLU	3B: Land	Estimated	• There is a lack of emission factors by vegetation class.
AFOLU	3.C.1b – Biomass burning in Croplands	Not estimated	• There is a lack of data on biomass burning on cropland in terms of areas specific to crop

			types. This problem can be addressed through the use of remote sensing to map cropland in terms of crop types with the help of field surveys. • There is no data on crop residue management practices among farmers across the country. This poses challenges to emissions estimations from crop residues. There is a need to conduct a survey to establish crop residue management practices across the country.
AFOLU - Aggregate Sources and Non-CO2 emissions from Land	3.C.2 – Liming	Estimated – Not comprehensively	Lime data collected through the Crop Forecast Survey by the Ministry of Agriculture and CSO does not distinguish the lime as dolomitic or calcitic. Additionally, it appears that the data is underreported in terms of quantities used. Future Crop Forecast surveys should categorize agriculture lime as calcitic or dolomitic and endeavor to address the problem of underreporting.
AFOLU – Aggregate Sources and Non-CO2 emissions from Land	3.C.6 Indirect N_20 Emissions from Manure Management - leaching and runoff from land of N from urine and dung deposition from grazing animals	Not estimated	Lack of Activity Data
Waste	4.B Biological treatment of solid waste	Not estimated	Biological Treatment of Waste was non occurring due to the lack of activity data

			(Composting and anaerobic digestion at biogas facilities

2 TRENDS IN GREENHOUSE GAS EMISSIONS

2.5 Description of emission and removal trends for aggregated GHG emissions and removals

2.5.3 Emissions trends for GHG emissions

In 2022, Zambia's GHG emissions (without AFOLU) amounted to 18,410.3 Gg CO_2 equivalent (CO_2e). In comparison with the base year, 5,942.5 Gg CO_2e (1990), GHG emissions without AFOLU increased by 209.81%. The emissions increased steadily from 1990 to 2008 and continued to increase sharply from 2008 to 2022.

Zambia's total GHG emissions (with AFOLU) stood at 220462.1 Gg CO_2e in 2022, representing an increase of 121% against 99578.7 Gg in the 1990 base year. The GHG removals (sink) reduced by 2.6% from -164745.1 CO2e in the current year (2022) to -160443.0 CO2e in the base year (1990). The net GHG emissions indicate that Zambia was a net Sink for the period 1990 to 2006 and a net source from 2007 to 2022. (Figure 4).

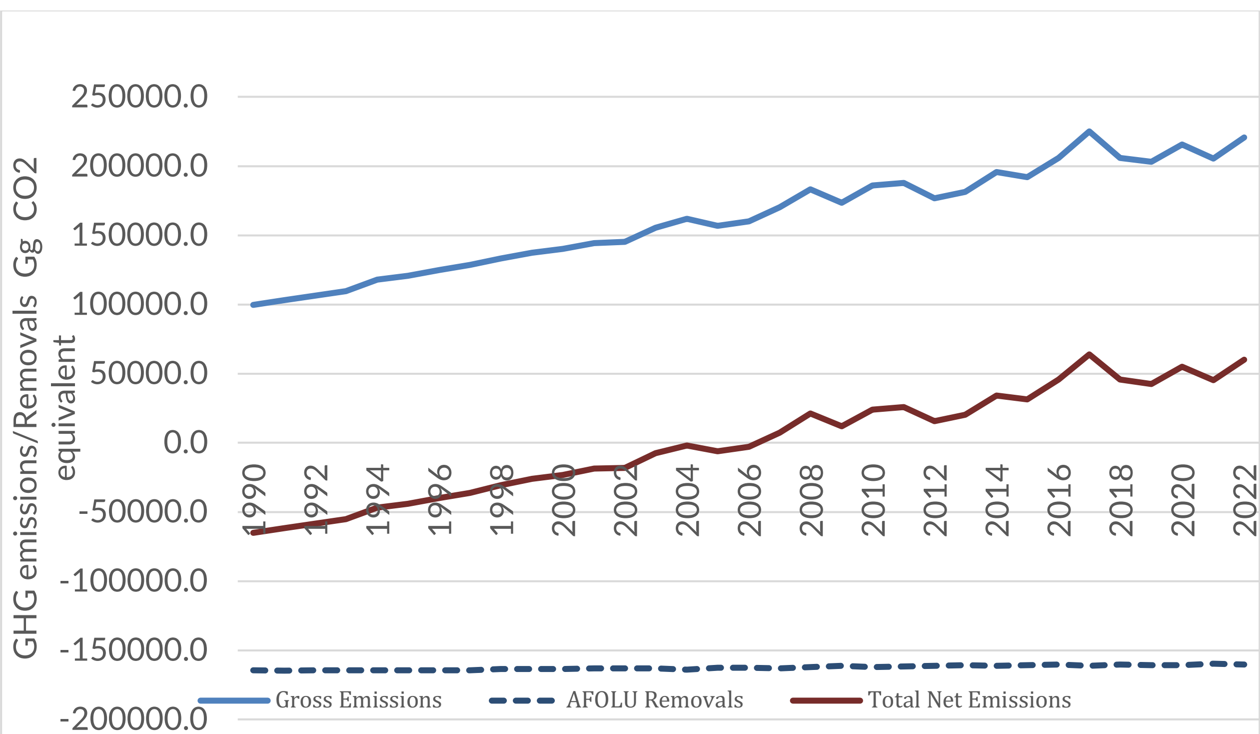


Figure 4: Trends of GHG emissions and removals

The details on quantities of total GHG emissions and removals (with and without AFOLU) for the period 1990 to 2022 are provided in table 5.

Table 5: Quantities of GHG emissions and removals - 1990 to 2022

Sector	Gross Uptake/ Removals	Total AFOLU emissions	Energy	IPPU	Waste	Emissions Without AFOLU	Emissions with AFOLU	Net Emissions
1990	-164745.1	93636.2	3926.2	1161.3	855.0	5942.5	99578.7	-65166.4
1991	-164778.3	97855.7	3314.6	1140.8	872.8	5328.2	103184.0	-61594.3
1992	-164678.5	99987.5	4018.1	1151.3	890.9	6060.3	106047.8	-58630.7
1993	-164665.4	103284.3	3997.4	1176.9	909.2	6083.6	109367.9	-55297.5
1994	-164652.3	111924.7	3901.5	1153.3	927.8	5982.7	117907.3	-46744.9
1995	-164621.5	114609.9	3879.6	1096.5	946.7	5922.7	120532.6	-44088.9
1996	-164716.0	118853.9	3988.6	1088.0	965.8	6042.3	124896.2	-39819.8
1997	-164720.5	122109.8	4157.7	1084.0	965.8	6207.5	128317.3	-36403.2
1998	-163737.4	127357.0	3776.7	1065.1	1005.2	5847.1	133204.0	-30533.4
1999	-163510.9	131204.1	4139.5	1061.4	1025.1	6226.1	137430.2	-26080.7
2000	-163476.7	133699.6	4100.2	1081.6	1046.4	6228.2	139927.8	-23548.9
2001	-163345.8	137847.7	4450.2	1077.2	1066.8	6594.2	144441.9	-18903.9
2002	-163222.3	138702.3	4256.1	1111.9	1079.4	6447.4	145149.7	-18072.7
2003	-163076.9	148243.2	4829.1	1178.3	1109.2	7116.6	155359.7	-7717.1
2004	-163930.5	154401.8	4959.7	1242.5	1137.1	7339.3	161741.1	-2189.4
2005	-162841.0	148942.4	5295.9	1299.7	1161.9	7757.6	156700.0	-6141.0
2006	-162726.9	151059.1	6236.2	1308.6	1187.9	8732.7	159791.8	-2935.1
2007	-162909.9	161559.3	5848.2	1327.1	1215.0	8390.3	169949.6	7039.7
2008	-162327.8	174795.5	5808.9	1375.2	1243.5	8427.6	183223.1	20895.4
2009	-161498.4	164823.7	5917.5	1509.4	1273.5	8700.3	173524.0	12025.6
2010	-162184.5	176915.4	6222.2	1515.3	1304.5	9042.0	185957.4	23772.9
2011	-161887.0	178053.2	6807.6	1491.7	1336.2	9635.5	187688.7	25801.7
2012	-161045.4	166890.9	6725.7	1628.3	1373.7	9727.7	176618.6	15573.2
2013	-160900.5	170840.1	7094.4	1745.7	1412.3	10252.4	181092.6	20192.1
2014	-161451.7	184796.9	7598.2	1589.6	1459.3	10647.1	195444.0	33992.3
2015	-160609.0	181181.1	7458.3	1888.0	1527.8	10874.2	192055.3	31446.3
2016	-160414.2	192416.8	9860.4	2073.8	1607.3	13541.5	205958.3	45544.1
2017	-161171.1	210849.2	10681.6	1796.0	1648.0	14125.6	224974.8	63803.8
2018	-160176.9	189895.8	12456.4	1873.4	1682.7	16012.5	205908.2	45731.3
2019	-160881.9	186340.8	13316.1	1780.5	1783.5	16880.0	203220.8	42338.9
2020	-160737.2	198994.0	12834.1	1767.0	1882.6	16483.7	215477.7	54740.5
2021	-159743.1	187778.6	13615.0	1766.2	1980.7	17361.9	205140.5	45397.4

2022	-160443.0	202051.8	14571.4	1744.3	2094.6	18410.3	220462.1	60019.1

2.6 Emissions and Removals Trends by Gas

2.6.3 GHG emissions and removals by gas

In 2022, most of the GHG emissions existed as CO_2 (87%) followed by CH_4 at 11%, N_2O was 2% while HFC and SF6 were negligible. Contribution of SF6 and HFC to the emissions was negligible. SF6 has been largely negligible across all the years (Figure 5).

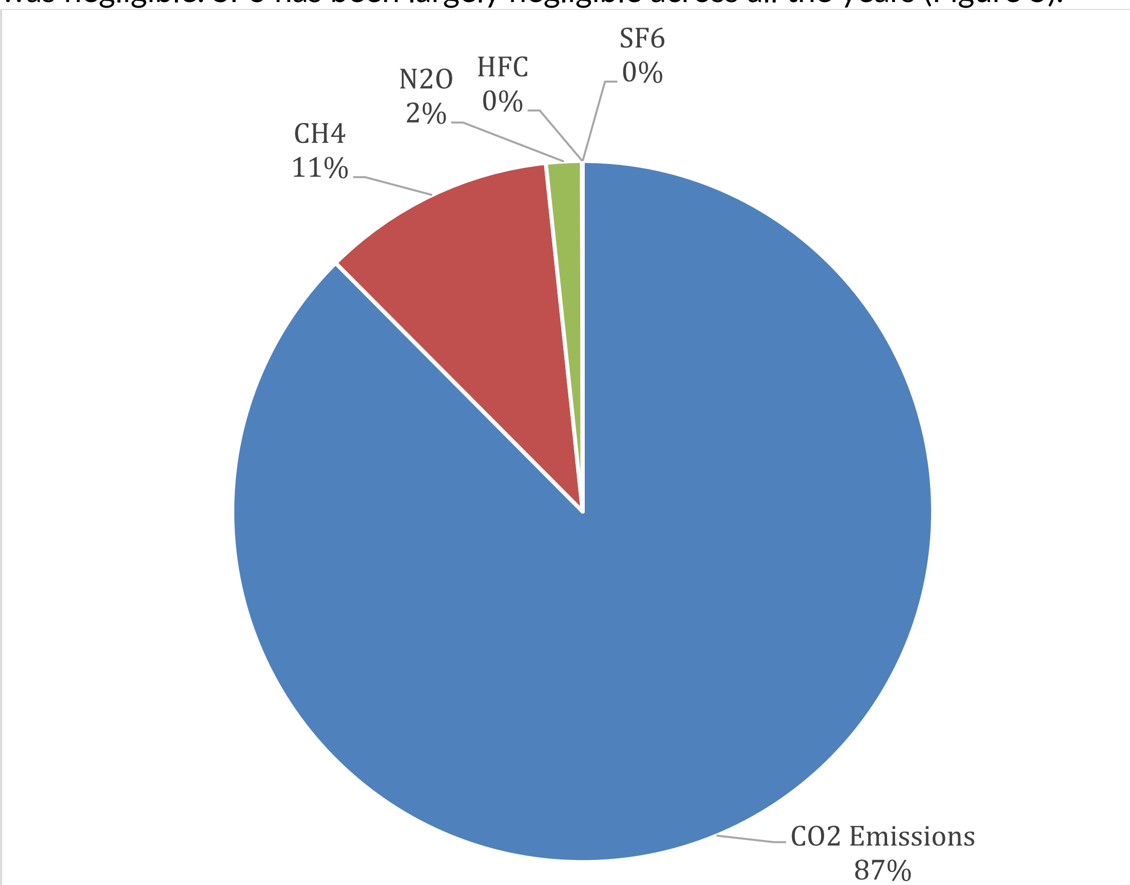


Figure 5: Share of GHG emissions by gas

The emissions of CO_2 increased from 88549.0 Gg CO_2e in the base year(1990) to 189215.2 Gg CO_2e in the current year (2022) representing a 113 % increase. In the same period, CH_4, N_2O, and HFCs increased from 9,437.3 Gg CO_2e, 633.2 Gg CO_2e, 0.2 Gg CO_2e and 0.2 Gg CO_2e in the base year 1990 to 23,296.7 Gg CO_2e, 3,561.6Gg CO_2e and 69.3Gg CO_2e in the current year 2022, respectively (Table 6).

Table 6: GHG emission trends by gas (Gg CO2e) - 1990 to 2022

	CO2 Emissions	CO2 Removals	CH4	N2O	HFC	SF6
1990	88549.0	-164745.1	9437.3	633.2	0.2	0.0005
1991	90565.5	-164778.3	10367.2	784.9	0.6	0.0010
1992	93072.8	-164678.5	10545.8	1134.0	0.9	0.0010
1993	95831.2	-164665.4	10782.6	1143.1	1.3	0.0109
1994	102392.5	-164652.3	11225.2	1326.8	1.6	0.0199
1995	104358.2	-164621.5	11240.0	1470.2	1.9	0.0199
1996	108166.0	-164716.0	11097.4	1674.7	2.3	0.0199
1997	109195.3	-164720.5	12807.8	1857.4	2.6	0.0199
1998	113043.7	-163737.4	13246.5	2012.7	3.0	0.0199
1999	115607.7	-163510.9	14155.0	2205.7	3.4	0.0199
2000	117638.1	-163476.7	13827.8	2501.5	3.8	0.0339
2001	121313.2	-163345.8	14359.5	2542.4	4.2	0.0339
2002	122201.9	-163222.3	13822.7	2652.2	4.7	0.0339
2003	131324.3	-163076.9	14267.8	2882.6	6.0	0.0339
2004	138566.2	-163930.5	13859.8	2892.5	8.2	0.0333
2005	126758.9	-162841.0	17293.2	3583.8	12.1	0.2264
2006	134956.3	-162726.9	16119.0	2779.3	16.2	0.2296
2007	145588.3	-162909.9	15619.9	2860.2	19.8	0.2296
2008	158030.7	-162327.8	16601.7	3058.3	26.1	0.2296
2009	148766.1	-161498.4	16664.7	2626.9	27.8	0.2296
2010	159966.0	-162184.5	16985.8	2939.9	29.8	0.3909
2011	162314.7	-161887.0	15916.6	2972.9	34.3	0.5052
2012	147584.9	-161045.4	19762.7	3140.8	42.5	0.5167
2013	150443.6	-160900.5	20012.2	3272.5	50.9	0.5167
2014	160790.7	-161451.7	25487.4	3013.2	50.7	0.6450
2015	159732.3	-160609.0	20425.6	4171.8	54.2	0.8983
2016	173947.9	-160414.2	21405.1	3339.5	54.0	0.9159
2017	190889.8	-161171.1	25974.3	2803.4	56.3	0.9159
2018	177671.6	-160176.9	20285.8	2727.0	63.3	0.9159
2019	168386.6	-160881.9	17008.0	3563.2	68.4	0.9159
2020	186452.1	-160737.2	19544.7	3059.0	68.6	0.9159
2021	175942.1	-159743.1	20813.1	3422.7	70.8	0.9159
2022	189215.2	-160443.0	23296.7	3561.3	69.3	0.9159

As represented in figure 6, emissions of all the gases (CO_2, CH_4, N_2O, HFC and SF6) increased steadily over the period under review. In Zambia, the main source of CO_2 is AFOLU sector, particularly from wood removals (timber harvesting), fuelwood extractions and disturbances (wildfires, pest outbreaks, and natural land degradation). The energy sector is the second highest emitter of CO_2 and spearheaded by fossil fuel combustions for electricity generation. The majority of CH_4 comes from enteric fermentation under livestock sub-category while most N_2O is produced from aggregate sources, mainly burning on land (forest land, cropland and grassland) and direct emissions from managed soils. CO_2 removals are primarily from AFOLU sector and reduced significantly from 1990 to 2022.

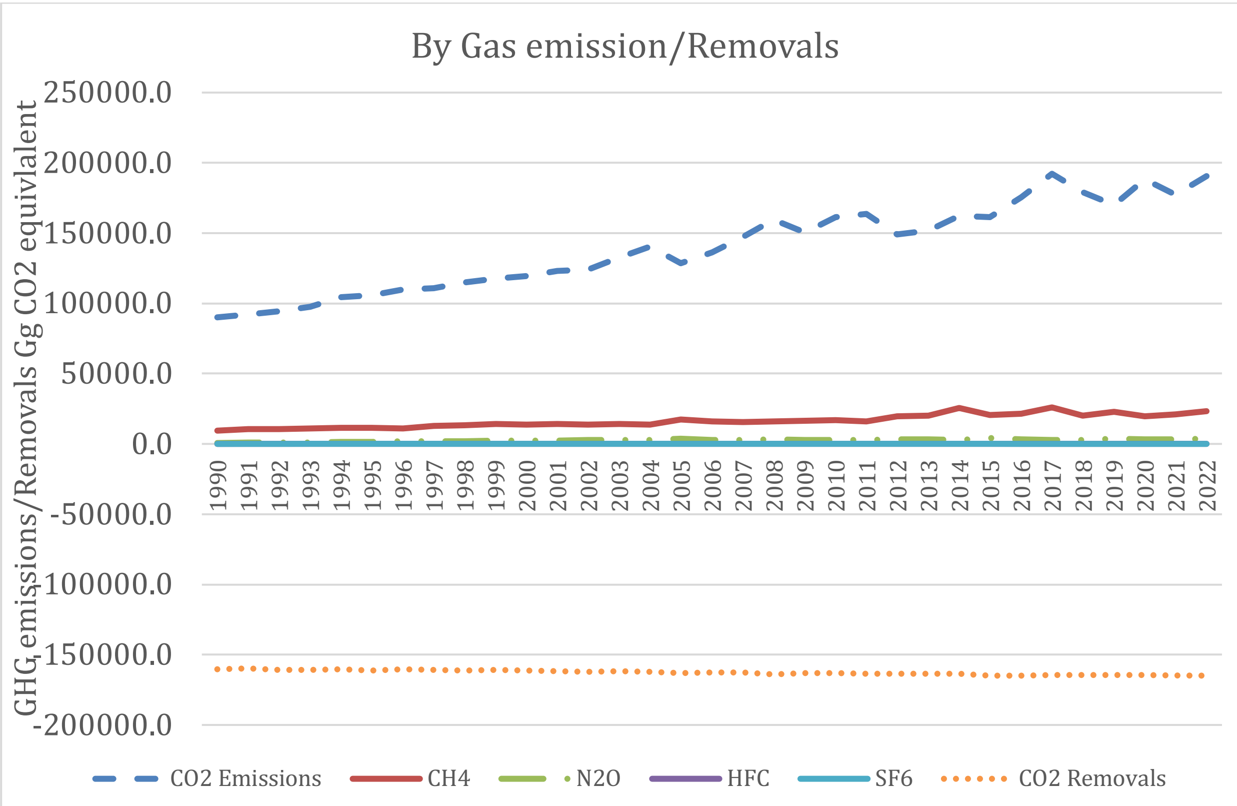


Figure 6: Emission and removal trends by gas – 1990 to 2022

In 2022, total CO_2 emissions from AFOLU sectors were primarily driven by three key activities: wood removal (timber harvesting), fuelwood extraction, and disturbances (wildfires, pest outbreaks, and natural land degradation). Figure 7, shows that wood removal contributed 40% of the total CO_2 emissions. This is attributed to commercial logging and land conversion, where large tracts of forested land were cleared for agricultural expansion and infrastructure development. Fuelwood extraction accounted for 30% of emissions. This is primarily driven by rural and urban household reliance on wood fuel and charcoal for energy, while disturbances (including wildfires, pest outbreaks, and natural land degradation) contributed 30%. This is attributed to recurring wildfires and environmental disturbances due to climate variability, prolonged dry spells, and deforestation.

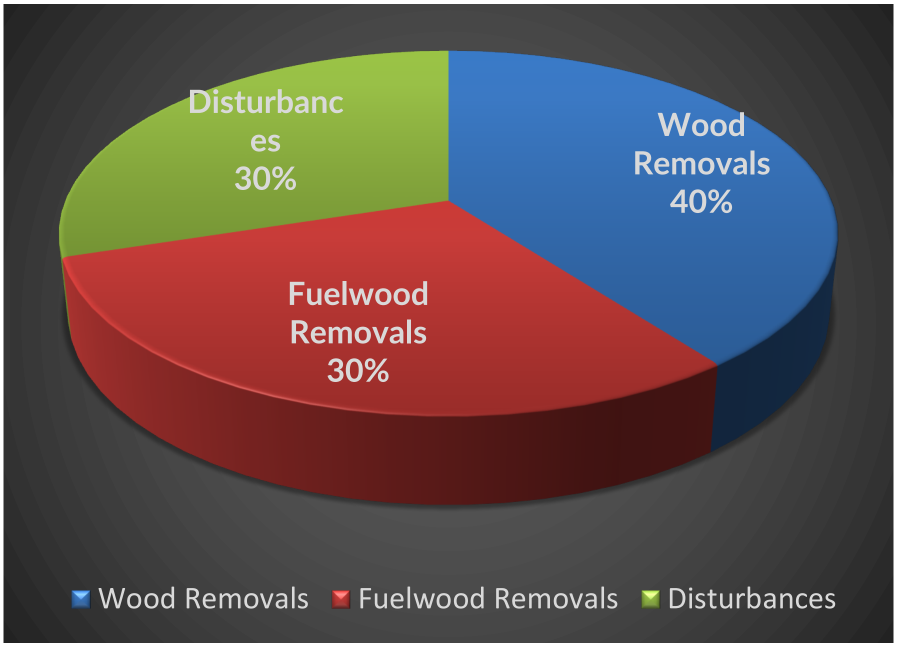
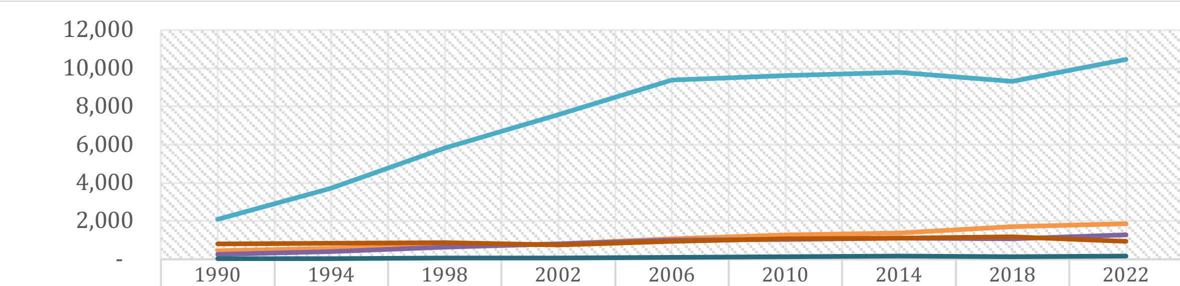


Figure 7 : Contribution of wood removals and disturbances to CO_2 emissions

2.6.4 Precursor gases

In Zambia, the key precursor gases assessed in the current review include carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), nitrogen oxides (NOx), sulfur dioxide (SO_2), and ammonia (NH_3). Between 1990 and 2022, emissions of NMVOCs, NOx, SO_2, and NH_3 increased steadily, while CO emissions rose sharply. The Agriculture, Forestry, and Other Land Use (AFOLU) sector was the dominant source, contributing 62% of emissions, followed by the energy sector at 38%. Emissions from industrial processes and product use (IPPU) and the waste sector remained minimal. Figure 7 illustrates the sectoral trends in precursor gas emissions.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
NOx	450	564	709	801	1,061	1,280	1,374	1,697	1,861
CO	2,092	3,729	5,823	7,581	9,395	9,615	9,774	9,311	10,467
NMVOCs	257	416	623	793	1,007	1,055	1,105	1,074	1,281
SOX	807	835	873	751	954	1,075	1,097	1,177	955
NH3	34	42	61	81	99	141	155	134	168

Figure 8: Trends of precursor emissions

As of 2022, CO accounted for the largest share of precursor gas emissions at 71%, followed by NOx (13%), NMVOCs (9%), and SO_2 (6%), with NH_3 contributing just 1%. Despite its small share, NH_3 emissions rose significantly 400% from 34 Gg in 1990 to 168 Gg in 2022. Similarly, CO emissions increased by approximately 400%, from 2,092 Gg to 10,467 Gg over the same period. NOx and NMVOCs also saw sharp increases of 313% and 399%, respectively.

The rise in emissions is largely attributed to increased fossil fuel combustion for electricity ggeneration and transportation, as well as biomass burning particularly through inefficient technologies and open burning in land-use sectors.

3.0 SECTORIAL AND CATEGORY-SPECIFIC TRENDS

3.1 Sectoral GHG emission trends

Zambia's greenhouse gas (GHG) emissions are reported across four main sectors: Energy, Industrial Processes and Product Use (IPPU), Waste, and Agriculture, Forestry, and Other Land Use (AFOLU), which includes both emissions and removals. According to figure 9 the AFOLU sector was by far the largest contributor, accounting for 92% of total GHG emissions. The energy sector followed with 6%, while the waste and IPPU sectors each contributed approximately 1% in the current year (2022). This distribution has remained consistent throughout the time series, (1990 to 2022) with AFOLU consistently being the dominant source, followed by energy, IPPU, and waste.

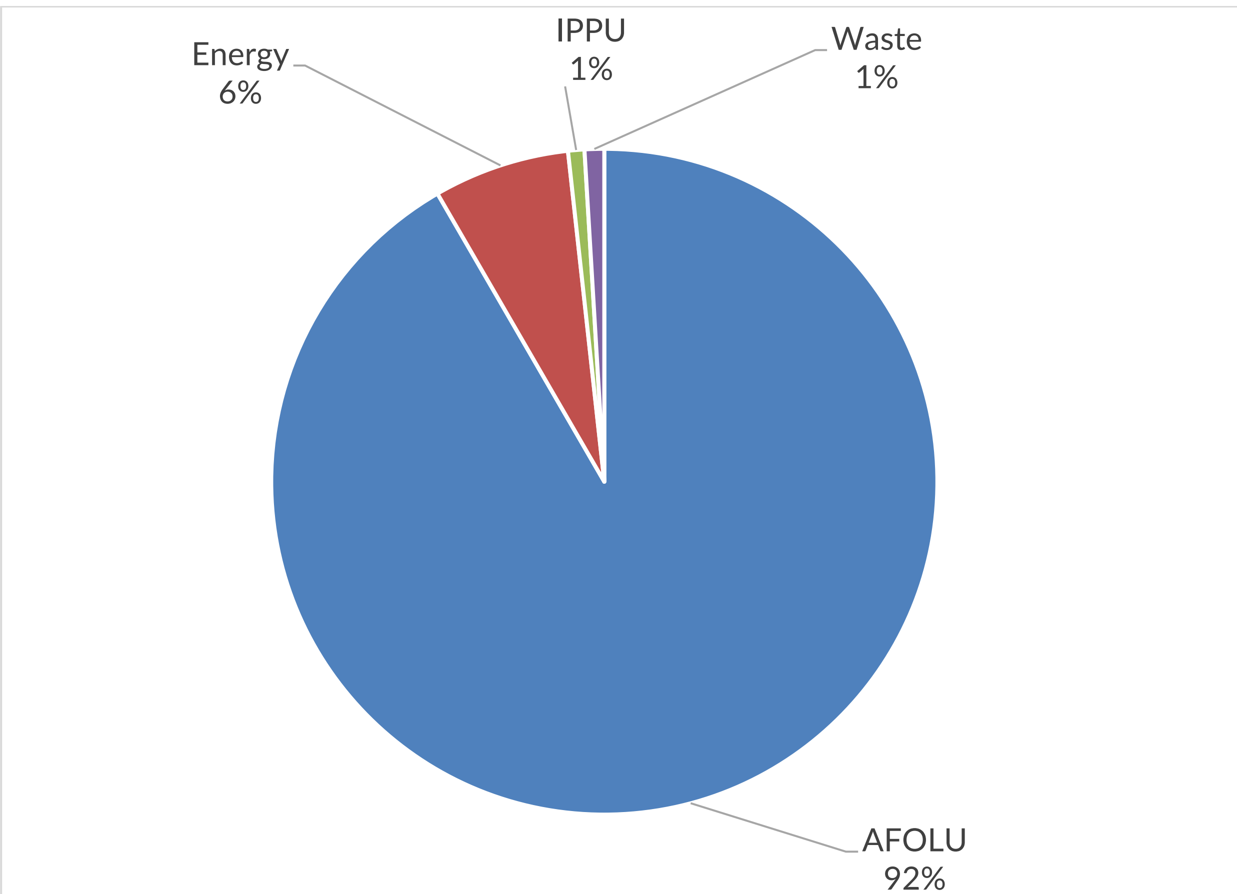


Figure 9: Emissions contribution by sector for 2022

Provided in Table 7 is a summary of reporting Table for 2022.

Table 7: Summary Reporting Table for 2022

	Emissions (Gg)			Emissions CO2 Equivalents (Gg)					Emissions (Gg)				
Categories	Net CO2 (1)(2)	CH4	N2O	HFCs	PFCs	SF6	NF3	Other halogenated gases with CO2 equivalent conversion factors (3)	Other halogenated gases without CO2 equivalent conversion factors (4)	NOx	CO	NMVOCs	SO2
Total National Emissions and Removals	30098.83196	832.024	13.439	69.281	NO	0.916	NO	0	0				0
1 - Energy	10814.96656	151.404	1.3506	0	0	0	0	0	0				0
1.A - Fuel Combustion Activities	10814.93171	61.1622	1.1722	0	0	0	0	0	0				0
1.A.1 - Energy Industries	3540.255757	0.39475	0.1027							0	0	0	0
1.A.2 - Manufacturing Industries and Construction	3491.873011	1.55351	0.0903							0	0	0	0
1.A.3 - Transport	3139.099967	0.56459	0.2567							0	0	0	0
1.A.4 - Other Sectors	618.0440151	58.6488	0.7224							0	0	0	0
1.A.5 - Non-Specified	25.65895952	0.00055	0.0001							0	0	0	0
1.B - Fugitive emissions from fuels	0.034849048	90.2416	0.1784	0	0	0	0	0	0				0
1.B.1 - Solid Fuels	0.034849048	90.2416	0.1784										0
1.B.2 - Oil and Natural Gas	NO	NO	NO										0
1.B.3 - Other emissions from Energy Production	NO	NO	NO										0
1.C - Carbon dioxide Transport and Storage	NO	NO	NO	NO	NO	NO	NO	NO	0				0
1.C.1 - Transport of CO2	NO									0	0	0	0
1.C.2 - Injection and Storage	NO									0	0	0	0
1.C.3 - Other	NO									0	0	0	0
2 - Industrial Processes and Product Use	1674.067205	0	0	69.281	0	0.916	0	0	0	0	0	0	0
2.A - Mineral Industry	1635.971265	0	0	0	0	0	0	0	0	0	0	0	0

2.A.1 - Cement production	512.93476									0	0	0	0
2.A.2 - Lime production	1123.036505									0	0	0	0
2.A.3 - Glass Production	NO									0	0	0	0
2.A.4 - Other Process Uses of Carbonates	NO									0	0	0	0
2.A.5 - Other (please specify)	NO	NO	NO							0	0	0	0
2.B - Chemical Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	0	0	0	0
2.B.1 - Ammonia Production	NO									0	0	0	0
2.B.2 - Nitric Acid Production			NO							0	0	0	0
2.B.3 - Adipic Acid Production			NO							0	0	0	0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			NO							0	0	0	0
2.B.5 - Carbide Production	NO	NO								0	0	0	0
2.B.6 - Titanium Dioxide Production	NO									0	0	0	0
2.B.7 - Soda Ash Production	NO									0	0	0	0
2.B.8 - Petrochemical and Carbon Black Production	NO	NO								0	0	0	0
2.B.9 - Fluorochemical Production				0					0	0	0	0	0
2.B.10 - Hydrogen Production	NO	NO	NO							0	0	0	0
2.B.11 - Other (Please specify)	NO	NO	NO							0	0	0	0
2.C - Metal Industry	19.2525004	0	0	0	0	0	0	0	0	0	0	0	0
2.C.1 - Iron and Steel Production	19.2342004	NO								0	0	0	0
2.C.2 - Ferroalloys Production	NO	NO								0	0	0	0
2.C.3 - Aluminium production	NO				NO				NO	0	0	0	0
2.C.4 - Magnesium production	NO									0	0	0	0
2.C.5 - Lead Production	0.0183									0	0	0	0
2.C.6 - Zinc Production	NO									0	0	0	0
2.C.7 - Rare Earths Production	NO									0	0	0	0
2.C.8 - Other (please specify)	NO	NO	NO							0	0	0	0
2.D - Non-Energy Products from Fuels and Solvent Use	18.84344	NO	NO	NO	NO	NO	NO	NO	NO	0	0	0	0
2.D.1 - Lubricant Use	18.84344									0	0	0	0

2.D.2 - Paraffin Wax Use	NE									0	0	0	0
2.D.3 - Solvent Use										0	0	0	0
2.D.4 - Other (please specify)	NO	NO	NO							0	0	0	0
2.E - Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	0	0	0	0
2.E.1 - Integrated Circuit or Semiconductor			NO							0	0	0	0
2.E.2 - TFT Flat Panel Display			NO							0	0	0	0
2.E.3 - Photovoltaics										0	0	0	0
2.E.4 - Heat Transfer Fluid										0	0	0	0
2.E.5 - Other (please specify)	NO	NO	NO		NO	NO			0	0	0	0	0
2.F - Product Uses as Substitutes for Ozone Depleting Substances	0	0	0	69.281	0	0	0	0	0	0	0	0	0
2.F.1 - Refrigeration and Air Conditioning				69.281		NO			0	0	0	0	0
2.F.2 - Foam Blowing Agents										0	0	0	0
2.F.3 - Fire Protection										0	0	0	0
2.F.4 - Aerosols										0	0	0	0
2.F.5 - Solvents										0	0	0	0
2.F.6 - Other Applications (please specify)										0	0	0	0
2.G - Other Product Manufacture and Use	NO	NO	NO	NO	NO	0.916	NO	NO	NO	0	0	0	0
2.G.1 - Electrical Equipment						0.916			NO	0	0	0	0
2.G.2 - SF6 and PFCs from Other Product Uses						NO			NO	0	0	0	0
2.G.3 - N2O from Product Uses			NO							0	0	0	0
2.G.4 - Other (Please specify)	NO	NO	NO							0	0	0	0
2.H - Other										0	0	0	0
2.H.1 - Pulp and Paper Industry	NO	NO	NO							0	0	0	0
2.H.2 - Food and Beverages Industry	NE	NE	NE							0	0	0	0
2.H.3 - Other (please specify)	0	0	0							0	0	0	0
3 - Agriculture, Forestry, and Other Land Use	17609.37835	605.85	12.086	0	0	0	0	0	0	141.481	3042.596	0	0
3.A - Livestock	0	482.976	0.2394	0	0	0	0	0	0	0	0	0	0
3.A.1 - Enteric Fermentation		465.058								0	0	0	0

3.A.2 - Manure Management		17.9183	0.2394							0	0	0	0
3.B - Land	17488.5645	0	0	0	0	0	0	0	0	0	0	0	0
3.B.1 - Forest land	- 11942.96438									0	0	0	0
3.B.2 - Cropland	8505.389243									0	0	0	0
3.B.3 - Grassland	20522.53528									0	0	0	0
3.B.4 - Wetlands	41.57970432									0	0	0	0
3.B.5 - Settlements	362.0246464									0	0	0	0
3.B.6 - Other Land	NE									0	0	0	0
3.C - Aggregate sources and non-CO2 emissions sources on land	120.8138552	122.874	11.847	0	0	0	0	0	0	141.481	3042.596	0	0
3.C.1 - Burning	0	116.483	7.6177							141.481	3042.596	0	0
3.C.2 - Liming	8.18191									0	0	0	0
3.C.3 - Urea application	112.6319452									0	0	0	0
3.C.4 - Direct N2O Emissions from managed soils			3.7323							0	0	0	0
3.C.5 - Indirect N2O Emissions from managed soils			0.4957							0	0	0	0
3.C.6 - Indirect N2O Emissions from manure management			0.0012							0	0	0	0
3.C.7 - Rice cultivation		6.39114								0	0	0	0
3.C.8 - CH4 from Drained Organic Soils		NE								0	0	0	0
3.C.9 - CH4 from Drainage Ditches on Organic Soils		NE								0	0	0	0
3.C.10 - CH4 from Rewetting of Organic Soils		NE								0	0	0	0
3.C.11 - CH4 Emissions from Rewetting of Mangroves and Tidal Marshes		NE								0	0	0	0
3.C.12 - N2O Emissions from Aquaculture			NE							0	0	0	0
3.C.13 - CH4 Emissions from Rewetted and Created Wetlands on Inland Wetland Mineral Soils		NE								0	0	0	0
3.C.14 - Other (please specify)	0	NE	0							0	0	0	0
3.D - Other	0	0	0	0	0	0	0	0	0	0	0	0	0
3.D.1 - Harvested Wood Products	NE									0	0	0	0

3.D.2 - Other (please specify)	NO	NO	NO							0	0	0	0
4 - Waste	0.419842129	74.77	0.0023	0	0	0	0	0	0	0	0	0	0
4.A - Solid Waste Disposal		52.6554								0	0	0	0
4.B - Biological Treatment of Solid Waste		NO	NO							0	0	0	0
4.C - Incineration and Open Burning of Waste	0.419842129	0.18783	0.0023							0	0	0	0
4.D - Wastewater Treatment and Discharge		21.9268	0							0	0	0	0
4.E - Other (please specify)	NO	NO	NO							0	0	0	0
5 - Other	0	0	0	0	0	0	0	0	0	0	0	0	0
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3			NE							0	0	0	0
5.B - Indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOC	NE									0	0	0	0
5.C - Other	NO	NO	NO					0	0	0	0	0	0
Memo Items (5)													
International Bunkers	87.2539668	0.00061	0.0024	0	0	0	0	0	0	0	0	0	0
1.A.3.a.i - International Aviation (International Bunkers)	87.2539668	0.00061	0.0024							0	0	0	0
1.A.3.a.i - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOX and NH3			NE										
1.A.3.a.i - Indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOC	NE												
1.A.3.d.i - International water-borne navigation (International bunkers)	NE	NE	NE							0	0	0	0
1.A.3.d.i - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOX and NH3			NE										
1.A.3.d.i - Indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOC	NE												
1.A.5.c - Multilateral Operations	0	0	0	0	0	0	0	0	0	0	0	0	0

1.A.5.c - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOX and NH3			0										
1.A.5.c - Indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOC	0												

Table 8 presents a summary of Zambia's anthropogenic GHG emissions by sector, for the period under review (1990 to 2022). The table 8 also provides the GHG removals, from AFOLU sector, during the same period.

Table 8: Summary Reporting Table

Sector	Gross Uptake/ Removals	Total AFOLU emissions	Energy	IPPU	Waste	Emissions Without AFOLU	Emissions with AFOLU	Net Emissions
1990	-164745.1	93636.2	3926.2	1161.3	855.0	5942.5	99578.7	-65166.4
1991	-164778.3	97855.7	3314.6	1140.8	872.8	5328.2	103184.0	-61594.3
1992	-164678.5	99987.5	4018.1	1151.3	890.9	6060.3	106047.8	-58630.7
1993	-164665.4	103284.3	3997.4	1176.9	909.2	6083.6	109367.9	-55297.5
1994	-164652.3	111924.7	3901.5	1153.3	927.8	5982.7	117907.3	-46744.9
1995	-164621.5	114609.9	3879.6	1096.5	946.7	5922.7	120532.6	-44088.9
1996	-164716.0	118853.9	3988.6	1088.0	965.8	6042.3	124896.2	-39819.8
1997	-164720.5	122109.8	4157.7	1084.0	965.8	6207.5	128317.3	-36403.2
1998	-163737.4	127357.0	3776.7	1065.1	1005.2	5847.1	133204.0	-30533.4
1999	-163510.9	131204.1	4139.5	1061.4	1025.1	6226.1	137430.2	-26080.7
2000	-163476.7	133699.6	4100.2	1081.6	1046.4	6228.2	139927.8	-23548.9
2001	-163345.8	137847.7	4450.2	1077.2	1066.8	6594.2	144441.9	-18903.9
2002	-163222.3	138702.3	4256.1	1111.9	1079.4	6447.4	145149.7	-18072.7
2003	-163076.9	148243.2	4829.1	1178.3	1109.2	7116.6	155359.7	-7717.1
2004	-163930.5	154401.8	4959.7	1242.5	1137.1	7339.3	161741.1	-2189.4
2005	-162841.0	148942.4	5295.9	1299.7	1161.9	7757.6	156700.0	-6141.0
2006	-162726.9	151059.1	6236.2	1308.6	1187.9	8732.7	159791.8	-2935.1
2007	-162909.9	161559.3	5848.2	1327.1	1215.0	8390.3	169949.6	7039.7
2008	-162327.8	174795.5	5808.9	1375.2	1243.5	8427.6	183223.1	20895.4
2009	-161498.4	164823.7	5917.5	1509.4	1273.5	8700.3	173524.0	12025.6
2010	-162184.5	176915.4	6222.2	1515.3	1304.5	9042.0	185957.4	23772.9
2011	-161887.0	178053.2	6807.6	1491.7	1336.2	9635.5	187688.7	25801.7
2012	-161045.4	166890.9	6725.7	1628.3	1373.7	9727.7	176618.6	15573.2
2013	-160900.5	170840.1	7094.4	1745.7	1412.3	10252.4	181092.6	20192.1
2014	-161451.7	184796.9	7598.2	1589.6	1459.3	10647.1	195444.0	33992.3
2015	-160609.0	181181.1	7458.3	1888.0	1527.8	10874.2	192055.3	31446.3
2016	-160414.2	192416.8	9860.4	2073.8	1607.3	13541.5	205958.3	45544.1
2017	-161171.1	210849.2	10681.6	1796.0	1648.0	14125.6	224974.8	63803.8
2018	-160176.9	189895.8	12456.4	1873.4	1682.7	16012.5	205908.2	45731.3
2019	-160881.9	186340.8	13316.1	1780.5	1783.5	16880.0	203220.8	42338.9
2020	-160737.2	198994.0	12834.1	1767.0	1882.6	16483.7	215477.7	54740.5
2021	-159743.1	187778.6	13615.0	1766.2	1980.7	17361.9	205140.5	45397.4
2022	-160443.0	202051.8	14571.4	1744.3	2094.6	18410.3	220462.1	60019.1

Within the AFOLU sector, gross greenhouse gas (GHG) emissions rose steadily from 99578.7 Gg CO_2e in 1990 to 220462.1 Gg CO_2e in 2022 representing an increase of 121%. A notable surge in emissions occurred in 2014, largely due to increased wood removals from timber harvesting, fuelwood extraction and disturbances (wildfires, pest outbreaks and land degradation). Similarly, emissions from the energy sector increased by 271% over the same period, rising from 3,926.2 Gg CO_2e in 1990 to 14,571 Gg CO_2e in 2022.

Gross carbon uptake / removals declined slightly, from -164,745.1 Gg CO_2e in 1994 to -160,443.0 Gg CO_2e in 2022 attributed to stability in electricity supply and reduced usage of fuelwood. The Energy sector emissions increased gradually between 1990 and 2012, followed by a sharp rise from 2013 onwards. This increase is attributed to expanded fossil fuel use for electricity generation, including the commissioning of a residual fuel-based power plant in 2013 and a coal-fired power plant in 2016.

The Emissions from the IPPU and waste sectors also increased during the review period by 50% and 145%, respectively. In 2022, the sub-sectoral contributions to net national GHG emissions and removals were as shown in Table 9(Key Category Analysis). Land use was the dominant source of emissions within AFOLU, while the energy industry led within the energy sector. The mineral industry was the highest emitter under IPPU attributed to the increased construction activities in the economy, and solid waste disposal was the main source of emissions in the waste sector, driven by population increase and GDP.

Table 9: Percentage contribution to overall GHG emissions by sub-category – 2022

Category	Emissions (Gg CO2 e	Percentage contribution (%)
1.A.1 - Energy Industries	3578.5	1.91
1.A.2 - Manufacturing Industries and Construction	3559.3	1.90
1.A.3 - Transport	3222.9	1.72
1.A.4 - Other Sectors	1611.0	0.86
1.A.5 - Non-Specified	25.7	0.01
1.B.1 - Solid Fuels	2574.1	1.38
2.A - Mineral Industry	1636.0	0.87
2.B - Chemical Industry	0.0	0.00
2.C - Metal Industry	19.3	0.01
2.D - Non-Energy Products from Fuels and Solvent Use (6)	18.8	0.01
2.E - Electronics Industry	0.0	0.00
2.F - Product Uses as Substitutes for Ozone Depleting Substances	69.3	0.04
2.G.1 - Electrical Equipment	0.9	0.00
3.A.1 - Enteric Fermentation	13021.6	6.96
3.A.2 - Manure Management (1)	565.0	0.30
3.B.1 - Forest land-Emissions	148473.3	79.38

3.B.2 - Cropland	7,453.578	3.98
3.B.3 - Grassland	20,247.722	10.82
3.B.4 - Wetlands	41.580	0.02
3.B.5 - Settlements	362.025	0.19
3.B.6 - Other Land	0.0	0.00
3.C.1 - Burning	5280.3	2.82
3.C.2 - Liming	0.0	0.00
3.C.3 - Urea application	0.0	0.00
3.C.4 - Direct N2O Emissions from managed soils (3)	989.0	0.53
3.C.5 - Indirect N2O Emissions from managed soils	131.4	0.07
3.C.6 - Indirect N2O Emissions from manure management	0.3	0.00
3.C.7 - Rice cultivation	178.9	0.10
4.A - Solid Waste Disposal	1474.4	0.79
4.B - Biological Treatment of Solid Waste	0.0	0.00
4.C - Incineration and Open Burning of Waste	6.3	0.00
4.D - Wastewater Treatment and Discharge	613.9	0.33

3.2 Energy

3.2.1 Overview

This section provides respective emissions, activity data, emission factors and methodologies for energy categories. The IPCC 2006 guidelines broadly classifies energy-related activities into 3 main categories, namely: fuel combustion activities (1.A), fugitive emissions from fuels (1.B) and Carbon dioxide transport and storage (1.C). The categories covered in the emissions estimate for energy are: i) fuel Combustion (i.e. Energy Industries, Manufacturing Industries and Construction, Transport, Other Sectors and Non-Specified), (ii) Fugitive emissions from fuels (i.e. Solid Fuels-Coal mining and handling and Fuel transformation).

3.2.2 Methodology and Emission Factors

Tier 1 was used in the emissions estimate of all the categories including; include energy industries (1.A.1), manufacturing industries and construction (1.A.2), transport (1.A.3), other sectors (1.A.4) and non-specified (1.A.5). A simple methodological approach (based on tier 1 of the IPCC guidelines) was used to estimate emissions. It involved multiplying activity data with emission factor. Tier 1 approach was used, instead of high tiers, owing to limitations in activity data and unavailability of country-specific emission factors.

Emissions = Activity Data (AD) * Emissions Factor (EF)

Tier 1 of the IPCC 2006 guidelines was used to estimate fugitive emissions, for solid fuels as well as petroleum refining.

global average method for surface mines was used as shown in equation 3.1:

$$Methane\ Emissions = CH_4\ Emission\ Factor\ X\ Surface\ Coal\ Production\ X\ Conversion\ Factor$$

Where units are: Methane Emissions (Gg $year^{-1}$); CH_4 Emission Factor (m^3 $tonne^{-1}$); Surface Coal Production (tonne $year^{-1}$); Emissions Factor: Low CH4 Emission = 0.3 m^3 $tonne^{-1}$ Average CH_4 Emission Factor = 1.2 m^3 $tonne^{-1}$ High CH_4 Emission Factor = 2.0 m^3 $tonne^{-1}$

3.2.3 Activity Data

Zambia's energy sector has evolved significantly, primarily due to the country's enduring efforts to improve energy access and supply, since its independence in 1964. The country depends on several energy resources, such as biomass, petroleum (which is wholly imported), coal (sub-bituminous coal produced locally while the other coal types are imported), hydro, and solar, for various socio-economic activities. These include agriculture, energy industry, construction, manufacturing, mining, transport, commercial, and residential, among others. Zambia's energy demand has steadily increased over the years driven by socio-economic changes, including population growth from approximately 8 million in 1990[7] to 20 million in 2022[8] and an annual growth rate of 2.7% per annum. Further, Zambia's GDP grew by over $25 billion from $3.3 billion in 1990 to $29.2 billion in 2022.[9], while the annual copper production almost doubled from 400 kilotons to 764 kilotons[10] during the same period, despite slight fluctuations production between 2021 and 2022 . Zambia's total energy consumption (biomass, coal, and petroleum) by sector increased steadily and doubled from 151,958.98 TJ in 1990 to 322,014.93 TJ in 2022 as shown in Figure 10.

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[7] Population of Zambia 1990 - PopulationPyramid.net
[8] https://www.zamstats.gov.zm/2022-census/
[9] https://www.macrotrends.net/global-metrics/countries/ZMB/zambia/gdp-gross-domestic-product
[10] Production Figures – Zambia Chamber of Mines

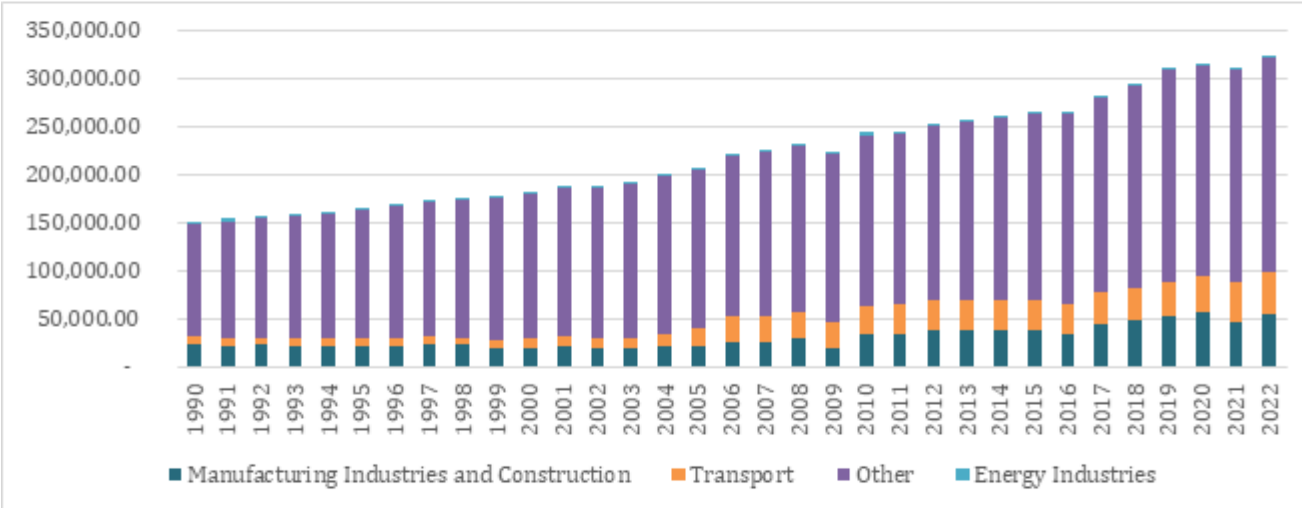


Figure 10 Energy consumption by sector (TJ)

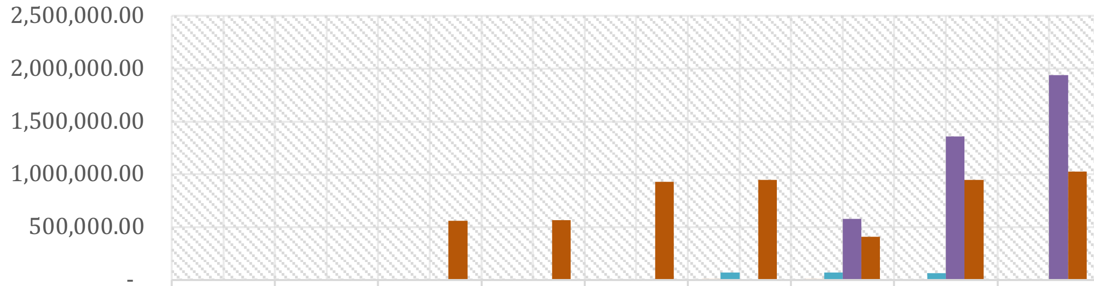
The following sub-sections provide details on the energy trends for the various categories including energy industries, manufacturing industries and construction, transport and other energy-consuming sectors.

3.2.3.1 Energy Industry

This category covered fuel combustion in energy production industries including electricity generation and petroleum refinery. Zambia predominantly depended on hydro, taking up over 80% of the country's installed capacity, as a source of electricity. In 2022, the country's total installed capacity was 3,777.3 MW, with 3,164.14 MW being hydro, 300 MW from coal-fired power plant, 110 MW from HFO, 84.80 MW from diesel and 89.38 MW from on-grid solar PV[11]. The daily peak demand for electricity increased from 1,700 MW in 1990 to 2,300 MW in 2022. Despite having a higher installed capacity, Zambia could not generate enough electricity to meet its demand in some years and this was attributed to the country's over dependency on hydro which was prone to climate variability and changes, particularly extended droughts[12]. Zambia diversified its energy mix by adding electricity produced from fossil fuel-fired thermal power plants, i.e. from HFO (starting in 2013) and coal (starting in 2016) to the national grid. The electricity from biomass was auto-generated by Zambia Sugar Plc from bagasse (a waste product from sugarcane processing) while diesel-based generation has been from small isolated systems including a backup system at Copperbelt Energy Corporation (CEC). Figure 11 shows the quantities (in MT) of various fuels used for electricity generation during the period under review.

[11] esr2023.pdf

[12] PRESS-STATEMENT-ON-THE-ELECTRICITY-SITUATION-IN-ZAMBIA-AT-GOVERNMENT-COMPLEX-12.06.2024.pdf

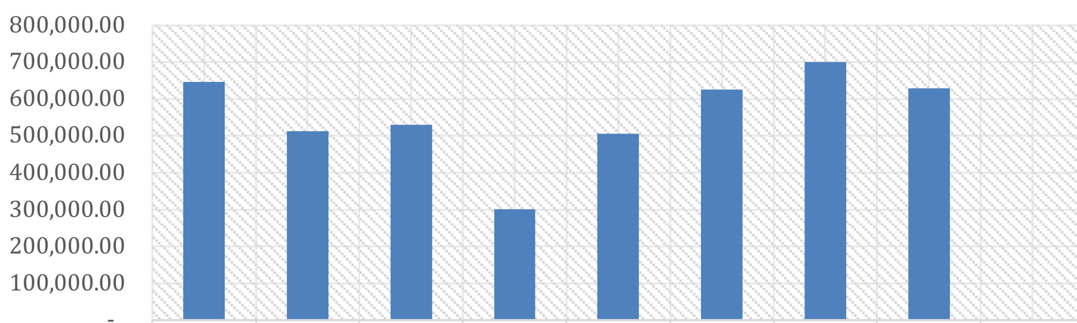


	1990	1995	2000	2005	2010	2013	2016	2020	2022
Diesel (MT)	4,777.85	5,460.40	5,218.44	4,401.03	4,346.57	7,760.01	9,266.49	6,260.00	7,290.00
Residue Fuel Oil (MT)	-	-	-	-	-	69,500.0	67,951.0	66,000.0	-
Sub-Bituminous Coal (MT)	-	-	-	-	-	-	579,740.	1,356,71	1,936,38
Biomass (MT)	-	-	563,100.	568,200.	930,900.	946,200.	408,800.	948,878.	1,026,46

Figure 11: fuel consumed in Electricity Generation

3.2.3.2 Petroleum Refining

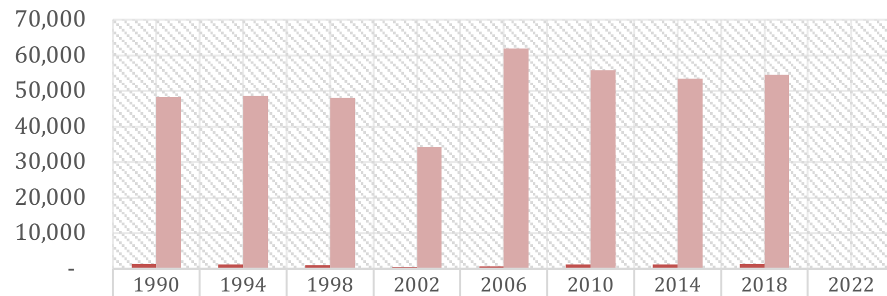
During the period under review, Zambia imported and refined crude oil into petroleum products (i.e., petrol, diesel, kerosene, liquefied petroleum gas, bitumen and other products). The country's annual consumption of petroleum products steadily increased from about 384,360 MT in 1990 to 1,549,270 MT in 2022. A total of 15,366,370 MT of crude oil was refined from 1990 to 2021, with the minimum being 16,850 MT in 2000 and the maximum of 701,330 MT in 2014 as provided in figure 12, at the INDENI refinery plant located in the Ndola district in Copperbelt province of Zambia.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
Crude Oil - Refined (MT)	647,400.0	512,263.0	530,407.0	301,704.0	506,657.6	625,140.0	701,330.0	629,394.0	-

Figure 12: Quantities of Crude Oil refined

The crude oil was delivered from Dar-es-Salaam in Tanzania to the INDENI Refinery plant through a 1,710 km-long pipeline (design capacity of 1,100 kilo tonnes per year), owned by TAZAMA, having a total of seven (7) pumping stations (five (5) stations located in Tanzania and two (2) in Zambia). Significant quantities of crude oil were combusted as fuel in pumping (pipeline transport) and refinery processes, as shown in Figure 13.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
Crude Oil - Combusted in Pipeline (MT)	1,430	1,230	960	530	760	1,190	1,190	1,321	
Crude Oil - Combusted in Refinery (MT)	48,200	48,550	48,056	34,102	61,878	55,809	53,435	54,608	-

Figure 13: Quantities of Crude Oil combusted in pipeline transport and refinery processes.

