

DEPARTMENT OF FORESTRY, FISHERIES AND THE ENVIRONMENT

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29 May 2026

I, Willem Abraham Stephanus Aucamp, Minister of Forestry, Fisheries and the Environment, hereby publish the draft 10th National Greenhouse Gas Inventory Report, which will form part of the Second Biennial Transparency Report to the United Nations Framework Convention on Climate Change (UNFCCC), for public comment as set out in the Schedule hereto.

Members of the public are invited to submit to the Minister, within 30 days from the date of publication of this Notice in the Government Gazette or in the newspaper, whichever date is the last date, written inputs or comments to the following addresses:

By post to: The Director-General: Department of Forestry, Fisheries and the Environment
Attention: Mr Jongikhaya Witi
Department of Forestry, Fisheries and the Environment
Private Bag X447
Pretoria
0001

By e-mail to: GHGreporting@dfre.gov.za

Hand delivered at: Environment House, 473 Steve Biko Road, Arcadia, Pretoria, 0083.

Any inquiries in connection with the notice can be directed to Mr Jongikhaya Witi at Tel: +2712 399 9048.

For Communication and media enquiries kindly contact Dr. Nomxolisi Mashiyi at Tel: (012) 399 9484 / Email: NMashiyi@dfre.gov.za, Call Centre: 086 111 2468

Comments received after the closing date may be disregarded.



MR WILLEM ABRAHAM STEPHANUS AUCAMP
MINISTER OF FORESTRY, FISHERIES AND THE ENVIRONMENT

SCHEDULE

DRAFT 10th NATIONAL GHG INVENTORY
1990 – 2024 REPORT FOR THE REPUBLIC OF SOUTH AFRICA
FOR PUBLIC COMMENT

NATIONAL GHG INVENTORY DOCUMENT

SOUTH AFRICA

1990 - 2024

February 2026

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Report compilation details

Internal report reviewer: Sindisiwe Mashele' Jongikhaya Witi

External Reviewer: Luanne Stevens

Compilers and technical contributors

Executive Summary

Lead Author: Lungile Moyo (DFFE)

Other Contributors: Sewela Malaka (DFFE), Tshamaano Khalushi (DFFE), Sindisiwe Mashele (DFFE)

Chapter 1: National circumstances, institutional arrangements and cross-cutting information

Lead Author: Malebo Rebecca Seeletse (DFFE)

Chapter 2: Trends in GHG emissions and removals

Lead Author: Sindisiwe Mashele (DFFE)

Other Contributors: Luanne Stevens (Gondwana Environmental Solutions), Sewela Malaka (DFFE), Tshamaano Khalushi (DFFE), Malebo Rebecca Seeletse (DFFE), Lungile Moyo

Chapter 3: Energy (CRF Sector 1)

Lead Author: Malebo Rebecca Seeletse (DFFE)

Other Contributors: Sewela Malaka (DFFE), Tshamaano Khalushi (DFFE), Thapedi Phadu

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Chapter 4: Industrial Processes and Product Use (CRF Sector 2)

Lead Author: Tshamaano Khalushi (DFFE)

Other Contributors: Tidimalo Makobe (DFFE)

Chapter 5: Agriculture (CRF Sector 3)

Lead Author: Sewela Malaka (DFFE)

Chapter 6: Land use, Forestry and Land Use Change (LULUCF) (CRT sector 4)

Lead Author: Luanne Stevens (Gondwana Environmental Solutions)

Other contributors: Lungile Moyo (DFFE)

Chapter 7: Waste (CRF Sector 5)

Lead Author: Tshamaano Khalushi (DFFE)

Other Contributors: Thapedi Phadu (DFFE)



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List of abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
AGB	Above-ground biomass
ARC	Agricultural Research Council
Bbl/d	Barrels per day
BCEF	Biomass conversion and expansion factor
BEF	Biomass expansion factor
BNF	Biological nitrogen fixing
BOD	Biological oxygen demand
C	Carbon
C ₂ F ₄	Tetrafluoroethylene
C ₂ F ₆	Carbon hexafluoroethane
CF ₄	Carbon tetrafluoromethane
CALC	Computer Automated Land Cover
CFC	Chlorofluorocarbons
CH ₄	Methane
CO	Carbon monoxide
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
CRT	Common reporting tables
DAFF	Department of Agriculture Affairs, Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform and Rural Development
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and Environment
DFID	Department for International Development
DM	Dry matter
DMD	Dry matter digestibility
DMR	Department of Mineral Resources
DMRE	Department of Mineral Resources and Energy
DEE	Department of Electricity and Energy
DoE	Department of Energy
DOM	Dead organic matter
DTI	Department of Trade and Industry
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry



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EF	Emission factor
FAO	Food and Agriculture Organisation
FertASA	Fertiliser Association of South Africa
F-gases	Flourinated gases: e.g., HFC, PFC, SF ₆ and NF ₃
FOD	First order decay
FRA	Forest resource assessment
FSA	Forestry South Africa
GDP	Gross domestic product
GEI	Gross energy intake
GFRSA	Global Forest Resource Assessment for South Africa
Gg	Gigagram
GHG	Greenhouse gas
GHGI	Greenhouse Gas Inventory
GIS	Geographical Information Systems
GPG	Good Practice Guidance
GWH	Gigawatt hour
GWP	Global warming potential
HFC	Hydrofluorocarbons
HWP	Harvested wood products
IEF	Implied emission factor
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ISO	International Organization for Standardization
ISRIC	International Soil Reference and Information Centre
ISWC	Institute of Soil, Water and Climate
KCA	Key category analysis
LC	Land cover
LPG	Liquefied petroleum gas
LTO	Landing/take off
LULUCF	Land Use, Land Use Change and Forestry
MCF	Methane conversion factor
MEF	Manure emission factor
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MW	Megawatt
MWH	Megawatt hours



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MWTP	Municipal wastewater treatment plant
NAEIS	National Atmospheric Emissions Inventory System
N ₂ O	Nitrous oxide
NCCC	National Climate Change Committee
NCV	Net calorific value
NID	National Inventory Document
NE	Not estimated
NERSA	National Energy Regulator of South Africa
NGER	National Greenhouse gas Emissions Regulation
NGHGIS	National Greenhouse Gas Inventory System
NIU	National Inventory Unit
NMVOC	Non-methane volatile organic compound
NO	Not occurring
NO _x	Oxides of nitrogen
NTCSA	National Terrestrial Carbon Sinks Assessment
NWBIR	National Waste Baseline Information Report
PFC	Perfluorocarbons
PPM	Parts per million
PRP	Pastures, rangelands and paddocks
QA/QC	Quality assurance/quality control
RSA	Republic of South Africa
SAAQIS	South African Air Quality Information System
SADC	Southern African Development Community
SAEON	South African Environmental Observation Network
SAGERS	South African GHG Emissions Reporting System
SAISA	South African Iron and Steel Institute
SAMI	South African Minerals Industry
SANLC	South African National Land Cover
SAPIA	South African Petroleum Industry Association
SAR	Second Assessment Report
SARS	South African Revenue Service
SASQF	South African Statistical Quality Assurance Framework
SF ₆	Sulphur hexafluoride
SNE	Single National Entity
SOC	Soil organic carbon
SOM	Soil organic matter
Stats SA	Statistics South Africa

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TAM	Typical animal mass
TAR	Third Assessment Report (IPCC)
TJ	Terajoule
TM	Tier method
TMR	Total mixed ratio
TOW	Total organics in wastewater
UN	United Nations
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute
WWTP	Wastewater treatment plant-derived
VS	Volatile solids



Executive summary

E.S.1. Background

E.S.1.1. Background information on greenhouse gas inventories

This report documents South Africa's submission of its national greenhouse gas (GHG) inventory for the year 2024. It also reports on the GHG trends for the period 1990 to 2024. It is compiled in accordance with the guidelines provided by the United Nations Framework Convention on Climate Change (UNFCCC) and follows the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National GHG Inventories (IPCC, 2006), IPCC Good Practice Guidance (GPG) (IPCC, 2000; IPCC, 2003; IPCC, 2014), the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) and sections of the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014a). This report provides an explanation of the methods (Tier 1, 2 and 3 approaches), activity data and emission factors used to develop the inventory. In addition, it assesses the uncertainty and describes the quality assurance and quality control (QA/QC) activities.

In August 1997, the Republic of South Africa joined the majority of countries in the international community in ratifying the UNFCCC. The first national GHG inventory for South Africa was prepared in 1998, using 1990 data (Van der Merwe & Scholes, 1998). It was updated to include 1994 data and published in 2004. It was developed using the 1996 IPCC Guidelines for National Greenhouse Gas Inventories. For the 2000 national inventory (DEAT, 2009), a decision was made to use the recently published IPCC 2006 Guidelines (IPCC, 2006) to enhance accuracy and transparency, and to familiarise researchers with the latest inventory preparation guidelines. South Africa has continued to use these guidelines and has produced six updated inventories since then (DEA, 2014; DEA, 2017; DEA, 2019; DFFE, 2021; DFFE, 2023) with the latest submission being for the period 2000 to 2022 (DFFE, 2025). This current inventory includes the historic period from 1990 to 2024.



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E.S.1.2. Institutional arrangements for inventory preparation

The Department of Forestry, Fisheries and Environment (DFFE) is responsible for the co-ordination and management of all climate change-related information, including mitigation, adaption, monitoring and evaluation, and GHG inventories. Although the DFFE takes a lead role in the compilation, implementation and reporting of the national GHG inventories, other relevant agencies and ministries play supportive roles in terms of data provision across relevant sectors. Figure ES 1 gives an overview of the institutional arrangements for the compilation of the 1990 – 2024 GHG emissions inventory.

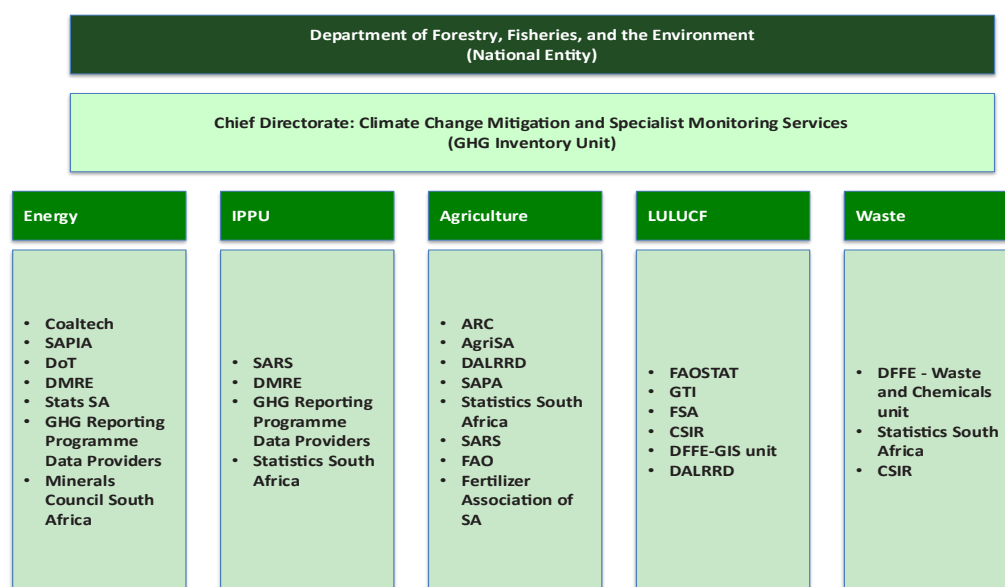


Figure ES 1: Institutional arrangements for the compilation of the 1990 – 2024 inventory for South Africa

The Minister of DFFE promulgated the National Greenhouse Gas Emission Reporting Regulations (NGER), 2016 under Notice No. 275 in the Gazette No. 40762 of 03 April 2017 (DEA, 2017a). The purpose of the NGER is to enable the DFFE to collate and publish GHG emissions data and information in an effective and efficient manner.



The NGER were promulgated in fulfilment of the implementation of the regulatory framework to support the collection of the requisite activity and GHG emissions data necessary for the compilation of the National GHG Emissions Inventory to improve the quality, sustainability, accuracy, completeness and consistency of the National GHG Inventories. The NGER came into effect on 03 April 2017. In accordance with regulation 7(1) of the regulation the initial reporting cycle commenced on 31 March of 2018 requiring data providers to register and submit activity and GHG emissions data to the competent authority (DFFE).

As required in the 2011 White Paper (DEA, 2011), the DFFE has developed the South African Greenhouse Gas Emissions Reporting System (SAGERS) which is the GHG module of National Atmospheric Emissions Inventory System (NAEIS). The SAGERS module and the manual reporting program helps to facilitate the process of enabling Industry to meet its GHG reporting requirements and facilitates the data collection process for energy related activities and Industrial Processes and Product Use (IPPU).

E.S.1.3. Organisation of report

This report follows a standard National Inventory Document (NID) format in line with the UNFCCC Reporting Guidelines or requirements under the enhanced transparency framework. Chapter 1 is the introductory chapter which contains background information for South Africa, the country's inventory preparation and reporting process, key categories, a description of the methodologies, activity data, emission factors, QA/QC process and uncertainty. A summary of the aggregated GHG trends by gas and emission source is provided in Chapter 2. Chapters 3 to 7 deal with detailed explanations of the emissions in the Energy; IPPU; Agriculture; Land Use, Land Use Change and Forestry (LULUCF) and Waste sectors, respectively. They include an overall trend assessment, methodology, data sources, recalculations, uncertainty and time-series consistency, QA/QC and planned improvements and recommendations. Chapter 8 focuses on indirect CO₂ and N₂O emissions while Chapter 9 details improvements and recalculations, the improvement plan and the impacts of recalculations on the overall emission estimates.



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E.S.2. Overview of source and sink category emission estimates and trends

E.S.2.1. Aggregated emission trends

South Africa's national emissions increased between 1990 and 2024, but there has been a decline since 2000 (Table ES 1). Emissions excluding LULUCF show an increase since the last submission, however with the increasing LULUCF sink the national emission including LULUCF show a 1.7% decline since the last submission in 2022.

Table ES 1: Changes in South Africa's emissions excluding and including LULUCF between 1990, 2000, 2022 and 2024

	Emissions (Gg CO ₂ e)				% Change in emissions		
	1990	2000	2022	2024	Change between 1990 and 2024	Change between 2000 and 2024	Change between 2022 and 2024
Emissions (excl. LULUCF)	405 260	481 534	472 193	477 576	17.8%	-0.8%	1.1%
Emissions (incl. LULUCF)	402 802	468 891	451 889	444 164	10.3%	-5.3%	-1.7%

E.S.2.2. Gas trends

Carbon dioxide

Carbon dioxide (CO₂) is the largest contributor to South Africa's emissions. CO₂ emissions contribute 82.5% to South Africa's emissions (excl. LULUCF) in 2024, which is an increase of 1.3% since 1990 (Figure ES 2). Majority of these CO₂ emissions are from the Energy sector, which contributed an average of 93.5% between 1990 and 2024.



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Methane

Methane (CH₄) is the second largest contributor to South Africa's emissions. CH₄ contributes 12.7 % to South Africa's emissions (excl. LULUCF) in 2024 (Figure ES 2) and this has decreased from 15.1% in 1990. The Agriculture (specifically *Enteric Fermentation*) and Waste (specifically *Wastewater Treatment and Discharge*) sectors are the major contributors to the total CH₄ emissions in 2024.

Nitrous oxide

Nitrous oxide (N₂O) contributed 3.4 % to South Africa's emissions (excl. LULUCF) in 2024 (Figure ES 2) and this declined from 3.7% in 1990. The main contributor to N₂O emissions is the Agriculture sector followed by the Energy sector, contributing 78.4% and 11.1% respectively.

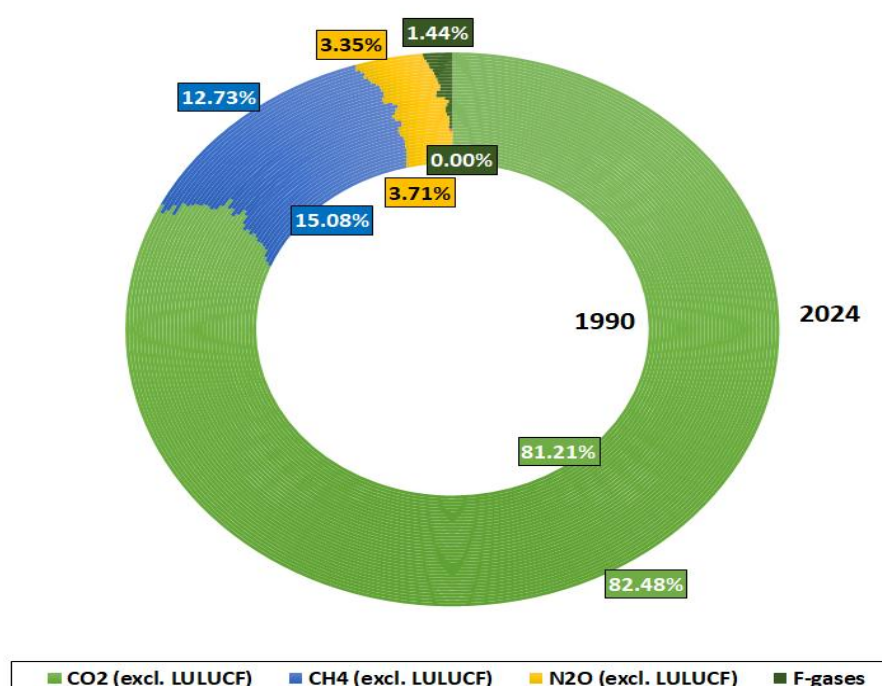


Figure ES 2: Gas contribution to South Africa's emissions (excl. LULUCF), 1990-2024.



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F-gases

Fluorinated gas (F-gas) emissions are only estimated for the IPPU sector in South Africa. F-gas emissions have increased from 0% to 1.4% of the total emissions (excl. LULUCF) since 1990. Emissions increased from 2011 due to the addition of hydrofluorocarbons (HFCs) emissions from *Air conditioning, foam blowing agents, fire protection and aerosols*. There is no data prior to 2005, so this time-series is not consistent. The replacement of ozone depleting substances did contribute to this increase. Perfluorocarbons (PFCs) data is not available prior to 2000, so this time-series is also not consistent.

E.S.2.3. GHG precursors

Carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs) were estimated from biomass burning only. CO emissions varied between 232 Gg CO to 1 190 Gg CO between 1990 and 2024. The NO_x emissions were between 11 Gg NO_x and 62 Gg NO_x, while NMVOCs were between 34 Gg NMVOCs and 167 Gg NMVOCs over the period 1990 to 2024. There is annual variability because the emissions include wildfires.

E.S.3. Overview of emissions estimates and trends by sector

E.S.3.1. Sectoral trends

Energy

Energy sector emissions amount to 375 216 Gg CO₂e in 2024 (Table ES 2). In 2024 Energy emissions account for 78.6% of total emissions (excl. LULUCF) for South Africa (Figure ES 3). The majority of the Energy sector emissions are from *Energy Industries* (61%) and *Transport* (16%), while the *Manufacturing Industries and Construction* emissions contribute (6%). The lowest emissions are from *Solid Fuels* (0.6%) and *Oil and Natural Gas* activities (0.03%).

Since 1990, Energy sector emissions have increased by 19.5%. The highest percentage increase in emissions since 1990 is seen in the *Transport* and the *Manufacturing industries and construction* sub-sectors. This is due to a growing population and to growth in the manufacturing industry resulting in increased energy demand. Fugitive emissions



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from fuels declined by 15% between 1990 and 2024, with substantial reductions in emissions from oil and natural gas systems.

Since 2000, Energy sector emissions decreased by 0.3%. Between 2001 and 2010, emissions became more variable, with sharper increases of up to 5% and occasional declines of between 2% and 5%, indicating sensitivity to economic and operational factors. From 2011 onward, annual changes stabilised, although small fluctuations persisted, typically within the -2% to +2% range. A significant drop of 6% is observed in 2020, likely linked to reduced activity during the COVID-19 pandemic, followed by a strong rebound of 3% in 2021.

Energy emissions increased by 1.4% since 2022. In 2023 emissions decreased by 2.1% but then increased again in 2024. The *Energy Industries* sub-sector emissions decreased by 5% while fugitive emissions from fuels also decreased by 10%.

Table ES 2: Change in sector emissions since 1990, 2000 and since the last inventory submission (2022)

	Emissions (Gg CO ₂ e)				Change 1990 to 2024		Change 2000 to 2024		Change 2022 to 2024	
	1990	2000	2022	2024	Gg CO ₂ e	%	Gg CO ₂ e	%	Gg CO ₂ e	%
Energy	312 936	376 305	370 030	375 216	62 280	19.9	-1 089	-0.3	5 186	1.4
IPPU	21 242	32 783	30 984	30 372	9 130	43.0	-2 411	-7.4	-612	-2.0
Agriculture	58 804	57 317	52 073	52 744	-6 060	-10.3	-4 573	-8.0	672	1.3
LULUCF	-2 458	-12 643	-20 305	-33 412	-30 954	1 259	-20 769	164	-13 107	65
Waste	11 346	14 430	19 107	19 245	7 899	69.6	4 814	33.4	138	0.7

Calculated with AR5 GWP



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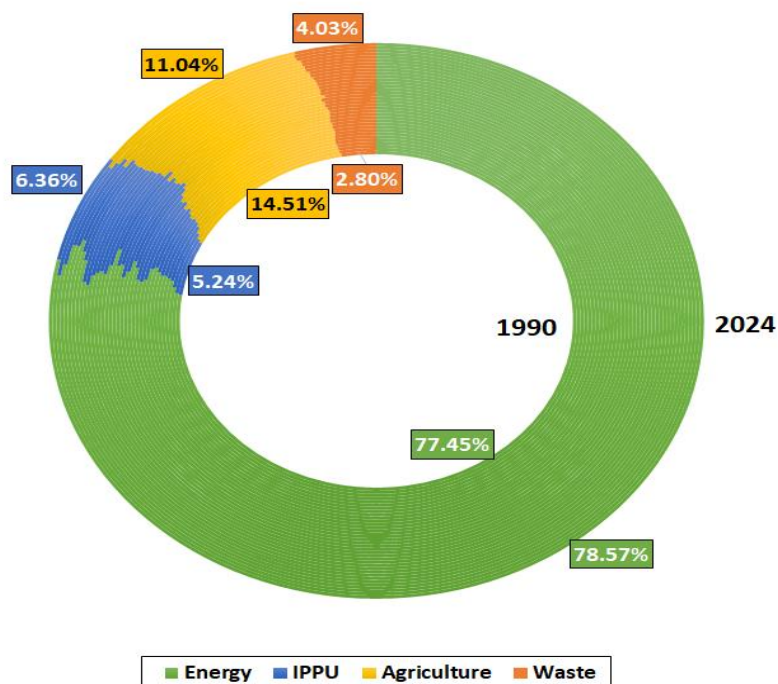


Figure ES 3: Sector contribution to total emissions (excl. LULUCF), 1990-2024

Industrial processes and product use (IPPU)

In 2024 the IPPU sector produced 30 372 Gg CO₂e which is 6.4% of South Africa's emission (excl. LULUCF) (Figure ES 3). The largest source category is the *Ferroalloy production* category which contributes 52.6% to the total IPPU sector emissions. The *Mineral industry* and the *Product used as substitutes for ozone depleting substances* subsectors contribute 16.4% and 22.9%, respectively, to the IPPU sector emissions.

Since 1990, IPPU emissions have increased by 43.0% (Table ES 2). The largest source category is the *Metal industry* category.

Since 2000, IPPU emissions have decreased by 7.4%. The decline can be attributed to the decline in metals production by 39%, specifically Iron and Steel, and Aluminium. This can be ascribed to the deteriorating economy. The chemicals industry also declined by 31.4%.



The IPPU sector emissions decreased by 2% since 2022. According to the NCPC (2023) report, the decline in cement production can be attributed to cheap import, and this has been compounded by the rapid increase in local prices for fuels. The year 2020 was used by some industries for maintenance during the covid period. Other sector such as the chemical and the metal industry showed a slight decline compared to 2022.

Agriculture

Agriculture emissions in 2024 amounted to 52 744 Gg CO₂e (Table ES 2), accounting for approximately 11% of total emissions excluding LULUCF and 12% including LULUCF for South Africa (Figure ES 3). The majority of Agriculture sector emissions originate from *Enteric fermentation* (68%), followed by *Agricultural soils* (18%) and *Manure management* (8%).

Agricultural emissions have remained relatively stable between 1990 and 2024, fluctuating between approximately 55 000 and 60 000 Gg CO₂e, with a modest long-term decline. Total Agriculture sector emissions decreased from 58 804 Gg CO₂e in 1990 to 52 744 Gg CO₂e in 2024, representing an overall decrease of 10.3% (Table ES 2).

LULUCF

LULUCF sector is a sink of 33 412 Gg CO₂e in 2024 (Table ES 2). *Forest lands* are the largest contributors to this sink, while all other land sectors are estimated to be an overall source of emissions. The dominant *Forest land* sinks are thickets and woodlands. *Harvested wood products (HWP)* are a sink in 2024 (1 718 Gg CO₂e).

The LULUCF sector increased its sink by 30 954 Gg CO₂e since 1990. The largest percentage changes are seen in the *Wetland* and *Forest land* categories. *Wetland* category showed a 4-fold increase (503 Gg CO₂e to 2 105 Gg CO₂e) in emissions, while the *Forest land* increased its sink by 39 776 Gg CO₂e between 1990 and 2024. The increasing sink is due to the increasing *Forest land* area. *Croplands* show the least variation and have the lowest overall change (27.2%) over this period.

The LULUCF sector increased its sink by 20 769 Gg CO₂e since 2000. The largest changes are seen in the *Grassland* followed by the *Wetland* category, mainly due to conversions of *Forest Land* to *Grasslands* and *Other Land* to *Wetlands* respectively. The increasing *Forest Land* sink between 2018 and 2024 is attributed to an increasing conversion of *Grasslands*



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to *Forest land*. In terms of emission sources, *Other lands* contribute the most and the emissions increased between 2014 and 2024.

The LULUCF sink grew by 65% between 2022 and 2024, with *Grassland* and *Wetland* categories showing the largest changes, and *Harvested wood products (HWP)* contributing the least.

Waste

Waste sector emissions for 2024 accounted for 4% (excl. LULUCF) and 4.4% (incl. LULUCF) of the national emissions (Figure ES 3). The majority of Waste sector emissions are from *Wastewater treatment and discharge* which is contributing 46.8% to the total Waste sector emissions. This is, followed by *Solid waste disposal* which contributes 38.3%. *Biological treatment of solid waste* and *Incineration and Open Burning of Waste* contributed 13.6% and 0.01% of the total Waste emissions respectively.

Waste sector emissions have increased by 69.6% since 1990 *Solid waste disposal* emissions have increased by 161% since 1990. *Incineration and open burning of waste* emissions increased by 155% since 1990, while emissions from *Wastewater treatment and discharge* increased by 128% throughout the time series.

Waste sector emissions have increased by 44.1% since 2000 (Table ES 2). *Solid waste disposal* emissions have increased by 47.6% since 2000. *Incineration and open burning of waste* emissions increased by 53.1% since 2000, while emissions from *Wastewater treatment and discharge* increased slightly throughout the time series. This is largely driven by increases of 35.6% in *Domestic wastewater treatment and discharge* emissions, whilst there was a 9.4% decline in *Industrial wastewater treatment and discharge* emissions.

E.S.4. Other information

Planned improvements

Table ES 3 summarizes the planned actions to improve various sectors of inventory. Further details on current efforts, barriers, and future goals are provided in Chapter 9.



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Table ES 3: Improvements that are currently in progress and improvements planned or proposed

Sector	Improvement
Tasks in progress	
Energy	Improve uncertainty data for all sectors by incorporating more country specific uncertainty values
	Incorporate NO _x , CO, NMVOC, and SO _x emissions
	Update of the VKT study, including segregation of on-road/off-road
	Comparison of next VKT approach with fuel statistics
Agriculture	Incorporate all background data and equations for the Tier 2 calculations of enteric fermentation
LULUCF	Improve the uncertainty analysis for the Land sector to incorporate more detail.
	Improvement of land change data through detailed assessment of maps and tracking of land parcels
	Improve the biomass burning emissions
	Incorporate organic soils study to include emissions from organic soils
	Move to a higher tier level for DOM in forest lands
Waste	Data collection on quantities of waste disposed of into managed and unmanaged landfills
Tasks outstanding	
Cross cutting	Implement the IPCC Software
Energy	Further disaggregation of 1A2
	Collect more activity data for estimating emissions associated with non-energy fuel use
	Inclusion of methodology documentation/summary/approval process for tier 3 methods
	CO ₂ , CH ₄ and N ₂ O from spontaneous combustion of coal seams
	CH ₄ emissions from abandoned mines
	Investigate pipeline transport
	Investigate ground activities at airports and harbours
	Comparison of next VKT approach with fuel statistics
	Segregation of military energy use.
	Incorporate emissions from biogas
	CO ₂ transport and storage
	CO ₂ , CH ₄ and N ₂ O emissions from combined heat and power (CHP) combustion systems
IPPU	Update the fluorinated gasses with higher accuracy figures from SARS
	Include emissions from electronics industry
	Incorporate emissions SF ₆ emissions



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Agriculture	Improve manure management data, including biogas digesters as a management system
LULUCF	Update SOC reference data
	Initiate data collection on controlled fires
	Perform a more detailed assessment of HWP to include a wider range of products
	Collect data on other disturbances besides fire in forest lands
Waste	Include economic data for different population groups
	Include information on population distribution in rural and urban areas as a function of income
	Include HWP in solid waste
	Obtain data on waste streams and the bucket system
	CH ₄ , N ₂ O emissions from biological treatment of waste
	CO ₂ , CH ₄ and N ₂ O from waste incineration

Key category analysis

A Tier 1 level and trend assessment were conducted, following Approach 1 (IPCC, 2006), on both the emissions including and excluding LULUCF to determine the key categories for South Africa. In the previous inventory there were 53 key categories, while in this inventory there are 43. Table ES 4 shows the top 10 key categories with full details being provided in section 1.4 of this report.

Other sectors – solid fuels, *Forest land converted to grassland*, other sectors – liquid fuels, and Other – solid fuels are new to the top 10 key categories in the 2024 inventory. In the previous inventory, these categories were ranked 16th (Other sectors – solid fuels), 26th (*Land converted to grassland*), 35th (Other sectors – liquid fuels), and 10th (Other – solid fuels), respectively.

Table ES 4: Top 10 key categories for South Africa for 2024 (incl. LULUCF)

Rank	IPCC code	IPCC Category	GHG [#]	Criteria
1	1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	L,T
2	1.A.4	Other Sectors - Solid Fuels	CO ₂	L,T
3	4.A.2.b	Grassland converted to forest land – all pools	CO ₂	L,T
4	4.C.2.a	Forest land converted to Grassland – all pools	CO ₂	L,T
5	1.A.3.b	Road Transportation	CO ₂	L,T
6	4.A.1.a	Forest land remaining forest land – biomass (above and below)	CO ₂	L,T



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7	4.C.2.e	Other land converted to Grassland – all pools	CO ₂	L,T
8	1.A.4	Other Sectors - Liquid Fuels	CO ₂	L,T
9	4.C.1.a	Grassland remaining Grassland – biomass (above and below)	CO ₂	L,T
10	1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	L,T

#C=Confidential

E.S.5. Improvements introduced

Energy

Energy sector emission estimates were improved through the application of country-specific CO₂ emission factors for solid fuels. These factors are based on a study completed in 2022, which developed temporary Tier 2 CO₂ emission factors for solid fuels. In addition, the time series was extended back to 1990, compared to the previous series which covered the period from 2000 onward.

IPPU

The IPPU sector emission estimates were extended from 2000 back to 1990 to complete the timeseries. Tier 2 and Tier 3 estimates were introduced into the SAGERS data from 2022 onwards in the IPPU sector. Calculations with increased accuracy were achieved for *Other Chemicals and Product Use*, specifically ceramics, soda ash and dolomite usage. Verification of some selected production plants identified areas previously not included and increased accuracy.

Agriculture

The Agriculture sector inventory is subject to continuous improvement, resulting in periodic recalculations. Key updates include the inclusion of organic soils for cropland and grassland within the Agriculture sector and the application of 2019 IPCC Refinement emission factors for soil management, which are disaggregated by wet and dry climate conditions. For the agriculture sector, historical data for the early years (1990–1999) have been included, extending the dataset to cover the full period from 1990 to 2024 and ensuring time-series completeness.

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LULUCF

Several improvements were made in the LULUCF sector including the addition of burnt-area data for early years (1990-1999), enhanced historical information for harvested wood products and fuelwood use, updated biomass and carbon stock datasets, refined wetland methodologies, and improved soil carbon estimates through soil-specific land-change matrices. Recent years also incorporated the updated 2020–2022 land-change data, revised land-use change assumptions, and the removal of a previous land conversion error, resulting in more consistent and accurate land-use information.

Waste

A change in the source of the waste composition data to a more country-specific source led to changes in emission estimates in this sector. An additional improvement was the use of the waste composition and the update of the Methane Correction Factor (MCF) that is on the State of the waste report (DFFE, 2019).

E.S.6. Indicator trends

The carbon intensity indicators show that overall South Africa's carbon intensity is decreasing overtime. Carbon intensity of the population, carbon intensity of the economy and the carbon intensity of the energy supply have declined by 29%, 58% and 35% respectively since 1990.

E.S.7. Conclusions

This report incorporates significant improvements, including the completion of the 1990–1999 time series across all sectors. It provides a comprehensive analysis of South Africa's emissions profile from 1990 -2024. The 2024 emissions profile indicates that the Energy sector remains the dominant contributor to national emissions. In 2024, energy-related emissions accounted for 78.6% South Africa's total emissions (excl. LULUCF). This is followed by the Agriculture sector (11.0%), IPPU sector (6.4%), and the Waste sector (4.0%). With the inclusion of LULUCF these contributions increase to 84.5%, 6.8%, 11.9% and 4.3% respectively. The LULUCF sector contributes a sink of 33 412 Gg CO₂e.

An assessment of historical trends from 1990 to 2024 shows that the share of emissions (excl. LULUCF) has declined in the Agriculture sector, while other sectors show an



increase. The long-term trends for total emissions excluding LULUCF demonstrate a pattern of initial growth followed by stabilisation and a gradual decline in more recent years. Emissions including the LULUCF sector, which shows a slow increasing sink, has a similar trend but with slightly reduced emissions.

The Energy sector has consistently been the largest contributor to national GHG emissions, in line with findings from previous inventory submissions. Total emissions from the Energy sector increased steadily from 1990 until approximately 2009, after which emissions fluctuated and then gradually declined towards 2024. Fuel combustion activities remain the dominant source of emissions throughout the time series, accounting for the largest share in all years. Emissions from fuel combustion rose steadily during the 1990s and early 2000s, peaked around 2008-2009, and subsequently stabilised before declining gradually over the following decade.

Emissions from the Agriculture sector remained relatively stable over the period 1990-2024, with a slight overall decline. In 2024, the LULUCF sector continued to function as a net sink of 33 412 Gg CO₂e, with forest land contributing the largest share of removals, while other land-use categories were estimated to be net sources of emissions.

Waste sector emissions have increased by 69.6% since 1990. The total emissions from the Waste sector in 2024 is 19 245 Gg CO₂e. Majority of Waste sector emissions are from *Wastewater treatment and discharge* accounting for 47% of the emissions, followed by *Solid waste disposal* accounting for 38%.



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Chapter 1: National circumstances, institutional arrangements and cross-cutting information

1.1 Background information on GHG inventories and climate change

1.1.1 Background information on climate change

South Africa became a Party to the UNFCCC after signing the Convention in 1993 and ratifying it in 1997. As a Party, South Africa is obligated to address climate change by systematically monitoring, compiling, and reporting trends in anthropogenic greenhouse-gas emissions and removals. These obligations have been strengthened by the Paris Agreement, adopted in 2015 and entered into force in 2016, which requires Parties to prepare, communicate, and maintain successive Nationally Determined Contributions (NDCs). The Paris Agreement further mandates regular updates to these NDCs to reflect increasing ambition over time, as well as participation in the global stocktake process to assess collective progress toward the long-term temperature goal. These international commitments form the foundation for South Africa's national GHG inventory system and guide ongoing improvements in transparency, accuracy, completeness, consistency, and comparability in reporting.

1.1.2 Background information on GHG inventories

The first national GHG inventory for South Africa was prepared in 1998, using 1990 data (Van der Merwe & Scholes, 1998). It was updated to include 1994 data and published in 2004. It was developed using the 1996 IPCC Guidelines for National Greenhouse Gas Inventories. For the 2000 national inventory (DEAT, 2009), a decision was made to use the recently published IPCC 2006 Guidelines (IPCC, 2006) to enhance accuracy and transparency, and to familiarise researchers with the latest inventory preparation guidelines. South Africa has maintained a consistent schedule of compiling and publishing its national greenhouse-gas (GHG) inventories in line with UNFCCC and Paris Agreement transparency requirements. The first comprehensive inventory covering 2000 to 2010 was published in 2014, followed by updates released in 2017 for 2011–2012, in 2019 for

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2013–2015, and in 2021 for the 2016–2017 inventory year. Further updates were published in 2023 for the 2018–2020 inventory and in 2024 for the 2021–2022 series. This regular publication cycle demonstrates South Africa’s ongoing commitment to producing transparent, accurate, and up-to-date national GHG inventory information.

1.2 National circumstances and institutional arrangements

1.2.1 National Entity

In South Africa the DFFE is the central co-ordinating and policy-making authority with respect to environmental conservation. The DFFE is mandated by the Air Quality Act (Act 39 of 2004) (RSA, 2004) to formulate, co-ordinate and monitor national environmental information, policies, programmes and legislation. The work of the DFFE is underpinned by the Constitution of the Republic of South Africa (RSA) and all other relevant legislation and policies applicable to government to address environmental management, including climate change.

In its capacity as a lead climate institution, the DFFE is responsible for co-ordination and management of all climate change-related information, such as mitigation, adaption, monitoring and evaluation programmes, including the compilation and update of National GHG Inventories. The branch responsible for the management and co-ordination of GHG inventories at the DFFE is the Climate Change and Air Quality branch (Figure 1.1), whose purpose is to monitor and ensure compliance on air and atmospheric quality, as well as support, monitor and report international, national, provincial and local responses to climate change.

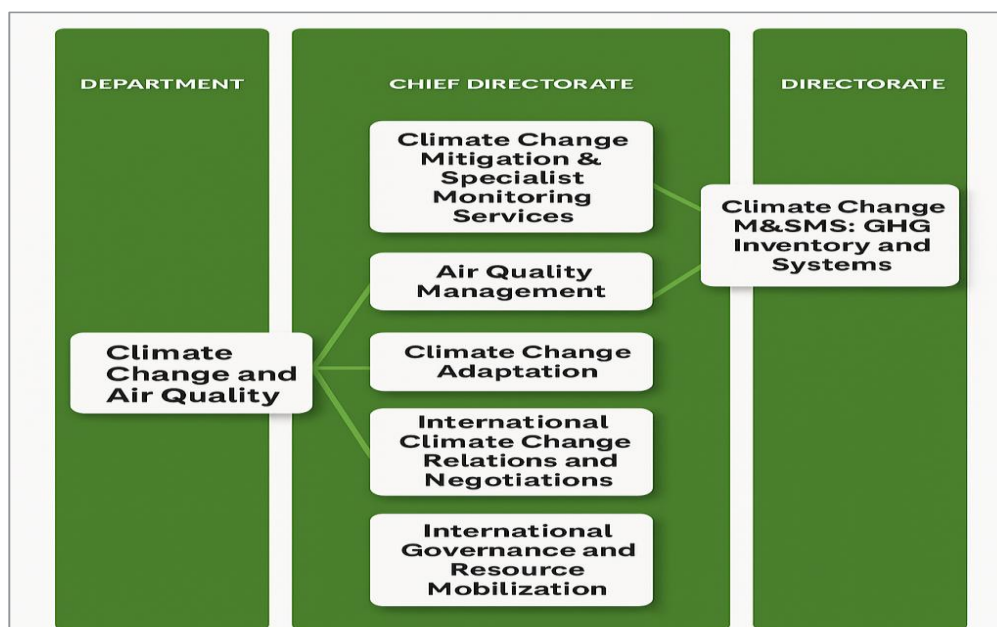


Figure 1.1: Organogram showing where the GHG Inventory compilation occurs within DFFE

DFFE is currently responsible for managing all aspects of the National GHG Inventory development. The Director of the Climate Change Monitoring and Evaluation (M&E): GHG Inventory and Systems directorate is the National Inventory Co-ordinator (NIC) and the tasks of the coordinator include:

- Managing and supporting the National GHG Inventory staff, schedule, and budget to develop the inventory in a timely and efficient manner:
 - Prepare work plans;
 - Establish internal processes;
 - Ensure funding is in place;
 - Appoint consultants where necessary; and
 - Oversee consultants and internal DFFE technical staff handling the report compilation.
- Identifying, assigning, and overseeing national inventory sector leads.
- Assigning cross-cutting roles and responsibilities, including those for QA/QC, archiving, key category analysis (KCA), uncertainty analysis, and compilation of the inventory section of the National Communications (NC) and/or Biennial

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Update Report (BUR)/Biennial Transparency Report (BTR). Managing the QA (external review and public comment) process:

- Appoint external reviewers;
- Liaise between the reviewers and the NID authors;
- Obtain approval from the minister of the DFFE for the NID to go for public comment; and
- Manage the incoming public comments and liaise with NID authors and experts to address any issues
- Maintaining and implementing a national GHG inventory improvement plan:
 - Manage the GHG Improvement programme (including sourcing of funds and appointing service providers for required projects).
- Obtaining official approval (from Cabinet) of the GHG inventory and the NID and submit reports (NID, BUR, NC) to the UNFCCC.