In 2000, INDENI Refinery experienced a fire at one of the units resulting in reduced or no production at the refinery. In 2021, the refinery was put on care and maintenance in readiness for it to have a different business model. The short fall from local production was met through imports of finished petroleum products based on prevailing demand/ requirements for the products.

In 2022, the government revised the policy on the supply of petroleum products by doing away with importation and refining of crude oil locally. Consequently, the country switched to importation of finished petroleum products, thereby converting the TAZAMA pipeline from transporting crude oil to refined low-Sulphur diesel and transformation of INDENI refinery from crude oil processing to operating as an Oil Marketing Company (OMC)[13]. Other petroleum products were mainly transported by road using tankers.

During the period under review, Zambia's energy industry revolved around conversion of primary energy resources to secondary energy resources. The country imported and refined crude oil into petroleum products (i.e., petrol, diesel, kerosene, liquefied petroleum

[13] Petroleum-Sector-Diagnostics-Policy-Brief.pdf

gas, bitumen and other products) and also generated electricity from coal, diesel, heavy fuel oil (HFO), hydro and solar. Zambia's annual consumption of petroleum products steadily increased from about 384.36 kilo tonnes in 1990 to 1,549.27 kilo tonnes in 2022. A total of 15,366.37 kilo tonnes of crude oil was refined from 1990 to 2021, with the minimum being 16.85 kilo tonnes in 2000 and the maximum 701.33 kilo tonnes in 2014 (Figure 9). The crude oil was delivered from the Port in Tanzania to the refinery plant in Zambia through a 1,710 km-long pipeline (design capacity of 1,100 kilo tonnes per year). The pipeline has a total of 7 pumping stations (5 stations located in Tanzania and 2 in Zambia). Crude oil was used as fuel in pumping and refinery processes.

3.2.3.3 Manufacturing Industry and Construction

The manufacturing industries and construction sector in Zambia comprises several sub-sectors (i.e., mining, quarry, steel production, cement production, food and beverage processing, etc.) and consumes various types of fuels, including biomass, coal and petroleum (diesel, petrol, HFO, etc.). In the years under consideration, the mining and quarry industry remained the most energy consuming sub-sector with significant fuel consumption also recorded in construction and unspecified industries. Generally, the manufacturing industries and construction sector recorded a steady increase in energy consumption over the reference period. The decrease in energy consumption, observed in some years i.e., 2009, 2016 and 2021, was due to slow down in the country's economic activity. The reduction in energy consumption in 2021 was also due to the effect of COVID-19 on the country's economy. Figure 14 shows trend of energy consumption in the manufacturing industries and construction sector in TJ.

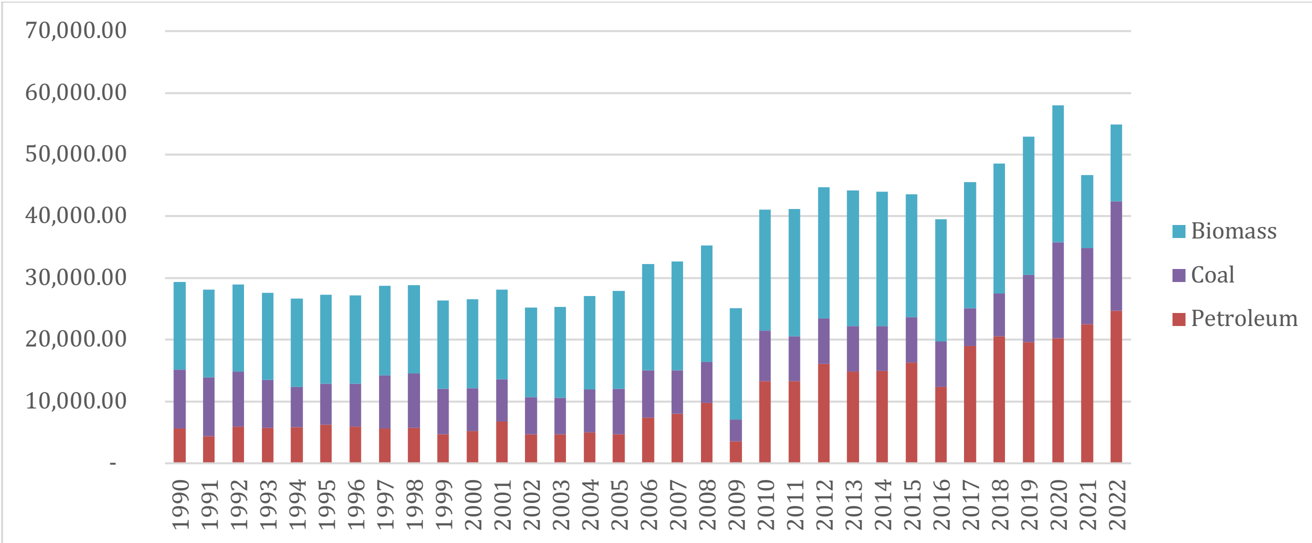


Figure 14:Trend of energy consumption in the manufacturing industries and construction sector in TJ.

The production of steel, manganese and cement in Zambia also expanded significantly during the period under review. Cement production was relatively low in the 1990s but marked a substantial growth in later years (starting from 2010). The quantity of cement produced increased by 8.4% to 3.5 million tonnes in 2022[14]. Similarly, there was significant increase in investments in steel and manganese production.

3.2.3.4 Transport

The transport sector in Zambia comprises of several modes including aviation, road, railway, water-borne navigation and pipeline transportation systems. Over the period under review, the road was the most prevalent mode of transport and the highest consumer of fuel (diesel and motor spirit). The number of automobiles under the transport sector increased, with the population of vehicles having grown by 45% between 2015 and 2022 (from 663,543 to 960,237)[15] while consumption of petroleum products (diesel and motor spirit) increased from 134.92 kilo tonnes in 1990 to 985.57 in 2022.

The sub-sector also recorded an in-flow of a limited number of electric vehicles. On the other hand, the aviation sub-sector comprised of domestic flights, which consumed only about 7.5% of the Zambia's total Jet A1 supply (on average) during the period under

[14] Zambia's annual cement production increased by +8.4% | CCF2Up
[15] RTSA Report, 2023

review, and international aviation (consumed about 92.5% of Jet A1). Zambia also used aviation gasoline for aviation during the period under consideration. Figure 15 shows the trend on energy consumption by various modes of transport in TJ.

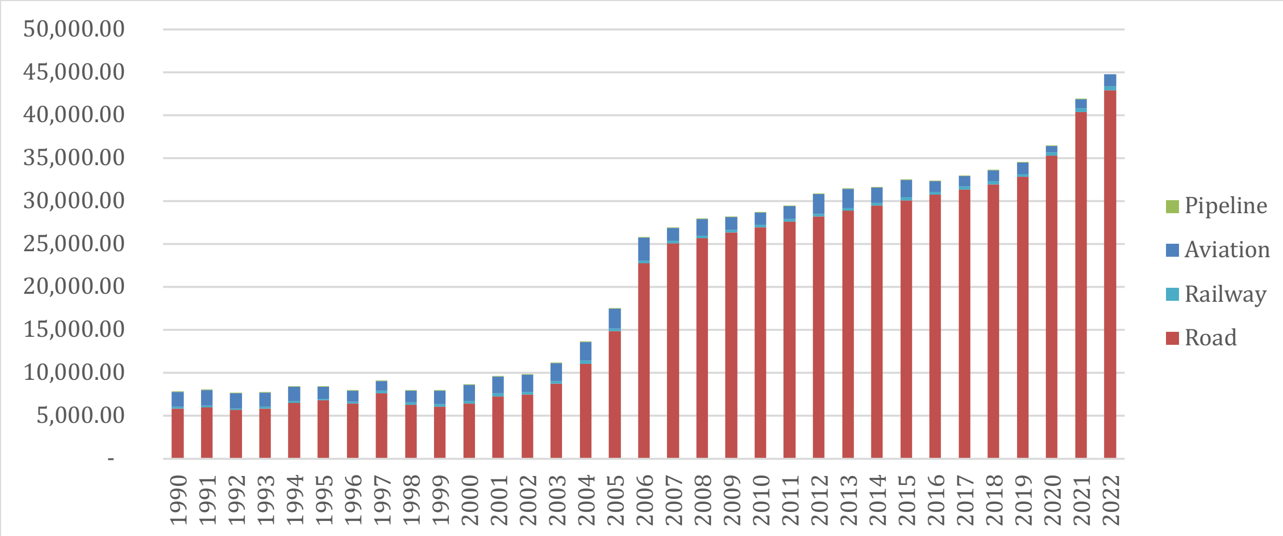


Figure 15: trend on energy consumption by various modes of transport in TJ.

3.2.3.5 Other – Agriculture, Residential and Commercial Sectors

This sector includes the formal and informal sector such as agriculture, residential, and commercial, among others. The residential sub-sector accounted for fuel consumption through domestic activities, i.e., cooking and heating needs by households and consume fuels like biomass (charcoal, firewood, etc.) and liquid fuels (LPG and kerosene). Similarly, the commercial sub-sector accounted for fuel consumed to undertake commercial activities by the various entities, i.e., businesses, public and private institutions. The agriculture sub-sector took care of fuel (diesel) consumed through agricultural activities, such as powering machinery and equipment for crop production as well as fisheries and livestock management. It also accounts for fuel (firewood) consumed in drying kilns for fish and crops (mainly tobacco). Figure 16 shows the trend of energy consumption (in TJ) by various sub-sectors from 1990 to 2022.

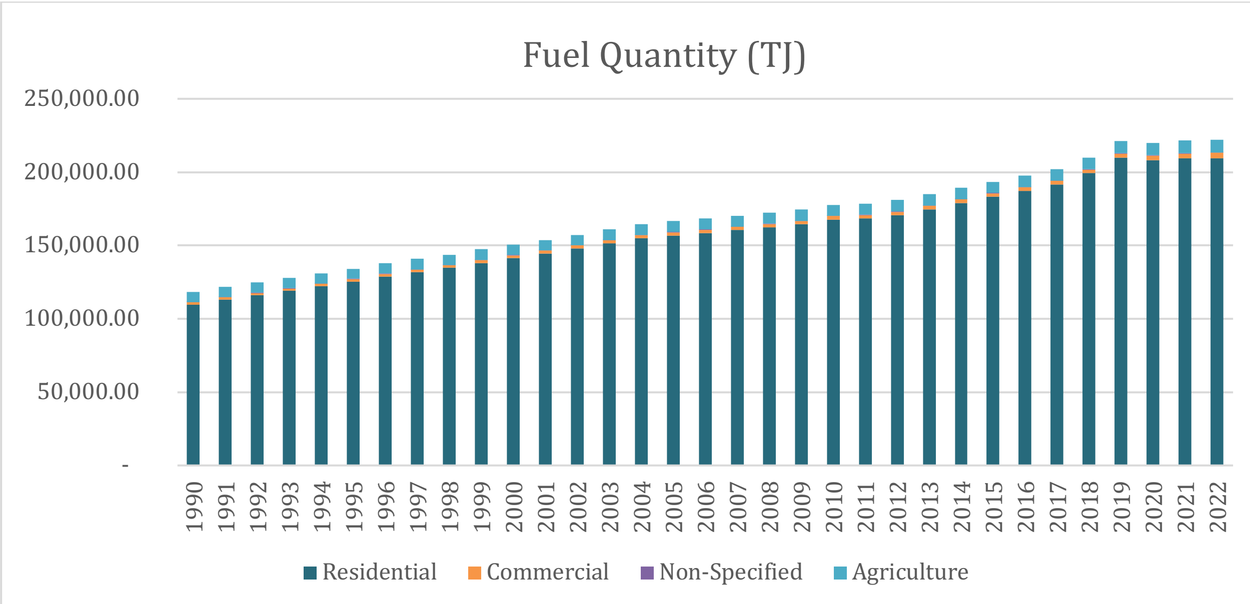


Figure 16: Trend of energy consumption (in TJ) by various sub-sectors from 1990 to 2022.

3.2.3.6 Coal Production

Zambia mines coal from both open pit and underground mines. Coal mining activities increased during the period under review, with addition of new coal mines. The production of coal increased from about 400 kilo tonnes in 1990 to over 1800 kilo tonnes in 2022 as shown in Figure 17. Coal production was low, prior to 2016 and thereafter, production increased significantly up to 2022. The increase in coal production can be attributed to the increased coal consumption especially for electricity generation and to the mines for process heat.

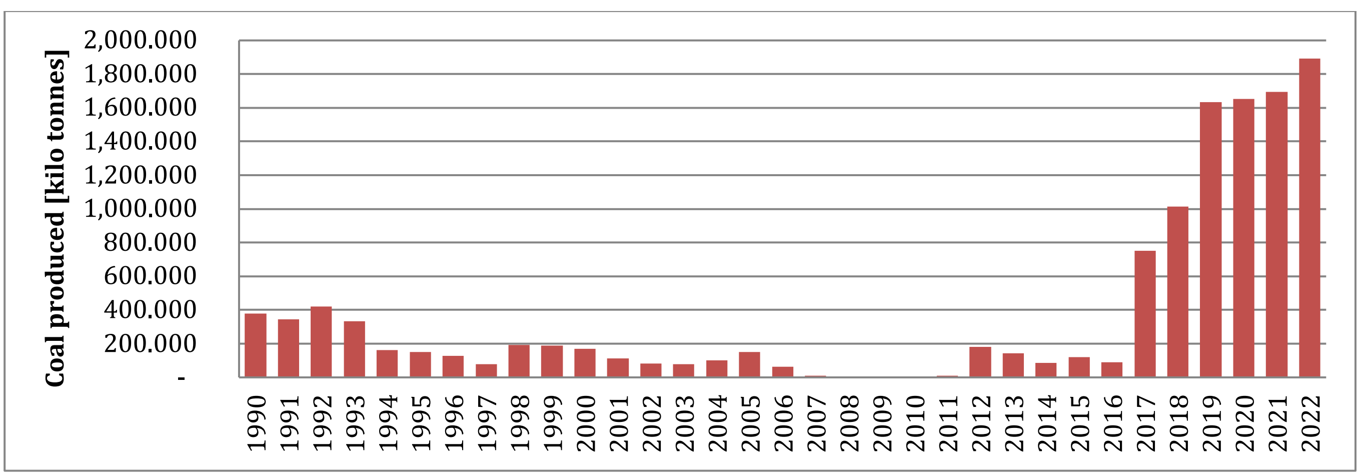


Figure 17: Coal Production

3.2.3.7 Charcoal Production

In Zambia, production of charcoal is rampant primarily driven by high demand, especially in urban areas. Annual production of charcoal increased by 260% from 619.6 kilo tonnes in 1990 to 2,229.8 kilo tonnes in 2022 as presented in Figure 15. Charcoal production was characterised by deeps and spikes as shown in the graph (Figure 18). The decline was attributed to an economic slowdown (i.e., shrinking GDP) and spikes reflected periods of economic growth.

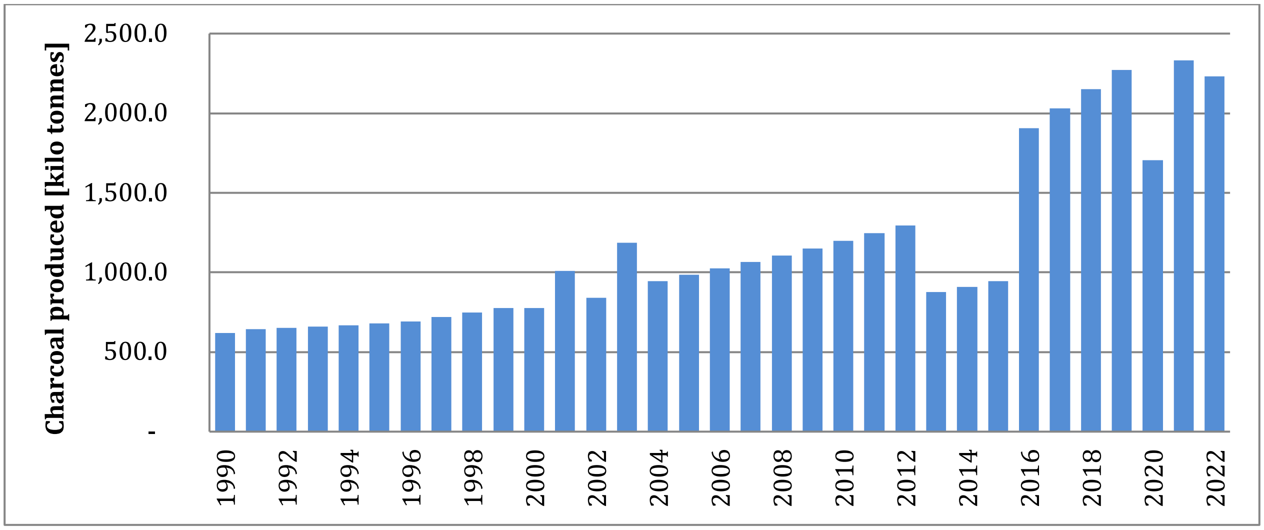


Figure 18: Charcoal Production

3.2.4 Emissions Trends in Energy Sector

Generally, emissions from the energy sector are increasing in Zambia. Energy emissions increased from 3,926.2 Gg CO_2e in 1990 to 14,571.4Gg CO_2e in 2022 as presented in Figure 19 and Table 8. The trend is attributed mainly to an increase in consumption of petroleum products driven by increase in economic activities and vehicle population.

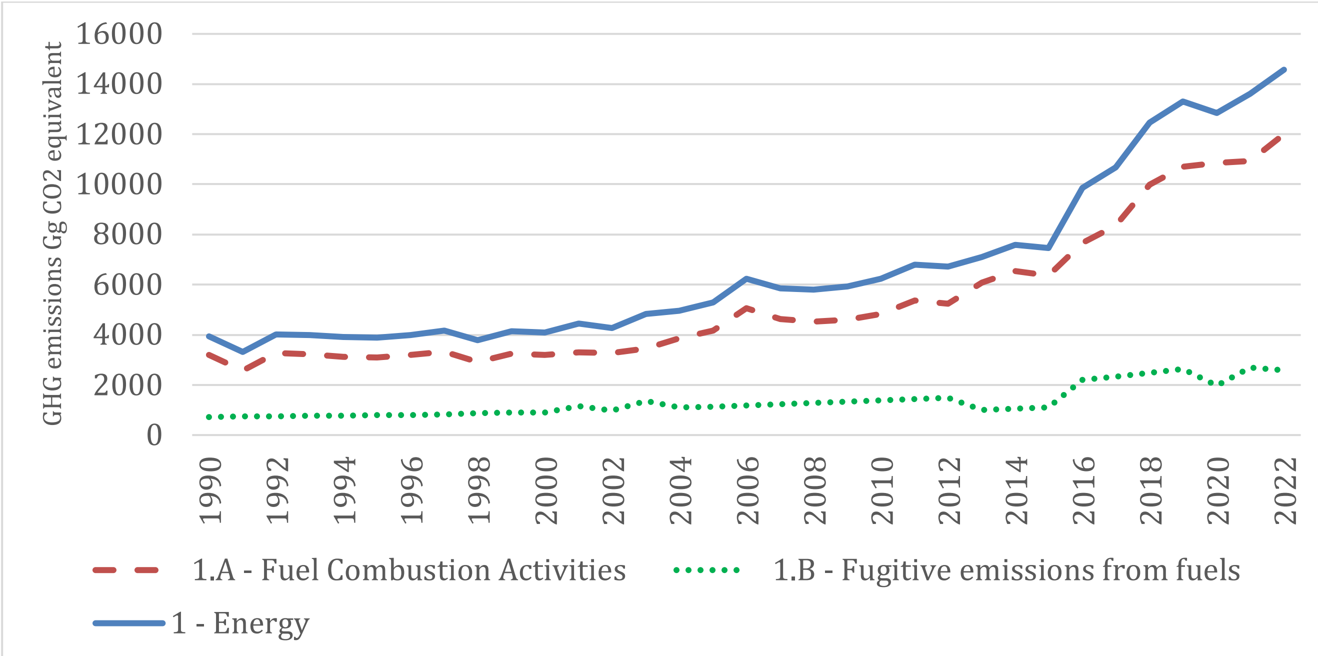


Figure 19: Emissions Trends in the Energy Sector

Table 10 provides details of emissions for categories in the energy sector.

Table 10: provides emissions for categories in the energy sector with the exclusion of carbon storage and capture

Categories	1 - Energy	1.A - Fuel Combustion Activities	1.B - Fugitive emissions from fuels
1990	3926.2	3208.7	717.5
1991	3314.6	2570.3	744.2
1992	4018.1	3263.0	755.0
1993	3997.4	3232.3	765.1
1994	3901.5	3127.2	774.4
1995	3879.6	3094.9	784.7
1996	3988.6	3190.8	797.8
1997	4157.7	3328.4	829.2
1998	3776.7	2913.1	863.6
1999	4139.5	3242.4	897.1
2000	4100.2	3204.4	895.8
2001	4450.2	3286.8	1163.4
2002	4256.1	3282.3	973.8
2003	4829.1	3463.1	1366.0
2004	4959.7	3867.3	1092.4
2005	5295.9	4160.3	1135.7
2006	6236.2	5055.8	1180.4

2007	5848.2	4620.6	1227.5
2008	5808.9	4532.2	1276.7
2009	5917.5	4589.2	1328.3
2010	6222.2	4840.6	1381.6
2011	6807.6	5370.5	1437.1
2012	6725.7	5230.5	1495.2
2013	7094.4	6083.4	1011.0
2014	7598.2	6546.3	1051.9
2015	7458.3	6364.9	1093.4
2016	9860.4	7663.6	2196.9
2017	10681.6	8345.0	2336.6
2018	12456.4	9974.8	2481.6
2019	13316.1	10691.3	2624.8
2020	12834.1	10863.8	1970.3
2021	13615.0	10923.9	2691.1
2022	14571.4	11997.4	2574.1

Provided in Table 11 is a summary report for energy sector.

Table 11: Energy sector sub-category emissions by gas for the year 2022 Gg

	Emissions (Gg)						
Categories	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
1 - Energy	10814.9	124.599	1.01	0.156	490.556		
1.A - Fuel Combustion Activities	10814.865	34.3571	0.832				
1.A.1 - Energy Industries	3540.2558	0.39475	0.103				
1.A.1.a - Main Activity Electricity and Heat Production	3540.2558	0.39475	0.103				
1.A.1.a.i - Electricity Generation	3540.2558	0.39475	0.103				
1.A.1.a.ii - Combined Heat and Power Generation (CHP)							
1.A.1.a.iii - Heat Plants							
1.A.1.b - Petroleum Refining							
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	NO	NO	NO				
1.A.1.c.i - Manufacture of Solid Fuels	NO	NO					
1.A.1.c.ii - Other Energy Industries							
1.A.2 - Manufacturing Industries and Construction	3491.873	1.55351	0.09				
1.A.2.a - Iron and Steel							
1.A.2.b - Non-Ferrous Metals							
1.A.2.c - Chemicals							
1.A.2.d - Pulp, Paper and Print							
1.A.2.e - Food Processing, Beverages and Tobacco	EE	EE	EE				

1.A.2.f - Non-Metallic Minerals							
1.A.2.g - Transport Equipment							
1.A.2.h - Machinery							
1.A.2.i - Mining (excluding fuels) and Quarrying	2174.2863	0.25385	0.039				
1.A.2.j - Wood and wood products							
1.A.2.k - Construction	91.696881	0.00372	7E-04				
1.A.2.l - Textile and Leather							
1.A.2.m - Non-specified Industry	1225.8898	1.29593	0.051				
1.A.3 - Transport	3139.0338	0.56459	0.257				
1.A.3.a - Civil Aviation	16.786503	0.00012	5E-04				
1.A.3.a.i - International Aviation (International Bunkers) (1)							
1.A.3.a.ii - Domestic Aviation	16.786503	0.00012	5E-04				
1.A.3.b - Road Transportation	3091.1649	0.56273	0.244				
1.A.3.b.i - Cars	3091.1649	0.56273	0.244				
1.A.3.b.i.1 - Passenger cars with 3-way catalysts							
1.A.3.b.i.2 - Passenger cars without 3-way catalysts							
1.A.3.b.ii - Light-duty trucks							
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts							
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts							
1.A.3.b.iii - Heavy-duty trucks and buses							
1.A.3.b.iv - Motorcycles							
1.A.3.b.v - Evaporative emissions from vehicles							
1.A.3.b.vi - Urea-based catalysts							
1.A.3.c - Railways	31.082357	0.00174	0.012				
1.A.3.d - Water-borne Navigation							
1.A.3.d.i - International water-borne navigation (International bunkers) (1)							
1.A.3.d.ii - Domestic Water-borne Navigation							
1.A.3.e - Other Transportation							
1.A.3.e.i - Pipeline Transport							
1.A.3.e.ii - Off-road							
1.A.4 - Other Sectors	618.04402	31.8437	0.382				
1.A.4.a - Commercial/Institutional	470.14545	0.06283	0.004				
1.A.4.b - Residential	39.882998	29.6379	0.308				
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	108.01557	2.14294	0.07				
1.A.4.c.i - Stationary	0	2.13689	0.028				
1.A.4.c.ii - Off-road Vehicles and Other Machinery	108.01557	0.00605	0.042				
1.A.4.c.iii - Fishing (mobile combustion)							
1.A.5 - Non-Specified	25.65896	0.00055	1E-04				

1.A.5.a - Stationary	25.65896	0.00055	1E-04				
1.A.5.b - Mobile							
1.A.5.b.i - Mobile (aviation component)							
1.A.5.b.ii - Mobile (water-borne component)							
1.A.5.b.iii - Mobile (Other)							
1.A.5.c - Multilateral Operations (1)(2)							
1.B - Fugitive emissions from fuels	0.034849	90.2416	0.178	0.156	490.556		
1.B.1 - Solid Fuels	0.034849	90.2416	0.178	0.156	490.556		
1.B.1.a - Coal mining and handling	0.034849	0.38069					
1.B.1.a.i - Underground mines	0						
1.B.1.a.i.1 - Mining							
1.B.1.a.i.2 - Post-mining seam gas emissions							
1.B.1.a.i.3 - Abandoned underground mines	0						
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO2							
1.B.1.a.ii - Surface mines	0.034849	0.38069					
1.B.1.a.ii.1 - Mining	0.034849	0.38069					
1.B.1.a.ii.2 - Post-mining seam gas emissions	0	0					
1.B.1.a.ii.3 - Abandoned surface mines	0	0					
1.B.1.b - Uncontrolled combustion and burning coal dumps							
1.B.1.c - Fuel transformation	0	89.8609	0.178	0.156	490.556		
1.B.1.c.i - Charcoal and Biochar production		89.8609	0.178	0.156	490.556		
1.B.1.c.ii - Coke production							
1.B.1.c.iv - Gasification transformation	0	0	0				
1.B.2 - Oil and Natural Gas							
1.B.2.a - Oil							
1.B.2.a.i - Venting							
1.B.2.a.ii - Flaring							
1.B.2.a.iii - All Other							
1.B.2.a.iii.1 - Exploration							
1.B.2.a.iii.2 - Production and Upgrading							
1.B.2.a.iii.3 - Transport							
1.B.2.a.iii.4 - Refining							
1.B.2.a.iii.5 - Distribution of oil products							
1.B.2.a.iii.6 - Other							
1.B.2.b - Natural Gas							
1.B.2.b.i - Venting							
1.B.2.b.ii - Flaring							
1.B.2.b.iii - All Other							
1.B.2.b.iii.1 - Exploration							
1.B.2.b.iii.2 - Production							
1.B.2.b.iii.3 - Processing							

1.B.2.b.iii.4 - Transmission and Storage							
1.B.2.b.iii.5 - Distribution							
1.B.2.b.iii.6 - Other							
1.B.3 - Other emissions from Energy Production	NO	NO	NO				
1.C - Carbon dioxide Transport and Storage	0						
1.C.1 - Transport of CO2	0						
1.C.1.a - Pipelines	0						
1.C.1.b - Ships	0						
1.C.1.c - Other (please specify)	0						
1.C.2 - Injection and Storage	0						
1.C.2.a - Injection	0						
1.C.2.b - Storage	0						
1.C.3 - Other							

In 2022, the most significant gas in the energy sector was CO_2 with 70%, followed by CH_4 with 28% and the least was N2O with 2%. Figure 20 presents emissions by gas for 2022.

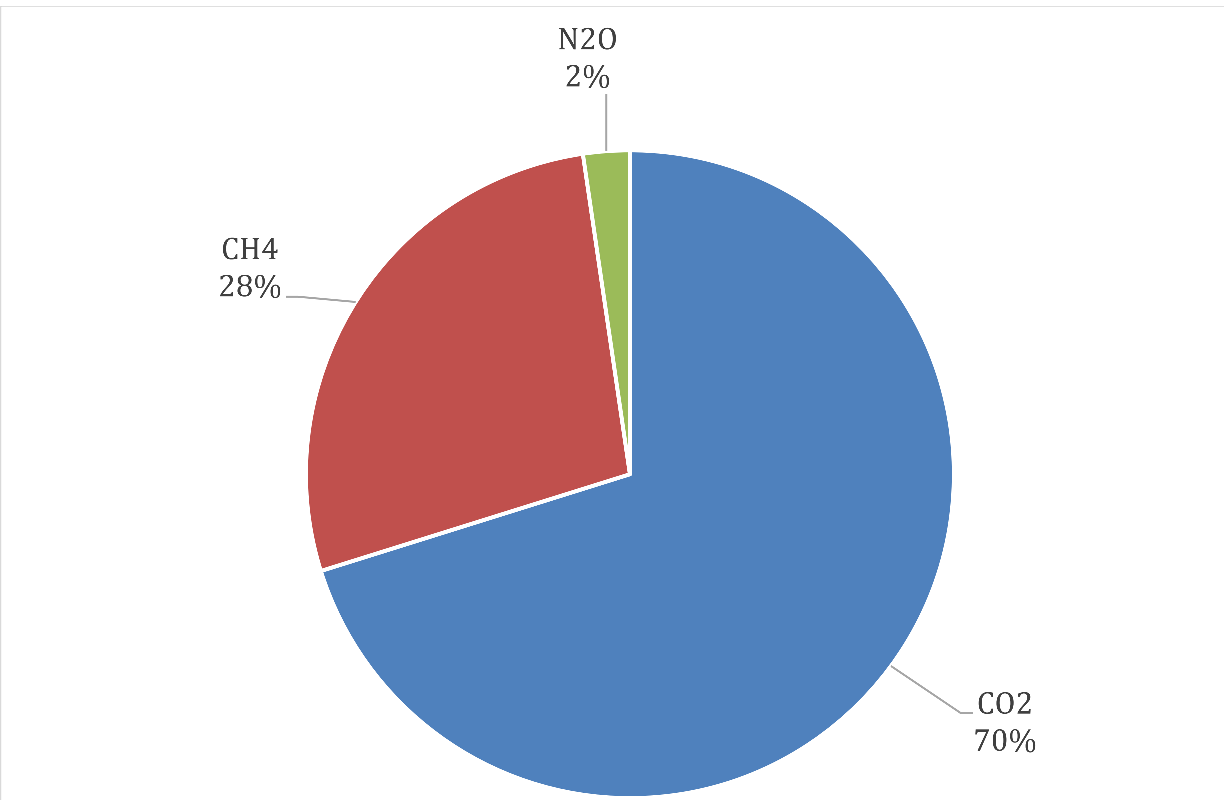


Figure 20: Emissions by gas for the energy sector for 2022

Provided in Figure 21 are trends of emissions by gas Gg CO_2e and respective percentage contribution. Across the time series CO2 has been the major contributor to the emissions.

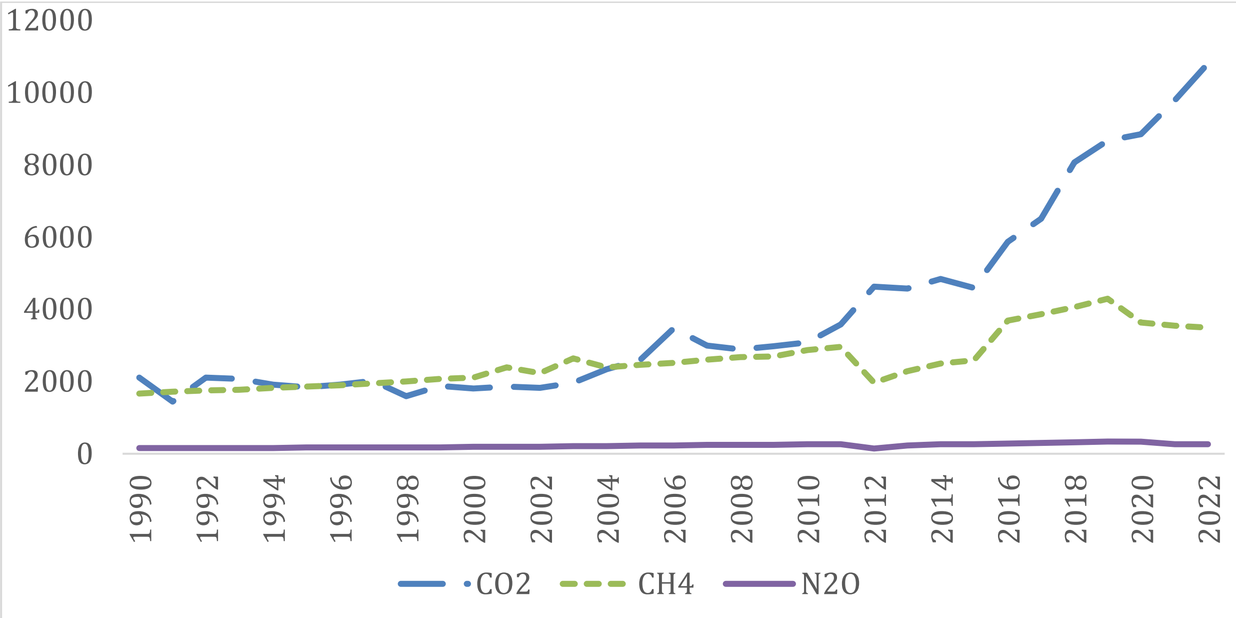


*Figure 21:*Emissions *trends by gas Gg CO2 eq.*

3.2.5 Emissions based on Reference approach

Reference and sectoral approaches were used to estimate the CO_2 emissions from the energy sector for the current year (2022). Provided in Table 12 is a comparison made of CO_2 emissions between the two approaches. The emission estimates from both approaches were comparable within a variation range of up to ±5.5%. This is slightly above the acceptable variation (±5%) and is attributed to lack of a robust mechanism to assure accurate capturing and documenting of fuel consumption in various sectors of the economy.

Table 12: Comparison of CO2 emissions between Sectoral and Reference approach for 2022

	Reference Approach				Sectoral Approach		Difference	
Fuel	Apparent Consumption (TJ)	Excluded consumption (TJ)	Apparent Consumption (excluding non-energy use and feedstocks) (TJ)	CO2 Emissions (Gg)	Energy Consumption (TJ)	CO2 Emissions (Gg)	Energy Consumption (%)	CO2 Emissions (%)

Aviation Gasoline	83.7	0.0	83.7	5.9	83.8	5.9	-0.053	-0.005
Bitumen	0.0	0.0	0.0	0.0			0.000	0.000
Crude Oil	0.0	0.0	0.0	0.0			0.000	0.000
Ethane	0.0	0.0	0.0	0.0			0.000	0.000
Gas/Diesel Oil	46287.4	0.0	46287.4	3428.3	46240.5	3426.4	0.101	0.056
Jet Gasoline	0.0	0.0	0.0	0.0			0.000	0.000
Jet Kerosene	152.9	0.0	152.9	10.91	152.8	10.9	0.065	0.060
Liquefied Petroleum Gases	1257.7	0.0	1257.7	79.3	1249.9	78.9	0.624	0.580
Lubricants	0.0	0.0	0.0	0.0			0.000	0.000
Motor Gasoline	22136.7	0.0	22136.7	1534.1	22147.2	1534.8	-0.047	-0.047
Naphtha	0.0	0.0	0.0	0.0			0.000	0.000
Natural Gas Liquids	0.0	0.0	0.0	0.0			0.000	0.000
Orimulsion	0.0	0.0	0.0	0.0			0.000	0.000
Other Kerosene	6918.2	0.0	6918.2	497.2	6925.4	497.9	-0.104	-0.150
Other Petroleum Products	0.0	0.0	0.0	0.0			0.000	0.000
Paraffin Waxes	0.0	0.0	0.0	0.0			0.000	0.000
Petroleum Coke	0.0	0.0	0.0	0.0			0.000	0.000
Refinery Feedstocks	0.0	0.0	0.0	0.0			0.000	0.000
Refinery Gas	0.0	0.0	0.0	0.0			0.000	0.000
Residual Fuel Oil	705.0	0.0	705.0	54.5	745.5	57.7	-5.441	-5.481
Shale Oil	0.0	0.0	0.0	0.0			0.000	0.000
White Spirit and SBP	0.0	0.0	0.0	0.0			0.000	0.000
Anthracite	0.0	0.0	0.0	0.0			0.000	0.000

Blast Furnace Gas	0.0	0.0	0.0	0.0			0.000	0.000
Brown Coal Briquettes	0.0	0.0	0.0	0.0			0.000	0.000
Coal Tar	0.0	0.0	0.0	0.0			0.000	0.000
Coke Oven Coke / Lignite Coke	0.0	0.0	0.0	0.0		0.0	0.000	0.000
Coke Oven Gas	0.0	0.0	0.0	0.0			0.000	0.000
Coking Coal	3592.4	0.0	3592.4	339.8	3592.4	339.8	0.000	0.000
Gas Coke	0.0	0.0	0.0	0.0			0.000	0.000
Gas Works Gas	0.0	0.0	0.0	0.0			0.000	0.000
Lignite	0.0	0.0	0.0	0.0			0.000	0.000
Oil Shale / Tar Sands	0.0	0.0	0.0	0.0			0.000	0.000
Other Bituminous Coal	9277.7	0.0	9277.7	877.7	9276.6	877.6	0.011	0.011
Oxygen Steel Furnace Gas	0.0	0.0	0.0	0.0			0.000	0.000
Patent Fuel	0.0	0.0	0.0	0.0			0.000	0.000
Sub-Bituminous Coal	41447.1	0.0	41447.1	3981.7	41466.6	3984.9	-0.047	-0.082
Natural Gas (Dry)	0.0	0.0	0.0	0.0			0.000	0.000
Industrial Wastes	0.0	0.0	0.0	0.0			0.000	0.000
Municipal Wastes (nonbiomass fraction)	0.0	0.0	0.0	0.0			0.000	0.000
Waste Oils	0.0	0.0	0.0	0.0			0.000	0.000
Peat	0.0	0.0	0.0	0.0			0.000	0.000

3.2.6 Emissions from Energy Categories

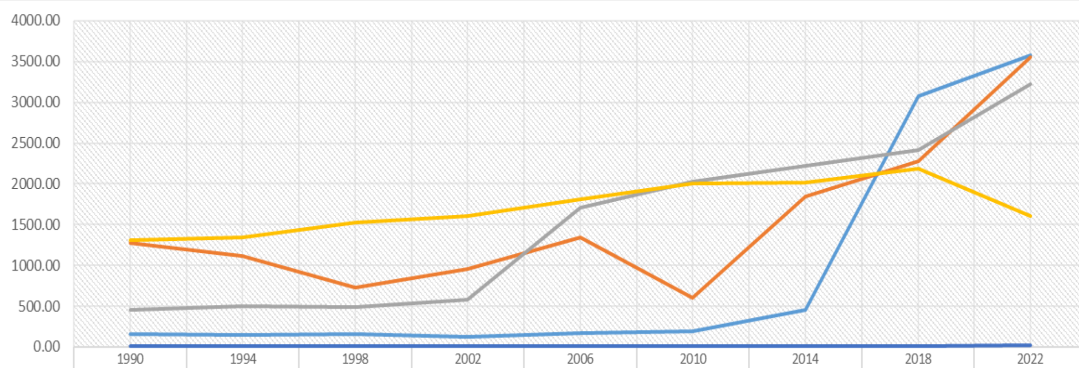
This section provides respective emissions, activity data, emission factors and methodologies for energy categories. The IPCC 2006 guidelines broadly classifies energy-related activities into 3 main categories, namely: fuel combustion activities (1.A), fugitive emissions from fuels (1.B) and Carbon dioxide transport and storage (1.C).

Fuel Combustion Activities

The sub-categories under fuel combustion activities include energy industries (1.A.1), manufacturing industries and construction (1.A.2), transport (1.A.3), other sectors (1.A.4) and non-specified (1.A.5).

In 2022, Zambia's major contributor to emissions under the fuel combustion activity was energy industries with 29.8% followed by manufacturing industries and construction with 29.6%. Transport was third with 26.8% and other sectors (commercial/institutional, residential, Agriculture/Forestry/Fishing, and Fish) contributed 13.4%.

GHG emissions from energy industries increased gradually (198%) from 152.9 Gg CO_2e in 1990 to 456.3 Gg CO_2e in 2014 and recorded rapid increase by 684% (from 2014) to 3,578.5 Gg CO_2e in 2022. Emissions from manufacturing industries and construction increased by 178% from 1990 and 2022 while emissions in transport sector increased by 607% during the same period. Emissions in other sectors increased by 23%. Figure 22 shows the trend of emissions for categories in the energy sector (Gg CO_2e).



	1990	1994	1998	2002	2006	2010	2014	2018	2022
1.A.1 - Energy Industries	152.90	151.66	154.73	129.22	168.06	193.54	456.29	3079.05	3578.53
1.A.2 - Manufacturing Industries and Construction	1279.52	1117.03	725.91	959.21	1349.19	600.61	1841.51	2278.39	3559.30
1.A.3 - Transport	455.66	503.59	494.47	580.99	1712.82	2028.36	2217.26	2415.62	3222.87
1.A.4 - Other Sectors	1310.29	1344.54	1527.60	1602.50	1815.31	2007.66	2020.82	2187.54	1610.96
1.A.5 - Non-Specified	10.33	10.35	10.37	10.39	10.41	10.43	10.45	14.21	25.70

Figure 22:Trend of emissions for categories in the Energy Sector (Gg CO2e)

Fugitive Emissions from Fuels

In the Zambian context, fugitive emissions come from charcoal production and coal mining as well as handing activities (under 1.B.1. Solid Fuels) and petroleum refining (under 1.B.2. Oil and Natural Gas). During the period under review, fugitive emissions from solid fuels (charcoal production and coal mining) increased from 713.1 Gg CO_2e in 1994 to 2,574.07Gg CO_2e in 2022. In 2022, and across the time series, the major contributor to emissions from solid fuels was charcoal production, representing 99.6%. The increase in emissions was driven by the growth in demand for charcoal, leading to increased production. Similarly, coal production increased with introduction of new mines, resulting in increased fugitive emissions from solid fuels.

As regards fugitive emissions from petroleum refining, emissions have been varying over the time period. In 2022 petroleum refinery ceased operation in Zambia and for that reason, there were no emissions from this source in 2022. Table 13 provides the details of the quantities of fugitive emissions for Zambia for the period 1990 to 2022.

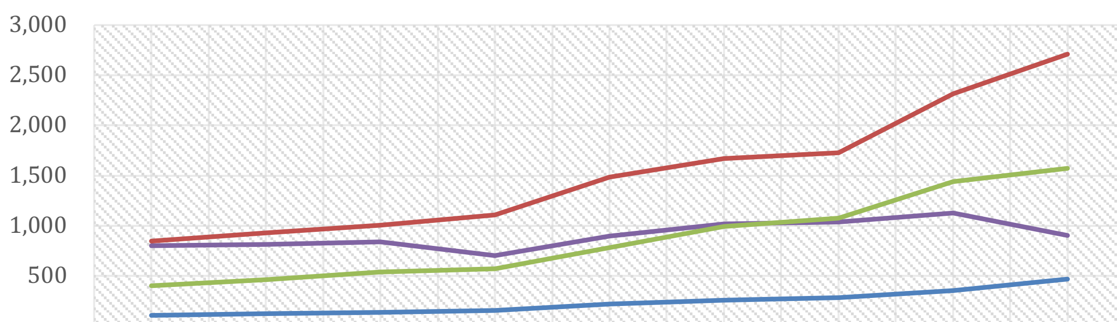
Table 13 Trends of emissions from fugitive emissions

GHG	Solid Fuels	Oil and Natural Gas
	Emissions (Gg CO_2e)	
1990	713.15	4.35
1991	740.57	3.67
1992	750.84	4.20
1993	761.31	3.79
1994	770.92	3.44
1995	781.67	3.01
1996	794.98	2.85
1997	826.43	2.79
1998	860.08	3.56
1999	895.80	1.27
2000	895.69	0.11
2001	1161.87	1.54
2002	971.76	2.02
2003	1362.94	3.04
2004	1089.13	3.24
2005	1132.96	2.71
2006	1177.75	2.65
2007	1224.56	2.98
2008	1273.47	3.22
2009	1324.41	3.94
2010	1377.39	4.20

2011	1432.57	4.49
2012	1490.78	4.40
2013	1007.29	3.74
2014	1047.19	4.71
2015	1089.25	4.18
2016	2193.20	3.65
2017	2332.68	3.94
2018	2477.35	4.21
2019	2620.34	4.47
2020	1967.89	2.37
2021	2690.75	0.36
2022	2574.07	0.00

3.2.7 Precursor gases emissions in energy sector

Emissions of precursor gases (i.e. NOx, CO, NMVOC and SO_2) in energy sector increased steadily from 1990 to 2014. Beyond 2014, NOx, CO, NMVOC emissions continued to increase sharply until 2022. On the contrary, SO_2 emissions reduced slightly in 2022. This reduction is attributed to reduced activities on refinery of crude. Figure 23 shows the trend of precursor gases emissions in the energy sector by gas.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
SO2	799	815	837	703	896	1,019	1,041	1,127	902
NMVOC	107	123	137	155	220	256	282	352	469
CO	848	926	1,006	1,107	1,484	1,670	1,725	2,315	2,711
NOx	403	463	538	572	783	991	1,079	1,440	1,573

Figure 23: Trend of precursor gases emissions in the energy sector by gas.

3.2.8 Quality assurance/quality control measures applied

Activity data used in estimating GHG emissions from the energy sector came from the energy balance reports. To confirm and verify data, data from sources such as Energy Regulation Board, Oil Marketing Companies, Indeni oil refinery, Maamba Collieries, Railway Companies, Central Statistics Office and Zambia Revenue Authority were collected and compared. Efforts were made to check and verify the data from all sources to ensure good quality data was utilized in the inventory preparation for the energy sector.

3.2.9 Sectoral uncertainties,

The Uncertainty analysis for the year 2022 for the Energy sector was estimated using approach 1 and computed using the IPCC 2006 software. Generally, uncertainty for activity data from energy is ± 5%. Detailed uncertainty values are provided in Annex I. Base year for uncertainty assessment was 1990.

3.2.10 Planned Improvements

Provided in Table 14 are gaps and planned improvements for the energy sector.

Table 14: Gaps and planned improvements for the energy sector

<table>
<tr><th>-</th><th>GAPS</th><th>RECOMMENDATIONS</th></tr>
<tr><td>1.</td><td>Need for one entity assigned with the role of leading the national energy statistics system and the responsibility for official energy statistics. Currently various entities produce energy statistics leading to an overlap and inconsistencies in energy data sets. The involvement of a variety of organizations in the collection, compilation, management and dissemination of energy statistics leads to confusion or result in numerous energy-related data sets.</td><td rowspan="2">Formalise the responsibilities of the Ministry of Energy (MoE) as the leading entity for the national energy statistics system for the regular elaboration of energy statistics and the energy balance and formalise the roles and responsibilities of all other
relevant entities involved in energy statistics (e.g., Energy Regulation Board (ERB), Zambia Revenue Authority (ZRA) and Zambia Statistics Agency (ZamStats).

Establish a governance structure and a framework to guide the management of energy statistics in Zambia.</td></tr>
<tr><td>2</td><td>It was noted that there is completely no data on fuel consumption by Marine transportation</td></tr>
</table>

3	As for Avgas and Jet A1 Consumption the team had difficulties in obtaining and disaggregating Activity Data	Clarify competences and prepare MOUs specifying roles and responsibilities, similarly to the GHG MOUs with all the institutions that have relevant energy statistics data. Further to the inclusion of the NDA, the framework should address all inconsistencies. Formalise the establishment of working groups for the regular update of energy balances and energy statistics (collection, compilation, management and dissemination of energy statistics), improving collaboration between entities involved in energy statistics and exploiting the synergies with other national statistics (economic, demographic, physical – forestry, transport- GHG inventory) include clear mandates, roles and responsibilities, for the working groups of energy statistics and define these in specific terms of references. Ensure the consistency and alignment of the definitions and categories of energy products used among all stakeholders involved in energy statistics, using internationally agreed definitions of energy products and their classification.
4	There is no information on confidentiality agreements or how to deal with confidential information, it was noted that some information on Activity Data was challenging due to reasons that included confidential information, among others.	
5.	The data provided in the energy balances by Zambia are not consistent with the energy balances of the country published in the UN Statistical Division.	
6	Need to provide information on how policymaking is informed by the energy statistics and GHG emissions inventory report.	
7	The Ministry of Energy relies on data collected by the Energy Regulation Board (ERB) which produces annual commodity balance in the Energy Sector Reports. ERB collects data from entities Licensed under the Energy Regulation Act. The ERB compiles commodity balances for Petroleum and Electricity related commodities. Commodity balances related to Biomass or wood fuel are not compiled because the ERB does not regulate this industry. There is	Funds should be made available to facilitate the undertaking of the periodic surveys in order to supplement data from ERB.

	also a gap regarding the consumption statistics of energy.	
9.	High rate of Staff turnover in the energy sector who are familiar with GHG inventory preparation.	Need for continuous capacity building in GHG inventory preparation both within and outside the Country. Also implement capacity building for all staff working on energy statistics, specifically focusing on data providers, on technical know-how to carry out their tasks, such as the approach to energy balance compilation. Involve national staff on energy statistics in relevant capacity building events and exercises from the International Energy Agency (IEA) and United Nations Statistics Division (UNSD) to get familiar with the Handbook IRES (International Recommendations on Energy Statistics). Develop a capacity-building system to transfer knowledge to new staff.
10.	It was noted that there were inconsistencies between the categories reflected in the national Energy Balance and the IPCC Guidelines.	Need for alignment of these differences to be addressed in future National Communications.

3.2.11 Carbon capture and storage (CCS)

Carbon capture and storage (CCS) is a chain process that involves the capture, compression of CO_2 (usually at a large industrial installation) and transportation to a storage location and its long-term isolation from the atmosphere. There are no activities occurring in Zambia under this category and hence there were no emissions estimates undertaken.

3.3 INDUSTRIAL PROCESSES AND PRODUCT USE(IPPU)

3.3.1 Overview

Zambia's industrial processes and product use (IPPU) sector is characterized by activities in mineral industry (2.A), chemical industry (2.B), metal industry (2.C), non-energy products from fuels and solvent use (2.D), product uses as substitutes for Ozone depleting substances (2.F) and other product manufacture and use (2.G). Within the mineral industry, Zambia is involved in cement and lime production. Zambia also produces nitric acid and ammonia (under chemical industry), zinc, lead and steel (metal industry) while also consume lubricants, use refrigeration and air conditioning, and produce electrical equipment.

Broadly, macroeconomic performance improved in 2016. Real GDP is estimated to have grown by 3.4% compared to 2.9% in 2015[16]. In 2023, estimates suggest that real GDP growth reached 5.4%, up from 5.2% in 2022. The outturn was on account of positive performance in the Information and Communication technology and construction sectors. Contraction in the Agriculture, Forestry and Fishing and Mining and quarrying industries weighed negatively on growth. In terms of shares of the GDP in nominal terms, the Wholesale and Retail trade industry had the largest proportion at 18.6 percent. The Mining and Quarrying, Construction and Transportation and Storage industries accounted for 13.7 percent, 12.4 percent and 11.3 percent, respectively[17].

This was attributed to the delayed resolution of challenges at some major mines, operational impediments at some mines and low ore grades. Manufacturing growth slowed down to 1.5 percent in 2023 from 4.7 percent in 2022. This was largely on account of depreciation of the Kwacha against major convertible currencies which led to an increase in imported intermediate goods. The slowdown notwithstanding, high growth was positive in the pulp and paper products and the non-metallic products sub-sectors.

Zambia has a high propensity for consumption of manufactured goods. Domestic demand factors provide ready local markets for manufactured goods while the country's membership to regional organizations such as the Common Market for Eastern and Southern Africa (COMESA) and the Southern African Development Community (SADC) provide export markets in the region for the value-added manufactured products. The priority areas for investment in the sector include; food processing, textiles and clothing, mineral processing, chemical products, engineering, leather products, electrical goods, pharmaceutical products and packaging materials. Zambia is also endowed with mineral deposits for the production of other chemical products such as cement, adhesives and

[16] Bank of Zambia Annual Report 2016
[17] 2023, ANNUAL ECONOMIC REPORT, MINISTRY OF FINANCE AND NATIONAL PLANNING

explosives, as well as; glass, batteries, argon gas, sulphuric acid, paints, cosmetics, soaps and detergents.

Zambia has a variety of minerals which are exported as raw materials. At present there is very little value addition being made to these mineral exports which include; copper, iron and steel, cobalt and other minerals. Zambia has a high demand for imports of electronic goods in the country. Cotton is grown, ginned and spun in Zambia at industrial sites with state of the art spinning, weaving and processing factories as well as warehouses. The European Union is a major export market for the textile products from Zambia, with South Africa and Mauritius being other potential markets. There are a limited number of manufacturing companies and pharmaceutical trading companies in the country. The majority of essential health drugs are still being imported.[18] Currently most packaging materials used by manufacturing companies in the country are imported from the Republic of South Africa, China, India and Europe.

3.3.2 Methodology and Emission Factor

Mineral Industry

Under this sub-category, estimates were based on the Tier 1 method (Equation 4.1). For cement production, estimates were based on clinker production estimates inferred from cement production data. Further, correcting factors were applied for imports and exports of clinker.

CO_2 Emissions = $[\Sigma(M_{c,i} \times C_{Cl,i}) - Im + Ex] \times EF_{Clc}$ -----------------------------------Equation4.1

Where; $M_{c,i}$ - mass of cement produced of type i, tonnes, $C_{Cl,i}$ - clinker fraction of cement type i, fraction, Im - imports for consumption of clinker, tonnes, Ex - exports of clinker, tonnes; EF_{Clc} - emission factor for clinker, tonnes CO_2/tonne clinker; Emissions factor for clinker =0.4985 tonne CO_2/tonne of clinker; clinker fraction in cement=0.95

For lime, default emission factor and national level lime production data was used.

$CO_2 = \sum_i \quad EFlimei\ X\ Ml,i$ X CFlkd, I X Ch,i) -----------------------------------Equation 4.2

Where:

CO_2 Emissions = emissions of CO_2 from lime production, tonnes; EF $_{lime,i}$ = emission factor for lime of type i, tonnes CO_2/tonne lime(0.75 tonne of CO_2/tonne of lime high

[18] ZDA, manufacturing sector profile in Zambia

calcium lime); $M_{l,i}$ = lime production of type i, tonnes; $CF_{lkd,i}$ = correction factor for LKD for lime of type i, dimensionless; $C_{h,i}$ = correction factor for hydrated lime of the type i of lime, dimensionless; i = each of the specific lime types

For non-metallurgical magnesia production, estimates were based on the amount of products manufactured, along with emission factors that represent the amount of CO_2 emitted per unit of mass. The Tier 1(equation 4.3) method assumes that only limestone and dolomite are used as carbonate input in industry, and allows for the use of a default fraction of limestone versus dolomite consumed.