Fostering and establishing links with related national projects, and other regional, international programmes as appropriate.

1.2.2 Inventory preparation process

1.2.2.1 Legal arrangements

Data is sourced from many institutes, associations, companies and ministerial branches. There are no formal agreements between the various government departments for the collection of data for the GHG Inventory. To aid in the collection of data from the energy sector and industries (including forestry plantation industries and certain agricultural industries) the government published the NGER (DEA, 2017a), under Section 53(a), (o) and (p) read with section 12 of the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004), in the Government Gazette of the 3rd April 2017. The purpose of the GHG reporting regulation is to introduce a single national reporting system for the transparent reporting of GHG emissions, which will be used (a) to update and maintain a National GHG Inventory; (b) for the Republic of South Africa to meet its reporting obligations under the UNFCCC and instrument treaties to which it is bound; and (c) to inform the formulation and implementation of legislation and policy.

The NGER were promulgated in fulfilment of the implementation of the regulatory framework to support the collection of the requisite activity and GHG emissions data necessary for the compilation of the National GHG emissions Inventory to improve the quality, sustainability, accuracy, completeness and consistency of the National GHG Inventories. In accordance with regulation 7(1) of the NGER the initial reporting cycle



commenced on 31 March of 2018 requiring data providers to register and submit activity and GHG emissions data to the competent authority, namely DFFE.

The DFFE is in the process of upgrading the former SAGERS through the development of a new reporting platform, the South African Industrial GHG Emission Management System (SAIGE). Once implemented, SAIGE is intended to serve as the national platform for the management and reporting of industrial GHG emissions. The proposed system is envisaged as a comprehensive, web-based platform to support accurate reporting, monitoring, and management of GHG emissions by major emitters in South Africa.

The purpose of SAIGE is to integrate key functionalities, including GHG reporting, Carbon Budgets, and Mitigation Plans. Upon completion, the platform is expected to facilitate the submission, approval, data management, and data analytics of these modules, thereby supporting regulatory compliance by data providers and enabling national strategic decision-making on emission reductions by the DFFE.

The inventory compilation process (Figure 1.2) is co-ordinated through a central web-based inventory management system (National GHG Information Management System (NGHGIS)).

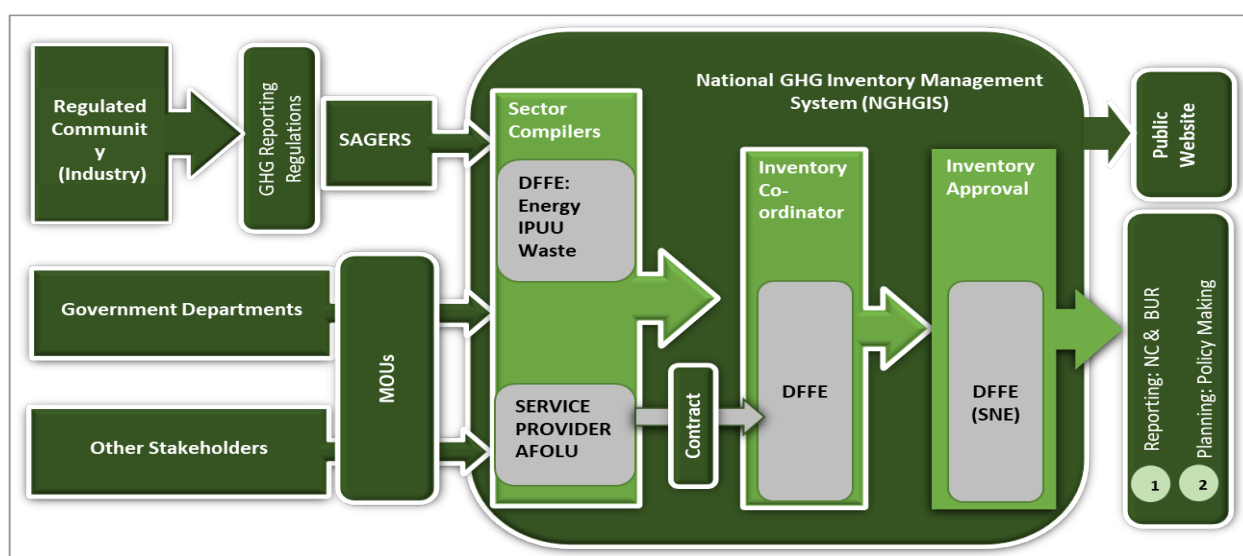


Figure 1.2: The inventory compilation process in South Africa

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1.2.2.2 Inventory management

South Africa uses a hybrid (centralised/distributed) approach to manage the inventory programme. Management and coordination of the inventory programme, as well as compilation, publication and submission of the inventory are carried out by the Single National Entity (being the DFFE) in a centralised manner. Currently DFFE is responsible for collecting data, compiling and QC of the Energy, IPPU, Agriculture and Waste sector inventories, while the LULUCF sector is compiled (in collaboration with DFFE) by external consultants (Gondwana Environmental Solutions (GES)) who are appointed on contract and funded through donor support. DFFE assists with the QC of the LULUCF sector. DFFE were also responsible for combining and compiling the overall inventory and compiling the draft National Inventory Report.

1.2.2.3 Procedural arrangements**1.2.2.3.1 Inventory planning**

A planning meeting was held in January 2024 to engage with the whole team and to plan the timelines for the inventory preparation process, from data collection to finalisation of the NID. Since there were several new team members various training sessions (on inventory preparation, calculation files, QC procedures, time-series consistency, splicing techniques, and uncertainty analysis) were included in the inventory compilation plan. The planning phase also involved the preparation of files and templates for the inventory compilation.

1.2.2.3.2 Inventory preparation

After planning there are five main steps in the preparation of a National GHG Inventory:

- Collect;
- Compile;
- Write;
- Improve; and
- Finalise

The stages and activities undertaken in the inventory update and improvement process are shown in Figure 1.3.

The collection phase is dedicated to data collection and preliminary processing, such as data cleansing, data checks and preliminary formatting for further use. The compilation phase involves the preparation and QC of initial estimates, as well as the uncertainty and

key category analysis. This phase may also include analysis of potential recalculations involved in the inventory.

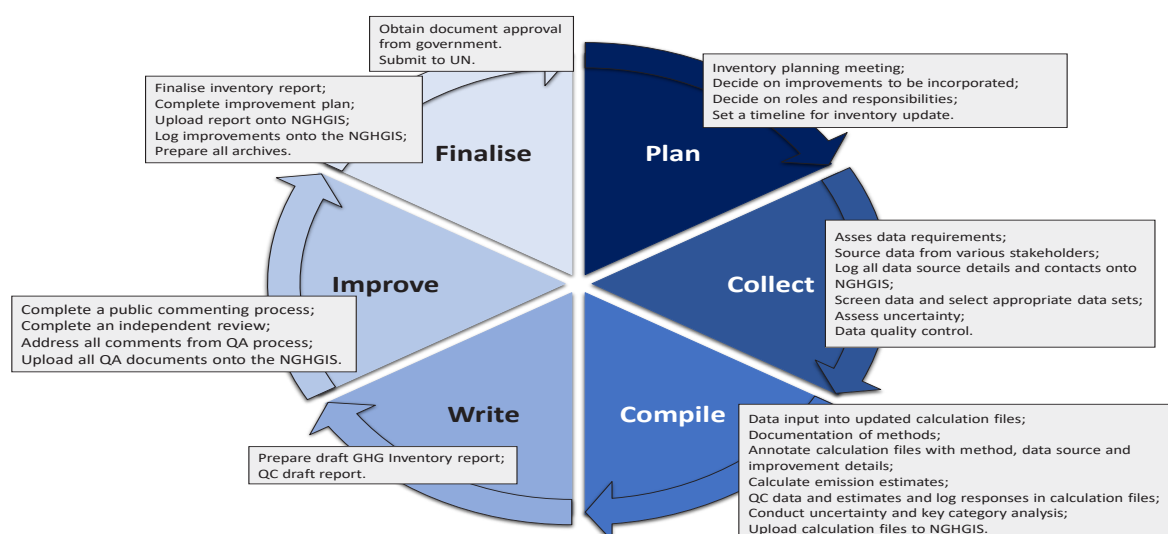


Figure 1.3 : Overview of the phases of the GHG inventory compilation and improvement process undertaken for South Africa's 2024 GHG inventory

The writing phase is where the draft inventory report is prepared, including all crosscutting components (KCA, trends by gas and sector, etc.) and QC of the draft is completed. At the end of this component the draft document is subjected to a QA, or review process. The review is done by independent consultants and/or public commenting process. For the 2024 inventory only the public commenting process was utilised. Comments from the review process are used to improve the Report, after which it is finalized. During the finalization phase the archives are prepared and final Report approvals are obtained before being submitted to UNFCCC.

1.2.2.3.3 Data collection

Data collection and documentation take place under the responsibility of the relevant experts. Three different processes are used to collect data for South Africa's inventory. The first is by obtaining data from South Africa's GHG Reporting Programme, as per the legal arrangements and from government departments, institutes, and organisations

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through an informal process, i.e. where data is obtained without any formal data collection agreements. The third is through the evaluation of publicly available data, official statistics, association statistics, studies, periodicals and third-party research projects. DFFE administers the GHG Reporting Programme, which facilitates the mandatory reporting of GHG emissions by companies in accordance with the NGER. Under this programme, regulated entities submit activity data and emissions information directly through the designated GHG reporting platform, which serves as a primary data source for the national inventory compilation process. The programme strengthens and streamlines data collection, thereby improving the completeness, consistency, accuracy, comparability, and transparency of South Africa's national GHG inventories in line with international reporting principles.

1.2.2.3.4 Data preparation and emission calculation

The process of data preparation and emissions calculation comprises the following steps:

- Data entry;
- Data preparation (model formation, disaggregation, aggregation);
- Calculation of emissions;
- Preparation of report sections (texts); and
- Approval by the relevant experts.

Report texts are prepared along with the time series for activity data, emission factors, uncertainties, and emissions. As a result, the term "data" is understood in a broad sense. In addition to number data, time series, etc., it also includes contextual information such as the sources for time series, and descriptions of calculation methods, and it also refers to preparation of report sections for the NID and documentation of recalculations.

After all checks have been carried out, and the relevant parties have been consulted where necessary, the emissions are calculated in excel by each sector lead based on the following principle:

activity data * emission factor = emission

As much of the data as possible is included in the calculation files, but where larger data sets are referred to these are stored in the NGHGIS.

Following complete preparation of data, report sections and QC/QA checklists by the experts responsible, these materials are transmitted to the Single National Entity where it is



reviewed by category-specific specialists at the Single National Entity. The results of this review are then provided to the sector lead experts to revise and finalise their contribution.

1.2.2.3.5 Report preparation

Report preparation includes the following steps:

- Aggregation of emissions data for the national trend tables and reporting formats, preparation of data tables for the NID;
- Compilation of submitted report texts to form a report draft, and editing of the complete NID;
- Internal review of the draft (national trend tables and NID) by DFFE;
- Public commenting process;
- External review by 3rd party;
- Finalisation of NID report;
- Approval by DFFE Minister;
- Submission to UNFCCC; and
- Archiving.

1.2.3 Data storage and archiving

The NGHGIS for South Africa assists in managing and storing the inventory related documents and processes. The NGHGIS, amongst other things, keeps records of the following:

- Stakeholder list with full contact details and responsibilities;
- List of input datasets which are linked to the stakeholder list;
- QA/QC plan;
- QA/QC checks;
- QA/QC logs which will provide details of all QA/QC activities;
- All method statements;
- IPCC categories and their links to the relevant method statements together with details of the type of method (Tier 1, 2 or 3) and emission factors (default or country-specific) applied;
- Calculation and supporting files;
- Key references;
- Key categories; and
- All inventory reports.

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The procedures for data storage and archiving are described in detail in the QA/QC plan that has been developed and is discussed in section 1.6 below. The NGHGIS is used to archive inventory data.

1.2.4 Processes for official consideration and approval of inventory

The NIDs are endorsed by the Project Steering Committee (PSC), being chaired by the DFFE and comprising of various stakeholder before they are submitted to the Minister of the DFFE for approval. Once the reports are approved by Minister, they are submitted to the UNFCCC by the Chief Directorate for Climate Change International Relations and Reporting and undergo an international review process.

1.3 Brief description of data sources and methodologies

1.3.1 Data sources

1.3.1.1 Energy sector

The primary source of data for the Energy sector is derived from reports submitted by data providers under South Africa's GHG Reporting Programme. These data providers include, but are not limited to, the main electricity provider, Eskom, as well as petroleum companies such as Engen, PetroSA, and Sasol. Additional data are obtained from annual reports submitted by Transnet and other manufacturing industries reporting emissions from fuel combustion activities.

Data from South Africa's GHG Reporting Programme is supplemented by energy balance data compiled by the Department of Electricity and Energy (DEE), formerly the Department of Mineral Resources and Energy (DMRE). At present, there are no formal processes in place for requesting or obtaining data directly from DEE. The data collection process for the Energy sector is illustrated in Figure 1.4, while the corresponding data sources are presented in Table 1.1. For the historical period 1990–1999, aggregated energy balance data were used, and splicing techniques were applied to address gaps in the time series.



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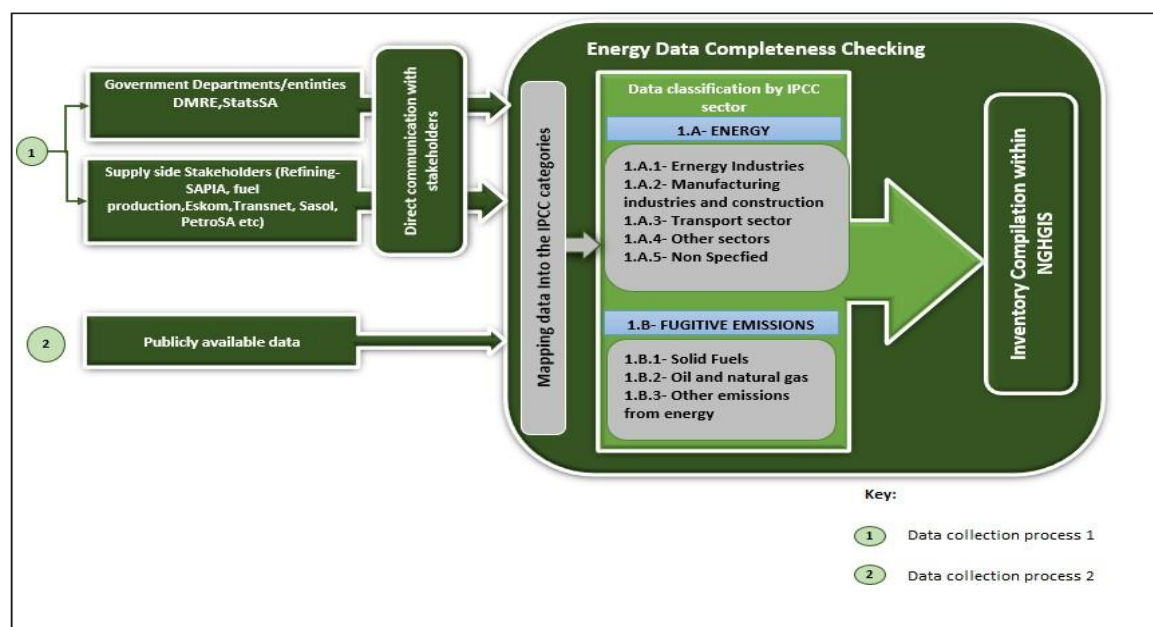


Figure 1.4: Data collection process for the 2024 Energy inventory

Table 1.1: Principal data sources for the Energy sector inventory

Sub-category	Activity data	Activity data sources
Electricity generation	Fuel consumption for public electricity generation	GHG Reporting Programme (Eskom GHG Emissions reports)
	Fuel consumption for auto electricity producers	GHG Reporting Programme (Kelvin Power, Peakers Operations and Ngodwana Energy GHG emissions reports)
	NCVs	GHG Reporting Programme
Petroleum refining	Fuel consumption	GHG Reporting Programme (Refineries)
Manufacture of solid fuels and other energy industries	No activity data, only emission data - based on Mass Balance and measurement	GHG Reporting Programme, Food and Agriculture Organisation (FAO) of UN
Manufacturing industries and construction	Other kerosene, bitumen and natural gas consumption	Energy balance (DEE)
	Gas/Diesel consumption	Energy balance (DEE)
	Residual fuel oil consumption	Energy digest



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Sub-category	Activity data	Activity data sources
	LPG consumption	SAMI report (DEE)
Transport	Vehicle kilometres travelled for road transport	Fuel consumption study
	Domestic aviation gasoline consumption	Fuel consumption study
	Domestic aviation jet kerosene consumption	Fuel consumption study
	Road transport fuel consumption	Fuel consumption study
	Road transportation other kerosene consumption	Energy balance (DEE)
	Railway fuel oil consumption	Energy balance (DEE)
	Railway gas/diesel oil consumption	Energy balance (DEE)
Commercial/ institutional	Water-borne navigation fuel consumption	Energy balance (DEE) / Fuel consumption study
	International aviation Jet Kerosene consumption	Energy balance (DEE) / Fuel consumption study
	Other kerosene, gas/diesel oil, gas works gas and natural gas consumption	Energy balance (DEE)
	Sub-bituminous coal consumption	Energy balance (DEE)
Residential	Residual fuel oil consumption	Energy balance (DEE)
	Coal consumption	Energy balance (DEE)
	LPG consumption	Energy balance (DEE)
	Sub-bituminous coal consumption	Energy balance (DEE)
Agriculture/forestry/fishing/fishfarms	Other fuel consumption	Energy balance (DEE)
	Other kerosene consumption	Energy balance (DEE)
	Gas/diesel oil consumption	Energy balance (DEE)
Stationary non-specified	Other fuel consumption	Energy balance (DEE)
	Fuel consumption	Energy balance (DEE)
Fugitive emissions	Solid fuels	Mineral Council Of South Africa Reports GHG Reporting Programme
	Oil and Natural Gas	GHG Reporting Programme and Energy balance
	Other fugitive emissions	GHG Reporting Programme and Energy balance / Fuel consumption study

1.3.1.2 IPPU sector

Data for the IPPU sector is obtained mostly through South Africa's GHG Reporting Programme (Table 1.2). The HFC and PFC data was supplied by the DFFE Waste and Chemicals branch and supplemented with the 2016 5-year periodic survey conducted by DFFE. There is no formal data collection process in place for this.

Data sources for extending the time-series from 2000 back to 1990 are provided in Table 1.3.

Table 1.2: Principal data sources for the IPPU sector inventory

Sub-category	Activity data	Data source
Cement production	Cement produced	GHG reporting Programme
	Clinker fraction	GHG reporting Programme
Lime production	Mass of lime produced	GHG reporting Programme
Glass production	Glass production	GHG reporting Programme
Other product uses of carbonates (OPUC)	Emissions from OPUC	GHG reporting Programme
Ammonia production	Emissions from ammonia production	GHG reporting Programme
Nitric acid production	Emissions from nitric acid production	GHG reporting Programme
Carbide production	Raw material (petroleum coke) consumption	GHG reporting Programme
Titanium dioxide production	Emissions from titanium dioxide production	GHG reporting Programme
Soda Ash production	Emissions from soda ash production	GHG reporting Programme
Carbon black production	Amount of carbon black produced	GHG reporting Programme
Hydrogen production	Emissions from hydrogen production	GHG reporting Programme
Other chemical processes	Emissions from other chemical processes	GHG reporting Programme
Iron and steel production	Production data	GHG reporting Programme
Ferroalloys production	Production data	GHG reporting Programme
Aluminium production	Production data	GHG reporting Programme
Lead production	Production data	GHG reporting Programme
Zinc Production	Production data	GHG reporting Programme
Lubricant use	Lubricant consumption	Extrapolated
Paraffin wax use	Paraffin wax consumption	Extrapolated



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Sub-category	Activity data	Data source
Refrigeration and air conditioning	Existing, new and retired refrigerators	HFC Survey, Stats SA
	Annual data on stationary air conditioning units	HFC Survey, DEA 2016;BSRIA
	Existing, new and retired refrigeration trucks	HFC study;South African Refrigerated Distribution Association (SARDA)
	Existing. New and retired vehicles	eNaTIS; National Association of Automobile Manufacturers of South Africa (NAAMSA)
Foam blowing agents	Total HFC used in foam manufacturing in a year	HFC Survey (DEA, 2016)
Fire protection	Bank of agent in fire protection equipment in a year	HFC Survey (DEA, 2016)

Table 1.3: Data sources for estimating emissions between 1990 and 1999 in the IPPU sector

Category	Data source description
Mineral Industry	The GDP data (World Bank) was used to estimate the production data for 1994 to 1990.
	The Energy balance data used for 1999 to 1995.
	Statistics South Africa Publications: Manufacturing statistics Indices of the physical volume of manufacturing production Base: 2000=100 January 1990 to November 2002 was used to estimate production data.
Chemical Industry	The year 2000 was used as a baseline, and GDP data (World Bank) was used to estimate the production data for 1999 to 1990.
Metal Industry	The GDP data (World Bank) was used to estimate the production data for 1994 to 1990.
	The Energy balance data used for 1999 to 1995.
	DMRE production statistics was used for subsectors such as ferroalloys for 1999 going backwards.
Non-Energy Products from Fuels and Solvent Use	No improvement in the 1990 to 1999. Emissions estimation was built from the previous inventory.
Product Uses as Substitutes for Ozone Depleting Substances	No emissions data from 1990 to 2007. Emissions data was only estimated from 2008 to 2024 by means of extrapolation.



1.3.1.3 Agriculture sector

Agricultural data are sourced from multiple institutions, as outlined in Table 1.4, as there is no single, formalised data collection system covering all agriculture-related data. Data is obtained from available government reports, statistical databases, and published literature. Cropland data are provided by the Department of Agriculture, Land Reform and Rural Development (DALRRD). Data on fertiliser use and liming are obtained from the South African Revenue Service (SARS), the Department of Mineral Resources and Energy (DMRE), and the Fertilizer Association of South Africa (FertASA). Some crop statistics are sourced from Statistics South Africa (Stats SA).

Livestock data are primarily obtained from DALRRD and the Agricultural Research Council (ARC). ARC data are generated on a project-specific basis and are therefore often once-off. More recently, the SAGERS is collecting limited agricultural data, including manure management data from poultry farms. Although reporting only commenced in 2022, the system is expected to play an increasing role in agricultural data collection going forward. The same data sources were used for the historical dataset covering the early years (1990–1999).

Table 1.4: Principal data sources for the Agriculture sector inventory

Sub-category	Activity data	Data source	Data collection mechanism
Livestock	Livestock population data (Cattle, sheep, Goats and swine)	DALRRD	DFFE is in the process of developing an MOU with DALRRD
	Livestock population data (Horses, mules and asses)	FAO	Statistics available on FAO Stats website (unofficial)
	Poultry data	South African Poultry Association (SAPA)	Information obtained through direct contact. No formal mechanism is in place.
	Livestock and manure management data	ARC, Tshwane University of Technology (TUT) and University of Pretoria	Data is available through scientific publications.
3C Aggregated & non-CO ₂ emissions from land	Limestone and dolomite data	South African Mineral Industry Report compiled by DMRE	No formal mechanism is in place, but data is currently publicly available.
	Burned area data	MODIS burnt area data	No formal process for obtaining this data.
	Planted/harvested areas	FAO	Statistics available on FAO Stats website



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Sub-category	Activity data	Data source	Data collection mechanism
	Crop management data	ARC	DFFE is in the process of developing an MOU with ARC.
	Planted/harvested areas	Statistics SA	Agricultural census data are available from Statistics SA. No formal mechanism is in place.
	Fertilizer data	Fertilizer Association of SA	Annual nitrogen application data for crops
	Urea data	SARS	Provides annual import data for urea
	SOC data	ISRIC	SOC ref data

1.3.1.4 LULUCF sector

Data for the LULUCF sector sub-categories is obtained from various sources as indicated in Table 1.5. DFFE developed a Computer Automated Land Cover (CALC) model which can generate land cover maps based on Sentinel 2 data and these maps can be developed from 2016 onwards, however the first map developed was for 2018 and subsequently for 2020 and 2022. The aim is to generate a map every two years. All South African National Land Cover (SANLC) data (including the CALC data) can be obtained from <https://www.dffe.gov.za/egis>. Other spatial land data, such as the carbon density maps, are obtained from <https://catalogue.saeon.ac.za/>. These products are developed on a project-by-project basis.

There are no formal data collection processes in place for all the other land, such as carbon stock data and fuel wood removals. Data is obtained from available government reports, agricultural association reports, statistical databases and scientific literature. Plantation data is supplied by Forestry SA, and the cropland data is supplied by DALRRD. Burnt area data is obtained from the MODIS burnt area product which is processed by Gondwana Environmental Solutions.

Plantation data is also being reported to DFFE through South Africa's GHG Reporting Programme via the SAGERS system and manual submissions. This data could be utilised in future inventories.



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Table 1.5: Principal data sources for the LULUCF sector inventory

Sub-category	Activity data	Data source	Data collection mechanism
All land types (Forest land, Cropland, Grassland, Wetland, Settlements, Other land)	Land cover and land use change maps	DFFE	Data and land maps are developed by DFFE and are freely available on the EGIS website. SANLC maps to be produced every 2 years. (https://www.dffe.gov.za/egis)
	Soil maps	ISRIC	Available online (https://www.isric.org/)
	Carbon stock data	Scientific literature	Carbon stock data for the various vegetation classes is obtained for literature which is available online. Where data not available information is obtained from the carbon density maps.
	Carbon density maps	SAEON	Carbon density maps were produced through a project name the Terrestrial Carbon Sinks Assessment. This data is available online (https://catalogue.saeon.ac.za/).
	Burnt area data	MODIS	Available online
Forest land	Timber statistics	DFFE	Statistical data is released annually and is freely available. DFFE is in the process of developing an MOU with DALRRD
	Plantation data	Forestry South Africa	Data obtained through direct request, no formal mechanism in place. Data is also freely available on their website.
	Plantation fertilizer data	DFFE GHG Reporting Programme	Plantation data from industry obtained from DFFE Reporting programme
	Household number and wood fuel use	Statistics SA	Available online
	Household fuel consumption data	Scientific literature	Available online
Harvest wood products	Production data	Forestry South Africa	Data obtained through direct request, no formal mechanism in place. Data is also freely available on their website.
	Import/export data	FAOStat	Available online



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1.3.1.5 Waste sector

Waste data is collected from various data reports, statistics and global data sets (Table 1.6). As with the Agriculture and LULUCF sectors there are no formal data collection processes. The main data providers for the Waste sector are Statistics SA, DFFE, Department of Water and Sanitation (DWS) and UN. In time it may be possible to collect some of the Waste data through South Africa's GHG Reporting Programme.

Table 1.6: Principal data sources for the Waste sector inventory

Sub-category	Activity data	Data source
Solid waste disposal	Population data	Statistics SA (2025); UN (2012)
	Waste composition	IPCC 2006 Guidelines
	Waste generation rate for each component	State of Waste Report (2018)
	GDP	World bank
Biological treatment of solid waste	Mass of organic waste by biological treatment type	SAWIC, DFFE (wastewater treatment and biological treatment of solid waste study)
Open burning of waste	Population data	Statistics SA (2025); UN (2012)
	Fraction of population burning waste	Assumption based on population without access to waste collection services.
Wastewater treatment and discharge	Population data	Statistics SA (2025); UN (2012)
	Split of population by income group	Statistics SA (2025)
	BOD generation rates per treatment type	IPCC 2006 Guidelines, DWS
	Per capita nitrogen generation rate	IPCC 2006 Guidelines

1.3.2 Methodologies

The inventory is compiled in accordance with the guidelines provided by the UNFCCC and follows the 2006 IPCC Guidelines for National GHG Inventories (IPCC, 2006) (hereinafter referred to as IPCC 2006 Guidelines), IPCC Good Practice Guidance (GPG) (IPCC, 2000; IPCC, 2003; IPCC, 2014), the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) (hereinafter referred to as IPCC 2019 Refinement) and sections of the 2013 Supplement to the 2006 IPCC Guidelines for



National Greenhouse Gas Inventories: Wetlands (IPCC, 2014a) (hereinafter referred to as IPCC 2013 Wetland Supplement).

The methods used for the individual categories are outlined in the sector overview sections in each of the sector chapters. In addition, detailed descriptions are provided in the relevant category chapters.

A distinction is made between calculations made with country-specific ("CS") methods and calculations made, in the various categories, with IPCC calculation methods of varying degrees of detail ("Tiers"). Similarly for the emission factors. The manner in which a calculation is assigned to the various IPCC methods depends on the pertinent category's share (expressed as equivalent emissions) of total emissions and this determined via the key category analysis (section 1.4).

1.4 Key categories

A key category is one that is prioritised within the national inventory system because its estimate has a significant influence (either as a source or a sink) on a country's total inventory of GHG's in terms of the absolute level, the trend, or the uncertainty in emissions and removals (IPCC, 2006). There are two approaches which can be used to determine the key categories: namely, the level approach and the trend approach. The former is used if only one year of data is available, while the latter can be used if there are two comparable years. The level assessment determines the contribution from the categories to the total national inventory. The trend assessment identifies categories that may not be large enough to be identified by the level assessment, but whose trend is significantly different from the trend of the overall inventory and should therefore receive particular attention. The trend can be an increase or a decrease in emissions. This inventory provides emissions for more than one year; therefore, both the level and trend assessments for key category analysis were performed.

The key categories were assessed using the Approach 1 level (L1) and Approach 1 trend (T1) methodologies from the IPCC 2006 Guidelines (IPCC, 2006). Key categories based on uncertainty have not yet been included due to a lack of country specific data on uncertainties. The level and trend key category analysis identify key categories of emissions and removals as those that sum to 95% of the gross (excl. LULUCF) or net (incl. LULUCF) emissions and those that are within the top 95% of the categories that contribute to the change between 2000 and 2024, or the trend of emissions. This includes both source and sink categories. The level assessment was conducted on the base year



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(1990) and the current year (2024), while the trend assessment utilised the base year 1990 and 2024.

In the previous inventory there were 54 key categories, while in this inventory there are 43 (Table 1.7).

Table 1.7: Key categories for South Africa for 2024 (incl. LULUCF) and their ranking

Rank	IPCC code	IPCC Category	GHG [#]	Criteria
1	1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	L,T
2	1.A.4	Other Sectors - Solid Fuels	CO ₂	L,T
3	4.A.2.b	Grassland converted to forest land – all pools	CO ₂	L,T
4	4.C.2.a	Forest land converted to Grassland – all pools	CO ₂	L,T
5	1.A.3.b	Road Transportation	CO ₂	L,T
6	4.A.1.a	Forest land remaining forest land – biomass (above and below)	CO ₂	L,T
7	4.C.2.e	Other land converted to Grassland – all pools	CO ₂	L,T
8	1.A.4	Other Sectors - Liquid Fuels	CO ₂	L,T
9	4.C.1.a	Grassland remaining Grassland – biomass (above and below)	CO ₂	L,T
10	1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	L,T
11	2.C.2	Ferroalloys Production	CO ₂	L,T
12	2.C.1	Iron and Steel Production	CO ₂	L,T
13	1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO ₂	L,T
14	5.A	Solid Waste Disposal	CH ₄	L,T
15	3.A.1.a.ii	Non-dairy Cattle	CH ₄	L,T
16	3.A.2	Sheep	CH ₄	L,T
17	1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO ₂	L,T
18	4.F.2.c	Grassland converted to other land – all pools	CO ₂	L,T
19	4.B.2.a	Forest land converted to Cropland – all pools	CO ₂	L,T
20	1.A.3.a	Domestic Aviation	CO ₂	L,T
21	1.B.3	Fugitive emissions from - Other emissions from energy production	CO ₂	L,T
22	4.E.1.a	Settlements remaining Settlements – biomass (above and below)	CO ₂	L,T
23	1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO ₂	L,T
24	4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH ₄	T
25	5.D	Wastewater Treatment and Discharge - Domestic	CH ₄	L,T
26	1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO ₂	L,T
27	1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO ₂	T
28	4.F.2.a	Forest land converted to other land – all pools	CO ₂	T
29	2.C.3	Aluminium Production	CO ₂	T
30	5.B	Biological Treatment of Solid Waste	CH ₄	T



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Rank	IPCC code	IPCC Category	GHG [#]	Criteria
31	2.B.2	Nitric Acid Production	N ₂ O	L,T
32	4.C.2.c	Wetland converted to Grassland – all pools	CO ₂	T
33	4.C.2.b	Cropland converted to Grassland – all pools	CO ₂	L,T
34	4.E.2.b	Cropland converted to settlements – all pools	CO ₂	T
35	2.D.2	Non-energy Products from Fuels and Solvent Use - Paraffin wax use	CO ₂	T
36	1.B.2	Oil and Natural Gas	CO ₂	T
37	3.A.4	Goats	CH ₄	L,T
38	4.G	Harvested Wood Products	CO ₂	T
39	3.A.1.a.i	Dairy Cattle	CH ₄	L,T
40	3.B.4	Poultry	N ₂ O	T
41	3.G	Liming	CO ₂	L,T
42	3.H	Urea Application	CO ₂	T
43	1.A.4	Other Sectors - Gaseous Fuels	CO ₂	T

[#]L=Level assessment; T=Trend assessment; C=Confidential

In the 2024 inventory, fuel combustion – energy industries – solid fuels, other sectors – solid fuels, *Grassland converted to forest land*, *Forest land converted to grassland*, and *Road transportation* have emerged among the top 10 key categories. In the previous 2022 inventory, these categories were ranked 4th (Energy industries – solid fuels), 16th (Other sectors – solid fuels), 1st (*Grassland converted to forest land*), 26th (*Forest land converted to grassland*), and 2nd (*Road transportation*), respectively.

Conversely, certain categories previously ranked within the top 10 in 2022 have declined in relative contribution and are no longer classified among the leading contributors. Specifically, *Forest land remaining forest land – biomass*, *Direct N₂O emissions from managed soils*, other – solid fuels, and ferroalloys production, which were ranked 3rd, 5th, 8th, and 9th in 2022, respectively, have exited the top 10 in 2024.

Annex I contains the full key category analysis results for the level assessments (1990 and 2024) and trend assessment, including and excluding LULUCF.



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1.5 General description quality assurance, quality control and verification plans and implementation

1.5.1 Guiding principles

This report is guided by the inventory quality principles as defined in IPCC 2006 Guidelines (IPCC, 2006) (Table 1.8).

Table 1.8: Guiding principles applied during the preparation of the 2024 inventory

Principle	Application of principle
Transparency	Sufficient and clear documentation is provided such that individuals or groups other than the inventory compilers can understand how the inventory was compiled and can assure themselves it meets the good practice requirements for national GHG emissions inventories.
Completeness	Estimates are reported for all relevant categories of sources and sinks, and gases. The entire geographic area of South Africa is included. Where elements are missing their absence is clearly documented together with a justification for exclusion.
Consistency	Estimates for different inventory years, gases and categories are made in such a way that differences in the results between years and categories reflect real differences in emissions. Inventory annual trends, as far as possible, are calculated using the same method and data sources in all years and aim to reflect the real annual fluctuations in emissions or removals and not be subject to changes resulting from methodological differences.
Comparability	The national GHG inventory is reported in a way that allows it to be compared with national GHG inventories for other countries. This comparability is reflected in the appropriate choice of key categories and in the use of the reporting guidance and tables and use of the classification and definition of categories of emissions and removals.
Accuracy	The national GHG inventory contains neither over- nor under-estimates so far as can be judged. All endeavours were made to remove bias from the inventory estimates.



1.5.2 QA/QC plan and procedures

As part of the NGHGIS, South Africa developed a formal quality assurance/quality control plan (Annex IV). This provides a list of QC procedures that are to be undertaken during the preparation of the inventory. In this inventory the relatively new team was provided with QA/QC training, and each team member was assigned to a sector. Each quality controller went through the sector calculation files and provided comments. A programme, QA Analyst, assisted with the process of tracking the comments by keeping a log in the front of each file.

1.5.3 General QC procedures

The QC procedures are performed by the experts during inventory calculation and compilation. QC measures are aimed at the attainment of the quality objectives. The QC procedures comply with the IPCC good practice guidance and the IPCC 2006 Guidelines. General inventory QC checks include routine checks of the integrity, correctness and completeness of data, identification of errors and deficiencies and documentation and archiving of inventory data and quality control actions.

In addition to general QC checks, category-specific QC checks including technical reviews of the source categories, activity data, emission factors and methods are applied on a case-by-case basis focusing on key categories and on categories where significant methodological and data revisions have taken place.

The general quality checks are used routinely throughout the inventory compilation process. Although general QC procedures are designed to be implemented for all categories and on a routine basis, it is not always necessary or possible to check all aspects of inventory input data, parameters, and calculations every year. Checks are then performed on selected sets of data and processes. A representative sample of data and calculations from every category may be subjected to general QC procedures each year.

The general QC checks carried out on South Africa's 2024 inventory are provided in Table 1.9.



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Table 1.9: Quality control checks carried out on South Africa's 2024 GHG inventory

ID	Type of check	Description	Level
QC001	Activity data source	Is the appropriate data source being used for activity data?	Calculation file
QC002	Correct units	Check that the correct units are being used	Calculation file
QC003	Unit carry through	Are all units correctly carried through calculations to the summary table? This includes activity data and emission factors.	Calculation file
QC004	Method validity	Are the methods used valid and appropriate?	Calculation file
QC005	Uncertainties	Carry out uncertainties analysis	Supporting file
QC006	Double counting – Categories	Check to ensure no double counting is present at category level	Calculation file
QC007	Notation keys	Review the use of notation keys and the associated assumption to ensure they are correct.	Calculation file
QC008	Trend check	Carry out checks on the trend to identify possible errors. Document any stand out data points.	Calculation file
QC009	Emission factor applicability	Where default emission factors are used, are they correct? Is source information provided?	Calculation file
QC010	Emission factor applicability	Where country specific emission factors are used, are they correct? Is source information provided?	Calculation file
QC011	Recalculations	Check values against previous submission. Explain any changes in data due to recalculations.	Calculation file
QC012	Sub-category completeness	Is the reporting of each sub-category complete? If not this should be highlighted.	Calculation file
QC013	Time series consistency	Are activity data and emission factor time series consistent?	Calculation file
QC014	Colour coding	Has colour coding been used in a consistent and accurate manner? Are there any significant data gaps or weaknesses?	Calculation file
QC015	Cross check data	Where possible cross check data against alternative data sources. This includes activity data and EF. If CS EF are used they must be compared to IPCC values as well as any other available data sets.	Supporting file
QC016	Spot checks	Complete random spot checks on a data set.	Calculation file
QC017	Transcription checks	Complete checks to ensure data has been transcribed from models to spreadsheet correctly.	Calculation file
QC018	Transcription to document	Complete checks to ensure data has been transcribed from spreadsheets to documents correctly.	Sector report
QC019	Data source referencing	All source data submitted must be referenced	Calculation file



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ID	Type of check	Description	Level
QC020	Data traceability	Can data be traced back to its original source?	Calculation file
QC021	Links to source data	Where possible, links to the source data must be provided	Calculation file
QC022	Raw primary data	All raw primary data must be present in the workbook	Calculation file
QC023	QA review	Data must be reviewed and checked by a second person	Calculation file
QC024	Verification	Where possible have calculated emissions been checked against other data sets?	Sector report
QC025	Archiving	Are all supporting files and references supplied?	Archive manager
QC026	Data calculations	Can a representative sample of the emission calculations be reproduced?	Calculation file
QC027	Unit conversions	Have the correct conversion factors been used?	Calculation file
QC028	Common factor consistency	Is there consistency in common factor use between sub-categories (such as GWP, Carbon content, Calorific values)?	Calculation file
QC029	Data aggregation	Has the data been correctly aggregated within a sector?	Calculation file
QC030	Trend documentation	Have significant trend changes been adequately explained?	Sector report
QC031	Consistency between sectors	Identify parameters that are common across sectors and check for consistency.	Draft NID
QC032	Data aggregation	Has the data been correctly aggregated across the sectors?	Draft NID
QC033	Documentation - CRF tables	Check CRF tables are included.	Draft NID
QC034	Documentation - KCA	Check that key category analyses have been included.	Draft NID
QC035	Documentation - Uncertainty	Check uncertainty analysis have been included.	Draft NID
QC036	Documentation - Overall trends	Check overall trends are described both by sector and gas species.	Draft NID
QC037	Documentation - NID sections complete	Check all relevant sections are included in the NID.	Draft NID
QC038	Documentation - Improvement plan	Check that the improvement plan has been included.	Draft NID
QC039	Documentation - Completeness	Check for completeness	Draft NID
QC040	Documentation - Tables and figures	Check numbers in tables match spreadsheet; check for consistent table formatting; check the table and figure numbers are correct.	Draft NID



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ID	Type of check	Description	Level
QC041	Documentation - References	Check consistency of references.	Draft NID
QC042	Documentation - General format	Check general NID format - acronyms, spelling, all notes removed; size, style and indenting of bullets are consistent.	Draft NID
QC043	Documentation - Updated	Check that each section is updated with current year information.	Draft NID
QC044	Double counting - Sectors	Check there is no double counting between the sectors.	Draft NID
QC045	National coverage	Check that activity data is representative of the national territory.	Calculation file
QC046	Review comments implemented	Check that review comments have been implemented.	Calculation file
QC047	Methodology documentation	Are the methods described in sufficient detail?	Sector report
QC048	Recalculation documentation	Are changes due to recalculations explained?	Sector report
QC049	Trend documentation	Are any significant changes in the trend explained?	Sector report
QC050	Documentation - QA/QC	Check the QA/QC procedure is adequately described.	Draft NID
QC051	Complete uncertainty check	Check that the uncertainty analysis is complete.	Draft NID
QC052	Consistency in methodology	Check that there is consistency in the methodology across the time series	Calculation file
QC053	Data gaps	Is there sufficient documentation of data gaps?	Sector report
QC054	Steering committee review	Has the draft NID been approved by the steering committee? Was there public consultation?	Draft NID
QC055	Check calorific values	Have the correct net calorific values been used? Are they consistent between sectors? Are they documented?	Calculation file
QC056	Check carbon content	Have the correct carbon content values been used? Are they consistent between sectors? Are they documented?	Calculation file
QC057	Supplied emission check	If emissions are supplied by industry have they been calculated using international standards? Have the methods been adequately described?	Sector report
QC058	Livestock population checks	Have the livestock population data been checked against the FAO database?	Calculation file
QC059	Land area consistency	Do the land areas for the land classes add up to the total land area for South Africa?	Calculation file



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ID	Type of check	Description	Level
QC060	Biomass data checks	Have the biomass factors been compared to IPCC default values or the EFDB?	Calculation file
QC061	Fertilizer data checks	Has the fertilizer consumption data been compared to the FAO database?	Calculation file
QC062	Wastewater flow checks	Do the wastewater flows to the various treatments add up to 100?	Calculation file
QC063	Reference approach	Has the reference approach been completed for the Energy sector? Have the values been compared to the sector approach? Has sufficient explanation of differences been given?	Calculation file
QC064	Coal production checks	Has the industry-specific coal production been checked against the coal production statistics from Department of Mineral Resources?	Calculation file

1.5.4 Workshops

Several workshops and training sessions between the team and the wider group at the DFFE were held during the preparation of this inventory. An initial planning meeting started the process off, followed by several team meetings to share data and queries. This has been useful even with the previous inventories. Everyone had a chance to understand other sectors, and it also improved the cross linkages. This should continue in future inventories.

1.5.5 Review process

General public review (Figure 1.5). The expert and public reviews each present opportunity to uncover technical issues related to the application of methodologies, selection of activity data, or the development and choice of emission factors. The expert and public reviews of the draft document offer a broader range of researchers and practitioners in government, industry and academia, as well as the general public, the opportunity to contribute to the final document. The comments received during these processes are reviewed and, as appropriate, incorporated into the NID or reflected in the inventory estimates.



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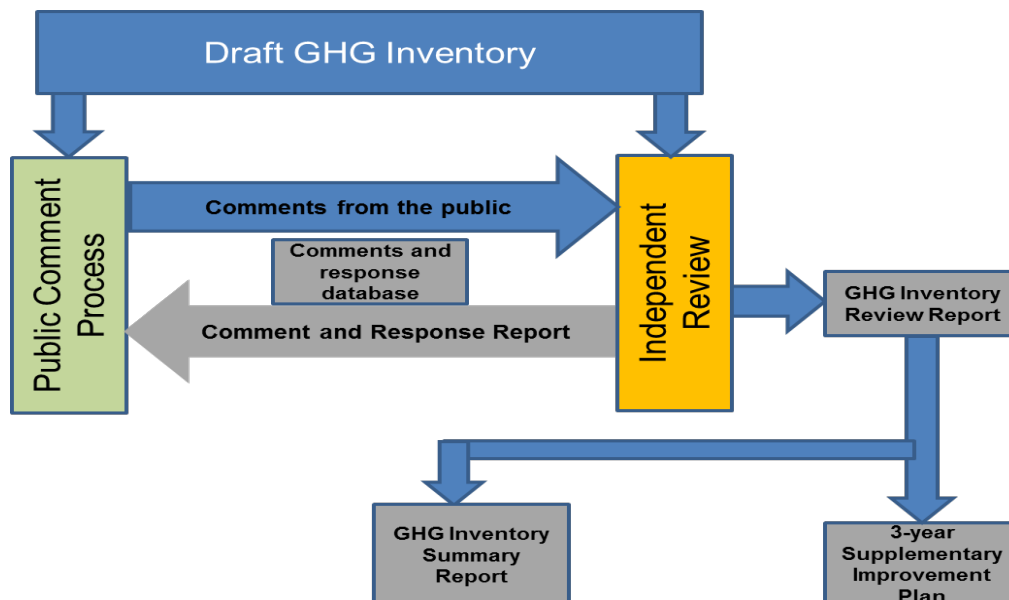


Figure 1.5: The quality assurance review process for the 1990-2024 inventory

1.5.6 Verification activities

Emission and activity data are verified by comparing them with other available data compiled independently of the GHG inventory system where available. These include national and international statistics, measurement and research projects and programmes initiated to support the inventory system, or for other purposes, but producing information relevant to the inventory preparation. The specific verification activities are described in detail in the relevant category chapters.

1.6 General uncertainty assessment

1.6.1 Procedures for uncertainty determination

Uncertainty is inherent within any kind of estimation and arises from the limitations of the measuring instruments, sampling processes and model complexities and assumptions. Managing these uncertainties, and reducing them over time, is recognised



by IPCC 2006 Guidelines as an important element of inventory preparation and development. Chapter 3 of the IPCC 2006 Guidelines (IPCC, 2006) describes the methodology for estimating and reporting uncertainties associated with annual estimates of emissions and removals. There are two methods for determining uncertainty:

- Tier 1 methodology which combines the uncertainties in activity rates and emission factors for each source category and GHG in a simple way; and
- Tier 2 methodology which is generally the same as Tier 1; however, it is taken a step further by considering the distribution function for each uncertainty and then carries out an aggregation using the Monte Carlo simulation.

South Africa still lacks data in terms of country specific uncertainty for all sectors. Based on this the uncertainty in this inventory was determined using the simple propagation of error (Approach 1) method. A trend uncertainty between the base year (1990) and 2024 was determined, as well as a combined uncertainty of activity data and emission factor uncertainty. As more uncertainty data becomes available it will be incorporated but there is a general need to build capacity and develop projects to assess the uncertainty in each sector.

1.6.2 Uncertainty assessment results

Emission estimate uncertainties typically are low for CO₂ from energy consumption as well as from some industrial process emissions. Uncertainty surrounding estimates of emissions are higher for LULUCF and synthetic gases. Uncertainty ranges for the various sectors (Annex II) are largely consistent with typical uncertainty ranges expected for each sector (IPCC, 2014).

The total uncertainty for the inventory including LULUCF was determined to be between 14.1% and 14.51%, with a trend uncertainty of 16%¹. This is an increase on the uncertainty in the last inventory (8.8%), however there were a few new categories in this inventory and a more detailed uncertainty assessment for *Forest lands* have been included. This led to an increase in uncertainty on the activity data, but a reduction in the emission factor uncertainty. Excluding LULUCF reduces the overall uncertainty to 5.7%-6.4%, which is a reduction of the uncertainty from the last inventory.

The Energy sector uncertainty was reduced slightly (by 5% on the upper limit) compared to the previous inventory. The IPPU trend uncertainty increased by 32% compared to the

¹ The full uncertainty assessment is provided in Annex II.



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last inventory. The IPPU sector did introduce some new categories in 2022 and 2024 and update some of the uncertainty estimates to be based on country specific data rather than defaults so these changes could contribute to the uncertainty change. The Agriculture sector uncertainty reduced for both the overall uncertainty and trend uncertainty. The uncertainty data did not really change but the emission estimates did, and there was also reallocation of some categories between Agriculture and LULUCF to align with the ETF CRT reporting. LULUCF uncertainty increased by about 30% compared to the previous inventory uncertainty analysis. Part of this change was due to the introduction of new land change maps, however additional changes were made due to a more in-depth analysis of the uncertainty data rather than it being an actual change in uncertainty. The uncertainty data is one aspect of the inventory, which is being improved, so it is likely there will be further changes in the next inventory. Waste sector uncertainty was reduced, but this is likely due to the reduction in the emissions in this sector due to improvements.

1.7 General assessment of completeness

1.7.1 Information on completeness

Table 1.10 provides information on the completeness of the inventory. It shows which activities are not estimated (NE), included elsewhere (IE) or that is not occurring (NO) within the South African jurisdiction.

Table 1.10: Activities in the 2024 inventory which are not estimated (NE), included elsewhere (IE) or not occurring (NO)

NE, IE or NO	IPCC Category	Activity	Comments
NE	1B1b	CO ₂ , CH ₄ and N ₂ O from spontaneous combustion of coal seams	Research to be initiated in future, depended on availability of funding to initiate a study.
	1B1ai2	CH ₄ emissions from abandoned mines	Research to be initiated in future, depended on availability of funding to initiate a study.
	1C1	CO ₂ transport	Insufficient data to include
	2D2	CH ₄ and N ₂ O emissions from paraffin wax use	Insufficient data to include,
	2E	Electronics industry	Insufficient data to include, an assessment to assess the significance of this source in South Africa.



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NE, IE or NO	IPCC Category	Activity	Comments
	2F5	PFCs and HFCs from solvents	Insufficient data to include
	2G1	PFCs from electrical equipment	Insufficient data to include
	2G2	PFCs from other product uses	Insufficient data to include
	2G3	N ₂ O from product uses	Insufficient data to include
	3C7	CH ₄ emissions from Rice cultivation	CH ₄ emissions from Rice cultivation is assessed to be Insignificant.
	3I	Other carbon containing fertilisers	Research needs to be done to investigate the availability of this category in South Africa.
	4(I)C & 4(I)D	Direct and indirect N ₂ O emissions from N inputs to managed soils	Not included due to insufficient data.
	4(II)A & 4(II)E	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	Not included due to insufficient data. Organic soils are also only partially included for Croplands and Grasslands.
	4D1a, 4D2a	Emissions from peat extraction	Some data has been identified but time series is not complete and there was insufficient time to verify and include the data. This will be incorporated as part of the proposed land mapping system.
	Energy, IPPU, Waste	NO _x , CO, NMVOC emissions	These have only been included for biomass burning in the Agriculture and LULUCF sectors due to a lack of data in other sectors
IE	Energy, IPPU, Waste	SO ₂ emissions	Insufficient data.
	1A1aii	CO ₂ , CH ₄ and N ₂ O emissions from Combined Heat and Power (CHP) combustion systems	Not separated out but is included within 1A1ai
	1A3eii	CO ₂ , CH ₄ and N ₂ O emissions from off-road vehicles and other machinery	Included under Road transportation.
	1A5b	Non-specified mobile	Included under Non-specified Mobile (1A3b)
	3E	Prescribed burning of savannas	Emissions are included under LULUCF Forest land (4A) as prescribed burning could not be separated from wildfires.
NO	4A, 4D-4F	Organic soils	Included under mineral soils as insufficient data to separate.
	2B3	CO ₂ , CH ₄ and N ₂ O emissions from Adipic acid production	
	1C2	Injection and storage	
	2B4	CO ₂ , CH ₄ and N ₂ O Caprolactam, Glyoxal and Glyoxylic acid production	
	3J	Other	



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1.7.2 Description of insignificant categories

Rice cultivation is not included in this Inventory. Rice is not grown in South Africa as it is not considered one of the country's primary crops. In the current inventory, consultations with experts at the ARC continue to indicate that rice cultivation in South Africa is limited to small experimental plots, with the exact cultivated area remaining uncertain but estimated to be less than 50 ha. In the previous inventory, proxy data from an international source (FAOSTAT) was used to assess the negligible impact of rice cultivation. According to FAO data, South Africa had 1 067 hectares of rice cultivation in 2022.

IPCC 2006 Guidelines (Vol. 4, Chapter 5) Equation 5.1 was used to estimate the annual methane emissions from rice cultivation. All other factors affecting CH₄ emissions from rice cultivation were not considered because there is insufficient data on various ecosystems, water management practices, types and quantities of organic amendments, and other conditions related to CH₄ emissions for rice cultivation. Therefore, the equation was adjusted, and the below equation was used:

$$\text{CH}_4 \text{ Rice} = \text{EF} * \text{time} * \text{Area} * 10^{-6}$$

Where:

CH₄ Rice = Annual methane emissions from rice cultivation, (Gg CH₄ yr⁻¹)

EF = A daily emission factor, (kg CH₄ ha⁻¹ day⁻¹)

time = cultivation period of rice

Area = Annual harvested area of rice, ha yr⁻¹

The IPCC default emission factor of 1.3 kg CH₄ ha⁻¹ d⁻¹ was used. The IPCC default of 180 days cultivation period of rice was used.

1.7.3 Total aggregated emissions considered insignificant

The annual methane emissions from rice cultivation were estimated to be 6.99 Gg CO₂e, and this is 0.001% of the national total GHG emissions (excl. LULUCF). Therefore, rice cultivation is considered insignificant since the level of emissions is below the threshold of 0.05% of the national total GHG emissions (excl. LULUCF), as prescribed by the IPCC 2006 Guidelines.



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1.8 Metrics

As GHG's vary in their radiative activity, and in their atmospheric residence time, converting emissions into carbon dioxide equivalents (CO₂e) allows the integrated effect of emissions of the various gases to be compared. To comply with international reporting obligations under the UNFCCC, emissions are presented as CO₂e using the 100- year global warming potentials (GWPs) from the 2014 IPCC Fifth Assessment Report (AR5) in accordance with the Modalities, Procedures, and Guidelines (MPGs) for transparency framework for action and support referred to in Article 13 of the Paris Agreement (Table 1.11).

Table 1.11: AR5 Global warming potentials (GWP) applied in this report (IPCC, 2014b)

GHG	Chemical formula	AR5 GWP
Carbon dioxide	CO ₂	1
Methane	CH ₄	28
Nitrous oxide	N ₂ O	265
Hydrofluorocarbons (HFCs)		
HFC-23	CHF ₃	12 400
HFC-32	CH ₂ F ₂	677
HFC-125	CHF ₂ CF ₃	3170
HFC-134a	CH ₂ FCF ₃	1300
HFC-143a	CF ₃ CH ₃	4 800
HFC-227ea	C ₃ HF ₇	3350
HFC-365mfc	C ₄ H ₅ F ₅	804
HFC-152a	CH ₃ CHF ₂	138
Perfluorocarbons (PFCs)		
PFC-14	CF ₄	6 630
PF-116	C ₂ F ₆	11 100

1.9 Summary of flexibilities applied

South Africa's 2024 NID includes one flexibility provision related to completeness for insignificant emissions. The rationale to applying this flexibility is as follows:

Completeness Provisions for Insignificant Emissions:



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Flexibility Provision: Emissions sources contributing less than 0.1% of total national GHG emissions (excl. LULUCF) or less than 1,000 kilotons (kt) of CO₂-equivalent may be considered insignificant. South Africa commits to assessing categories that are not estimated in the current NID for significance by 2028.

Covered Sectors and Specific Emissions Categories (Table 1.12):

- IPPU: Subcategories involving N₂O, HFCs, PFCs, and SF₆, specifically in the electronics industry, solvents, and other product uses.
- Agriculture: Emissions from other carbon containing fertilisers (CO₂).
- Waste: Emissions from waste incineration (CH₄).

Improvement Timeline: The significance of these emissions categories will be evaluated and updated by the third Biennial Transparency Report (BTR 3), due December 2028.

Table 1.12: Summary of Flexibility Provision Applied by Sector

Year	Sector	Category	Gas	Explanation for using flexibility provision	Timeframe for improvement
2024	IPPU	2.E Electronics Industry	N ₂ O HFCs PFCs SF ₆	Completeness (32) Flexibility to consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO ₂ eq, whichever is lower. South Africa will assess the significance of this source and report if significant.	BTR 3 (December 2028)
		2.F.5. Solvents	HFCs PFCs SF ₆	Completeness (32) Flexibility to consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO ₂ eq, whichever is lower. South Africa will assess the significance of this source and report if significant.	BTR 3 (December 2028)
		2.G.1 Electrical equipment	HFCs PFCs SF ₆	Completeness (32) Flexibility to consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO ₂ eq, whichever is lower. South Africa will assess the significance of this source and report if significant.	BTR 3 (December 2028)



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Year	Sector	Category	Gas	Explanation for using flexibility provision	Timeframe for improvement
		2.G.2. SF ₆ and PFCs from other product use	PFCs SF ₆	Completeness (32) Flexibility to consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO ₂ eq, whichever is lower. South Africa will assess the significance of this source and report if significant.	BTR 3 (December 2028)
		2.G.3. N ₂ O from product uses	N ₂ O	Completeness (32) Flexibility to consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO ₂ eq, whichever is lower. South Africa will assess the significance of this source and report if significant.	BTR 3 (December 2028)
2024	Agriculture	3.I. Other carbon-containing fertilizers	CO ₂	Completeness (32) Flexibility to consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO ₂ eq, whichever is lower. South Africa will assess the significance of this source and report if significant.	BTR 3 (December 2028)
2024	Waste	5.C.1 Waste Incineration	CH ₄	Completeness (32) Flexibility to consider emissions insignificant if the likely level of emissions is below 0.1 per cent of the national total GHG emissions, excluding LULUCF, or 1,000 kt CO ₂ eq, whichever is lower. South Africa will assess the significance of this source and report if significant.	BTR 3 (December 2028)



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1.10 Chapter 1 References

IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). ed. Japan: IGES.



Chapter 2: Trends in GHG emissions and removals

2.1 Description of trends for aggregated GHG emissions and removals

This chapter provides a description and interpretation of the national aggregated emission trends and a discussion of trends by gas and sector.

2.1.1 National trends

2.1.1.1 Overall emissions (excl. LULUCF)

The overall emissions (excl. LULUCF) include those from Energy, IPPU, Agriculture and Waste. It does not include the sources and removals from land use change and *Harvested wood products*, which together form the LULUCF sector.

2.1.1.1.1 2024

The national emissions (excl. LULUCF) are 477 576 Gg CO_{2e} in 2024. The profile shows that the Energy sector remains the dominant contributor to national emissions in 2024 (78.7%). This is followed by the Agriculture sector (11.0%), IPPU (6.4%), and the Waste sector (4.0%) contributions.

2.1.1.1.2 1990 – 2024

National emissions have evolved significantly over this period, reflecting changes in the structure of the economy, energy production patterns, industrial activity. South Africa's GHG emissions (excl. LULUCF) increased by 17.8% between 1990 and 2024.

The long-term trends for total emissions excluding LULUCF demonstrate a pattern of initial growth followed by stabilisation and a gradual decline in more recent years. Emissions show an increasing trend between 1990 and 2004, with only 2 years in this period showing a small annual decline (Table 2.1). There is then a plateau period between about 2005 and 2012 where the average annual increase is only 0.36%. After 2012 there



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is a decline in emissions, with most years (except 2018, 2021 and 2024) showing an annual decline in emissions.

2.1.1.1.3 2000- 2024

There has been a reduction of only 0.8% in national emissions (excl. LULUCF) between 2000 and 2024. This is because in 2000 emissions were increasing while by 2024 emissions were on the decline as the national energy and industrial systems evolved.

2.1.1.1.4 2022 - 2024

There has been a modest increase in emissions of 1.1% between 2022 and 2024 which is consistent with post-pandemic economic recovery and fluctuations in electricity generation patterns.

Table 2.1: Trends and annual change in emissions, 1990-2024

	Emissions (excl. LULUCF)		Emissions (incl. LULUCF)	
	Gg CO ₂ e	Annual change (%)	Gg CO ₂ e	Annual change (%)
1990	405 260		402 802	
1991	413 144	1.95	409 258	1.60
1992	417 336	1.01	414 292	1.23
1993	424 530	1.72	422 713	2.03
1994	426 798	0.53	426 008	0.78
1995	435 635	2.07	434 393	1.97
1996	451 338	3.60	443 586	2.12
1997	464 566	2.93	456 891	3.00
1998	475 143	2.28	469 056	2.66
1999	466 301	-1.86	458 201	-2.31
2000	481 534	3.27	468 891	2.33
2001	479 530	-0.42	473 159	0.91
2002	489 338	2.05	480 646	1.58
2003	504 898	3.18	481 361	0.15
2004	516 456	2.29	506 317	5.18
2005	514 670	-0.35	517 311	2.17
2006	506 969	-1.50	508 337	-1.73
2007	528 898	4.33	518 580	2.02
2008	524 762	-0.78	527 917	1.80
2009	537 875	2.50	521 845	-1.15



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	Emissions (excl. LULUCF)		Emissions (incl. LULUCF)	
	Gg CO ₂ e	Annual change (%)	Gg CO ₂ e	Annual change (%)
2010	520 354	-3.26	511 064	-2.07
2011	520 858	0.10	507 588	-0.68
2012	530 436	1.84	512 050	0.88
2013	520 727	-1.83	493 875	-3.55
2014	519 511	-0.23	497 080	0.65
2015	511 784	-1.49	509 504	2.50
2016	505 938	-1.14	490 682	-3.69
2017	495 816	-2.00	495 756	1.03
2018	497 825	0.41	499 644	0.78
2019	495 645	-0.44	490 990	-1.73
2020	466 822	-5.82	446 350	-9.09
2021	482 104	3.27	472 202	5.79
2022	472 193	-2.06	451 889	-4.30
2023	466 625	-1.18	453 946	0.46
2024	477 576	2.35	444 164	-2.15

2.1.1.2 Net emissions (incl. LULUCF)

Overall emissions including LULUCF represent the sum of emissions from the Energy, IPPU, Agriculture, and Waste sectors, combined with the sources and removals from the LULUCF sector. This integrated total reflects the full national contribution to anthropogenic GHG emissions.

2.1.1.2.1 2024

The overall emissions (incl. LULUCF) are 444 164 Gg CO₂e in 2024. The LULUCF sector continues to play an important mitigation role, significantly lowering the net national emissions. Within the sector, *Forest land* remains the dominant contributor to net removals, reinforcing its critical role in offsetting emissions from other sectors and stabilising the national emissions profile.

2.1.1.2.2 1990 – 2024

South Africa's GHG emissions (incl. LULUCF) were 402 802 Gg CO₂e in 1990 and these have increased by 10.3%. Despite this overall rise, the consistent contribution of LULUCF removals has played an important role in moderating national emission growth, particularly during periods of increasing emissions from energy and industrial activities.



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The emission trend including LULUCF is like that of emissions excluding LULUCF except that the emissions are reduced due to the LULUCF sector being a sink (Figure 2.1). This sink increased slightly between 2018 and 2024 leading to an increased reduction in overall emissions. The long-term trend highlights the sustained importance of land-based mitigation in the national inventory.

2.1.1.2.3 2000-2024

Between 2000 to 2024, the emissions including LULUCF fell by 5.3%, consistent with a strengthening land-sector sink.

2.1.1.2.4 2022-2024

Since the last submission in 2022, net emissions have decreased by 1.7% as opposed to a 1.1% excluding LULUCF, reinforcing the importance of the land sector.

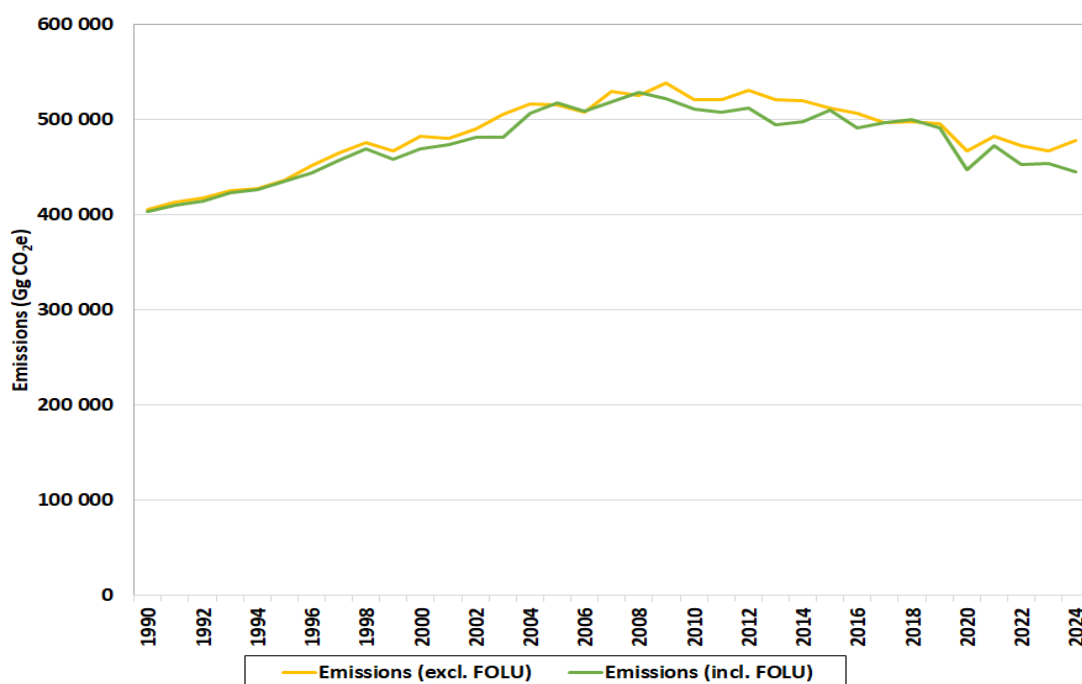


Figure 2.1: National emission trends including LULUCF, 1990-2024



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2.1.2 Indicator trends

South Africa's carbon and energy intensity trends are determined from GHG emissions, GDP data (StatsSA 2023)², total primary energy supply data (DRME 2023) and population data (Stats SA 2022).

2.1.2.1 Total emission indicators

The carbon intensity of the population (i.e. total net emissions per capita) has decreased by 29% since 1990 (Figure 2.2) with 2020 experiencing the highest annual decrease of 10% while 2024 had an annual decrease of 4%. Similarly, both the carbon intensity of economy and the carbon intensity of the energy supply have decreased, by 58% and 35% respectively, since 1990. These carbon intensity indicators show that overall South Africa's carbon intensity is decreasing overtime.

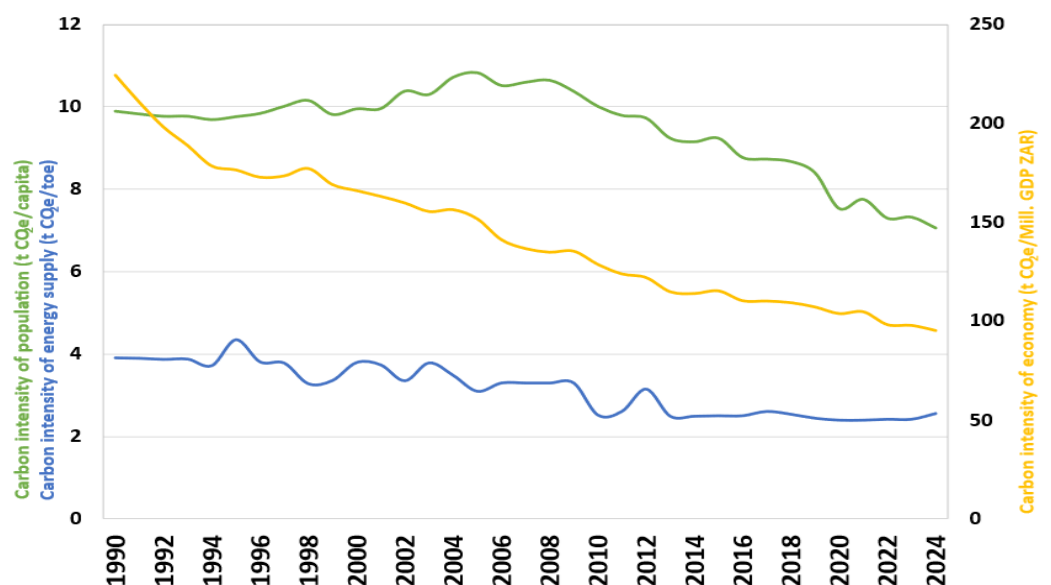


Figure 2.2: Trends in overall carbon intensity of the population and the economy of South Africa, 1990-2024

² In previous inventories the GDP at constant 2010 prices was used. However, in this inventory the GDP at constant 2015 prices was used in line with the changes made by StatsSA in their publication.



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The carbon intensity of the primary energy supply shows a slower but downward trend. Although progress is evident, the gentler slope relative to the other indicators underscores that the pace of energy-system decarbonisation remains slower than demographic or economic decoupling.

Across all three indicators, Figure 2.2 shows broad and sustained declines in carbon intensity, signalling meaningful progress in reducing emissions relative to population growth, economic activity, and energy use. The most significant gains are seen in the economy wide carbon intensity indicator, confirming that South Africa is experiencing a structural decoupling where emissions grow more slowly than the GDP.

2.2 Description of emission and removal trends by greenhouse gas

Emissions remain CO₂ dominated (Table 2.2), reflecting persistent dependence on carbon-intensive energy systems. Changes in CH₄ and N₂O are comparatively small, while F-gases show rapid growth since 2000.

Table 2.2: Trend in CO₂, CH₄, N₂O and F-gases, 1990-2024

	Emissions						
	CO ₂ (excl. LULUCF)	CO ₂ (incl. LULUCF)	CH ₄ (excl. LULUCF)	CH ₄ (incl. LULUCF)	N ₂ O (excl. LULUCF)	N ₂ O (incl. LULUCF)	F-gases
	Gg CO ₂ e						
1990	329 121	323 962	61 122	62 753	15 017	16 087	0
1991	336 495	329 932	61 493	63 094	15 155	16 232	0
1992	341 515	335 799	60 906	62 507	14 915	15 985	0
1993	350 010	345 520	59 735	61 340	14 785	15 853	0
1994	352 699	349 221	59 310	60 935	14 788	15 851	0
1995	360 694	356 751	60 182	61 826	14 758	15 817	0
1996	373 646	363 593	62 220	63 592	15 472	16 401	0
1997	385 773	375 866	63 071	64 410	15 721	16 615	0
1998	395 557	387 018	63 648	65 104	15 938	16 934	0
1999	387 275	376 797	63 198	64 628	15 828	16 776	0
2000	401 244	386 202	63 194	64 635	16 071	17 029	1 025
2001	398 695	389 616	63 486	65 091	16 298	17 402	1 051
2002	408 864	397 548	63 122	64 681	16 418	17 483	935



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	Emissions						
	CO ₂ (excl. LULUCF)	CO ₂ (incl. LULUCF)	CH ₄ (excl. LULUCF)	CH ₄ (incl. LULUCF)	N ₂ O (excl. LULUCF)	N ₂ O (incl. LULUCF)	F-gases
	Gg CO ₂ e						
2003	425 093	399 208	63 162	64 601	15 710	16 618	934
2004	436 277	423 941	63 197	64 557	16 055	16 892	927
2005	432 154	431 928	63 934	65 642	16 831	17 990	1 751
2006	424 306	422 901	63 612	65 280	16 935	18 039	2 116
2007	445 137	431 947	65 075	66 896	16 592	17 643	2 094
2008	440 940	441 004	65 847	67 798	16 352	17 494	1 622
2009	455 359	436 834	65 091	66 589	16 313	17 310	1 112
2010	436 959	425 116	65 172	66 686	15 963	17 002	2 260
2011	435 342	419 581	64 628	66 106	16 019	17 033	4 868
2012	442 627	421 977	66 429	67 778	16 689	17 604	4 691
2013	435 139	405 966	65 477	66 877	16 496	17 417	3 615
2014	433 970	409 168	65 501	66 920	16 586	17 537	3 454
2015	426 647	422 384	65 005	66 201	16 215	17 002	3 917
2016	421 574	404 795	64 336	65 285	15 909	16 483	4 119
2017	412 295	410 139	63 114	64 372	15 997	16 835	4 411
2018	413 131	412 689	63 155	64 509	16 789	17 696	4 750
2019	411 646	404 767	62 197	63 581	16 705	17 545	5 097
2020	383 617	360 831	61 675	63 173	16 043	16 858	5 488
2021	398 807	385 341	61 522	63 877	15 939	17 149	5 836
2022	388 527	364 841	61 661	64 072	15 869	16 839	6 136
2023	382 681	365 548	61 205	64 242	16 176	17 592	6 563
2024	393 917	356 334	60 791	63 732	15 986	17 216	6 883

2.2.1 Carbon dioxide (CO₂)

Carbon dioxide (CO₂) is the largest contributor to South Africa's emissions. CO₂ emissions contribute 82.5% (excl. LULUCF) to South Africa's emissions in 2024. The majority of CO₂ emissions are from the Energy sector. The Energy, IPPU and Agriculture sectors contribute 93.5%, 5.8% and 0.7% respectively. The average contribution to total CO₂ (excl. LULUCF) between 1990 and 2024 from these sectors is 92.6%, 6.9% and 0.6% respectively (Figure 2.3).



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The LULUCF sector contributes a sink of 37 584 Gg CO₂ in 2024 which is an increase from the 1990 sink (Table 2.2). The sink in 2024 reduced the total CO₂ emissions from 393 917 Gg CO₂ to 356 334 Gg CO₂.

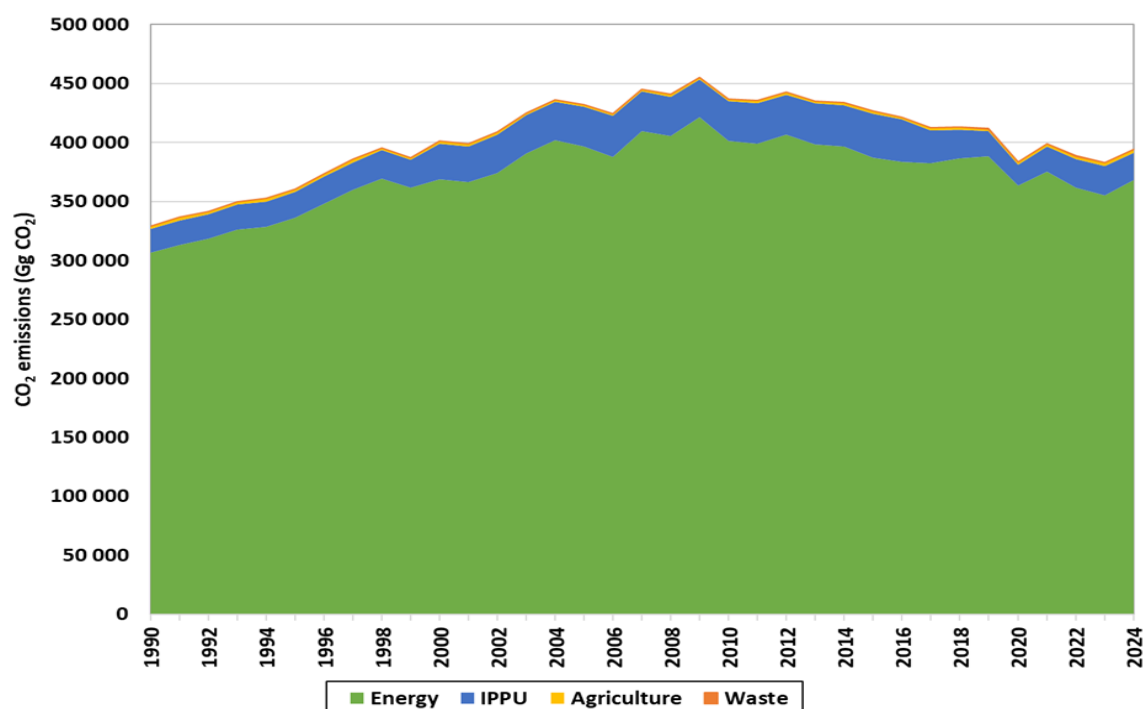


Figure 2.3: Trend and sectoral contribution to CO₂ emissions (excl. LULUCF), 1990-2024

2.2.2 Methane (CH₄)

Methane (CH₄) is the second-largest contributor to South Africa's total GHG emissions (Table 2.2). In 2024, CH₄ accounts for 12.7% and 14.3% of national emissions excluding and including LULUCF respectively. This is a decline from 15.1% (excl. LULUCF) and 15.8% (incl. LULUCF) in 1990. Agriculture and Waste sectors are the dominant sources of CH₄ emissions (Figure 2.4). Within Agriculture, *Enteric Fermentation* is the primary contributor, while in the Waste sector, the largest share originates from *Wastewater Treatment and Discharge*.