CO_2 Emissions = M_c x ($0.85EF_{ls}$ + $0.15EF_d$) -----------------------------------Equation 4.3

Where:
CO_2 Emissions = emissions of CO_2 from other process uses of carbonates, tonnes; M_c = mass of carbonate consumed, tonnes; EF_{ls} or EF_d = emission factor for limestone or dolomite calcination, tonnes CO_2/tonne carbonate (0.43971 tonnes CO_2/tonne of carbonate)

Chemical Industry

The Tier 1 method was used for estimating emissions CO_2 emissions from ammonia production which requires the default emissions factor and data on national production of NH_3(Equation 4.3).

$$CO_{2\ Emissions} = \left(AP\ x\ FR\ xCCF\ x\ \ COFx\ \frac{44}{12}\right) - RCO_2$$ -----------------Equation 4.3

Where: $CO_{2Emissions}$ = emissions of CO_2, kg; AP = ammonia production, tonnes; FR = fuel requirement per unit of output, GJ/tonne ammonia produced(FR=42.5 GJ/tonne) ; CCF = carbon content factor of the fuel, kg C/GJ(CCF=21 kg C/GJ); COF = carbon oxidation factor of the fuel, fraction(COF=1); RCO_2 = CO_2 recovered for downstream use (urea production), kg Ammonia production and emission factors can be obtained from national stat

Similarly, Tier 1 method was also used for nitric acid emissions estimate which requires default emission factor and nitric acid production data. Equation 4.4 provides N_2O emissions from nitric acid production – Tier 1.

$$N_2O_{Emissions} = EF\ X\ NAP$$ -----------------Equation 4.4

Where: $N_2O_{Emissions}$ = N_2O emissions, kg; EF = N_2O emission factor (default), kg N_2O/tonne nitric acid produced (EF=9 kg N_2O/tonne nitric acid); NAP = nitric acid production, tonnes

Metal Industry

Tier 1 method was used to estimate emissions across the metal industry mainly from lead, iron and steel production. In Zambia, emissions result from the recycling of iron and steel using the Electric Arc Furnace (EAF) method. Equation 4.5 was used to estimate CO_2 emissions from iron and steel production.

$$CO_{2\,non\,energy\,emissions} = BOF\ x\ EF_{BOF} + EAF\ X\ EF_{EAF} + OHFX\ EF_{OHF}$$ ----------Equation 4.5

$CO_{2\,non\,energy\,emissions}$ = emissions of CO_2 to be reported in IPPU Sector, tonnes BOF= quantity of BOF crude steel produced, tonnes EAF = quantity of EAF crude steel produced, tonnes OHF = quantity of OHF crude steel produced, tonnes; EF= emission factor, tonnes CO_2/tonne produced (EF=0.08 tonnes CO_2/tonne steel produced)

emissions estimate from Lead were derived using equation 4.6 where default emission factors were multiplied by lead production.

$$CO_2 = DS\ X\ EF_{DS}$$ ----------Equation 4.6

CO_2 = CO_2 emissions from lead production, tonnes; DS = quantity of lead produced by Direct Smelting, tonnes; EF_{DS} = emission factor for Direct Smelting, tonne CO_2/tonne lead produced (EF =0.25 tonne CO_2/tonne lead product)

Non-Energy Products from Fuels and Solvent Use

Tier 1 method (equation 4.7) was used for estimating CO_2 emissions from Non-Energy Product Uses. In this method, the default emissions factor is composed of carbon content factor and the factor that represents the fraction of fossil fuel carbon that is Oxidised During Use (ODU).

$$CO_2 = \sum_i (NEU_i\ x\ CC_i\ x\ ODU_i) * 44/12$$ ----------Equation 4.7

CO_2 = CO_2 emissions CO_2 Emissions from non-energy product uses, tonne CO_2; NEU_i = non-energy use of fuel i, T_J ; CC_i = specific carbon content of fuel i, tonne C/TJ (CC=20kg C/GJ); ODU_i = ODU factor for fuel(ODU=0.2);, fraction 44/12 = mass ratio of CO_2/C

Electronics Industry

No activity occurred under this category in Zambia from 1990 to 202022 and hence, emissions estimates were not calculated

Products Uses as Substitutes for Ozone Depleting Substances

The Tier 1a/b method back-calculates the development of banks of a refrigerant from the current reporting year to the year of its introduction. Equation 4.8 was used to estimate emission

$$E_{lifetime,\ t} = B_t\, x\, \frac{x}{100}$$ ----------Equation 4.8

$E_{lifetime,\ t}$= amount of HFC emitted during system operation in year t, kg Bt = amount of HFC banked in existing systems in year t (per sub-application), kg x = annual emission rate (i.e., emission factor) of HFC-134a of each sub-application bank during operation, accounting for average annual leakage and average annual emissions during servicing, percent (0.1%), Assume life of equipment=20 years; percentage of gas destroyed at the end of life=0%

Other Product Manufacture and Use

Tier 1 method was used in which emissions are estimated by multiplying default regional emission factors by the SF6 consumption of equipment and the capacity of the equipment at each lifecycle stage.

$$Equipment\ Use\ Emissions = \sum Nameplate\ capacity\ of\ equipment\ installed\ X\ Use\ emission\ factor$$ Equation 4.6

Emission factor = 0.002

3.3.3 Activity Data

Activity data for IPPU was collected from industries, ZRA and ZAMSTATS and this include; Clinker production Lime, Refrigeration Charge in refrigeration and air conditioning, Sulphur Hexafluoride in electrical equipment, Iron and Steel production, Lead Production, Zinc Production, Nitric acid production and Lubricant. The use Nameplate capacity was used in estimating the emissions for SF_6 in use of electrical equipment. Table 15 presents the activity data for IPPU.

Table 15 Activity data for IPPU

Year	Clinker production (tonnes)	Lime (tonnes)	Refrigeration Charge (tonnes)	Sulphur Hexafluoride (SF6) (tonnes)	Iron and Steel (tonnes)		Amount of Lead Production (tonne)	Amount of Zinc Production (tonne)	Nitric acid production (tonnes)	Lubricant
					Direct Reduced Iron	Electric Arc Furnace				
1990	286606	1174525.86	1.86	0.00		10896.0	10600	4100	23663	
1991	286750	1175116.07	2.04	0.01		10901.4	6500	2700	20641	
1992	286894	1175706.29	2.24	0.01		10906.9	7300	2600	24438	
1993	287038	1176296.5	2.45	0.07		10912.4	5600	1600	28523	
1994	287182	1176886.72	2.69	0.12		10917.9	100		23054	
1995	287326	1177476.93	2.95	0.12		10923.3			13648	
1996	287470	1178067.14	3.23	0.12		10928.8			12984	
1997	287614	1178657.36	3.54	0.12		10934.3			9425	
1998	287758	1179247.57	3.88	0.12		10939.8			3928	
1999	287902	1179837.79	4.26	0.12		10945.3			1996	
2000	295140	1180428	4.67	0.21		10950.7			8497	
2001	272156	1211140.08	5.12	0.21		10956.2			1827	
2002	302080	1241852.16	5.61	0.21		10961.7			0	
2003	372936	1272564.24	10.28	0.21		10967.2			1603	
2004	450807	1303276.32	16.09	0.20		10972.6			0	
2005	511537	1333988.4	20.54	1.38		10978.1			0	
2006	483840	1361329.32	27.88	1.40		10983.6			0	
2007	466938	1388670.24	31.40	1.40		10989.1			0	
2008	508253	1416011.16	47.55	1.40		10994.5			0	
2009	730815	1443352.08	29.23	1.40		11000.0			0	
2010	697219	1470693	31.95	2.38		18546.0			0	
2011	991559	1225646.72	46.24	3.07		48690.0			0	

Year	Clinker production (tonnes)	Lime (tonnes)	Refrigeration Charge (tonnes)	Sulphur Hexafluoride (SF6) (tonnes)	Iron and Steel (tonnes)		Amount of Lead Production (tonne)	Amount of Zinc Production (tonne)	Nitric acid production (tonnes)	Lubricant
					Direct Reduced Iron	Electric Arc Furnace				
2012	1120074	1305950.5	68.53	3.14		68042.0			0	
2013	1208844	1387148.52	75.53	3.14		90423.0			0	
2014	1439260	1024063	33.21	3.92		19240.0			973.35	
2015	1549569	1339144	56.94	5.46		64642.9			0	
2016	1855823	1354508.78	40.38	5.57		45619.0			6850.36	
2017	1237435	1444033.66	53.27	5.57	3738.6	73345.0				
2018	1289326	1517156.54	59.21	5.57	3977.0	73436.0				
2019	1148352	1479788.42	53.56	5.57	14.0	73058.0				
2020	1142526	1459081.3	37.73	5.57	0.0	64548.7	452.2			
2021	1087559	1461228.18	31.84	5.57	12505.0	84527.9	579.8			
2022	986413	176494	45.59	5.57	14920.5	109873.5	91.5			

3.3.4 Emissions Trends under IPPU

The emissions in this sector increased from 1,160.3 Gg CO_2e in the base year (1990) to 1,744.26 Gg CO_2e in the current year (2022). The increase in the IPPU sectoral emissions observed over the longer term are primarily due to growth in emissions associated with the manufacture of mineral products, product uses as substitutes for Ozone Depleting Substances, and other product manufacture and use as presented in Figure 24.

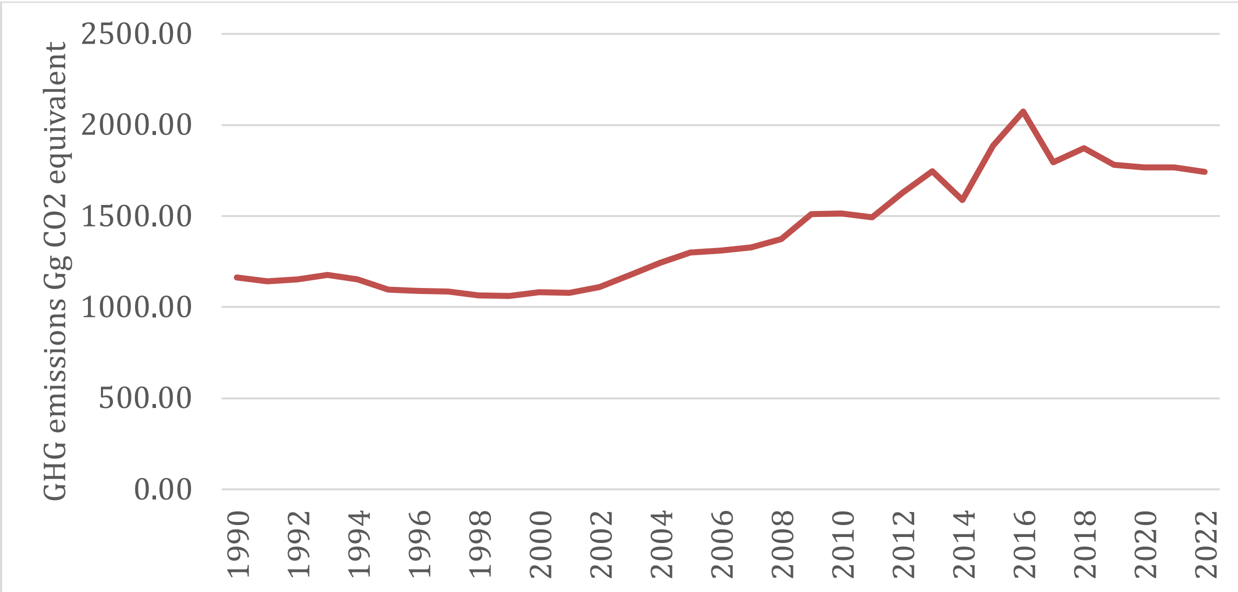


Figure 24: Emissions trends for IPPU

In 2022, the highest source of emissions in the IPPU sector was from the mineral industry at 93.79% with emissions generated from lime and cement production followed by Product Uses as Substitutes for Ozone Depleting Substances at 3.9%, emissions from Metal Industry at 1.10%, emissions from Non-Energy Products from Fuels and Solvent Use with 1.08% and emissions from Other Product Manufacture and Use was almost negligible with 0.05. The details of quantities of emissions (Gg CO_2e) from IPPU by category is provided in table 16.

Table 16: Emissions trends for categories in the IPPU sector(Gg CO2 equivalent)

Categories	2 - Industrial Processes and Product Use	2.A - Mineral Industry	2.B - Chemical Industry	2.C - Metal Industry	2.D - Non-Energy Products from Fuels and Solvent Use	2.E - Electronics Industry	2.F - Product Uses as Substitutes for Ozone Depleting Substances	2.G - Other Product Manufacture and Use	2.H - Other
1990	1161.30	1029.93	99.96	13.44	17.74	0.00	304.20	11.60	0.00
1991	1140.80	1030.45	83.11	8.90	17.75	0.00	0.59	0.00	0.00
1992	1151.27	1030.96	92.47	9.14	17.76	0.00	0.93	0.00	0.00
1993	1176.94	1031.48	119.86	6.54	17.77	0.00	1.28	0.01	0.00
1994	1153.34	1032.29	100.71	0.93	17.78	0.00	1.61	0.02	0.00
1995	1096.46	1032.52	43.33	0.87	17.79	0.00	1.94	0.02	0.00
1996	1087.95	1033.03	33.96	0.87	17.80	0.00	2.27	0.02	0.00
1997	1084.04	1033.55	29.17	0.87	17.80	0.00	2.61	0.02	0.00
1998	1065.13	1034.07	9.37	0.88	17.81	0.00	2.98	0.02	0.00
1999	1061.44	1034.59	4.76	0.88	17.82	0.00	3.37	0.02	0.00
2000	1081.58	1038.79	20.27	0.88	17.83	0.00	3.78	0.03	0.00
2001	1077.19	1049.88	4.36	0.88	17.84	0.00	4.21	0.03	0.00
2002	1111.90	1088.47	0.00	0.88	17.85	0.00	4.67	0.03	0.00
2003	1178.32	1149.75	3.82	0.88	17.86	0.00	5.98	0.03	0.00
2004	1242.53	1215.52	0.00	0.88	17.88	0.00	8.22	0.03	0.00
2005	1299.74	1268.68	0.00	0.88	17.88	0.00	12.08	0.23	0.00
2006	1308.65	1273.42	0.00	0.88	17.88	0.00	16.24	0.23	0.00
2007	1327.06	1288.25	0.00	0.88	17.89	0.00	19.80	0.23	0.00
2008	1375.24	1330.09	0.00	0.88	17.90	0.00	26.14	0.23	0.00
2009	1509.36	1462.55	0.00	0.88	17.91	0.00	27.80	0.23	0.00
2010	1515.31	1465.75	0.00	1.48	17.92	0.00	29.76	0.39	0.00
2011	1491.71	1435.08	0.00	3.90	17.93	0.00	34.31	0.51	0.00

2012	1628.31	1561.90	0.00	5.44	17.94	0.00	42.51	0.52	0.00
2013	1745.75	1669.13	0.00	7.23	17.94	0.00	50.93	0.52	0.00
2014	1589.60	1516.47	2.32	1.54	17.96	0.00	50.66	0.65	0.00
2015	1888.01	1810.17	0.00	5.17	17.96	0.00	54.19	0.52	0.00
2016	2073.78	1980.94	16.34	3.65	17.97	0.00	53.96	0.92	0.00
2017	1796.03	1712.30	0.00	8.48	17.98	0.00	56.35	0.92	0.00
2018	1873.40	1782.51	0.00	8.66	17.99	0.00	63.33	0.92	0.00
2019	1780.48	1687.26	0.00	5.85	18.00	0.00	68.44	0.92	0.00
2020	1767.05	1672.12	0.00	5.25	20.12	0.00	68.64	0.92	0.00
2021	1766.22	1644.91	0.00	15.63	33.93	0.00	70.83	0.92	0.00
2022	1744.26	1635.97	0.00	19.25	18.84	0.00	69.28	0.92	0.00

3.3.5 Emissions Trends by Gas

Provided in Figure 25 is the emissions trend by gas for IPPU for the period 1990 to 2022

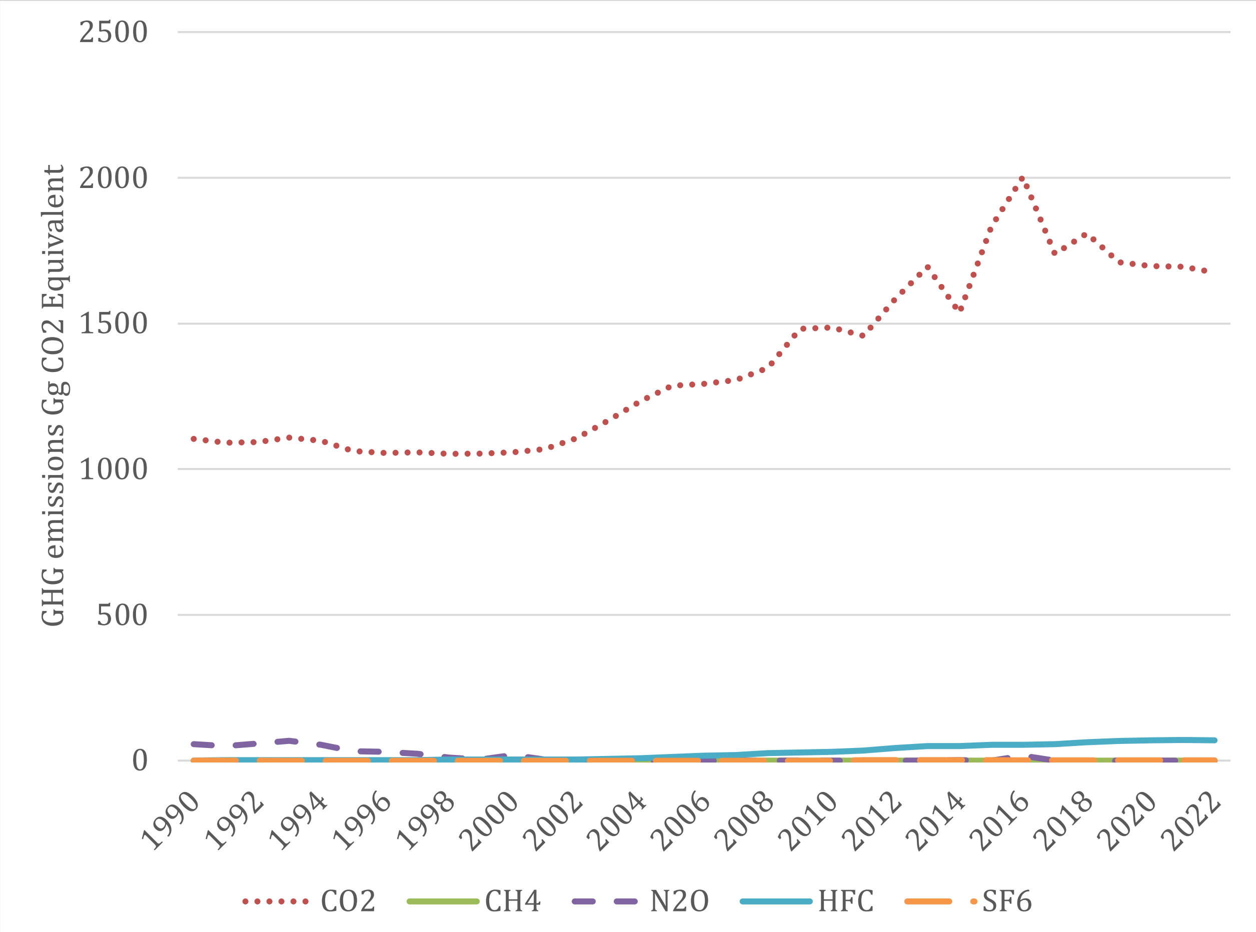


Figure 25;Emissions trend by gas from 1990 to 2022 for the IPPU Sector

In the year 2022, CO_2 was the highest emitted gas in the IPPU sector at 95.98% followed by HFCs at 3.97%. SF6 was almost negligible with 0.05 as shown in Figure 26.

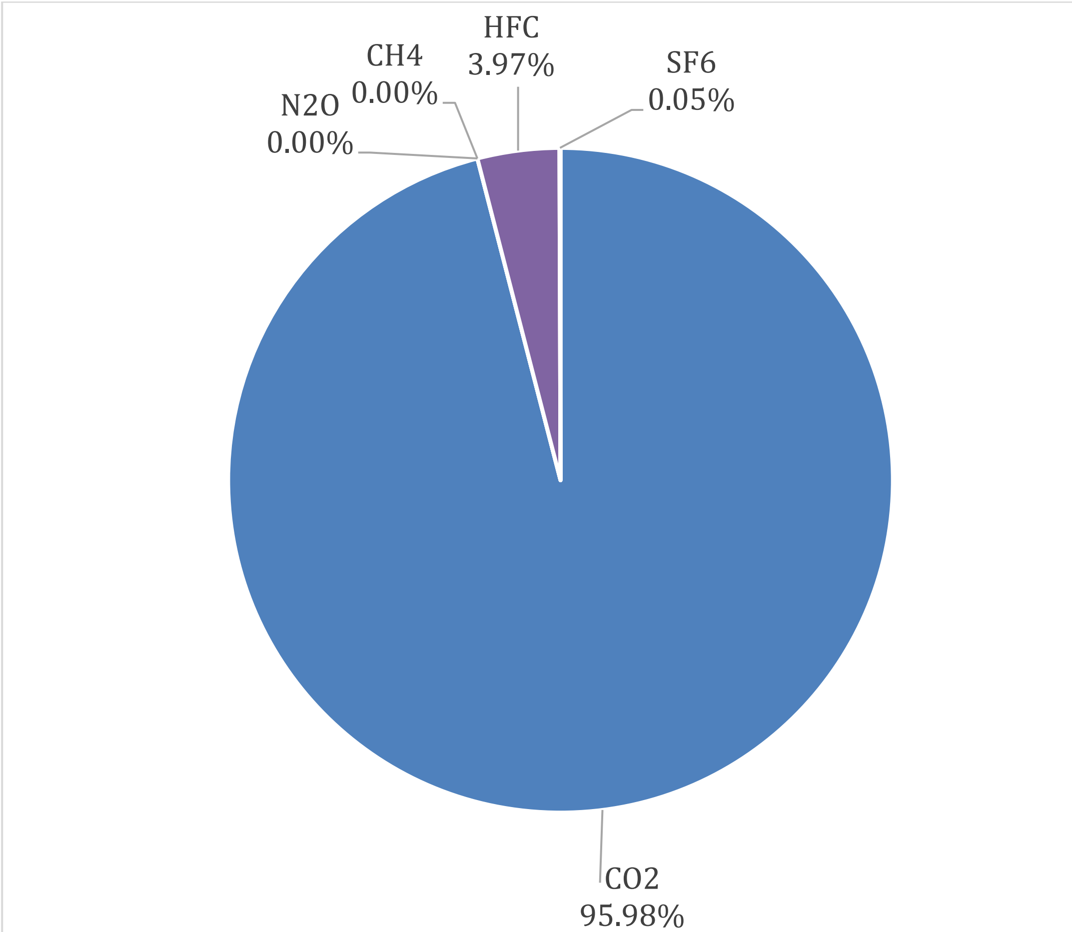


Figure 26: Emissions by gas in 2022 for the IPPU Sector

The main contribution of emissions within the IPPU sector was CO_2 emissions from cement and lime industries. Lubricant use, iron and steel production also contributed marginally to the CO_2 emissions. HFCs were mainly emitted from Refrigeration and Air Conditioning while SF_6 was from electrical equipment. Trends of precursor gases from the IPPU sector are provided in Table 17.

Table 17: Trend of precursor gases for IPPU sector (Gg)

Gas (Gg)	NOx	NMVOC	CO	SO2	NH3
1990	0.698	0.001	0.019	0.009	N/E
1991	0.566	0.001	0.019	0.006	N/E
1992	0.607	0.001	0.019	0.006	N/E
1993	0.835	0.001	0.019	0.004	N/E
1994	0.715	0.001	0.019	0.001	N/E
1995	0.252	0.001	0.019	0.001	N/E
1996	0.163	0.001	0.019	0.001	N/E
1997	0.166	0.001	0.019	0.001	N/E

1998	0.041	0.001	0.019	0.001	N/E
1999	0.021	0.001	0.019	0.001	N/E
2000	0.086	0.001	0.019	0.001	N/E
2001	0.020	0.001	0.019	0.001	N/E
2002	0.001	0.001	0.019	0.001	N/E
2003	0.017	0.001	0.019	0.001	N/E
2004	0.001	0.001	0.019	0.001	N/E
2005	0.001	0.001	0.019	0.001	N/E
2006	0.001	0.001	0.019	0.001	N/E
2007	0.001	0.001	0.019	0.001	N/E
2008	0.001	0.001	0.019	0.001	N/E
2009	0.001	0.001	0.019	0.001	N/E
2010	0.002	0.001	0.032	0.001	N/E
2011	0.006	0.002	0.083	0.003	N/E
2012	0.009	0.003	0.116	0.004	N/E
2013	0.012	0.004	0.154	0.005	N/E
2014	0.012	0.001	0.033	0.001	N/E
2015	0.008	0.003	0.110	0.004	N/E
2016	0.074	0.002	0.078	0.003	N/E
2017	0.010	0.004	0.131	0.005	N/E
2018	0.010	0.004	0.132	0.005	N/E
2019	0.009	0.003	0.124	0.004	N/E
2020	0.008	0.003	0.110	0.004	N/E
2021	0.013	0.004	0.165	0.006	N/E
2022	0.016	0.006	0.212	0.008	N/E

Provided in Table 18 is a Summary report table for IPPU for 2016.

Table 18 Summary table for IPPU for 2022

Categories	(Gg)			CO2 Equivalents(Gg)					(Gg)				
	CO2	CH4	N2O	HFCs	PFCs	SF6	NF3	Other halogenated gases with CO2 equivalent conversion factors (1)	Other halogenated gases without CO2 equivalent conversion factors (2)	NOx	CO	NMVOCs	SO2
2 - Industrial Processes and Product Use	1674.07	0.00	0.00	69.28	0.00	0.92							
2.A - Mineral Industry	1635.97	0.00	0.00										
2.A.1 - Cement production	512.93												
2.A.2 - Lime production	1123.04												
2.A.3 - Glass Production	NO												
2.A.4 - Other Process Uses of Carbonates	NO												
2.A.4.a - Ceramics	NO												
2.A.4.b - Other Uses of Soda Ash	NO												
2.A.4.c - Non Metallurgical Magnesia Production	NO												
2.A.4.d - Other (please specify) (3)	NO												
2.A.5 - Other (please specify) (3)	NO	NO	NO										
2.B - Chemical Industry	NO NO	NO	NO	NO									
2.B.1 - Ammonia Production	NO												
2.B.2 - Nitric Acid Production			NO										
2.B.3 - Adipic Acid Production			NO										

2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			NO										
2.B.5 - Carbide Production	NO	NO											
2.B.6 - Titanium Dioxide Production	NO												
2.B.7 - Soda Ash Production	NO												
2.B.8 - Petrochemical and Carbon Black Production	NO	NO											
2.B.8.a - Methanol	NO	NO											
2.B.8.b - Ethylene	NO	NO											
2.B.8.c - Ethylene Dichloride and Vinyl Chloride Monomer	NO	NO											
2.B.8.d - Ethylene Oxide	NO	NO											
2.B.8.e - Acrylonitrile	NO	NO											
2.B.8.f - Carbon Black	NO	NO											
2.B.8.x - Other petrochemical production	NO	NO											
2.B.9 - Fluorochemical Production				NO									
2.B.9.a - By-product emissions (4)				NO									
2.B.9.b - Fugitive Emissions (4)													
2.B.10 - Hydrogen Production	NO	NO	NO										
2.B.11 - Other (Please specify) (3)	NO	NO	NO										

2.C - Metal Industry	19.25	NO			0.00								
2.C.1 - Iron and Steel Production	19.23	NO											
2.C.2 - Ferroalloys Production	NO	NO											
2.C.3 - Aluminium production	NO				NO								
2.C.4 - Magnesium production (5)	NO												
2.C.5 - Lead Production	NO												
2.C.6 - Zinc Production	NO												
2.C.7 - Rare Earths Production	NO												
2.C.8 - Other (please specify) (3)	NO												
2.D - Non-Energy Products from Fuels and Solvent Use (6)	18.84	NO	NO										
2.D.1 - Lubricant Use	18.84												
2.D.2 - Paraffin Wax Use	NE												
2.D.3 - Solvent Use (7)													
2.D.4 - Other (please specify) (3), (8)	NO	NO	NO										
2.E - Electronics Industry			0.00		0.00	0.00							
2.E.1 - Integrated Circuit or Semiconductor (9)			NO										
2.E.2 - TFT Flat Panel Display (9)			NO										
2.E.3 - Photovoltaics (9)													
2.E.4 - Heat Transfer Fluid (10)													
2.E.5 - Other (please specify) (3)	NO	NO	NO		NO	NO							

2.F - Product Uses as Substitutes for Ozone Depleting Substances				69.28		NO							
2.F.1 - Refrigeration and Air Conditioning				69.28		NO							
2.F.1.a - Refrigeration and Stationary Air Conditioning				69.28		NO							
2.F.1.b - Mobile Air Conditioning													
2.F.2 - Foam Blowing Agents													
2.F.3 - Fire Protection													
2.F.4 - Aerosols													
2.F.5 - Solvents													
2.F.6 - Other Applications (please specify) (3)													
2.G - Other Product Manufacture and Use			0.00			0.92							
2.G.1 - Electrical Equipment						0.92							
2.G.1.a - Manufacture of Electrical Equipment													
2.G.1.b - Use of Electrical Equipment						0.92							
2.G.1.c - Disposal of Electrical Equipment													
2.G.2 - SF6 and PFCs from Other Product Uses						0.00							

2.G.2.a - Military Applications						NO							
2.G.2.b - Accelerators						NO							
2.G.2.c - Other (please specify) (3)						NO							
2.G.3 - N2O from Product Uses			0.00										
2.G.3.a - Medical Applications			NO										
2.G.3.b - Propellant for pressure and aerosol products			NO										
2.G.3.c - Other (Please specify) (3)			NO										
2.G.4 - Other (Please specify) (3)	NO	NO	NO										
2.H - Other	NO	NO	NO										
2.H.1 - Pulp and Paper Industry	NO	NO	NO										
2.H.2 - Food and Beverages Industry	NO	NO	NO										
2.H.3 - Other (please specify) (3)													

3.3.6 Emissions by IPPU Category

This section provides respective emissions, activity data and emission factors and methodologies for categories under IPPU.

Mineral Industry

The emissions source categories resulting from the consumption of carbonates from cement and lime production, including non-metallurgical magnesia were estimated. Emissions for the mineral industry increased from 1,029.93Gg $CO_{2\ eq.}$ in the base year 1990 to 1,635.97 Gg $CO_{2\ eq.}$ in the current year 2022 as presented in Figure 27. The major sources of emissions are attributed to lime production at 68.6% followed by cement production at 31.3% with CO_2 being the only emitted gas from the mineral industry in 2022.

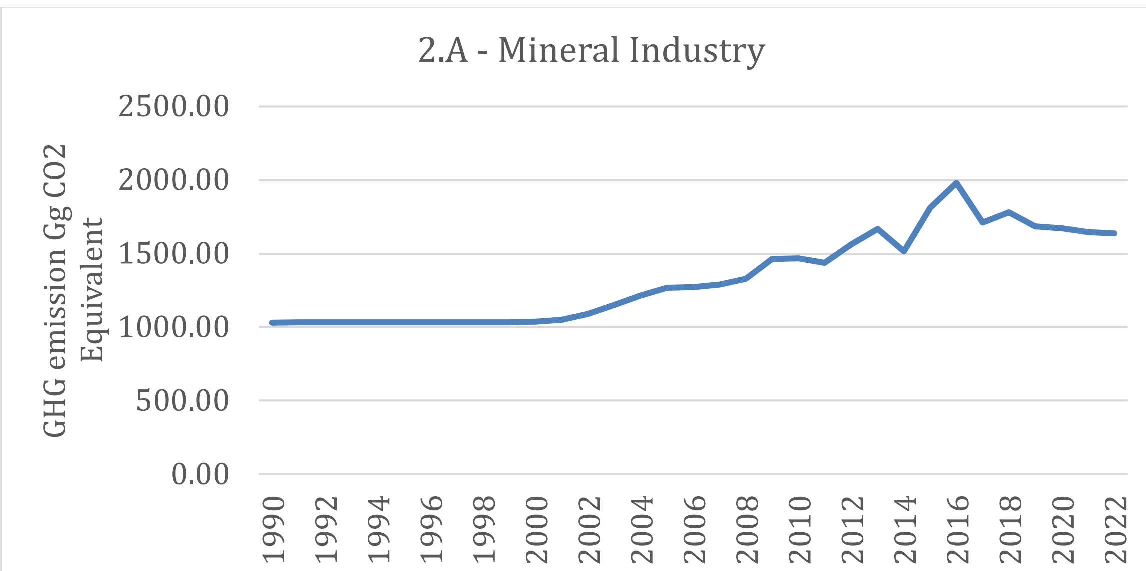


Figure 27: Trends of emissions for Mineral Industry Category.

Chemical Industry

GHG emissions from the chemical industry arise from the production of various in-organic and organic chemicals. The chemical industries include: Ammonia production; nitric acid production; adipic acid production; caprolactam, glyoxal, and glyoxylic acid; production of carbide; titanium dioxide; and soda ash. While CO_2 and N_2O were reported for 1994, 2000, 2014 and 2016, no emissions occurred in this category for the years 2005 to 2013 and 2015 and 2020 due to discontinuity in the production of ammonia and nitric acid in

Zambia. Figure 28 provides emissions from the chemical industry. Emissions reduced from 99.96 Gg $CO_{2\ eq,}$ in 1990 to zero in 2022.

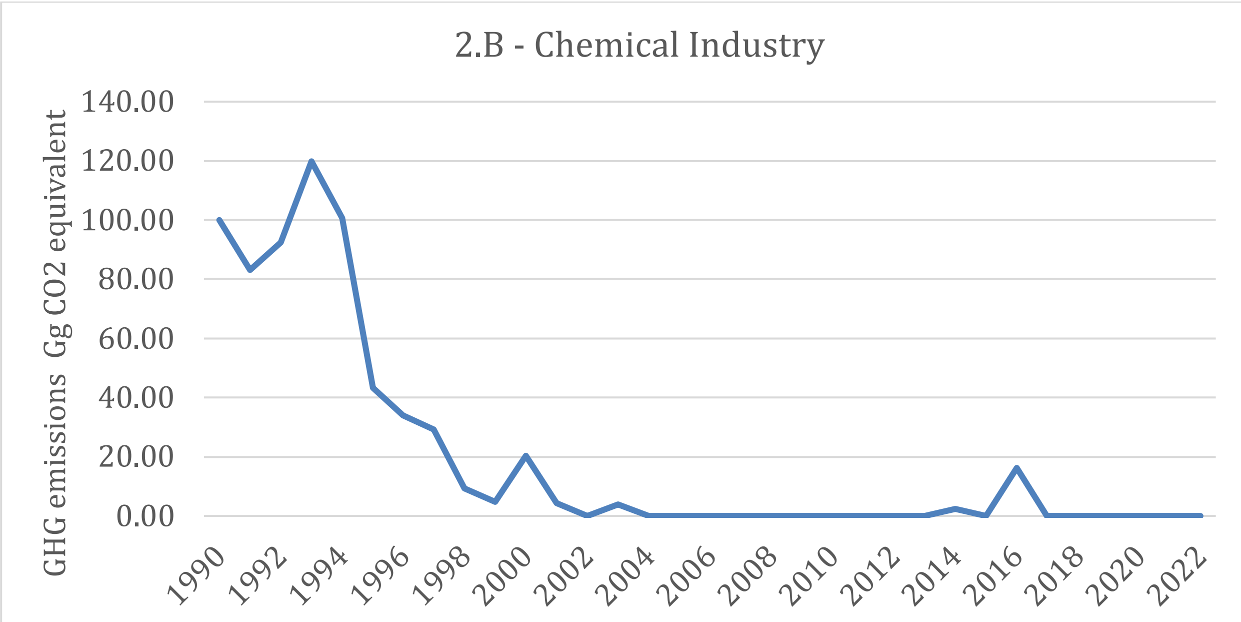


Figure 28: Emission from Chemical Industry

Metal Industry

Metal industry covers emissions from the production of iron and steel, metallurgical coke, ferroalloy, aluminum, magnesium, lead and zinc. In this subsector, lead and steel production were the primary sources of emissions. However, there was no data for metal industry production for the years 2000 and 2005. In 1990 to 1994 production of lead and zinc contributed to the emissions however, the production subsequently ceased as a result of closure of the mine. Emissions declined from 1990 to 1994, and remained marginal up to 2010. After 2010, the emissions increased moderately until 2020 and thereafter recorded a sharp increase until 2022 as shown in figure 29.

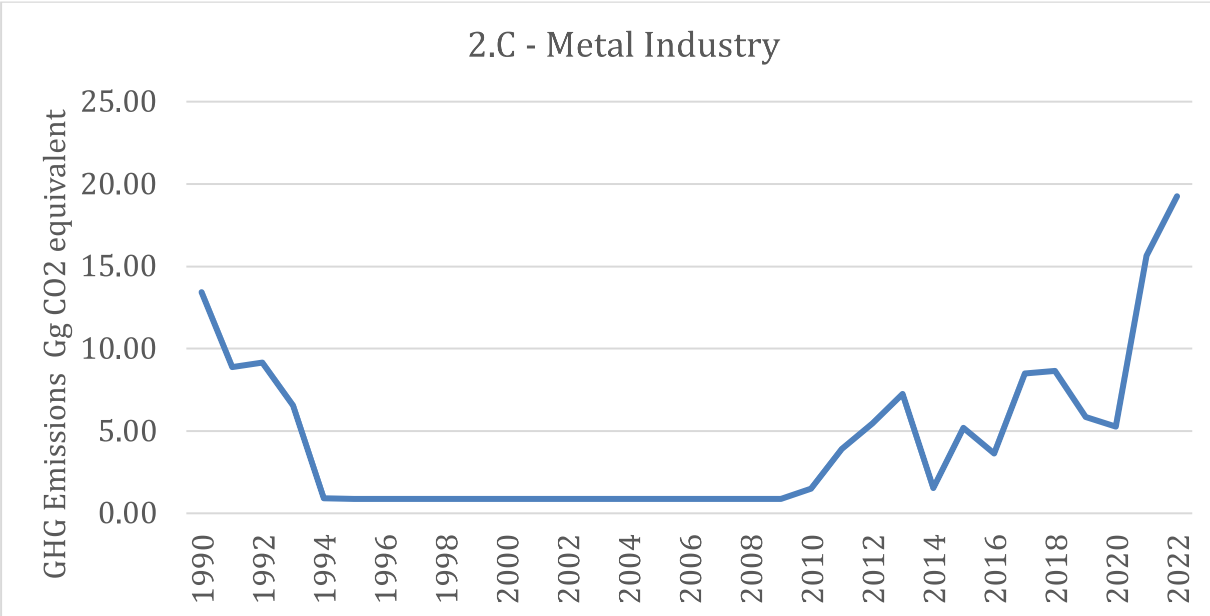


Figure 29: Emissions from the metal industry

In the period under review, the Metal Industry in Zambia was characterised by Iron and Steel production. The Iron and Steel production has been growing rapidly by demand from the construction and mining industries both in the domestic and regional markets. Many local and foreign investors had set up their manufacturing bases of steel products in Zambia and the factories utilise scrap metal as the primary raw material. Several steel makers began operations and have continued expanding their operations. This explains the sharp increase in iron and steel production between 2011 and 2014. However, as steel manufacturers expanded their production, it was getting harder for the companies to find steel scrap at reasonable prices. It became clear that steel scrap alone will not be able to sustain Zambian steel-making, hence the decline in production in 2015 and 2016 and then increased steadily through to 2022.

Non-Energy Products from Fuels and Solvent Use

This category presents the GHG emissions from the use of non-energy products (lubricants, waxes, greases, and solvents). In 2005, the emissions from non-energy products from fuels and Solvent Use was 17.74 Gg CO_2eq. and remained steady until 2020. Emissions increased sharply in 2021 and declined again in 2022 as presented in Figure 30. The emissions were estimated from use of lubricants.

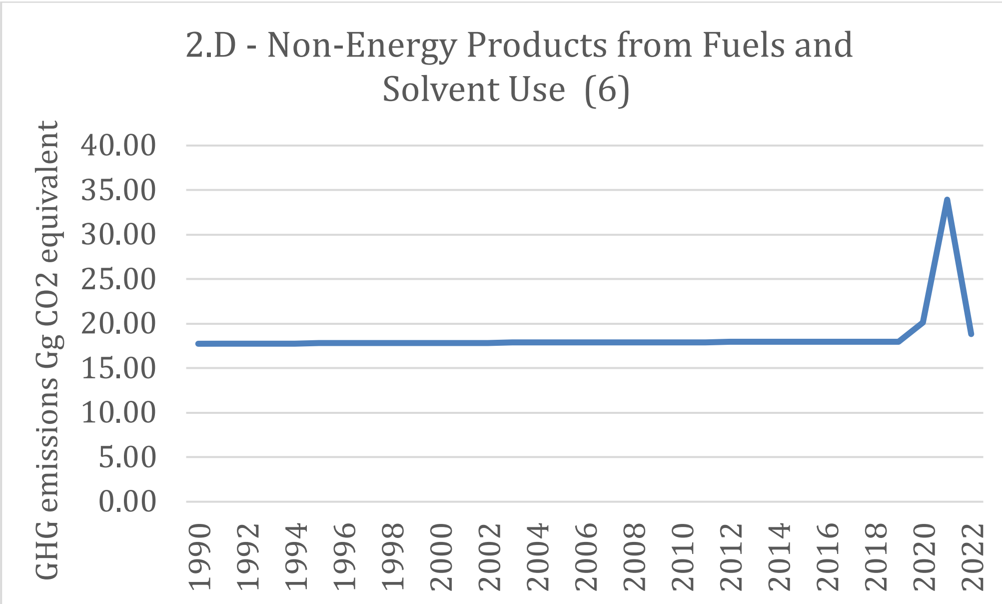


Figure 30: Emissions from the Non-Energy products from fuels and Solvent Use

Non-energy use of fuels and solvents includes lubricants, paraffin wax and solvents. Emissions from solvents and paraffin wax are not estimated due to a lack of activity data. Lubricants are divided into two types, namely, motor and industrial oils, and greases that differ in physical characteristics. Lubricants are mainly used in industrial and transport applications. This market is segmented into commercial and retail. The market continues to be plagued by unlicensed operators who continue to flood the market with imported lubricants[19].

Electronics Industry

No activity occurred under this category in Zambia from 1990 to 2022 and hence, emissions estimates were not calculated

Products Uses as Substitutes for Ozone Depleting Substances

Under this category Hydrofluorocarbons (HFCs) serving as alternatives to Ozone Depleting Substances (ODS) is used in refrigeration and air conditioning; fire suppression and explosion protection; aerosols; solvent cleaning; foam blowing; and other applications. Emissions in this category were mainly from refrigeration and air conditioning and the gas considered was HFC-134 a (CH_2FCF_3). The emissions increased from 0.23 Gg CO_2 eq. in the base year 1990 to 69.28 Gg CO_2 eq. in the current year 2022 as shown in Figure 31 This significant increase is attributed to both growth in refrigeration and air conditioning.

[19] (UNCTAD/DITC/CLP/2011/1)

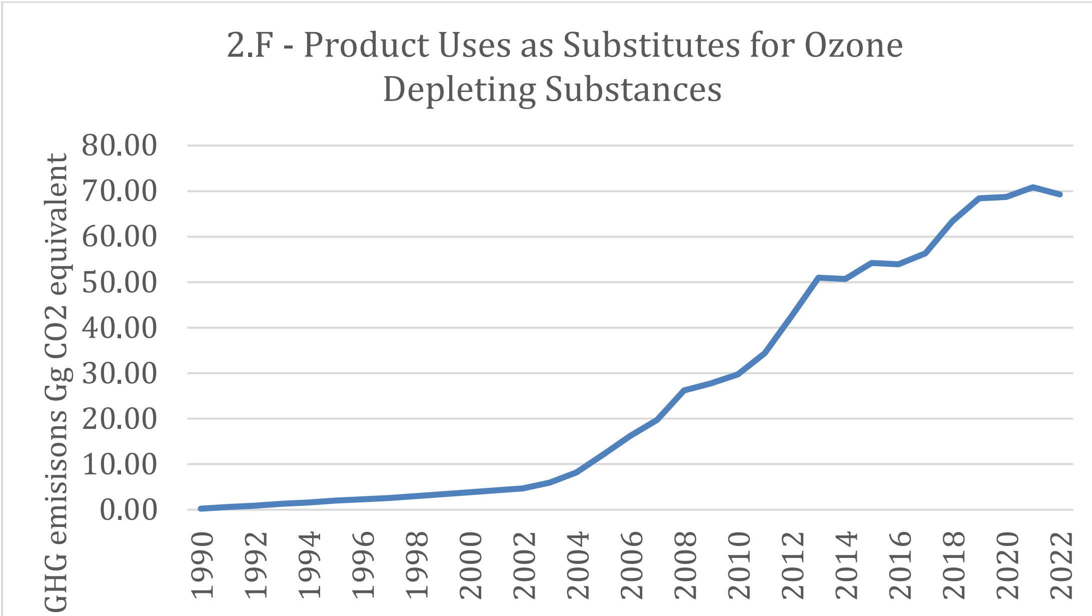


Figure 31: Emissions from Product Uses as Substitutes for Ozone Depleting Substances

Other Product Manufacture and Use

The sources of emissions under this category were SF_6 and PFCs from the manufacture and use of electrical equipment. N_2O emissions are generated from several products, but data was unavailable. Calculations of emissions were based on the use of electric equipment. Emissions increased from 0.00 Gg CO_2 eq. in 1990 to 0.92 Gg CO_2 eq. in 2022. Figure 32 shows the emissions generated from electrical equipment for the period 1990 to 2022.

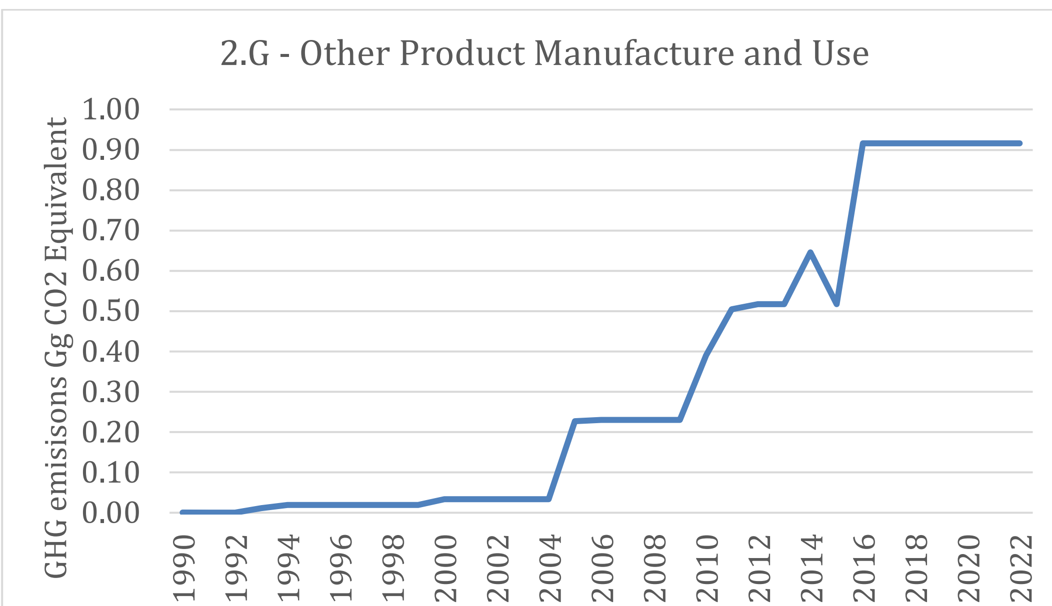


Figure 32: SF_6 Emissions from use of electric equipment

3.3.7 Quality assurance/quality control measures

Activity data used in estimating GHG emissions from the IPPU was obtained from industries (Lubricants), ZAMSTATS, Zambia Revenue Authority. Efforts were made to compare data from various sources and compile the most suitable data sets for use in emissions estimates. Efforts were made to check and verify the data from all sources to ensure good quality data was utilised in the inventory preparation from the IPPU sector.

3.3.8 Sectoral uncertainties,

The Uncertainty Analysis (UA) for the year 2022 for IPPU sector was estimated using approach 1 and computed using the IPCC 2006 software and is provided in Annex II . Uncertainty arose from the quantity of cement and lime produced. Slight differences were observed between data from the Zambia Revenue Authority, ZAMSTATs, and from manufacturers. As regards nitric acid and ammonia production data was obtained from factory records with uncertainty of ±2%. Data on steel production was obtained from ZRA and ZAMSTAT database whose uncertainty was about ±5%. Data on lubricants were obtained from the Ministry of Energy database. Uncertainty for data on SF6 in electrical equipment was ±2% obtained from nameplate capacity from electricity utility companies.

3.3.9 Planned improvements

The activity data for IPPU was derived from Central Statistical Office (CSO), and Zambia Revenue Authority (ZRA). Further, there is a need to incorporate GHG inventory parameters in the ZRA data capturing instruments. This will enable capturing of activity data accurately for refrigeration, fertilisers, petroleum products (lubricants), fire protection, solvents, aerosols and N_2O for medical applications. Improvement in future inventories would require use of clinker production quantities as opposed to cement production figures. It is recommended that activity data be collected from all lime production plants in Zambia and obtain information of dolomitic lime. Another improvement would be the development of country-specific emission factors and hydrated lime correction factors. Other activity data gaps in the IPPU Sector include the following:

- Limited activity data in fuel used as feedstock and lubricant consumption records.
- Inconsistent/insufficient activity data. It was observed that non-ferrous metals present an inconsistent fuel *use* (majorly coal) reporting from the current data sources. Industry facilities produce ferro-alloys through integrated unit operations; it is difficult for data sources like CSO to keep a measure of exact production statistics of ferro-alloys. The Chemical Industry; activity data is insufficient from the current data sources. Other areas that need improvement in data collection are

Textile and leather/ Paper and pulp, Food and Beverage: Wood and wood products. The activity data obtained from the ZRA and CSO for many of these sectors is not consistent across the years. There is therefore need harmonise data from these two sources.

- Industry specific information lies mainly within the individual manufacturing units. An annual Survey of manufacturing Industries, can be used as a prime source of information for the GHG estimations in the IPPU sector.

3.4 Agriculture Forestry and Other Land Use(AFOLU)

The Agriculture Forestry and Other Land Use (AFOLU) sector in Zambia contributes significantly to GHG emissions, primarily through activities like deforestation (wood removals – Timber harvesting, fuelwood extraction and disturbances – (wildfires, pest outbreaks and land degradation), agricultural practices, and livestock management. Emission Reductions from Deforestation and Forest Degradation, Conservation, Enhancement of Carbon Stocks and Sustainable Forest Management (also known as REDD+) is a key outcome of the United Nations Framework Convention on Climate Change (UNFCCC) aimed to reduce emissions from tropical deforestation and degradation in developing countries.

Emissions Trend by Category in the AFOLU Sector

AFOLU consists of three categories namely Livestock, Land and Aggregate Sources and Non-CO2 emissions on land. Zambia recorded a progressive increase in emissions from AFOLU across the time series, during the period under review. Overall gross emissions from AFOLU increased by 115% from 93636.2Gg CO_2 e in the base year 1990 to 202051.8 Gg CO_2e in the current year 2022 as given in Figure 33. On the other hand, gross removals reduced from -164745.1Gg CO_2 in the base year 1990 to -160,443.0Gg CO_2 in current year 2022, representing a reduction of 3%.

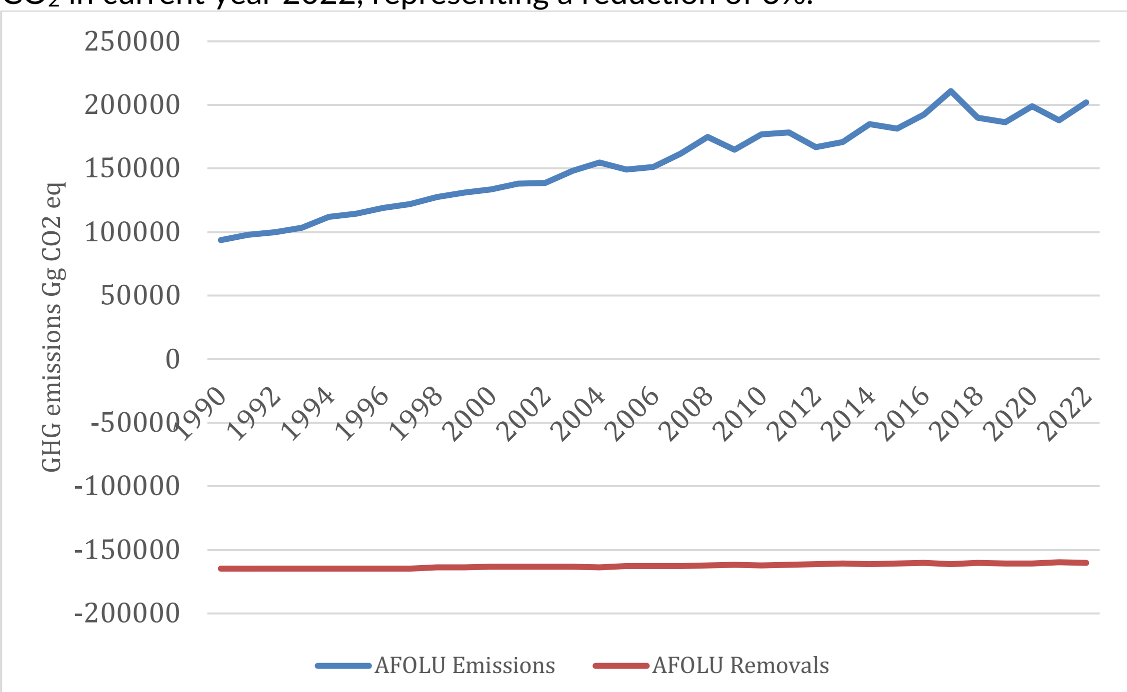


Figure 33: Trends of emissions and removals for AFOLU

Provided in Table 19 Trends of emissions and removals for AFOLU

Table 19: Trends of emissions and removals for AFOLU

	AFOLU Emissions	AFOLU Removals
1990	93636.19	-164745
1991	97855.75	-164778
1992	99987.53	-164679
1993	103284.3	-164665
1994	111924.7	-164652
1995	114609.9	-164621
1996	118853.9	-164716
1997	122109.8	-164721
1998	127357	-163737
1999	131204.1	-163511
2000	133699.6	-163477
2001	137847.7	-163346
2002	138702.3	-163222
2003	148243.2	-163077
2004	154401.8	-163931
2005	148942.4	-162841
2006	151059.1	-162727
2007	161559.3	-162910
2008	174795.5	-162328
2009	164823.7	-161498
2010	176915.4	-162185
2011	178053.2	-161887
2012	166890.9	-161045
2013	170840.1	-160901
2014	184796.9	-161452
2015	181181.1	-160609
2016	192416.8	-160414
2017	210849.2	-161171
2018	189895.8	-160177
2019	186340.8	-160882
2020	198994	-160737
2021	187778.6	-159743
2022	202051.8	-160443

In terms of AFOLU sub - categories, the trends show increasing growth of emissions from Livestock, Land, and Aggregate sources and non-CO_2 emissions sources on land as presented in Figure 34. In the current reporting year, 2022, the highest GHG emissions contribution was from Land with 87.4% (176604.9Gg CO_2e) followed by Livestock at 6.7% (13,586.7 Gg CO_2e). The least was "Aggregate sources and Non-CO_2 emissions sources on Land" which contributed 6% (11860.2Gg CO_2e).

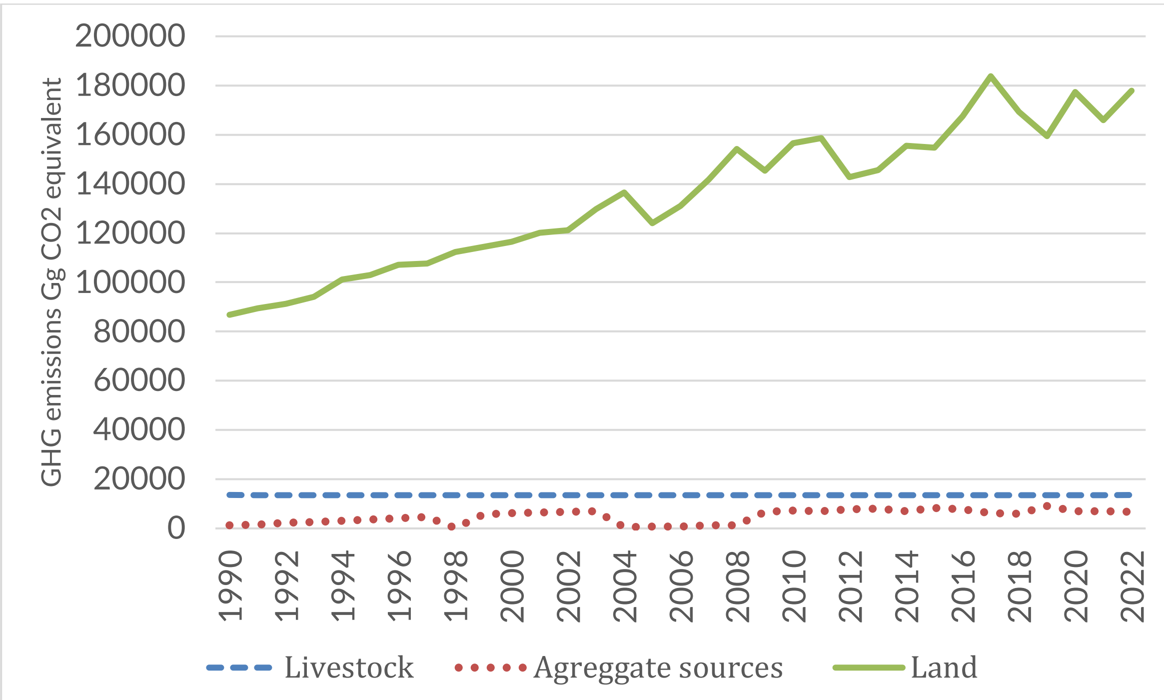


Figure 34: Emissions trends and contribution by category from AFOLU sector

Emissions Trend by Gas for AFOLU Sector

The emissions by gas for the period 1990 to 2022 as shown in table 35 indicates that the most dominant gas across the timeline was CO_2, followed by CH_4 and N_2O. Emissions of CO_2 increased from 85331.7Gg CO_2e. in the base year 1990 to 176725.7 Gg CO_2e in the current year 2022. As regards CH_4, it indicated an increase from 6915.7Gg CO_2e in the base year 1990 to 16963.8Gg CO_2e in the current year 2022. In the case of N_2O, the emissions increased by 72.4% from 424.8 Gg CO_2e in 1990 to 3202.8 Gg CO_2e. in 2022 as shown in (Table 20).

Table 20 Trend of Emissions by Gas for AFOLU (Gg CO2e.)

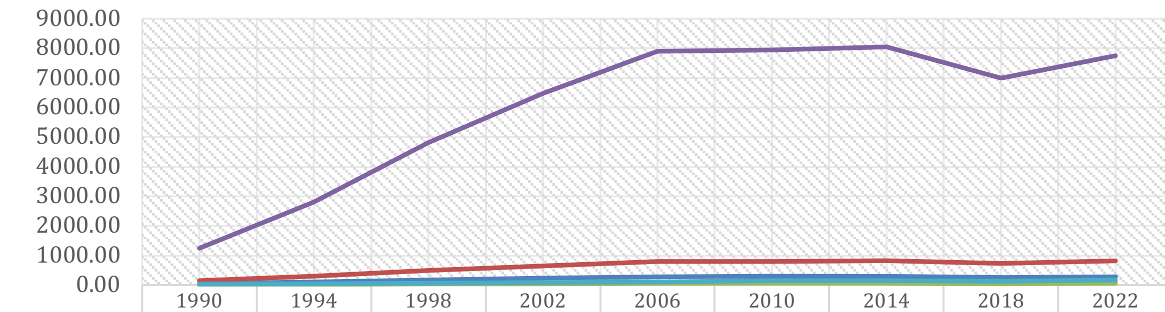
	CO2	CH4	N2O	Total Emissions	Removals
1990	85331.7	6915.7	424.8	92672.2	-164745.1

1991	88021.1	7777.0	583.5	96381.6	-164778.3
1992	89866.9	7901.3	916.6	98684.8	-164678.5
1993	92640.0	8109.6	916.6	101666.2	-164665.4
1994	99377.2	8473.6	1107.4	108958.3	-164652.3
1995	101440.7	8432.2	1269.6	111142.5	-164621.5
1996	105190.8	8230.3	1471.5	114892.6	-164716.0
1997	106107.2	9885.8	1657.3	117650.3	-164720.5
1998	110395.8	10231.0	1826.4	122453.2	-163737.4
1999	112664.8	11057.1	2018.0	125739.9	-163510.9
2000	114769.1	10679.0	2289.1	127737.2	-163476.7
2001	118378.9	10903.3	2337.0	131619.2	-163345.8
2002	119259.5	10517.5	2452.0	132229.1	-163222.3
2003	128173.9	10518.2	2666.2	141358.3	-163076.9
2004	134982.2	10322.4	2677.3	147981.9	-163930.5
2005	122851.0	13673.8	3361.0	139885.8	-162841.0
2006	130178.0	12412.4	2544.3	145134.7	-162726.9
2007	141275.8	11798.6	2620.6	155694.9	-162909.9
2008	153776.5	12689.4	2813.8	169279.7	-162327.8
2009	144308.7	12689.4	2384.2	159382.3	-161498.4
2010	155398.6	12803.0	2676.8	170878.3	-162184.5
2011	157280.6	11621.1	2701.1	171602.9	-161887.0
2012	141377.1	15472.5	2875.3	159724.9	-161045.4
2013	144170.3	16163.8	3020.2	163354.4	-160900.5
2014	154416.4	21526.1	2753.4	178695.9	-161451.7
2015	153293.5	16302.1	3912.7	173508.4	-160609.0
2016	166070.2	16103.2	3032.9	185206.3	-160414.2
2017	182639.1	20462.3	2498.2	205599.6	-161171.1
2018	167797.8	14536.8	2405.4	184740.0	-160176.9
2019	157993.9	10929.7	3224.8	172148.4	-160881.9
2020	175891.1	14025.1	2725.3	192641.5	-160737.2
2021	164442.9	14486.4	3072.4	182001.6	-159743.1
2022	176725.7	16963.8	3202.8	196892.3	-160443.0

The source for CO_2 was mainly from land use change conversion, wood removals (timber harvesting), fuelwood removals, biomass burning and liming. N_2O and CH_4 emissions were mainly from manure management and enteric fermentation, respectively.

Precursor Gas Emissions trend for AFOLU

Precursor gases that include; NOx, CO, NMVOC, SOx and NH_3 were estimated from Aggregate sources and non-CO_2 emissions sources on land and these include; biomass burning (in forestland, grassland and cropland), livestock (manure management) and crop farming (rice cultivation and fertiliser application). The estimations were based on EMEP/EEA air pollutant emission inventory guidebook 2023[20]. Provided in Figure 35 are trends of precursor gases (Gg) in AFOLU for the period 1990 to 2022.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
NO2	47.02	100.28	170.81	229.02	277.87	288.95	294.67	257.06	288.28
NMVOC	149.44	292.58	485.52	637.75	786.82	798.74	822.87	721.70	811.66
SOX	7.92	20.60	35.93	48.15	57.64	56.23	56.19	49.56	53.50
CO	1244.50	2802.82	4817.85	6473.19	7910.68	7945.26	8048.34	6995.96	7756.55
NH3	33.55	41.55	61.37	81.13	98.58	141.32	154.62	134.49	168.09

Figure 35: Precursor gases under AFOLU.

Generally, the trend showed a steady increase in emission of all the precursor gases, with the highest share being for CO and followed by NMVOC. In the current reporting year (2022), CO emissions amounted to 7,756.55 Gg representing over 500% increase against CO emissions (1,244.50 Gg) in the base year, 1990. The main contributors to emission of CO were biomass burning and rice cultivation. Table 22 provides details of emissions of precursor gases from the assessed sub-categories in AFOLU for the current year, 2022.

Table 21: Precursor gases from the assessed sub-categories in AFOLU for the year 2022

	Emissions (Gg)				
Precursor Gases	**NOx**	**NMVOC**	**SOX**	**CO**	**NH3**
3B1a Dairy cattle	0.16	3.77	N/A	N/A	0.93
3B1b Other cattle	0.97	39.78	N/A	N/A	8.94
3B2 Sheep	0.00	0.04	N/A	N/A	0.21
3B3 Swine	0.55	1.28	N/A	N/A	0.00
3B4a Buffalo	0.00	0.01	N/A	N/A	0.01
3B4d Goats	0.05	2.42	N/A	N/A	3.56
3B4e Horses	0.09	1.60	N/A	N/A	2.28
3B4f Mules and asses	0.00	0.00	N/A	N/A	0.02
Poultry	0.61	7.38	N/A	N/A	0.00

[20] EMEP/EEA air pollutant emission inventory guidebook 2023 | European Environment Agency's home page

Sub-total – Livestock	2.44	56.28	0.00	0.00	15.94
Forestry					
3.C.1.a - Burning in Forest Land	17.54	52.63	3.51	526.26	3.51
3.C.1.b - Burning in Cropland	0.01	0.00	0.00	0.43	0.02
3.C.1.c - Burning in Grassland	155.56	406.84	35.90	4463.29	35.90
Sub-total – Forestry	173.11	459.47	39.41	4989.98	39.42
3.C.3 - Urea Application	4.19				
3.C.7 - Rice cultivation	112.73	295.92	14.09	2766.57	112.73
Sub-total - Crop farming	112.73	295.92	14.09	2766.57	112.73
Total	**288.28**	**811.66**	**53.50**	**7756.55**	**168.09**

Provided in Table 22 are trends of precursor gases Biomass Burning in Forest Land.

Table 22: Trend of precursor gases for AFOLU (Gg)

	NOx	NMVOC	SOX	CO	NH3
1990	47.0	149.4	7.9	1244.5	33.5
1991	69.3	209.0	12.1	1845.1	46.0
1992	84.6	249.1	15.4	2274.5	51.2
1993	99.7	290.2	18.9	2717.1	53.7
1994	100.3	292.6	20.6	2802.8	41.6
1995	122.9	352.0	25.1	3430.1	51.3
1996	139.7	396.5	28.8	3914.4	54.8
1997	162.4	461.8	33.2	4539.0	65.6
1998	170.8	485.5	35.9	4817.8	61.4
1999	204.1	574.7	41.7	5709.4	82.4
2000	205.6	579.2	43.5	5813.3	70.5
2001	224.6	629.9	46.7	6317.3	83.2
2002	229.0	637.7	48.2	6473.2	81.1
2003	242.5	671.0	52.0	6882.2	79.4
2004	215.3	598.7	47.9	6184.2	58.0
2005	231.2	645.0	51.4	6641.0	64.7
2006	277.9	786.8	57.6	7910.7	98.6
2007	258.7	718.0	53.1	7250.3	105.4
2008	285.2	788.5	57.6	7968.8	119.5
2009	256.4	713.4	49.9	7059.2	125.6
2010	289.0	798.7	56.2	7945.3	141.3
2011	279.2	770.5	54.3	7692.6	134.6
2012	289.9	813.6	57.1	8030.0	134.8
2013	316.4	885.6	61.3	8720.6	154.3
2014	294.7	822.9	56.2	8048.3	154.6

2015	327.6	916.8	62.6	9002.3	165.1
2016	277.3	781.8	55.6	7719.8	122.5
2017	248.0	699.1	47.5	6764.0	130.5
2018	257.1	721.7	49.6	6996.0	134.5
2019	352.0	989.5	66.2	9641.2	181.9
2020	269.7	763.0	52.4	7409.1	133.2
2021	297.1	832.8	54.5	8010.4	172.6
2022	288.3	811.7	53.5	7756.6	168.1

3.4.1 Livestock

3.4.1.1 Overview

The livestock sub-sectors are key to agricultural development in Zambia and plays a pivotal role to job creation and economic diversification. However, the sub-sector also contributes significantly to greenhouse gas (GHG) emissions more than 25% (3.8 gigatons of CO2e) from food systems, particularly methane from livestock manure and enteric fermentation. The sub-sector accounts for 82.5% of the 1,417,992 smallholder farmers, which sustains over 60% of the population (2023 Livestock Survey Report-ZAMSTATS), faces growing challenges due to climate change, and environmental degradation.

There are three Livestock production systems practiced in Zambia and these are; extensive, semi-intensive and intensive. Under the extensive system, the livestock is expected to meet all its nutritional requirements including water, by itself. This is the most commonly practiced production system among smallholder farmers and is associated with high greenhouse gas emissions. In the semi-intensive production system, the livestock are given some supplementary feed in addition to own grazing in the rangelands. In an intensive production system, the farmers provide all the nutritional requirements of the livestock.

The extensive production system is the most commonly practiced according to the 2017/2018 Livestock and Aquaculture census Report Summary. This system mostly involves rearing the livestock in an open and communally grazed rangeland. This means livestock are left to graze in open grasslands which are communally owned and the different herds of livestock mix with each other. The system is mostly characterised by poor rangeland management largely due to uncontrolled grazing which usually leads to over-grazing and ultimately, soil degradation. In Zambia 72.2% of the Agricultural households are involved in livestock-raising activities and this entails that the majority of the total livestock population is owned by (1,417,992) smallholder farmers. The average typical livestock weight is 450kg. In the extensive grazing system, livestock requires 15 hectares of land to survive in the entire year without any feed interventions.

Most farmers in Zambia do not apply recommended manure management practices, such as roofing animal housing, having a water-proof floor or covering manure during storage, causing large nutrient losses during manure storage, increasing greenhouse gas emissions, and reducing the quality of the manure as a fertilizer. In general Dairy cattle are kept mostly under a confined system where they are kept in a small area. This entails most of the cow dung is cleaned and piled for use in gardens and field crops as fertilizer.
In the recent past, the Government and its cooperating partners have been promoting the construction of bio digesters using animal manure where farmers can benefit from the gas produced which is used for cooking. Some notable organisations that are promoting the use of bio digesters are SNV and Musika.

3.4.1.2 Methodology and Emission factors

(a) Enteric Fermentation

For Dairy Cattle and Other Cattle, Tier 2 methodology was used while Tier 1 was used for other livestock. The following Tier 2 methodologies were used for Dairy cattle and Other cattle.

Emission factor for each animal category was determined using equation 10.2.1 as provided for in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

EF=(GE*Ym/100*365)/55.65	Equation 10.21

Where:

EF	emission factors, kg CH4 head^{-1} year^{-1}
GE	gross energy intake, MJ head^{-1} day^{-1}
Ym	methane conversion factor, % of gross energy in feed converted to methane
55.65	energy content of methane, MJ/kg CH4

Net Energy for Maintenance

Net energy for maintenance (NEm) is the net energy required for maintenance, which is the amount of energy needed to keep the animal in equilibrium where body energy is neither gained nor lost. It is determined from the equation 10.13 below:

$NE_m = CF_i * (Weight)^{0.75}$	Equation 10.13

Where:

NE_m	net energy required by the animal for maintenance MJ day^{-1}
CF_i	a coefficient which varies for each animal category (Table 4.1),
$Weight$	live-weight of animal, kg

$CF_{i(in\_cold)} = CF_i * 0.0048 * (20 - {}^oC)$	**Equation 10.13**

Where:

$CF_{i(in\_cold)}$	coefficient which varies for each animal category MJ day^{-1} kg^{-1}
CF_i	a coefficient which varies for each animal category (Table 4.1),
${}^oC$	mean daily temperature in winter season

Table 23: Average Coefficient for Calculating Net Energy for Maintenance

	Cf(in_cold)
Lactating Cows	0.386
Non-lactating cows	0.322
Bulls	0.37

SOURCE: 2019 REFINEMENT TO THE 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES.

Results of Net energy required by the animal for maintenance for dairy cattle and Other cattle is provided below. Net energy required by the animal for maintenance under dairy cattle for Adult cows, Adult bulls, Heifers, Growing males and Calves is provided in Table 23.

Net Energy for Animal Activity

Net energy for activity: (NEa) is the net energy for activity, or the energy needed for animals to obtain their food, water and shelter. It is based on its feeding situation rather than characteristics of the feed itself. Net energy for activity is determined using equation 10.14

$NE_a = C_a * NE_m$	**Equation 10.14**

Where:

NE_a	net energy for activity, MJ day^{-1}
C_a	a coefficient corresponding to animal's feeding situation (Table 25)

Table 2 COEFFICIENT CORRESPONDING TO ANIMAL'S FEEDING SITUATION

Feed situation	**Ca**
Stall	0
Pasture	0.17
Grazing Large Areas	0.36

Source: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Net Energy for Growth

Net energy for growth: (NEg) is the net energy needed for growth (i.e., weight gain).

$NE_g = 22.02 * \left(\frac{BW}{C * MW}\right)^{0.75} * WG^{1.097}$	**Equation 10.14**

Where:

NE_g	net energy needed for growth, MJ day $^{-1}$
C	a coefficient (table 28) with a value of 0.8 for females, 1.0 for castrates, and 1.2 for bulls
BW	The average live body weight of the animals in the population (kg)
MW	The mature body weight of an adult animal individually, mature females, mature males and steers) in moderate body condition (kg)
WG	The average daily weight gain of the animals in the population (kg day^{-1})

Table 24: Coefficient

Growth	Cg
Females	0.8
Castrates	1
Bulls	1.2

Results of Net energy for growth for dairy cattle and Other Cattle is provided below.

Net Energy for Lactation

Net energy for lactation: NEl) is the net energy for lactation. For cattle and buffalo, the net energy for lactation is expressed as a function of the amount of milk produced and its fat content expressed as a percentage.

The methodology for determining Net Energy for Lactation is provided in equation 10.8

$NE_l = Milk * (1.47 + 0.40 * Fat)$	**Equation 10.8**

Where:

NE_l	net energy for lactation, MJ day $^{-1}$
$Milk$	amount of milk produced kg of milk day^{-1}
Fat	fat content of milk, percent by weight

Net Energy for work

Net energy for work: (NEwork) is the net energy for work. It is used to estimate the energy required for draft power for cattle and buffalo and is estimated using the equation 10.1.1 below. Various authors have summarized the energy intake requirements for providing draft power. The strenuousness of the work performed by the animal influences the energy requirements, and consequently a wide range of energy requirements have been estimated. The values by Bamualim and Kartiarso (year) showed that about 10 percent of a day's NEm requirements are required per hour for typical work for draft animals.

$\boldsymbol{NE_{work} = 0.10 * NE_m * Hours}$	Equation 10.11

Where:

NE_{work}	net energy for work, MJ day $^{-1}$
NE_m	net energy for maintenance MJ day $^{-1}$
$Hours$	number of hours of work per day

Net Energy for Pregnancy

Net energy for pregnancy: (NEp) is the energy required for pregnancy. For cattle and buffalo, the total energy requirement for pregnancy for a 281-day gestation period averaged over an entire year is calculated as 10 percent of NEm.

$\boldsymbol{NE_p = c_{pregnancy} * NE_m}$	**Equation 10.11**

Where:

NE_p	net energy for pregnancy, MJ day $^{-1}$,
NE_m	net energy for maintenance MJ day $^{-1}$
$c_{pregnancy}$	Pregnancy coefficient (0.1)

Ratio of Net Energy for Maintenance

Ratio of net energy available in diet for maintenance to digestible energy consumed (REM): For cattle, buffalo, sheep and goats, the ratio of net energy available in a diet for maintenance to digestible energy (REM) is estimated using equation 10.14 (2019 Refinement to the 2006 IPCC Guidelines).

$\boldsymbol{REM = [1.123 - (4.092 * 10^{-3} * DE) + (1.126 * 10^{-5} * (DE^2) - \left(\frac{25.4}{DE}\right)]}$	Equation 10.14

Where:

REM	ratio of net energy available in a diet for maintenance to digestible energy
DE	digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy
REM	ratio of net energy available in a diet for maintenance to digestible energy

Ratio of Net Energy Available for Growth

Ratio of net energy available for growth in a diet to digestible energy consumed (REG): For cattle, buffalo, sheep and goats the ratio of net energy available for growth (including wool growth) in a diet to digestible energy consumed (REG) is estimated using the following equation.

$\boldsymbol{REG = [1.164 - (5.16 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE^2) - \left(\frac{37.4}{DE}\right)]}$	Equation 10.15

Where:

REG	ratio of net energy available for growth in a diet to digestible energy consumed

DE	digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy

Gross Energy Requirement

Gross energy (GE) requirement is derived based on the summed net energy requirements and the energy availability characteristics of the feed(s). Equation 10.16 represents good practice for calculating GE requirements for cattle, buffalo, sheep and goats using the results of the equations presented above.

$$GE = \frac{\left(\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM}\right) * \left(\frac{NE_g + NE_{wool}}{REG}\right)}{DE}$$	Equation 10.16

Where:

GE	gross energy intake, MJ head^{-1} day^{-1}
NE_m	net energy required by the animal for maintenance MJ day^{-1}
NE_a	net energy for animal activity MJ day^{-1}
NE_l	net energy for lactation MJ day^{-1}
NE_{work}	net energy for work MJ day^{-1}
NE_p	net energy required for pregnancy MJ day^{-1}
NE_g	net energy needed for growth MJ day^{-1}
NE_{wool}	net energy required to produce a year of wool
REM	ratio of net energy available in a diet for maintenance to digestible energy
REG	ratio of net energy available for growth in a diet to digestible energy consumed
DE	digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy

Emission Factor for CH_4

Emission factor for methane is determined using equation 10.21

$$EF = \frac{GE * \left(\frac{Y_m}{100}\right) * 365}{55.65}$$	Equation 10.21

Where:

EF	emission factor , kg CH_4 head^{-1} yr^{-1}
GE	gross energy intake, MJ head^{-1} day^{-1}
Y_m	methane conversion factor, percent of gross energy in feed converted to methane

(b) Manure management

Tier 2 was used for estimating emissions from Dairy Cattle and Other Cattle while Tier 1 was used for Buffalo, Sheep, Goats, Swine, Broilers, Layers, and Indigenous village chickens.

Provided in the equations is Tier 2 methodology use for Dairy Cattle and Other Cattle.

For Dairy Cattle and Other Cattle, country-specific EFs for CH_4 from manure management in Zambia were used, including Direct N_2O Emission factors from Cattle Manure Management. This tier 2-based approach involved estimation of country-specific volatile solids for manure as well as assessment of the impact of interactions between manure management systems and animal categories in relation to CH_4 emissions during excretion, storage and treatment of manure. The volume of CH_4 emitted is driven primarily by the amount of manure produced and the portion of the manure that decomposes anaerobically[21]. The EF for methane from manure was determined using equation 10.2

$EF = (VS_T * 365)[B_{o(T)} * 0.67 * \sum_{s,k} \frac{MCF_{s,k}}{100} * AWMS_{(T,s,k)}$	Equation 10.23

Where:

EF	annual CH_4 emission factor for livestock category T, kg CH_4 head^{-1} yr^{-1}
$VS_{(T)}$	daily volatile solid excreted for livestock category T, kg dry matter head^{-1} day^{-1}
365	basis for calculating annual VS production, days yr^{-1}
$B_{o(T)}$	maximum methane producing capacity for manure produced by livestock category T, m^3 CH_4 kg^{-1} of VS excreted
0.67	conversion factor of m^3 CH_4 to kilograms CH_4
$MCF_{(s,k)}$	methane conversion factor for manure management system, S, by climate region, k
$AWMS_{(T,s,k)}$	fraction of livestock category manure handled using manure management system, s

Direct N2O Emissions from Cattle Manure Management

The direct N_2O emissions from manure management is estimated as a product of the total amount of N excretion (from all cattle categories) in each type of manure management system and the associated EF, based on equation 10.25 of the IPCC guidelines.

$N_2O_D = [\sum_S \left[\sum_{T,P} \left(\left(N_{T,P} * Nex_{T,P}\right) * AWMS_{T,S,P}\right) + N_{cdg(s)}\right] * EF_S] * \frac{44}{28}$	Equation 10.25

Where:

N_2O_D	direct N_2O emission from manure management, kg N_2O yr^{-1}
$N_{T,P}$	number of head of cattle category T in the country, for productivity system P, when applicable
$Nex_{T,P}$	annual average N excretion per head of cattle category T in the country, for productivity system P, when applicable in kg N animal^{-1} yr^{-1}
$AWMS_{(T,S,P)}$	fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country
EF_S	emission factor for direct N_2O emissions from manure management system S in the country, kg N_2O -N/kg N in manure management system S
$\frac{44}{28}$	conversion of N_2O -N(mm) emissions to N_2O (mm) emissions

[21] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

The annual amount of N excreted by each livestock species/category depends on the total annual N intake and total annual N retention of the animal. Equation 10.31 was used to determine the average amount of N excreted annually.

$N_{ex,T} = N_{intake,T} * \left(1 - N_{retension_{frac},T}\right) * 365$	Equation 10.31

Where:

$N_{ex,T}$	annual N excretion rates, kg N animal^{-1} yr^{-1}
$N_{intake,T}$	the daily N intake per head of animal of category T, kg N animal^{-1} day^{-1}.
$N_{retension,T}$	fraction of daily N intake that is retained by animal of category T.
365	number of days in a year.

The daily N intake rate was derived, using equation 10.32, as follows:

$N_{intake,T} = \frac{GE}{18.45} * \left(\frac{CP\%}{6.25}\right)$	Equation 10.32

Where:

GE	Gross energy intake of the animal, MJ animal^{-1} day^{-1}.
$CP\%$	Percent crude protein in dry matter for growth stage.
6.25	Conversion from kg of dietary protein to kg of dietary N, kg feed protein (kg N)$^{-1}$.

The total N retained for cattle was derived, using equation 10.33, as follows:

$N_{retension,T} = \left[milk * \left(\frac{milk.PR\%}{6.38}\right)\right] + \left[\frac{WG * \frac{\left[268 - \left(\frac{7.03 * NE_g}{WG}\right)\right]}{1000}}{6.25}\right]$	Equation 10.33

Where:

Milk	milk production, kg animal^{-1} day^{-1} (applicable to dairy cows only).
$milk.PR\%$	percentage protein in milk.
6.38	conversion from milk protein to milk N, kg Protein (kg N)$^{-1}$.
WG	weight gain, input for each livestock category, kg day^{-1}.
260 and 7.03	constants, g Protein kg^{-1} animal^{-1} and g Protein MJ^{-1} animal^{-1} respectively.
NE_g	net energy for growth, MJ day^{-1}.
6.25	conversion from kg of dietary protein to kg of dietary N, kg feed protein (kg N)$^{-1}$.

The estimation of EFs for direct N_2O emissions was based on the amount of nitrogen consumed (N-intake), the fraction of nitrogen retained (N-retention) and nitrogen excretion rate (Nex). The study estimated the EFs for direct N_2O emissions for various production systems of Dairy and Other cattle. The EFs for direct N_2O emissions for Dairy cattle manure management are presented in tables 20 for commercial production systems. The table provided N_intake, N_retention, Nex and N_2O.

Indirect N2O Emissions from Cattle Manure Management

To estimate the N volatilization (in forms of NH3 and NOx) from manure management systems, the amount of nitrogen excreted (from all cattle categories) and managed in each manure management system is multiplied by a fraction of volatilized nitrogen based on Equation 10.26 of the IPCC guidelines.

$N_{volatisation} = [\sum_{S} \left[\sum_{T,P} \left(\left(N_{T,P} * Nex_{T,P}\right) * AWMS_{T,S,P}\right) + N_{cdg(s)}\right] * Frac_{GasMS}]$	Equation 10.26

Where:

$N_{volatisation}$	amount of manure nitrogen that is lost due to volatilisation of NH3 and NOx, kg N_2O yr^{-1}
$N_{T,P}$	number of head of cattle category T in the country, for productivity system P, when applicable
$Nex_{T,P}$	annual average N excretion per head of cattle category T in the country, for productivity system P, when applicable in kg N $animal^{-1}$ yr^{-1}
$AWMS_{(T,S,P)}$	fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country
$Frac_{GasMS}$	fraction of managed manure nitrogen for livestock category T that volatilises as NH3 and NOx in the manure management system S

The amount of N lost through leaching and runoff from manure management systems was determined as a product of the amount of nitrogen excreted (from all livestock categories) and managed in each manure management system by a fraction of nitrogen leached. Equation 10.27 was used to estimate the N leached from manure management system.

$N_{leaching} = [\sum_{S} \left[\sum_{T,P} \left(\left(N_{T,P} * Nex_{T,P}\right) * AWMS_{T,S,P}\right) + N_{cdg(s)}\right] * Frac_{leachMS}]$	Equation 10.27

Where:

$N_{volatisation}$	amount of manure nitrogen that is lost due to volatilisation of NH3 and NOx, kg N_2O yr^{-1}

$N_{T,P}$	number of head of cattle category T in the country, for productivity system P, when applicable
$Nex_{T,P}$	annual average N excretion per head of cattle category T in the country, for productivity system P, when applicable in kg N animal^{-1} yr^{-1}
$AWMS_{(T,S,P)}$	fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country
$Frac_{leachMS}$	fraction of managed manure nitrogen for livestock category T that is leached from manure management system S

Tier 1 is a simplified method that only requires livestock population data by animal species/category and climate region or temperature, in combination with IPCC default emission factors, to estimate emissions. Basic characterisation for Tier 1 was used involving use of animal population and default emission factors. A complete list of all livestock populations that have default emission factor values estimated (i.e., dairy cows, other cattle, buffalo, sheep, goats, rabbits, and asses, swine, and poultry). Poultry populations were further subdivided (e.g., layers, broilers, turkeys, ducks, and other poultry), as the waste characteristics among these different populations varied significantly.

$$CH_4Emissions = \sum_T \frac{EF_T X\ N_T}{10^6}$$

Equation 5.2

Where: CH_4Emissions = CH_4 emissions from manure management, for a defined population, Gg CH4 yr^{-1}; $EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 head^{-1} yr^{-1}(Table 34); $N_{(T)}$ = the number of head of livestock species/category T in the country T = species/category of livestock.

Table 26: Emissions factor for Livestock-Manure management

Category	**Emission Factor (kg CH4 / Head per year)**
Dairy cattle	1.00
Non-Dairy Cattle	1.00
Buffalo	2.00
Sheep	0.15
Goats	0.17
Swine	1.00
Broilers	0.02

Layers	0.02
Indigenous	0.02
Others	0.02

3.4.1.3 Activity Data

Non-Dairy Cattle

There was a 10.65 percent decline in the total livestock emissions between 2000 and 2005. The reduction in emissions was as a result of declining cattle population in 2005 due to the Contagious Bovine Pluero-Pneumonia outbreak reported in Zambia that led to high cattle mortalities. Further, during disease control operations, all cattle that tested positive to the disease were slaughtered. Methane emissions from buffalo under captivity have been taken into consideration in the calculation of emissions for the years 2005 and 2010. Therefore, the numbers of buffalo that were being held in captivity were relatively fewer, about 503 to 935 for 2005 and 2010, respectively.

There was an increase in non-dairy cattle population from 1,748,856 in 2011 to 2,109,231 in 2016 as shown in Figure 26. This translates into a 17% increase in population across 5 years. This is attributed to the Government's efforts in promoting livestock production in the country. Some of the notable specific interventions include improved pasture and rangeland production programmes, stocking and restocking activities. Further, the Government has promoted routine vaccinations against Contagious Bovine Pleuropneumonia (CBPP) and immunisation against East Coast Fever (ECF). These interventions have reduced mortalities in cattle and this has led to an increase in population.

In 2011 the population dropped by 16% and this is attributed to data gaps because in the aforementioned year, there were no disease outbreaks that could have led to a reduction in population. However, a 6% drop in population was observed from 2015 to 2016. This drop was attributed to the El nino effect which was experienced in the 2015/16 farming season. The impact of an El Niño-induced shock on income and productivity. In Zambia, the effects of El Niño were classified as the most severe in the last fifty years (ZVAC, 2016). The population of the other cattle (beef) has essentially stabilized since then to about three million six hundred thousand heads from 2017 to 2021.

The recent 2023 Livestock survey puts the beef cattle population at four million four hundred and sixty-nine (thousand one hundred and twenty heads. (4,469,120) The surge could be attributed to Government and private sector interventions in enhancing production and productivity in the sector. Farmers now have access to animal input supply from the Fertiliser Input Support Programme (FISP) and the boost in AI services. The El Nino affected cattle population in that the drought resulted in reduced availability of grazing and browsing resources for the animals. Non-dairy animals kept by smallholder households were affected under these circumstances and the most affected categories of animals are pregnant ones and most of them died from a condition called Dystocia which is a condition resulting from lack of energy for muscle contraction at the time of giving birth.

Dairy Cattle

The population of dairy cattle increased from 874,268 in 2011 to 1,279,734 in 2012 due to an increase in the number of entities investing in the dairy value chain. Government and its cooperating partners also started constructing milk collection Centres around 2011 and has to date constructed seventy-nine (79) milk collection Centres. This led to a guaranteed market for raw milk, hence making it attractive for dairy farmers. A steady population trend was observed from 2012 to 2014 due to a steady demand in dairy products by the market.

The general increase in population from 2014 to 2015 is attributed to a number of interventions which include, the Government and its cooperating partners having embarked on stocking and restocking activities through programmes such as Loan a cow promoted by Zanaco, Send a cow programme supported by a UK charity and, Heifer international that promoted dairy production through the pass on the gift scheme'. This means selected communities were empowered with livestock in areas where livestock numbers reduced due to mortalities from livestock diseases.

However, from 2015 to 2016, the dairy cattle population reduced by 44% from 1,995,677 to 1,320,609 heads of cattle. This is attributed to poor preparedness to receive the livestock assets by most beneficiaries. The stocking and restocking were occurring in high numbers but within a season, most of the dairy animals died due to inadequate grazing resources in the dry months, coupled with poor management by small scale farmers. Some of the dairy breeds introduced in some areas could not acclimatize to the harsh conditions in the areas they were introduced to.

The dairy cattle population was noted to stabilize at just under one hundred and fifty thousand heads (150,000) from 2015 to 2021. There was however a surge to over two hundred thousand heads (200,000) noted in 2022. This could be as a result of renewed efforts by both the government and the private sector to import breeding dairy animals and semen from South Africa and other countries for distribution. It must be mentioned that the definition of dairy animals in this report is restrictive to dairy cows unlike the loose definition previously employed which include all other categories.

In the recent past, there has been an increase in attention to training communities in good animal husbandry practices which has led to an increase in numbers. This is as a result of the creation of the Ministry of Fisheries and Livestock in 2015. This resulted in more attention being paid to good animal husbandry practices and this has led to a steady increase in livestock population. Over the period under review several disease outbreaks did occur more notably Foot and mouth Disease (FMD), which does not cause a lot of deaths (Mortality) but has high loss of Production (morbidity) as a result it did not depress the cattle numbers.

Small ruminants (Goats and Sheep)

Small ruminants animals equally recorded an increase in population from 1,855,366 in 2011 to 2,632,277 in 2016 which translates into 30%[22] increase in population.

Goats

Goat population has generally been on the increase from 2011 to 2016 due to a number of interventions particularly stocking through the pass on the gift model. This pass on the gift model implemented by the government and its Cooperating Partners works by giving a certain number of goats to a beneficiary who in turn has to pass on the offspring to the next beneficiary. This model has led to an increase in goat numbers because measures are also being taken to provide intensive training to beneficiaries. This system has led to internal monitoring among farmers themselves, particularly the ones waiting to receive from the first beneficiary.

From 2015 to 2016, a reduction in population of 22% was observed and this was attributed to the high flock offtake due to the drought that was experienced in the 2015/16 season. Due to reduced income resulting from low crop yield, most farmers opted to sell their small livestock to generate income and cushion against the shock. Results show that households affected by the drought experienced a decrease in maize yield by around 20%, as well as a reduction in income up to 37%. Practices that moderated the impact of the drought included livestock diversification, income diversification, and the adoption of agroforestry[23]. Additionally, there has been an increase in demand for goat meat in the recent past and this has led to high numbers of goats being sold for consumption.

There was a surge in the goat population from 1,664,216 in 2015 to 3,503,099 in 2016 which was more or less maintained till 2019. There was another wave of increase to above

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[22] Central Statistics Office

[23] *Climate-change vulnerability in rural Zambia: the impact of an El Niño-induced shock on income and productivity, 2019*

the four million (4,000,000) mark from 2020 to 2022. All these points to the goat production and marketing activities promoted by the government and seen as rewarding by the private sector.

Sheep

The sheep population has generally been lower than the goat population for all the years under consideration. The sheep population was generally less than one hundred thousand from 1990 to 2005. Thereafter, the number increased to just below five hundred thousand heads between 2009 and 2015. There has been a decline in the sheep population to an average of about two hundred and fifty thousand between 2020 to 2022. These could be due to the increased interest in goat production at the expense of sheep. Sheep production in Zambia has been noted to be fraught with a number of challenges mostly due to the high management practices required compared to goat farming.

Poultry

Most of the livestock being given to communities are mostly procured locally and this does not directly increase the livestock population.

Broilers

What has led to an increase in the population has increased the number of hatcheries that have entered the value chain. Some of the notable hatcheries are Ross breeders, Tiger chicks, Habdard, Zamchick. Government and cooperating partners have also been empowering vulnerable but viable farmers with climate resilient livestock packages. The broiler population has been consistent at slightly over twenty million heads since 2019 to 2022. The ecosystem for broiler production has been supportive of the growth achieved with the active participation even by smallholder farmers.

Layers

The layer birds population has been on the upward swing since 2017 when it stands at 1,744,188 to 2022 with the population at 2,217,434. The egg production sales have recorded an increase in the demand for eggs for consumption and other culinary activities.

Village chickens

The village chickens are the most prominent of the poultry kept by producers. The population in 2017 was 12,303,332 which has since risen to above twenty million from 2018 to 2022. The increase could be attributed to the change in consumer preferences of the urban dwellers from fast foods to healthier meat products.

Pigs (Swine)

A trend of increasing livestock population country wide from 2011 to 2013, attributed to increased market demand for pork products within the country was observed. There was a drop in the pig population in 2014 due to an outbreak of African Swine Fever which led to massive mortalities and slaughter of pigs. Lusaka and southern provinces were the most affected[24] . The pig population was steady at just over seven hundred thousand heads for the period 2009 to 2015. There was however a surge to above the one million (1,000,000) mark in 2016 which has since been sustained to 2022. Though there was an outbreak of ASF in 2022, the management of the disease did not result in any reduction in the pig population but rather there was an increase to just below four million five hundred heads.

Buffalo

The buffalo population has been steadily increasing from 769 in 2017 to just above 2000 in 2022. There is increasing interest in rearing buffalos among the game ranchers and there is good collaboration with Department of National Parks and Wildlife.

Donkey

The annual population of donkeys in the country was generally less than a thousand heads from 1990 until 1996 when it started to increase rapidly to about four thousand heads between 2005 and 2007. Thereafter, there was a decline in the donkey population to less than a thousand heads from 2008 till 2014. The population has been hovering around two thousand five hundred between 2019 to 2022. The undulating population could be as a result of inadequate population data capture.

Horses

The annual population of horses was generally less than three hundred and fifty heads from 1990 until 1998. It then rose to between eight hundred and nine hundred to about four thousand heads between 1999 and 2001. Thereafter, there was a decline in the donkey population to less than a two hundred heads between 2002 and 2004. The population suddenly rose to over four hundred thousand heads from 2005 and have since stabilized at just over three hundred and seventy thousand heads since 2010. The population data would require further investigation which may relate to population data capture methodology.

Activity data on livestock population used for estimating enteric fermentation emissions is provided in Table 23.

[24] *Ministry of Fisheries and Livestock*

Table 23 Livestock Population Trends

Livestock	Dairy Cattle	Other Cattle	Sheep	Swine	Buffalo	Goats	Horses	Mules and Asses	Poultry
1990	130,030	2,481,087	52,814	240,859	0	68,284	104	290	3,967,807
1994	127,712	2,451,005	65,890	251,982	0	430,570	136	673	5,340,269
1998	102,900	2,644,276	84,284	317,929	0	722,072	299	1,110	14,907,819
2002	147,000	2,370,547	24,019	135,045	0	498,173	27	2,648	3,293,730
2006	142,778	2,658,897	117,928	398,634	0	1,762,459	541,030	4,346	49,734
2010	153,990	2,944,538	466,506	711,707	0	758,501	372,230	325	853
2014	151,278	3,923,354	492,658	736,919	0	1,483,073	372,598	1,089	4,078,529
2018	145,263	3,568,234	170,262	1,082,766	706	3,583,696	372,966	1,853	31,952,353
2022	210,287	4,469,120	260,560	1,160,843	2,097	4,455,860	373,334	2,617	29,036,391

3.4.1.4 Emission Trend from Livestock

This section provides emissions related to enteric fermentation and manure management. Overall, emissions in this subcategory increased by 119.2% from 6197.5 Gg CO_2e in 1990 to 13586.7Gg CO_2e in 2022 as illustrated in Figure 36. In 2022, approximately 95.8% of methane emissions were attributed to enteric fermentation and 4.2% to manure management.

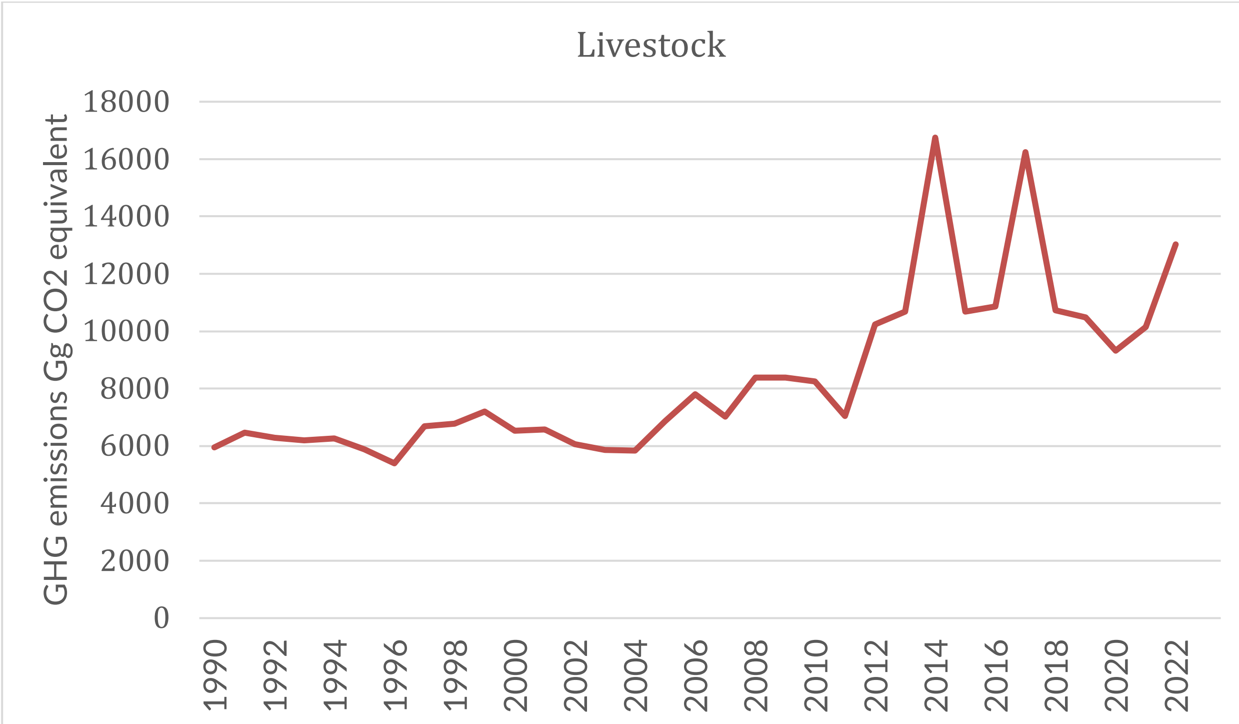


Figure 36: Emission Trend from Livestock

Provide in Table 24 are trends of emissions for sub categories under livestock.

Table 24: Trends of emissions for sub categories under livestock (Gg CO2 equivalent)

	3.A - Livestock	3.A.1 - Enteric Fermentation	3.A.2 - Manure Management (1)
1990	6197.5	5960.4	237.2
1991	6714.4	6475.6	238.8
1992	6545.2	6294.9	250.3
1993	6438.9	6188.3	250.6
1994	6505.3	6253.8	251.4
1995	6137.8	5877.0	260.8
1996	5623.3	5395.3	228.0
1997	6962.9	6680.4	282.5
1998	7065.0	6778.3	286.8
1999	7494.7	7198.5	296.1
2000	6815.7	6531.7	284.0
2001	6863.6	6574.5	289.1
2002	6305.5	6067.6	237.8
2003	6110.6	5871.3	239.3

	2004	6086.0	5850.1	235.8
	2005	7146.8	6866.1	280.7
	2006	8127.0	7802.8	324.2
	2007	7317.3	7021.6	295.7
	2008	8770.4	8376.4	393.9
	2009	8779.6	8376.4	403.2
	2010	8629.7	8246.6	383.1
	2011	7353.2	7035.7	317.5
	2012	10706.3	10240.7	465.6
	2013	11176.2	10688.3	487.9
	2014	17456.3	16750.0	706.3
	2015	11928.0	10687.8	1240.2
	2016	11320.8	10861.6	459.2
	2017	16943.0	16236.4	706.6
	2018	11200.1	10720.5	479.6
	2019	11000.2	10478.1	522.0
	2020	9782.2	9317.9	464.3
	2021	10593.2	10149.3	443.9
	2022	13586.7	13021.6	565.0

Enteric Fermentation

The quality of pasture determines the amount of emissions. This means that livestock fed on poor quality roughages will emit more methane than those fed on good quality roughage. The low quality roughage is associated with smallholder farmers. Government has taken steps in promoting improved pastures to over 80,000 households. This is done by providing improved pasture seeds to smallholder farmers who plant it in the rainy season then harvest towards the end of the rainy season and conserve the pasture in hay and silage form which they then feed to their livestock in the dry months when good quality pastures are not available.

Some of the notable programmes promoting improved pastures and legumes are Enhanced Smallholder Livestock Investment Programme (E-SLIP), World Vision, Heifer international, GIZ and Dairy Association of Zambia. Government through E-SLIP has also embarked on a programme to improve the communal grazing areas (rangelands) where farmers take their animals for grazing. These communal grazing areas are overgrazed and depleted in terms of good quality pastures. The intervention Government is promoting 'oversow' with hardy leguminous pasture species to improve feed quality. These interventions are expected to reduce emissions from enteric fermentation in the smallholder livestock farming operations. Other notable organisations promoting rangeland improvement programmes are Solidaridad and Grassroots Trust. Emissions under enteric fermentation grew from 5960.3Gg CO_2 in 1990 to 13021.624 Gg CO_2 in 2022, representing an increase of 118.4% as shown in Figure 37.

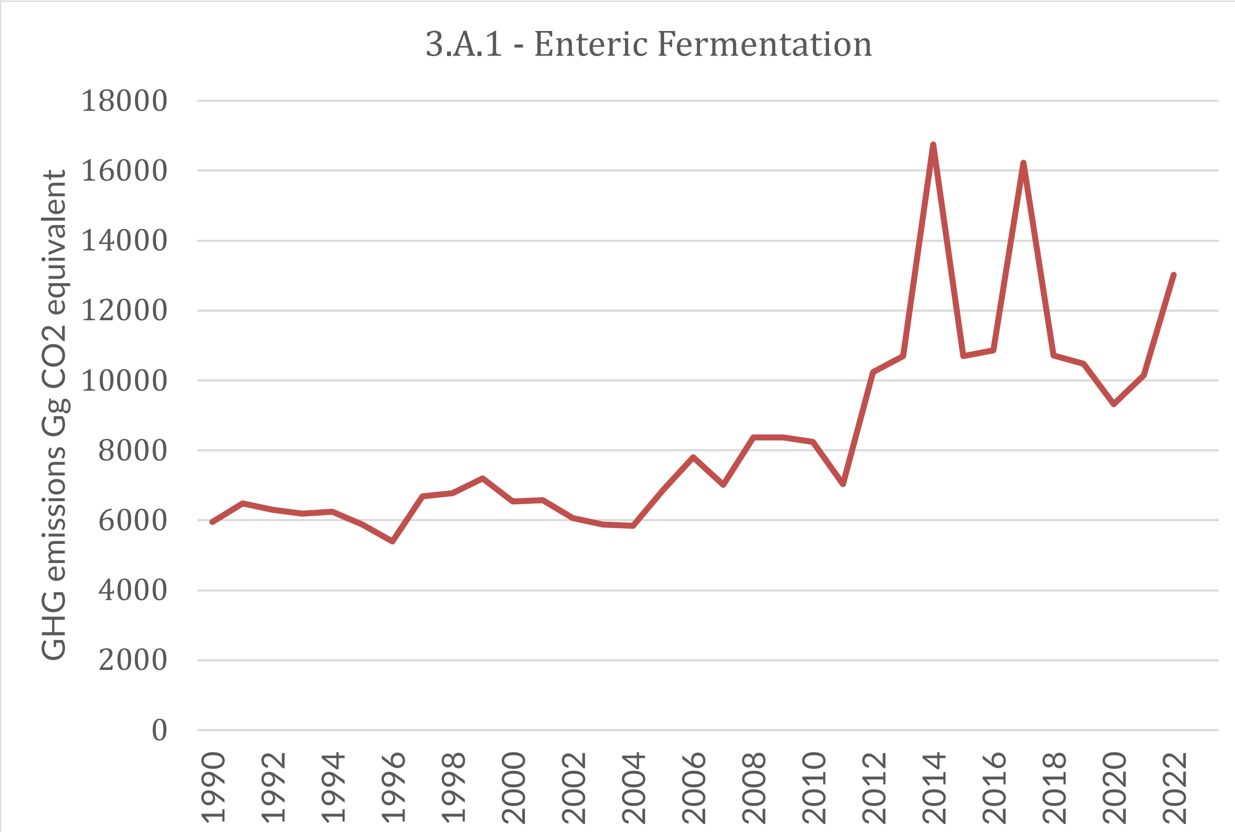


Figure 37: Trends of emissions for enteric fermentation

Manure Management (CH4 and N2O)

Manure management is the process in which livestock manure is collected, heaped, treated and stored. During the storage phase, methane is produced as a result of the decomposition of organic matter. N_2O emissions from manure management systems can also occur through a process of nitrification and denitrification. Nitrification is the biological oxidation of ammonia or ammonium to nitrite followed by the oxidation of the nitrite to nitrate. Indirect N_2O emissions also occur from runoff and leaching, and the deposition of N volatilized from the manure management systems. Denitrification is a microbial facilitated process where nitrate is reduced and ultimately produces molecular nitrogen (N_2) through a series of intermediate gaseous nitrogen oxide products. The composition of livestock manure which is primarily a function of the animal species and diet, determines its methane producing potential. In the tropics cattle are mainly fed on roughage diet which will produce less biodegradable manure containing more complex organic substances such as hemi-cellulose, cellulose and lignin.

On the other hand, however, because of the lower digestibility of the natural pastures, cattle will take in a lot of this roughage to meet their nutrient requirements in the available space and time, and in turn, produce much more manure. The climatic parameters such as temperature and rainfall affect both the rate and total amount of methane production in manure. A warm and moist environment promotes methane production.

Most farmers in Zambia do not apply recommended manure management practices, such as roofing animal housing, having a water-proof floor or covering manure during storage, causing large nutrient losses during manure storage, and thereby reducing the quality of the manure as a fertilizer[25]. In general Dairy cattle are kept mostly under a confined system where they are kept in a small area. This entails most of the cow dung is cleaned and piled for use in gardens and field crops as fertilizer.

In Zambia, manure management also contributes significantly to GHG emissions under livestock subcategory. In this report, only methane produced from manure management has been calculated and the results presented. Compared to the base year 1990, emissions in the current year, 2022 increased by 138.2% as shown in Figure 38 from 237.2 Gg CO_2e to 565.1 Gg CO_2e respectively. Other cattle were the largest contributors of methane in the years under consideration.

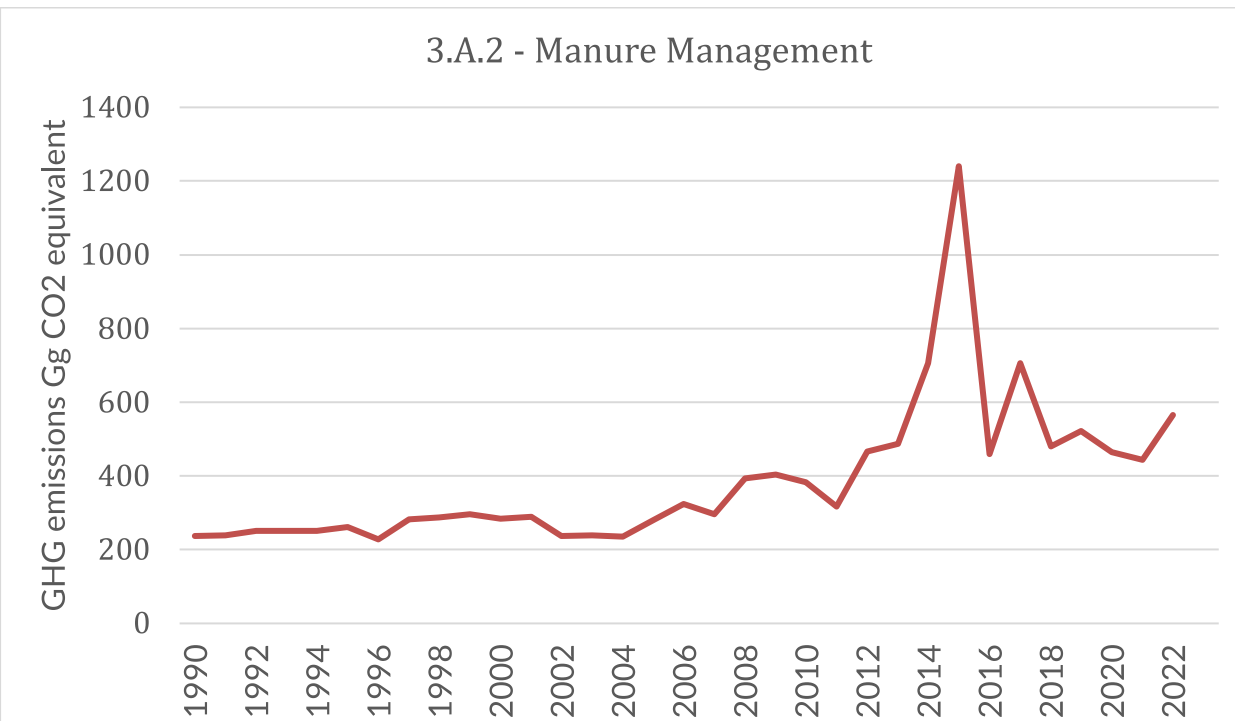


Figure 38:Trend of emissions under Manure management

[25] Manure Management Practices and Policies in Sub-Saharan Africa: Implications on Manure Quality as a Fertilizer

3.4.1.5 Quality assurance/quality control measures

Activity data used in estimating GHG emissions was obtained from ZAMSTATS and Ministry of Fisheries and Livestock. Efforts were made to compare data from various sources and compile the most suitable data sets for use in emissions estimates. Effort were made to check and verify the data from all sources to ensure good quality data was utilised in the inventory preparation from the AFOLU sector.

3.4.1.6 Sectoral uncertainties,

All the population data for Dairy, other cattle, Buffalo, Sheep, Goat, Swine and poultry were sourced from ZAMSTATS whose uncertainty is 5%.

3.4.1.7 Planned improvements

Data Gaps**:** There is a general lack of information on what quantities of methane is generated from the three production systems described above. Research areas**:** Determining emission factors for extensive, semi-intensive and intensive livestock system in Zambia.

3.4.2 Land

3.4.2.1 Overview

Zambia has an estimated area of 45.94 million hectares of forest, representing approximately 61.01% of its total land, and is one of the forested countries in Southern Africa. The estimated annual rate of deforestation stands at 276,000 hectares. The major drivers of deforestation and forest degradation are agricultural expansion; settlement expansion; wood extraction; and uncontrolled fires. According to the Preliminary Study on the Drivers of Deforestation and Potential for REDD+ in Zambia under the UN-REDD Programme, the underlying causes have been elaborated as inadequate Policy and Legal Framework, Socio economic factors, Demography changes, inadequate Institutional arrangements and Environmental factors.

Under the current reporting period for the BTR (2017-2022), it has been noted that agricultural expansion has been evident in the opening up of farm blocks. During the period under review, Zambia launched several farm blocks, as part of its Farm Block Development Programme (FBDP), including the Nansanga Farm Block (Central Province), Luena Farm Block (Luapula Province), Mushindamo Farm Block (North-Western Province), Kalumwange Farm Block (Western Province), Luswishi Farm Block (Copperbelt Province), Manshya Farm Block (Muchinga Province), Musokotwane Farm Block (Southern Province) and Chikumbilo Farm Block (Eastern Province), among others.

For example, out-migrations from Southern Province into Lusaka and Copperbelt Provinces due to shortage of land and persistent droughts is causing areas such as Chongwe, Lufwanyama and Masaiti Districts to be opened up for new settlements and agriculture. The other cause of forest degradation is wood extraction for various purposes such as timber for domestic and export market; charcoal and fuelwood for domestic and commercial purposes.

Similarly, the areas for settlements increased due to growth in socio-economic activities, including declaration of new districts and mining activities both small and large scale in various parts of the country. This has been evidently noted in the Northwestern and Central provinces. During the period under review, it has been observed that Northwestern has been largely dominated by large scale mines and Central Province by small mines for copper and manganese production and refining respectively. The opening up of forest land for plantations has also been noted as significant such as the Pine Plantations in Kawambwa and Shiwangandu Districts located in Luapula and Muchinga Provinces respectively, by Zambia Forest Forestry Industrial Cooperation (ZAFFICO) Limited.

Disturbances such as wildfires, pest outbreaks and land degradation are among the causes of forest degradation. The effects of fire normally disturbs even the regenerating saplings as well as the forest as a whole. The uncontrolled forest fires usually occur as a result of poor fire management schedules or plans. It has however been noted that most of the fires that have been occurring are as a result of traditional practices such as late burning regimes on traditional lands. In the period under review, the effects of climate change such as dry spells or drought have affected forest burning.

The 2006 IPCC Guidelines defines the six land-use categories which includes: forest land, cropland, grassland, wetlands, settlements, and other land. Each land use category is divided into two subcategories: land that remains in the same use (e.g., Forest Land remaining Forest Land, or FL-FL) and land that has been converted from one land use to another (e.g., Forest Land converted to Cropland, or FL-CL). These subdivisions are used to estimate changes in carbon (C) stocks. The total CO_2 emissions or removals associated with each land-use category are calculated by summing the contributions from both subcategories.

Zambia's classification scheme for the National Land Cover Datasets (NLCD) is the main input dataset for AFOLU and was developed to provide baseline data for the land use, land-use change and forestry (LULUCF) for GHG monitoring. This resource has multiple applications, including reporting on the annualized deforestation rate for the country, updating the vegetation cover, protected forest areas, deriving and formulating land use plans amongst others. The classification scheme used was based on the IPCC as shown in Table 25.