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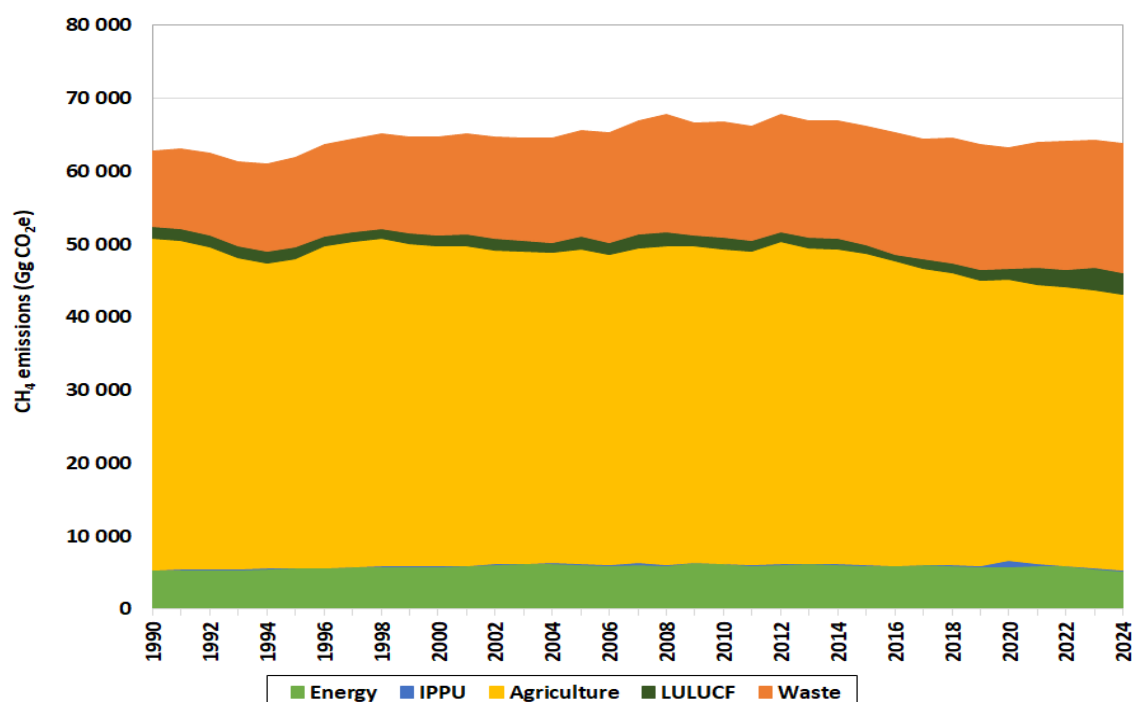


Figure 2.4: Trend and sectoral contribution to CH₄ emissions, 1990-2024

2.2.3 Nitrous oxide (N₂O)

N₂O emissions accounted for 3.9% of South Africa's national GHG emissions (excl. LULUCF) in 1990. By 2024, this share had declined to 3.3%. This gradual decrease shows that, while agriculture and certain industrial activities continue to generate N₂O, their relative contribution to the country's total emissions has slightly reduced over time. With the inclusion of the LULUCF sector the N₂O contribution was 4.3% and 3.9% in 1990 and 2024 respectively, indicating that the LULUCF N₂O emissions increased in 2024 (Figure 2.5).

The Agriculture sector remains the dominant source of N₂O emissions, contributing 71.7% to total emissions (incl. LULUCF) in 2024, followed by Energy (9.9%) and Waste (9.3%) sectors.



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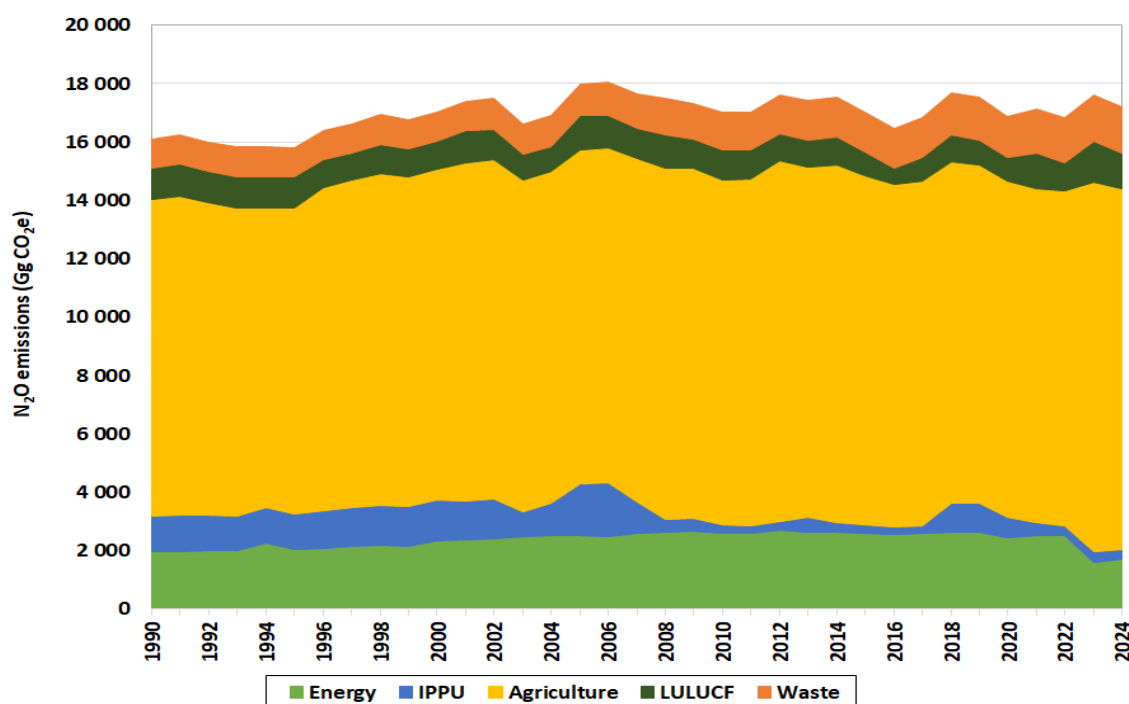


Figure 2.5: Trend and sectoral contribution to N₂O emissions, 1990-2024

2.2.4 F gases

HFC and PFC emissions are only estimated for the IPPU sector in South Africa. F-gas emission estimates varied annually (Figure 2.6) and contribute 1.5% to overall emissions (incl. LULUCF) in 2024. Emissions increase from 2011 due to the addition of HFC emissions from *Air conditioning, foam blowing agents, fire protection and aerosols*. There is no data prior to 2005 so this time-series is not consistent. The elevated F-gas emissions are therefore not necessarily due to an increase in emissions but rather due to the incorporation of new categories.

PFCs are produced during the production of aluminium. The *Aluminium production* data was updated for the years 2014 onwards and the updated data was an order of magnitude lower than the previous years. This is causing the decline in the PFC emissions. There is a sharp decline in emissions from the *Metal industry* between 2007 and 2009 and this is



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attributed to reduced production caused by electricity supply challenges and decreased demand following the economic crisis that occurred during 2008/2009. Increases in 2011 and 2012 were due to increased emissions from aluminium plants due to inefficient operations. The industry was used to assist with the rotational electricity load shedding in the country at the time and which necessitated switching on and off at short notice leading to large emissions of Tetrafluoroethylene (C_2F_6) and Carbon tetrafluoromethane (CF_4).

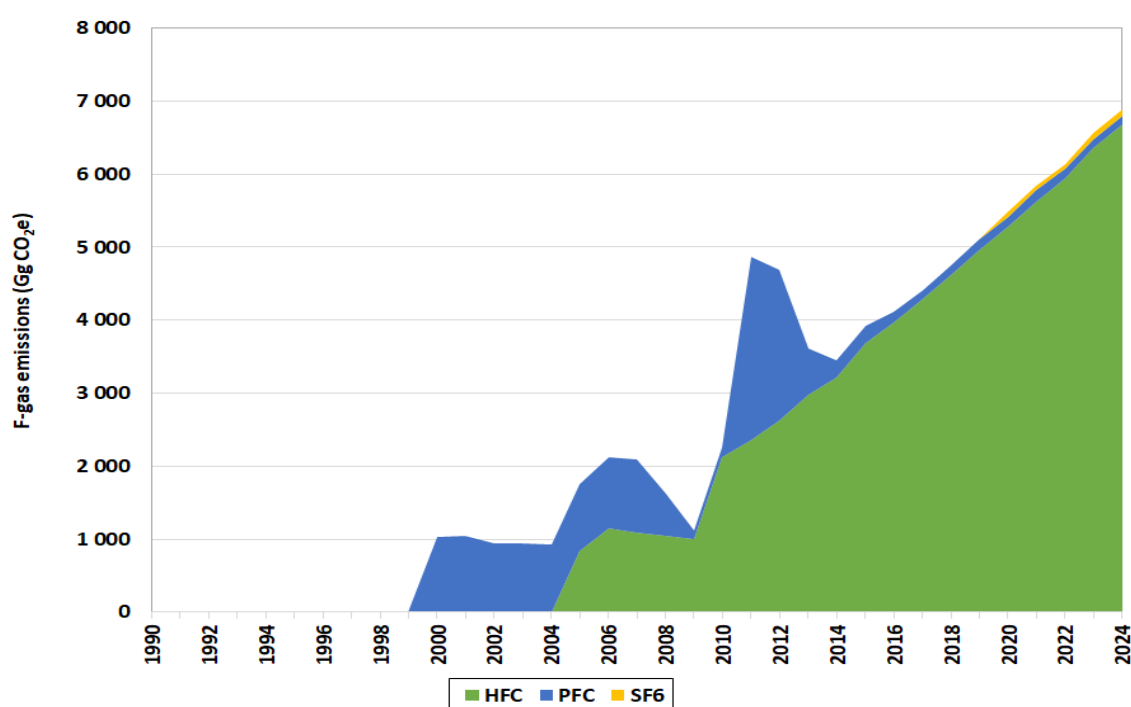


Figure 2.6: Trend in F-gas emissions, 1990-2024

2.2.5 Precursor gases

The trend in emissions of CO, NO_x and NMVOCs is shown in Table 2.3. These emissions were estimated for biomass burning only. There is annual variability because the emissions include wildfires as well as controlled fires.



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Table 2.3: Trends in precursor gas emissions, 1990-2024

	NO _x	CO	NMVOC
	(Gg)		
1990	46.3	917.9	111.3
1991	45.6	894.8	105.0
1992	45.6	895.8	105.5
1993	45.7	900.4	107.0
1994	46.1	917.6	112.1
1995	46.6	933.5	116.8
1996	38.0	700.1	65.8
1997	35.6	664.5	66.0
1998	41.7	775.5	76.3
1999	39.5	742.5	76.1
2000	40.8	756.9	72.4
2001	50.9	923.7	80.8
2002	48.1	874.2	78.1
2003	37.6	731.5	83.7
2004	32.9	652.0	79.1
2005	54.8	1 008.5	94.0
2006	51.3	964.1	97.2
2007	49.8	1 063.2	155.3
2008	56.7	1 190.2	167.3
2009	43.1	805.9	79.5
2010	45.9	833.3	73.6
2011	44.3	801.0	69.1
2012	37.0	673.9	60.8
2013	37.9	715.4	73.2
2014	40.0	740.5	70.6
2015	27.1	503.1	48.8
2016	10.9	232.3	33.9
2017	27.1	515.3	55.0
2018	30.0	581.1	66.2
2019	26.8	508.3	52.5
2020	26.7	506.5	52.6
2021	51.4	919.2	75.0
2022	31.9	584.6	54.4
2023	62.2	1 096.6	83.0
2024	48.0	876.7	78.9



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2.3 Description of emission and removal trends by sector

Figure 2.7 presents a comparative view of South Africa's GHG emissions profile for the years 1990 and 2024, illustrating how the relative contribution of key sectors has evolved over three decades. The overall pattern reflects a system dominated by the Energy sector, highlighting the continued reliance on fossil fuel-based energy production and energy intensive economic activity. Despite growth in renewable energy deployment in recent years, the sector's proportional contribution remains largely unchanged. There are smaller but important contributions from the remaining sectors (Figure 2.7, Table 2.4), each following distinct trajectories shaped by structural and policy drivers.

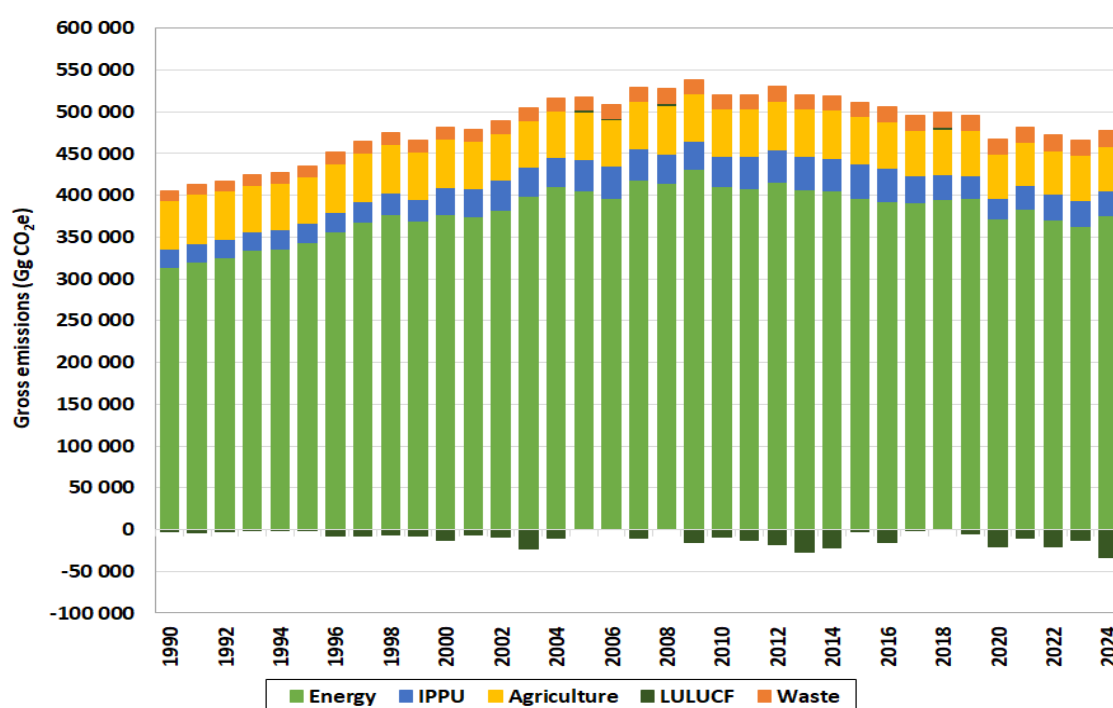


Figure 2.7: National sectoral GHG emissions (incl. LULUCF), 1990-2024



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Table 2.4: Sectoral GHG emissions, 1990-2024

	Energy	IPPU	Agriculture	LULUCF	Waste
	Emissions (Gg CO ₂ e)				
1990	313 869	21 242	58 804	-2 458	11 346
1991	320 518	22 070	58 537	-3 886	12 018
1992	325 712	22 127	57 161	-3 044	12 336
1993	333 721	22 350	55 777	-1 817	12 682
1994	336 180	22 907	54 737	-790	12 974
1995	343 804	23 407	55 207	-1 241	13 215
1996	355 959	24 095	57 824	-7 752	13 460
1997	367 444	24 972	58 467	-7 675	13 683
1998	377 444	25 432	58 342	-6 088	13 924
1999	369 425	25 113	57 578	-8 100	14 184
2000	377 004	32 783	57 317	-12 643	14 430
2001	374 350	33 057	57 412	-6 370	14 711
2002	382 602	35 035	56 744	-8 692	14 957
2003	399 123	34 425	56 150	-23 537	15 200
2004	410 606	34 495	55 955	-10 139	15 400
2005	404 784	37 594	56 574	2 641	15 718
2006	396 361	38 760	55 705	1 368	16 142
2007	418 120	37 164	56 879	-10 317	16 735
2008	414 215	35 433	57 736	3 155	17 378
2009	430 543	33 563	57 238	-16 031	16 531
2010	410 323	35 956	56 981	-9 289	17 093
2011	407 273	39 675	56 934	-13 270	16 975
2012	415 455	38 810	58 723	-18 387	17 449
2013	407 094	38 913	57 412	-26 852	17 308
2014	405 051	39 234	57 718	-22 431	17 509
2015	395 736	41 597	56 750	-2 279	17 701
2016	392 064	40 337	55 487	-15 256	18 050
2017	390 857	32 508	54 690	-60	17 761
2018	394 993	30 269	53 952	1 819	18 611
2019	396 575	27 469	52 988	-4 655	18 614
2020	371 513	25 098	52 351	-20 472	17 861
2021	383 643	27 841	52 041	-9 902	18 578
2022	370 030	30 984	52 073	-20 305	19 107
2023	362 459	31 788	53 321	-12 679	19 057
2024	375 216	30 372	52 744	-33 412	19 245

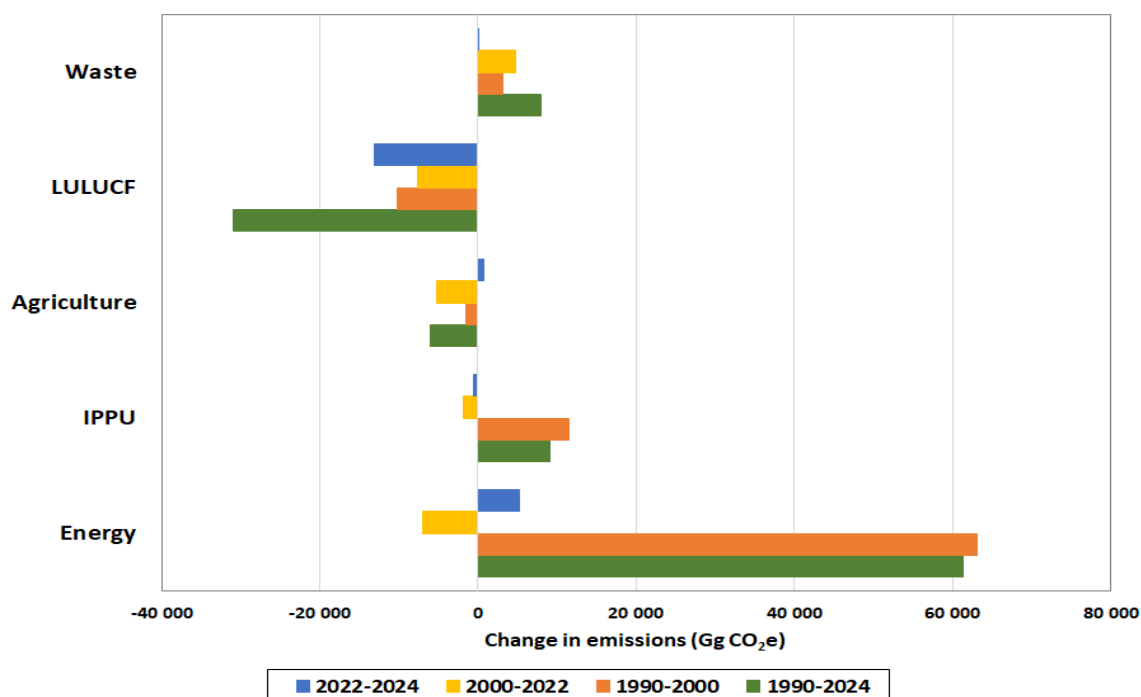


Figure 2.8: Change in sectoral emissions between 1990, 2000, 2022 and 2024

2.3.1 Energy

The Energy sector is the largest contributor to South Africa's emissions (Figure 2.7), contributing 78.6% to emissions (excl. LULUCF) in 2024 and on average since 1990. In 1990, the Energy sector contributed 77.4% to total emissions (excl. LULUCF), which means a small overall increase in contribution of around 1.2% over the 34-year period.

The Energy sector emissions have increased by 19.5% since 1990, but most of this increase is between 1990 and 2000 (Figure 2.8). Emissions showed a decline between 2000 and 2022. Between 2019 and 2020, the Energy sector's share of total emissions declined slightly from 80.9% to 79.6%, representing a reduction of approximately 1.3%. This is due to an annual reduction of 6% in 2020 which is likely to be caused by the impacts of COVID-19.



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Energy sector emissions started to show an increase again (1.4%) between 2022 and 2024. In 2023 annual change in energy emissions decreased by 2% and then increased by 3.5% in 2024. The 2% decline in emissions observed in 2023 may have been influenced by intensified loadshedding, which reduced electricity generation and associated emissions. In contrast, the 3.5% increase in 2024 corresponds with reduced loadshedding and a rebound in energy supply.

2.3.2 IPPU

In 2024 the IPPU sector produced 30 372 Gg CO₂e which is 6.4% and 6.8% of South Africa's emission excluding and including LULUCF. The IPPU sector shows a modest increase in its contribution, shifting from 5.2% in 1990 to 6.4% in 2024 (excl. LULUCF).

The IPPU sector produced CO₂ emissions (75.8%), fluorinated gases 22.6% and small amounts (<1.5%) of CH₄ and N₂O in 2024. Carbon dioxide and any other emissions from combustion of fuels in these industries are reported under the Energy sector.

The largest source category is the *Ferroalloy production* category, which contributes 52.6% to the total IPPU sector emissions. The *Mineral industry* and the *Product used as substitutes for ozone depleting substances* subsectors contribute 16.4% and 22.9%, respectively, to the IPPU sector emissions.

IPPU sector emissions have increased by 43.0% since 1990 but, as with the Energy sector, much of this increase is between 1990 and 2000 (Figure 2.8). After 2000 there was a decrease in emissions. Even though the South African economy recovered after the COVID-19 pandemic, estimated emissions from the IPPU sector are 2 411 Gg CO₂e (7.4%) lower than the emissions in 2000. The decline can be attributed to the decline in metals production (39.0%), specifically Iron and Steel, and Aluminium. This can be ascribed to a decrease in global demand. The chemicals industry also declined (31.4%). *Cement Production* and *Non-Energy Product Use from Fuels and Solvents* increased emissions from 2000 by 2 081 Gg CO₂e. The local demand for cement increased dramatically from 2000.

2.3.3 Agriculture

The Agriculture sector contributed between 10% and 14% to total emissions (excluding and including LULUCF) over the period 1990 to 2024 (Figure 2.7). Overall Agriculture sector emissions have declined by 4 573 Gg CO₂e since 1990, representing a decrease of 10.3% over the period (**Error! Reference source not found.**). The largest portion of this



decline was between 2000 and 2022, with a small increase (1.3%) between 2022 and 2024 (Figure 2.8). The main driver of change in the Agriculture sector is the livestock population, as livestock contribute to emissions from *Enteric fermentation*, *Manure management*, and direct and indirect N₂O emissions from managed soils.

The Agriculture sector demonstrates a noticeable decline in contribution to the total emissions from 14.5% in 1990 to 11.0% in 2024. The declining share may be attributed to changes in livestock populations, improvements in agricultural management practices, and shifts in land use patterns that reduce enteric fermentation and associated emissions relative to other sectors.

Livestock-related emissions contribute approximately 77% to total Agriculture sector emissions in 2024. The largest contributor is CH₄ emissions from *Enteric fermentation* (about 68.3%), while *Manure management* contributes about 8.3% to total Agriculture sector emissions. Emissions from *Enteric fermentation* shows a declining trend, reflecting reductions in livestock population numbers. Dairy cattle, pigs, and poultry are the largest contributors to *Manure management* emissions and increasing poultry numbers have contributed to a gradual rise in *Manure management* emissions over the 1990–2024 period.

Agricultural soils contribute approximately 18.4% to total Agriculture sector emissions, while the smallest contributions are from *Liming* (about 3.6%), *Urea application* (about 1.3%), and *Field burning of agricultural residues* (about 0.1%).

2.3.4 LULUCF

The LULUCF sector is a sink of 33 412 Gg CO₂e in 2024, and this is a sink increase of 20 769 Gg CO₂e since 1990 (Figure 2.8). There has been annual variation in the removals and emissions in the LULUCF sector, but overall the sink has been increasing gradually over time. Between 2022 and 2024 the sink increased by a further (64.5%).

Between 1990 and 2024 the greatest percentage increases were seen in the *Forest land*, while for the periods 2000 to 2024, and 2022 to 2024 the *Grassland* and *Wetland* categories showed the largest changes. Converted lands were the largest contributors to all land category emission and removals except *Settlements*.

Forest lands are estimated to be a sink of 55 037 Gg CO₂e. The dominant *Forest land* sinks are thickets and woodlands. Between 1990 and 2000 the *Forest land* sink was smaller than the later years and this is attributed to the burnt area data that was extrapolated over this period. The increased annual variability, particularly in *Forest lands*, from 2001



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onwards was due to changes in burnt area and the associated losses. The trends show an increase in the *Forest land* sink between 2018 and 2024 attributed to an increasing conversion of *Grasslands* to *Forest land*.

While *Forest Lands* are the largest contributor to the sink, all other land categories, except for a small sequestration from *Settlements*, are a source of emissions in 2024, with *Other lands* being the largest. *Other lands* show an increase in emissions between 2014 and 2024, due to an increase in conversion of *Forest land* to *Other land* between 2014 and 2018 and an increase in conversion of *Grasslands* to *Other lands* from 2018 onwards. Much of these conversions are, however, thought to be related to seasonal variation rather than being actual change. *Croplands* are a consistent source across the time-series except for an increase in emissions between 2019 and 2020 due to an increase in conversion from *Forest land* to *Croplands*. *Grasslands* show increased emissions over time due mainly to the conversion of *Forest lands* to *Grasslands*. The *Wetland* source is small but increases from 1990 to 2024 as there is an increase in conversion of all other land types to *Wetlands*.

2.3.5 Waste

The Waste sector's share of total national emissions increases over the period from about 2.8% in 1990 to 4.0% in 2024. The Waste sector showed a 69.6% increase in emissions since 1990 and this increase has occurred slowly over time (Figure 2.8).

In South Africa the total Waste sector emissions for 2024 are 19 245 Gg CO₂e. Most of these emissions are from *Wastewater treatment and discharge* contributing 9 007 Gg CO₂e (47%) of the total Waste sector emissions. *Solid waste disposal* contributed a further 7 377 Gg CO₂e (38%) of waste emissions while *biological treatment of solid waste* contributed 2 620 Gg CO₂e (14%). Emissions from *Incineration and Open Burning of Waste* were estimated to be 241 Gg CO₂e (1%), this excludes emissions from pyrolysis.

Solid waste disposal emissions have increased 47.6% since 2000. *Incineration and open burning of waste* emissions increased by 53.1% since 2000, while emissions from *Wastewater treatment and discharge* increased slightly across the time series. This overall increase in emissions is largely driven by increases of 35.6% in *Domestic wastewater treatment and discharge* emissions, whilst there was a 9.4% decline in *Industrial wastewater treatment and discharge* emissions.



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Chapter 3: Energy (CRT Sector 1)

3.1 Sector overview

South Africa's Energy sector inventory includes:

- Exploration and exploitation of primary energy sources;
- Conversion of primary energy source into more useable energy forms in refineries and power plants;
- Transmission and distribution of fuels; and
- Final use of fuels in stationary and mobile applications.

The Energy sector is South Africa's largest emitting sector. This sector is the largest source of CO₂ emissions (Figure 3.1) and the second largest source of N₂O emissions mainly as a result of *Fuel Combustion* activities.

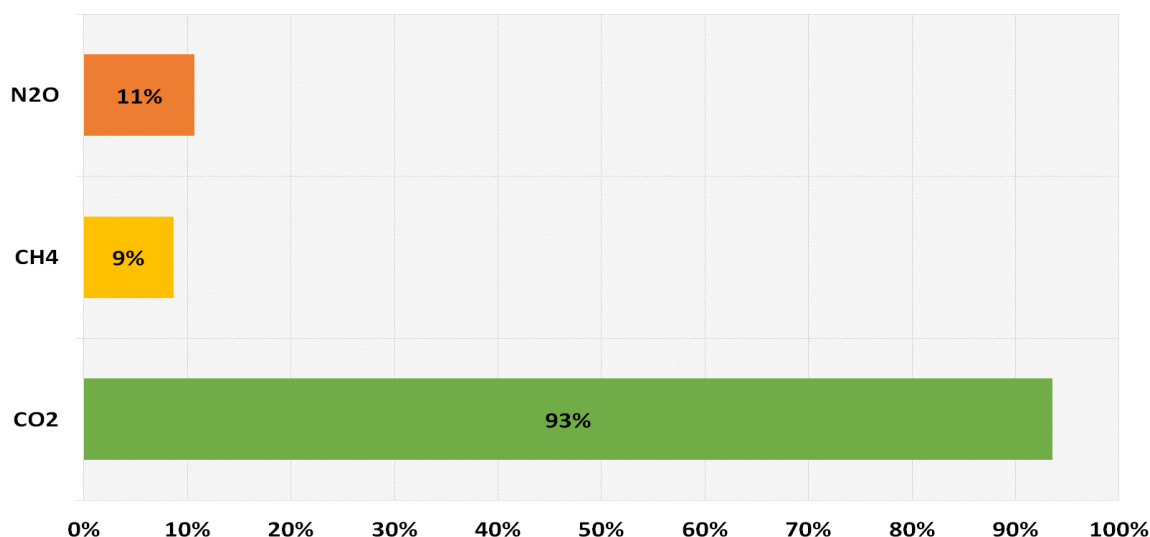


Figure 3.1: Energy sector contribution by gas for 2024

The primary energy supply for South Africa is dominated by coal and renewables and waste as shown in Figure 3.2. The share of renewable energy in South Africa's total primary energy supply has increased from approximately 11% in 2020 to about 15% in 2022, reflecting a gradual but steady expansion of renewable energy sources in the national energy mix.

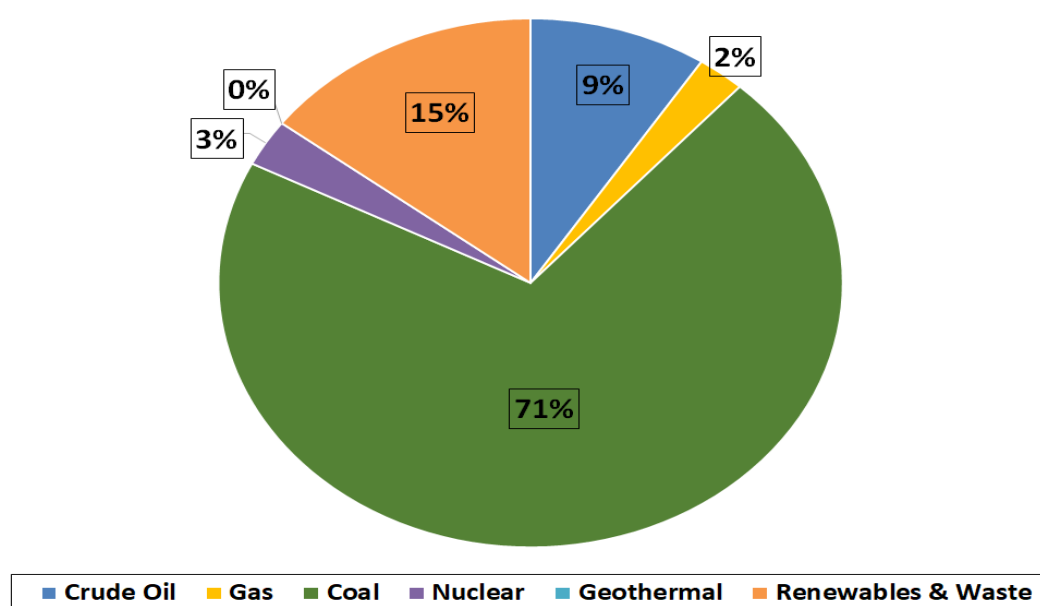


Figure 3.2: Total primary energy supply in South Africa, 2022³

3.1.1 Shares and trends in emissions

The total emissions from the Energy sector for 2024 are shown in Table 3.1. Emissions from *Fuel Combustion* activities account for 92% of the Energy sector emissions. Within this category, Energy Industries were the dominant source, accounting for approximately 65% of emissions from *Fuel Combustion* activities, reflecting the significant contribution of electricity and heat production to the sector's overall emissions profile. Fugitive Emissions from Fuels contributed 8% of total Energy sector emissions.

³ Values from the 2022 Energy Balance, DMRE 2024 [Statutes & Practices / Department: Energy / REPUBLIC OF SOUTH AFRICA](#)



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Table 3.1: Summary of emissions from the Energy sector in 2024

GHG source and sink categories	CO ₂	CH ₄		N ₂ O		Total
	Gg CO ₂ e	Gg	Gg CO ₂ e	Gg	Gg CO ₂ e	Gg CO ₂ e
1. ENERGY	368 289	187	5 223	6	1 703	375 216
1A Fuel combustion activities	344 347	16	459	6	1 699	346 505
1B Fugitive emissions from fuels	23 942	170	4 764	0	5	28 711
1C CO ₂ transport and storage	NO	NO	NO	NO	NO	NO

The time series of energy emissions by sector is shown in Figure 3.3. Total emissions from the energy sector show a long-term upward trend from 1990 to around 2009, followed by a period of fluctuation and a gradual decline towards 2024. Fuel combustion activities form the dominant source of emissions throughout the period, consistently contributing the largest share. Emissions from combustion increased steadily through the 1990s and early 2000s, peaking around 2008-2009, before stabilising and gradually decreasing in the following decade.

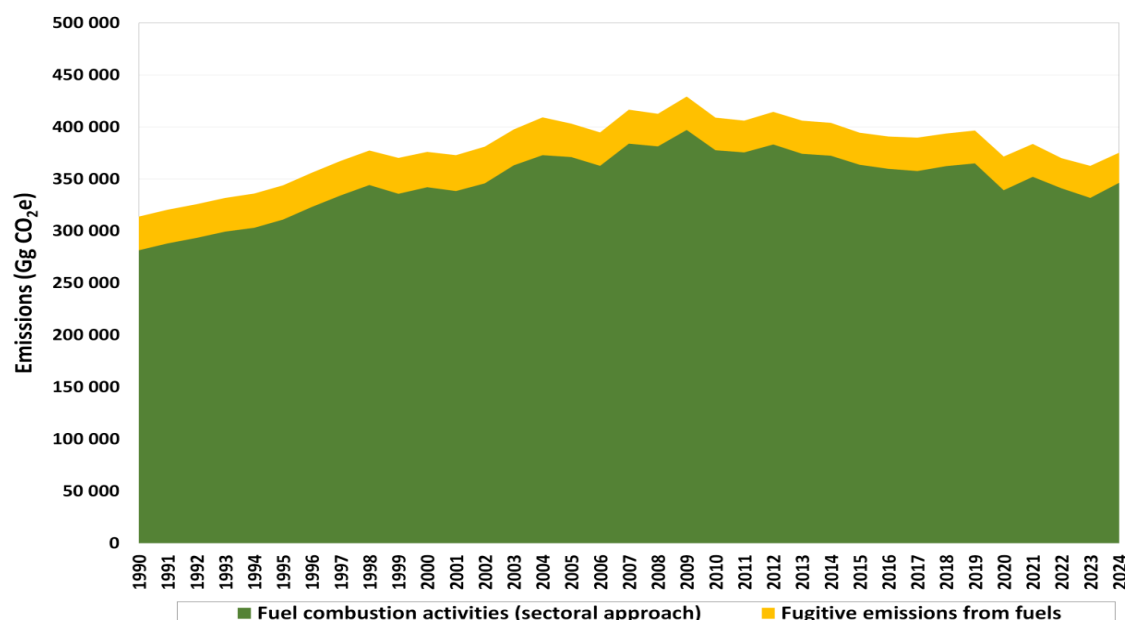




Figure 3.3: Energy emissions by sub-sector, 1990-2024

Fugitive emissions from fuels represent a much smaller portion of total energy sector emissions. These emissions remained relatively stable over time, with moderate increases observed in the mid-2000s and slight variations thereafter.

The changes in Energy sector emissions since 1990, at an aggregated level, are shown in Figure 3.4. The annual change in emissions from 1990 to 2024 shows a fluctuating pattern, characterised by alternating periods of moderate increases and decreases. Early years (1990–2000) reflect generally modest growth, with annual changes mostly between 0% and 4%. Between 2001 and 2010, emissions became more variable, with sharper increases of up to 5% and occasional declines of between 2% and 5%, indicating sensitivity to economic and operational factors.

From 2011 onward, annual changes stabilised, although small fluctuations persisted, typically within the –2% to +2% range. A significant drop of 6% is observed in 2020, likely linked to reduced activity during the COVID-19 pandemic, followed by a strong rebound of 3% in 2021. The most recent years (2022–2024) show a return to moderate variability, with a decline of 4% in 2023 and a subsequent increase of 4% in 2024.



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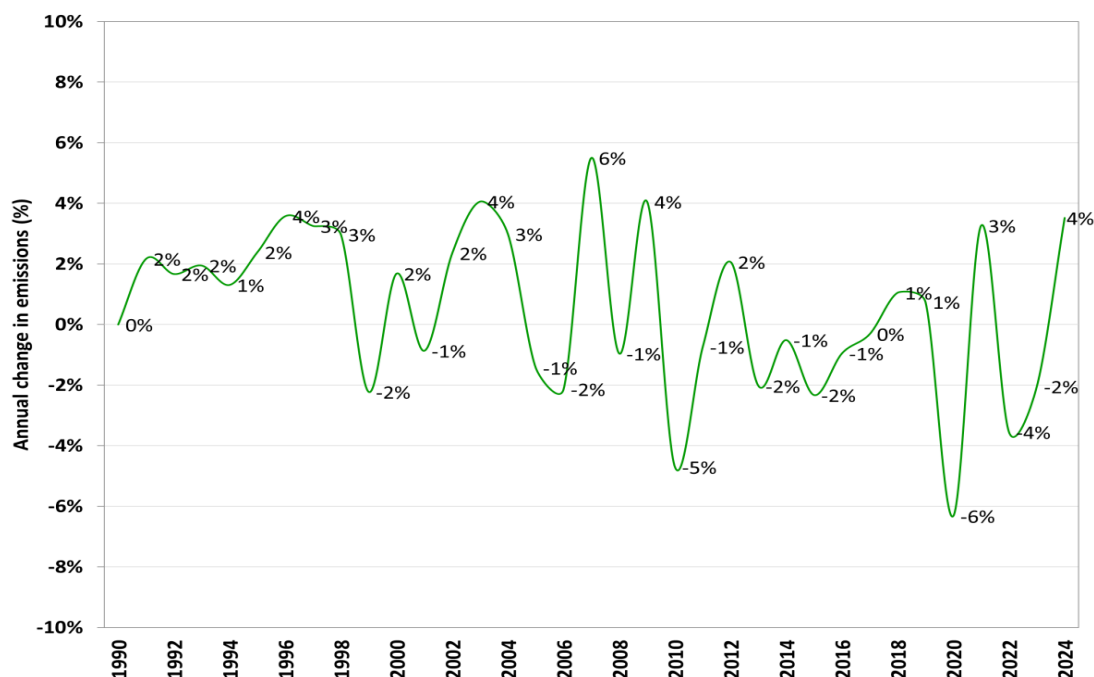


Figure 3.4: Trend in annual change in the total Energy sector emissions, 1990-2024

Table 3.2 shows the disaggregated changes in emissions from 1990 and from 2024. Energy industries, particularly Electricity and heat production, show the largest absolute increase (+60,481 Gg CO₂e; +43.6% from 1990-2024), confirming continued reliance on fossil-fuel-based power generation. Transport (1.A.3) emissions rose significantly by 26.7% from 1990-2024, largely driven by Road transportation (1.A.3.b) (+36.1%), indicating increasing vehicle activity and fuel consumption. Conversely, Other sectors (1.A.4) declined sharply (-53.1%), mainly due to reductions in Residential emissions (-83.1%), likely reflecting electrification and reduced direct fuel use in households.

Total fugitive emissions show a moderate long-term decline, these masks contrasting trends: strong reductions in oil and gas-related fugitives, offset partly by increases in solid fuel-related emissions. Overall, the Energy sector exhibits long-term growth with shifting sub-sector dynamics, while recent trends indicate a modest 1% increase between 2022 and 2024.