Table 25: Land cover classification scheme

	Land cover categories	National land cover descriptions
1	Settlements	Land covered mainly by densely populated and organized or irregular settlement patterns surrounding cities, towns, chiefdoms and rural centres commonly referred to as urban and rural built-up areas.
2	Cropland	Land actively used to grow agriculture (annual and perennial) crops which may be irrigated or rain-feed for commercial, peasant and small scale farms around urban and rural settlements
3	Grassland	Land that includes wooded rangeland that may be covered mainly by grasslands, plains, dambos, pans found along major river basins and water channels.
4	Forests	This is land covered both by natural and planted forest meeting the threshold of 10% canopy cover growing over a minimum area of 0.5 ha with trees growing above 5m height.
5	Wetlands	Land which is waterlogged, may be wooded such as marshland, perennial flooded plains and swampy areas (surface water bodies included).
6	Other land	Barren land covered by natural bare earth / soil such as sandy dunes, beach sand, rocky outcrops and may include old open quarry sites for mines and related infrastructure outside settlements.

Adapted from ILUAII, 2016

The GHGi for the forest subcategory of the AFOLU sector covers all CO_2 emissions and removals due to gains and losses in the relevant carbon pools of the predefined six land-use categories, as well as non-CO_2 emissions from biomass burning and disturbances associated with land-use conversions. GHG emissions estimates were based on comprehensive forestry statistical data presented in the 2016 Integrated Land Use Assessment Final Report. However, default emission factors were used to a limited extent.

All data relating to the land areas is streamlined and reported according to the six broader forest types of Zambia (in accordance with the methodology recommended by IPCC 2006). The largest vegetation type is the forest woodlands which comprises the Kalahari, Miombo, Mopane and Munga woodlands, of which the Miombo woodlands alone covers over 60% of all the forest types in Zambia. Other vegetation types used for reporting are: dry deciduous forests; dry evergreen forests; moist evergreen forests; the wooded grasslands and forest plantations (Table 26). The forest plantations consist of Broad-leaf Forest plantations (Eucalyptus) and Coniferous Forest plantation (Pine).

Table 26: Major Forest types for reporting

Major Vegetation and Other Land	Floristic Based Forest Types
Dry evergreen forest	Parinari forest and Copperbelt chipya
	Marquesia forest
	Lake basin chipya
	Chryptosepalum forest
	Kalahari sand forest
Dry deciduous forest	Baikiaea forest and deciduous thicket
	Itigi forest
Moist evergreen forest	Montane forest
	Swamp forest
	Riparian forest
Forest woodlands	Miombo woodland on plateau
	Miombo woodland on hills
	Kalahari woodland on sands
	Mopane woodland on clay
	Munga woodland on heavy soils
Forest plantations	Broad leaf forest plantation (Eucalyptus)
	Coniferous forest plantation (Pine)
Wooded grasslands (including pans and shrubs with some trees)	Termitary vegetation and bush groups
	Shrubs / thickets

3.4.2.2 Methodology and Emission Factors

. The emissions and removals of CO_2 for the AFOLU Sector, based on changes in ecosystem C stocks, are estimated using equations 5.3-5.9, for each land-use category (including both land remaining in a land-use category as well as land converted to another land use).

$\Delta C_{AFOLU} = \Delta C_{FL} + \Delta C_{CL} + \Delta C_{GL} + \Delta C_{WL} + \Delta C_{SL} + \Delta C_{OL}$ Equation 5.3

Where: ΔC = carbon stock change, FL = Forest Land, CL = Cropland, GL = Grassland, WL = Wetlands SL = Settlements, OL = Other Land

annual change in carbon stocks in biomass in land remaining in a particular land-use category (gain-loss method).

$\Delta_{CB} = \Delta_{CG} - \Delta_{CL}$ Equation 5.4

Where: Where: Δ_{CB} = annual change in carbon stocks in biomass for each land sub-category, considering the total area, tonnes C yr^{-1}, Δ_{CG} = annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tonnes C yr^{-1}, Δ_{CL} = annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tonnes C yr^{-1}

$$\Delta_{CB} = \frac{(C_{t2} - C_{t1})}{t_2 - t_1}$$ Equation 5.5

Where: Where: Δ_{CB} = annual change in carbon stocks in biomass in land remaining in the same category (e.g., Forest Land Remaining Forest Land), tonnes C yr^{-1} ; C_{t2} = total carbon in biomass for each land sub-category at time t_2 , tonnes C, C_{t1} = total carbon in biomass for each land sub-category at time t_1 , tonnes C; C = total carbon in biomass for time t_1 to t_2

Equation 5.6

$$C = \sum_{i,j} \left(A_{ij} * V_{ij} * BCEF_{Sij} * (1 + R_{ij}) * CF_{ij}\right)$$

Where: A = area of land remaining in the same land-use category, ha (see note below) V = merchantable growing stock volume, m3 ha-1 , i = ecological zone i (i = 1 to n), j = climate domain j (j = 1 to m), R = ratio of below-ground biomass to above-ground biomass, tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)-1 CF = carbon fraction of dry matter, tonne C (tonne d.m.)-1, BCEFS = biomass conversion and expansion factor for expansion of merchantable growing stock volume to above-ground biomass, tonnes above-ground biomass growth (m3 growing stock volume)-1

BCEFS = BEFS * D Equation 5.7

Where: Basic wood densities (D), Biomass expansion factor (BEFS)

Annual increase in biomass carbon stocks due to biomass increment in land remaining in the same land-use category is estimated using equation 5.8.

Equation 5.8

$$\Delta C_G = \sum_{i,j} \left(A_{ij} * G_{TOTAL\,ij} * CF_{ij}\right)$$

Where: ΔCG = annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone, tonnes C yr-1 , A = area of land remaining in the same land-use category, ha; GTOTAL= mean annual biomass growth, tonnes d. m. ha-1 yr-1 ; i = ecological zone (i = 1 to n); j = climate domain (j = 1 to m); CF = carbon fraction of dry matter, tonne C (tonne d.m.)-1

Annual decrease in carbon stocks due to biomass losses in land remaining in the same land-use category is estimated using equation 5.9.

ΔCL = Lwood −removals + Lfuelwood + Ldisturbance Equation 5.9

Where: ΔCL = annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category, tonnes C yr-1 ; Lwood-removals = annual carbon loss due to wood removals, tonnes C yr-1 ; Lfuelwood = annual biomass carbon loss due to fuelwood removals, tonnes C yr-1 ; Ldisturbance = annual biomass carbon losses due to disturbances, tonnes C yr-1

Emission factors for the Land category are provided in Table 27

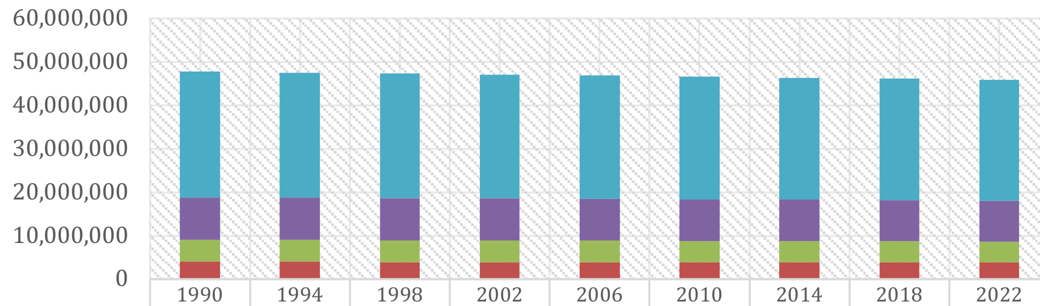
Table 27: forest classification land use type data

Land Type	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Woodlands (Open Forests)	Other wooded land	Eucalyptus Plantations	Pinus Plantations

Whether natural forest?	Yes	Yes	yes	Yes	Yes	No	No
Species	Other broadleaf	Other broadleaf	Other broadleaf	Other broadleaf	Other broadleaf	Eucalyptus	Pinus
Age class (year)	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
CF (carbon Fraction) tonnes C/tonnes d.m.	0.47	0.47	0.47	0.47	0.47	0.47	0.47
R(Ratio of below ground to above ground)	0.42	0.42	0.42	0.42	0.42	0.2	0.2
BCEF (td.m./m3)	0.65	0.71	0.72	0.67	0.86	1.44	0.77
AGB (td.m./ha)	67.8	37.2	34.2	43.1	6.6	165	80
AGB Growth (td.m./ha/yr)	0.9	0.9	0.9	0.9	0.9	13	9
Reference C stock/EF	27.6	45.5	49.3	36.7	34.8	47	47
Litter	2.1	2.1	2.1	2.1	2.1	2.1	5.2

3.4.2.3 Activity Data

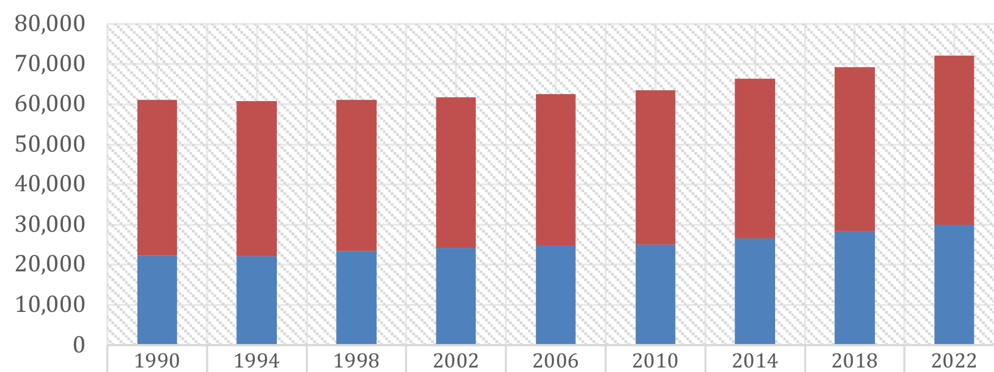
Generally, the trend in the carbon uptake in the natural forest indicates a decline for the period under review. This can be attributed to the continuous rise in the deforestation rate and forest degradation. As reflected in Figure 44, Zambia's natural forest suffered a steady decline, at an average rate of about 60,000 hectares per annum.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
Forest Woodland (Ha)	28,951,822	28,807,618	28,663,413	28,519,210	28,375,009	28,230,804	28,086,602	27,942,399	27,798,197
Moist Evergreen Forest (Ha)	9,810,121	9,761,259	9,712,396	9,663,534	9,614,672	9,565,810	9,516,948	9,468,086	9,419,224
Dry Deciduous Forest (Ha)	5,024,696	4,999,669	4,974,642	4,949,615	4,924,588	4,899,561	4,874,534	4,849,507	4,824,480
Dry Evergreen Forest (Ha)	4,006,539	3,986,583	3,965,960	3,945,102	3,923,995	3,902,890	3,879,719	3,856,535	3,833,337

Figure 39:: Decline of Zambia's natural forest

On the other hand, Zambia's land used for plantations (Pine and Eucalyptus) increased over the period under review. The increase was due to the establishment of new forest. Figure 45 indicates the trend of plantations over the period 1990 to 2022.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
Pinus Plantation (Ha)	38,801	38,608	37,776	37,443	37,745	38,420	39,679	40,944	42,215
Eucalyptus Plantation (Ha)	22,271	22,160	23,357	24,287	24,827	24,998	26,649	28,306	29,971

Figure 40:Trend in carbon uptake in Eucalyptus and Pine plantations

Trends in the Land Area of Dry Evergreen Forests Sub-Category

Dry evergreen forests form part of the transitional zone between the Guineo Congolian rainforest and Zambia's dry woodlands. These forests cover less than 3–5% of the country's land area and are limited to the North-Western and Western provinces of Zambia[26]. The three main sub-types are distributed across different landscapes: Cryptosepalum forests on Kalahari sands, Marquesia forests in lake basins, and Parinari

[26] Siampale, 2008; Chidumayo, 2012a

forests on the plateau[27].These forest types typically feature a three-story structure with a canopy height of up to 27 meters and a dense shrub layer ranging between 1.5–6.0 meters. Occasionally, an understory measuring 0.3–1.3 meters high can also be found[28]. The dominant species vary depending on the forest sub-type and include *Cryptosepalum exfoliatum*, *Guibourtia coleosperma*, *Marquesia acuminata*, *Marquesia macroura*, *Parinari excelsa*, *Syzygium guineense*, and *Anisophyllea pomifera* [34]. This woodland type is restricted to the wetter northern parts of the region, receiving mean annual rainfall of 800–1400 mm. Most of these forests occur at elevations of 1000–1500 meters. Disturbance to these woodland ecosystems often leads to variations of miombo woodland and Chipya forests[34].

The trend in the land area covered by dry evergreen forests has shown a steady decline over the years from 1990 to 2022, as illustrated in figure 41. This reduction is primarily attributed to land use change conversions for agriculture and settlements. Additionally, the eco - region is under threat from deforestation, forest degradation, unsustainable land use practices, and wild fires. Historically, these threats were driven by open-access exploitation and uncoordinated resource management policies in game management and protected areas. However, recent efforts have been made to improve the management of protected areas.

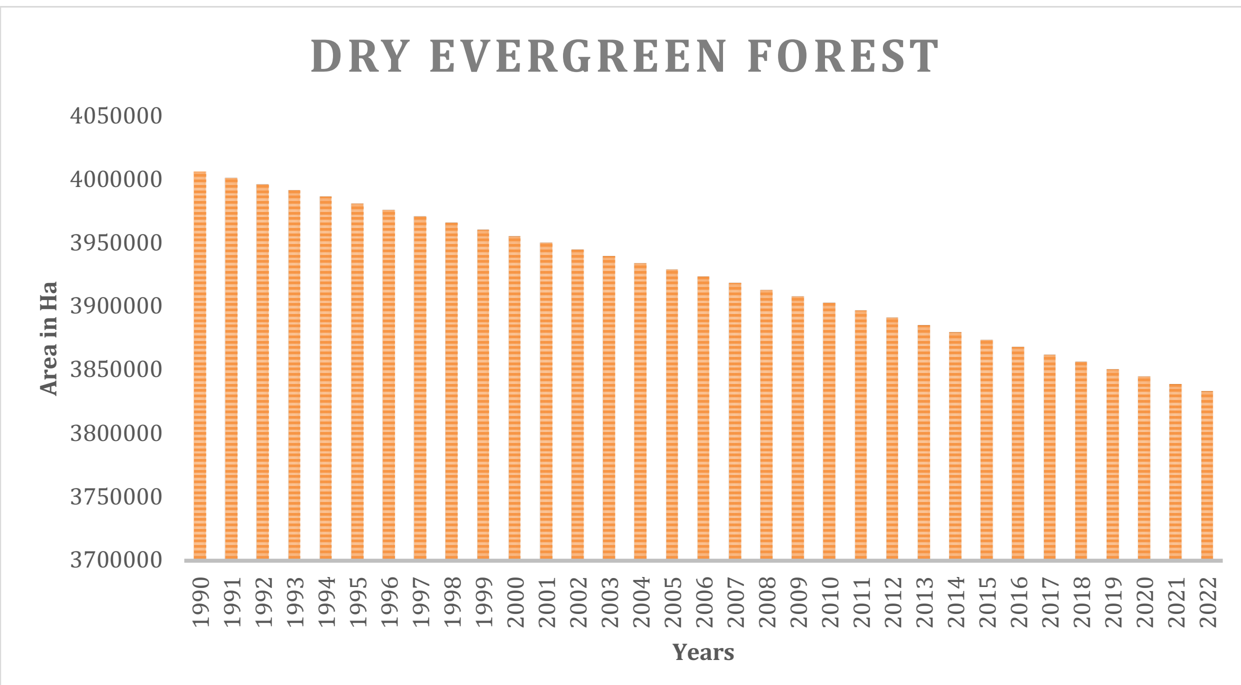


Figure 41: Trends of forest areas under dry evergreen forest

The Trend in Land Area for the Dry Deciduous Forest Sub - Category

[27] Kindt et al., 2011
[28] Fanshawe, 2010

The dry deciduous forests of Zambia are of two major types: the Baikiaea forest and the Itigi forest. The Baikiaea forest, restricted to the Kalahari sands in Western Zambia, is dominated by species such as *Baikiaea plurijuga* (commonly known as Zambezi teak) and Pterocarpus antunesii. These species play a crucial ecological role, contributing to both timber production and the support of local wildlife. On the other hand, the Itigi forest is ecologically related to Tanzania's famous Itigi thicket. It shares similarities in terms of its floristic composition, with dominant species from the genera Baphia, Burthia, and Bussea. The Itigi forest has a unique two-storey structure, with an open canopy made up of various deciduous and semi-deciduous tree species, contributing to its distinctive appearance.

Despite their ecological importance, these dry deciduous forests are experiencing a steady decline in coverage. The trend, observed over an extended time series 1990 to 2022 as provided in Figure 42, indicates a reduction in forest area due to increasing land use change conversions. The primary drivers of this deforestation include the expansion of agricultural activities, the development of human settlements, and other land-use changes. As a result, these forests are under threat, jeopardizing both their biodiversity and the ecosystem services they provide, such as carbon sequestration, soil stabilization, and support for local livelihoods.

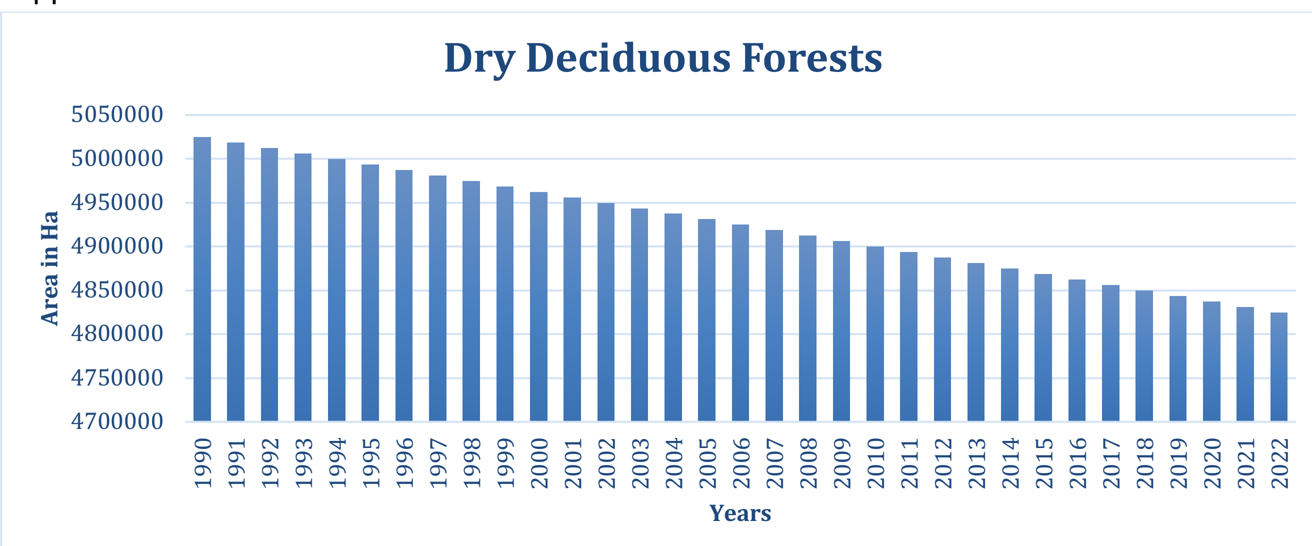


Figure 42:Trends of forest land areas under dry deciduous

The Trend in Land Area for the Moist Evergreen Forest Sub-Category.

The Moist Evergreen Forest, a variable three-storeyed forest system divided into montane, swamp, and riparian types, has shown a consistent decline in area over time from 1990 to 2022. This trend is largely due to land use change conversion for agriculture and human settlements. The expansion of these activities encroaches on forested areas, reducing the forest cover and affecting the ecosystems within. The loss of such forests poses significant ecological concerns, as they are critical to biodiversity, water regulation, and carbon sequestration. Shown in Figure 43 is the decline in the Moist Evergreen Forest from 1990 to 2022.

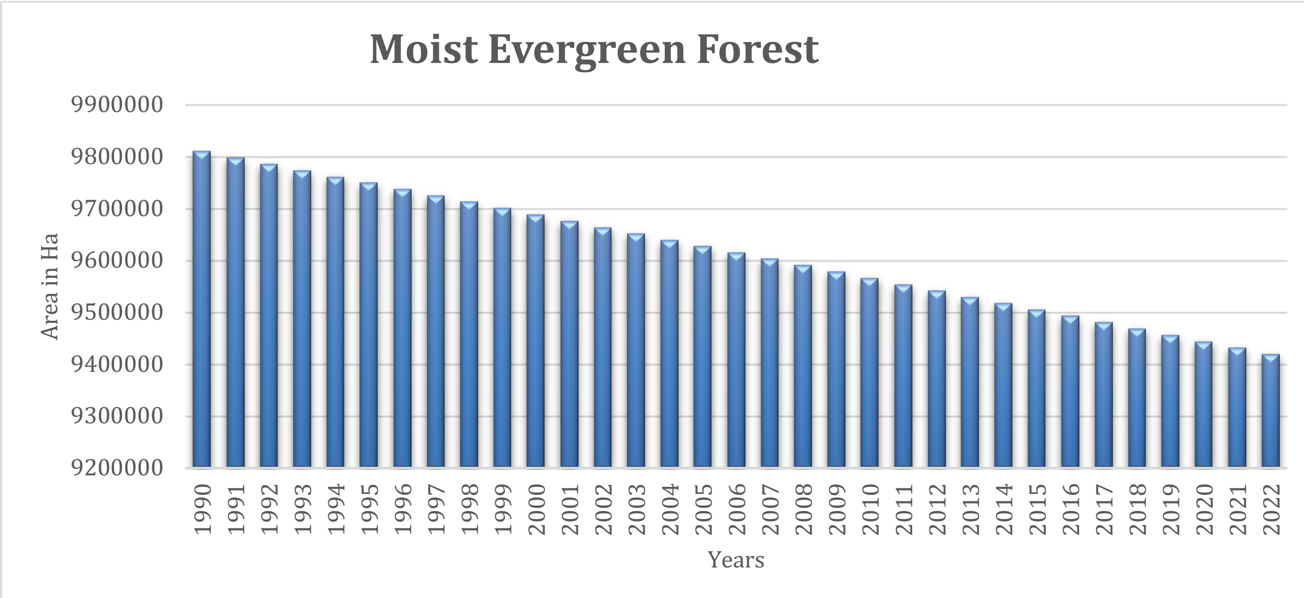


Figure 43:Trends of forest land areas under dry evergreen forest

The Trend in Land Area for the Woodland (Semi-Evergreen) Forest Sub-Category

The trend for the woodland (semi-evergreen) forest subcategory shows a consistent reduction in the land area over the entire time series as shown in Figure 44. This decline is primarily attributed to land use change conversions for agriculture and settlements, as well as the expansion of plantation estates led by the Zambia Forests and Forest Industries Corporation (ZAFFICO) who have been replanting forest plantation areas where removals have taken place and have also established new plantations in Luapula and Muchinga provinces. It is estimated that over 12,000 ha has been planted with exotic tree species in the country since 2011, of which 10% has been on additional acquired land (ZAFFICO 2011, ZAFFICO 2014). This expansion has been driven by the increasing demand from the construction industry.

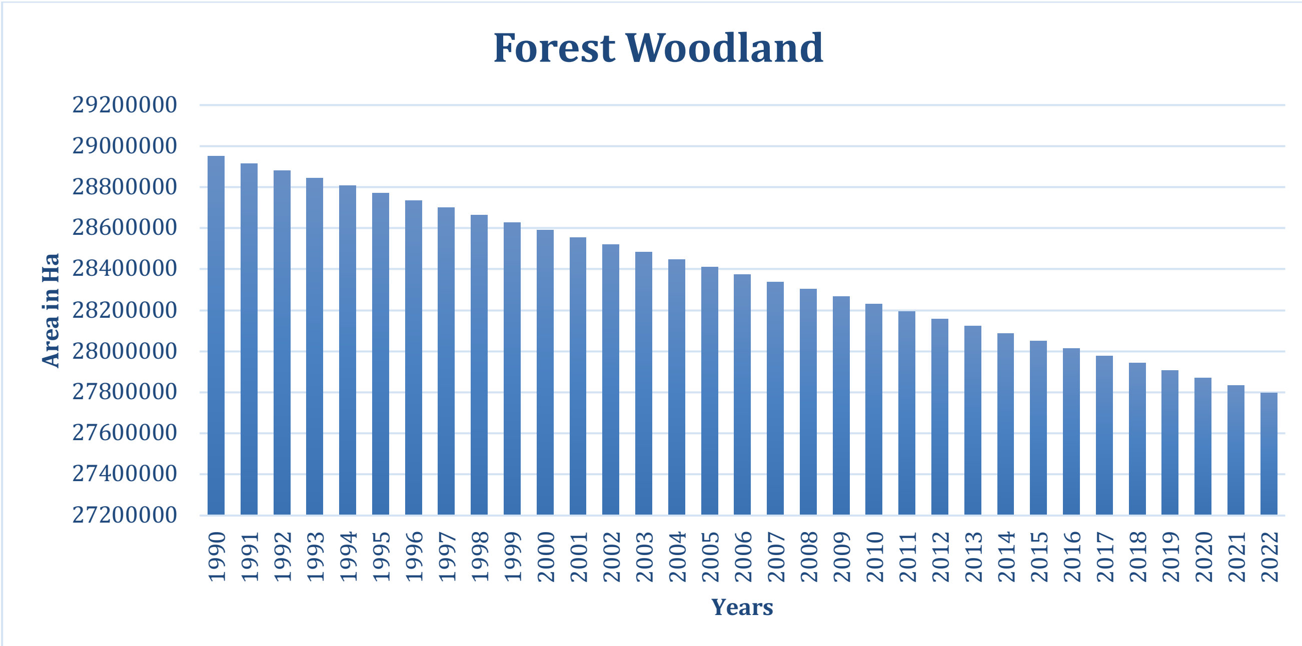


Figure 44:Trends of forestland areas under forest woodland

The Trend in Land Area for the Eucalyptus Plantations

The trend in Eucalyptus plantation land areas reflects a steady overall increase over the time series as provided in Figure 45, primarily driven by the growing demand for timber in the construction industry. Key observations include:

- **1990 to 2006**: The land area of Eucalyptus plantations showed a slight increase, likely due to the initial demand for timber and gradual expansion efforts.
- **2006 to 2010**: There was a noticeable decline in plantation hectarage was observed. This is attributed to several factors such as market fluctuations, shifts in land use, and changes in policy affecting forestry operations.
- **2011 to 2022**: A significant expansion in plantation hectarage occurred, primarily driven by an increased demand for timber, particularly in the construction sector. This boom may also be attributed to economic growth, urbanization, and infrastructure development during this period.

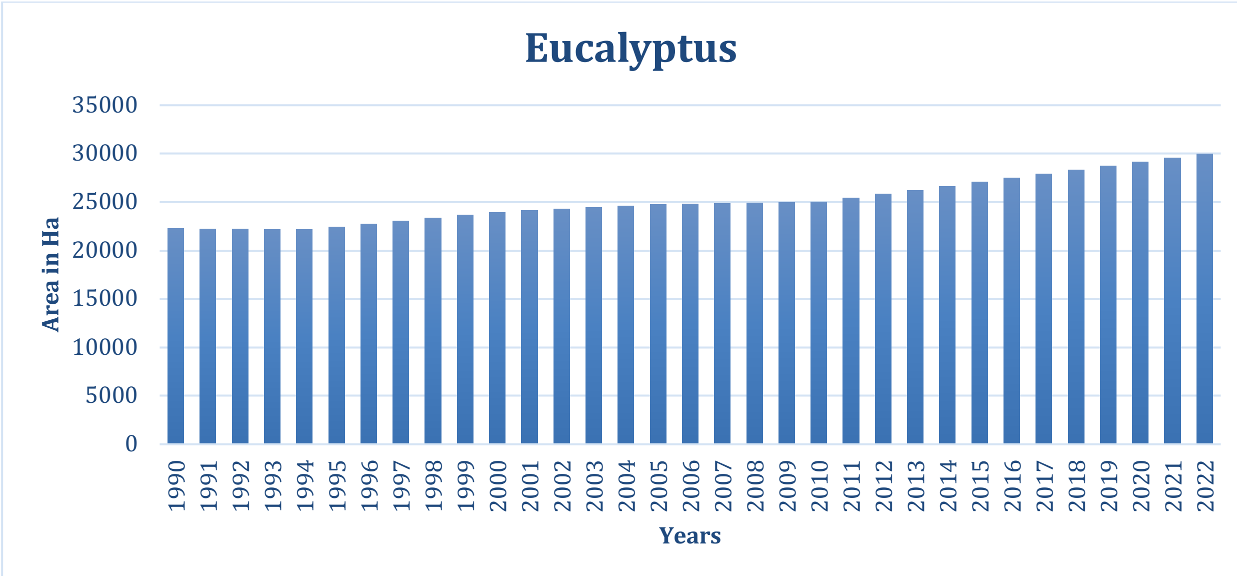


Figure 45: Trends of forest areas under Eucalyptus

The Trend in Area for the Pine Plantations

The trend in Pine plantation as given in Figure 46 reflects a steady overall increase over the time series in land areas, primarily driven by the growing demand for timber in the construction industry and electricity pole production. Key observations include:

- **1992 to 2000**: During this period, the area of pine plantations showed a slight decrease. This could be attributed to reduced afforestation and reforestation activities for the areas as there was no replanting of the areas cut between 1985 and 2000[29].
- **2001 to 2022**: There was a gradual increase in the area of the forest plantations. This is attributed to increased demand for timber, particularly in the construction sector. This boom may also be attributed to economic growth, urbanization, and infrastructure development during this period.

[29] James T Mulenga, 2022: The state of industrial plantations in Zambia

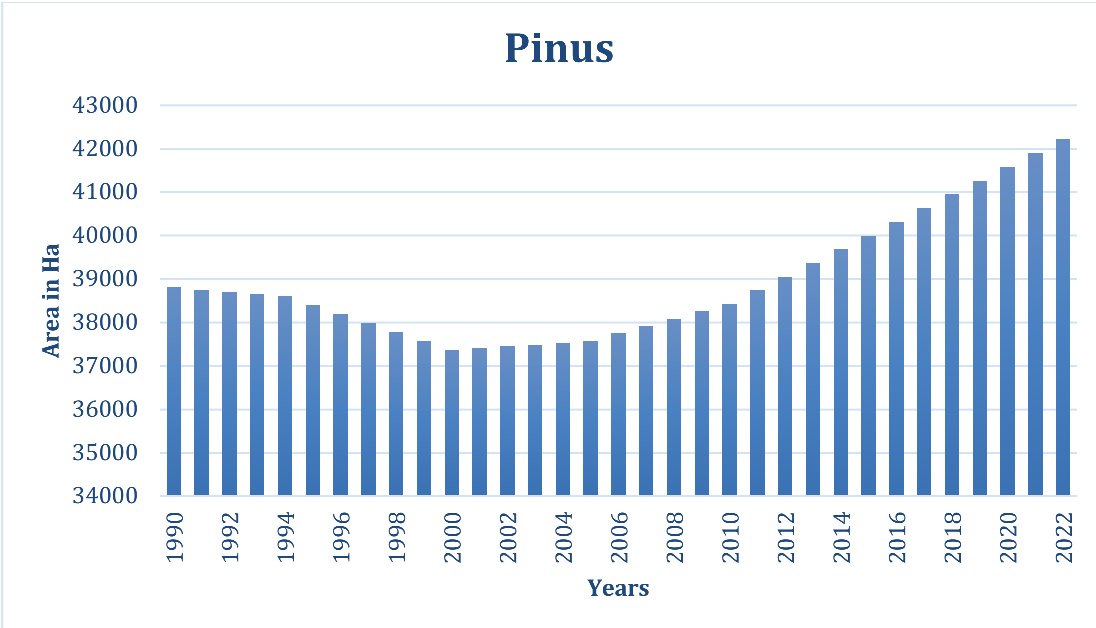


Figure 46: Trends of forestland areas under dry evergreen forest

Wood removals (Timber harvesting)

The trend in wood removals (timber harvesting) as given in Figure 47 illustrates that the highest removals occurred in woodland (semi-evergreen) and pine plantations, while the least was observed in dry deciduous forests, moist evergreen forests, and eucalyptus plantations. Forest woodland, a major forest sub - category, comprises of Miombo, Kalahari, Mopane, and Munga woodlands[30] .

Additionally, there was a marked increase in the harvesting of commercial species such as *Pterocarpus Chrysothrix* (Mukula), *Guibourtia Coleosperma* (Rosewood), and *Pterocarpus Angolensis* (Mukwa) among other high-value tree species. This surge, particularly between 2016 and 2022, was driven by growing demand for timber in both domestic and export markets.

[30] Shakacite et al., 2016: ILUA II, p. 20

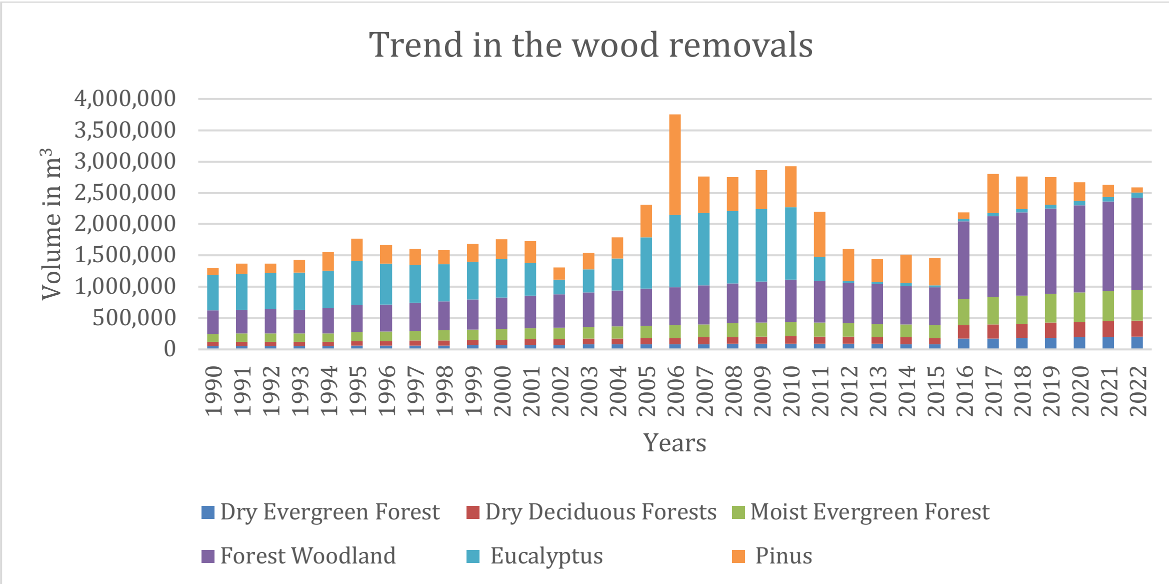


Figure 47: Trends in wood removals for commercial timber harvesting

Trends in Fuel Wood Removals

Fuelwood removals exhibited a steady upward trend from 1990 to 2010, followed by a decline between 2010 and 2015 as presented in Figure 48. However, there was a significant surge from 2016 to 2022, driven primarily by increases in electricity tariffs. This prompted heightened demand for charcoal, particularly in urban and peri-urban areas. Notable spikes in fuelwood removals were observed in 2015 and 2022, largely attributed to rising electricity costs and load management policies implemented by the electricity utility company during these years. These factors led many households to adopt charcoal as a more accessible energy source, further increasing fuelwood removals. Among forest sub-categories, forest woodlands recorded the highest levels of removals, while dry deciduous and moist evergreen forests experienced the least. Overall, the data analysis reveals a growing trend in fuelwood removals across most forest sub-categories.

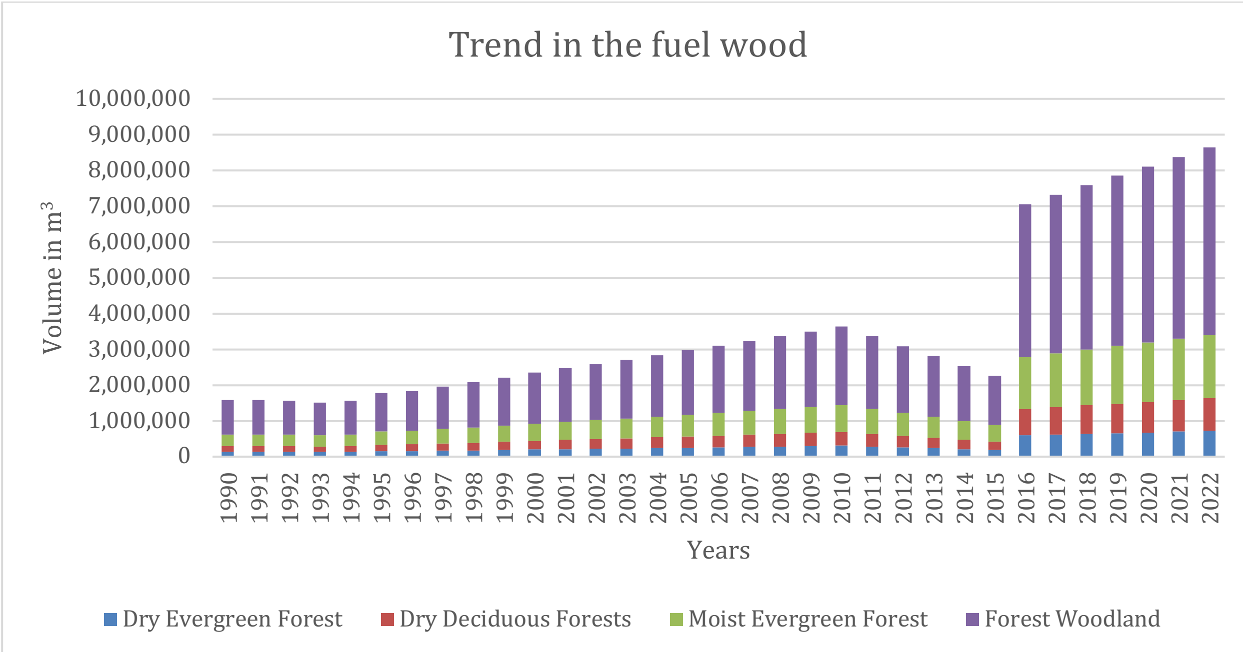


Figure 48:Trends in fuelwood removals

Trends in the Wood Removal for Charcoal

Wood removals associated with charcoal production have shown a moderate upward trend from 1990 to 2010, followed by a steady increase from 2010 to 2014, and a sharp rise from 2015 to 2022 (Figure 49). This surge is largely attributed to increases in electricity tariffs, which have driven heightened demand for charcoal in urban and peri-urban areas. Significant spikes in wood removals were recorded in 2015 and 2022, primarily due to rising electricity costs and load management policies implemented by the electricity utility company during this period. These factors prompted many households to rely on charcoal as a more accessible energy source, further escalating fuelwood removals.

Among forest sub-categories, forest woodlands experienced the highest levels of removals, whereas dry deciduous and moist evergreen forests recorded the least. Overall, the data analysis shows a consistent increase in wood removals for charcoal across most forest sub-categories.

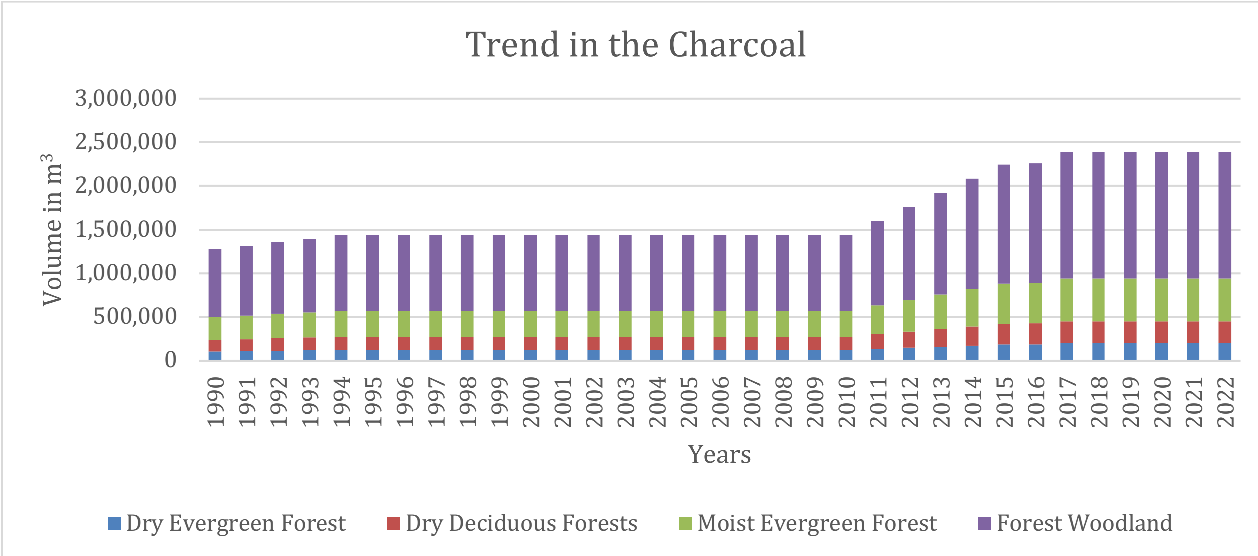


Figure 49: Trends in wood removals for charcoal

Disturbance (Wild-fires, pest out-breaks and natural land degradation)

Disturbances mostly attributed to wild fires in forest and grassland areas are primarily associated with late burning, often conducted for purposes such as land preparation, while early burning is typically classified as a management practice to mitigate fire risks. These burning activities are categorized into three regimes: early-season fires (April–June), mid-season fires (July–August), and late-season fires (September–November). During the period under review (1990–2022), disturbances included areas within forest and grassland ecosystems. The general trend in forest disturbances revealed fluctuations, with the highest levels observed in 2017 and the lowest in 1990 as presented in Figure 50.

Regards the forest sub-categories, semi-evergreen forest woodlands exhibited the largest burnt areas, followed by moist evergreen forests. Conversely, dry deciduous and dry evergreen forests recorded the smallest burnt areas, suggesting they were less impacted by fires compared to other forest types.

Regarding burnt biomass, semi-evergreen forest woodlands displayed the highest levels, followed by moist evergreen and dry deciduous forests. Dry evergreen forests consistently showed the lowest levels of burnt biomass throughout the analysis period. The spike in disturbances and burnt biomass in 2017 was likely driven by the prolonged dry spell experienced in the 2017/2018 season. Additionally, El Niño-induced droughts during the 2015/2016 season may have increased biomass vulnerability, contributing to higher levels of burnt biomass during these years.

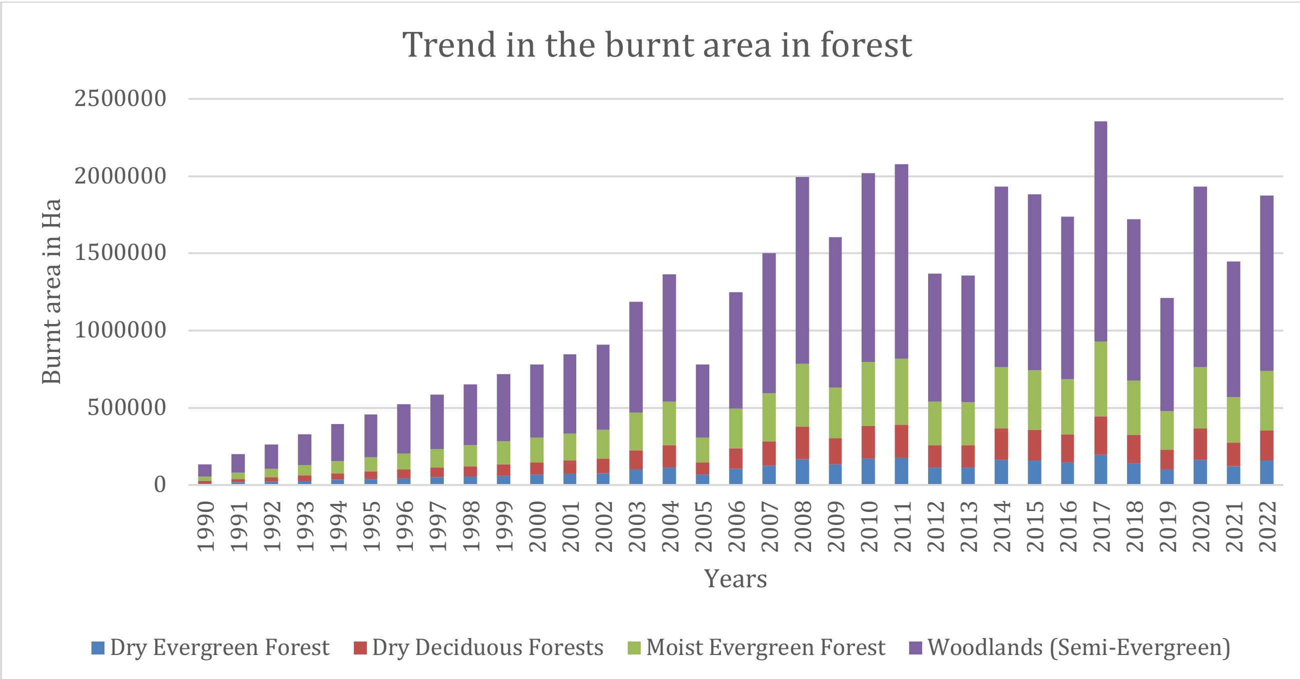


Figure 50:Trends in the disturbances (Wildfires, Pest outbreaks and natural land degradation)

Activity data used to estimate emissions under Land category are provided in Tables 28 to 37.

Table 28: Land Cover / Class Land Areas (Ha)

	Forest	Cropland	Grassland	Wetlands	Settlements	Other lands
1990	47863257	5199425	19561589	1906825	494721.4	235581.6
1991	47803669	5238920	19576140	1907518	499571.6	235581.6
1992	47744081	5278414	19590691	1908211	504421.8	235581.6
1993	47684492	5317909	19605241	1908904	509272	235581.6
1994	47624904	5357403	19619792	1909597	514122.3	235581.6
1995	47565316	5396898	19634343	1910290	518972.5	235581.6
1996	47505727	5436392	19648893	1910983	523822.7	235581.6
1997	47446139	5475887	19663444	1911676	528672.9	235581.6
1998	47386551	5515382	19677994	1912368	533523.1	235581.6
1999	47326962	5554876	19692545	1913061	538373.3	235581.6
2000	47267374	5594371	19707096	1913754	543223.5	235581.6
2001	47207786	5633865	19721646	1914447	548073.7	235581.6
2002	47148198	5673360	19736197	1915140	552923.9	235581.6
2003	47088609	5712854	19750748	1915833	557774.1	235581.6
2004	47029021	5752349	19765298	1916526	562624.4	235581.6
2005	46969433	5791844	19779849	1917219	567474.6	235581.6
2006	46909844	5831338	19794400	1917912	572324.8	235581.6
2007	46850256	5870833	19808950	1918604	577175	235581.6
2008	46790668	5910327	19823501	1919297	582025.2	235581.6
2009	46731080	5949822	19838051	1919990	586875.4	235581.6

2010	46671491	5989316	19852602	1920683	591725.6	235581.6
2011	46611903	6028811	19867153	1921376	596575.8	235581.6
2012	46552315	6068305	19881703	1922069	601426	235581.6
2013	46492726	6107800	19896254	1922762	606276.2	235581.6
2014	46433138	6147295	19910805	1923455	611126.5	235581.6
2015	46373550	6186789	19925355	1924148	615976.7	235581.6
2016	46313962	6226284	19939906	1924840	620826.9	235581.6
2017	46254373	6265778	19954456	1925533	625677.1	235581.6
2018	46194785	6305273	19969007	1926226	630527.3	235581.6
2019	46135197	6344767	19983558	1926919	635377.5	235581.6
2020	46075608	6384262	19998108	1927612	640227.7	235581.6
2021	46016020	6423757	20012659	1928305	645077.9	235581.6
2022	45956432	6463251	20027210	1928998	649928.1	235581.6

Table 29: Area coverage by forest type (Ha)

Sub-category	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Forest Woodland	Eucalyptus	Pinus
1990	4006539	5024696	9810121	28951822	22270.84	38800.91
1991	4001550	5018440	9797906	28915771	22243.11	38752.59
1992	3996561	5012183	9785690	28879720	22215.38	38704.28
1993	3991572	5005926	9773475	28843669	22187.64	38655.96
1994	3986583	4999669	9761259	28807618	22159.91	38607.65
1995	3981428	4993412	9749043	28771567	22457.74	38400.33
1996	3976272	4987156	9736827	28735515	22756.54	38192.55
1997	3971117	4980899	9724612	28699464	23056.32	37984.28
1998	3965960	4974642	9712396	28663413	23357.09	37775.52
1999	3960803	4968385	9700180	28627361	23658.85	37566.29
2000	3955646	4962128	9687965	28591310	23961.63	37356.55
2001	3950375	4955872	9675749	28555260	24123.46	37399.46
2002	3945102	4949615	9663534	28519210	24286.59	37442.98
2003	3939827	4943358	9651319	28483160	24451.02	37487.11
2004	3934550	4937102	9639103	28447110	24616.78	37531.86
2005	3929271	4930845	9626888	28411060	24783.88	37577.24
2006	3923995	4924588	9614672	28375009	24826.65	37745.42
2007	3918720	4918331	9602457	28338958	24869.49	37913.81
2008	3913443	4912075	9590241	28302907	24912.4	38082.43
2009	3908167	4905818	9578025	28266855	24955.39	38251.27
2010	3902890	4899561	9565810	28230804	24998.46	38420.33
2011	3897098	4893304	9553594	28194754	25410.3	38734.49
2012	3891306	4887048	9541379	28158703	25822.6	39049.02
2013	3885513	4880791	9529163	28122652	26235.35	39363.92
2014	3879719	4874534	9516948	28086602	26648.57	39679.2
2015	3873924	4868277	9504732	28050551	27062.25	39994.87

2016	3868129	4862021	9492517	28014501	27476.39	40310.91
2017	3862332	4855764	9480301	27978450	27891.01	40627.34
2018	3856535	4849507	9468086	27942399	28306.09	40944.15
2019	3850737	4843251	9455870	27906349	28721.65	41261.36
2020	3844938	4836994	9443655	27870298	29137.69	41578.95
2021	3839138	4830737	9431439	27834247	29554.21	41896.93
2022	3833337	4824480	9419224	27798197	29971.21	42215.31

Table 30: Area affected by disturbances (Ha)

YEAR OF ASSESSMENT	Indigenous forest	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Woodlands (Semi-Evergreen)
1990	Area (Ha)	11287	14152	27630	81541
1991	Area (Ha)	16698.42	20942.08	40886.75	120664.8
1992	Area (Ha)	22109.83	27732.17	54143.5	159788.5
1993	Area (Ha)	27521.25	34522.25	67400.25	198912.3
1994	Area (Ha)	32932.67	41312.33	80657	238036
1995	Area (Ha)	38344.08	48102.42	93913.75	277159.8
1996	Area (Ha)	43755.5	54892.5	107170.5	316283.5
1997	Area (Ha)	49166.92	61682.58	120427.3	355407.3
1998	Area (Ha)	54578.33	68472.67	133684	394531
1999	Area (Ha)	59989.75	75262.75	146940.8	433654.8
2000	Area (Ha)	65401.17	82052.83	160197.5	472778.5
2001	Area (Ha)	70812.58	88842.92	173454.3	511902.3
2002	Area (Ha)	76224	95633	186711	551026
2003	Area (Ha)	99550	124907	243867	719704
2004	Area (Ha)	114337	143471	280110	826667
2005	Area (Ha)	65368	82030	160153	472648
2006	Area (Ha)	104625	131304	256354	756558
2007	Area (Ha)	125720	157790	308065	909168
2008	Area (Ha)	166944	209545	409111	1207377
2009	Area (Ha)	134335	168627	329225	971614
2010	Area (Ha)	168946	212089	414078	1222035
2011	Area (Ha)	174024	218509	426613	1259029
2012	Area (Ha)	114472	143764	280681	828352
2013	Area (Ha)	113639	142748	278699	822501
2014	Area (Ha)	161837	203335	396987	1171594
2015	Area (Ha)	157571	198016	386602	1140948
2016	Area (Ha)	145318	182657	356615	1052450
2017	Area (Ha)	197085	247777	483756	1427669
2018	Area (Ha)	143824	180855	353098	1042069
2019	Area (Ha)	101366	127492	248914	734599
2020	Area (Ha)	161659	203370	397055	1171797
2021	Area (Ha)	120972	152218	297188	877066
2022	Area (Ha)	156718	197239	385086	1136473

Table 31: Wood removals by forest classification (m3/yr)

Sub-category	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Forest Woodland	Eucalyptus	Pinus
1990	52594.77	65960.36	128779.8	380057.3	563000	113000
1991	53220.8	66745.48	130312.6	384581.1	573000	160000
1992	53651.4	67285.51	131367	387692.7	573000	160000
1993	53437.94	67017.81	130844.3	386150.2	587000	205000
1994	55308.31	69363.48	135423.9	399665.7	597000	300000
1995	59225.65	74279.4	145021.7	427990.8	709000	356000
1996	60290.6	75618.21	147635.5	435704.9	650000	300000
1997	62349.04	78203.26	152682.6	450599.8	611000	250000
1998	64683.3	81134.52	158405.5	467489.4	592000	219000
1999	67164.55	84250.43	164488.9	485442.9	604000	278000
2000	69700.78	87435.59	170707.6	503795.6	615000	310000
2001	71866.98	90159.42	176025.5	519490	528000	339000
2002	74088.02	92952.53	181478.7	535583.6	227000	199000
2003	76345.52	95791.83	187022.2	551943.4	371000	262000
2004	78657.83	98700.42	192700.8	568702.4	512000	335000
2005	81006.57	101655.2	198469.7	585727.6	827000	522000
2006	83373.42	104633.1	204283.7	602885.9	1155000	1601000
2007	85795.1	107680.3	210232.9	620443.4	1155000	585000
2008	88271.6	110796.7	216317.4	638400.1	1155000	543000
2009	90802.89	113982.5	222537.2	656756	1155000	620000
2010	93407.35	117260.5	228937.3	675644.1	1155000	658000
2011	91287.19	114622.7	223787.2	660445.2	385595	718513
2012	89167.78	111984.8	218637	645245.8	29500	510500
2013	87049.1	109346.8	213486.6	630045.9	36000	364000
2014	84931.17	106708.7	208336.1	614845.6	46000	455000
2015	82813.99	104070.6	203185.4	599644.7	37973	434906
2016	170969.3	214898.8	419564.3	1238226	38603	110831
2017	178261.9	224112.7	437553.3	1291316	45322	624224
2018	183110.1	230256.9	449549.1	1326718	52041	515889
2019	187956.2	236401.3	461545.3	1362122	58760	448621
2020	192800.3	242545.9	473542	1397526	65479	299219
2021	197642.3	248690.8	485539.1	1432933	72198	190884
2022	202482.3	254835.9	497536.8	1468340	78917	82549

Table 32: Estimated Consumption of Woodfuel ('000 Tonnes')

Year	Firewood	Wood for charcoal production	**Total**
1994	4,634.91	2,566.59	**7,201.50**
1995	4,729.50	2,618.97	**7,348.47**
1996	4,826.02	2,728.09	**7,554.12**
1997	4,924.51	2,841.77	**7,766.28**
1998	5,025.01	2,960.17	**7,985.19**
1999	5,127.57	3,083.51	**8,211.08**
2000	5,232.21	3,211.99	**8,444.20**
2001	5,338.99	3,277.54	**8,616.53**

2002	5,447.95	3,414.11	**8,862.06**
2003	5,559.13	3,556.36	**9,115.49**
2004	5,672.58	3,704.54	**9,377.13**
2005	5,788.35	3,858.90	**9,647.25**
2006	5,904.12	4,013.26	**9,917.37**
2007	6,022.20	4,173.79	**10,195.99**
2008	6,142.64	4,340.74	**10,483.38**
2009	6,265.50	4,514.37	**10,779.86**
2010	6,390.81	4,694.94	**11,085.75**
2011	6,518.62	4,882.74	**11,401.36**
2012	6,648.99	5,078.05	**11,727.04**
2013	6,781.97	5,281.17	**12,063.15**
2014	6,917.61	5,492.42	**12,410.03**
2015	7,055.97	5,712.11	**12,768.08**
2016	7,385.94	5,426.01	12,811.95

NB. 0.618 cubic meter of wood volume is equivalent to one tonne of wood.