Table 3.2: Summary of the change in emissions from the Energy sector, 1990-2024

Greenhouse gas source and sink categories	Emissions (Gg CO ₂ e)				Difference (Gg CO ₂ e)			Change (%)	
	1990	2000	2022	2024	1990-2024	2000-2024	2022-2024	1990-2024	2000-2024
1.ENERGY	312 936	376 305	370 030	375 216	62 280	-1 089	5 186	19.9	-0.3
1.A Fuel combustion activities	281 795	342 204	341 185	346 505	64 710	4 301	5 321	0.2	1.3
1.A.1 Energy industries	166 631	221 901	226 694	228 181	61 550	6 281	1 487	36.9	2.8
1.A.1.a Electricity and heat production	138 634	187 325	198 016	199 114	60 481	11 789	1 099	43.6	6.3
1.A.1.b Petroleum refining	2 550	4 012	1 080	1 493	-1 056	-2 519	413	-41.4	-62.8
1.A.1.c Manufacture of solid fuels	25 448	30 563	27 599	27 574	2 126	-2 990	-25	8.4	-9.8
1.A.2 Manufacturing industries and construction	15 786	18 946	24 367	21 927	6 141	2 981	-2 440	38.9	15.7
1.A.2.a Iron & Steel	1 185	1 424	1 583	1 674	489	250	90	41.3	17.5
1.A.2.b Non-ferrous Metals	432	474	732	366	-66	-108	-365	-15.3	-22.8
1.A.2.-ab 1A2 Remainder	14 169	17 048	22 052	19 887	5 718	2 839	-2 165	40.4	16.7
1.A.3 Transport	47 244	41 664	52 786	59 868	12 624	18 205	7 082	26.7	43.7
1.A.3.a Domestic aviation	3 434	2 333	689	781	-2 653	-1 552	92	-77.2	-66.5

1.A.3.b transportation	42 643	38 245	51 159	58 025	15 382	19 780	6 866	36.1	51.7	13.4
1.A.3.c Railways	733	613	395	449	-284	-164	53	-38.8	-26.8	13.4
1.A.3.d Water-borne navigation (domestic)	394	432	500	568	174	135	67	44.2	31.3	13.4
1.A.3.e Other transportation	40	40	42	46	6	6	4	14.2	14.2	9.3
1.A.4 Other sectors	39 464	45 184	18 487	18 502	-20 962	-26 682	15	-53.1	-59.1	0.1
1.A.4.a Commercial/Institutional	16 069	18 388	11 843	11 820	-4 250	-6 569	-24	-26.4	-35.7	-0.2
1.A.4.b Residential	21 307	24 404	3 559	3 608	-17 699	-20 796	49	-83.1	-85.2	1.4
1.A.4.c Agriculture/Forestry/Fishing/Fish farms	2 088	2 391	3 085	3 074	986	683	-10	47.2	28.6	-0.3
1.A.5 Non-specified	12 669	14 510	18 849	18 026	5 357	3 516	-823	42.3	24.2	-4.4
1.B Fugitive emissions from fuels	31 141	34 100	28 845	28 711	-2 431	-5 390	-135	-0.1	-15.8	-0.5
1.B.1 Solid fuels	1 549	2 028	2 314	2 411	862	383	97	55.7	18.9	4.2
1.B.2 Oil and natural gas	784	976	121	86	-699	-890	-35	-89.1	-91.2	-28.9
1.B.3 Other emissions from energy production	28 808	31 325	26 410	26 214	-2 594	-5 111	-197	-9.0	-16.3	-0.7
1.C Carbon dioxide transport and storage	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Note: Columns may not add up exactly due to rounding off.



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3.1.1.1 Fuel combustion activities

The trends and subcategory contributions to emissions from *Fuel Combustion activities* since 1990 are shown in Figure 3.5. *Energy Industries* continues to be the largest source of emissions and this due to the high carbon intensity of South Africa's electricity production sector. The second largest source of emissions from *Fuel Combustion activities* is the *Transport* sector, which is largely dominated by emissions from road transportation.

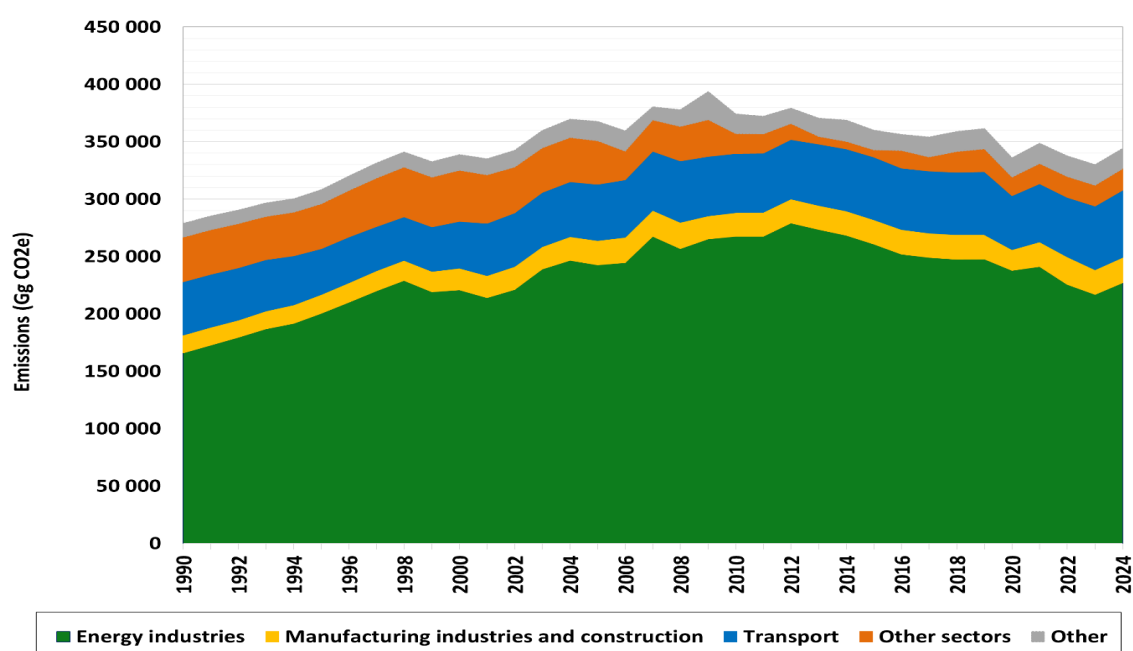


Figure 3.5: Trends and subcategory contributions to fuel combustion activity emissions, 1990-2024

Overall emissions increased steadily from 1990, reaching a peak around 2007–2010, before gradually declining and stabilising in the period after 2015. Energy industries remained the dominant source of emissions throughout the time series, showing strong growth during the 1990s and early 2000s, followed by a plateau and slight reduction in recent years. Transport emissions also rose consistently over the time series, contributing significantly to the overall upward trend, particularly between 2000 and

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2015. Overall, the figure demonstrates that while total Energy sector emissions expanded during the first two decades, structural and operational changes in the energy system have contributed to stabilisation and slight reductions in more recent years.

All the *Fuel Combustion* activity subcategories experienced a drop in emissions in 2020 due to stringent COVID19 lockdown restrictions.



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3.1.1.1.1 Energy industries

Emissions from *Electricity and Heat Production* contribute the most to the *Energy Industries* sub-sector with *Petroleum Refining* contributing the least (Figure 3.6).

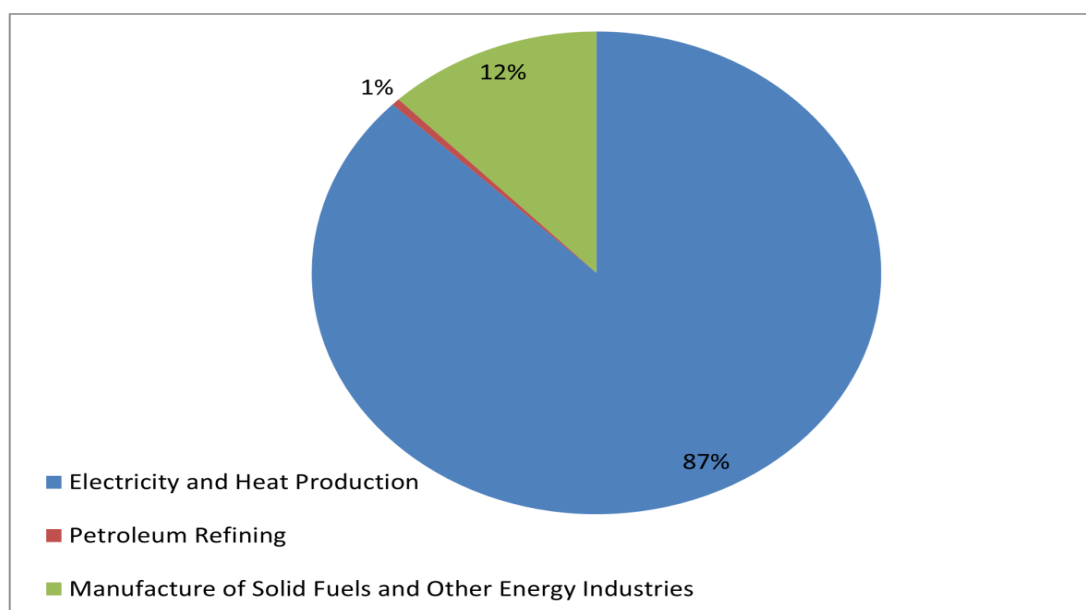


Figure 3.6: Contributions to *Energy Industries* emissions, 2024



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Main electricity producer (1.A.1.a)

Table 3.3 shows historical emissions from electricity produced by the main electricity producer in South Africa. Emissive electricity in South Africa is mainly produced from coal, diesel and fuel oil.

Table 3.3: Emission trends for the main electricity producer, 1990 – 2024

	CO ₂	CH ₄	N ₂ O	Total
	Gg CO ₂	Gg CH ₄ (CO ₂ e)	Gg N ₂ O (CO ₂ e)	Gg CO ₂ e
1990	125 011	36	513	125 561
1991	133 424	39	548	134 011
1992	141 838	41	583	142 461
1993	150 348	44	618	151 009
1994	153 938	45	632	154 615
1995	160 675	46	660	161 381
1996	169 643	49	697	170 389
1997	178 700	52	734	179 486
1998	185 870	54	763	186 687
1999	175 174	51	720	175 944
2000	175 174	51	720	175 944
2001	174 803	51	718	175 572
2002	182 292	53	749	183 094
2003	196 045	57	805	196 907



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2004	205 802	60	845	206 707
2005	207 331	60	851	208 243
2006	208 592	60	857	209 509
2007	229 351	66	942	230 359
2008	219 703	64	902	220 669
2009	225 762	66	926	226 754
2010	232 623	68	954	233 645
2011	234 418	69	960	235 447
2012	244 784	73	1 001	245 858
2013	238 705	72	974	239 751
2014	233 324	71	950	234 346
2015	225 166	70	914	226 150
2016	218 228	64	894	219 187
2017	215 762	63	884	216 710
2018	214 442	63	878	215 383
2019	211 948	64	865	212 876
2020	204 017	61	833	204 912
2021	208 398	63	849	209 310
2022	194 961	60	793	195 814
2023	186 053	58	754	186 866
2024	196 649	60	801	197 509



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GHG emissions from the main electricity producer increased in 2024 compared to 2022. This increase is primarily attributable to higher electricity generation coal in 2024, reflecting improved operational availability of the power system. In particular, South Africa experienced significantly reduced load shedding in 2024 relative to 2022, resulting in increased utilisation of coal-fired power plants to meet electricity demand. Figure 3.8 shows a steady increase in electricity generated from renewable energy, marked by strong growth in wind and solar PV, stabilisation of CSP, and variable performance in hydro.



Figure 3.7: Historical energy availability factors and electricity generation information⁴

⁴ Data from Eskom's Annual Integrated reports 2011 – 2022. [Integrated results - Eskom](#) and from CSIR Statistics of utility-scale power generation in South Africa reports, 2020 - 2024



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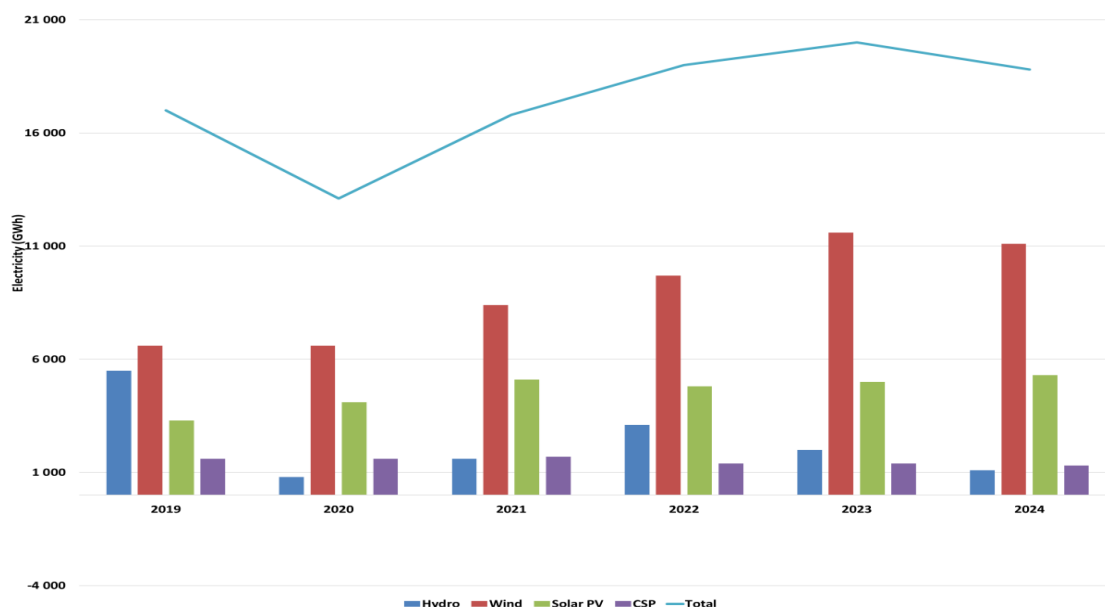


Figure 3.8: Annual electricity from renewable energy, 2019 - 2024⁵

Other electricity producers (1.A.1.a)

Emissions from other electricity producers have varied since 1990, as shown in Table 3.4. However, since 2019 these emissions have been decreasing and this is likely due to the increasing infiltration of renewable energy in this sector.

Table 3.4: Trend in emissions from other electricity producers, 1990-2024

	CO ₂	CH ₄	N ₂ O	Total
	Gg CO ₂	Gg CH ₄ (CO ₂ e)	Gg N ₂ O (CO ₂ e)	Gg CO ₂ e
1990	13 016	3.9	53.2	13 073
1991	11 671	3.5	47.7	11 723
1992	10 327	3.1	42.2	10 372
1993	8 982	2.7	36.7	9 022
1994	9 027	2.7	36.9	9 067

⁵ Data from CSIR Statistics of utility-scale power generation in South Africa reports, 2020 - 2024



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	CO ₂	CH ₄	N ₂ O	Total
	Gg CO ₂	Gg CH ₄ (CO ₂ e)	Gg N ₂ O (CO ₂ e)	Gg CO ₂ e
1995	10 105	3.0	41.3	10 150
1996	9 699	2.9	39.7	9 742
1997	9 968	3.0	40.8	10 012
1998	10 743	3.2	43.9	10 790
1999	11 094	3.3	45.4	11 143
2000	11 331	3.4	46.3	11 381
2001	4 623	1.4	18.9	4 643
2002	5 010	1.5	20.5	5 032
2003	8 010	2.4	32.8	8 046
2004	6 282	1.9	25.7	6 309
2005	2 737	0.8	11.2	2 749
2006	3 869	1.1	15.8	3 886
2007	4 239	1.3	17.3	4 257
2008	3 521	1.0	14.4	3 536
2009	6 009	1.8	24.6	6 036
2010	1 987	0.6	8.1	1 996
2011	805	0.2	3.3	809
2012	1 081	0.3	4.4	1 086
2013	1 074	0.3	4.4	1 079
2014	1 101	0.3	4.5	1 106
2015	1 086	0.3	4.4	1 090
2016	187	0.1	0.8	188
2017	665	0.2	2.7	667
2018	665	0.2	2.7	667
2019	3 867	2.8	11.8	3 881
2020	2 235	1.2	7.9	2 244
2021	2 917	1.6	10.2	2 929
2022	2 193	1.4	7.3	2 202
2023	1 787	1.0	12.1	1 801
2024	1 589	1.4	15.1	1 605

Petroleum refining (1.A.1.b)



Figure 3.9 illustrates the emission trends for 1A1b Petroleum refining and 1A1c Manufacture of solid fuels and other energy industries over the period 1990–2024.

Emissions from petroleum refining (1A1b) increased steadily from the early 1990s, rising from about 2 500 Gg CO₂e in 1990 to a peak of around 4 000 Gg CO₂e in the late 1990s and early 2000s. This growth reflects increased refinery throughput and higher demand for refined petroleum products.

From the mid-2000s onwards, emissions fluctuated but showed an overall gradual decline, with a more pronounced reduction after 2018. The sharp decrease observed between 2020 and 2022 is consistent with reduced refining activity, likely associated with lower fuel demand and operational disruptions. By 2024, emissions remain significantly below their historical peak, indicating a structural decline in refinery-related emissions.

Manufacture of solid fuels and other energy industries (1.A.1.c)

Emissions from the manufacture of solid fuels and other energy industries (1A1c) remained substantially higher throughout the time series. Emissions increased from approximately 26 000 Gg CO₂e in 1990 to a maximum of about 32 000–33 000 Gg CO₂e in the early 2000s, reflecting expansion in coal-based energy and related industrial activities. After this peak, emissions fluctuated at a relatively high level until the mid-2010s, followed by a gradual downward trend.

The decline after 2015 suggests reduced activity in solid fuel manufacturing and efficiency improvements in energy industries. By 2024, emissions decreased to below 28 000 Gg CO₂e, though they remain a dominant source within the energy sector.



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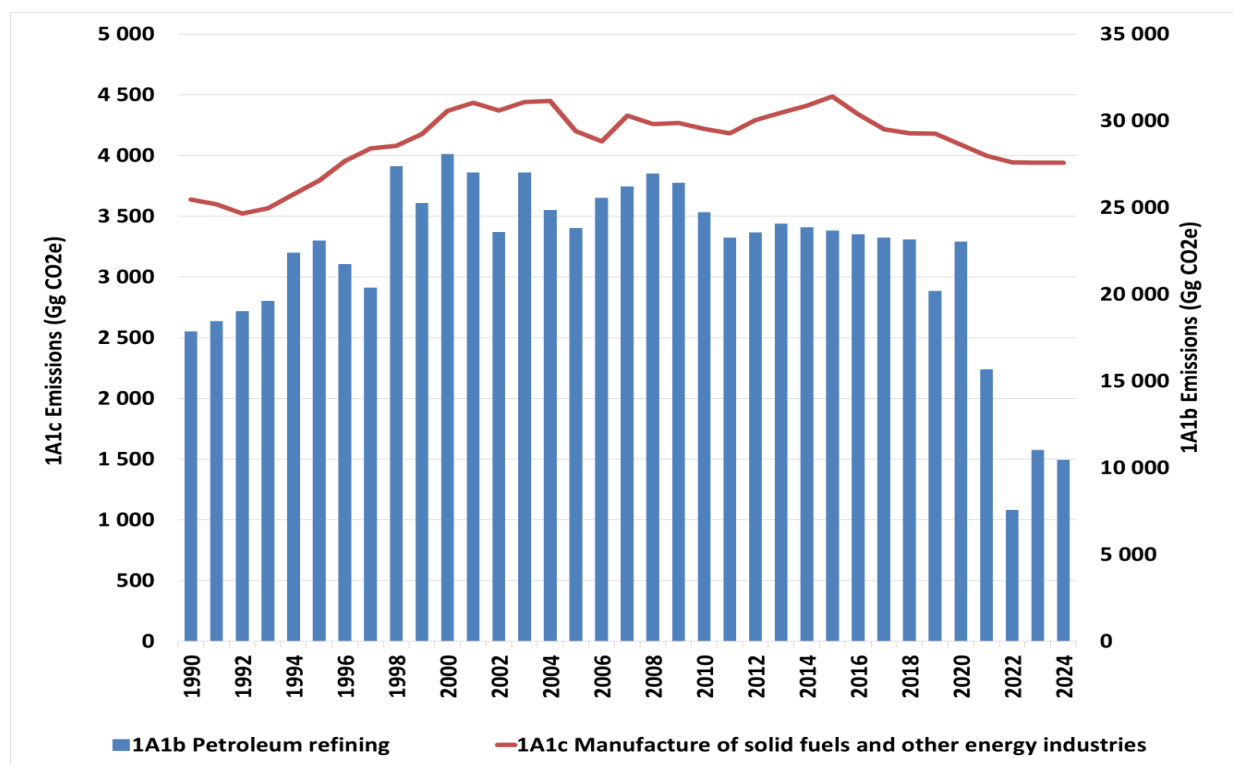


Figure 3.9: Historical emissions from *Petroleum Refining (1A1b)* and *Manufacture of solid fuels and other energy industries (1A1c)*

3.1.1.1.2 Manufacturing industries and construction

Total emissions from fuel combustion activities in the *Manufacturing industries and construction* sectors are shown in Figure 3.10. Emissions from this sector include disaggregated estimates from the *Iron and Steel* and *Non-ferrous Metals* and aggregated emissions for the remainder of 1A2. Emissions from the remainder of 1A2 emissions are reported at an aggregated level because of insufficient data to disaggregate these emissions per manufacturing industry.

Emissions from Manufacturing Industries and Construction show a long-term increase from 1990 to the late 2000s, followed by periods of stabilisation and variability through to 2024, with 1A2 (remainder) consistently dominating sectoral emissions. A decline around 2009 reflects reduced industrial activity during the global economic downturn,



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while a sharper decrease in 2020 is associated with COVID-19-related impacts on manufacturing output.

Emissions increased again after 2020, with higher levels in 2024 linked to the recovery of industrial activity and improved electricity supply conditions, including reduced load shedding.

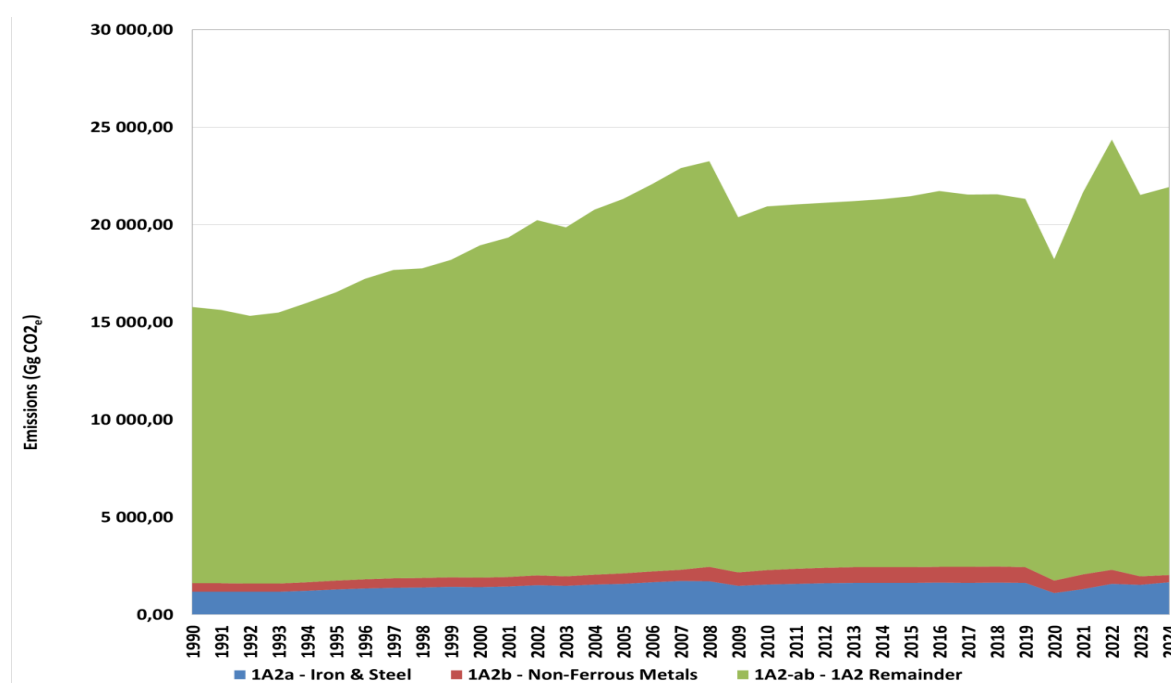


Figure 3.10: 1A2 Disaggregated emissions for subcategory 1A2, 1990-2024

Figure 3.11 shows the trends in fuel use in the *Manufacturing industries and construction* sector. Coal usage dominates the energy demand in industry in South Africa.

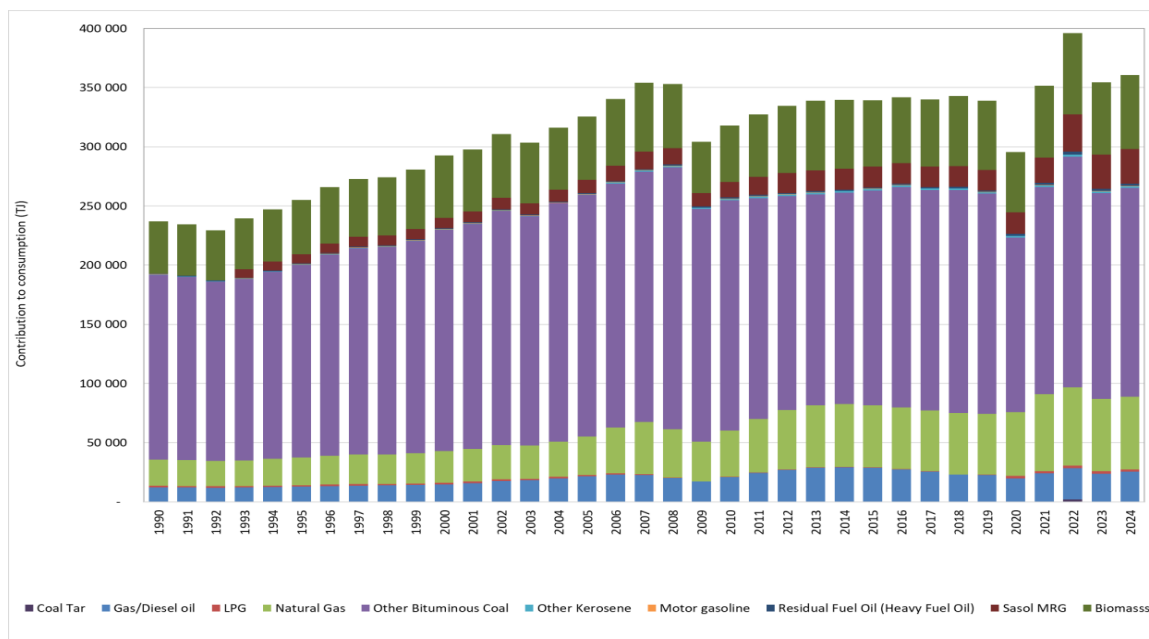


Figure 3.11: Manufacturing industries and construction – fuel consumption contributions

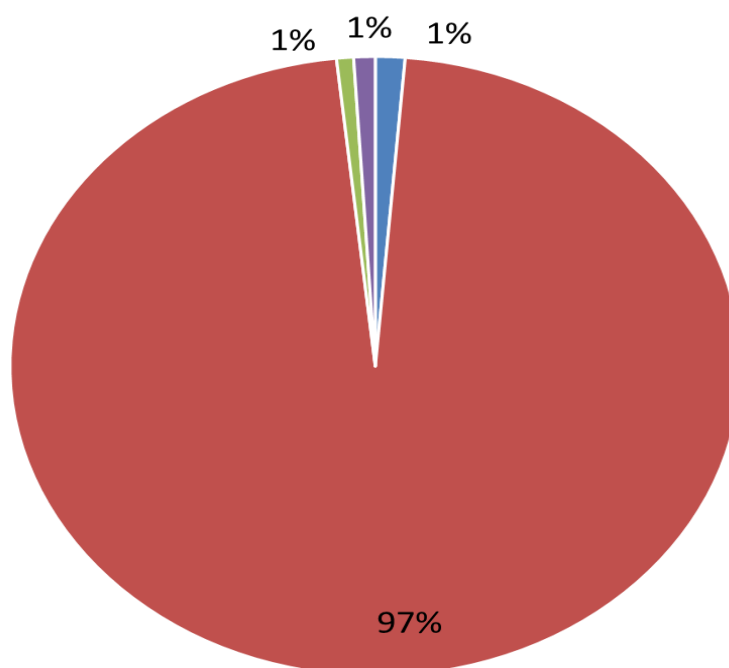
Total fuel consumption in Manufacturing Industries and Construction (Figure 3.11) increased steadily from 1990 to the mid-2000s, driven primarily by coal-based fuels, particularly other bituminous coal, which consistently represent the largest share of energy use. A decline is observed around 2009 and again in 2020, reflecting reduced industrial activity associated with the global economic downturn and COVID-19 impacts, respectively. Consumption recovered thereafter, with higher levels in 2022–2024 linked to increased industrial output and improved electricity supply conditions, while natural gas and liquid fuels remain secondary contributors to total energy use.

Historical emissions from different modes of transport are shown in Table 3.2. *Road transport* has always contributed the most to Transport sector emissions. Figure 3.12 shows the sub-sector contributions for 2024



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■ Domestic aviation ■ Road transportation ■ Railways ■ Domestic navigation

Figure 3.12: Transport sector emission contributions, 2024

Civil Aviation, Railway Transport & Waterborne navigation (1.A.3.a, 1.A.3.c & 1.A.3.d)

Emissions from civil aviation, railway transport and waterborne navigation cumulatively contribute 3 % of the *Transport* sector emissions in 2024. In South Africa these three modes of transportation typically use jet fuel, diesel and fuel oil.

Figure 3.13 shows the annual changes of volumes sold for these fuels since 2018. In 2020, jet fuel experienced the largest decrease sales which in turn resulted in a large drop in emissions from *Civil aviation*.

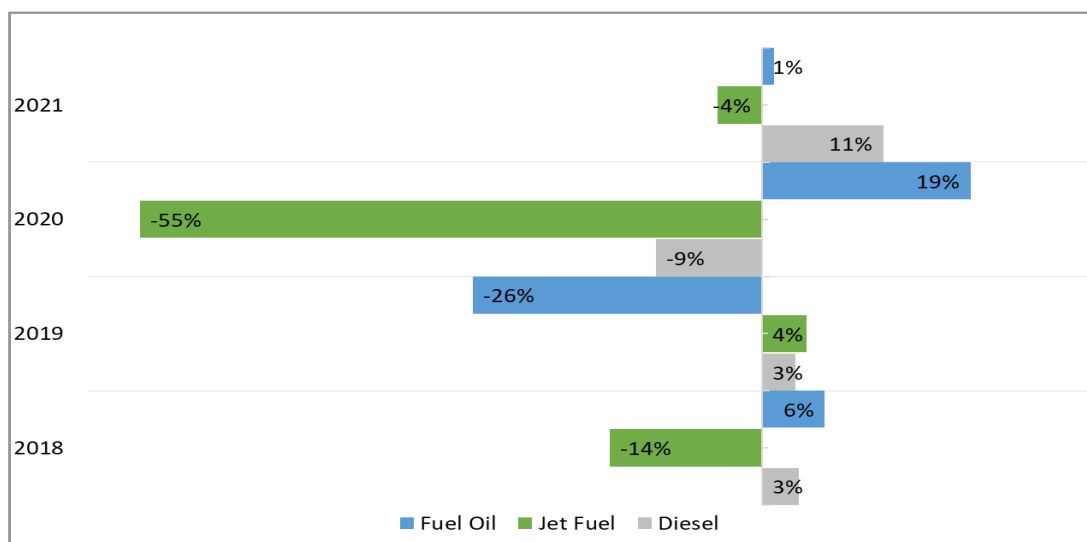


Figure 3.13:: Annual volume changes for fuel oil, jet fuel and diesel sold since 2018⁶

Road Transport (1.A.3.b)

The contribution of motor gasoline to total liquid fuel consumption shows a clear declining trend from approximately 66% in 1990 to about 45% in 2024, while the share of gas/diesel oil increased correspondingly over the same period (Figure 3.14). This shift reflects structural changes in fuel use, including increased reliance on diesel for freight transport, industrial applications, and back-up power generation, particularly during periods of electricity supply constraints.

From around 2016 onwards, gas/diesel oil became the dominant liquid fuel, indicating a sustained transition in consumption patterns.

The share of diesel consumption for *Road transportation* has increased significantly since 2000, from 34% to 55%. This trend has resulted in a decrease in motor gasoline consumption from 66 % to 45 % (Figure 3.14). The historical shares of motor gasoline and diesel consumption in the road transport sector indicate a clear structural shift in fuel use over the period 1990–2024. In the early 1990s, motor gasoline dominated road transport energy consumption, accounting for approximately two-thirds of total fuel use,

⁶ Data from SAPIA 2021 Annual Report, https://www.sapia.org.za/wp-content/uploads/2023/01/SAPIA_AR-2021_Final_LR.pdf

while diesel contributed about one-third. This pattern remained relatively stable until around 2000.

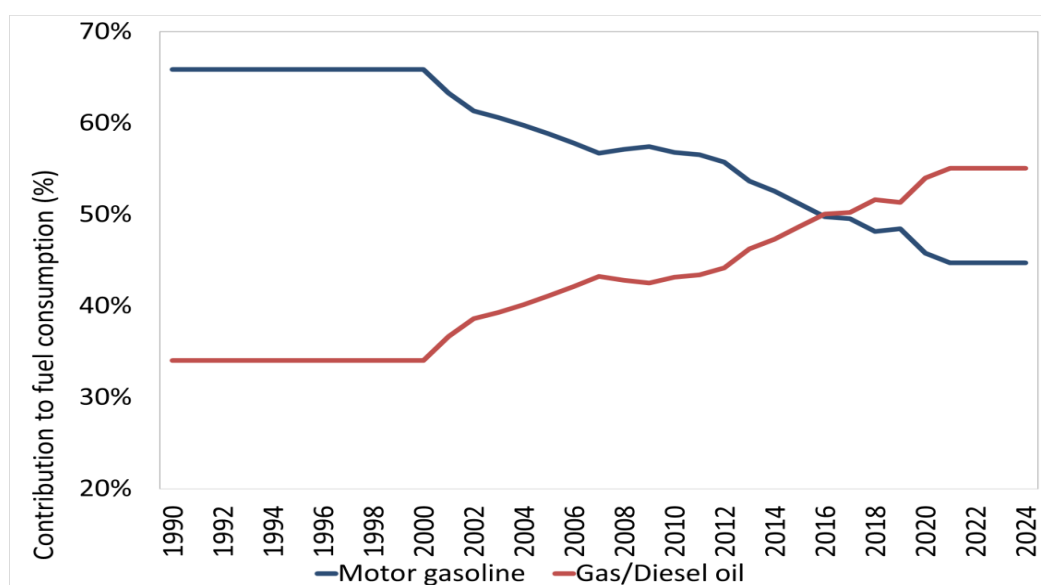


Figure 3.14: Historical share of diesel and motor gasoline consumption for road transportation

3.1.1.1.3 Other Sectors

Table 3.5 shows the disaggregated and total emissions from *Other* sectors. The *Commercial/institutional* and *Residential* sectors have both significantly contributed to emissions *Other* sectors.



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Table 3.5: Trend in emissions from *Other sectors*, 1990-2024

	Commercial/ Institutional	Residential	Agriculture/ Forestry/ Fishing/ Fish farms	Total
	Gg CO ₂ e			
1990	16 069	21 307	2 088	39 464
1991	16 018	21 239	2 081	39 339
1992	15 855	21 023	2 060	38 938
1993	15 516	20 574	2 016	38 106
1994	15 708	24 404	2 041	42 153
1995	16 210	20 827	2 106	39 144
1996	16 713	21 494	2 171	40 378
1997	17 432	22 160	2 259	41 851
1998	17 885	23 113	2 324	43 321
1999	17 974	23 714	2 335	44 023
2000	18 388	23 832	2 391	44 612
2001	18 158	22 168	2 399	42 725
2002	18 001	20 110	2 423	40 534
2003	18 785	18 246	2 487	39 518
2004	20 102	16 377	2 547	39 025
2005	19 481	16 405	2 557	38 443
2006	8 180	14 529	2 588	25 297
2007	8 805	16 122	2 642	27 569
2008	10 199	17 550	2 678	30 427
2009	11 424	18 498	2 737	32 659
2010	7 054	7 506	2 907	17 468
2011	5 152	8 710	3 095	16 956
2012	3 267	7 879	3 043	14 190
2013	1 615	2 453	2 997	7 064
2014	1 639	2 288	2 990	6 917
2015	1 444	2 159	3 003	6 607
2016	10 388	2 065	3 050	15 503
2017	6 631	2 646	3 091	12 368
2018	13 253	2 069	3 133	18 455
2019	14 435	2 778	3 122	20 335
2020	10 773	2 941	3 034	16 748
2021	11 442	3 501	3 048	17 991
2022	11 843	3 559	3 085	18 487



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	Commercial/ Institutional	Residential	Agriculture/ Forestry/ Fishing/ Fish farms	Total
	Gg CO ₂ e			
2023	11 852	3 708	3 085	18 645
2024	11 859	3 708	3 085	18 652

The historical fuel consumption profile for the Commercial sector over the period 1990–2024 shows significant changes in both total energy use and fuel composition (Figure 3.15). In the early part of the time series, total consumption was relatively high and dominated by other bituminous coal, with notable contributions from residual fuel oil and smaller shares of motor gasoline, diesel, LPG, and kerosene. This fuel mix reflects legacy energy-use patterns in commercial and institutional applications, including space heating and on-site energy generation.

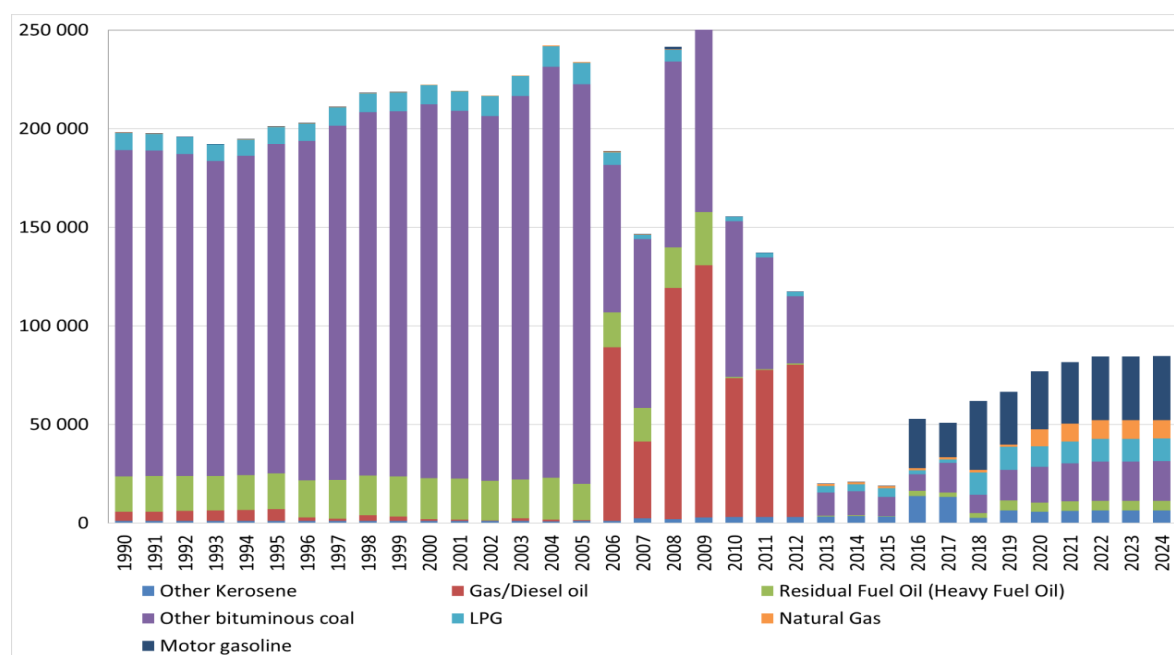


Figure 3.15: Fuel consumption trends for the Commercial/Institutional sector

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From approximately 2005 onwards, a pronounced structural shift in the fuel mix is observed. Consumption of other bituminous coal and residual fuel oil declined sharply, while gas/diesel oil increased substantially, becoming the dominant fuel by the late 2000s. This transition is consistent with fuel switching in the Commercial sector, driven by energy efficiency improvements, regulatory changes, and the gradual phase-out of solid and heavy liquid fuels.

Between 2010 and 2015, total fuel consumption in the Commercial sector decreased markedly, indicating reduced energy demand and/or improved efficiency in commercial activities. From 2016 onwards, a gradual recovery is observed, led primarily by increases in motor gasoline and gas/diesel oil, with emerging contributions from natural gas and LPG in the later years of the time series.

Emissions from the *Residential* sector have significantly decreased steadily by 86% since 2000 and this is aligned with the energy supply trends in households seen in Figure 3.16. The number of households using electricity and other electricity (i.e. generators) has increased since 2002 and because of this the number of households using fuels for cooking have also decreased since 2002, with the exception of the use of gas which has been increasing since 2012.