Table 33: Cropland converted to forestland

	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Forest Woodland	Eucalyptus	Pinus
1990	754.1	945.8	1846.5	5449.6	4.2	7.3
1991	754.1	945.8	1846.5	5449.6	4.2	7.3
1992	754.1	945.8	1846.5	5449.6	4.2	7.3
1993	754.1	945.8	1846.5	5449.6	4.2	7.3
1994	754.1	945.8	1846.5	5449.6	4.2	7.3
1995	754.1	945.8	1846.5	5449.6	4.3	7.3
1996	754.1	945.8	1846.5	5449.6	4.3	7.2
1997	754.0	945.8	1846.5	5449.6	4.4	7.2
1998	754.0	945.8	1846.5	5449.6	4.4	7.2
1999	754.1	945.8	1846.5	5449.6	4.2	7.3
2000	754.1	945.8	1846.5	5449.6	4.2	7.3
2001	754.1	945.8	1846.5	5449.6	4.2	7.3
2002	754.1	945.8	1846.5	5449.6	4.2	7.3
2003	754.1	945.8	1846.5	5449.6	4.2	7.3
2004	754.1	945.8	1846.5	5449.6	4.2	7.3
2005	754.1	945.8	1846.5	5449.6	4.2	7.3
2006	754.1	945.8	1846.5	5449.6	4.2	7.3
2007	754.1	945.8	1846.5	5449.6	4.2	7.3
2008	754.1	945.8	1846.5	5449.6	4.2	7.3
2009	754.1	945.8	1846.5	5449.6	4.2	7.3
2010	754.1	945.8	1846.5	5449.6	4.2	7.3
2011	754.1	945.8	1846.5	5449.6	4.2	7.3
2012	754.1	945.8	1846.5	5449.6	4.2	7.3
2013	754.1	945.8	1846.5	5449.6	4.2	7.3
2014	754.1	945.8	1846.5	5449.6	4.2	7.3
2015	754.1	945.8	1846.5	5449.6	4.2	7.3
2016	754.1	945.8	1846.5	5449.6	4.2	7.3

2017	754.1	945.8	1846.5	5449.6	4.2	7.3
2018	754.1	945.8	1846.5	5449.6	4.2	7.3
2019	754.1	945.8	1846.5	5449.6	4.2	7.3
2020	754.1	945.8	1846.5	5449.6	4.2	7.3
2021	754.1	945.8	1846.5	5449.6	4.2	7.3
2022	754.1	945.8	1846.5	5449.6	4.2	7.3

Table 34: Forest Land converted to cropland

	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Forest Woodland	Eucalyptus	Pinus
1990	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1991	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1992	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1993	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1994	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1995	4234.6	5311.0	10369.1	30601.4	23.9	40.8
1996	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1997	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1998	4234.8	5311.0	10369.1	30601.4	23.5	41.0
1999	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2000	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2001	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2002	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2003	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2004	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2005	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2006	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2007	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2008	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2009	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2010	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2011	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2012	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2013	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2014	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2015	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2016	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2017	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2018	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2019	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2020	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2021	4234.8	5311.0	10369.1	30601.4	23.5	41.0
2022	4234.8	5311.0	10369.1	30601.4	23.5	41.0

Table 35: Forestland converted to settlements

	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Forest Woodland	Eucalyptus	Pinus
1990	1218.2	1527.8	2982.9	8803.1	6.8	11.8
1991	1218.2	1527.8	2982.9	8803.1	6.8	11.8
1992	1218.2	1527.8	2982.9	8803.1	6.8	11.8
1993	1218.2	1527.8	2982.9	8803.1	6.8	11.8
1994	1218.2	1527.8	2982.9	8803.1	6.8	11.8
1995	1218.2	1527.8	2982.9	8803.1	6.9	11.7
1996	1218.1	1527.8	2982.9	8803.1	7.0	11.7
1997	1218.1	1527.8	2982.9	8803.1	7.1	11.7
1998	1218.0	1527.8	2982.9	8803.1	7.2	11.6
1999	1218.0	1527.8	2982.9	8803.1	7.3	11.6
2000	1217.9	1527.8	2982.9	8803.1	7.4	11.5
2001	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2002	1217.7	1527.8	2982.9	8803.1	7.5	11.6
2003	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2004	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2005	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2006	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2007	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2008	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2009	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2010	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2011	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2012	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2013	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2014	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2015	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2016	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2017	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2018	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2019	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2020	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2021	1217.8	1527.8	2982.9	8803.1	7.4	11.5
2022	1217.8	1527.8	2982.9	8803.1	7.4	11.5

Table 36: Land use change matrix conversions

	Grassland converted to Cropland (Ha)	Cropland converted to Grassland (Ha)	Settlement converted to Grassland (Ha)	Grassland converted to Wetland (Ha)	Cropland converted to Settlement (Ha)	Grassland converted to Settlement (Ha)

1990	4157	4850	693	693	1386	693
1991	4157	4850	693	693	1386	693
1992	4157	4850	693	693	1386	693
1993	4157	4850	693	693	1386	693
1994	4157	4850	693	693	1386	693
1995	4157	4850	693	693	1386	693
1996	4157	4850	693	693	1386	693
1997	4157	4850	693	693	1386	693
1998	4157	4850	693	693	1386	693
1999	4157	4850	693	693	1386	693
2000	4157	4850	693	693	1386	693
2001	4157	4850	693	693	1386	693
2002	4157	4850	693	693	1386	693
2003	4157	4850	693	693	1386	693
2004	4157	4850	693	693	1386	693
2005	4157	4850	693	693	1386	693
2006	4157	4850	693	693	1386	693
2007	4157	4850	693	693	1386	693
2008	4157	4850	693	693	1386	693
2009	4157	4850	693	693	1386	693
2010	4157	4850	693	693	1386	693
2011	4157	4850	693	693	1386	693
2012	4157	4850	693	693	1386	693
2013	4157	4850	693	693	1386	693
2014	4157	4850	693	693	1386	693
2015	4157	4850	693	693	1386	693
2016	4157	4850	693	693	1386	693
2017	4157	4850	693	693	1386	693
2018	4157	4850	693	693	1386	693
2019	4157	4850	693	693	1386	693
2020	4157	4850	693	693	1386	693
2021	4157	4850	693	693	1386	693
2022	4157	4850	693	693	1386	693

Activity data requirements under this section under aggregate Sources and Non-CO_2 Emissions on Land are provided in Tables 36 to 39.

Table 37: Shows area burnt in forest land (ha)

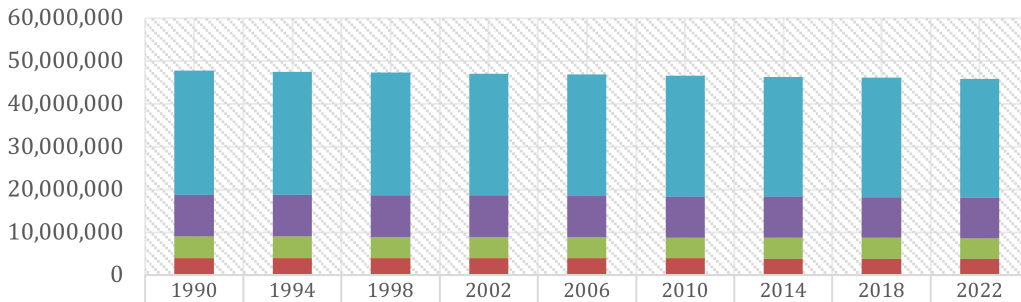
YEAR OF ASSESSMENT	Dry Evergreen Forest	Dry Deciduous Forests	Moist Evergreen Forest	Woodlands (Semi-Evergreen)
1990	2813.518349	3528.500934	6888.978007	20330.89
1991	5627.036698	7057.001868	13777.95601	40661.77
1992	8440.555046	10585.5028	20666.93402	60992.66
1993	11254.0734	14114.00374	27555.91203	81323.55
1994	14067.59174	17642.50467	34444.89004	101654.4
1995	16880.46566	21171.07956	41334.01242	121985.7
1996	19693.12061	24699.67957	48223.18387	142317.2
1997	22505.5548	28228.30491	55112.40477	162648.8
1998	25317.76637	31756.9558	62001.67555	182980.6

1999	28129.75349	35285.63245	68890.99662	203312.5
2000	30941.51427	38814.33507	75780.36839	223644.5
2001	32345.82011	40578.86707	79225.40705	233811.6
2002	33749.92045	42343.42264	82670.49175	243978.8
2003	32528.12498	40813.51371	79683.52669	235163.6
2004	30545.66453	38328.91999	74832.65324	220847.6
2005	70798.94978	88845.65053	173460.5556	511920.2
2006	34481.71555	43274.32406	84487.96593	249342.5
2007	35696.78004	44802.54244	87471.63036	258148
2008	42208.91138	52979.77063	103436.6949	305264.4
2009	29735.16349	37325.76148	72874.10563	215067.5
2010	29432.87841	36949.07956	72138.67901	212897.1
2011	33484.3073	42043.82118	82085.5555	242252.5
2012	41308.25447	51878.57283	101286.7373	298919.4
2013	43762.02407	54971.70866	107325.7168	316741.7
2014	28885.83437	36292.57282	70856.92783	209114.3
2015	47432.68209	59607.63283	116376.8069	343453.5
2016	41666.16829	52372.03608	102250.1656	301762.7
2017	22963.83045	28870.36538	56365.95144	166348.3
2018	15507.88547	19500.82303	38073.03544	112361.9
2019	58056.59168	73020.47534	142563.7852	420737
2020	32902.08083	41391.35137	80811.68606	238493
2021	26984.21655	33953.88984	66290.92785	195639.1
2022	14658.02489	18447.98853	36017.50146	106295.6

3.4.2.4 Emissions Trends for Land Category

Forestland

Managed Forest Land is partitioned into two sub categories namely; Forest Land Remaining Forest Land and Land Converted to Forest Land. The relevant carbon pools and non-CO_2 gases for which methods include; biomass (above-ground and below-ground biomass), dead organic matter (dead wood and litter), soil organic matter. Non-CO_2 gases include CH_4, CO, N_2O and NO_X. Forest land-use classification was undertaken according to geographic detail while considering ecosystem types, biomass densities, fractions of cleared biomass which are burnt, climate, ecology or species, forest types, land-use or forestry practices, fuelwood and wood removals. Emissions from forestland increased from 85299.6Gg CO_2e in the base year, 1990 to 176,604.91CO_2e in the current 2022 as given in Figure 51 and 52.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
Forest Woodland (Ha)	28,951,822	28,807,618	28,663,413	28,519,210	28,375,009	28,230,804	28,086,602	27,942,399	27,798,197
Moist Evergreen Forest (Ha)	9,810,121	9,761,259	9,712,396	9,663,534	9,614,672	9,565,810	9,516,948	9,468,086	9,419,224
Dry Deciduous Forest (Ha)	5,024,696	4,999,669	4,974,642	4,949,615	4,924,588	4,899,561	4,874,534	4,849,507	4,824,480
Dry Evergreen Forest (Ha)	4,006,539	3,986,583	3,965,960	3,945,102	3,923,995	3,902,890	3,879,719	3,856,535	3,833,337

Figure 51: Trends of Emissions from forestland sub categories under *Land*

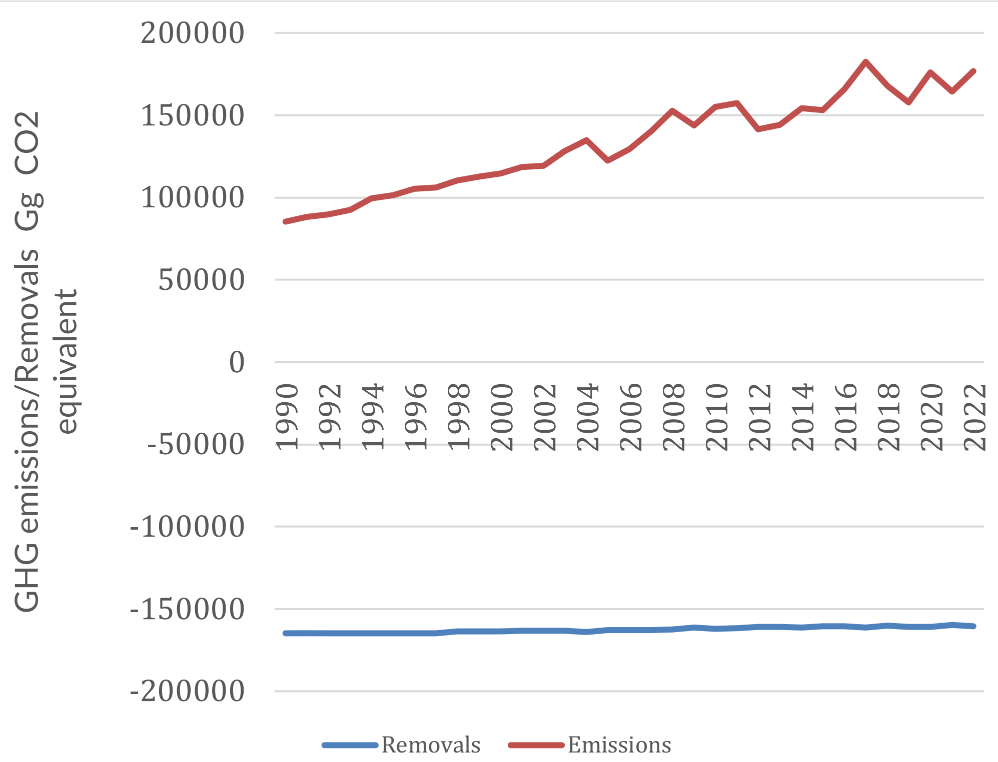


Figure 52: Trends of Emissions from Forestland

In Zambia, land use change (LUC) contributes significantly to the country's total GHG emissions. During the period under review (1990 to 2022), national statistics show a significant reduction in the forest land category, primarily due to the conversion of forest land to other land uses. This reduction highlights the impact of expanding agricultural activities and urban development over time. Correspondingly, there has been an increase in other land-use categories such as cropland, settlements, grasslands, and wetlands. The land use changes highlight the influence of economic and developmental pressures on land use dynamics. The total GHG emission removals reduced from -84,996.2 Gg CO_2 in the base year 1990 to -11,942.9 Gg CO_2 in the current year 2022, representing a reduction of 86%(Figure 53). The emission removals or sink in land category was from annual increase in biomass carbon stock estimated from mean annual increment in tonnes of dry matter per hectare per year.

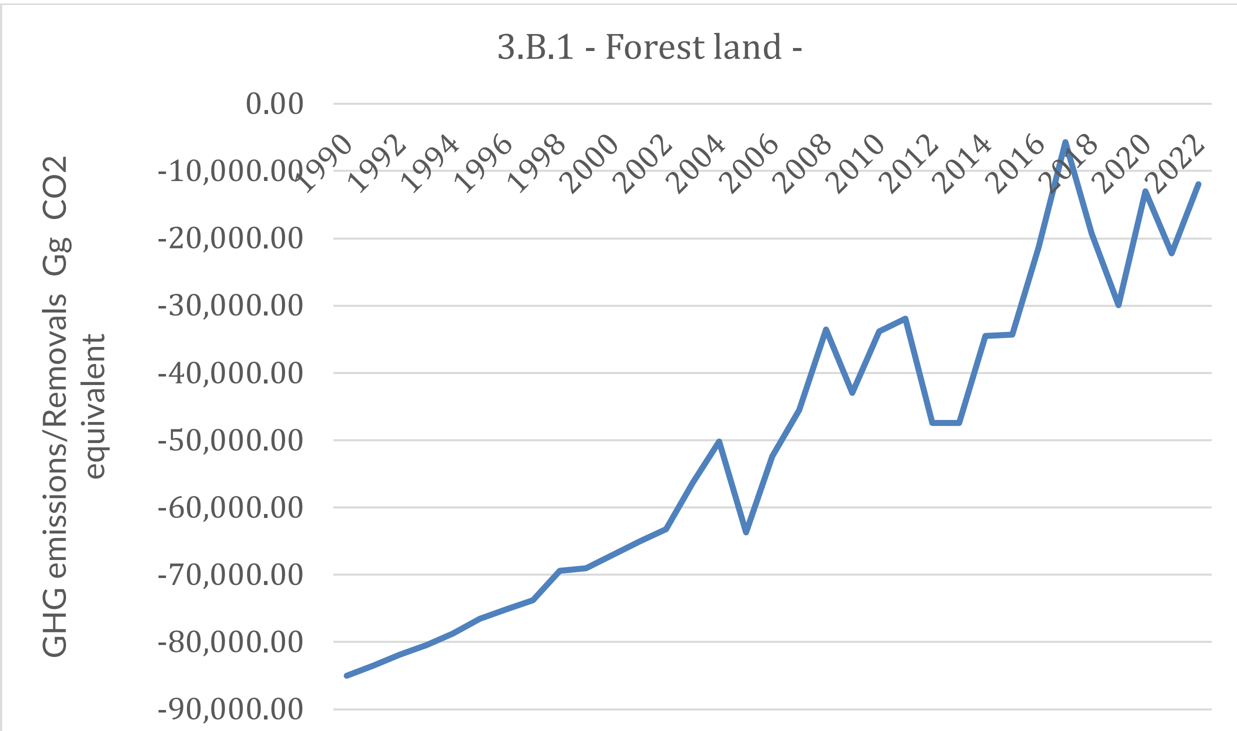


Figure 53: Emission Removals from Forestland remaining Forestland

Cropland

Cropland includes arable and tillable land, rice fields, and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category, and is not expected to exceed those thresholds at a later time. Cropland includes all annual and perennial crops as well as temporal fallow land (i.e., land set at rest for one or several years before being cultivated again). Crop Land is partitioned into two sub categories namely, Cropland Remaining Cropland (CC) and Land Converted to Cropland (LC) because of the difference in carbon dynamics. Land-use conversions to Cropland from Forest Land, Grassland and Wetlands usually result in a net loss of carbon from biomass and soils as well as N_2O to the atmosphere. The main drivers of cropland expansion in Zambia are;

- **Commodity prices and market demand.** One of the main drivers of cropland expansion in Zambia is commodity prices and market demand. In the case of maize, the most cultivated crop, the Government sets the annual purchase price on a 50kg quantity for purchase by the country's Food and Reserve Agency (FRA) from small-scale farmers. Private buyers, dominated by agro-processing companies, also purchase maize and other crops from farmers. The crops that fetch attractive prices in a given marketing season normally result in an increase in cropland cultivation for the particular crops in the next cropping season. Crops like maize and soybean have a huge market demand for food and livestock feed. This demand results in an expansion of cultivation on cropland, especially when it is coupled with high commodity prices.

- **Policies and regulatory support.** The Zambian Government, through the Ministry of Agriculture (GRZ, 2004) and Zambia Development Agency (ZDA, 2011), supported the commercial development and expansion of the agriculture sector through farm block development during the period under review. The expansion of the agriculture sector is contained in the policy and strategic documents such as Vision 2030 (GRZ,2013), the Sixth National Development Plan (GRZ,211), Revised Sixth National Development Plan (GRZ, 2014) and The First National Agricultural Policy of 2004 - 2015 (GRZ,2004).

- **Internal migration.** The frequent occurrence of droughts in the southern parts of Zambia, particularly in Southern Province, has resulted in the migration of farming households to provinces that experience favourable rains for farming. The farming households migrated to North Western, Copperbelt and Central provinces where new land has been opened for farming.

Emissions from crop land grew from 3214.6 Gg CO_2e in the base year 1990 to 7453.5 Gg CO_2e in the current year 2022. (Figure 54).

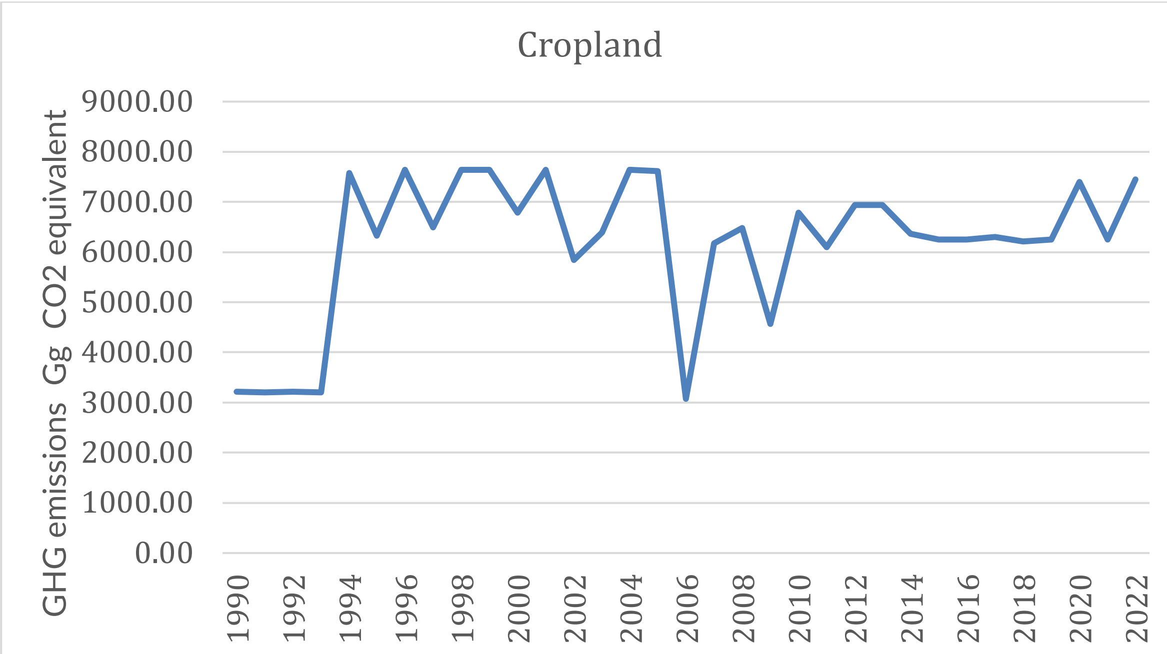


Figure 54: Emissions from crop land

Settlements, Grasslands, and Wetlands

This section provides estimates of carbon stock changes and greenhouse gas emissions and removals associated with changes in biomass, dead organic matter (DOM), and soil carbon on lands classified as settlements. Settlements including all developed land i.e., residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size. Emissions from Settlements increased sharply from 1990 to 2009 and thereafter remained steady until 2022 as shown in Figure 55.

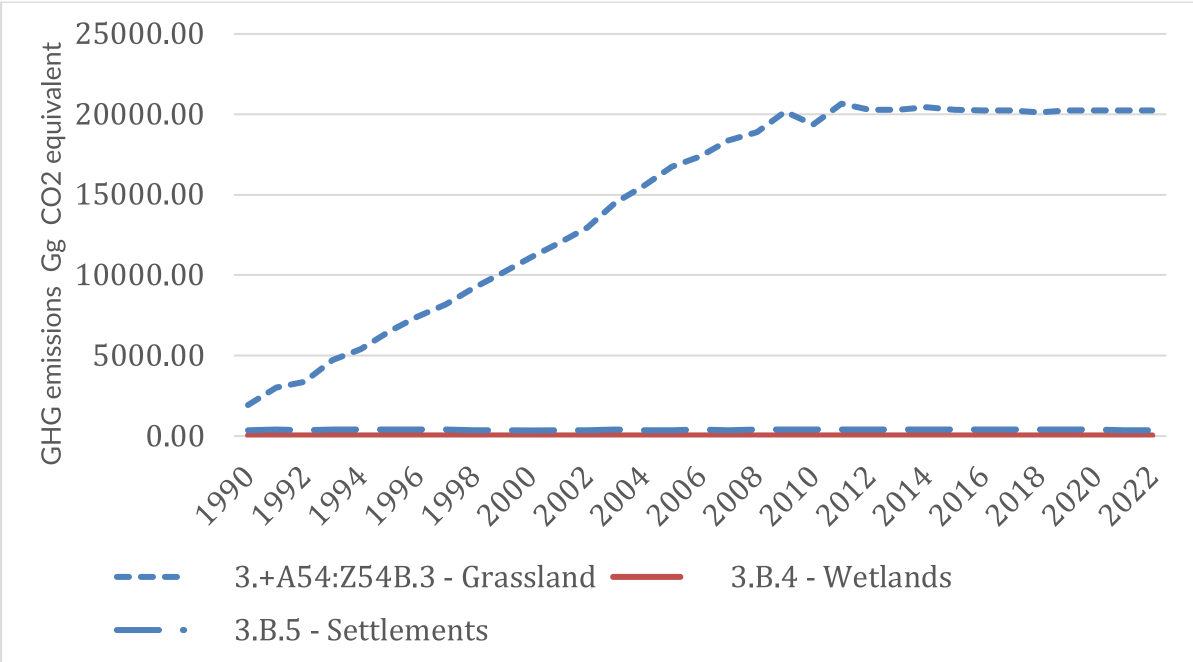


Figure 55:Trends of emissions from settlements, grassland and wetlands

Generally, emissions from Grassland, wetlands and settlements increased by from 1932.5Gg CO_2e, 41.6 Gg CO_2e, 362.02 Gg CO_2e in 1990 to 20247.7, Gg CO_2e, 41.6 Gg CO_2e, and 362.0 Gg CO_2e in 2022, respectively.

3.4.2.5 Quality assurance/quality control measures

Activity data used in estimating GHG emissions from the AFOLU was obtained from Forest Department (ILUA II data set), ZAMSTATS, Zambia Revenue Authority. Efforts were made to compare data from various sources and compile the most suitable data sets for use in emissions estimates. Effort were made to check and verify the data from all sources to ensure good quality data was utilised in the inventory preparation from the AFOLU sector. 3.4.1.5 Sectoral uncertainties,

The Uncertainty Analysis (UA) was estimated using approach 1 and computed using the IPCC 2006 software and is provided in Annex I Data for estimating emissions in the Land category was obtained from the ILUA data and ZAMSTATS with uncertainty of ±5%.

3.4.1.6 Planned improvements

Gaps on activity data and emission factor are elaborated as follows:

Data Gaps

There is a lack of emission factors by vegetation class.

Improvements

(i). There is a need to institute a two-year data collection for activity data using improved methods. This can be addressed through the newly calculated emission factors for the vegetation classes for the 2020 forest reference emission level.

(ii). There is need for the stratification of the vegetation types in the category forest woodland and other wooded land.

(iii).

Propose emission factor and activity data research areas/projects for inventory improvement projects

(i). There is need for validation of the emission factors newly calculated from ILUA II data.

(ii). Mapping of Peatland areas in collaboration with relevant sectors such as Agriculture Research.

(iii). Capacity building in fire data processing and estimation from Modis and, any other recommended data sources.

(iv). Obtain accurate growth rate estimates for all categories for future GHG updates.

(v). Enhance capacity in carrying out sample-based estimates for land use changes.

(vi). Establish a dedicated GHG unit within the department.

(vii). Enhance the sector's capacity in data collection, analysis, and utilization of IPCC software for improved greenhouse gas inventory reporting.

(viii). Integrate GHG data collection into the department's daily operations and reporting processes to ensure consistent data availability for national reporting.

3.4.3 Aggregate Sources and Non-CO2 emission on Land

3.4.3.1 Overview

Aggregate sources and non-CO_2 emissions on land were considered according to source subcategories as outlined in the IPCC guidelines (IPCC, 2006), namely; Emissions from Biomass burning, Liming, Urea application, Direct N2O emissions from managed soils, Indirect N2O emissions from managed soils, Indirect N2O emissions from manure management, Rice cultivation and Other as given in Figure 56.

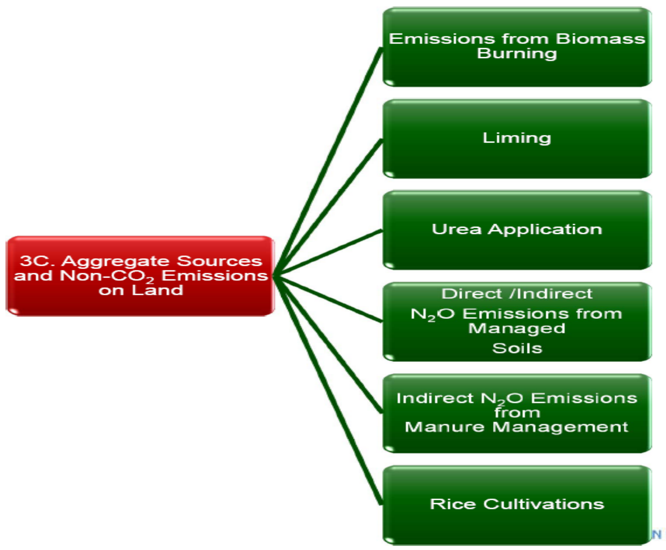


Figure 56: Aggregate Sources and Non-CO2 emissions on land

3.4.3.2 Methodology and Emission Factors

Tier 1 method was used in estimating emissions in (i) direct N_2O emissions from managed soils are estimated, (ii) N_2O emissions from atmospheric deposition of N volatilised from managed soil are estimated and (iii) CO_2 Emissions from additions of carbonate limes to soils. Tier 1 emission factors were used in the estimates.

3.4.3.3 Activity Data

Biomass burning in forest land

Biomass burning in forestland under aggregate sources primarily includes areas affected by early-season fires, often employed as a management practice to reduce fuel loads. These fires are classified into three burning regimes based on timing: early-season fires (April–June), mid-season fires (July–August), and late-season fires (September–November). For the period under review, fires included under aggregate sources in forestland primarily occurred between January and July.

The general trend of biomass burnt in forestland from 1990 to 2022 exhibited fluctuations, with the highest levels recorded in 2005 and the lowest in 1990 (Figure 57). In terms of forest subcategories, woodlands (semi-evergreen) accounted for the largest burnt areas, followed by moist evergreen forests. Conversely, dry deciduous and dry evergreen forests experienced the smallest burnt areas, suggesting they were less affected by fires compared to other forest types.

Regarding burnt biomass, semi-evergreen woodlands showed the highest levels, followed by moist evergreen and dry deciduous forests. Dry evergreen forests consistently recorded the lowest burnt biomass throughout the analysis period (1990–2022). The year 2005 marked a significant spike in burnt biomass, likely due to the prolonged dry spell Zambia experienced during the 2004/2005 season[31]. Similarly, El Niño-induced droughts in the 2017/2018 season may have left substantial biomass susceptible to fire disturbances, further contributing to increased burnt biomass during these years.

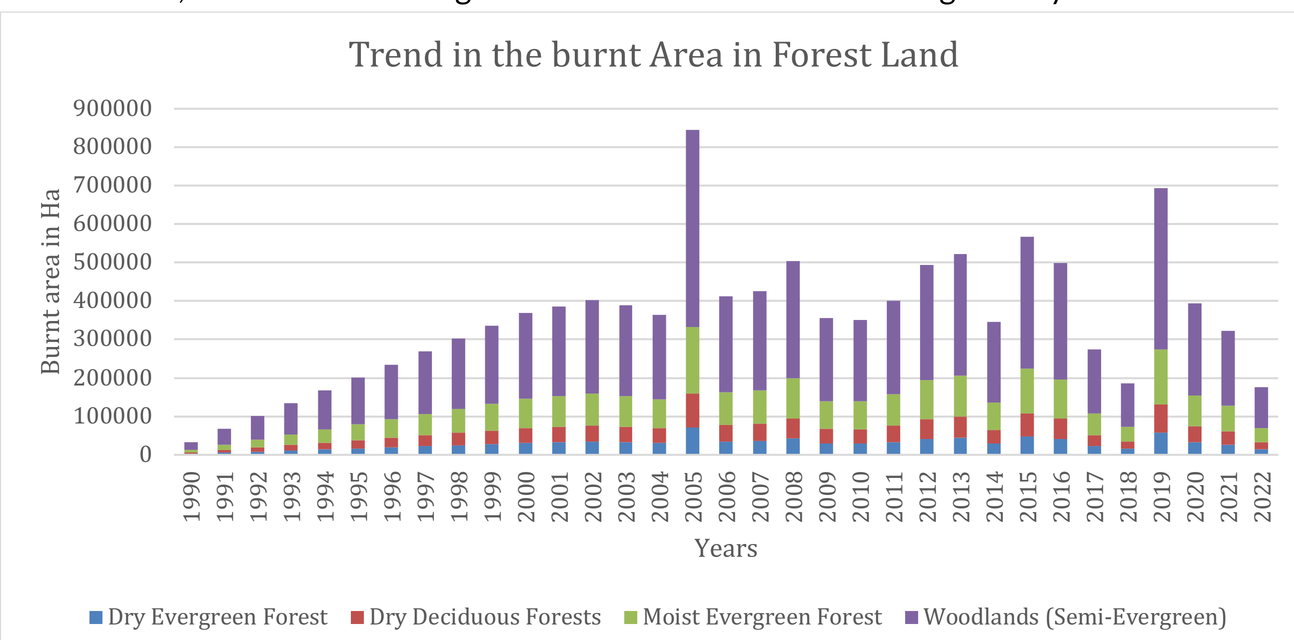


Figure 57:Trends in burnt area in forest land

[31] Lekprichakul, M. 2008. Impact of 2004/2005 Drought on Zambia's Agricultural Production: Preliminary Results

Biomass burning in Grassland

The analysis of fire trends in grasslands, the largest burnt area during the fire trend analysis was recorded in 2005, while the smallest burnt area was observed in 1990 (Figure 58). This discrepancy can be attributed to the linear extrapolation method applied for the period 1990 to 2001. The overall trend reveals fluctuations in the burnt area over the years, likely influenced by varying fire occurrences, climate conditions, land management practices, and fire prevention measures

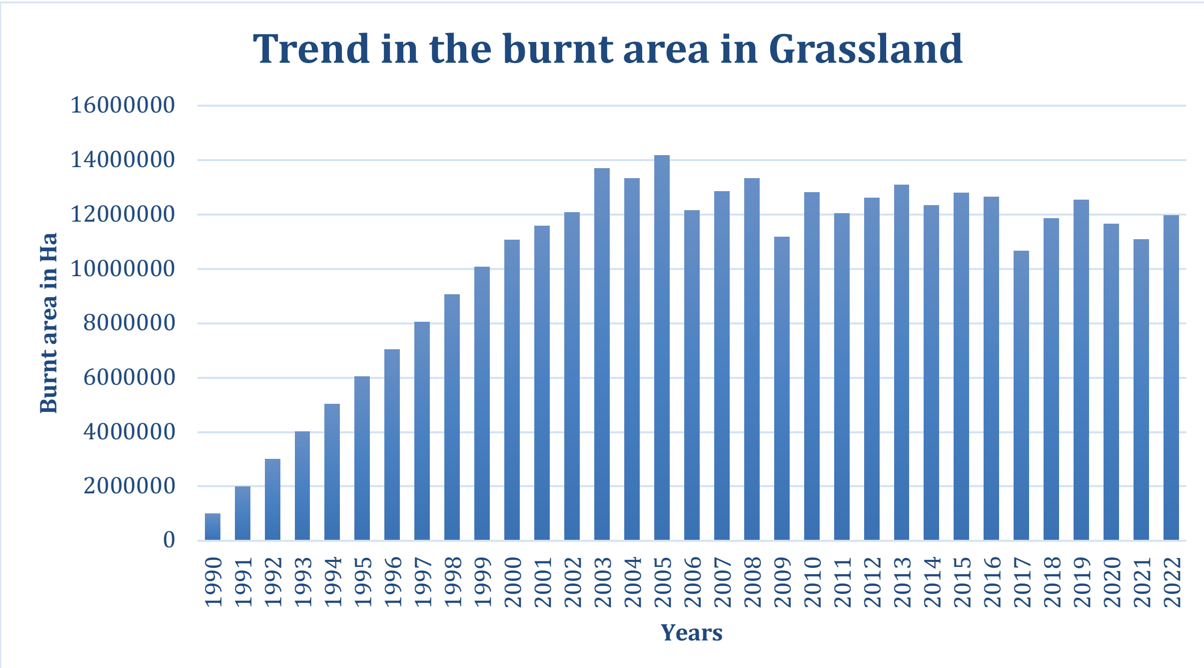


Figure 58: Trends in burnt area in Grassland

Biomass Burning in All Other Land

In grassland, the largest burnt area during the fire trend analysis was recorded in 2005 while the lowest was observed in 1990 (Figure 59). It was however worth noting the areas burnt under for biomass burning in all other lands were quite moderate from the MODIS fire data set that was used.

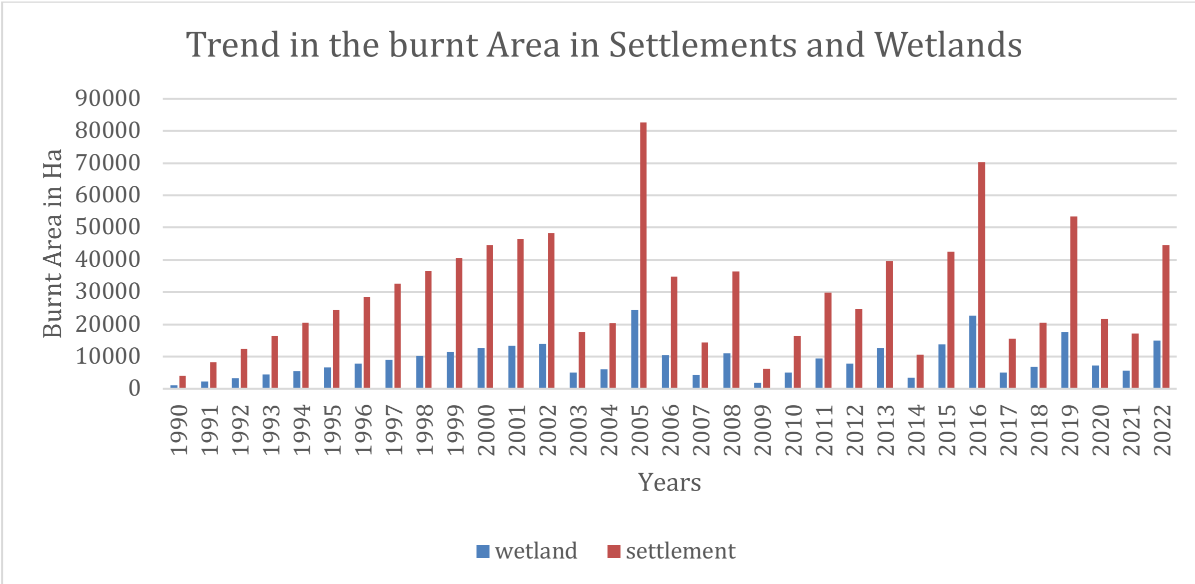


Figure 59: Trends in burnt area in Other land

Liming

Liming is used to reduce soil acidity and improve plant growth in managed systems, particularly agricultural lands and managed forests. Adding carbonates to soils in the form of lime (e.g., calcic limestone ($CaCO_3$), or dolomite ($CaMg(CO_3)_2$) leads to CO_2 emissions as the carbonate limes dissolve and release bicarbonate (2HCO3), which evolves into CO_2 and water (H2O). Lime consumption in Zambia for agriculture purposes is mostly by large -scale farmers. Large scale farmers, particularly in high rainfall areas of the country, where crop commercial farming is concentrated, use dolomitic or calcitic lime to increase the pH of acidic soils. Dolomitic and calcitic lime are both available on the Zambian market. In this report the lime consumed has therefore been taken to be dolomitic, based on the assumption that farmers would prefer it over calcitic because it contains large amounts of magnesium which are an important mineral for plant health.

Lime usage has been periodic over time. From 2000 to 2011, limestone ($CaCO_3$) calcite was applied in Regions I and II, while from 2011 to 2015, dolomite ($CaMgCO_3$) was used in Regions II and III. The use of lime and its recommendations were driven by promotional programs, including those rolled out by the Programme Against Malnutrition (PAM) and the activities of the Ministry of Agriculture

Urea Application

Adding urea to soils during fertilisation leads to the release of CO_2 that 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 releases enzymes. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO2 and water. Consumption of urea presents the total quantity of urea used in the crop sector, showing an increasing trend, especially after the year 2000. Before 2000, urea usage was relatively low, but it has significantly risen since then, with the cultivated hectarage having quadrupled by the year 2000. Maize production accounts for the highest urea usage compared to other crops or agricultural enterprises.

Direct N2O Emissions from Managed Soils

In most soils, an increase in available Nitrogen (N) enhances nitrification and denitrification rates which then increase the production of N_2O. Increases in available N can occur through human-induced N additions or change of land-use and/or management practices that mineralise soil organic Direct N_2O emissions from managed soils occur from sources which include; synthetic N fertilisers, N in crop residues and drainage/management of organic soils. In most soils, an increase in available N enhances nitrification and denitrification rates which then increase the production of N_2O. Increases in available N can occur through human-induced N additions or change of land-use and/or management practices that mineralise soil organic N. The following N sources are included in the methodology for estimating direct N2O emissions from managed soils:

a) synthetic N fertilisers (FSN);
b) Organic N applied as fertiliser (e.g., animal manure, compost, sewage sludge, rendering waste) (FON);
c) Urine and dung N deposited on pasture, range and paddock by grazing animals (FPRP);
d) N in crop residues (above-ground and below-ground), including from N-fixing crops 2 and from forages during pasture renewal 3 (FCR);
e) N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils (FSOM); and
f) Drainage/management of organic soils (i.e., Histosols) 4 (FOS).

The largest source of nitrogen emissions comes from agricultural crop cultivation residues, followed by organic fertilizers, with livestock being the third largest emitter of nitrous oxide. The proportion of nitrogen emissions from crop cultivation residues compared to urine and dung consistently ranges between 50% and 80%, indicating a steady variation between these two sources.

Indirect N2O Emissions from Managed Soils

Indirect emissions of N_2O from managed land take place through two indirect pathways; (a) the volatilisation of N as NH3 and oxides of N (NOx), and the deposition of these gases and their products NH4+ and NO3- onto soils and the surface of lakes and other waters; (b) The leaching and runoff from land of N from synthetic and organic fertiliser additions, crop residues, mineralisation of N associated with loss of soil C in mineral and drained/managed organic soils through land-use change or management practices, and urine and dung deposition from grazing animals. Methane (CH_4) is generated during wetland rice growing from the decomposition of plant residues and other organic carbon material in the soil. This generation occurs through microbial action under anaerobic environments following flooding of the rice crop.

Indirect N2O Emissions from Manure Management

The leaching and runoff from land of N from urine and dung deposition from grazing animals. Methane (CH_4) is generated during wetland rice growing from the decomposition of plant residues and other organic carbon material in the soil. Emissions from this sub category were not estimated due to lack of activity data.

Rice Cultivation

Methane (CH_4) is generated during wetland rice growing from the decomposition of plant residues and other organic carbon material in the soil. This generation occurs through microbial action under anaerobic environments following flooding of the rice crop

The area under rice production increased steadily from about 33,000 ha in 2011 to 43,000 ha 2015 before dropping sharply to 25,500 ha in 2016. This can be attributed to the Ministry of Agriculture's Crop Diversification Programme which has recognized rice as one of the strategic commodities that contributes to food security, and with potential to significantly increase incomes and employment among rural producers[32].

Government's decision to include rice as one of the nine crops supported by the Farmer Input Support Programme (FISP) has also contributed to the upswing of areas under rice cultivation. According to the Second National Rice Development Strategy [33]. rice growing has been promoted vigorously across the ten provinces of Zambia. However, the decline in production of rice in the 2015/16 farming period could be attributed to the drought that occurred during the season. Area expected to be harvested under rice dropped slightly from 27,000 ha in 2011 to 26,000 ha in 2012.

The succeeding years of 2013 and 2014 shows an increase in area expected to be harvested exceeding 30,000 ha. This is in view of the fact that rice has become an important staple food in Zambia in the recent past with a steady increase in demand and growing importance as evidenced by its current status as a strategic food crop[41]. Production areas of rice are largely concentrated in Northern, Muchinga, Western, Eastern and Luapula Provinces. This is in view of the abundance of water which creates favourable conditions for rice cultivation especially in the dambos and wetlands. The promotion of

[32] CSO data 2011 to 2014

[33] Second National Rice Development Strategy, 2016

rice growing in upland areas has been emphasized in recent years due to the introduction of up-land rice varieties.

Maize production 1990 to 2022

A staggered analysis of the four-year trends from 1990 to 2022 for Zambia's maize cultivation indicated progressive expansion of areas under the cropland category. From 1990 to 1994 this dropped by 11% from the initial 763,000 Ha to 679,000, thereafter, this increased by 14.9% from 1995 to 1999. From 2000 to 2004, maize cultivation saw a steady increase of 12.3%. This was followed by a significant expansion in the area planted between 2005 and 2009, rising by 34.8% to exceed one million hectares. Growth continued, with the area increasing by 14.2% from 2010 to 2015, then by 4.2% from 2015 to 2019. The most recent period, 2020 to 2022, saw a 16% surge, bringing the total maize cultivation area to a record 1.9 million hectares. This expansion reflects enhanced support to smallholder farmers through targeted programs such as the Farmer Input Support Programme (FISP).

Notably, the largest area expansions occurred in 2005–2009 (34.8%) and 2020–2022 (16.0%), aligning with production increases during the same periods. Maize production soared by 117.8% in 2005–2009 and by 42.7% in 2000–2004. However, between 2015 and 2019, production dropped by 23.4%, primarily due to prolonged droughts.

Looking further back, maize production declined from 1.1 million metric tons (MT) in 1990 to 1 million MT in 1994, reaching a low of 737,000 MT in 1995. By 1999, production had recovered slightly to 800,000 MT and increased to 850,000 MT in 2000. A notable rise followed, reaching 1.2 million MT in the early 2000s. Though it dipped to 866,000 MT in 2005, production surged to 1.8 million MT by 2009. It then rose further to 2.6 million MT in the early 2010s, peaking at 3 million MT. However, it fell again to 2.6 million MT and then to 2 million MT between 2015 and 2019 a period marked by severe droughts. These declines persisted through 2020–2022. In summary, while maize cultivation area has generally trended upward with major expansions in 2005 to 2009 and 2020 to 2022. The production has experienced both substantial growth and significant setbacks, often influenced by climatic conditions.

The wheat expansions 1990 to 2022

Wheat started off in 1990 around 11,000ha with slight improvement by 0.3% at the end of 1994. This went on to a steady rise by 27.1% within the 1995 to 1999 period, which rose by 37.2% in the years 2000 to 2004, when it reached its peak change of 53.6% in the 2005 to 2009 period. Thereafter there was a slight drop by 4.2% in the 2010 to 2014 phase. Thereafter, this dropped by 36.7% within the 2015 to 2019 period by 40.9%rise to the highest peak in the 2020 to 2023 cultivated cropland areas. This started off around 53,000 MT which has increased over the production to the highest 277,000MT.

The production increase is a steady one, but checked on a staggered approach, rose by 13.7% within the 1990 to 1994 phase. Which dramatically increased in the 1995/1999 by 82.1 %, and continued to grow in the 2000/2004 period and progressively into the 2005/2009 period by 42.8%. The increased production reached its highest in 2010/2015 period by 17.7 %. This, then dropped by 24.4% in the 2015/2019 era. Definitely influenced by the droughts, while the last period increased by 44.8%. All these rises have evidenced increasing production capacity and potential for wheat production in Zambia. The area planted with wheat has generally increased over the years, with significant growth periods in 2005-2009 (53.6%) and 2020-2023 (40.9%). Wheat production has shown substantial increases, particularly in 1995-1999 (82.1%) and 2020-2023 (44.8%).

Cultivated area soybean

In Zambia, soybean cultivation and production have shown a generally upward trend over the past three decades, with notable fluctuations driven by climatic conditions and shifts in policy support. From 1990 to 1994, the area under soybean cultivation ranged between 25,000 and 29,000 hectares, accounting for 14.7% of the total. This area sharply declined in the 1995–1999 period, dropping 45.9% from 21,000 hectares to approximately 11,000 hectares.

A remarkable recovery occurred from 2000 to 2004, with the area expanding from 2,500 hectares to 33,000 hectares, representing an exceptional 1,220% increase. However, this growth plateaued in 2005–2009, with a slight decrease of 0.8%, as the area declined marginally from 65,000 to 64,000 hectares. The growth trend resumed in the 2010 to 2014 period, when cultivated area rose from 62,000 to 116,000 hectares, an 86.9% increase. This was followed by another significant increase from 129,000 hectares to 235,000 hectares between 2015 and 2019, marking an 81.6% growth.

The most dramatic expansion occurred in 2020–2022, when the cultivated area jumped from 229,000 to 700,000 hectares, representing a 205.7% increase—the largest recorded during the entire period. These trends illustrate the long-term expansion of soybean cropland, driven by increased demand and supportive agricultural policies. Soybean production mirrored these shifts in cultivated area, though with more dramatic changes in certain periods.

During 1990–1994, production remained modest at 24,000 to 26,000 metric tons (MT). Slight improvement was noted in 1995–1999, with production increasing to 21,000–26,000 MT, a modest 6.4% rise. A breakthrough occurred in 2000–2004, when production soared from 1,800 MT to 54,000 MT, marking an extraordinary 2,873.5% increase. This rapid growth continued through 2005–2009, maintaining the upward momentum.

The 2010–2014 period saw production grow from 111,000 MT to approximately 214,000 MT, representing a 91.4% increase. From 2015 to 2019, production rose from 226,000 MT to 281,000 MT, followed by another significant increase in 2020–2023, where output jumped from 296,000 MT to 760,000 MT, a 155.9% increase. Both the area under cultivation and total soybean production in Zambia have shown substantial long-term growth, with key surges during 2000–2004 and 2020–2023. These periods align with broader agricultural development initiatives and growing market demand for soybeans. The data from ZAMSTAT (1990–2022) underscores a positive trajectory for Zambia's soybean sector, despite intermittent setbacks. Continued investment in farmer support programs and climate-resilient practices is likely to sustain this upward trend.

Activity Data

Provided in Tables 38 to 40 is the actual activity data used.

Table 38: Biomass Burning in Grassland, wetland and settlements (ha)

	Grassland	wetland	settlement	Otherland
1990	1,006,078	1,067	4,114	508
1991	2,012,157	2,151	8,215	1,015
1992	3,018,235	3,252	12,301	1,519
1993	4,024,313	4,368	16,372	2,021
1994	5,030,392	5,500	20,430	2,520
1995	6,036,470	6,649	24,474	3,018
1996	7,042,549	7,813	28,504	3,514
1997	8,048,627	8,994	32,521	4,008
1998	9,054,705	10,190	36,523	4,499
1999	10,060,784	11,401	40,513	4,989
2000	11,066,862	12,628	44,488	5,476
2001	11,569,901	13,293	46,432	5,714
2002	12,072,940	13,965	48,369	5,950
2003	13,700,654	5,082	17,457	2,147
2004	13,331,570	5,957	20,292	2,494
2005	14,175,866	24,445	82,589	10,148
2006	12,143,370	10,357	34,708	4,263
2007	12,840,796	4,287	14,249	1,750
2008	13,334,747	11,061	36,474	4,477
2009	11,169,142	1,883	6,162	756
2010	12,813,835	5,011	16,264	1,995
2011	12,038,402	9,288	29,912	3,668
2012	12,602,396	7,693	24,584	3,013
2013	13,090,938	12,461	39,518	4,842
2014	12,329,994	3,329	10,478	1,283
2015	12,787,024	13,648	42,632	5,220

2016	12,647,990	22,693	70,358	8,611
2017	10,665,853	5,051	15,544	1,902
2018	11,860,128	6,723	20,538	2,512
2019	12,541,025	17,617	53,428	6,532
2020	11,647,079	7,231	21,771	2,661
2021	11,077,182	5,699	17,035	2,081
2022	11,965,912	14,970	44,431	5,426

Table 39: Quantities of crop production in t/year

Crop	1994	2000	2005	2010
Maize	1020749.4	850466	866187	2795483
Maize (for seed)				37,550
Wheat	60944.4	66544.6	136833	172256
Rice	16589.9	6358.2	13337.5	51655.9
Sorghum	35067.51	8167.7	18,714	27732.1
Millet	62643.51	42743	29,583	47996.9
Sunflower	9820.9	6393.2	8,112	26420.4
Soya beans	24629.76	1839.1	89,660	111888
Groundnuts	34732.08	23446.9	74,218	164602
Mixed Beans	23179.59	1850.5	23,098	65265.2
Cowpeas		35210.7	1,249	2721.8
Bambara nuts	512.9		1,237	
Irish Potatoes			14,035	22940.5
Cassava	183,742.40	968521	-	
Sweet Potatoes		9841.4	66,926	252867
Cotton			155,213	72482.3
Virginia Tobacco		3066	23,211	22073.9
Burley Tobacco		7610	13,094	9808.6

Table 40: Quantities of Compound D and rea fertilizer used in t/year

Year	Fertiliser (t)				N- Total
	Compound- D	N- Content	Urea	N- Content	
1994					
2000	32,095.70	4,012.00	30040.8	13818.8	17,830.70
2005	25,060.00	3,132.50	25060	11527.6	14,660.10
2010	121,861.20	15,232.60	114665.6	52746.2	67,978.80

3.4.3.4 Trends of Emissions Under Aggregate Sources

The emissions from aggregate Sources and Non-CO2 emissions on land varied while increasing from 2139.0 Gg CO_2e in the base year 1990 to 11860.2 Gg CO_2e in current year 2022 as presented in Figure 60.

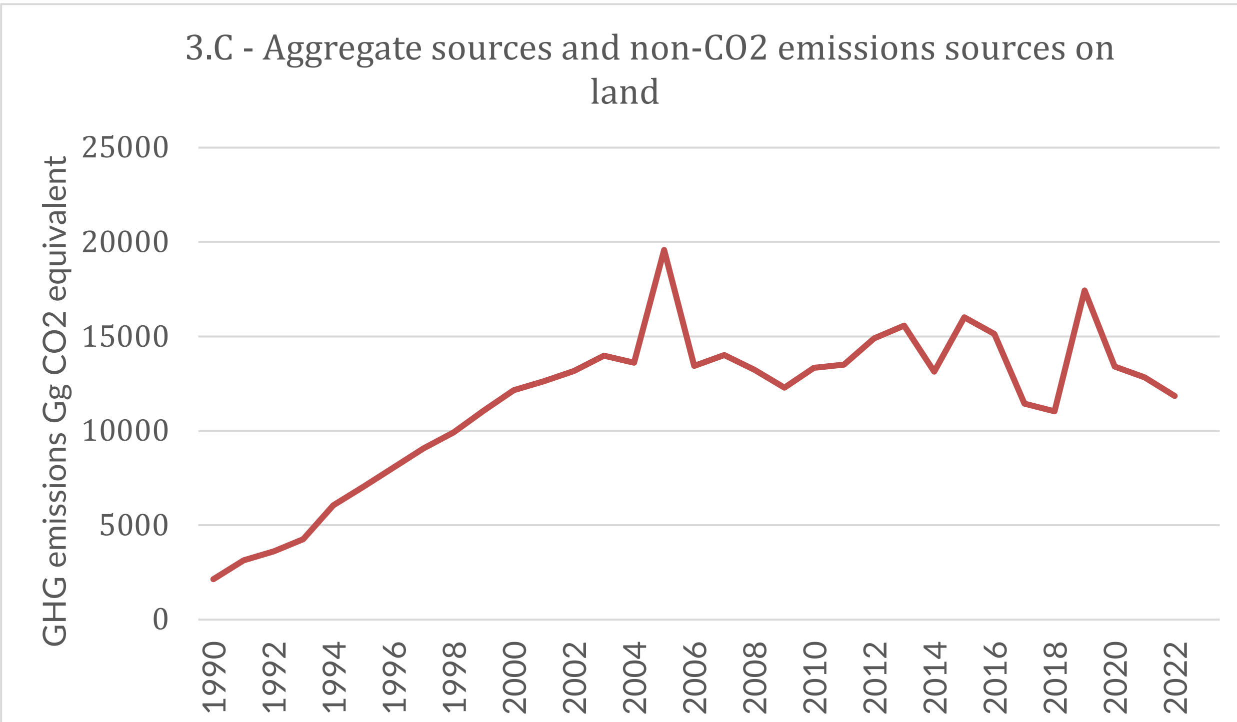


Figure 60: Emissions trend for the Aggregate sources and non-CO2 emissions sources

In 2022, emissions from biomass burning were the highest contributor to emissions for Aggregate sources and non-CO_2 emissions sources on land with 80%. This was followed by emissions from Direct N_2O emissions from managed soils was at 15%. Emissions from Indirect N2O Emissions from managed soils was 2% and the least was emissions from rice cultivation at 3% as given in Figure 61.

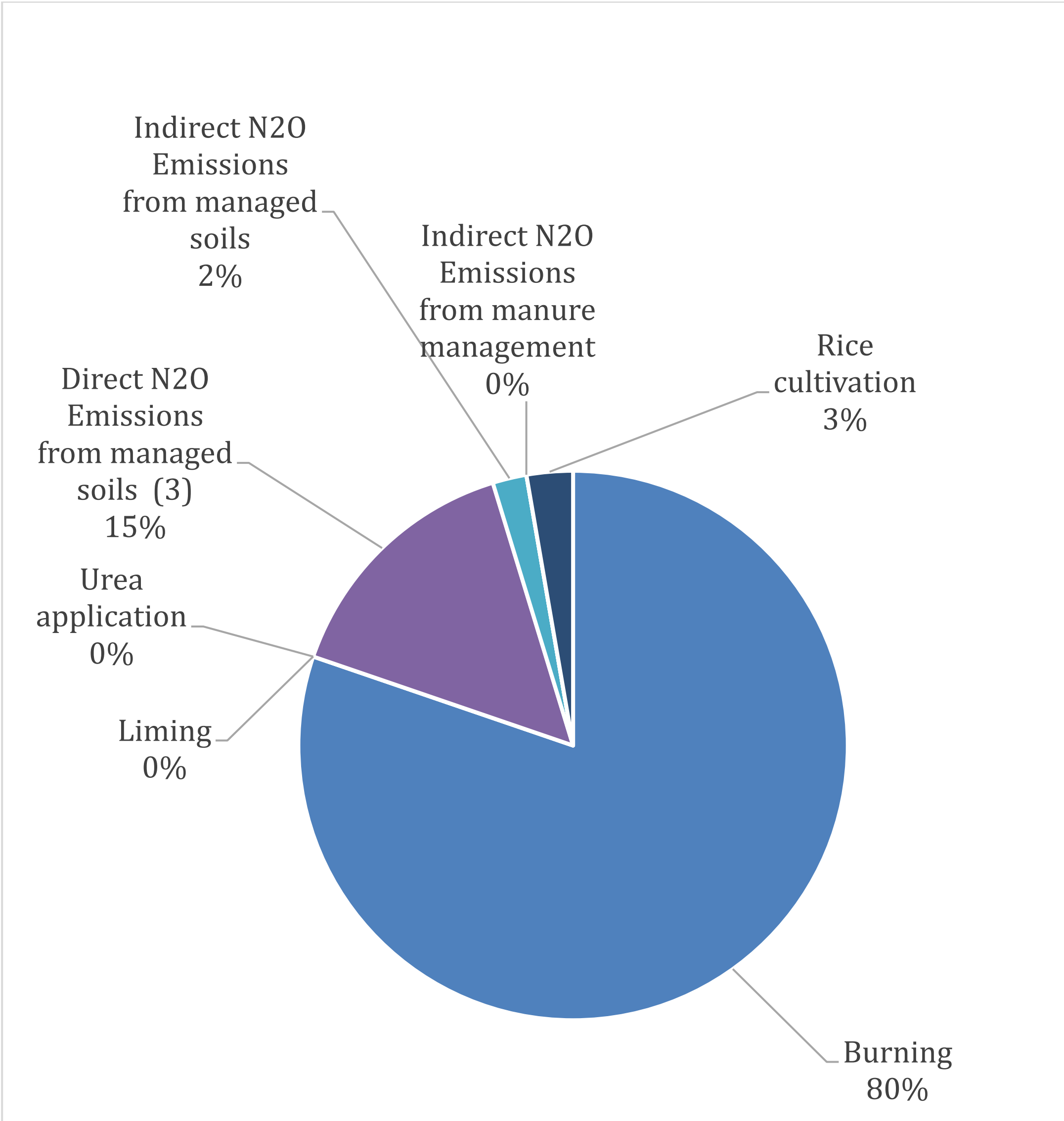


Figure 61: Percentage contribution to Aggregate sources and non-CO2 emissions on Land

By gas, CH_4 was the highest contributor to emissions under Aggregate sources on land with 51% followed by N_2O at 47%. The least was CO_2 at 2% given in Figure 62.