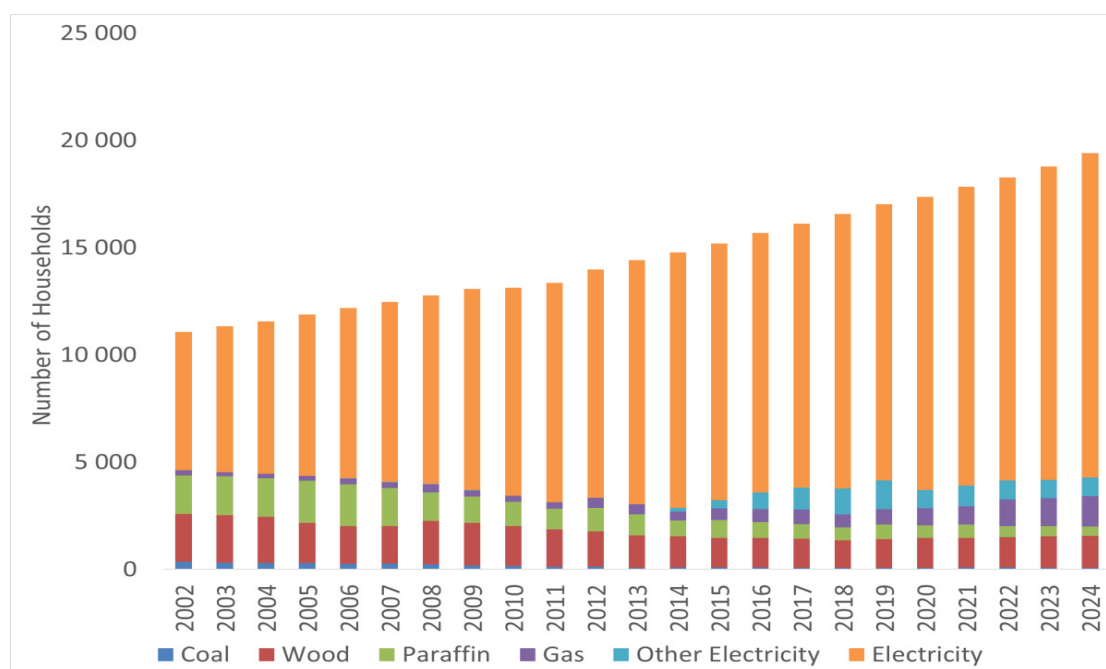


Figure 3.16: Trends in household energy supply for cooking⁷

3.1.1.1.4 Non-specified

The *Non-specified* category is used to report on other *Fuel Combustion* activities that do not fall under the other four sectors (*Energy industries, Manufacturing and construction, Transport & Other*). Emissions allocated to the category are shown in Table 3.2. In 2024, this category made up 7% of the emissions from *Fuel Combustion* activities.

3.1.1.2 **Fugitive emissions from fuels**

The *Fugitive emissions from fuels* sector in 2024 contributed 7.7% to total emissions from the *Energy* sector. The majority of these emissions are from the *Other emissions from energy production*.

⁷ Figure 3.16 shows the cooking energy supply trends of households since 2002. This data excludes the “Other” proportion (which contributes on average about 1% each year) from the StatsSA data. [GHS 2020 P0318 \(statssa.gov.za\)](https://www.statssa.gov.za/publications/P03182020.pdf)



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Table 3.6 shows total historical disaggregated emissions. Fugitive emissions from fuels (Category 1.B) exhibit a stable to moderately declining trend over the time series, increasing gradually to a peak in the mid-2010s before declining to 28 711 Gg CO₂e in the most recent year. The trend is dominated by other emissions from energy production (1.B.3), which account for the majority of emissions and largely drive the observed changes. Emissions from solid fuels (1.B.1) remain small and increase modestly over time, while oil and natural gas (1.B.2) emissions are very low and show a declining trend, contributing a negligible share to total energy-sector emissions.

Table 3.6: Trend in fugitive emissions, 1990-2024

	Solid Fuels	Oil and Natural Gas	Other Emissions from Energy Production	Total
	Gg CO ₂ e			
1990	1 549	784	28 808	31 141
1991	1 580	753	29 037	31 370
1992	1 602	722	29 266	31 590
1993	1 686	691	29 495	31 871
1994	1 753	839	29 723	32 315
1995	1 849	807	29 952	32 608
1996	1 843	775	30 181	32 799
1997	1 967	703	30 410	33 080
1998	2 047	1 452	30 638	34 137
1999	2 033	1 343	30 867	34 243
2000	2 028	976	31 096	34 100
2001	2 077	1 025	31 325	34 426
2002	2 193	1 825	31 830	35 848
2003	2 647	1 175	30 190	34 012
2004	2 467	1 533	32 027	36 026
2005	2 633	1 332	28 217	32 181
2006	2 658	1 146	28 057	31 861
2007	2 701	1 055	28 523	32 279
2008	2 667	1 167	27 129	30 963
2009	3 063	1 300	27 426	31 789
2010	2 917	1 015	27 206	31 138



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	Solid Fuels	Oil and Natural Gas	Other Emissions from Energy Production	Total
	Gg CO ₂ e			
2011	2 685	767	26 817	30 270
2012	2 655	693	27 821	31 169
2013	2 794	686	28 227	31 707
2014	2 765	783	27 783	31 331
2015	2 609	728	27 343	30 680
2016	2 526	744	27 548	30 818
2017	2 662	625	28 446	31 733
2018	2 697	755	27 548	31 000
2019	2 408	666	28 362	31 436
2020	3 292	434	28 381	32 108
2021	3 208	198	27 973	31 379
2022	2 314	121	26 410	28 845
2023	2 400	107	27 869	30 376
2024	2 411	86	26 214	28 711

3.1.1.2.1 Solid fuels

Solid fuels contribute a relatively small share of total fugitive emissions. Emissions from this subcategory increase gradually over time, with some interannual variability, but remain minor compared to 1.B.3. On average, solid fuels account for less than 1% of total energy-sector emissions, indicating a limited influence on overall trends.

3.1.1.2.2 Oil and natural gas

Oil and natural gas emissions are low in absolute terms and display a declining trend, particularly in the later years of the series. This reduction suggests changes in production, improved leakage control, or updated estimation assumptions, and the subcategory contributes only a negligible share ($\approx 0.03\%$) to total energy emissions. Additionally, emissions from the *Oil and natural gas* industry have been decreasing steadily. Two refineries have shut down since 2020 and although the remaining refineries still operational they have not been processing any crude oil in the recent years.



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3.1.1.2.3 *Other emissions from energy production*

Within Category 1.B, Other emissions from energy production (1.B.3) are the dominant source throughout the time series, contributing most fugitive emissions. This subcategory largely drives the overall trend observed in total 1.B emissions, including the post-2015 decline, which may reflect improvements in operational practices, changes in production levels, or updated activity data.

3.1.2 Overview of methodology and completeness

Emissions for the *Energy* sector were estimated with a sectoral approach. Table 3.7 provides a summary of the methods and emission factors applied to each subsector.

Table 3.7: Summary of methods, emission factors and completeness for the Energy sector

GHG Source and sink category		CO ₂		CH ₄		N ₂ O		NO _x	CO	NMV OC	SO ₂
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
1A	Fuel combustion activities										
1A1	Energy industries										
	a. Main activity electricity and heat production	T2	CS	T1	DF	T1	DF	NE	NE	NE	NE
	b. Petroleum refining	T1, T2	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
	c. Manufacture of solid fuels and other energy industries	T3	CS	T3	CS	T3	CS	NE	NE	NE	NE
1A2	Manufacturing industries and construction	T1, T2	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
1A3	Transport										
	a. Civil aviation	T1	CS	T1	DF	T1	DF	NE	NE	NE	NE
	b. Road transportation	T2	CS	T1	DF	T1	DF	NE	NE	NE	NE
	c. Railways	T2	CS	T1	DF	T1	DF	NE	NE	NE	NE
	d. Water-borne navigation	T2	CS	T1	DF	T1	DF	NE	NE	NE	NE


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GHG Source and sink category		CO ₂		CH ₄		N ₂ O		NO _x	CO	NMV OC	SO ₂
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
	e. Other transportation	NO		NO		NO		NO	NO	NO	NO
1A4	Other sectors										
	a. Commercial/ Institutional	T1, T2	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
	b. Residential	T1, T2	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
	c. Agriculture/ Forestry/ Fishing/ Fish farms	T1, T2	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
1A5	Non-specified										
	a. Stationary	T1, T2	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
	b. Mobile	IE		IE		IE		IE	IE	IE	IE
1B	Fugitive emissions from fuels										
1B1	Solid fuels										
	a. Coal mining and handling	T2	CS	T2	CS						
	b. Uncontrolled combustion and burning coal dumps	NE		NE		NE		NE	NE	NE	NE
	c. Solid fuel transformation	T1	DF	T1	DF	T1	DF	NE	T1	NE	NE
1B2	Oil and natural gas										
	a. Oil	T3		T3		T3		NE	NE	NE	
	b. Natural gas	T3		T3		T3		NE	NE	NE	
1B3	Other emissions from energy production	T3		T3		NO		NE	NE	NE	NE
1C	Carbon dioxide transport and storage										
1C1	Transport of CO ₂										
	a. Pipelines	NE									
	b. Ships	NE									
	c. Other	NE									
1C2	Injection and storage										
	a. Injection	NE									



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GHG Source and sink category		CO ₂		CH ₄		N ₂ O		NO _x	CO	NMV OC	SO ₂
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
	b. Storage		NE								
1C3	<i>Other</i>		NE								

3.1.3 Improvements and recalculations

Recalculations were performed for the Energy sector due to methodological improvements, specifically the application of country-specific CO₂ emission factors for solid fuels in place of default IPCC values. These factors were derived from a Study, completed in 2022, consequently, emissions for the entire time series were recalculated for the applicable fuel combustion activities to ensure methodological consistency and improved national representativeness.

Figure 3.17 shows the historical trend in total energy sector GHG emissions from 1990 to 2024, comparing the current submission with the previous submission.

Minor differences between the current and previous submissions result from recalculations undertaken to maintain time-series consistency in line with the IPCC 2006 Guidelines. The improvements mentioned above resulted in the current inventory being lower than the previous inventory estimates, indicating a slight reduction in total emissions between the two inventory years



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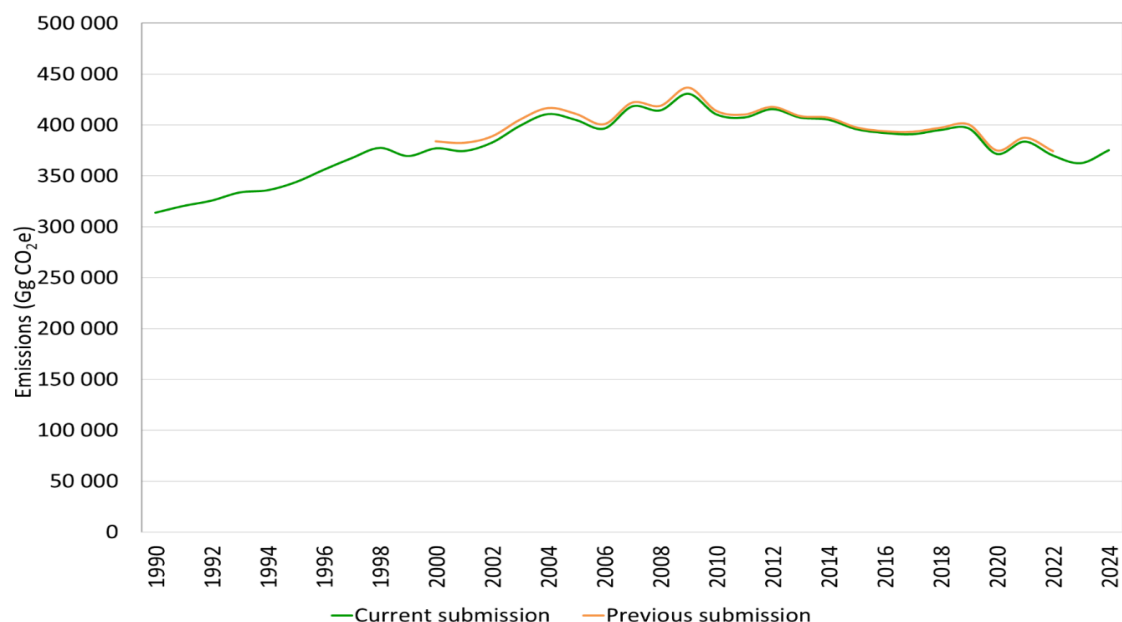


Figure 3.17: Recalculations for the Energy sector since the last submission in 2022

3.1.4 Key categories in the energy sector

The key categories for the Energy sector as determined by the level (L) and trend (T) assessment are shown in Table 3.8.

Table 3.8: Key categories identified in the Energy sector

IPCC code	IPCC Category	GHG [#]	Criteria
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	L,T
1.A.4	Other Sectors - Solid Fuels	CO ₂	L,T
1.A.3.b	Road Transportation	CO ₂	L,T
1.A.4	Other Sectors - Liquid Fuels	CO ₂	L,T
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	L,T
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO ₂	L,T
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO ₂	L,T
1.A.3.a	Domestic Aviation	CO ₂	L,T



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IPCC code	IPCC Category	GHG#	Criteria
1.B.3	Fugitive emissions from - Other emissions from energy production	CO ₂	L,T
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO ₂	L,T
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO ₂	L,T
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO ₂	T
1.B.2	Oil and Natural Gas	CO ₂	T

3.1.5 QA/QC process and verification

Generic QA/QC measures were conducted for the *Energy* sector calculation file, as indicated in Table 3.9.

Table 3.9: QA/QC measures for the Energy sector inventory

QA/QC principle	Check
Accuracy	Activity data source
Accuracy	Correct units
Accuracy	Unit carry through
Accuracy	Method validity
Accuracy	Calculations check
Accuracy	Uncertainties
Accuracy	Double counting
Accuracy	Correct GWP
Accuracy	Notation keys
Accuracy	Calorific values
Accuracy	Oxidation factors
Accuracy	Carbon content
Accuracy, Completeness, Consistency, Transparency	Trend check
Accuracy, Transparency	Emission factor applicability
Accuracy, Transparency, Consistency, Completeness	Recalculations
Completeness, Comparability	Sub-category completeness
Consistency	Time series consistency
Transparency	Documentation
Transparency, Completeness, Consistency, Accuracy	Colour coding
Accuracy, Comparability	Cross check data
Accuracy	Spot checks
Transparency, Consistency	Data source referencing
Transparency	Links to source data



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QA/QC principle	Check
Transparency	Raw primary data
Accuracy	QA review

3.1.6 Planned improvements

Improvements planned for the Energy sector are as follows:

- Improving activity data for fuel wood consumption in different sub-sectors.
- Including emissions from abandoned mines and spontaneous combustion.
- Disaggregating the uncertainty assessment to align with the disaggregation used for key category analysis.

3.2 Fuel combustion (CRT 1.A)

3.2.1 Comparison between sectoral and reference approach

The emissions reported for *Fuel combustion* activities are estimated using the Sectoral Approach. The Reference Approach was also used estimate emissions, and the comparison of the two approaches is shown in Figure 3.18. The comparison is done until 2022 in accordance with the latest available energy balance data from the DEE.

The Reference Approach resulted in higher estimates than the Sectoral Approach, as was the case with previous inventories. The comparison between the Reference Approach (RA) and Sectoral Approach (SA) shows that both time-series follow a similar overall trajectory, with steady growth in CO₂ emissions from 1992 to approximately 2008, followed by a period of stabilisation and moderate inter-annual fluctuations. Emissions increased significantly during the pre-2008 period, reflecting expansion in fossil fuel combustion, particularly in electricity generation and industrial activities. A noticeable dip is observed around 2020, consistent with reduced economic activity, followed by a recovery in 2021 and 2022.

However, the magnitude of emissions differs substantially between the two approaches, with the Reference Approach consistently reporting higher values than the Sectoral Approach, and the gap widening over time. While differences were minimal in the early



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1990s, they become pronounced from the mid-2000s onward, indicating growing divergence between energy balance data and sectoral fuel consumption statistics.

The increasing discrepancy between the Reference Approach (RA) and the Sectoral Approach (SA) over time is primarily attributable to structural and methodological differences in the underlying datasets and calculation procedures. The RA is based on national energy balance statistics and includes adjustments for stock changes, transformation sector inputs, and energy industry own-use, whereas the SA relies on disaggregated sectoral fuel consumption data reported by end-users. Differences may therefore arise from inconsistencies between energy supply and sectoral consumption data, variations in calorific values applied, the treatment of non-energy use, and the allocation of transformation losses. As total fuel consumption increased over the time series, minor inconsistencies in activity data or conversion parameters may have been amplified, contributing to the widening divergence observed in recent years.

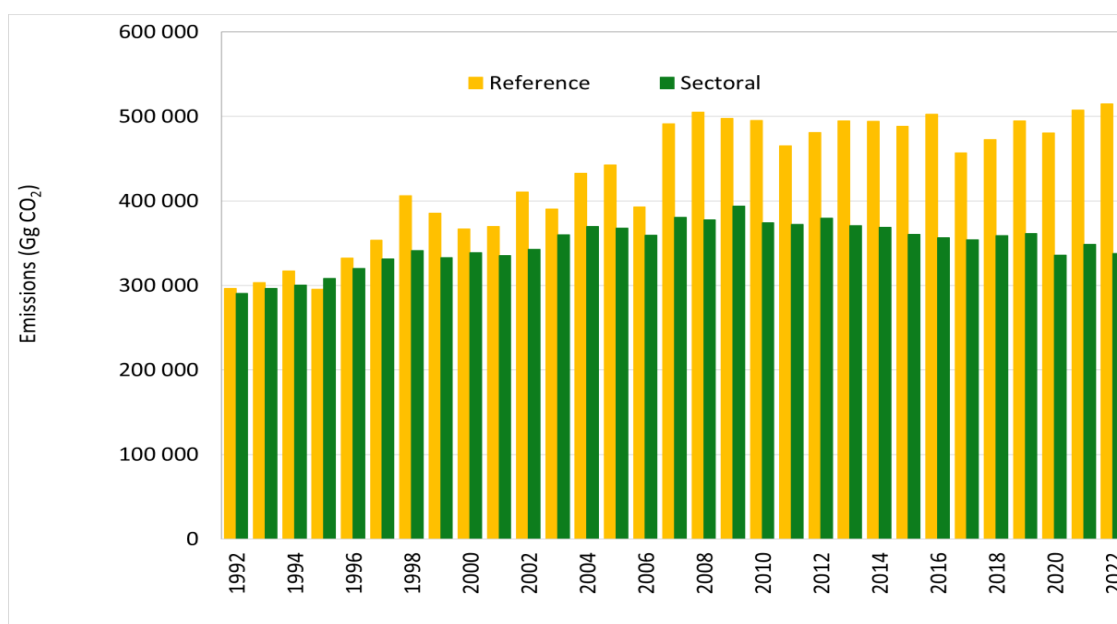


Figure 3.18: Comparisons between the reference and sectoral approach of determining the CO₂ emissions for the energy sector

Annex III shows the comparison between the Reference and Sectoral Approach for solid, fuel and gaseous fuels consumption between 1992 and 2022. The comparison of fuel

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consumption data from 1990 to 2022 reveals varying levels of alignment across fuel categories. Solid fuel consumption shows a persistent and widening gap, with the Reference Approach consistently exceeding the Sectoral Approach by approximately 30%, suggesting potential under-reporting in end-use sectors or significant transformation losses. Gaseous fuels exhibited a similar structural discrepancy for much of the time series, often showing a Reference-to-Sectoral ratio of 2:1, until a notable convergence in 2021–2022 indicated improved data reconciliation. Conversely, liquid fuels demonstrated the strongest alignment, particularly between 2004 and 2018, despite early-period volatility and a significant Reference spike in 2002.

Overall, while the inventory shows improving trends in data consistency for gaseous and liquid fuels, the sustained discrepancy in solid fuels highlights a key area for further investigation into national energy balance statistics and sectoral coverage. The difference in consumption and estimates for both approaches is due to:

- Missing information on stock changes that may occur at the final consumer level. The relevance of consumer stocks depends on the method used for the Sectoral Approach.
- Unrecorded consumption of gas or other fuels may lead to an underestimation of the Sectoral Approach.
- The treatment of transfers and reclassifications of energy products may cause a difference in the Sectoral Approach estimation since different net calorific values and emission factors may be used depending on how the fuel is classified.
- Activity data on liquid fuels in the Sectoral Approach particularly for energy industries is sourced directly from the companies involved and has been reconciled with other publicly available datasets.
- Inconsistencies on the sources of activity data within the time series and in some cases the application of extrapolation.
- The misallocation of the quantities of fuels used for conversion into derived products (other than power or heat) or quantities combusted in the energy sector.

3.2.2 International bunker fuel

As per the IPCC 2006 Guidelines international aviation as well as marine bunkers must be reported separately from the national total emissions. The activity data for both international aviation and Navigation bunkers was sourced from the fuels consumption study. The Fuel Consumption Study looked into estimating fuel consumption from all



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domestic, international, cargo, courier and other non-passenger flights, including non-scheduled flights. This was done by considering data from the Airports Company South Africa such as the record statement of air traffic movements.

Table 3.10 provides the emissions data from international bunker fuels, covering two major sources: International Aviation and International Navigation Bunkers. Total emissions increased during the early 1990s, reaching a peak in the early 1990s primarily driven by higher emissions from international waterborne navigation. Following this peak, total emissions declined through the mid-1990s, reflecting reduced maritime activity. From the late 1990s to around 2008, total emissions showed a generally upward trend, supported by steady growth in international aviation emissions and relatively stable but elevated emissions from international waterborne navigation.

Table 3.10: Emissions from International Bunker Fuels

Year	International Aviation Emissions (Gg CO ₂ e)	International Waterborne Navigation Emissions (Gg CO ₂ e)	Total Emissions (Gg CO ₂ e)
1990	3 996	8 608	12 605
1991	3 996	8 591	12 587
1992	3 193	12 216	15 408
1993	2 833	9 594	12 427
1994	2 717	9 286	12 004
1995	2 787	7 698	10 485
1996	2 588	7 671	10 259
1997	2 407	10 118	12 525
1998	2 229	8 044	10 272
1999	2 264	7 198	9 462
2000	2 813	8 703	11 516
2001	3 017	8 740	11 757
2002	3 333	7 997	11 330
2003	3 616	8 157	11 773
2004	3 857	7 537	11 394
2005	4 109	8 085	12 194
2006	4 354	7 789	12 142
2007	4 517	8 074	12 591
2008	4 559	8 166	12 724
2009	4 536	7 717	12 252
2010	4 530	2 218	6 749
2011	4 578	2 100	6 678



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Year	International Aviation Emissions (Gg CO ₂ e)	International Waterborne Navigation Emissions (Gg CO ₂ e)	Total Emissions (Gg CO ₂ e)
2012	4 642	3 767	8 409
2013	4 808	2 182	6 990
2014	4 839	1 512	6 351
2015	4 897	1 824	6 721
2016	4 945	1 558	6 502
2017	5 102	1 681	6 783
2018	5 115	1 376	6 490
2019	5 317	1 376	6 693
2020	2 378	1 375	3 754
2021	2 285	1 375	3 660
2022	2 328	1 376	3 704
2023	2 491	1 472	3 963
2024	2 641	1 560	4 201

A pronounced decline in total emissions is observed around 2009–2010, corresponding to a sharp reduction in international waterborne navigation emissions. This period aligns with the global economic downturn, which significantly affected international trade and shipping activity. After 2010, emissions partially recovered but remained below pre-2009 levels, with moderate inter-annual variability.

International aviation emissions increased steadily up to 2019, indicating growth in international air traffic, while emissions from international waterborne navigation remained comparatively lower and more stable. A substantial decrease in both categories is evident in 2020, reflecting the impact of COVID-19 travel restrictions and disruptions to global transport. Although some recovery is observed after 2021, emissions in 2024 remain below historical maxima, particularly for international aviation.

Overall, the trends indicate that international waterborne navigation has historically been the dominant contributor to total emissions, while international aviation shows stronger long-term growth and higher sensitivity to economic shocks. The post-2010 and post-2020 declines highlight the influence of global economic conditions and structural changes in international transport activity on South Africa's international bunker fuel emissions.

3.2.3 Feedstock and non-energy use of fuels



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There are cases where fuels are used as raw materials in production processes. For example, in iron and steel production, coal is used as a feedstock in the manufacture of steel. The IPCC 2006 Guidelines emphasize the significance of separating energy and process emissions to prevent double counting the industrial and energy sectors. Therefore, to avoid double counting, coal used for metallurgical purposes has been accounted for under the IPPU sector. Information on feed stocks and non-energy use of fuels has been sourced from the national energy balance tables. The sources considered include coal used in iron and steel production, the use of fuels as solvents, lubricants and waxes, and the use of bitumen in road construction.

3.2.4 Common Data used for Fuel Combustion Activities

This section outlines the net calorific values, densities (Table 3.11) and emission factors (Table 3.12) used to estimate emissions from fuels used in under the various Fuel Combustion subcategories.

Table 3.11: Country-specific net calorific values and densities for solid, liquid and gaseous fuels⁸

Fuel	Net calorific value	Unit	Density (kg/l)
Coal: Eskom Average	20.1	MJ/kg	
Coal: General purpose	24.3	MJ/kg	
Coal: Coking	30.1	MJ/kg	
Coke	27.9	MJ/kg	
Biomass (wood dry typical)	17	MJ/kg	
Wood charcoal	31	MJ/kg	
Paraffin	37.5	MJ/l	0.765
Diesel	35.5	MJ/l	0.826
Heavy Fuel Oil	43	MJ/kg	0.994
Fuel Oil 18 Yeah0	42	MJ/kg	0.99
Petrol	32.5	MJ/l	0.741
Avgas (100LL)	33.9	MJ/l	0.714
Jet Fuel (Jet-A1)	37.5	MJ/l	0.79
LPG	46.29	MJ/Nm ³	0.555
Sasol gas (MRG)	33.6	MJ/Nm ³	
Natural gas	38.1	MJ/Nm ³	
Blast furnace gas	3.1	MJ/Nm ³	
Refinery gas	20	MJ/Nm ³	

⁸ Values are from the South African Petroleum Industry Association (SAPIA) and from the study Development of country-specific CO₂ emissions factors for key liquid and gaseous fuels in South Africa <https://energyjournal.africa/article/view/13592>



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Fuel	Net calorific value	Unit	Density (kg/l)
Coke oven gas	17.3	MJ/Nm ³	

Table 3.12: IPCC default and country-specific emission factors for fuel combustion⁹

Fuel ¹⁰		CO ₂		CH ₄	N ₂ O
		DF (Tier 1)	CS (Tier 2)	DF (Tier 1)	DF (Tier 1)
Liquid	Motor gasoline	69 300	72 430	3	0.6
	Aviation gasoline	70 000	65 752	3	0.6
	Jet gasoline	70 000	65 752	3	0.6
	Jet kerosene	71 500	73 463	3	0.6
	Other kerosene	71 900	64 640	3	0.6
	Gas/Diesel oil	74 100	74 638	3	0.6
	Residual fuel oil	77 400	73 090	3	0.6
	Liquified petroleum gases	63 100	64 852	1	0.1
	Bitumen	80 700	NA	3	0.6
	Petroleum coke	97 500	NA	3	0.6
Solid	Anthracite	98 300	93 331	1	1.5
	Coking coal	94 600	87 099	1	1.5
	Other bituminous coal	94 600	76 710	1	1.5
	Sub-bituminous coal	96 100	96 773	1	1.5
	Coke oven coke and lignite coke	107 000	NA	1	1.5
	Gas coke	107 000	NA	1	0.1
	Gas works gas	44 400	NA	1	0.1
	Coke oven gas	44 400	NA	1	0.1
	Blast furnace gas	260 000	NA	1	0.1
	Oxygen steel furnace gas	182 000	NA	1	0.1
Gases	Natural gas	56 100	55 709	1	0.1
Biomass	Wood/wood waste	112 000	NA	30	4
	Other primary solid biomass	100 000	NA	30	4
	Charcoal	112 000	NA	30	4

South Africa's country-specific CO₂ emission factors were higher than the IPCC default emission factors for motor gasoline (5%), jet kerosene (3%), diesel (1%), LPG (3%) and sub-bituminous coal (0.2%). On the other hand, the country-specific CO₂ emission factors

⁹ Country-specific emission factors for liquid and gaseous fuels are from the study *Development of country-specific CO₂ emissions factors for key liquid and gaseous fuels in South Africa* <https://energyjournal.africa/article/view/13592>

¹⁰ These fuels are defined as per the definitions given in the IPCC 2006 Guidelines.



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were lower than the default emission factors for aviation gasoline (6%), jet gasoline (6%), other kerosene (10%) and residual fuel oil (6%).

The country-specific CO₂ emission factors in Table 3.12 were developed from studies that included collecting fuel samples from across the country and during different seasons, where applicable.¹¹ Hence, even though these emission factors may differ from the IPCC default emissions factors, they more accurately represent the fuels used in the country.

3.2.5 Energy industries (CRT 1.A.1)

3.2.5.1 Category description

The *Energy Industries* sub-category includes fuel combustion activities from the following industries:

- 1A1a *Electricity and heat production* – In South Africa's inventory this is further disaggregated into main electricity producer and other electricity producers and hence includes all emissive electricity production plants that feed into the national grid. Emissions from auto-producers are accounted for under the respective main industry for which the fuel combustion occurs.
- 1A1b *Petroleum refining* – this includes all fuel combustion emissions from crude oil refining as well as natural extraction. Emissions from this activity have been decreasing due to limited oil reserves and the closure of major refineries in the recent years.
- 1A1c *Manufacture of solid fuels and other energy industries* – this includes fuel combustion emissions associated with the production of secondary and tertiary fuels, including natural gas processing and upgrading. This sub-category currently does not include combustion emissions from charcoal and coke production. Combustion emissions from both are currently included elsewhere under the respective 1A2 sub-categories due mass balance approaches that currently do not disaggregate these emissions explicitly.

3.2.5.2 Methodological issues

Table 3.7 indicates the type of methods and emission factors used for all categories under the Energy sector, including at sub-category level.

¹¹ LPG is the only exception due to limitations on analysis. More details on this can be found in the journal article for the study.
<https://energyjournal.africa/article/view/13592>



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The activities shown in Table 3.13 were indicated as key categories in the 1990-2024 inventory. Emissions from 1A1a *Electricity and Heat Production* (solid) and 1A1c *Manufacture of solid fuels and other energy industries* (liquid) were estimated using higher tier methods for the 1990-2024 inventory. Hence, no change in methodology was required for these sub-categories for the 1990-2024 inventory.

However, to ensure that good practise was followed, changes in methodology were required for emissions from 1A1a *Electricity and Heat Production* (liquid) and 1A1b *Petroleum Refining* (gas). These changes are indicated in Table 3.13. The only deviation is the estimation of emissions from refinery gas under 1A1b *Petroleum Refining*, which still uses Tier 1 and the IPCC default emission factor. This deviation is due to a lack of country specific emission factors.

Table 3.13: Methodological details - Energy Industries

1990-2024 Key category	2000-2022 inventory		1990-2024 inventory		Notes
	Method	Emission Factor	Method	Emission Factor	
1A1a Electricity and heat production (solid, CO ₂)	T1	DF	T2	CS	Emissions from solid fuels estimated using CS parameters.
1.A.4 Other Sectors - Solid Fuels	T2	CS	T2	CS	Emissions from all liquid fuels estimated using CS parameters.
1.A.3.b Road Transportation	T1	DF	T1, T2	DF, CS	Natural gas: T2, CS MRG: T2, CS Refinery gas: T1, DF
1.A.4 Other Sectors - Liquid Fuels	T3	NA	T3	NA	NA

3.2.5.2.1 Activity data

Table 3.14 shows the type and sources of activity data used to estimate emissions from 1A1 *Energy industries*. Majority of the activity data for 2000-2024 for the *Energy industries* sub-category was retrieved from the GHG Reporting Program with the assistance of the NGER. Activity data for the period 1992-2000 were obtained from the national energy balance compiled by the Department of Electricity and Energy. No corresponding activity data were available for the years 1990-1991. To address this data



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gap, gross domestic product (GDP) data from Statistics South Africa (Stats SA) were used to back-cast and extrapolate the missing activity data for the early years of the time series.

Table 3.14: Activity data used for 1A1 Energy Industries

Sub-category	Activity Data	Source
1A1a <i>Electricity & heat production</i>	Fuel consumption for both main and other electricity producers	Energy balance, SAGERS and Manual GHG reporting program
	NCVs & densities	SAGERS and Manual GHG reporting program Kornelius <i>et al</i> 2023
1A1b <i>Petroleum refining</i>	Fuel consumption	Refineries SAGERS and Manual GHG reporting
	NCVs & densities	Kornelius <i>et al</i> 2023
1A1c <i>Manufacture of solid fuels & other energy industries</i>	NA – Emissions sourced from	Producers SAGERS and Manual GHG reporting

For the 1A1c sub-category emissions from South Africa's GHG Reporting Programme are used directly in the inventory. These emissions are from a mass balance approach used by the relevant companies over their operations. This approach and the resulting emissions have been independently verified as part of the GHG Emissions Verification Programme. Where petroleum refining and petrochemical production occurs at the same facility, the resulting emissions are differentiated.

Table 3.15 presents fuel consumption trends for public electricity producers, auto electricity producers, and petroleum refining over the period 1990–2024, expressed in terajoules (TJ).

Fuel consumption by public electricity producers dominates the time series and shows a strong long-term increase from 1.29 million TJ in 1990 to a peak of approximately 2.54 million TJ in 2012. This growth reflects the expansion of coal-based electricity generation to meet rising electricity demand. After 2012, fuel consumption declined gradually, reaching about 2.20 million TJ in 2019, consistent with reduced electricity generation, operational constraints, and increasing supply challenges in the power sector. A sharper reduction is observed in 2020, coinciding with lower economic activity. Partial recovery occurs thereafter; however, by 2024 fuel consumption (2.04 million TJ) remains below the historical peak, indicating a structural moderation in electricity sector fuel use.



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Table 3.15: Trend in fuel consumption for the various categories in the energy industry sector, 1990-2024

	Public electricity producer	Auto electricity producer	Petroleum refining
	Fuel consumption (TJ)		
1990	1 291 796	134 888	37 898
1991	1 378 736	120 954	39 153
1992	1 465 676	1 261	40 408
1993	1 553 616	93 086	41 663
1994	1 590 714	93 550	47 545
1995	1 660 325	104 725	49 046
1996	1 752 999	100 517	46 153
1997	1 846 589	103 304	43 260
1998	1 920 677	111 337	58 131
1999	1 810 155	114 971	53 626
2000	1 810 155	117 430	59 638
2001	1 806 320	47 910	57 599
2002	1 883 709	51 923	50 680
2003	2 025 822	83 014	57 487
2004	2 126 649	65 100	53 292
2005	2 142 682	28 363	51 610
2006	2 155 477	40 100	55 121
2007	2 369 988	43 928	56 073
2008	2 271 791	36 489	57 870
2009	2 335 101	62 276	56 523
2010	2 406 936	20 594	52 520
2011	2 426 965	8 346	50 235
2012	2 537 365	11 206	51 049
2013	2 477 632	11 129	51 890
2014	2 423 731	11 414	51 504
2015	2 343 934	11 250	51 118
2016	2 259 087	1 943	50 731
2017	2 233 426	6 887	50 345
2018	2 221 443	6 887	50 147
2019	2 199 965	46 215	49 952
2020	2 116 465	25 074	52 844
2021	2 165 560	32 941	35 140



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	Public electricity producer	Auto electricity producer	Petroleum refining
	Fuel consumption (TJ)		
2022	2 028 038	25 307	17 065
2023	1 938 547	18 531	24 060
2024	2 043 594	16 462	22 664

Fuel consumption by auto electricity producers is substantially lower and exhibits high inter-annual variability. Levels declined markedly from 134 888 TJ in 1990 to very low values in the early 1990s, followed by intermittent increases and decreases throughout the time series. Periods of relatively higher consumption, such as in the late 1990s, early 2000s, and again in 2019, suggest episodic operation of auto-generation facilities, likely driven by site-specific industrial demand and electricity supply constraints. From 2020 onwards, auto-producer fuel consumption declines again, reaching 16 462 TJ in 2024, indicating reduced reliance on or operation of auto-generation facilities.

Fuel consumption in petroleum refining increased gradually from 37 898 TJ in 1990 to levels exceeding 55 000 TJ in the late 1990s and mid-2000s, reflecting stable refinery operations and demand for refined petroleum products. From around 2010 onwards, fuel consumption shows a downward trend, with a pronounced decline after 2020. The sharp reduction observed between 2021 and 2022, followed by continued low levels through 2024, is consistent with reduced refinery throughput, refinery closures or maintenance outages, and structural changes in the domestic refining sector.

Overall, the trends indicate that public electricity production remains the primary driver of fuel consumption within the energy industries, while auto electricity production and petroleum refining contribute comparatively smaller but more variable shares. The post-2012 and post-2020 declines across all three categories highlight the combined influence of economic conditions, operational constraints, and structural changes in South Africa's energy and refining sectors.

3.2.5.2.2 Emission factors

The emission factors used are shown in Table 3.12. Where a country-specific emission factor is available, it was used to estimate emissions from that fuel.

3.2.5.3 **Uncertainty**



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The uncertainties for activity data and the emission factors used to estimate emission from *Energy Industries* is shown in Table 3.16.

Table 3.16: Uncertainty for the *Energy Industries* category.

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1A1a Electricity generation – liquid	5	IPCC 2006	7	IPCC 2006
	1A1a Electricity generation – solid	5	IPCC 2006	7	IPCC 2006
	1A1b Petroleum refining – liquid	5	IPCC 2006	7	IPCC 2006
	1A1b Petroleum refining – gaseous	5	IPCC 2006	7	IPCC 2006
	1A1c Manufacture of solid fuels – liquid	5	IPCC 2006	7	IPCC 2006
CH ₄	1A1a Electricity generation – liquid	5	IPCC 2006	75	IPCC 2006
	1A1a Electricity generation – solid	5	IPCC 2006	75	IPCC 2006
	1A1b Petroleum refining – liquid	5	IPCC 2006	75	IPCC 2006
	1A1b Petroleum refining – gaseous	5	IPCC 2006	75	IPCC 2006
	1A1c Manufacture of solid fuels – liquid	5	IPCC 2006	75	IPCC 2006
N ₂ O	1A1a Electricity generation – liquid	5	IPCC 2006	75	IPCC 2006
	1A1a Electricity generation – solid	5	IPCC 2006	75	IPCC 2006
	1A1b Petroleum refining – liquid	5	IPCC 2006	75	IPCC 2006
	1A1b Petroleum refining – gaseous	5	IPCC 2006	75	IPCC 2006
	1A1c Manufacture of solid fuels – liquid	5	IPCC 2006	75	IPCC 2006

3.2.5.4 Time-series consistency

3.2.5.4.1 1A1a Electricity and heat production

The time-series for 1A1a *Electricity and heat production* is complete and consistent from 1990-2024.

3.2.5.4.2 1A1b Petroleum refining

The time-series for 1A1b *Petroleum refining* is complete and consistent from 1990-2024.

3.2.5.4.3 1A1c Manufacture of solid fuels and other energy industries

The time-series for 1A1c *Manufacture of solid fuels and other energy industries* is complete and consistent from 1990-2024.



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3.2.5.5 Category specific QA/QC and verification

The QA/QC measures indicated in Table 3.9 were used for this category. In addition to this the following category-specific checks are done.

For 1A1a:

- Energy balance data on fuels used for electricity production
- Public domain reports on electricity production
- GHG Emissions Verification Programme

1A1b:

- 1B2 emissions trends
- GHG Emissions Verification Programme

1A1c:

- GHG Emissions Verification Programme

3.2.5.6 Category specific improvements and recalculations

Recalculations were performed for the *Energy industries* sector because of the following improvement:

- The use of country-specific emission factors for commonly used liquid and gas fuels. The emission factors result from a study that was completed in 2022. Emissions from the entire time-series were recalculated for the applicable *Fuel combustion* activities.