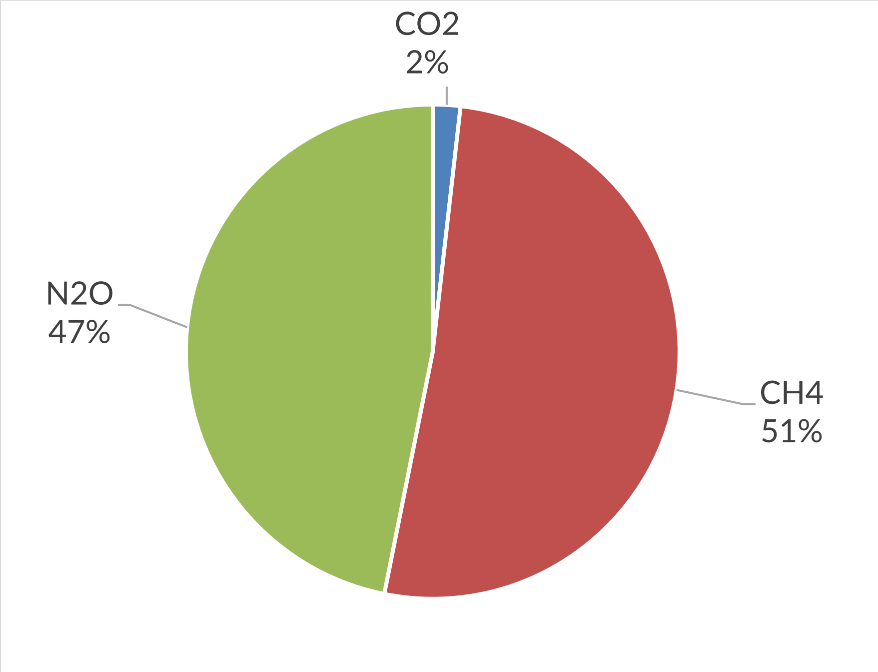


Figure 62: By gas percentage contribution to Aggregate sources and non-CO2 emissions on land

Results for emissions of greenhouse gases for subcategories on aggregate sources from 1990 to 2022 are provided in the subsequent sections.

Emissions from Biomass burning

Uncontrolled (wildfires) and managed (prescribed) fires can have a major impact on the non-CO_2 greenhouse gas emissions from forests. Biomass burning occurs in forest land, crop land, grass land and in all other land. In Forest Land Remaining Forest Land, emissions of CO_2 from biomass burning also are accounted for because they are generally not synchronous with rates of CO_2 uptake.

This is especially important after stand replacing wildfire, and during cycles of shifting cultivation in tropical regions. Biomass is defined as the total amount of aboveground living organic matter in trees expressed as oven-dry tons per unit area[34]. Generally, forest biomass that burns in a forest includes trees (bark, leaves), saplings, dead wood, grass and litter.

Where the type of forest changes (e.g., conversion of natural forests to plantation forests), there may be net emissions of CO_2 from biomass burning during the initial years, in particular if significant woody biomass is burnt during the conversion. Over time, however, the impacts are not as great as those that result from Forest Land Converted to Cropland or Grassland.

[34] FAO 1997: Estimating Biomass and Biomass Change of Tropical Forests

Every year, during the dry season, forest fires occur in most parts of Zambia. All burning in the early season (April to July) was classified as cultural management practice, while late burning (August to November) was classified as forest disturbance due to the damage caused on the plant stocks as a result of the dry fuel loads. The uncontrolled (wildfires) and managed (prescribed) fires contribute to greenhouse gas emissions to the atmosphere. The non-CO_2 gases that are emitted are Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen oxides (NOx) and Carbon monoxide (CO).

In Zambia fires occur annually on croplands after harvest particularly on fields of small farmers. The burning of residual crop material releases CH_4, N_2O, CO and NOx into the atmosphere. These gases are formed from carbon and nitrogen in the plant material during the combustion process. The burning of biomass in grasslands releases CH_4, N_2O, CO and NOx into the atmosphere in the same way that these gases are produced from burning of crop residues. The emissions from biomass burning varied across the timeline while increasing from 996.2 Gg CO_2e in base year 1990 to 5,280.21 Gg CO_2e in current year 2022. (Figure 63).

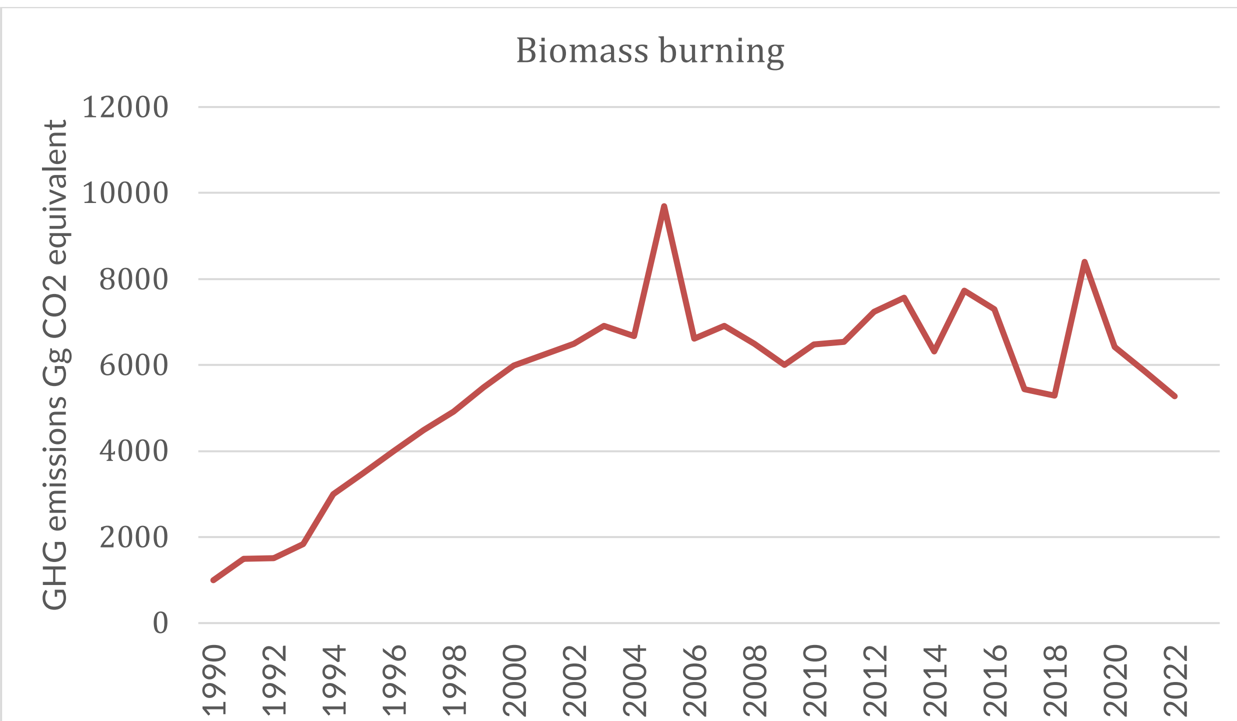


Figure 63: Emissions from biomass burning

Liming

The emissions from Liming have been varying from 1990 to 2022 with a peak occurring in 2007. The emissions in 1990 was 1.2 Gg CO_2e and it grew steadily until 2003 after which it grew sharply to 1020.5 Gg CO_2e followed by a sharp decline until 2011. The emissions varied after that with 2022 recording 8.2 Gg CO_2e.

Urea Application

The emissions from Urea application have been varying from 1990 to 2022. The lowest emissions were estimated in 1990 with 14.0 Gg CO_2e while the highest was in 2015 with 118.0 Gg CO_2e.

Direct N2O Emissions from Managed Soils

The emissions from Urea application have been varying from 1990 to 2022. The emissions in 1994 was estimated at 100 Gg CO_2e while the highest was in 2022 with 989.0 Gg CO_2e

Indirect N2O Emissions from Managed Soils

The emissions in 1990 was estimated at 19.0 Gg CO_2e while the highest was in 2022 with 131.3Gg CO_2e.

Rice Cultivation

The emissions from Rice cultivation increased from 27.5 Gg $CO_{2\ eq.}$ in the base year 1990 to 178.9 Gg $CO_{2eq.}$ in the current year 2022 (Figure 64)

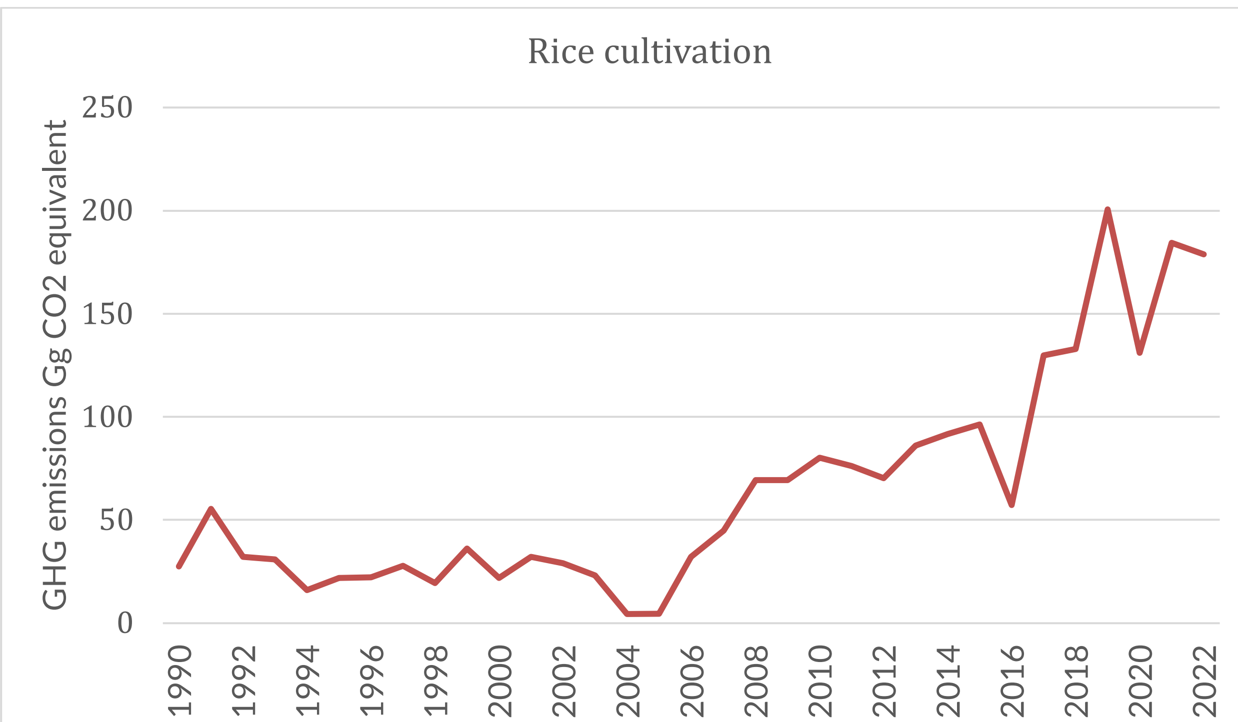


Figure 64: Emissions from Rice cultivation

3.4.3.5 Quality assurance/quality control measures

Activity data used in estimating GHG emissions from the AFOLU was obtained from Forest Department (ILUA II data set), ZAMSTATS, Zambia Revenue Authority. Efforts were made to compare data from various sources and compile the most suitable data sets for use in emissions estimates. Effort were made to check and verify the data from all sources to ensure good quality data was utilised in the inventory preparation from the AFOLU sector.

3.4.3.6 Sectoral uncertainties,

The Uncertainty Analysis (UA) was estimated using approach 1 and computed using the IPCC 2006 software and is provided in Annex I 3.11. Data for estimating emissions in the Land category was obtained from the ILUA data and Zamstats with uncertainty of ±5%.

3.4.2.7 Planned improvements

Data Gaps

a) There is a lack of data on biomass burning on cropland in terms of areas specific to crop types. This problem can be addressed through the use of remote sensing to map cropland in terms of crop types with the help of field surveys.
b) There is no data on crop residue management practises practicesamong farmers across the country. This poses challenges to emissions estimations from crop residues. There is a need to conduct a survey to establish crop residue management practices across the country.
c) Lime data collected through the Crop Forecast Survey by the Ministry of Agriculture and CSO does not distinguish the lime as dolomitic or calcitic. Additionally, it appears that the data is underreported in terms of quantities used. Future Crop Forecast surveys should categorize agriculture lime as calcitic or dolomitic and endeavor to address the problem of underreporting.

Improvements

a) The annual crop forecast survey conducted by the Ministry of Agriculture and CSO need to be customised to the data requirement of the GHG inventory where there are data gaps in the survey.
b) There is a need to establish country-specific emission factors.

c) The crops must be studied inclusive of the crop-watch softwares and google real time images. While for fertilizers real data from both the farms and suppliers must be used to come up with exact estimates.
d) Activity data collection on cropland should be customised to the requirement of the GHG inventory.
e) There is a need to produce annual cropland maps, with fine resolution and crop type mapping, to monitor fires and cropland expansion.,

Propose emission factor and activity data research areas/projects for inventory improvement projects

a) There is a need to conduct research/projects to establish country-specific emission factors for emissions from aggregate sources and non-CO2 emissions on land.

b) There is need to invest in research that generates country specific emission factors. Further, detailed livestock surveys, including its management systems are required to graduate to Tier 2 methodology for GHG emissions from the livestock sector. Additionally, there is need to update the existing soil map using the latest ILUA II data as well as to enhance the forest classification from 5 to 17, including enhancement of data collection on forest disturbance. There is also need for improvement in data collection for fertilizer and lime use by commercial farmers

c) There is need to invest in research that generates country specific emission factors. Further, detailed livestock surveys, including its management systems are required to graduate to Tier 2 methodology for GHG emissions from the livestock sector. Additionally, there is need to update the existing soil map using the latest ILUA II data as well as to enhance the forest classification from 5 to 17, including enhancement of data collection on forest disturbance. There is also need for improvement in data collection for fertilizer and lime use by commercial farmers.

3.5 Waste

3.5.1 Overview

According to the Environmental Management Act No. 12 of 2011 as read together as one with the Environmental Management (Amendment) Act No. 8 of 2023, Solid waste in Zambia is managed and regulated by the Local Authorities under the supervision of Ministry of Local Government and Rural Development (MLGRD) and are responsible for regulating solid waste under the Solid Waste Regulation and Management Act No. 20 of 2018. The Act shifted the regulatory responsibility for solid waste management from the ZEMA to the MLGRD. MLGRD provides for overall oversight by setting national policies and standards. Local authorities are responsible for implementing these policies, and managing waste collection, transportation, and disposal within their jurisdictions.

Despite the regulatory framework in place the sector experiences significant challenges driven by rapid urbanization, population growth, limited infrastructure, and inadequate waste management services. For a developing country like Zambia, municipal solid waste management plays a key role in ensuring accelerated development, public health, socio-economic and environmental protection.

Urbanisation and Population Growth

The Preliminary findings of the 2022 Census of Population indicate Zambia's population was estimated at 19,610,769, with an average annual growth rate of 3.4%. Compared to 2010, the population and average annual growth rate increased from 13,092,666 and 2.8% respectively. This represents a 49.8% increase in population. The average annual growth increased from 2.8% between 2000 and 2010. Zambia has experienced a rapid increase in urban populations, particularly in metropolitan cities such as Lusaka, Ndola, Kitwe, and Livingstone. Smaller transit towns, such as Choma, Kabwe, Kapiri Mposhi, and Petauke, have also seen an increase in population by 55%, 51.1%, 59.5% and 62.8% respectively. Arguably this population increase can be attributed to the growth of economic activities to meet the demands of transit towns.

The urban population expansion has resulted in increased waste generation, placing a significant strain on municipal waste management systems. These systems face financial and infrastructure limitations, making it difficult to keep up with the increased demand for waste disposal services. The resultant effect has been inadequate municipal solid waste disposal, burning and burying of waste, in both formal and informal settings. Cities and town streets are visibly choked with piles of waste before collection.

Waste Collection and Transportation

Historically, municipal solid waste has been collected directly by local authorities using equipment i.e tractors and tipper trucks. Occasionally, some local authorities such as Livingstone and Lusaka have received support from the MLGRD in terms of equipment such as skip trucks, compactors trucks and tipper trucks for waste collection. The collected waste is then transported to final disposal sites, mostly un-engineered sites commonly known as dumpsites, where crude dumping or un-engineered dumping is practiced. The sector has been inundated with or by informal waste collectors, often using end of life state of equipment leading inefficiency and haphazard collection systems. This results in accumulation of waste in compounds, residential areas among others.

Disposal Sites

Zambia has 116 districts, towns and cities with more than 99 percent of these using disposal sites that are not engineered and thus practice crude dumping. Regulation of access to these sites is inadequate causing women, children and the old accessing these dumps to recover valuable materials for sale. The lack of engineered disposal sites is mainly due to limited finances to construct such infrastructure that protects public health and the environment from hazards as a result of waste disposal. The resultant effect has been the risk of disease outbreaks and extensive underground water contamination from the leachate at these sites. Limited finances and sustainable maintenance regime have led to limited equipment such as bull dozers, excavators and front-end loaders for managing these sites. This is worsened by lack of sanitation infrastructure and welfare for personnel found at these sites. On average, waste disposed at disposal sites are relatively low, around 30 percent of the annual generated quantities.

Waste Recycling

The recycling sector in Zambia has experienced some growth, providing jobs for thousands in both the formal and informal sectors. However, recycling remains underdeveloped, with only a small percentage of the total waste generated being recycled. The lack of a national recycling policy, infrastructure, and incentives has stifled the growth of the recycling industry.

There have been isolated efforts to increase recycling rates, such as the installation of a Material Recovery Facility (MRF) at Longacres Market in Lusaka, which utilizes organic waste from restaurants. This initiative, in partnership with BORDA Zambia and the Lusaka Integrated Solid Waste Management Company, highlights the potential for recycling organic waste into compost and other by-products. However, the recycling of plastics, metals, and other waste streams remains limited, contributing to the increased volume of waste destined for dumpsites.

Liquid Waste

Liquid waste in Zambia is regulated primarily by the National Water Supply and Sanitation Council (NWASCO) and ZEMA (Act No. 28 of 1997; Act No. 12 of 2011). NWASCO, established in 1997, has the primary mandate to regulate water supply and sanitation services, including Commercial Utilities (CUs) and Private Schemes. Its oversight extends to onsite sanitation and faecal sludge management, within the country. Wastewater is generated by both domestic and industrial activities. In other cases, waste water is collected at individual households and company sites and delivered to the municipal sewage system where it is mixed with network sewage. However, the transportation of domestic and industrial wastewater is not separated because the system of transportation is combined. [35]

There are a total of 11 water commercial utilities (CUs) operating in all the ten (10) provinces of Zambia. The CUs are the main providers of waste water treatment services to urban and peri-urban areas. The CUs were formed by Local Authorities (LAs) following the 1994 - 1997 Water Sector Reforms. The reforms provided for the formation of joint ventures by Local Authorities to provide water supply and sanitation services and established the National Water Supply and Sanitation Council as a service regulator.[36] Lusaka. However, despite the numerous gains that were achieved through the reforms, there has been inadequate investment focusing on wastewater treatment facilities. This is due to inadequate allocation of funds in the national budget. In addition, the sector is perceived to be less lucrative to attract private sector investment.

Most of the infrastructure were constructed more than over 60 years ago and have been inadequately maintained and developed resulting in absolute and insufficient existing infrastructure for sanitation systems in both old and new areas[37]. As though this is not enough, where these facilities are in existence, critical components such as bulk meters at inlet and outlet points are either broken or missing rendering such facilities unreliable for primary data capture. This is also coupled by new challenges emanating in the sector such as encroachment of land harboring waste-water treatment facilities by illegal land developers due to rapid population growth and a in adequate of enforcement of Laws by Local Authorities. As such, compliance on the number of samples done, volume and quality of effluent discharged to the environment barely meets minimum requirements as demanded by ZEMA.

3.5.2 Methodology

This section provides respective emissions, activity data and emission factors and methodologies for solid waste disposal, Incineration and Open Burning of Waste, and Wastewater Treatment and Discharge categories.

Solid Waste Disposal

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[35] (GRZ, 2011). GRZ. 2011. *National Urban Water Supply and Sanitation (2011-2030)*: MLGH.

[36] NWASCO. (2016). *Sector Report*. NWASCO,

[37] (GRZ, 2011). *National Urban Water Supply and Sanitation (2011-2030)*: MLGH

Treatment and disposal of municipal, industrial and other solid waste produces significant amounts of methane (CH_4). Biogenic CO_2 and NMVOCs, N_2O, NOx and CO are also produced in SWDS. Methane was the dominant gas in the solid waste disposal.
The estimations in this category were made using Tier 1(Equations 6.1-6.3) based on the IPCC First Order Decay (FOD). This method assumes that the decaying organic component (degradable organic carbon) in waste decays slowly throughout a few decades, during which methane is formed. The FOD method requires data on solid waste disposal amounts and composition to be collected for at least 50 years. Zambia does not have 50 years of historical statistical data or equivalent data on solid waste disposal and as such, estimates were made using surrogates, extrapolated with population and GDP.

$$CH4_{generatedT} = DDOCm_{decompT} * F * 16/12 \quad \text{Equation 6.1}$$

Where: $CH4_{generatedT}$ = amount of CH4 generated from decomposable material; $DDOCm_{decompT}$ = DDOCm decomposed in year T, Gg; F = fraction of CH4, by volume, in generated landfill gas (fraction); 16/12 = molecular weight ratio CH4/C (ratio)

$$DDOCma = DDOCmd_T + (DDOCma_{T-1} * e^{-k}) \quad \text{Equation 6.2}$$

$$DDOCm_{decomp\ T} = DDOCma_{T-1} * (1 - e^{-k}) \quad \text{Equation 6.3}$$

Where: T = inventory year, $DDOCma_T$ = DDOCm accumulated in the SWDS at the end of year T, Gg; $DDOCma_{T-1}$ = DDOCm accumulated in the SWDS at the end of year (T-1), Gg; $DDOCmd_T$ = DDOCm deposited into the SWDS in year T, Gg $DDOCm_{decompT}$ = DDOCm decomposed in the SWDS in year T, Gg; k = reaction constant, k = ln(2)/t1/2 (y-1); t1/2 = half-life time (y).

Incineration and Open Burning of Waste

The Tier 1 method (Equation 6.4) was used in estimating emissions under this category. Data on the amount of waste incinerated/open-burned was used together with default data on characteristic parameters (such as dry matter content, carbon content and fossil carbon fraction) for different types of waste (MSW, sewage sludge, industrial waste and other waste such as hazardous and clinical waste). The calculation of the CO2 emissions is based on an estimate of the amount of waste (wet weight) incinerated or open-burned taking into account the dry matter content, total carbon content, fraction of fossil carbon and oxidation factor.

$$CO_{2\ Emissions} = \sum_i (SW_i * dm_i * CF_i * FCF_i * OF_i) * 44/12 \quad \text{Equation 6.4}$$

Where: $CO_{2\ Emissions}$ = CO_2 emissions in inventory year, Gg/yr; SW_i = total amount of solid waste of type i (wet weight) incinerated or open-burned, Gg/yr; dm_i = dry matter content in the waste (wet weight) incinerated or open-burned, (fraction); CF_i = fraction of carbon in the dry matter (total carbon content), (fraction); FCF_i = fraction of fossil carbon in the total carbon, (fraction) OFi = oxidation factor, (fraction) 44/12 = conversion factor from C to CO_2; i = type of waste incinerated/open-burned

Clinical waste and cremation are the only category that was used to determine the emissions from incineration because of lack of data for the other categories mentioned in the IPCC guideline. The amount of Health Care Waste incinerated was determined using the average for the generation rate per patient per day depending on the type of health facility and the number of hospital beds. Default values were used for the Dry matter content, fraction of carbon in dry matter, fraction of fossil carbon in total carbon and oxidation factor.

Under open burning an average between peri-urban and urban area of per capita waste generation rate was used. According to the 2015 Living Conditions Monitoring Survey, 68% of the population use pits to manage waste and based on expert judgement, what goes into pits is usually burnt as per current practice. A default value from the IPCC Guidelines was used to determine the fraction of the waste amount burned relative to the total amount of waste treated.

Wastewater Treatment and Discharge

The Tier 1 method (Equation 6.5) was used to estimates emissions and applies default values for the emission factor and activity parameters for estimating CH_4 and N_2O emissions. This method is considered good practice for countries with limited data.

Equation 6.5

$$CH_{4\ Emissions} = \left\{ \sum_{ij} (U_i * T_{ij} * EF_j) \right\} * (TOW - S_i) - R$$

Where: CH_4 Emissions = CH4 emissions in inventory year, kg CH_4/yr; TOW = total organics in wastewater in inventory year, kg BOD/yr; S = organic component removed as sludge in inventory year, kg BOD/yr; U_i = fraction of population in income group i in inventory year,; $T_{i,j}$ = degree of utilisation of treatment/discharge pathway or system, j, for each income group fraction i in inventory year; i = income group: rural, urban high income and urban low income; j = each treatment/discharge pathway or system; EF_j = emission factor, kg CH_4 / kg BOD R = amount of CH_4 recovered in inventory year, kg CH4/yr

3.5.3 Activity Data

Waste Generation Rates

In 2022, Zambia's population was estimated at 19,610,769 and per capita household waste generation (kg/day) in Zambia ranged from 0.413 to 0.859, with an average of 0.564[38]. Thus, the total Municipal Solid Waste (MSW) generated in the city in a day (House - Holds (HH) + Institution +Commercial + others like streets and parks) were estimated to 0.673 kg/day. Based on the 0.673 kg/day per capita waste generation rates and the population in 2022, the total MSW in the surveyed municipalities (38 towns) was 7,444 tons/day, with 5,726 tons/day from households, representing about 77% of the MSW generated, compared to 1,722 tons/day generated from institutional and commercial establishments, representing approximately 23%. Of the waste generated, only 15% of MSW, amounting to 1,117 tons/day, is either recovered or recycled.

Overall, only 3,006 tons/day are collected and disposed of at disposal facilities, representing only 40 % of waste disposed. The largest category in household (residential) waste is organic waste (59.60%), followed by plastic (11.35%), sanitary pads and diapers (10.36%), Glass (6.42%) and inert material that constitutes mainly sweeping in households accounted for 4.70%, while remaining fractions are negligible. From these results, approximately 60% of the residential waste disposed of in Zambia is degradable and will produce methane when disposed of.

Actual waste data was not used in the greenhouse gas inventory estimations because the data collected was inadequate. There were inconsistencies in the available data submitted by organisations and also the data was incomplete. Waste data estimations were done using other available data. These were

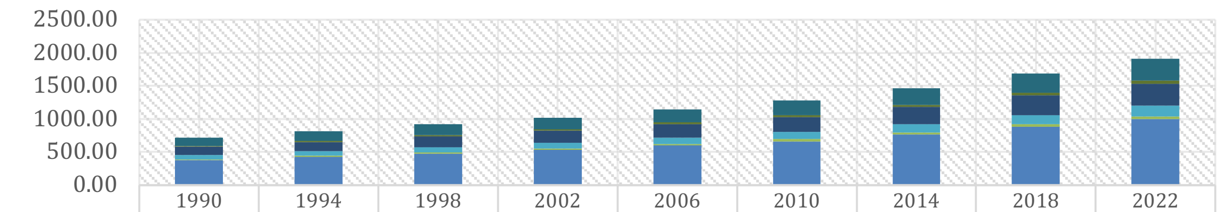
1) For solid waste generation disposal, peri-urban and urban population and gross domestic product per year was used to estimate solid waste generation at 0.146 kg per capita
2) Incineration of clinical waste, number of hospital beds per year were used to calculate health care waste generated at a generation rate of 0.2 kg per person per day
3) For open burning, a default factor of 0.6 from the IPCC software was applied of total solid waste generated
4) For domestic water, the default factor from the IPCC software was used.

Generally, the emissions from waste have consistently increased due to economic growth. Most waste disposal sites country wide are unmanaged shallow with depths less than 5 metres. For a few (Lusaka and Luanshya) that are designed to be managed waste disposal

[38] (ZEMA, 2024)

sites, they do not operate as such due to poor waste management practices and have been classified under 'unmanaged waste disposal sites'.

Activity data on population, fraction of waste disposed in landfills, per capita waste generation, were used to estimate emissions from waste disposal sites. Figure 65 presents the trend and amount (kilo tonnes) of waste disposed in solid waste disposal sites.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
Inert	125.39	141.57	159.85	177.94	199.88	222.36	255.71	294.07	333.06
Textile	17.05	19.25	21.74	24.20	27.18	30.24	34.78	39.99	45.30
Wood	125.39	141.57	159.85	177.94	199.88	222.36	255.71	294.07	333.06
Paper	60.52	68.33	77.15	85.89	96.48	107.33	123.42	141.94	160.76
Garden	17.39	19.63	22.17	24.67	27.72	30.83	35.46	40.78	46.18
Food	374.50	422.84	477.41	531.45	596.97	664.11	763.73	878.30	994.73

Figure 65: Quantities of solid waste (tonnes/yr) openly burnt by waste type

Provided in Table 41 is waste characterization data used in the estimation of the emissions. Waste generation was 146 kg/cap/year.

Table 41: Solid waste characterisation in percentages

Food Waste	Garden	Paper	Wood and Straw	Textiles	Disposable nappies	Plastics and other inert
32.7	5.45	19.07	13.63	8.17	2.72	18.26

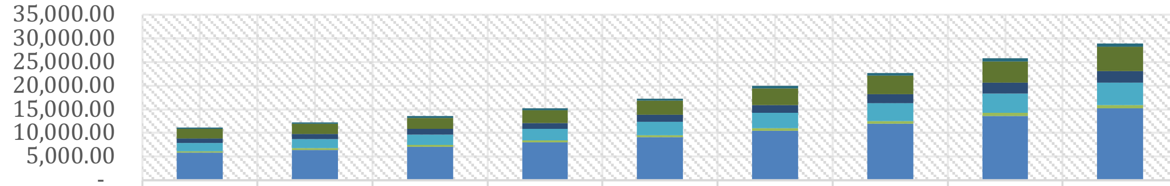
Source: Ministry of Local Government

Biological Treatment of Solid Waste

Biological treatment of waste has not been occurring for the period of the time series and hence emissions were not estimated for this source.

Incineration and Open Burning of Waste

The activity data used to estimate emissions under this category included the population, fraction of the population practicing burning waste and the per capita waste generation. were used in the emissions for open burning of waste. In case of incineration, data on clinical waste was used. Figure 66 provides the quantities (tonnes) of solid waste openly burnt disaggregated by type.

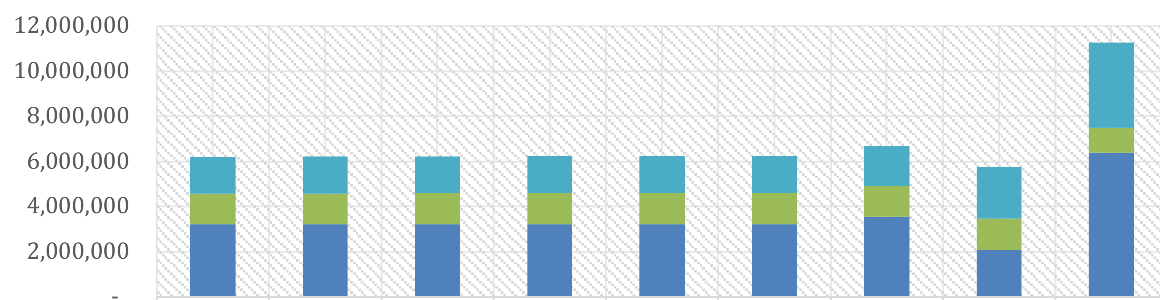


	1990	1994	1998	2002	2006	2010	2014	2018	2022
Textile	266.30	293.60	324.72	364.07	414.77	477.84	545.26	617.95	693.54
Wood	1,958.12	2,158.82	2,387.64	2,677.01	3,049.78	3,513.56	4,009.23	4,543.72	5,099.54
Papper	945.12	1,041.99	1,152.44	1,292.10	1,472.03	1,695.88	1,935.12	2,193.10	2,461.38
Nappies	1,806.70	1,991.87	2,203.00	2,469.98	2,813.93	3,241.84	3,699.18	4,192.34	4,705.17
Garden	271.53	299.36	331.09	371.21	422.90	487.21	555.95	630.06	707.14
Food Waste	5,848.26	6,447.68	7,131.09	7,995.33	9,108.67	10,493.83	11,974.23	13,570.59	15,230.62

Figure 66: MSW openly burnt (tonnes/yr)

Wastewater Treatment and Discharge

The activity data for this source category was the total amount of organically degradable material in the wastewater (TOW). This parameter is a function of human population and BOD generation per person (Table 63). It is expressed in terms of biochemical oxygen demand per annum (kg BOD/year). The average value used was 13.24kg BOD/year per capita. Maximum methane producing capacity - B0 [kg CH4/kg BOD] was 0.6. The activity data used to estimate emissions was the population using various wastewater disposal systems including pit latrines, sewer system and/ or septic tanks, as provided in figure 67.



	1990	1994	1998	2002	2006	2010	2014	2018	2022
Septic Tanks	1,630,84	1,634,12	1,637,40	1,640,68	1,643,95	1,647,23	1,754,48	2,314,72	3,771,27
Pit Latrine	1,361,32	1,364,06	1,366,79	1,369,53	1,372,27	1,375,00	1,377,74	1,378,38	1,104,72
Sewer System	3,209,38	3,215,83	3,222,29	3,225,58	3,225,73	3,225,88	3,544,89	2,080,08	6,399,53

Figure 67: Population using various wastewater treatment system

There was a steady increase in the population that was serviced during the period under review. However, the volumes of wastewater treated was inconsistent due to non-submission of accurate data by some commercial utilities. This was attributed to defective or missing meters and dilapidated infrastructure at the treatment facilities.

The availability of data on the number of pit latrines and population served by the commercial utilities was not consistent and had numerous gaps. Therefore, the activity data required for this purpose was estimated using expert judgement and literature from the available Central Statistics Office reports. The assumptions made were as follows:

a) The number of persons per household was estimated to be six (6), based on the WHO/UNCEF Joint Monitoring Programme (JMP) standard set of household categorization. The number of households was estimated by dividing the number of persons per household with the population.
b) The average households using pit latrine was estimated to be 74.8 percent, based on the 2015 Living Conditions Monitoring Survey report.

3.5.4 Waste Sector Emissions

GHG emissions from the Waste sector were calculated from solid waste disposal, incineration and open burning of waste and wastewater treatment and discharge. Methane (CH_4) emissions from Solid Waste Disposal Site (SWDS) are the largest source of GHG emissions in the Waste Sector. Methane (CH_4) was also emitted from wastewater treatment and discharge. Carbon Dioxide (CO_2) and Nitrous Oxide (N_2O produced during incineration and open burning of waste containing fossil carbon (e.g., plastics) are the primary sources of emissions in the Waste Sector. Emissions from Biological treatment of solid waste were not calculated because the activity does not occur in Zambia. The emissions in the Waste sector increased by 145% from the base year (1990) of 854.9 Gg CO_2e to 2.094.58 Gg CO_2e in the current year (2022) as presented in Figure 68.

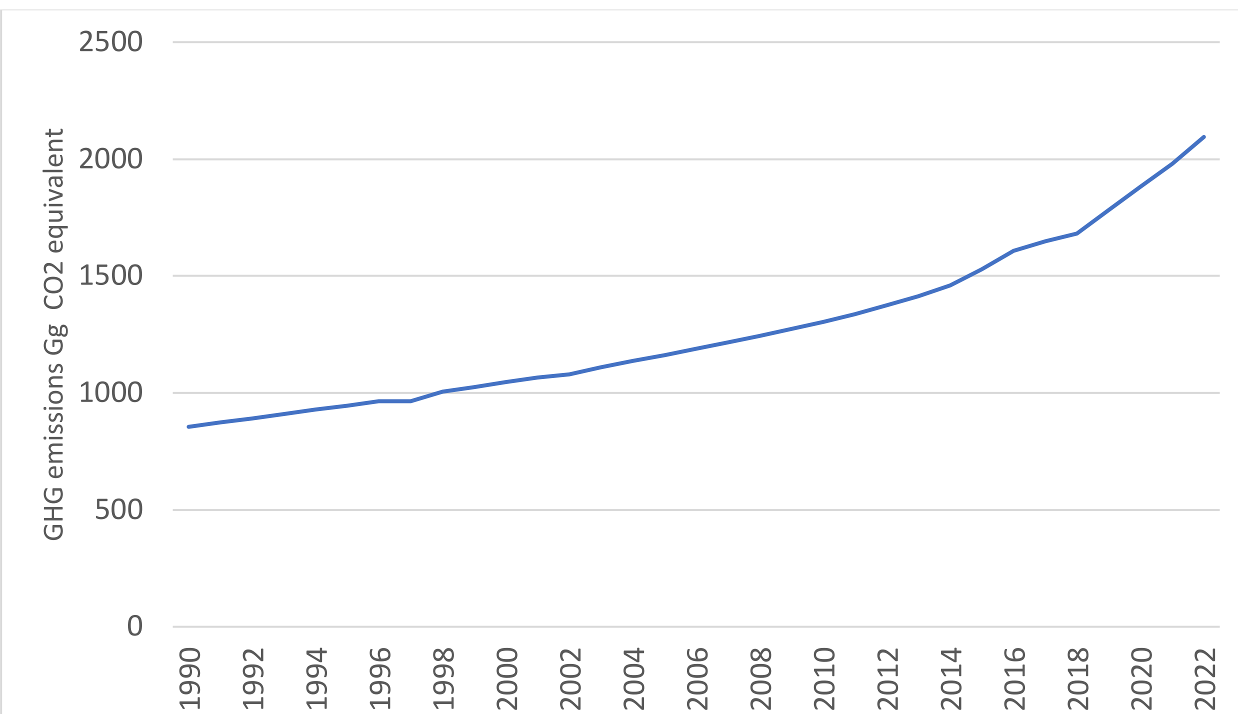


Figure 68: GHG Emissions Trends in the Waste Sector

3.5.4.1 Emissions Trends by Categories

Since 1990 across the time series, solid waste has been the highest source emissions followed by wastewater as presented in Figure 69.

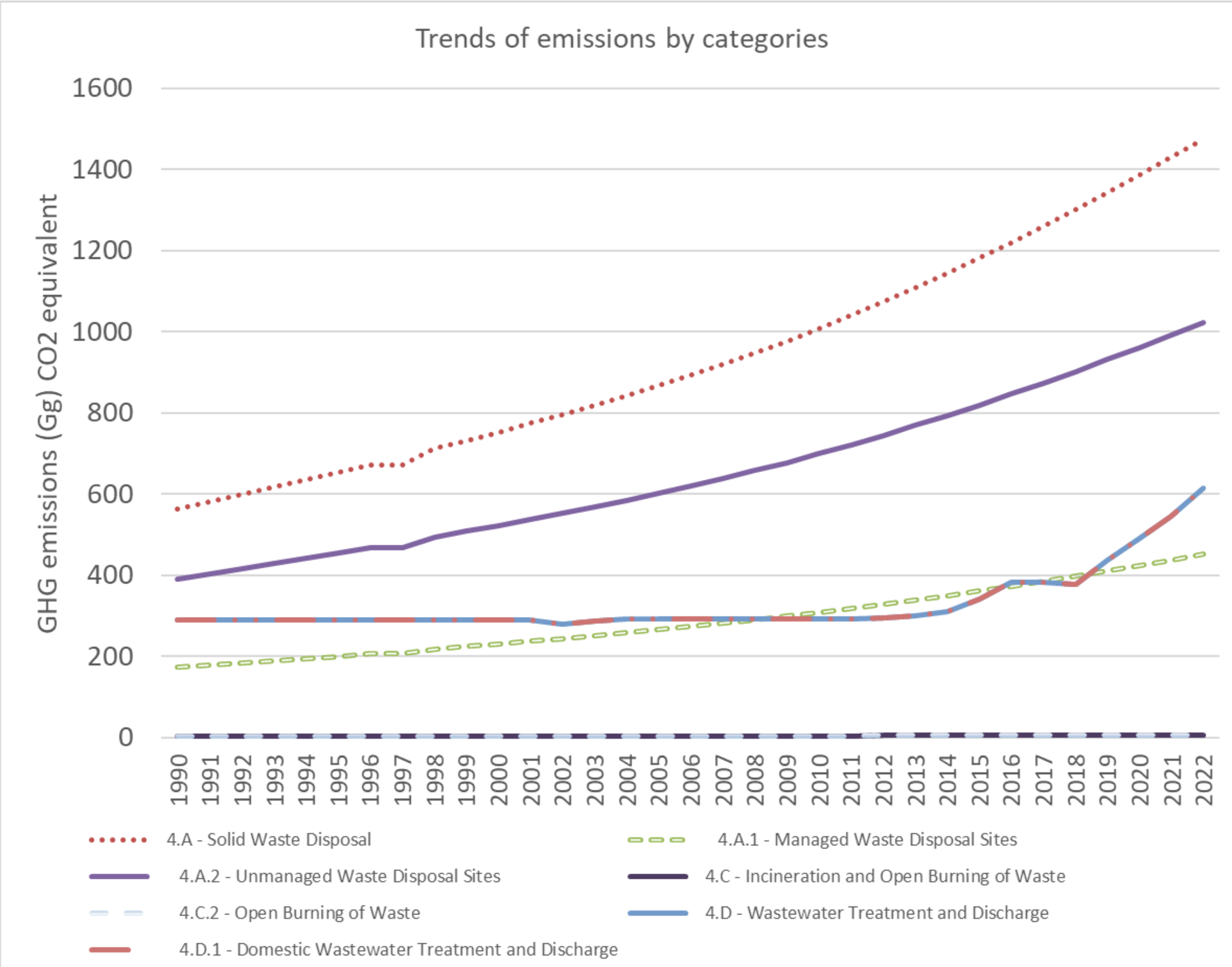


Figure 69: Trends of GHG emissions by category

Solid Waste Disposal emissions increased from 563.1 in the base year (1990) to 1,474.4 Gg CO_2e in current year (2022). Incineration and Open Burning of Waste increased from 2.42 to 6.29 Gg CO_2e during the same period. Biological Treatment of Waste was non occurring. With regards to wastewater Treatment and Discharge, emissions increased from 289.5 in the base year (1990) to 618.9 Gg CO_2e in the current year (2022). (Table 41)

Table 42: Trends of GHG emissions by category (Gg CO2 equivalent:

	4.A - Solid Waste Disposal	4.A.1 - Managed Waste Disposal Sites	4.A.2 - Unmanaged Waste Disposal Sites	4.C - Incineration and Open Burning of Waste	4.C.2 - Open Burning of Waste	4.D - Wastewater Treatment and Discharge	4.D.1 - Domestic Wastewater Treatment and Discharge
1990	563.1	172.4	390.7	2.4	2.4	289.5	289.5
1991	580.8	177.8	403.0	2.5	2.5	289.6	289.6
1992	598.6	183.3	415.4	2.5	2.5	289.7	289.7
1993	616.8	188.8	428.0	2.6	2.6	289.9	289.9
1994	635.1	194.4	440.7	2.7	2.7	290.0	290.0
1995	653.7	200.1	453.6	2.7	2.7	290.2	290.2
1996	672.7	205.9	466.8	2.8	2.8	290.3	290.3
1997	672.7	205.9	466.8	2.8	2.8	290.3	290.3
1998	711.7	217.9	493.8	2.9	2.9	290.6	290.6
1999	731.8	224.0	507.8	3.0	3.0	290.3	290.3
2000	752.4	230.3	522.1	3.1	3.1	290.9	290.9
2001	773.6	236.8	536.8	3.2	3.2	290.0	290.0
2002	795.6	243.6	552.0	3.3	3.3	280.5	280.5
2003	818.4	250.5	567.9	3.4	3.4	287.4	287.4
2004	842.1	257.8	584.3	3.5	3.5	291.5	291.5
2005	866.7	265.3	601.4	3.6	3.6	291.6	291.6
2006	892.4	273.2	619.2	3.8	3.8	291.7	291.7
2007	919.3	281.4	637.9	3.9	3.9	291.8	291.8
2008	947.5	290.1	657.5	4.0	4.0	292.0	292.0
2009	977.1	299.1	678.0	4.2	4.2	292.2	292.2
2010	1008.0	308.6	699.4	4.3	4.3	292.2	292.2
2011	1040.2	318.4	721.8	4.5	4.5	291.5	291.5
2012	1073.7	328.7	745.0	4.6	4.6	295.3	295.3
2013	1108.5	339.3	769.1	4.8	4.8	299.0	299.0

2014	1144.4	350.3	794.1	4.9	4.9	309.9	309.9
2015	1181.5	361.7	819.8	5.1	5.1	341.2	341.2
2016	1219.9	373.4	846.4	5.3	5.3	382.1	382.1
2017	1259.4	385.5	873.9	5.4	5.4	383.1	383.1
2018	1300.1	398.0	902.1	5.6	5.6	376.9	376.9
2019	1342.0	410.8	931.2	5.8	5.8	435.6	435.6
2020	1385.1	424.0	961.1	6.0	6.0	491.6	491.6
2021	1429.2	437.5	991.7	6.1	6.1	545.4	545.4
2022	1474.4	451.3	1023.0	6.3	6.3	613.9	613.9

In 2022, emissions from Solid Waste Disposal accounted for 70.4% of emissions, Waste-Water Treatment and Discharge was 29.3% and Incineration and open Burning of Waste at 0.3%, Biological Treatment of Waste was non occurring as presented in Figure 70.

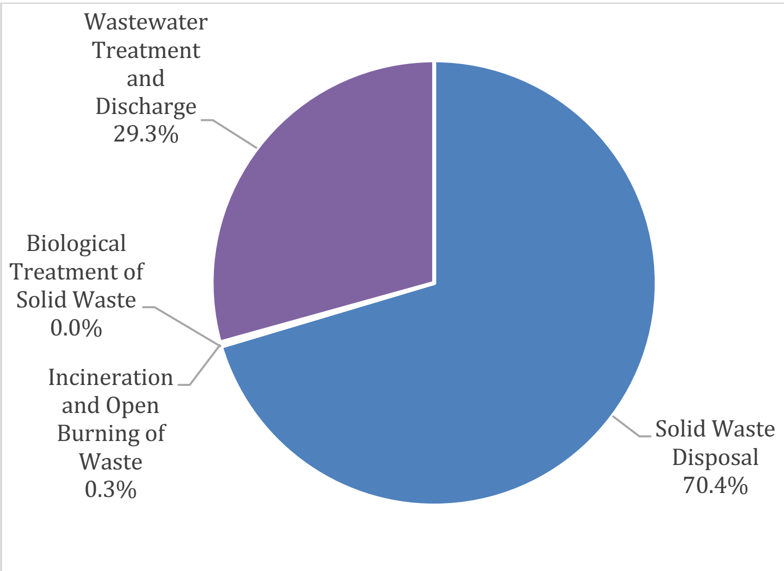


Figure 70: Emissions contributions by category in 2022

Trends by gas as given in Figure 71, indicates that CH_4 increased from 854.6 in the base year 1990 to 2,093.5 Gg CO_2 equivalent in the current year 2022 while CO_2 increased from 0.16 to 0.42 Gg CO_2e during the same period. As regards N_2O, it increased from 0.23 in 1990 to 0.61Gg CO_2e in 2022.

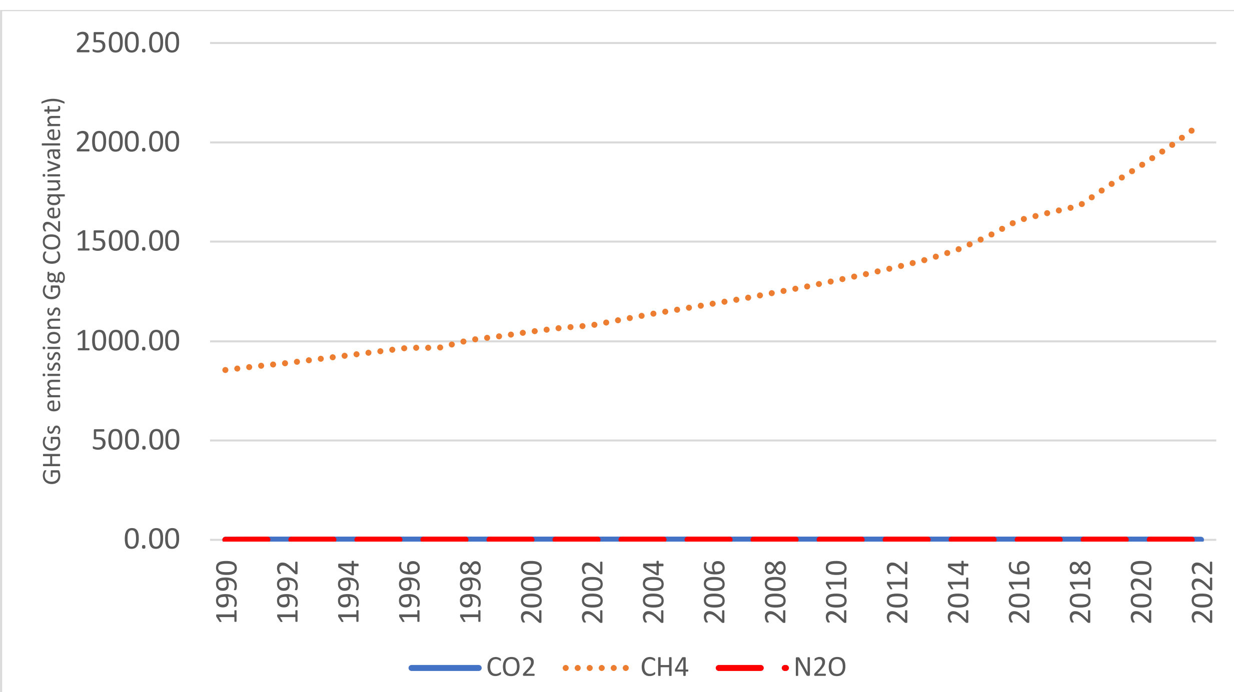


Figure 71: GHG emissions trends by gas in the waste sector

By gas, CH_4 accounted for 99% followed by CO_2 at 0.02%, the least was N_2O at 0.03% as illustrated in Figure 72.

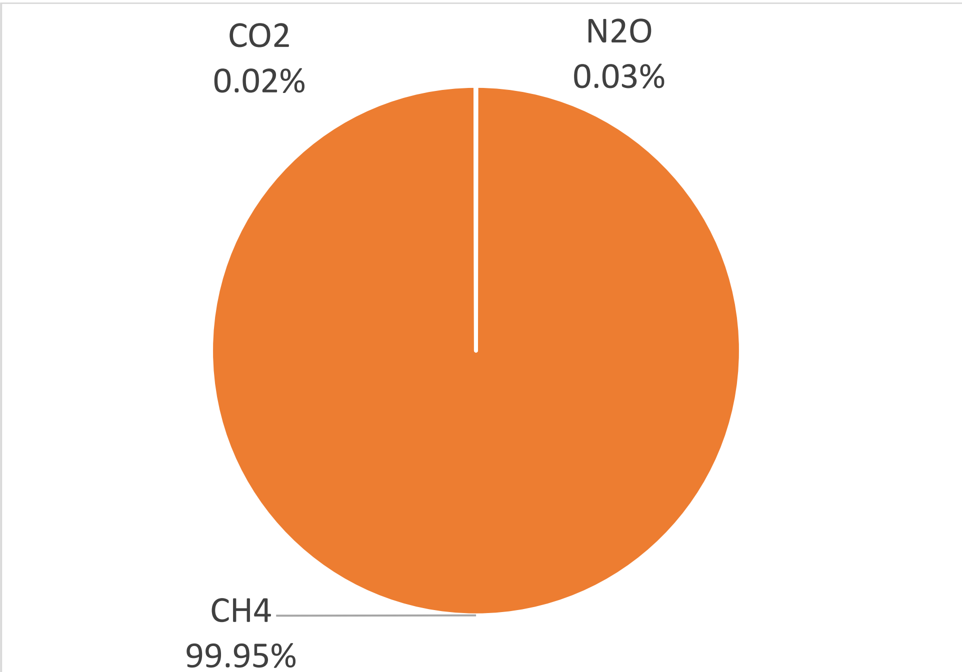


Figure 72: GHG Emissions by contributions by gas in 2022 in the waste sector

Provided in table 43 trends of emissions for precursor gas emissions for sector.

Table 43: Precursor gases emissions for waste sector

Gas (Gg)	NOx	CO	NMVOCs	SO2
1990	0.035267	0.000619	0.086044	0.00122
1991	0.036176	0.000635	0.088661	0.001251
1992	0.037066	0.000651	0.091304	0.001282
1993	0.037969	0.000667	0.093983	0.001313
1994	0.038902	0.000683	0.096704	0.001346
1995	0.039866	0.0007	0.099473	0.001379
1996	0.040891	0.000718	0.102305	0.001414
1997	0.041927	0.000736	0.105185	0.00145
1998	0.043025	0.000755	0.108141	0.001488
1999	0.044167	0.000775	0.111172	0.001528
2000	0.045407	0.000797	0.111651	0.001571
2001	0.046787	0.000821	0.117562	0.001618
2002	0.04824	0.000847	0.118124	0.001669
2003	0.049753	0.000873	0.124468	0.001721
2004	0.051246	0.0009	0.128089	0.001773

2005	0.05309	0.000932	0.131968	0.001836
2006	0.054957	0.000965	0.135993	0.001901
2007	0.056933	0.001	0.140217	0.001969
2008	0.059003	0.001036	0.144644	0.002041
2009	0.061138	0.001073	0.149269	0.002115
2010	0.063314	0.001112	0.154086	0.00219
2011	0.065489	0.00115	0.159074	0.002265
2012	0.067687	0.001188	0.164233	0.002341
2013	0.069747	0.001225	0.169493	0.002413
2014	0.072246	0.001268	0.175079	0.002499
2015	0.07459	0.00131	0.175985	0.00258
2016	0.076975	0.001351	0.181684	0.002663
2017	0.079409	0.001394	0.187557	0.002747
2018	0.081878	0.001437	0.198832	0.00011
2019	0.084378	0.001481	0.205185	0.002919
2020	0.08689	0.001525	0.21169	0.003006
2021	0.089394	0.001569	0.218332	0.003092
2022	0.091894	0.001613	0.225103	0.003179

Provided in Table 44 are emissions trend from the Waste Sector by gas.

Table 44: Emissions summary report for waste for 2022

Categories	Emissions [Gg]						
	CO2	CH4	N2O	NOx	CO	NMVOCs	SO2
4 - Waste	0.420	74.770	0.002				
4.A - Solid Waste Disposal		52.655					
4.A.1 - Managed Waste Disposal Sites		16.119					
4.A.2 - Unmanaged Waste Disposal Sites		36.536					
4.A.3 - Uncategorised Waste Disposal Sites		0.000					
4.B - Biological Treatment of Solid Waste							
Composting							
Anaerobic digestion at biogas facilities							
Other							
4.C - Incineration and Open Burning of Waste	0.420	0.188	0.002				
4.C.1 - Waste Incineration	0.000	0.000	0.000				
4.C.2 - Open Burning of Waste	0.420	0.188	0.002				
4.D - Wastewater Treatment and Discharge		21.927	0.000				
4.D.1 - Domestic Wastewater Treatment and Discharge		21.927	0.000				
4.D.2 - Industrial Wastewater Treatment and Discharge		0	0				
4.E - Other (please specify)	NO	NO	NO				

3.5.4.2 Incineration and Open Burning of Waste

Waste incineration is defined as the combustion of solid and liquid waste in a controlled facility. Types of waste incinerated include: Municipal solid waste (MSW), industrial waste, hazardous waste, clinical waste and sewage sludge. However, in Zambia incineration is mainly done for clinical waste. Emissions from incineration and open burning of waste increased by 160% from 2.42 Gg CO_2e in the base year 1990 to 6.29 Gg CO_2e in the current year 2022 as shown in Figure 73.