3.2.5.7 Category specific planned improvements

Improvements planned specifically for the *Energy Industries* sector are as follows:

- Updating the uncertainty values to incorporate uncertainty of the country-specific emission factors and plant specific emissions used.
- Completing the time-series for:
 - diesel consumption from other electricity producers prior to 2019 for 1A1a Electricity and Heat Production.
 - diesel, natural gas, MRG and LPG consumption prior to 2019 for 1A1b Petroleum refining.



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3.2.6 Manufacturing industries and construction (CRT 1.A.2)

3.2.6.1 Category description

The *Manufacturing industries and construction* sub-category includes fuel combustion activities from the industries shown in Table 3.17. In previous inventories emissions from this sub-category were reported at an aggregated level due to lack of information from South Africa's GHG Reporting Programme to disaggregate the fuel use. Table 3.17 also shows the disaggregation used for reporting the 1990 – 2024 inventory. Data from the Energy Balance data is disaggregated, however, for 2000-2022 is not used because it overestimates the amount of energy supplied to industry for combustion purposes by including the portion of fuels that are used for non-energy purposes in industrial processes. For example, fuels (i.e., coal) that are used as reducing agents or as feedstocks to processes. This is confirmed by the empty line items under the Non-energy Use section of the Energy Balance.¹²

Emissions from off-road and mobile machinery are included elsewhere under 1A3b Road Transportation. This is to avoid double counting.

Table 3.17: Disaggregation of Manufacturing industries and construction category for reporting

Reporting group	Activities included
1A2a	1A2a Iron & Steel
1A2b	1A2b Non-ferrous Metals
1A2-ab	1A2c Chemicals
	1A2d Pulp, Paper & Print
	1A2e Food Processing, Beverages & Tobacco
	1A2f Non-metallic Minerals
	1A2g Transport Equipment
	1A2h Machinery
	1A2i Mining & Quarrying

¹² An example of this can be found in the 2020 Energy Balance file (https://www.energy.gov.za/files/energyStats_frame.html.) under the Aggregate balance tab. Disaggregation of energy used by different industries is shown in rows 33 to 47 and the amount of fuels allocated for non-energy purposes in rows 64 to 67.



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	1A2j Wood & Wood Products 1A2k Construction 1A2l Textile & Leather 1A2m Brick Manufacturing 1A2n Manufacture of ceramic products

3.2.6.2 Methodological issues

Table 3.7 indicates the type of methods and emission factors used for all categories under the Energy sector, including at sub-category level.

The activities shown in Table 3.18 were identified as key categories in the 1990–2024 inventory. In order to ensure adherence to good practice principles, methodological revisions were implemented for emissions associated with all fuel types used in the Manufacturing Industries and Construction sector.

These revisions included the implementation of higher-tier methodologies for solid fuels, as presented in Table 3.12. The adoption of country-specific emission factors has improved the accuracy, transparency, and consistency of the emission estimates, thereby strengthening the overall quality of the inventory.

Table 3.18: Methodological details for the *Manufacturing industries and construction* category.

2000-2020 Key category	2000-2022 inventory		1990-2024 inventory		Notes
	Method	Emission Factor	Method	Emission Factor	
1A2 Manufacturing industries & construction (solid, CO ₂)	T1	DF	T1, T2	DF, CS	Country Specific Emission factors from Solid Fuel study applied.
1A2 Manufacturing industries & construction (liquid, CO ₂)	T1, T2	DF, CS	T1, T2	DF, CS	Coal Tar: T1, DF All others: T2, CS
1A2 Manufacturing industries & construction (gas, CO ₂)	T2	CS	T2	CS	NA

3.2.6.2.1 Activity data

Fuel consumption data for the *Manufacturing industries and construction* sector (Table 3.19) is taken from SAGERS from 2020 to 2022 and calculated from 2000-2019 based on SAGERS data and the Fuel Consumption Study. The Fuel Consumption Study looked at energy use in different industries as well as the portion that each fuel contributes to total fuel consumption.

Table 3.19: Fuel consumption (TJ) in the manufacturing industries and construction category, 1990 – 2024.¹³

Period	Coal Tar	Gas/Diesel oil	LPG	Natural Gas	Other Bituminous Coal	Other Kerosene	Motor Gasoline	Residual Fuel Oil (Heavy Fuel Oil)	Sasol MRG	Biomass	Total
1990	-	12 313	1 169	22 309	156 098	360	237	574	-	43 859	236 919
1991	-	12 187	1 157	22 082	154 508	357	234	568	-	43 413	234 506
1992	-	11 927	1 132	21 610	151 206	349	229	556	-	42 485	229 494
1993	-	12 074	1 146	21 876	153 071	353	232	563	7 292	43 009	239 616
1994	-	12 460	1 183	22 576	157 970	365	240	581	7 525	44 385	247 285
1995	-	12 847	1 219	23 276	162 867	376	247	599	7 759	45 761	254 951
1996	-	13 399	1 272	24 277	169 870	392	258	624	8 092	47 729	265 913
1997	-	13 748	1 305	24 908	174 287	402	264	641	8 303	48 970	272 828
1998	-	13 816	1 312	25 033	175 158	405	266	644	8 344	49 215	274 193
1999	-	14 148	1 343	25 634	179 362	414	272	659	8 545	50 396	280 773
2000	-	14 742	1 399	26 710	186 895	432	284	687	8 903	52 513	292 565
2001	-	15 897	1 377	27 397	190 082	340	310	714	9 132	52 631	297 880

¹³ LPG – Liquefied petroleum gases, NG – natural gas, Coal – other bituminous coal, OK – other kerosene, HFO – residual fuel oil, MRG – Sasol methane rich gas, Bio – biomass

2002	-	17 572	1 367	29 020	197 860	269	346	752	9 673	53 940	310 799
2003	-	18 173	1 234	28 118	193 902	227	356	729	9 373	51 561	303 673
2004	-	19 914	1 147	29 720	201 606	301	378	741	9 907	52 401	316 115
2005	-	21 522	1 011	32 792	204 047	524	384	747	10 931	53 482	325 440
2006	-	23 107	827	38 731	206 229	903	390	795	12 910	56 529	340 421
2007	-	22 618	617	44 093	211 501	1 217	377	869	14 698	58 169	354 159
2008	-	19 948	435	41 040	221 143	1 192	328	935	13 680	54 440	353 141
2009	-	17 084	288	33 500	196 613	1 004	249	877	11 167	43 401	304 183
2010	-	20 740	299	39 014	194 689	1 194	267	982	13 005	47 957	318 147
2011	-	24 319	336	45 460	186 577	1 326	288	1 051	15 153	52 853	327 363
2012	-	27 028	363	50 089	180 869	1 362	300	1 036	16 696	56 997	334 740
2013	-	28 701	376	52 315	178 419	1 417	309	979	17 438	59 023	338 977
2014	-	29 242	379	52 841	178 613	1 454	306	913	17 614	58 325	339 687
2015	-	28 617	373	52 494	181 544	1 457	293	867	17 498	56 290	339 433
2016	-	27 476	366	52 045	186 114	1 453	277	934	17 348	55 934	341 947
2017	-	25 438	354	51 412	186 102	1 425	258	1 098	17 137	56 829	340 053
2018	-	22 822	348	51 999	188 114	1 418	244	1 199	17 333	59 290	342 767
2019	-	22 568	344	51 420	186 020	1 403	241	1 185	17 140	58 630	338 951
2020	125	19 641	2 106	53 916	147 643	1 242	218	1 580	18 106	51 154	295 731
2021	290	23 691	2 059	64 986	174 905	1 471	259	1 827	21 217	60 802	351 507
2022	1 866	26 500	2 310	66 140	194 761	1 649	290	2 379	31 539	68 484	395 918
2023	-	23 621	2 346	61 094	173 943	1 468	266	1 886	28 678	61 346	354 648

2024	-	25 500	1 944	61 256	176 521	1 492	264	1 884	29 412	62 385	360 658

3.2.6.2.2 Emission factors

The emission factors used are shown in Table 3.12. Where a country-specific emission factor is available, it was used to estimate emissions from that fuel.

3.2.6.3 Uncertainty

The uncertainties for activity data and the emission factors used to estimate emission from *Energy Industries* is shown in Table 3.20.

Table 3.20: Uncertainty for the *Manufacturing industries and construction* category.

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1A2 Manufacturing industries and construction – liquid	10	IPCC 2006	7	IPCC 2006
	1A2 Manufacturing industries and construction – solid	10	IPCC 2006	7	IPCC 2006
	1A2 Manufacturing industries and construction – gaseous	10	IPCC 2006	7	IPCC 2006
CH ₄	1A2 Manufacturing industries and construction – liquid	10	IPCC 2006	75	IPCC 2006
	1A2 Manufacturing industries and construction – solid	10	IPCC 2006	75	IPCC 2006

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
	1A2 Manufacturing industries and construction – gaseous	10	IPCC 2006	75	IPCC 2006
N ₂ O	1A2 Manufacturing industries and construction – liquid	10	IPCC 2006	75	IPCC 2006
	1A2 Manufacturing industries and construction – solid	10	IPCC 2006	75	IPCC 2006
	1A2 Manufacturing industries and construction – gaseous	10	IPCC 2006	75	IPCC 2006

3.2.6.4 Time-series consistency



3.2.6.5

The time-series for 1A2 *Manufacturing industries and construction* is complete.

3.2.6.6 *Category specific QA/QC and verification*

The QA/QC measures indicated in Table 3.9 were used for this category. In addition to this the following category-specific checks are done.

- Energy Balance data on fuels used in different industries
- StatsSA data on manufacturing trends
- GHG Emissions Verification Programme

3.2.6.7 *Category-specific recalculations*

Recalculations were performed for the *Manufacturing industries and construction* sector because of the following improvements:

- To incorporate updated emission factors derived from the Solid Fuel Study. The study developed country-specific emission factors for solid fuel combustion, which replaced the previously applied default emission factors for this sector. No changes were made to the underlying activity data or methodological approach; the recalculations reflect only the application of nationally derived emission factors to improve the accuracy and country representativeness of the estimates for 1A2.

3.2.6.8 *Category-specific planned improvements*

Improvements planned specifically for the *Manufacturing industries and construction* sector are as follows:

- Disaggregating the remainder of the 1A2.
- Updating the uncertainty values to incorporate uncertainty of the country-specific emission factors used.

3.2.7 Transport (CRT 1.A.3)

3.2.7.1 *Category description*



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The *Transport* sub-category includes fuel combustion activities from the following types of transportation:

- 1A3a *Civil aviation* – domestic aviation with international aviation indicated as a memo item.
- 1A3b *Road transportation* – this includes the use of agricultural vehicles on paved roads as well as off-road and mobile machinery.
- 1A3c *Railways* – this includes both freight and passenger travel.
- 1A3d *Waterborne navigation* – this includes navigation bunkers as memo line items.
- 1A3e *Other Transportation* – this includes emissions from fuel combustion activities that support pipeline transportation in South Africa.

Emissions from military aviation and navigation have not been estimated and hence are not included in the inventory due to lack of data.

3.2.7.2 Methodological issues

Table 3.7 indicates the type of methods and emission factors used for all categories under the *Energy* sector, including at sub-category level.

The activities shown in Table 3.21 were indicated as key categories in the 1990-2024 inventory. To ensure that good practise was followed, changes in methodology were required for emissions from all fuels used in the *Transport* sector. The country-specific CO₂ emission factors indicated Table 3.12 were used .

Table 3.21: Methodological details for the *Transport* category.

1990-2024 Key category	1990-2024 inventory	
	Method	Emission Factor
1A3b Road transport (liquid, CO ₂)	T2	CS
1A3d Waterborne navigation (liquid, CO ₂)	T2	CS

3.2.7.2.1 Activity data

Table 3.22 shows the type and sources of activity data used to estimate emissions from 1A3 *Transport*.



For the 1A3a sub-category the Fuel Consumption Study looked into estimating fuel consumption from all domestic, international, cargo, courier and other non-passenger flights, including non-scheduled flights. This was done by considering data from the Airports Company South Africa such as the record statement of air traffic movements.

For the 1A3b sub-category the Fuel Combustion Study used a VKT approach to estimate fuel consumption for the road transport sector. The VKT approach was used instead of the fuel based approach because the fuel based approach would not allow for the easy separation of fuels used for road transportation and fuels used for other purposes such as for backup power generation.

Additionally, it should be noted that the use of biofuels for road transportation is not included in the inventory because of the insignificance of these emissions. A study by the Water Research Commission from November 2015, shows that for 2014 a total annual capacity of 1 309 ML was licensed for operation, of which 384 ML were allocated to bioethanol and 925 ML were allocated to biodiesel. Total annual emissions from this capacity is 176 GgCO₂e which is below 0.05 % of the total inventory (239 GgCO₂e). Noting that 0.05 % of the total inventory is lower than 500 Gg in this case.

For the 1A3d sub-category the Fuel Consumption Study considered the total number of containers transported along the South African coast as well as the ratio of domestic and international bound containers.

Table 3.22: Activity data used for 1A3 Transport

Sub-category	Activity Data	Source
1A3a Civil aviation	Fuel consumption	Fuel consumption study
1A3b Road Transport	VKT for Fuel consumption estimation	Fuel consumption study
1A3c Railways	Fuel consumption	SAPIA; SAGERS; and GHG Manual reporting
1A3d Water-borne navigation	Fuel consumption	Fuel consumption study
1A3e Other Transportation	Fuel consumption	SAGERS; Public information

Figure 3.19 shows the fuel consumption contribution per sub-category to the total Transport sector fuel consumption from 1990-2024. The majority of the fuel consumption is as a result of road transportation.



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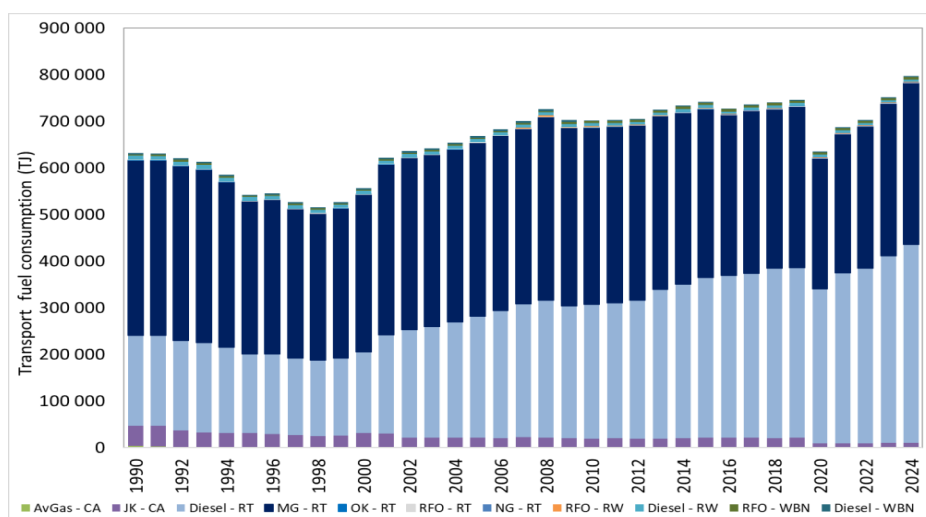


Figure 3.19: Fuel consumption for the *transport* sector (1A3), 1990-2024¹⁴

3.2.7.2.2 *Emission factors*

The emission factors used are shown in Table 3.12. Where a country-specific emission factor is available, it was used to estimate emissions from that fuel.

3.2.7.3 *Uncertainty*

The uncertainties for activity data and the emission factors used to estimate emission from the *Transport* sector is shown in Table 3.23.

Table 3.23: Uncertainty for South Africa's transport emission estimates

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
	1A3a Civil aviation – liquid	5	IPCC 2006	1.5	IPCC 2006

¹⁴ AvGas – aviation gasoline, JK – jet kerosene, MG – motor gasoline, OK – other kerosene, RFO – residual fuel oil, NG – natural gas, CA – civil aviation, RT – road transportation, RW – railways, WBN – waterborne navigation. Fuel consumption for international aviation and international bunkers are not included.



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Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1A3b Road liquid	5	IPCC 2006	2	IPCC 2006
	1A3c Railways liquid	5	IPCC 2006	2	IPCC 2006
	1A3d Waterborne navigation – liquid	5	IPCC 2006	3	IPCC 2006
	1A3e Other Transportation - Gas	5	IPCC 2006	7	IPCC 2006
CH ₄	1A3a Civil aviation – liquid	5	IPCC 2006	50	IPCC 2006
	1A3b Road liquid	5	IPCC 2006	9	IPCC 2006
	1A3c Railways – liquid	5	IPCC 2006	9	IPCC 2006
	1A3d Waterborne navigation – liquid	5	IPCC 2006	50	IPCC 2006
	1A3e Other Transportation - Gas	5	IPCC 2006	75	IPCC 2006
N ₂ O	1A3a Civil aviation – liquid	5	IPCC 2006	50	IPCC 2006
	1A3b Road liquid	5	IPCC 2006	72	IPCC 2006
	1A3c Railways - liquid	5	IPCC 2006	72	IPCC 2006
	1A3d Waterborne navigation – liquid	5	IPCC 2006	50	IPCC 2006
	1A3e Other Transportation - Gas	5	IPCC 2006	75	IPCC 2006

3.2.7.4 Time-series consistency

The time-series for all four sub-categories are complete and consistent.

3.2.7.5 Category specific QA/QC and verification

The QA/QC measures indicated in Table 3.9 were used for this category. In addition to this the following category-specific checks are done:

- Comparison of Activity Data with other sources - DMRE data on fuels used in different transport sectors

3.2.7.6 Category-specific improvements and recalculations

Recalculations were performed for the *Transport* sector because of the following improvement:

- The use of country-specific emission factors for commonly used liquid and gas fuels. The emission factors result from a study that was completed in 2022. Emissions from the entire time-series were recalculated for the applicable *Fuel combustion* activities.



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3.2.7.7 *Category-specific planned improvements*

Improvements planned specifically for the *Transport* sector is as follows:

- Updating the VKT and fuel consumption studies.
- Updating the uncertainty values to incorporate uncertainty of the country-specific emission factors used.

3.2.8 Other sectors (CRT 1.A.4)

3.2.8.1 *Category description*

The *Other sectors* sub-category includes fuel combustion activities from the following industries:

- 1A4a *Commercial/Institutional* – includes all fuel combustion in commercial and institutional buildings.
- 1A4b *Residential* – includes all fuel combustion from households.
- 1A4c *Agriculture/Forestry/Fishing/Fish Farms* – this includes fuel combustion from agriculture, forestry, fishing and fish farms.

3.2.8.2 *Methodological issues*

Table 3.7 indicates the type of methods and emission factors used for all categories under the *Energy* sector, including at sub-category level.

Table 3.7 indicates the type of methods and emission factors used for all categories under the *Energy* sector, including at sub-category level. The methodology used to estimate GHG emissions in “other sectors,” including Commercial/Institutional, Residential, and Agriculture/Forestry/Fishing/Fish farms is also shown in table 3.7. The methodology used for each sub-sector included T1 and T2 (default and country-specific) emission factors. Energy consumption data were reported for the Commercial/Institutional, Residential, and Agriculture/Forestry/Fishing/Fish farms sectors. Energy consumption in the Commercial/Institutional sector included other kerosene, gas/diesel oil, gas works gas, natural gas, sub-bituminous coal, and residual fuel oil, all sourced from the Energy Balance (DMRE). Residential sector consumption included coal, LPG, sub-bituminous coal, and other fuels, also from the Energy Balance (DMRE). Agriculture/Forestry/Fishing/Fish farms reported consumption of other kerosene, gas/diesel oil, and other fuels, as recorded in the Energy Balance (DMRE).



For other sectors, Fuel consumption for the period 1990–1999 was estimated using GDP values sourced from the World Bank for the period 1990–2024. The average annual GDP growth rate was used to extrapolate consumption backwards.

The changes also included the adoption of Tier 2 (country-specific) CO₂ emission factors, with updates applied to natural gas in the commercial/institutional sector and to other bituminous coal in other sectors.

The activities shown in Table 3.24 were indicated as key categories in the 1990-2024 inventory. To ensure that good practise was followed, changes in methodology were required for the sub-sector key categories. Changes included the use of T2 (country-specific) emission factors for CO₂. The emission factors for some gaseous fuels (natural gas) used in the commercial/institutional sector were updated to country-specific emission factors (Tier 2). The emission factor for some solid fuels (other bituminous coal) used in other sectors was also updated to Tier 2.

Table 3.24: Methodological details for the *Other sectors* category

1990-2024 Key category	1990-2024 inventory	
	Method	Emission Factor
1A4a Other Sectors - Solid Fuels (CO ₂)	T2	CS
1A4a Other Sectors - Liquid Fuels (CO ₂)	T2	CS
1A4a Other Sectors - Gaseous Fuels (CO ₂)	T2	CS

3.2.8.2.1 Activity data

Table 3.25 shows the type and sources of activity data used to estimate emissions from 1A4 *Other Sectors*.

Table 3.25: Activity data used for 1A4 *Other Sectors*

Sub-category	Activity Data	Source
1A4a <i>Commercial/Institutional</i>	Fuel consumption	Energy balance
1A4b <i>Residential</i>	Fuel consumption	Energy balance & Fuel consumption study
1A4c <i>Agriculture/Forestry/Fishing/Fish farms</i>	Fuel consumption	Fuel consumption study



Figure 3.20 and Figure 3.21 show the fuel consumption trends for the 1A4 *Other sectors* sub-categories, since 1990.

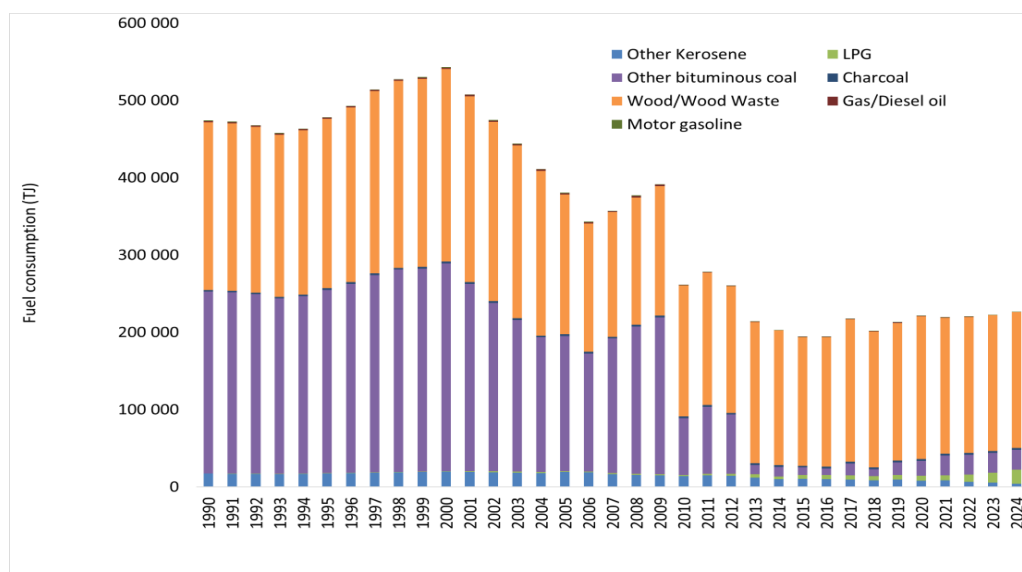


Figure 3.20: Fuel consumption for the 1A4b *residential* category, 1990-2024



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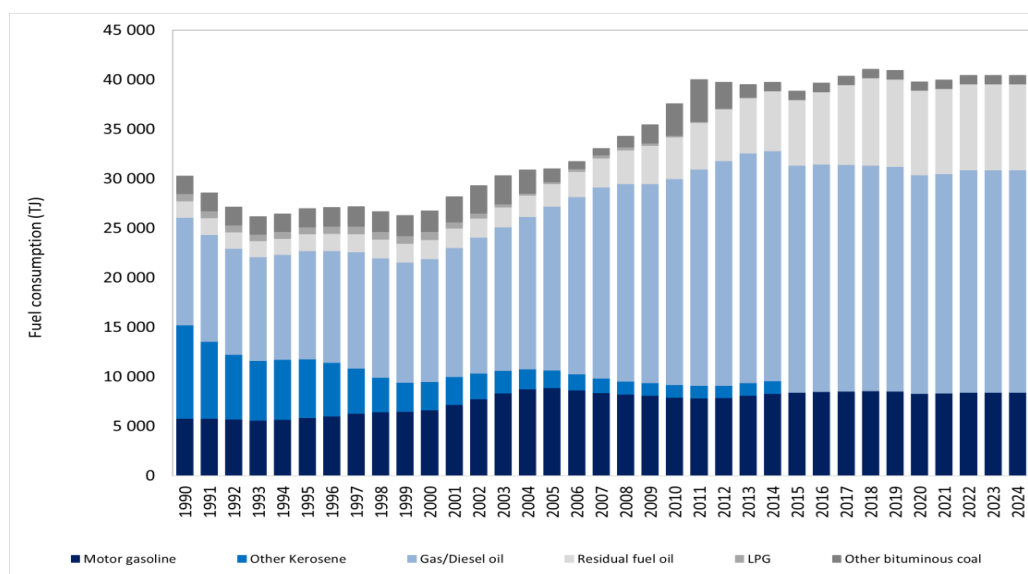


Figure 3.21: Fuel consumption for the 1A4c agriculture/forestry/fishing/fish farms category, 1990-2024

3.2.8.2.2 *Emission factors*

The emission factors used are shown in Table 3.12. Where a country-specific emission factor is available, it was used to estimate emissions from that fuel.

3.2.8.3 *Uncertainty*

The uncertainties for activity data and the emission factors used to estimate emission from *Other sectors* is shown in Table 3.26.

Table 3.26: Uncertainty for South Africa's *Other sectors* emission estimates

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1A4 Other sectors – liquid	10	IPCC 2006	7	IPCC 2006
	1A4 Other sectors – solid	10	IPCC 2006	7	IPCC 2006
	1A4 Other sectors – gaseous	10	IPCC 2006	7	IPCC 2006



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Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CH ₄	1A4 Other sectors – liquid	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – solid	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – gaseous	10	IPCC 2006	75	IPCC 2006
N ₂ O	1A4 Other sectors – liquid	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – solid	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – gaseous	10	IPCC 2006	75	IPCC 2006

3.2.8.4 Time-series consistency

The time-series for 1A4 *Other sectors* is complete.

3.2.8.5 Category specific QA/QC and verification

The QA/QC measures indicated in Table 3.9 were used for this category. In addition to this the following category-specific checks are done:

Comparison of Activity Data with other Sources:

- South Africa's GHG Reporting Programme
- StatsSA household statistics data

3.2.8.6 Category-specific recalculations

Recalculations were performed for *Other sectors* because of the following improvement:

- The use of country-specific emission factors for natural gas and other bituminous coal. The natural gas emission factor results from a study that was completed in 2022, while the other bituminous coal emission factor results from a study that was completed in 2024. Emissions from the entire time-series were recalculated for the applicable *Fuel combustion* activities.

3.2.8.7 Category-specific planned improvements

There are no category-specific improvements planned for *Other sectors*.

3.2.9 Other (CRT 1.A.5)

3.2.9.1 Category description



The *Other* sub-category includes fuel combustion activities from the following industries, referred to as Non-Specified Sectors in previous inventories:

- 1A5a *Stationary* – includes all fuel combustion not allocated in the other Fuel Combustion activities.
- 1A5b *Mobile*– no emissions are estimated for this sub-category.

3.2.9.2 **Methodological issues**

Table 3.7 indicates the type of methods and emission factors used for all categories under the *Energy* sector, including at sub-category level. For the 1990–2024 inventory period, the only key category identified under the *Other* category was 1A5a stationary combustion, specifically solid fuels (CO₂) and liquid fuels (CO₂).

In the 1990-2024 inventory emissions from this key category were estimated using Tier T1 and T2 (default and country-specific) emission factors. The methodology included the adoption of Tier 2 (country-specific) CO₂ emission factors, with updates applied to natural gas and to other bituminous coal.

3.2.9.2.1 Activity data

Fuel consumption data for the *Other* category is taken from the energy balance. Figure 3.22 shows the fuel consumption trends for 1A5 *Other* since 1990.



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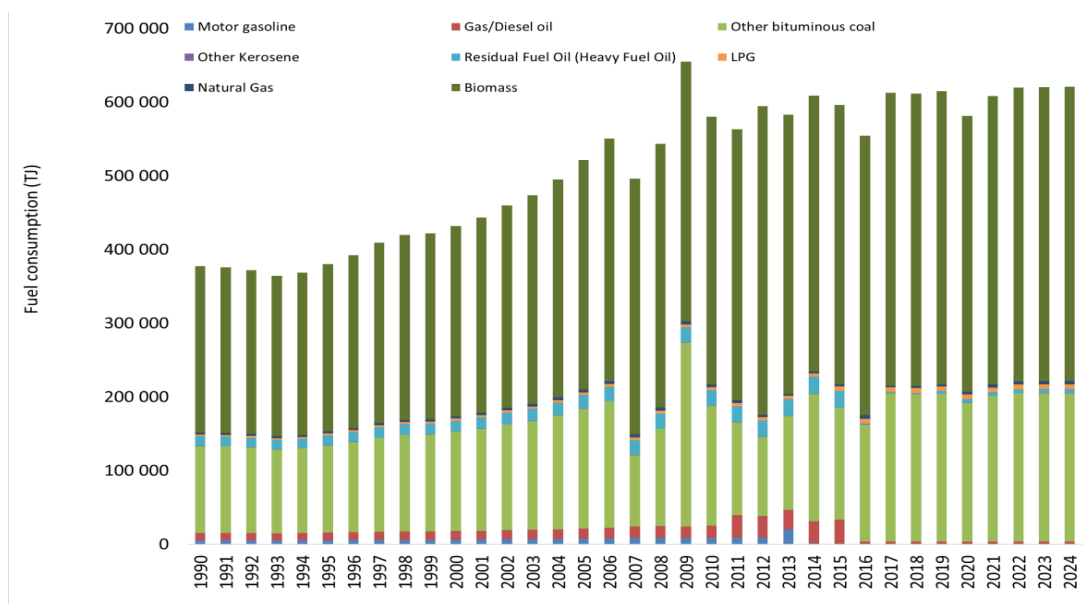


Figure 3.22: Fuel consumption for 1A5 Other, 1990-2024

3.2.9.2.2 Emission factors

The emission factors used are shown in Table 3.12. Where a country-specific emission factor is available, it was used to estimate emissions from that fuel.

3.2.9.3 Uncertainty

The uncertainties for activity data and the emission factors used to estimate emission from *Other* is shown in Table 3.27.

Table 3.27: Uncertainty for South Africa's *Non-specified sectors* emission estimates

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1A5 Other sectors – liquid	5	IPCC 2006	7	IPCC 2006
	1A5 Other sectors – solid	5	IPCC 2006	7	IPCC 2006
	1A5 Other sectors – gaseous	5	IPCC 2006	7	IPCC 2006



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Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CH ₄	1A5 Other sectors – liquid	5	IPCC 2006	75	IPCC 2006
	1A5 Other sectors – solid	5	IPCC 2006	75	IPCC 2006
	1A5 Other sectors – gaseous	5	IPCC 2006	75	IPCC 2006
N ₂ O	1A5 Other sectors – liquid	5	IPCC 2006	75	IPCC 2006
	1A5 Other sectors – solid	5	IPCC 2006	75	IPCC 2006
	1A5 Other sectors – gaseous	5	IPCC 2006	75	IPCC 2006

3.2.9.4 Time-series consistency

The time-series is complete this category.

3.2.9.5 Category specific QA/QC and verification

The QA/QC measures indicated in Table 3.9 were used for this category.

3.2.9.6 Category-specific recalculations

Recalculations were performed for *Non-specified sectors* because of the following improvement:

- The use of country-specific emission factors for natural gas and other bituminous coal. The natural gas emission factor results from a study that was completed in 2022, while the other bituminous coal emission factor results from a study that was completed in 2024. Emissions from the entire time-series were recalculated for the applicable *Fuel combustion* activities

3.2.9.7 Category-specific planned improvements

There are no category specific improvements planned for *Non-specified sectors*.

3.3 Fugitive emissions from fuels (CRT 1.B)

Fugitive emissions are intentional or unintentional releases of GHG's to the atmosphere during the extraction, processing, transformation and delivery of fossil fuels to the point of final use.



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3.3.1 Solid fuels (CRT 1.B.1)

3.3.1.1 Category description

The *Solid Fuels* sub-category includes fugitive emissions from the following activities:

- 1B1a *Coal mining and handling* – this includes emissions from stored gases during coal and surrounding strata breakage, as well as emissions from the processing, storage and transport of coal from surface and underground mines.
- 1B1c *Solid fuel transformation* – this includes all fugitive emissions associated with the manufacture of charcoal and coke.

This sub-category does not include emissions from abandoned mines or uncontrolled combustion and burning coal dumps.

3.3.1.2 Methodological issues

Table 3.7 indicates the type of methods and emission factors used for all categories under the *Energy* sector, including at sub-category level. The only key category identified for the 1B1 *Solid fuels* sector in the 1990-2024 inventory was 1B1a Coal mining and handling (CH₄).

In the 1990-2024 inventory emissions from this key category were estimated using Tier 2 and country-specific emission factors. Hence, no change in the methodology was required for the 1990-2024 to ensure good practise was implemented.

3.3.1.2.1 Activity data

Table 3.28 shows the type and sources of activity data used to estimate emissions from 1B1 *Solid fuels*.

Table 3.28: Activity data used for 1B1 Solid Fuels

Sub-category	Activity Data	Source
1B1a <i>Underground and surface mines</i>	Amount of coal produced from both underground and surface mines	SAMI and Minerals Council SA
1B1c <i>Solid fuel transformation - charcoal</i>	Amount of charcoal produced	FAO
1B1c <i>Solid fuel transformation - coke</i>	Amount of coke produced Amount of iron produced locally	SAGERS : Manual Reporting and Minerals Council SA



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Table 3.29 shows the production figures for coal (from surface and underground mines) and charcoal since 1990.

Table 3.29: Amount of coal and charcoal produced, 1990-2024^{15,16}

	Surface	Underground	Charcoal	Coke
	Amount produced (tonnes)			
1990	139 841 736	83 905 041	13 000	2 674 171
1991	142 630 994	85 578 596	13 000	2 973 160
1992	141 756 654	85 053 992	25 000	2 709 065
1993	147 025 874	88 215 524	35 000	2 554 432
1994	157 008 861	94 205 316	20 000	2 611 792
1995	164 349 645	98 609 786	26 000	2 716 713
1996	163 835 750	98 301 450	26 000	2 551 325
1997	175 241 338	105 144 803	26 000	2 757 343
1998	178 851 390	107 310 833	41 000	2 887 120
1999	177 642 178	106 585 307	41 000	2 306 350
2000	174 918 853	106 308 704	41 000	2 451 940
2001	179 330 802	108 990 110	41 000	2 547 566
2002	189 951 547	115 444 975	41 000	2 646 801
2003	191 768 929	116 549 508	200 600	2 891 467
2004	193 506 539	117 605 558	127 300	2 975 656
2005	193 348 574	117 509 553	188 900	2 874 759
2006	195 639 060	118 901 619	188 900	2 881 078
2007	199 587 383	121 301 252	188 900	2 970 030
2008	196 569 036	119 466 821	188 900	2 694 892
2009	175 784 200	141 515 800	188 900	2 003 359
2010	184 150 000	133 350 000	188 900	2 528 025
2011	195 727 800	120 472 200	188 900	2 356 492
2012	211 200 000	118 800 000	188 900	2 009 041
2013	204 681 600	126 518 400	188 900	2 225 078
2014	213 399 640	124 900 360	188 900	2 291 173
2015	207 716 400	116 283 600	188 900	1 798 356
2016	207 415 000	111 685 000	188 900	1 474 697
2017	212 733 600	116 066 400	209 783	1 718 018
2018	227 288 282	105 101 718	295 500	1 681 607

¹⁵ Coal production data calculated based on information published in the SAMI Annual reports and Minerals Council SA Facts & Figures reports.

¹⁶ Charcoal data from the FAO



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	Surface	Underground	Charcoal	Coke
	Amount produced (tonnes)			
2019	234 234 200	99 765 800	223 195	1 813 063
2020	217 240 013	103 472 569	231 779	1 433 006
2021	200 219 454	95 365 587	220 334	1 597 100
2022	197 015 943	93 839 738	220 334	1 504 969
2023	204 477 266	97 393 606	223 195	1 502 202
2024	206 630 588	98 419 244	220 334	1 508 354

3.3.1.2.2 *Emission factors*

1B1a coal mining and handling

Country-specific emission factors are available for CO₂ and CH₄ for surface and underground mining in South Africa (Table 3.30). The local study on emissions from coal mines indicated that the IPCC approach and hence the default methane emission factors from coal mining overstated emissions from South African coal since South African coal is not saturated in methane and the gas content of the mine air is significantly less than expected. The country-specific emission factors were developed on *in situ* gas contents and were supported by measurements of methane concentrations in mine ventilation and residual gas contents. The study considered underground mines with a typical depth, covering a range of *in situ* methane concentrations in coal typical of the whole industry.¹⁷

Table 3.30: Country-specific emission factors for coal mining and handling

Mining method	Activity	GHG	Emission factor (m ³ tonne ⁻¹)	
			South African EF	IPCC default
Underground mining	Coal mining	CH ₄	0.77	18
	Post-mining (handling and transport)		0.18	2.5
Surface mining	Coal mining		0	1.2
	Post-mining (storage and transport)		0	0.1
Underground mining	Coal mining	CO ₂	0.077	NA
	Post-mining (handling and transport)		0.018	NA
Surface mining	Coal mining		0	NA
	Post-mining (storage and transport)		0	NA

¹⁷ Methane release from South African Coal Mines Lloyd and Cook



1B1c solid fuel transformation

Emissions from charcoal and coke production were estimated using Tier 1 and the IPCC default emission factors shown in Table 3.31, with the exception of CO₂ emissions from coke production that are based on measurements.

Table 3.31: Tier 1 emission factors for charcoal and coke production

Activity	GHG	Emission factors (kg/tonne)	Source
Charcoal production	CO ₂	1 570	IPCC 2019 Refinement
	CH ₄	40.3	IPCC 2019 Refinement
	N ₂ O	0.08	IPCC 2019 Refinement
	CO	220	IPCC 2019 Refinement
Coke production	CH ₄	0.049	IPCC 2019 Refinement

3.3.1.3 Uncertainty

The uncertainties for activity data and the emission factors used to estimate emission from *Solid Fuels* is shown in Table 3.32.

Table 3.32: Uncertainty for 1B1 Solid fuels category

Gas	Sub-category	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1B1ai1 Mining	10	IPCC 2006	63	IPCC 2006
	1B1ai2 Post-mining seam gas emissions	10	IPCC 2006	50	IPCC 2006
	1B1ci Charcoal production	10	IPCC 2006	63	IPCC 2006
CH ₄	1B1ai1 Mining	10	IPCC 2006	63	IPCC 2006
	1B1ai2 Post-mining seam gas emissions	10	IPCC 2006	50	IPCC 2006
	1B1ci Charcoal production	10	IPCC 2006	63	IPCC 2006
	1B1cii Coke production	10	IPCC 2006	63	IPCC 2006
N ₂ O	1B1ci Charcoal production	10	IPCC 2006	63	IPCC 2006
CO	1B1ci Charcoal production	10	IPCC 2006	63	IPCC 2006

3.3.1.4 Time-series consistency

The time-series is complete for coal, charcoal and coke production.



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3.3.1.5 Category specific QA/QC and verification

The QA/QC measures indicated in Table 3.9 were used for this category. In addition to this the following category-specific checks are done:

Comparison of Activity Data with other Sources:

- For 1B1a Coal Mining:
 - Coal production data and splits from the Minerals Council of South Africa
 - Coal production statistics from DMRE and Mineral Council of South Africa.
- For 1B1ci Coke Production:
 - Iron ore production changes data from Mineral Council of South Africa.
 - Iron ore production data from the Minerals Council of South Africa

3.3.1.6 Category-specific recalculations

No category specific recalculations were conducted for coal mining. The improvement for this sector was the inclusion of emissions from charcoal and coke production.