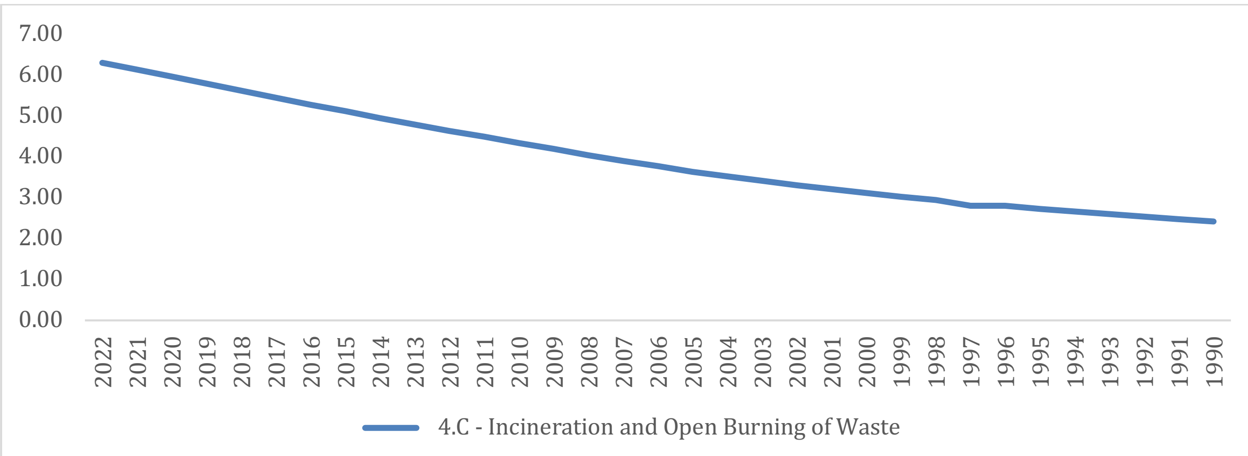


Figure 73: Emissions from incineration(Gg CO2 equivalent)

In 2022, by gas, CH_4 was the major contributing gas to emissions under incineration and open burning of waste with 83.6%. Other gases contributing to emissions under this category were N_2O at 9.7% and CO_2 at 6.7%. In Zambia, clinical waste is incinerated and to a small extent cremation is practiced. Cremation in the country is often done by the Asian community for religious reasons. Open burning of waste is a waste management practiced widely in Zambia in both rural and urban areas.

3.5.4.3 Wastewater Treatment and Discharge

Wastewater can be a source of CH_4 when treated or disposed anaerobically. It can also be a source of nitrous oxide emissions. Carbon dioxide emissions from wastewater were not considered because these are of biogenic origin and should not be included in national total emissions. Wastewater originates from a variety of domestic, commercial and industrial sources, may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated nearby or via an outfall. Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only. Domestic wastewater is treated in either centralized plants, pit latrines, septic systems or disposed of in unmanaged lagoons or waterways, via open or closed sewers[39].

Total emissions from waste water treatment increased by 112% from 289.45 Gg CO_2e in 1990 to 613.95 Gg CO_2e in 2022. The assessment considered pit latrines, septic tanks and central sewer systems in accounting for emissions under this category. Figure 74 shows the trend of emissions, in Gg CO_2e, during the period under review.

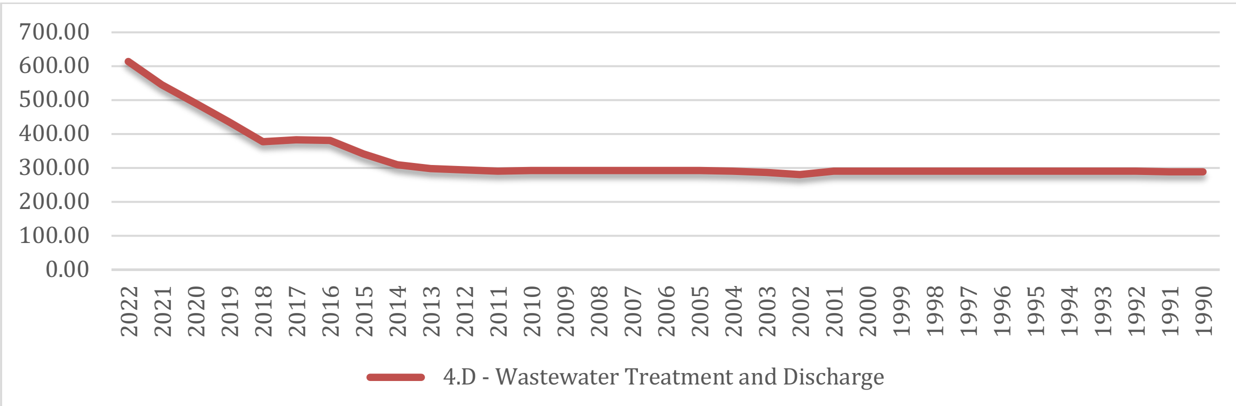


Figure 74: Trend of emissions, in Gg CO_2e, during the period under review

3.5.5 Quality assurance/quality control measures applied

The data used for estimating emissions for solid waste disposal, incineration and open burning of waste were based on population, GDP and per capita waste generation. Data on population and per capita waste generation was obtained from Central Statistical Office (CSO). Whilst part of the GDP data was obtained from CSO, the other data came from World Economy Report and the World Bank data base. Data on wastewater treatment and discharge were based on installed capacities. Default values for Biochemical Oxygen Demand (BOD) generation per capita were used.

3.5.6 Sectoral uncertainties,

The Uncertainty Analysis (UA) for the year 2010 for Waste sector was estimated using approach 1 and computed using the IPCC 2006 software and is provided in Annex II. Data for estimating emissions in the Waste sector was estimated from population, GDP, and other factors to include waste characterization. It was for this reason that the uncertainty

[39] 2006 IPCC guidelines Volume 5 page 6.6

was estimated to be ±50%. For wastewater activity data was obtained from installed capacities, thus the uncertainty were estimated at ±30%.

3.5.7 Planned improvements

Gaps on activity data collection, emission factors

There were so many gaps in the activity data due to inadequacy of data for all the sub categories. As a result, default values from the IPCC Guidelines and software were used as the sector lacks emission factors in all the sub categories. Generally, activity data collection needs to improve in order to move to higher tiers.

Planned improvements

There were some data gaps identified in all the sub categories, the notable ones include the following:

1. It was difficult to determine the quantities of waste disposed of as most of the designated dump sites do not have weighbridges to record quantities of solid waste received. There has been no framework to continuously generate and update data on solid waste disposal. The majority of accumulated waste that has been accumulated on land or burned was difficult to account for. This problem can be addressed if there could be a system, programme or strategies developed to segregate waste at household, company, market and waste disposal site levels. Further, there is a need to have functional weighbridges to collect quantities of waste dumped.
2. Biological waste treatment. There was no available data on biological waste treatment subcategory. This problem can be addressed if there could be a system or programme developed to collect data on waste composting or sludge digestor.
3. There was no data on quantities of waste incinerated and cremated. Therefore, there is a need to develop a strategy or programme for the collection of waste incinerated and cremated. There is also need to conduct surveys on types and conditions of incinerators used in health care facilities and the temperatures at which healthcare waste is being incinerated. Further, there is a need to conduct studies on different institutions that incinerate their waste.
4. There is no system in the country that separates domestic and industrial wastewater at treatment facilities. As a result, it was difficult to report on quantities of industrial wastewater treated and the COD. There is need for commercial Utility companies to collect data on quantities of sludge, composting and biogas digesters.

18. CONCLUSIONS

This GHG Inventory covers the period 2017 to 2022 with re-calculation from 2016 back to the base year (1990). The results of this GHGI were envisaged to feed into Zambia's 1st BTR to the UNFCCC. The GHG emissions were estimated in accordance with the IPCC 2006 Guidelines and its 2019 refinements (tiers 1 and 2 appropriately) using the IPCC software, version 2.930.8992.13493 released on 14th August 2024. Further, the assessment relied on the European Environment Agency EMEP/EEA air pollutant emission inventory guidebook 2023 for estimation of precursor gases. The inventory preparation process was accompanied by dedicated quality control to ensure use of acceptable quality data across all inventory sectors.

The observation of this assessment was that Zambia remained a net sink for the years 1990 to 2006 and transitioned into a net source in 2007 and it remained a net source for all the years to 2022. In 2022, Zambia's GHG emissions (without AFOLU) amounted to 18,410.3 Gg CO2 equivalent (CO2e). In comparison with the base year, 5,942.5 Gg CO2e (1990), GHG emissions without AFOLU increased by 209.81%. The emissions increased steadily from 1990 to 2008 and continued to increase sharply from 2008 to 2022. Zambia's total GHG emissions (with AFOLU) stood at 220462.1 Gg CO2e in 2022, representing an increase of 121% against 99578.7 Gg in the 1990 base year.

The GHG removals (sink) reduced by 2.6% from -164745.1 CO2e in the current year (2022) to -160443.0 CO2e in the base year (1990). The net GHG emissions indicate that Zambia was a net Sink for the period 1990 to 2006 and a net source from 2007 to 2022. In 2022, most of the GHG emissions existed as CO2 (87%) followed by CH4 at 11%, N2O was 2% while HFC and SF6 were negligible. Contribution of SF6 and HFC to the emissions was negligible. SF6 has been largely negligible across all the years. The emissions of CO2 increased from 88549.0 Gg CO2e in the base year(1990) to 189215.2 Gg CO2e in the current year (2022) representing a 113 % increase. In the same period, CH4, N2O, and HFCs increased from 9,437.3 Gg CO2e, 633.2 Gg CO2e, 0.2 Gg CO2e and 0.2 Gg CO2e in the base year 1990 to 23,296.7 Gg CO2e, 3,561.6Gg CO2e and 69.3Gg CO2e in the current year 2022, respectively.

In 2022, total CO2 emissions from AFOLU sectors were primarily driven by three key activities: wood removal (timber harvesting), fuelwood extraction, and disturbances (wildfires, pest outbreaks, and natural land degradation).

In Zambia, the key precursor gases assessed in the current review include carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), nitrogen oxides (NOx), sulfur dioxide (SO_2), and ammonia (NH_3). Between 1990 and 2022, emissions of NMVOCs, NOx, SO_2, and NH_3 increased steadily, while CO emissions rose sharply. The Agriculture, Forestry, and Other Land Use (AFOLU) sector was the dominant source, contributing 62% of emissions, followed by the energy sector at 38%. Emissions from industrial processes and product use (IPPU) and the waste sector remained minimal. Figure 7 illustrates the sectoral trends in precursor gas emissions. As of 2022, CO accounted for the largest share of precursor gas emissions at 71%, followed by NOx (13%), NMVOCs (9%), and SO_2 (6%), with NH_3 contributing just 1%. Despite its small share, NH_3 emissions rose significantly 400% from 34 Gg in 1990 to 168 Gg in 2022. Similarly, CO emissions increased by approximately 400%, from 2,092 Gg to 10,467 Gg over the same period. NOx and NMVOCs also saw sharp increases of 313% and 399%, respectively

In terms of share representation of individual gases, Carbon dioxide continued to be the most dominant gas among the GHGs emitted in Zambia, followed by methane and nitrous oxide. Other gases are HFC and SF6 from refrigeration and electrical equipment, respectively.

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ANNEX

Annex I

Base year for assessment of uncertainty in trend: 1990, Year T: 2022

2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO2 equivalent)	Year T emissions or removals (Gg CO2 equivalent)	Activity Data Uncertainty (%)	Emission Factor or Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Inventory trend in national emissions for year t increase with respect to base year (% of base year)	Uncertainty introduced into the trend in total national emissions (%)
1 - Energy									
1.A.1 - Energy Industries - Liquid Fuels	CO2	152.72208	23.228127	7.071067812	9.899494937	12.16552506	1.31254E-05	15.2094098	0.000153792
1.A.1 - Energy Industries - Liquid Fuels	CH4	0.0030051	0.00094041	7.071067812	141.4213562	141.5980226	2.91456E-12	31.29380054	1.061E-11
1.A.1 - Energy Industries - Liquid Fuels	N2O	0.00036243	0.000188082	7.071067812	141.4213562	141.5980226	1.16582E-13	51.8947107	2.20043E-13
1.A.1 - Energy Industries - Solid Fuels	CO2	0	3517.02763	5	7	8.602325267	0.300910366	0	0.284859895
1.A.1 - Energy Industries - Solid Fuels	CH4	0	0.036597582	5	100	100.124922	4.41411E-09	0	3.13123E-09

1.A.1 - Energy Industries - Solid Fuels	N_2O	0	0.054896373	5	100	100.124922	9.93174E-09	0	7.04527E-09
1.A.1 - Energy Industries - Biomass - solid	CO_2	0	0	5	7	8.602325267	0	100	0
1.A.1 - Energy Industries - Biomass - solid	CH_4	0	0.35721156	5	100	100.124922	4.20523E-07	0	2.98306E-07
1.A.1 - Energy Industries - Biomass - solid	N_2O	0	0.047628208	5	100	100.124922	7.47596E-09	0	5.30321E-09
1.A.1 - Energy Industries	CO_2	0	0	5	5	7.071067812	0	100	0
1.A.1 - Energy Industries	CH_4	0	0	5	5	7.071067812	0	100	0
1.A.1 - Energy Industries	N_2O	0	0	5	5	7.071067812	0	100	0
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CO_2	303.6742949	1806.548629	25.98076211	12.12435565	28.67054237	0.155047151	594.8967891	0.178229352
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	CH_4	0.011914514	0.073510937	25.98076211	173.2050808	175.1427989	9.50516E-09	616.9864683	8.0557E-09
1.A.2 - Manufacturing Industries and Construction - Liquid Fuels	N_2O	0.002381076	0.014696086	25.98076211	173.2050808	175.1427989	3.79841E-10	617.2035338	3.21925E-10
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CO_2	915.1359873	1685.324381	21.21320344	9.899494937	23.40939982	0.130778973	184.161087	0.14021241
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	CH_4	0.09596193	0.17738064	21.21320344	141.4213562	143.0034965	5.41066E-08	184.8448025	6.5638E-08
1.A.2 - Manufacturing Industries and Construction - Solid Fuels	N_2O	0.01439429	0.026607096	21.21320344	141.4213562	143.0034965	1.2174E-09	184.8448025	1.47685E-09
1.A.2 - Manufacturing Industries and Construction - Biomass - solid	CO_2	0	0	15.8113883	18.91441519	24.65268955	0	100	0
1.A.2 - Manufacturing Industries and Construction - Biomass - solid	CH_4	1.3747712	1.3026176	15.8113883	243.6856911	244.1981082	2.34095E-05	94.75159212	5.42574E-05
1.A.2 - Manufacturing Industries and Construction - Biomass - solid	N_2O	0.05565436	0.04900276	15.8113883	388.9087297	389.2300091	3.56376E-08	88.04837572	6.38864E-08
1.A.3.a - Civil Aviation - Liquid Fuels	CO_2	117.4418	104.1066856	21.21320344	7.071067812	22.36067977	0.000649039	88.64534225	0.0009861
1.A.3.a - Civil Aviation - Liquid Fuels	CH_4	0.000821388	0.000728898	21.21320344	141.4213562	143.0034965	1.29884E-12	88.73978482	3.72877E-12
1.A.3.a - Civil Aviation - Liquid Fuels	N_2O	0.00328555	0.00291559	21.21320344	212.1320344	213.1900561	4.61866E-11	88.73978482	1.33456E-10
1.A.3.b - Road Transportation - Liquid Fuels	CO_2	424.2347883	3091.164892	15	5	15.8113883	0.785304745	728.6448394	1.06938197
1.A.3.b - Road Transportation - Liquid Fuels	CH_4	0.085614798	0.562732584	15	100	101.1187421	1.06444E-06	657.2842513	9.7039E-07
1.A.3.b - Road Transportation - Liquid Fuels	N_2O	0.021363584	0.244239063	15	150	150.7481343	4.45644E-07	1143.249469	3.66098E-07
1.A.3.b - Road Transportation	CO_2	0	0	0	0	0	0	100	0

1.A.3.c - Railways - Liquid Fuels	CO_2	15.262377	31.0823565	5	2.024291498	5.394233594	9.24147E-06	203.6534447	1.30756E-05
1.A.3.c - Railways - Liquid Fuels	CH_4	0.000854776	0.00174078	5	150.6024096	150.6853868	2.26195E-11	203.6534447	3.19588E-11
1.A.3.c - Railways - Liquid Fuels	N_2O	0.005890742	0.011996699	5	200	200.0624902	1.89369E-09	203.6534447	2.67556E-09
1.A.3.e - Other Transportation - Liquid Fuels	CO_2	4.43586	0	15	5	15.8113883	0	0	8.09714E-08
1.A.3.e - Other Transportation - Liquid Fuels	CH_4	0	0	15	100	101.1187421	0	100	0
1.A.3.e - Other Transportation - Liquid Fuels	N_2O	0	0	15	150	150.7481343	0	100	0
1.A.4 - Other Sectors - Liquid Fuels	CO_2	275.8160408	618.0440151	25.98076211	11.09053651	28.24889378	0.021012055	224.0783434	0.027750657
1.A.4 - Other Sectors - Liquid Fuels	CH_4	0.035450822	0.073690643	25.98076211	206.1552813	207.7859476	1.36196E-08	207.8672366	1.73064E-08
1.A.4 - Other Sectors - Liquid Fuels	N_2O	0.012902019	0.04555234	25.98076211	206.1552813	207.7859476	1.30286E-08	353.0636653	1.37187E-08
1.A.4 - Other Sectors - Biomass - solid	CO_2	0	0	15.8113883	18.91441519	24.65268955	0	100	0
1.A.4 - Other Sectors - Biomass - solid	CH_4	32.909938	58.57515026	15.8113883	223.6067977	224.1651177	0.010767	177.9862067	0.016152203
1.A.4 - Other Sectors - Biomass - solid	N_2O	0.40974659	0.676815034	15.8113883	269.2582404	269.7220792	1.42955E-06	165.1789303	2.23694E-06
1.A.5 - Non-Specified - Liquid Fuels	CO_2	10.29760582	25.65895952	5	5	7.071067812	1.08219E-05	249.1740311	1.45079E-05
1.A.5 - Non-Specified - Liquid Fuels	CH_4	0.000346736	0.000545289	5	5	7.071067812	4.88739E-15	157.2633193	7.53209E-15
1.A.5 - Non-Specified - Liquid Fuels	N_2O	6.93472E-05	0.000109058	5	5	7.071067812	1.95496E-16	157.2633193	3.01283E-16
1.B.1.a - Coal mining and handling	CO_2	0.002794482	0.034849048	0	0	0	0	1247.066647	0
1.B.1.a - Coal mining and handling	CH_4	0.854746872	10.65926316	5	0	5	0	1247.066647	0
1.B.1.c - Fuel transformation	CO_2	0	0	0	0	0	0	100	0
1.B.1.c - Fuel transformation	CH_4	699.15664	2516.10632	0	0	0	0	359.8773402	0
1.B.1.c - Fuel transformation	N_2O	13.13552	47.27176	0	0	0	0	359.8773402	0
1.B.2.a - Oil	CO_2	3.78729	0	0	0	0	0	0	0
1.B.2.a - Oil	CH_4	0.543816	0	0	0	0	0	0	0
1.B.2.a - Oil	N_2O	0.0150459	0	0	0	0	0	0	0
1.B.2.b - Natural Gas	CO_2	0	0	0	0	0	0	100	0

1.B.2.b - Natural Gas	CH_4	0	0	0	0	0	0	100	0
1.B.2.b - Natural Gas	N_2O	0	0	0	0	0	0	100	0
1.B.3 - Other emissions from Energy Production	CO_2	0	0	0	0	0	0	100	0
1.B.3 - Other emissions from Energy Production	CH_4	0	0	0	0	0	0	100	0
1.B.3 - Other emissions from Energy Production	N_2O	0	0	0	0	0	0	100	0
1.C - Carbon dioxide Transport and Storage	CO_2	0	0	0	0	0	0	100	0
2 - Industrial Processes and Product Use									
2.A.1 - Cement production	CO_2	149.03512	512.93476	70.17834424	5	70.3562364	0.42813756	344.1703942	0.605213645
2.A.2 - Lime production	CO_2	880.894395	1123.036505	51.96152423	5	52.20153254	1.129817044	127.488211	1.604470632
2.A.3 - Glass Production	CO_2	0	0	35.35533906	0	35.35533906	0	100	0
2.A.4 - Other Process Uses of Carbonates	CO_2	0	0	0	0	0	0	100	0
2.A.5 - Other (please specify)	CO_2	0	0	0	0	0	0	100	0
2.A.5 - Other (please specify)	CH_4	0	0	0	0	0	0	100	0
2.A.5 - Other (please specify)	N_2O	0	0	0	0	0	0	100	0
2.B.1 - Ammonia Production	CO_2	43.5219125	0	5	0	5	0	0	0
2.B.2 - Nitric Acid Production	N_2O	56.436255	0	2	0	2	0	0	0
2.B.3 - Adipic Acid Production	N_2O	0	0	2	0	2	0	100	0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	0	0	10	0	10	0	100	0
2.B.5 - Carbide Production	CO_2	0	0	0	0	0	0	100	0
2.B.5 - Carbide Production	CH_4	0	0	0	0	0	0	100	0
2.B.6 - Titanium Dioxide Production	CO_2	0	0	7.071067812	0	7.071067812	0	100	0
2.B.7 - Soda Ash Production	CO_2	0	0	5	0	5	0	100	0
2.B.8 - Petrochemical and Carbon Black Production	CO_2	0	0	34.64101615	0	34.64101615	0	100	0
2.B.8 - Petrochemical and Carbon Black Production	CH_4	0	0	24.49489743	0	24.49489743	0	100	0
2.B.9 - Fluorochemical Production	CHF_3	0	0	14.14213562	0	14.14213562	0	100	0
2.B.10 - Hydrogen Production	CO_2	0	0	0	0	0	0	100	0
2.B.10 - Hydrogen Production	CH_4	0	0	0	0	0	0	100	0
2.B.10 - Hydrogen Production	N_2O	0	0	0	0	0	0	100	0
2.C.1 - Iron and Steel Production	CO_2	0.8716776	19.2342004	26.45751311	25	36.40054945	0.000161145	2206.572751	0.000178447

2.C.1 - Iron and Steel Production	CH4	0	0	14.14213562	0	14.14213562	0	100	0
2.C.2 - Ferroalloys Production	CO2	0	0	26.45751311	0	26.45751311	0	100	0
2.C.2 - Ferroalloys Production	CH4	0	0	10	0	10	0	100	0
2.C.3 - Aluminium production	CO2	0	0	22.36067977	0	22.36067977	0	100	0
2.C.3 - Aluminium production	CF4	0	0	10.39230485	0	10.39230485	0	100	0
2.C.3 - Aluminium production	C2F6	0	0	10.39230485	0	10.39230485	0	100	0
2.C.4 - Magnesium production	CO2	0	0	14.14213562	0	14.14213562	0	100	0
2.C.5 - Lead Production	CO2	5.512	0.0183	10	0	10	1.10092E-11	0.332002903	1.55803E-11
2.C.6 - Zinc Production	CO2	7.052	0	10	0	10	0	0	0
2.C.7 - Rare Earths Production	CO2	0	0	0	0	0	0	100	0
2.D - Non-Energy Products from Fuels and Solvent Use	CO2	17.74197333	18.84344	14.14213562	0	14.14213562	1.16728E-05	106.2082534	1.65194E-05
2.D - Non-Energy Products from Fuels and Solvent Use	CH4	0	0	0	0	0	0	100	0
2.D - Non-Energy Products from Fuels and Solvent Use	N2O	0	0	0	0	0	0	100	0
2.E - Electronics Industry	N2O	0	0	0	0	0	0	100	0
2.E - Electronics Industry	CF4	0	0	0	0	0	0	100	0
2.E - Electronics Industry	SF6	0	0	0	0	0	0	100	0
2.F.1 - Refrigeration and Air Conditioning	CH2FCF3	0.234	69.28104105	50	0	50	0.003944779	29607.2825	0.005582688
2.F.1 - Refrigeration and Air Conditioning	SF6	0	0	0	0	0	0	100	0
2.G - Other Product Manufacture and Use	SF6	0.0004935	0.915936	30	30	42.42640687	4.96428E-07	185600	5.27072E-07
2.G - Other Product Manufacture and Use	N2O	0	0	0	0	0	0	100	0
2.H - Other	CO2	0	0	0	0	0	0	100	0
2.H - Other	CH4	0	0	0	0	0	0	100	0
2.H - Other	N2O	0	0	0	0	0	0	100	0
3 - Agriculture, Forestry, and Other Land Use									
3.A.1 - Enteric Fermentation	CH4	5960.384339	13021.61731	0	0	0	0	218.4694235	0
3.A.2 - Manure Management	CH4	212.2263151	501.71212	0	0	0	0	236.4042931	0
3.A.2 - Manure Management	N2O	24.97810292	63.43046346	0	0	0	0	253.9442794	0

3.B.1.a - Forest land Remaining Forest land	CO_2	-84325.6527	-9976.514419	10	10	14.14213562	6.54397352	0	153.0721564
3.B.1.b - Land Converted to Forest land	CO_2	-670.5569374	-1966.449959	12.24744871	12.24744871	17.32050808	0.381365078	0	0.493246685
3.B.2.a - Cropland Remaining Cropland	CO_2	0	0	0	0	0	0	100	0
3.B.2.b - Land Converted to Cropland	CO_2	4458.993069	8505.389243	12.24744871	12.24744871	17.32050808	4.513231855	190.7468595	6.499584795
3.B.3.a - Grassland Remaining Grassland	CO_2	0	0	0	0	0	0	100	0
3.B.3.b - Land Converted to Grassland	CO_2	2207.324648	20522.53528	13.22875656	13.22875656	18.70828693	12.47096119	929.7470264	13.45720836
3.B.4.a.i - Peat Extraction remaining Peat Extraction	CO_2	0	0	0	0	0	0	100	0
3.B.4.a.iii - Other Wetlands Remaining Other Wetlands	CO_2	0	0	0	0	0	0	100	0
3.B.4.b.i - Land converted for Peat Extraction	CO_2	0	0	0	0	0	0	100	0
3.B.4.b.ii - Land converted to Flooded Land	CO_2	41.57970432	41.57970432	0	0	0	0	100	0
3.B.4.b.iii - Land converted to Other Wetlands	CO_2	0	0	0	0	0	0	100	0
3.B.5.a - Settlements Remaining Settlements	CO_2	0	0	0	0	0	0	100	0
3.B.5.b - Land Converted to Settlements	CO_2	362.0246464	362.0246464	11.18033989	11.18033989	15.8113883	0.002270124	100	0.004259694
3.B.6.b - Land Converted to Other land	CO_2	0	0	0	0	0	0	100	0
3.C.1 - Burning	CO_2	0	0	21.79449472	161.7096163	163.1716887	0	100	0
3.C.1 - Burning	CH_4	715.4862074	3261.510904	21.79449472	20.14000993	29.67524221	0.116778224	455.8453915	0.137181438
3.C.1 - Burning	N_2O	280.783044	2018.699457	21.79449472	0.173205081	21.79518295	0.025569067	718.953477	0.032423351
3.C.2 - Liming	CO_2	1.2151315	8.18191	10	5	11.18033989	2.75089E-06	673.3353551	3.60713E-06
3.C.3 - Urea application	CO_2	30.8966834	112.6319452	10	5	11.18033989	0.000521299	364.5438048	0.000701949
3.C.4 - Direct N_2O Emissions from managed soils	N_2O	100.0360012	989.0631752	11.18033989	14.14213562	18.02775638	0.104516605	988.7072284	0.110476563
3.C.5 - Indirect N_2O Emissions from managed soils	N_2O	19.00697783	131.3649728	18.02775638	15.00033333	23.4522292	0.003120208	691.1407694	0.003745759
3.C.6 - Indirect N_2O Emissions from manure management	N_2O	0	0.320514266	0	0	0	0	0	0
3.C.7 - Rice cultivation	CH_4	27.56361289	178.9520179	15	30	33.54101966	0.011843487	649.2328077	0.011906572
3.C.8 - CH_4 from Drained Organic Soils	CH_4	0	0	0	0	0	0	100	0
3.C.9 - CH_4 from Drainage Ditches on Organic Soils	CH_4	0	0	0	0	0	0	100	0
3.C.10 - CH_4 from Rewetting of Organic Soils	CH_4	0	0	0	0	0	0	100	0
3.C.11 - CH_4 Emissions from Rewetting of Mangroves and Tidal Marshes	CH_4	0	0	0	0	0	0	100	0

3.C.12 - N2O Emissions from Aquaculture	N2O	0	0	0	0	0	0	100	0
3.C.13 - CH4 Emissions from Rewetted and Created Wetlands on Inland Wetland Mineral Soils	CH4	0	0	0	0	0	0	100	0
3.C.14 - Other (please specify)	CO2	0	0	0	0	0	0	100	0
3.C.14 - Other (please specify)	CH4	0	0	0	0	0	0	100	0
3.C.14 - Other (please specify)	N2O	0	0	0	0	0	0	100	0
3.D.1 - Harvested Wood Products	CO2	0	0	0	0	0	0	100	0
3.D.2 - Other (please specify)	CO2	0	0	0	0	0	0	100	0
3.D.2 - Other (please specify)	CH4	0	0	0	0	0	0	100	0
3.D.2 - Other (please specify)	N2O	0	0	0	0	0	0	100	0
4 - Waste									
4.A - Solid Waste Disposal	CH4	563.1304177	1474.350632	0	0	0	0	261.8133537	0
4.B - Biological Treatment of Solid Waste	CH4	0	0	0	0	0	0	100	0
4.B - Biological Treatment of Solid Waste	N2O	0	0	0	0	0	0	100	0
4.C - Incineration and Open Burning of Waste	CO2	0.161211277	0.419842129	0	0	0	0	260.4297517	0
4.C - Incineration and Open Burning of Waste	CH4	2.01947866	5.259323261	0	0	0	0	260.4297517	0
4.C - Incineration and Open Burning of Waste	N2O	0.234471459	0.610633438	0	0	0	0	260.4297517	0
4.D - Wastewater Treatment and Discharge	CH4	289.4503032	613.9492266	0	0	0	0	212.1086832	0
4.D - Wastewater Treatment and Discharge	N2O	0	0	0	0	0	0	100	0
4.E - Other (please specify)	CO2	0	0	0	0	0	0	100	0
4.E - Other (please specify)	CH4	0	0	0	0	0	0	100	0
4.E - Other (please specify)	N2O	0	0	0	0	0	0	100	0
5 - Other									
5.A - Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3	N2O	0	0	0	0	0	0	100	0
5.B - Indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOC	CO2	0	0	0	0	0	0	100	0
Total									
		Sum(C): -65565.854	Sum(D): 55153.498				Sum(H): 27.141		Sum(M): 177.756
							Uncertainty in total inventory: 5.210		Trend uncertainty: 13.333

Annex II Key Category Analysis

Approach 1 Level Assesment

A	B	C	D	E	F	G
IPCC Category code	IPCC Category	Greenhouse gas	2022 Ex,t (Gg CO2 Eq)	|Ex,t| (Gg CO2 Eq)	Lx,t	Cumulative Total of Column F
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO2)	-9976.51	306923.14	0.81	0.81
3.B.3.b	Land Converted to Grassland	CARBON DIOXIDE (CO2)	20522.54	21129.04	0.06	0.87
3.A.1	Enteric Fermentation	METHANE (CH4)	13021.62	13021.62	0.03	0.90
3.B.2.b	Land Converted to Cropland	CARBON DIOXIDE (CO2)	8505.39	8516.85	0.02	0.92
1.A.1	Energy Industries - Solid Fuels	CARBON DIOXIDE (CO2)	3517.03	3517.03	0.01	0.93
3.C.1	Burning	METHANE (CH4)	3261.51	3261.51	0.01	0.94
1.A.3.b	Road Transportation - Liquid Fuels	CARBON DIOXIDE (CO2)	3091.16	3091.16	0.01	0.95
1.B.1.c	Fuel transformation	METHANE (CH4)	2516.11	2516.11	0.01	0.96
3.C.1	Burning	NITROUS OXIDE (N2O)	2018.70	2018.70	0.01	0.96
3.B.1.b	Land Converted to Forest land	CARBON DIOXIDE (CO2)	-1966.45	1976.99	0.01	0.97
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CARBON DIOXIDE (CO2)	1806.55	1806.55	0.00	0.97
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CARBON DIOXIDE (CO2)	1685.32	1685.32	0.00	0.98
1.A.4	Other Sectors - Biomass - solid	METHANE (CH4)	1640.10	1640.10	0.00	0.98
4.A	Solid Waste Disposal	METHANE (CH4)	1474.35	1474.35	0.00	0.98
2.A.2	Lime production	CARBON DIOXIDE (CO2)	1123.04	1123.04	0.00	0.99
3.C.4	Direct N2O Emissions from managed soils	NITROUS OXIDE (N2O)	989.06	989.06	0.00	0.99
1.A.4	Other Sectors - Liquid Fuels	CARBON DIOXIDE (CO2)	618.04	618.04	0.00	0.99
4.D	Wastewater Treatment and Discharge	METHANE (CH4)	613.95	613.95	0.00	0.99
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO2)	362.02	548.70	0.00	0.99
2.A.1	Cement production	CARBON DIOXIDE (CO2)	512.93	512.93	0.00	1.00
3.A.2	Manure Management	METHANE (CH4)	501.71	501.71	0.00	1.00
1.A.4	Other Sectors - Biomass - solid	NITROUS OXIDE (N2O)	179.36	179.36	0.00	1.00
3.C.7	Rice cultivation	METHANE (CH4)	178.95	178.95	0.00	1.00
3.C.5	Indirect N2O Emissions from managed soils	NITROUS OXIDE (N2O)	131.36	131.36	0.00	1.00
3.C.3	Urea application	CARBON DIOXIDE (CO2)	112.63	112.63	0.00	1.00
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	69.28	69.28	0.00	1.00
1.A.3.b	Road Transportation - Liquid Fuels	NITROUS OXIDE (N2O)	64.72	64.72	0.00	1.00

3.A.2	Manure Management	NITROUS OXIDE (N2O)	63.43	63.43	0.00	1.00
1.B.1.c	Fuel transformation	NITROUS OXIDE (N2O)	47.27	47.27	0.00	1.00
3.B.4.b.ii	Land converted to Flooded Land	CARBON DIOXIDE (CO2)	41.58	41.58	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - solid	METHANE (CH4)	36.47	36.47	0.00	1.00
1.A.3.c	Railways - Liquid Fuels	CARBON DIOXIDE (CO2)	31.08	31.08	0.00	1.00
1.A.5	Non-Specified - Liquid Fuels	CARBON DIOXIDE (CO2)	25.66	25.66	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	CARBON DIOXIDE (CO2)	23.23	23.23	0.00	1.00
2.C.1	Iron and Steel Production	CARBON DIOXIDE (CO2)	19.23	19.23	0.00	1.00
2.D	Non-Energy Products from Fuels and Solvent Use	CARBON DIOXIDE (CO2)	18.84	18.84	0.00	1.00
1.A.3.a	Civil Aviation - Liquid Fuels	CARBON DIOXIDE (CO2)	16.85	16.85	0.00	1.00
1.A.3.b	Road Transportation - Liquid Fuels	METHANE (CH4)	15.76	15.76	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	NITROUS OXIDE (N2O)	14.55	14.55	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - solid	NITROUS OXIDE (N2O)	12.99	12.99	0.00	1.00
1.A.1	Energy Industries - Biomass - solid	NITROUS OXIDE (N2O)	12.62	12.62	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	NITROUS OXIDE (N2O)	12.07	12.07	0.00	1.00
1.B.1.a	Coal mining and handling	METHANE (CH4)	10.66	10.66	0.00	1.00
1.A.1	Energy Industries - Biomass - solid	METHANE (CH4)	10.00	10.00	0.00	1.00
3.C.2	Liming	CARBON DIOXIDE (CO2)	8.18	8.18	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Solid Fuels	NITROUS OXIDE (N2O)	7.05	7.05	0.00	1.00
4.C	Incineration and Open Burning of Waste	METHANE (CH4)	5.26	5.26	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Solid Fuels	METHANE (CH4)	4.97	4.97	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	NITROUS OXIDE (N2O)	3.89	3.89	0.00	1.00
1.A.3.c	Railways - Liquid Fuels	NITROUS OXIDE (N2O)	3.18	3.18	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	METHANE (CH4)	2.06	2.06	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	METHANE (CH4)	2.06	2.06	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	METHANE (CH4)	1.02	1.02	0.00	1.00
2.G	Other Product Manufacture and Use	SF6, PFCs	0.92	0.92	0.00	1.00
4.C	Incineration and Open Burning of Waste	NITROUS OXIDE (N2O)	0.61	0.61	0.00	1.00
4.C	Incineration and Open Burning of Waste	CARBON DIOXIDE (CO2)	0.42	0.42	0.00	1.00
3.C.6	Indirect N2O Emissions from manure management	NITROUS OXIDE (N2O)	0.32	0.32	0.00	1.00
1.A.3.a	Civil Aviation - Liquid Fuels	NITROUS OXIDE (N2O)	0.13	0.13	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	NITROUS OXIDE (N2O)	0.05	0.05	0.00	1.00
1.A.3.c	Railways - Liquid Fuels	METHANE (CH4)	0.05	0.05	0.00	1.00
1.B.1.a	Coal mining and handling	CARBON DIOXIDE (CO2)	0.03	0.03	0.00	1.00

1.A.5	Non-Specified - Liquid Fuels	NITROUS OXIDE (N2O)	0.03	0.03	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	METHANE (CH4)	0.03	0.03	0.00	1.00
2.C.5	Lead Production	CARBON DIOXIDE (CO2)	0.02	0.02	0.00	1.00
1.A.5	Non-Specified - Liquid Fuels	METHANE (CH4)	0.02	0.02	0.00	1.00
1.A.3.a	Civil Aviation - Liquid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Peat	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.1	Energy Industries	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00

1.A.2	Manufacturing Industries and Construction - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Peat	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00

1.A.3.b	Road Transportation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00

1.A.3.c	Railways - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Liquid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Liquid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Liquid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.d	Water-borne Navigation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Liquid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00

1.A.3.e	Other Transportation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Liquid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Liquid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Peat	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00

1.A.4	Other Sectors - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Peat	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.B.2.a	Oil	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00

1.B.2 .a	Oil	METHANE (CH4)	0.00	0.00	0. 00	1.00
1.B.2 .a	Oil	NITROUS OXIDE (N2O)	0.00	0.00	0. 00	1.00
1.B.2 .b	Natural Gas	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
1.B.2 .b	Natural Gas	METHANE (CH4)	0.00	0.00	0. 00	1.00
1.B.2 .b	Natural Gas	NITROUS OXIDE (N2O)	0.00	0.00	0. 00	1.00
1.B.3	Other emissions from Energy Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
1.B.3	Other emissions from Energy Production	METHANE (CH4)	0.00	0.00	0. 00	1.00
1.B.3	Other emissions from Energy Production	NITROUS OXIDE (N2O)	0.00	0.00	0. 00	1.00
1.C	Carbon dioxide Transport and Storage	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.A.3	Glass Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.A.4	Other Process Uses of Carbonates	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.A.5	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.A.5	Other (please specify)	METHANE (CH4)	0.00	0.00	0. 00	1.00
2.A.5	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0. 00	1.00
2.B.1	Ammonia Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.B.2	Nitric Acid Production	NITROUS OXIDE (N2O)	0.00	0.00	0. 00	1.00
2.B.3	Adipic Acid Production	NITROUS OXIDE (N2O)	0.00	0.00	0. 00	1.00
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	NITROUS OXIDE (N2O)	0.00	0.00	0. 00	1.00
2.B.5	Carbide Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.B.5	Carbide Production	METHANE (CH4)	0.00	0.00	0. 00	1.00
2.B.6	Titanium Dioxide Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.B.7	Soda Ash Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.B.8	Petrochemical and Carbon Black Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.B.8	Petrochemical and Carbon Black Production	METHANE (CH4)	0.00	0.00	0. 00	1.00
2.B.9	Fluorochemical Production	SF6, PFCs, HFCs and other halogenated gases	0.00	0.00	0. 00	1.00
2.C.1	Iron and Steel Production - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.C.1	Iron and Steel Production - Solid Fuels	METHANE (CH4)	0.00	0.00	0. 00	1.00
2.C.1	Iron and Steel Production	METHANE (CH4)	0.00	0.00	0. 00	1.00
2.C.2	Ferroalloys Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.C.2	Ferroalloys Production	METHANE (CH4)	0.00	0.00	0. 00	1.00
2.C.3	Aluminium production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.C.3	Aluminium production	PFCs (PFCs)	0.00	0.00	0. 00	1.00
2.C.4	Magnesium production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00
2.C.6	Zinc Production	CARBON DIOXIDE (CO2)	0.00	0.00	0. 00	1.00

2.D	Non-Energy Products from Fuels and Solvent Use	METHANE (CH4)	0.00	0.00	0.00	1.00
2.D	Non-Energy Products from Fuels and Solvent Use	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
2.E	Electronics Industry	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
2.E	Electronics Industry	SF6, PFCs, HFCs and other halogenated gases	0.00	0.00	0.00	1.00
2.G	Other Product Manufacture and Use	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
2.H	Other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
2.H	Other	METHANE (CH4)	0.00	0.00	0.00	1.00
2.H	Other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
3.B.2.a	Cropland Remaining Cropland	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.B.3.a	Grassland Remaining Grassland	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.B.4.a.i	Peat Extraction remaining Peat Extraction	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.B.4.a.iii	Other Wetlands Remaining Other Wetlands	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.B.4.b.i	Land converted for Peat Extraction	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.B.4.b.iii	Land converted to Other Wetlands	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.B.5.a	Settlements Remaining Settlements	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.B.6.b	Land Converted to Other land	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.C.1	Burning	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.C.10	CH4 from Rewetting of Organic Soils	METHANE (CH4)	0.00	0.00	0.00	1.00
3.C.11	CH4 Emissions from Rewetting of Mangroves and Tidal Marshes	METHANE (CH4)	0.00	0.00	0.00	1.00
3.C.12	N2O Emissions from Aquaculture	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
3.C.13	CH4 Emissions from Rewetted and Created Wetlands on Inland Wetland Mineral Soils	METHANE (CH4)	0.00	0.00	0.00	1.00
3.C.14	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.C.14	Other (please specify)	METHANE (CH4)	0.00	0.00	0.00	1.00
3.C.14	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
3.C.8	CH4 from Drained Organic Soils	METHANE (CH4)	0.00	0.00	0.00	1.00
3.C.9	CH4 from Drainage Ditches on Organic Soils	METHANE (CH4)	0.00	0.00	0.00	1.00
3.D.1	Harvested Wood Products	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.D.2	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
3.D.2	Other (please specify)	METHANE (CH4)	0.00	0.00	0.00	1.00
3.D.2	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
4.B	Biological Treatment of Solid Waste	METHANE (CH4)	0.00	0.00	0.00	1.00
4.B	Biological Treatment of Solid Waste	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
4.D	Wastewater Treatment and Discharge	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
4.E	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00

4.E	Other (please specify)	METHANE (CH4)	0.00	0.00	0.00	1.00
4.E	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
5.A	Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
5.B	Indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOC	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.B.1.b	Uncontrolled combustion and burning coal dumps - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
1.B.1.b	Uncontrolled combustion and burning coal dumps - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	1.00
1.B.1.b	Uncontrolled combustion and burning coal dumps - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
1.B.1.c	Fuel transformation	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
2.B.10	Hydrogen Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
2.B.10	Hydrogen Production	METHANE (CH4)	0.00	0.00	0.00	1.00
2.B.10	Hydrogen Production	NITROUS OXIDE (N2O)	0.00	0.00	0.00	1.00
2.C.7	Rare Earths Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	1.00
Total						
			57027.08418	378674.82211	1	

Approach 1 Trend Assessment

A	B	C	D	E	F	G	H
IPCC Category code	IPCC Category	Greenhouse gas	1990 Year Estimate Ex0 (Gg CO2 Eq)	2022 Year Estimate Ext (Gg CO2 Eq)	Trend Assessment (Txt)	% Contribution to Trend	Cumulative Total of Column G
3.B.1.a	Forest land Remaining Forest land	CARBON DIOXIDE (CO2)	-84325.65	-9976.51	0.80	0.67	0.67
3.B.3.b	Land Converted to Grassland	CARBON DIOXIDE (CO2)	2207.32	20522.54	0.13	0.11	0.78
3.B.2.b	Land Converted to Cropland	CARBON DIOXIDE (CO2)	4458.99	8505.39	0.04	0.03	0.82
3.A.1	Enteric Fermentation	METHANE (CH4)	5960.38	13021.62	0.04	0.03	0.85
1.A.1	Energy Industries - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	3517.03	0.03	0.03	0.88
3.B.1.b	Land Converted to Forest land	CARBON DIOXIDE (CO2)	-670.56	-1966.45	0.02	0.02	0.90
1.A.3.b	Road Transportation - Liquid Fuels	CARBON DIOXIDE (CO2)	424.23	3091.16	0.02	0.01	0.91
2.A.2	Lime production	CARBON DIOXIDE (CO2)	880.89	1123.04	0.01	0.01	0.92
3.C.1	Burning	NITROUS OXIDE (N2O)	280.78	2018.70	0.01	0.01	0.93
3.C.1	Burning	METHANE (CH4)	715.49	3261.51	0.01	0.01	0.94

1.A.4	Other Sectors - Biomass - solid	METHANE (CH4)	921.48	1640.10	0.01	0.01	0.95
1.A.2	Manufacturing Industries and Construction - Solid Fuels	CARBON DIOXIDE (CO2)	915.14	1685.32	0.01	0.01	0.96
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	CARBON DIOXIDE (CO2)	303.67	1806.55	0.01	0.01	0.97
3.C.4	Direct N2O Emissions from managed soils	NITROUS OXIDE (N2O)	100.04	989.06	0.01	0.01	0.97
3.B.5.b	Land Converted to Settlements	CARBON DIOXIDE (CO2)	362.02	362.02	0.01	0.01	0.98
1.B.1.c	Fuel transformation	METHANE (CH4)	699.16	2516.11	0.00	0.00	0.98
1.A.1	Energy Industries - Liquid Fuels	CARBON DIOXIDE (CO2)	152.72	23.23	0.00	0.00	0.99
4.D	Wastewater Treatment and Discharge	METHANE (CH4)	289.45	613.95	0.00	0.00	0.99
1.A.4	Other Sectors - Liquid Fuels	CARBON DIOXIDE (CO2)	275.82	618.04	0.00	0.00	0.99
2.B.2	Nitric Acid Production	NITROUS OXIDE (N2O)	56.44	0.00	0.00	0.00	0.99
4.A	Solid Waste Disposal	METHANE (CH4)	563.13	1474.35	0.00	0.00	0.99
1.A.4	Other Sectors - Biomass - solid	NITROUS OXIDE (N2O)	108.58	179.36	0.00	0.00	0.99
2.B.1	Ammonia Production	CARBON DIOXIDE (CO2)	43.52	0.00	0.00	0.00	0.99
3.A.2	Manure Management	METHANE (CH4)	212.23	501.71	0.00	0.00	0.99
3.C.7	Rice cultivation	METHANE (CH4)	27.56	178.95	0.00	0.00	0.99
2.A.1	Cement production	CARBON DIOXIDE (CO2)	149.04	512.93	0.00	0.00	1.00
3.B.4.b.ii	Land converted to Flooded Land	CARBON DIOXIDE (CO2)	41.58	41.58	0.00	0.00	1.00
3.C.5	Indirect N2O Emissions from managed soils	NITROUS OXIDE (N2O)	19.01	131.36	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - solid	METHANE (CH4)	38.49	36.47	0.00	0.00	1.00
2.F.1	Refrigeration and Air Conditioning	HFCs, PFCs	0.23	69.28	0.00	0.00	1.00
1.A.3.b	Road Transportation - Liquid Fuels	NITROUS OXIDE (N2O)	5.66	64.72	0.00	0.00	1.00
2.D	Non-Energy Products from Fuels and Solvent Use	CARBON DIOXIDE (CO2)	17.74	18.84	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - solid	NITROUS OXIDE (N2O)	14.75	12.99	0.00	0.00	1.00
3.C.3	Urea application	CARBON DIOXIDE (CO2)	30.90	112.63	0.00	0.00	1.00
2.C.6	Zinc Production	CARBON DIOXIDE (CO2)	7.05	0.00	0.00	0.00	1.00
2.C.1	Iron and Steel Production	CARBON DIOXIDE (CO2)	0.87	19.23	0.00	0.00	1.00
2.C.5	Lead Production	CARBON DIOXIDE (CO2)	5.51	0.02	0.00	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	NITROUS OXIDE (N2O)	0.00	14.55	0.00	0.00	1.00
1.A.3.c	Railways - Liquid Fuels	CARBON DIOXIDE (CO2)	15.26	31.08	0.00	0.00	1.00
1.A.3.e	Other Transportation - Liquid Fuels	CARBON DIOXIDE (CO2)	4.44	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - solid	NITROUS OXIDE (N2O)	0.00	12.62	0.00	0.00	1.00
1.B.2.a	Oil	CARBON DIOXIDE (CO2)	3.79	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - solid	METHANE (CH4)	0.00	10.00	0.00	0.00	1.00
1.B.1.c	Fuel transformation	NITROUS OXIDE (N2O)	13.14	47.27	0.00	0.00	1.00

1.A.3.b	Road Transportation - Liquid Fuels	METHANE (CH4)	2.40	15.76	0.00	0.00	1.00
3.A.2	Manure Management	NITROUS OXIDE (N2O)	24.98	63.43	0.00	0.00	1.00
1.B.1.a	Coal mining and handling	METHANE (CH4)	0.85	10.66	0.00	0.00	1.00
3.C.2	Liming	CARBON DIOXIDE (CO2)	1.22	8.18	0.00	0.00	1.00
1.A.5	Non-Specified - Liquid Fuels	CARBON DIOXIDE (CO2)	10.30	25.66	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Solid Fuels	NITROUS OXIDE (N2O)	3.81	7.05	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Liquid Fuels	CARBON DIOXIDE (CO2)	7.08	16.85	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Solid Fuels	METHANE (CH4)	2.69	4.97	0.00	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	NITROUS OXIDE (N2O)	3.42	12.07	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	NITROUS OXIDE (N2O)	0.63	3.89	0.00	0.00	1.00
1.B.2.a	Oil	METHANE (CH4)	0.54	0.00	0.00	0.00	1.00
1.A.3.c	Railways - Liquid Fuels	NITROUS OXIDE (N2O)	1.56	3.18	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Liquid Fuels	METHANE (CH4)	0.33	2.06	0.00	0.00	1.00
1.A.1	Energy Industries - Solid Fuels	METHANE (CH4)	0.00	1.02	0.00	0.00	1.00
2.G	Other Product Manufacture and Use	SF6, PFCs	0.00	0.92	0.00	0.00	1.00
1.A.4	Other Sectors - Liquid Fuels	METHANE (CH4)	0.99	2.06	0.00	0.00	1.00
4.C	Incineration and Open Burning of Waste	METHANE (CH4)	2.02	5.26	0.00	0.00	1.00
3.C.6	Indirect N2O Emissions from manure management	NITROUS OXIDE (N2O)	0.00	0.32	0.00	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	NITROUS OXIDE (N2O)	0.10	0.05	0.00	0.00	1.00
1.A.1	Energy Industries - Liquid Fuels	METHANE (CH4)	0.08	0.03	0.00	0.00	1.00
4.C	Incineration and Open Burning of Waste	NITROUS OXIDE (N2O)	0.23	0.61	0.00	0.00	1.00
4.C	Incineration and Open Burning of Waste	CARBON DIOXIDE (CO2)	0.16	0.42	0.00	0.00	1.00
1.B.2.a	Oil	NITROUS OXIDE (N2O)	0.02	0.00	0.00	0.00	1.00
1.B.1.a	Coal mining and handling	CARBON DIOXIDE (CO2)	0.00	0.03	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Liquid Fuels	NITROUS OXIDE (N2O)	0.05	0.13	0.00	0.00	1.00
1.A.5	Non-Specified - Liquid Fuels	NITROUS OXIDE (N2O)	0.02	0.03	0.00	0.00	1.00
1.A.3.c	Railways - Liquid Fuels	METHANE (CH4)	0.02	0.05	0.00	0.00	1.00
1.A.5	Non-Specified - Liquid Fuels	METHANE (CH4)	0.01	0.02	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Liquid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00

1.A.1	Energy Industries - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Peat	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.1	Energy Industries	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Peat	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.2	Manufacturing Industries and Construction - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00

1.A.2	Manufacturing Industries and Construction - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.a	Civil Aviation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.b	Road Transportation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00

1.A. 3.b	Road Transportation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.b	Road Transportation	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.c	Railways - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Liquid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00

1.A. 3.d	Water-borne Navigation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Liquid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Liquid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.d	Water-borne Navigation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Liquid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A. 3.e	Other Transportation - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00

1.A.3.e	Other Transportation - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Liquid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.3.e	Other Transportation - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Peat	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.4	Other Sectors - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Gaseous Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00

1.A.5	Non-Specified - Other Fossil Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Peat	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - solid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - liquid	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Gaseous Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Other Fossil Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Peat	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - solid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - liquid	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Gaseous Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Other Fossil Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Peat	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - solid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - liquid	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.A.5	Non-Specified - Biomass - other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.B.2.b	Natural Gas	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.B.2.b	Natural Gas	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.B.2.b	Natural Gas	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.B.3	Other emissions from Energy Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.B.3	Other emissions from Energy Production	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.B.3	Other emissions from Energy Production	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.C	Carbon dioxide Transport and Storage	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.A.3	Glass Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.A.4	Other Process Uses of Carbonates	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.A.5	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.A.5	Other (please specify)	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.A.5	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00

2.B.3	Adipic Acid Production	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
2.B.5	Carbide Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.B.5	Carbide Production	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.B.6	Titanium Dioxide Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.B.7	Soda Ash Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.B.8	Petrochemical and Carbon Black Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.B.8	Petrochemical and Carbon Black Production	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.B.9	Fluorochemical Production	SF6, PFCs, HFCs and other halogenated gases	0.00	0.00	0.00	0.00	1.00
2.C.1	Iron and Steel Production - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.C.1	Iron and Steel Production - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.C.1	Iron and Steel Production	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.C.2	Ferroalloys Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.C.2	Ferroalloys Production	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.C.3	Aluminium production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.C.3	Aluminium production	PFCs (PFCs)	0.00	0.00	0.00	0.00	1.00
2.C.4	Magnesium production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.D	Non-Energy Products from Fuels and Solvent Use	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.D	Non-Energy Products from Fuels and Solvent Use	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
2.E	Electronics Industry	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
2.E	Electronics Industry	SF6, PFCs, HFCs and other halogenated gases	0.00	0.00	0.00	0.00	1.00
2.G	Other Product Manufacture and Use	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
2.H	Other	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.H	Other	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.H	Other	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
3.B.2.a	Cropland Remaining Cropland	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.B.3.a	Grassland Remaining Grassland	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.B.4.a.i	Peat Extraction remaining Peat Extraction	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.B.4.a.iii	Other Wetlands Remaining Other Wetlands	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.B.4.b.i	Land converted for Peat Extraction	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.B.4.b.iii	Land converted to Other Wetlands	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.B.5.a	Settlements Remaining Settlements	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00

3.B. 6.b	Land Converted to Other land	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.C. 1	Burning	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.C. 10	CH4 from Rewetting of Organic Soils	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
3.C. 11	CH4 Emissions from Rewetting of Mangroves and Tidal Marshes	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
3.C. 12	N2O Emissions from Aquaculture	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
3.C. 13	CH4 Emissions from Rewetted and Created Wetlands on Inland Wetland Mineral Soils	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
3.C. 14	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.C. 14	Other (please specify)	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
3.C. 14	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
3.C. 8	CH4 from Drained Organic Soils	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
3.C. 9	CH4 from Drainage Ditches on Organic Soils	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
3.D. 1	Harvested Wood Products	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.D. 2	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
3.D. 2	Other (please specify)	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
3.D. 2	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
4.B	Biological Treatment of Solid Waste	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
4.B	Biological Treatment of Solid Waste	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
4.D	Wastewater Treatment and Discharge	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
4.E	Other (please specify)	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
4.E	Other (please specify)	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
4.E	Other (please specify)	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
5.A	Indirect N2O emissions from the atmospheric deposition of nitrogen in NOx and NH3	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
5.B	Indirect CO2 emissions from the atmospheric oxidation of CH4, CO and NMVOC	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.B. 1.b	Uncontrolled combustion and burning coal dumps - Solid Fuels	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
1.B. 1.b	Uncontrolled combustion and burning coal dumps - Solid Fuels	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
1.B. 1.b	Uncontrolled combustion and burning coal dumps - Solid Fuels	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
1.B. 1.c	Fuel transformation	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.B. 10	Hydrogen Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
2.B. 10	Hydrogen Production	METHANE (CH4)	0.00	0.00	0.00	0.00	1.00
2.B. 10	Hydrogen Production	NITROUS OXIDE (N2O)	0.00	0.00	0.00	0.00	1.00
2.C. 7	Rare Earths Production	CARBON DIOXIDE (CO2)	0.00	0.00	0.00	0.00	1.00
Total							
			-64606.17241	57027.08418	1.19496	1	