3.3.1.7 Category-specific planned improvements

Improvements planned for the *1B1 Solid fuels* sector are as follows:

- Including emissions from abandoned mines and spontaneous combustion.

3.3.2 Oil and natural gas and other emissions from energy production (CRT 1.B.2)

3.3.2.1 Category description

The *Oil and natural gas* sub-category include fugitive emissions from the following activities:

- 1B2a *Oil* – this includes fugitive emissions from venting, flaring and all other sources associated with the exploration, production, transmission, upgrading and refining of crude oil and the distribution of crude oil products.
- 1B2b *Natural gas* – this includes fugitive emissions from venting, flaring and all other sources associated with the exploration, production, processing, transmission, storage, upgrading and the distribution of natural gas.

3.3.2.2 Methodological issues



No 1B2 activities were indicated as key categories in the 1990-2020 inventory.

3.3.2.2.1 Activity data

Emissions from this category are based on direct measurements, mass balance approaches and the use of Tier 1 default emission factors from the relevant companies. Prior to the implementation of South Africa's GHG Reporting Programme, consolidated emissions were estimated for oil and natural gas companies. The emissions reported cover flaring, venting, production, processing, upgrading, refining, transport, transmission, storage and distribution activities for oil and natural gas.

3.3.2.2.2 Emission factors

Emissions from this category are based on direct measurements and mass balance approaches of the relevant companies. Hence, no activity data or emission factors were used to estimate emissions.

3.3.2.3 **Uncertainty**

The uncertainty of the emission estimates (Table 3.33) is based on the assumption of a normal distribution of the emission estimates.

Table 3.33: Uncertainty for 1B2 Oil and natural gas category

Gas	Sub-category	Emissions uncertainty	
		%	Source
CO ₂	1B2 Oil & natural gas	65	GHG reporting Programme
CH ₄		0.005	GHG reporting Programme
N ₂ O		0.02	GHG reporting Programme

3.3.2.4 **Time-series consistency**

The time-series is complete for 1B2a *Oil*, however the time-series is not consistent as emissions estimates are sourced from SAGERS from 2019 onwards.



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For 1B2b *Natural gas* the time-series is not complete as emissions only from 2019 onwards from SAGERS are included in the inventory.

3.3.2.5 *Category specific QA/QC and verification*

The QA/QC measures indicated in Table 3.9 were used for this category. In addition to this Energy Balance data on production, imports and exports is used as a check.

3.3.2.6 *Category-specific recalculations*

No category specific recalculations were conducted for the 1B2 *Oil and natural gas* sector. The improvement for this sector was the inclusion of emissions from natural gas activities from 2019.

3.3.2.7 *Category-specific planned improvements*

An improvement planned for the *Oil and natural gas* sector is ensuring time-series completeness for fugitive emissions from natural gas

3.3.3 Other emissions from energy production (1.B.3)

3.3.3.1 *Category description*

The *Other emissions from energy production* sub-category includes fugitive emissions from the following activities:

- 1B3 *Other emissions from energy production* – this includes other fugitive emissions from energy production not included in 1B2 *Oil and natural gas*, such as emissions from coal to liquid and gas to liquid activities.

3.3.3.2 *Methodological issues*

Carbon dioxide from *Other emissions from energy production* was indicated as a key category in the 1990-2024 inventory. Emissions from this sector were already based on direct measurements, hence, no methodological changes were required for the 1990-2024 inventory to ensure alignment with good practise.

3.3.3.2.1 *Activity data*

Emissions from this category are based on direct measurements from the relevant producers. Hence, no activity data or emission factors were used to estimate emissions.



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3.3.3.2.2 *Emission factors*

Emissions from this category are based on direct measurements from the relevant producers. Hence, no activity data or emission factors were used to estimate emissions.

3.3.3.3 *Uncertainty*

The uncertainty of the emission estimates (Table 3.34) is based on the assumption of a normal distribution of the emission estimates.

Table 3.34: Uncertainty for 1B3 *Other emissions from energy production* category

Gas	Sub-category	Emissions uncertainty	
		%	Source
CO ₂	1B3 <i>Other emissions from energy production</i>	0.001	GHG reporting Programme
CH ₄		0.001	GHG reporting Programme

3.3.3.4 *Time-series consistency*

The times-series of emissions from 1B3 *Other emissions from energy production* is complete and consistent.

3.3.3.5 *Category specific QA/QC and verification*

The QA/QC measures indicated in Table 3.9 were used for this category as well as the GHG Emissions Verification Programme.

3.3.3.6 *Category-specific recalculations*

No category specific recalculations were conducted for the 1B3 *Other emissions from energy production* sector.

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3.3.3.7 Category-specific planned improvements

There are no category-specific improvements planned for the 1B3 *Other emissions from energy production* sector.



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Chapter 4: Industrial Processes and Product Use (IPPU) (CRT sector 2)

4.1 Sector overview

The IPPU sector includes non-energy related emissions from industrial processing plants. The main emission sources are released from industrial processes that chemically or physically transform raw materials and thereby release GHGs, (e.g., ammonia products manufactured from fossil fuels), GHG emissions released during these processes are CO₂, CH₄, N₂O, HFCs, PFCs and SF₆. Table 4.1 shows the industrial processes included in South Africa's IPPU sector.

Table 4.1: Industrial processes included in South Africa's IPPU sector emission estimates

IPPU Category	Industrial Process / Product Use
Mineral Industry	Cement Production
	Lime Production
	Glass Production
	Soda Ash Production
	Other Product Uses of Carbonates
Chemical Industry	Ammonia Production
	Nitric Acid Production
	Hydrogen Production
	Titanium Dioxide Production
	Other Chemicals Production
Metal Industry	Ferroalloys Production
	Production of Steel from Iron and Scrap Steel
	Aluminium Production
	Lead Production
	Zinc Production
	Vanadium Production
Petroleum & Petrochemical Industry	Carbide Production
	Petrochemical and Carbon Black Production
	Paraffin Wax Use
Product Uses as Substitutes for ODSs	Lubricant Use
	Use of HFCs, PFCs, SF ₆ etc. in refrigeration, air conditioning, foam blowing, fire protection, aerosols



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HFCs and PFCs are used in many products and in refrigeration and air conditioning equipment. PFCs are also emitted because of anode effects in aluminium smelting. Therefore, the IPPU sector includes estimates of PFCs from aluminium production, and HFCs from refrigeration and air conditioning. SF₆ is also included in IPPU due to the use of electrical equipment.

The estimation of GHG emissions from non-energy sources is often difficult because they are widespread and diverse. The difficulties in the allocation of GHG emissions between fuel combustion and industrial processes arise when by-product fuels or waste gases are transferred from the manufacturing site and combusted elsewhere in different activities.

The performance of the economy is the key driver for trends in the IPPU sector. The South African economy is related to the global economy, mainly through exports and imports. South Africa officially entered an economic recession in May 2009, which was the first in 17 years. Until the global economic recession affected South Africa in late 2008, economic growth had been stable and consistent.

As a result of the recession, GHG emissions during that period decreased across almost all categories in the IPPU sector. Since then, GDP annual growth has slowed compared to growth before the recession. The Covid 19 pandemic caused economic growth to decline during 2020, especially during the second half of the year when lockdown measures were stricter. During 2021 and 2022 economic growth recovered to pre-covid figures.

During 2022 South Africa moved away from Tier 1 reporting towards Tier 2 and Tier 3 calculations. In certain sectors, this made quite a difference. The Metal Industry was affected most, but the accuracy has improved. The 2023 and 2024 Verification programmes also enhanced accuracy of Tier 3 reporting. Due to these changes, comparison with historical figures is compromised in the short term.

The largest source of emissions in the IPPU sector in South Africa is the production of ferroalloys, iron and steel followed by 2.F.1 - Refrigeration and Air Conditioning.

4.1.1 Shares and trends in emissions

In 2024 the IPPU sector produced 30 372 Gg CO₂e which is 6.4% of South Africa's emission (excl. LULUCF).

The IPPU sector produces CO₂ emissions (75.8%), fluorinated gases 22.7% (Table 4.2). Carbon dioxide and any other emissions from combustion of fuels in these industries are reported under the Energy sector.



The largest source category is the *ferroalloy* category, which contributes 52.6% to the total IPPU sector emissions. The *Mineral industry* and the *Product used as substitutes for ozone depleting substances* subsectors contribute 16.4% and 22.9%, respectively, to the IPPU sector emissions

A summary table of all emissions from the IPPU sector by gas is provided in Annex VI.

Table 4.2: Summary of the estimated emissions from the IPPU sector in 2024

GHG source categories	CO ₂	CH ₄	N ₂ O	HFCs	PFCs	SF ₆	Total
	Gg CO ₂ e						
2.IPPU	23 030	119	340	6 685	113	85	30 372
2.A Mineral industry	4 956	NO	NO	NO	NO	NO	4 956
2.B Chemical industry	1 291	119	340	NE	NE	NE	1 750
2.C Metal industry	15 605	0	NO	NO	113	NO	15 718
2.D Non-energy products from fuels and solvents	1 178	NE	NE	NO	NO	NO	1 178
2.E Electronic industry	NE	NE	NE	NE	NE	NE	NE
2.F Product uses as substitute ODS	NO	NO	NO	6 685	NE	NO	6 685
2.G Other product manufacture and use	NE	NE	NE	NE	NE	85	85
2.H Other	NE	NE	NE	NE	NE	NE	NE

Numbers may not sum exactly due to rounding off.

Even though the South African economy recovered after the COVID-19 pandemic, estimated emissions from the IPPU sector are 2 411 Gg CO₂e (7.4%) lower than the emissions in 2000. The decline can be attributed to the decline in metals production (61.0%), specifically *Iron and Steel production* and *Aluminium production*. This can be ascribed to a deteriorating economy. The decline in the chemicals industry also made a huge difference (31.4%).

Figure 4.1 shows that IPPU emissions increased by 18.0% between 2000 and 2006, after which there was a 13.6% decline to 2009. This decrease was mainly due to the global economic recession and the electricity crisis that occurred in South Africa during this period. From 2010 emissions increased due to an increase in the *metal industry* and *products used as substitutes for ozone depleting substances* subsectors. The economy was also beginning to recover from the global recession.



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Emissions decreased from 2016 as demand for South African chemical and metals dropped. COVID-19 also had a major local and international impact between 2020 and 2021.

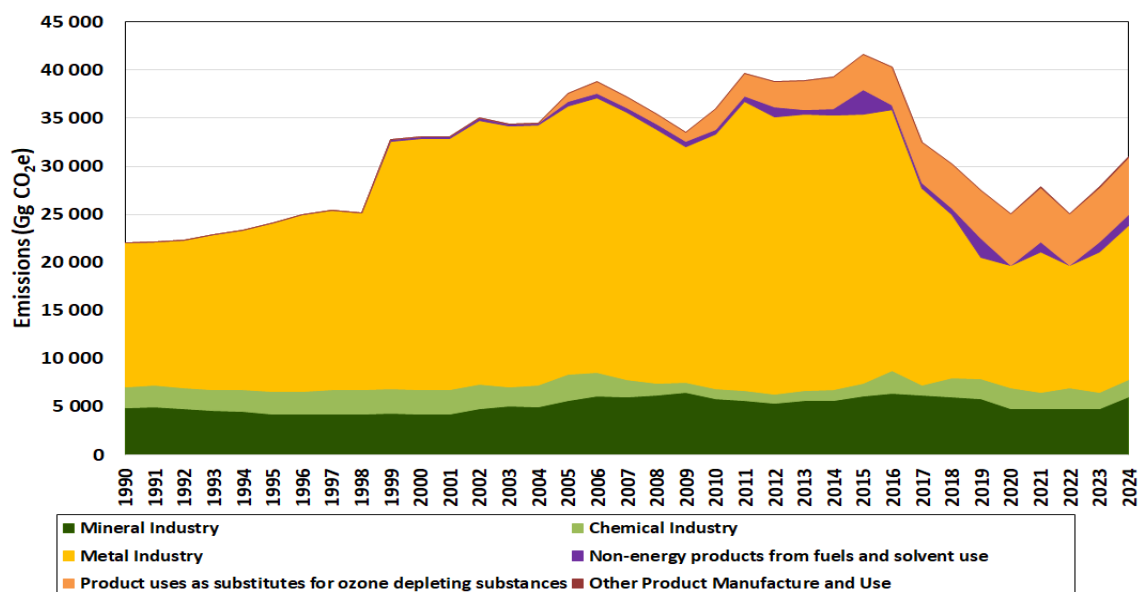


Figure 4.1: Trend in South Africa's IPPU sector emissions, 1990-2024

4.1.1.1 Mineral industry

In 2024 the mineral industries produced 4 898 Gg CO₂, which is 16.4% of the IPPU sector emissions. Cement production accounted for 78.5% of emissions from the Mineral industry. All the emissions in this category were CO₂ emissions.

The emissions for the mineral industry were 1.5% (77.2 Gg CO₂) higher than the 4 826 Gg CO₂ in 1990. There was a 49.9% increase in the *Mineral industry* emissions between 2000 and 2009, after which emissions declined by 17.3% in 2012 Figure 4.2. The increase between 2000 and 2009 was due to increased emissions from *cement* and *lime production* because of economic growth during this period. In 2009 the South African economy went into recession and the GDP decreased by 1.8% in that year.



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Cement demand in the residential market and construction industry in 2009/2010 decreased due to higher interest rates, increased inflation, and the introduction of the National Credit Act (DMR, 2010). *Other process uses of carbonates* was included in the category from the 2018 inventory. Emissions declined between 2019 and 2020 mainly due to the COVID-19 pandemic and the stringent lockdown regulations within South Africa during 2020. The market did recover after this.

Cement production is the largest contributor to the emissions from this category (Figure 4.2).

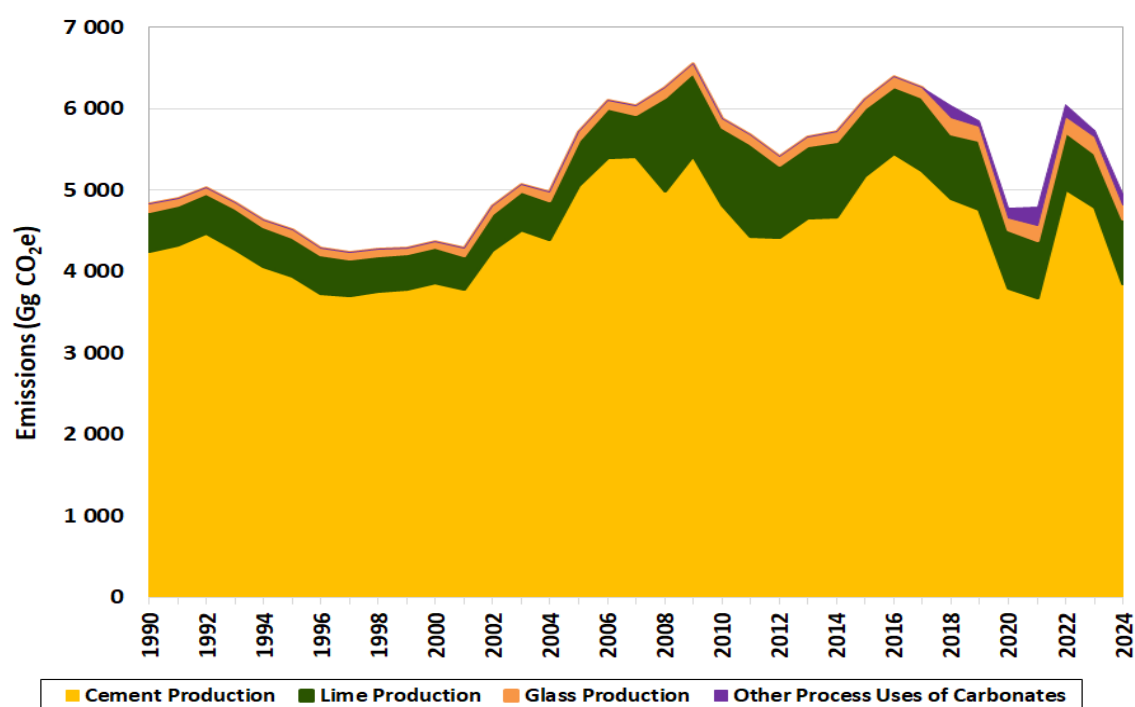


Figure 4.2: Category contribution and trend for the mineral subsector, 1990-2024

4.1.1.1.1 Cement production

Cement production was estimated to produce 13% of the IPPU sector emissions. Emissions were 0,9% above the 1990 level but fluctuate with economic conditions.



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4.1.1.1.2 Lime production

Lime production was estimated to produce 2.7% of the IPPU sector emissions. Emissions were 63% above the 1990 level. The fluctuations in *Lime production* were directly linked to developments and investments in the steel and metallurgical industries. It should however be noted that there is an inconsistency in the time series with the data prior to 2008. Only pyrometallurgical quicklime and hydrated lime (only included lime for water purification) were included.

The production data prior to 2008 is therefore much lower than the data for the later years. This means that the change from 2000 to 2020 is not only an increase due to emissions but also due to a change in the activity data. Emissions for 2018 and 2019 were extrapolated for quicklime due to a lack of activity data received. The 2019 inventory included the addition of dolomitic lime to the calculation, as previously this type of lime was not reported.

4.1.1.1.3 Glass production

Glass production was estimated to produce 0.6% of the IPPU sector emissions. Emissions were 109% above the 1990 level. Emissions increased steady until 2018 from when it stabilised.

4.1.1.1.4 Other Process Uses of Carbonates (OPUC)

Emissions from the *Other Process Uses of Carbonates (OPUC)* were only reported from the 2018 inventory due to a lack in activity data and emissions. No magnesia production occurs in South Africa. *OPUC* emissions were estimated to produce 0.5% of the IPPU sector emissions the main contributor is the Brick manufacturing activities.

4.1.1.2 **Chemical industry**

The *Chemical industries* were estimated to produce 1 720 Gg CO₂e in 2024, which is 5.8% of the IPPU sector emissions. The largest contributions are from *Titanium dioxide production*, *Nitric acid production* and *Ammonia production*.

Emissions from the *Chemical industries* decreased by 482 Gg CO₂e (22.6%) since 1990 (2 232 Gg CO₂e). Emissions from this subsector fluctuated considerably over the 30-year period (Figure 4.1) due to the nature of the business. Between 2000 and 2006 emissions fluctuated between 2 169 Gg CO₂e and 2 974 Gg CO₂e (Figure 4.1) then there was a decline of 55.4% between 2006 and 2008, largely due to N₂O emission reductions in



Nitric acid production. Hydrogen production was included since 2018, while Silicon carbide and Soda ash production since 2019 and Other chemicals since 2020.

4.1.1.3 Metal industry

The *Metal industry* was estimated to produce 15 178 Gg CO₂e in 2024, which is 53% of the IPPU sector emissions. The largest contribution to the *Metal industries* comes from *Ferroalloy production* (6 942 Gg CO₂e or 44.2%), followed by *Iron and steel production* (6 942 Gg CO₂e or 44%).

Emissions from the *Metal industry* increased by 1 534 Gg CO₂e (11%) above the 1990 emissions of 14 184 Gg CO₂e. Figure 4.3 shows that emissions from the *Metal industries* increased slowly (11.2%) between 2000 and 2006, mainly due to *Ferrometals production*. A sharp decline in production and related emissions from 2016 can be attributed to increased input cost, energy supply challenges and low-cost international alternatives in the *Iron and steel* and *Ferrometals* sectors. *Zinc production* was minimal for 2024. Various entities used the COVID-19 period to stop production in favour of major maintenance after which production increased again.

Aluminium production emissions more than doubled between 2010 and 2011 due to increased PFC emissions (Figure 4.3). In 2000 almost half (47.4%) of the *Aluminium production* emissions were PFC emissions. This rose to 65.0% in 2011 and 2012 due to the closure of the Soderberg and Side-Worked Pre-Bake processes in 2009. The aluminium plants released large amounts of C₂F₄ and CF₄ during 2011 and 2012 due to inefficient operations (switching on and off at short notice) as they were used to control the South African electricity grid. PFCs emissions afterwards stabilised to a point where it is currently (2024) contributing 8.97%.



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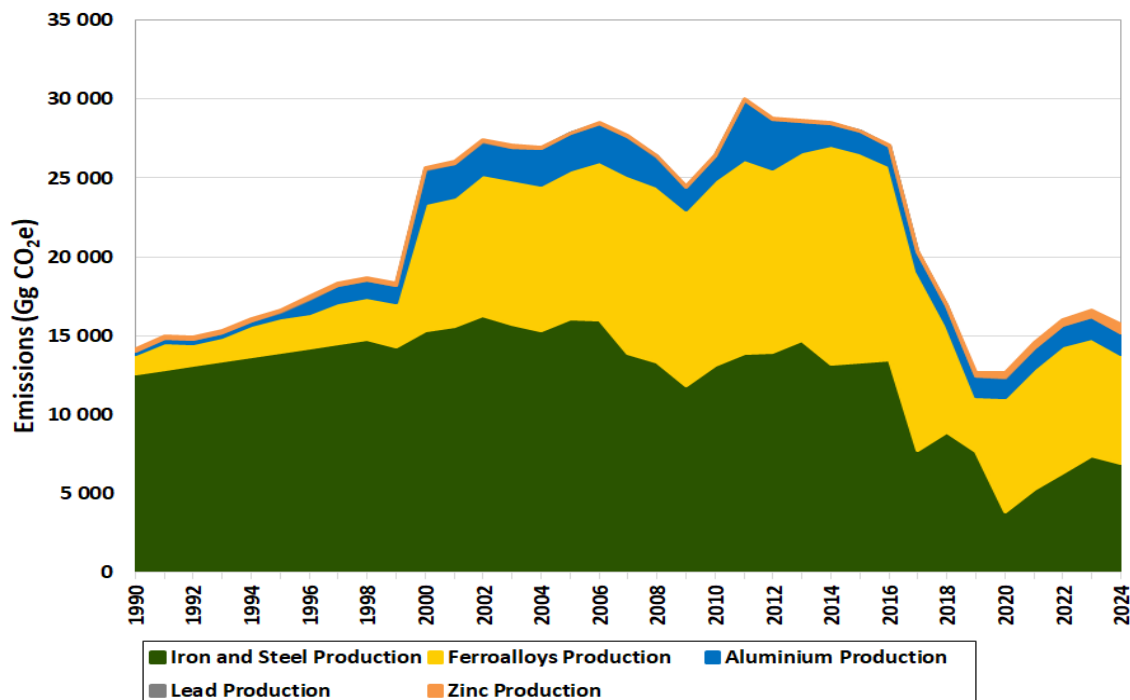


Figure 4.3: Trend and category contribution to emissions from the metal industries, 1990-2024

4.1.1.4 Non-energy products from fuels and solvents

The *Non-energy products from fuels and solvent use* were estimated to produce 1 178 Gg CO₂e in 2024, which is 3.9% of the IPPU sector emissions.

Emissions from the *Non-energy products from fuels and solvent use* category were 501% higher than the 2000 level of 196 Gg CO₂e. Emissions increased steadily from 2000 to 2015 to 2 495 Gg CO₂e as usage of lubricant wax increased. A sharp increase in paraffin wax usage was seen in 2015 which contributed largely to the steep increase in emissions (Figure 4.4). Emissions dropped from 2015 to 2018 to 639 Gg CO₂e as consumption of both lubricants and paraffin wax decreased. 2020 saw a steep decrease in the use of lubricants and paraffin wax, which is most probably ascribed to COVID-19. No information for 2021 and 2022 is available and extrapolation was done.

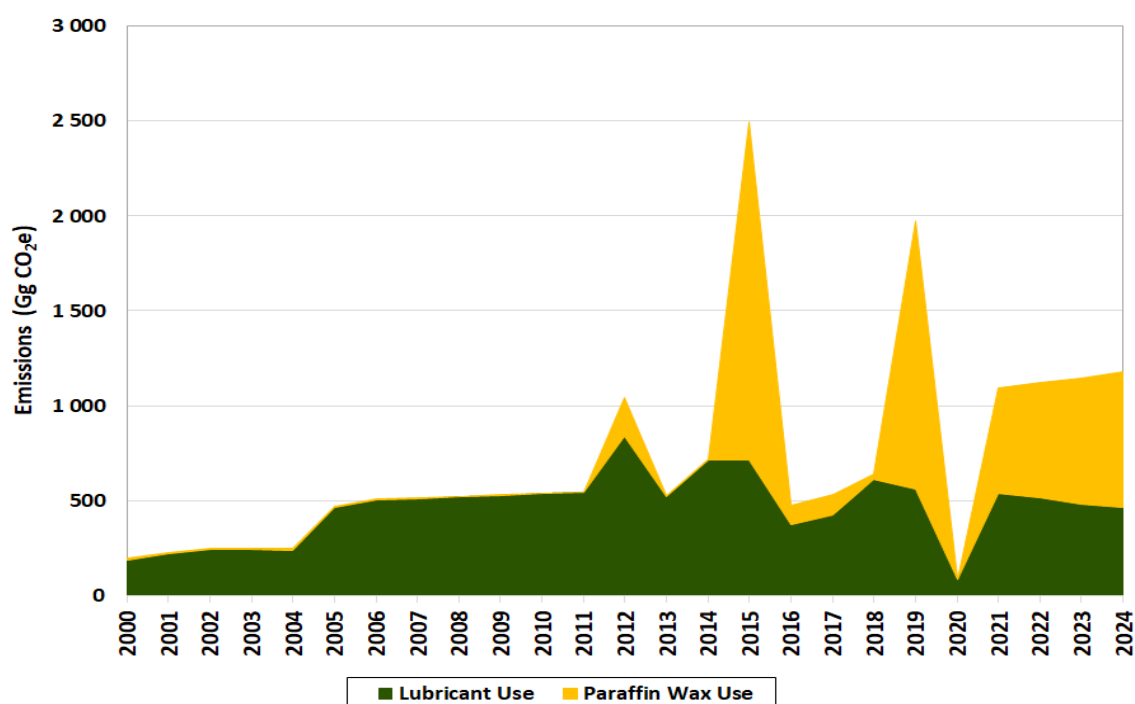


Figure 4.4: Trend and category contribution in the emissions from non-energy products from fuels and solvents, 2000-2024

4.1.1.5 Products used as substitutes ODS

The *Products used as substitutes for ODSs* category was estimated to produce 6 685 Gg CO₂e in 2024, which is 22,4% of the IPPU sector emissions. The largest contribution comes from *Refrigeration and air conditioning* (6 577 Gg CO₂e or 98,4%).

Emissions were only estimated from 2005 when emissions were estimated at 842 Gg CO₂e in 2005. In 2010 emissions more than doubled (Figure 4.5) due to an increase in the *Refrigeration and stationary air conditioning* emissions. In 2011 emissions from *Mobile air conditioning*, *Foam blowing agents*, *Fire protection* and *Aerosols* were added, therefore the emissions for this subcategory increased to 2 853 Gg CO₂e in 2013. Recalculations were not done for the years prior to 2011 due to a lack of data. *Refrigeration and air conditioning* as well as *Fire protection* has been extrapolated since 2016. Emissions from foam blowing agents and aerosols have not changed since 2015.



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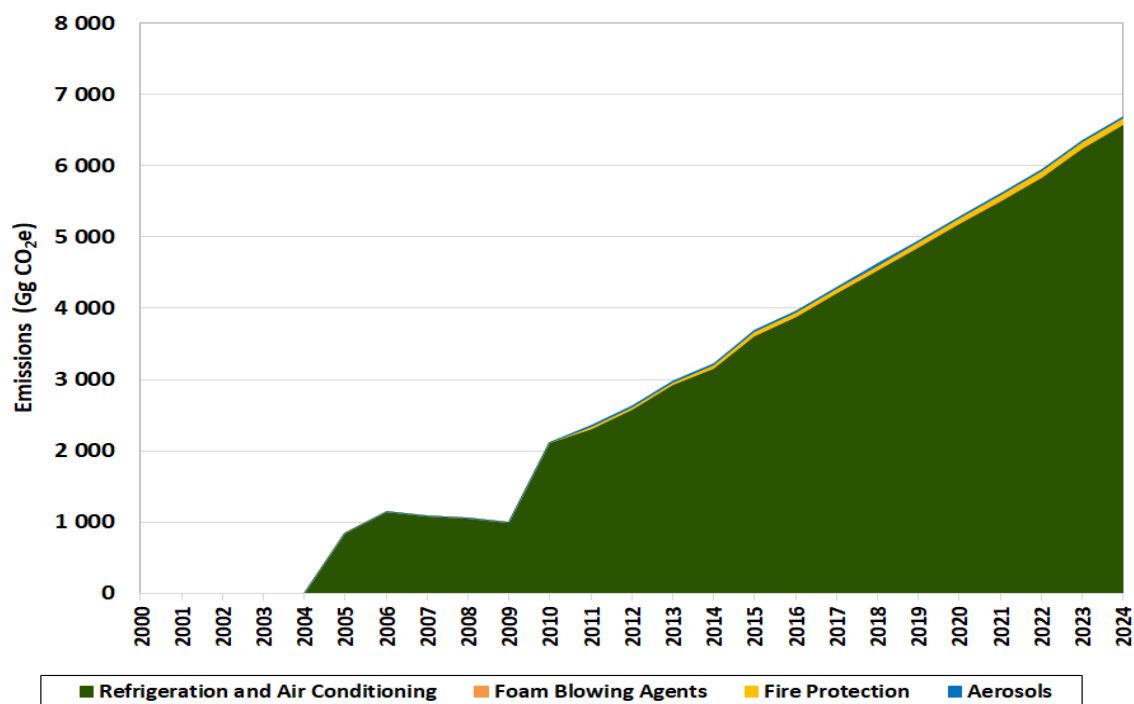


Figure 4.5: Trend and category contribution to the product uses as substitutes for ODS emissions, 2000-2024

4.1.2 Overview of methodology and completeness

Table 4.3 provides a summary of the methods and emission factors applied to each subsector of IPPU.

Table 4.3: Summary of methods and emission factors for the IPPU sector and an assessment of the completeness of the IPPU sector emissions

GHG Source and sink category	CO ₂		CH ₄		N ₂ O		HFCs		PFCs		SF ₆		NOx	CO	NM VOC	SO ₂
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
A Mineral industry																
1 Cement production	T2 & T3	CS	NE										NE	NE	NE	NE
2 Lime production	T3	CS	NE										NE	NE	NE	NE
3 Glass production	T3	CS	NE										NE	NE	NE	NE
4 Other process uses of carbonates	T3	CS	NE										NE	NE	NE	NE
B Chemical industry																
1 Ammonia production	T3	CS	T3	CS	NE								NE	NE	NE	NE
2 Nitric acid production	NE		NE		T3	CS							NE	NE	NE	NE
3 Adipic acid production	NO		NO		NO								NO	NO	NO	NO
4 Caprolactam, glyoxal and glyoxylic acid production	NO		NO		NO								NO	NO	NO	NO
5 Carbide production	T3	CS	T1	DF	NE								NE	NE	NE	NE
6 Titanium dioxide production	T3	CS	NE		NE								NE	NE	NE	NE
7 Soda Ash production	T3	CS	NE		NE								NE	NE	NE	NE
8a Methanol	IE		IE		IE								NE	NE	NE	NE
8b Ethylene	IE		IE		IE								NE	NE	NE	NE

8c	Ethylene Dichloride and Vinyl Chloride Monomer	NO	NO	NO	NO													NO	NO	NO	NO
8d	Ethylene Oxide	IE	IE	IE	IE													NE	NE	NE	NE
8e	Acrylonitrile	NO	NO	NO	NO													NO	NO	NO	NO
8f	Petrochemical and carbon black production	T1	DF	T1	DF	NE												NE	NE	NE	NE
8g	Hydrogen Production	T3	CS	NE	NE													NE	NE	NE	NE
9	Fluorochemical production							NO										NO	NO	NO	NO
11	Other	T2	CS	T2	CS	NE		NE										NE	NE	NE	NE
C	Metal industry																				
1	Iron and steel production	T3	CS	NE	NE													NE	NE	NE	NE
2	Ferroalloy production	T3	CS	T3	CS	NE												NE	NE	NE	NE
3	Aluminium production	T3	CS	NE														NE	NE	NE	NE
4	Magnesium production		NO					NO										NO	NO	NO	NO
5	Lead production	T1	DF															NE	NE	NE	NE
6	Zinc production	T1	DF															NE	NE	NE	NE
D	Non-energy products from fuels and solvents																				
1	Lubricant use	T1	DF															NE	NE	NE	NE
2	Paraffin wax use	T1	DF	NE	NE													NE	NE	NE	NE
3	Solvent use																	NE	NE	NE	NE
E	Electronics industry																				
1	Integrated circuit or semiconductor		NE															NE	NE	NE	NE
2	TFT flat panel display																	NE	NE	NE	NE
3	Photovoltaics																	NE	NE	NE	NE

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4.1.3 Improvements and recalculations

Through the introduction of the NGER in 2017 (DEA, 2017a), amendments to these regulation in 2020 (DEFF, 2020) as well as the introduction of the SAGERS, the GHG reporting tool, there have been various additions to the inventory as well as recalculations up to 2020. During 2020 a major change was the introduction of Tier 2 and Tier 3 calculation methods as far as possible. This did lead to improved accuracy of the inventory. An external verification process was launched for key emission contributors which increased the level of accuracy. The accuracy improvement has not been quantified.

The 2024 national inventory does not contain any recalculations see Figure 4.6 Below.

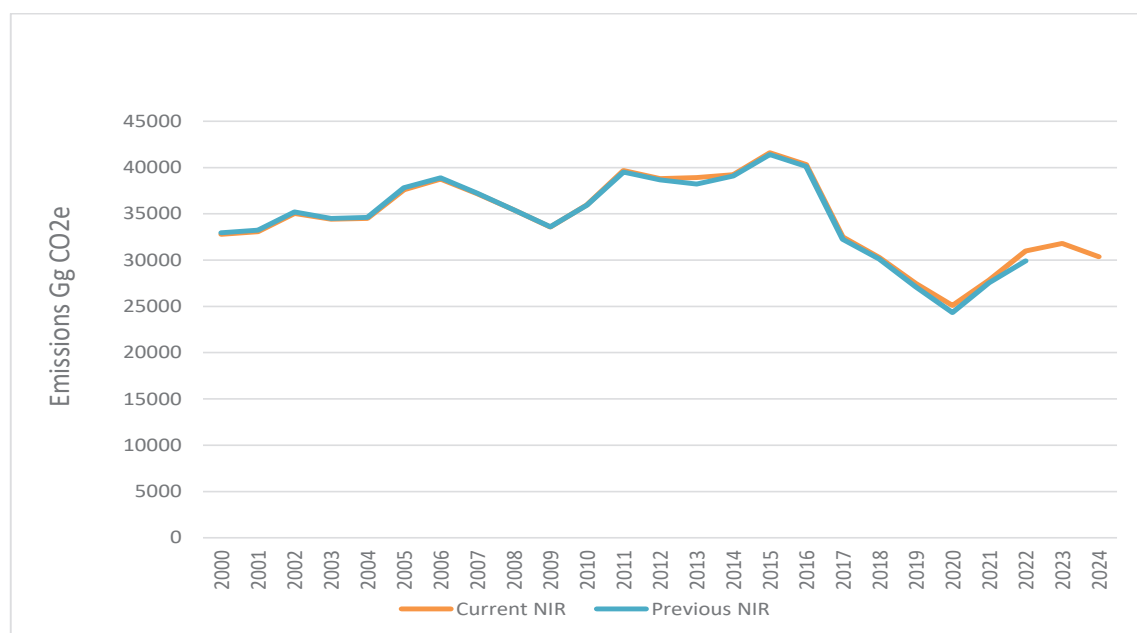


Figure 4.6. Recalculations

The 2024 NID incorporated the GHG emissions data from 1990 to 2024 and no categories were added from 2020.



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4.1.4 Key categories in the IPPU sector

The key categories identified in the IPPU sector by the level (L) and trend (T) analysis are shown in Table 4.4.

Table 4.4: Key categories identified in the IPPU sector.

IPCC Code	Category	GHG	Criteria
2A1	Cement Production	CO ₂	L, T
2B2	Nitric Acid production	N ₂ O	T
2C1	Iron and Steel Production	CO ₂	L, T
2C2	Ferroalloys Production	CO ₂	L, T
2C3	Aluminium Production	F-gases	T
2D2	Paraffin Wax Use	CO ₂	T
2F1	Refrigeration and Air Conditioning	HFCs	L, T

4.1.5 QA/QC Process and Verification

Generic QA/QC measures were conducted for the IPPU sector calculation file, as indicated in Table 4.5.

Table 4.5: QA/QC measures for the IPPU sector inventory

QA/QC principle	Check	Description
Accuracy	Activity data source	Verify that the correct data source is being used for activity data.
Accuracy	Correct units	Ensure that the appropriate units are used.
Accuracy	Unit carry through	Confirm that units are consistently carried through calculations, including activity data and emission factors, to the summary table.
Accuracy	Method validity	Ensure that the methods used are valid and appropriate for the calculations.
Accuracy	Calculations check	All calculations should be verified by a second person for accuracy.
Accuracy	Uncertainties	Conduct an uncertainties analysis.
Accuracy	Double counting	Ensure there is no double counting in the data.
Accuracy	Correct GWP	Confirm that the correct Global Warming Potential (GWP) is being applied where applicable.



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QA/QC principle	Check	Description
Accuracy	Notation keys	Review the use of notation keys and associated assumptions for correctness.
Accuracy	Calorific values	Verify the correctness of calorific values.
Accuracy	Oxidation factors	Ensure oxidation factor values are accurate.
Accuracy	Carbon content	Confirm the accuracy of carbon content values.
Accuracy, Completeness, Consistency, Transparency	Trend check	Check that non-energy fuels are correctly reported between Energy and IPPU sectors.
Accuracy, Transparency	Emission factor applicability	Ensure proper allocation of CO ₂ between Energy and IPPU sectors for Iron and Steel.
Accuracy, Transparency, Consistency, Completeness	Recalculations	Perform trend checks to identify errors and document any data outliers.
Completeness, Comparability	Sub-category completeness	Verify the accuracy of default emission factors and ensure source information is provided.
Consistency	Time series consistency	Compare values against previous submissions and explain any discrepancies.
Transparency	Documentation	Check that all sub-categories are fully reported; highlight any omissions.
Transparency, Completeness, Consistency, Accuracy	Colour coding	Ensure consistency across time series data for activity data and emission factors.
Accuracy, Comparability	Cross check data	Ensure there is sufficient documentation for the data.
Accuracy	Spot checks	Verify that colour coding is used consistently and accurately, and note any significant data gaps or weaknesses.
Transparency, Consistency	Data source referencing	Cross-check data against alternative sources, where possible.
Transparency	Links to source data	Perform random spot checks on the dataset.
Transparency	Raw primary data	Reference all source data used in submissions.
Accuracy	QA review	Provide links to source data, if available.
Transparency	Raw primary data	Ensure that all raw primary data is present in the workbook.
Accuracy	QA review	Data must be reviewed and checked by a second person for quality assurance.

4.1.6 Planned improvements

Planned improvements and recommendations are given in Table 4.6. These will be prioritised as required and are dependent on resources.



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Table 4.6: Planned improvements and recommendations

IPCC Code	Improvement/Recommendation
General	- Have sector specific engagements discussing the expectations regarding moving to the higher Tier methods. - Address time series consistency issues as data becomes available for specific categories that have been newly included in the inventory. - Ensure that facility intensity data is available (even though not publicly). - Expand reporting to have sector and technology specific intensities.
2A1	Investigate historical data for the imports and exports of clinker
2A2	Undertake a completeness assessment to determine if non-marketed lime is reported
2A3	Disaggregate the cullet ratio by facility.
2B6	Investigate the availability of the historical data.
2C5	Investigate the air quality database for those data providers that trigger reporting under Lead Battery processing
2C6	- Investigate if secondary zinc production occurs in South Africa - Investigate the air quality database regarding pyrometallurgical process involving the use of an imperial smelting furnace is used for combined zinc and lead production.
2D1	South Africa to undertake a desktop study regarding two-stroke engines and the use of blended lubricant.
2D	Investigate the availability of more accurate data
2F	Investigate the availability of more accurate data

4.2 Mineral industry (CRT 2.A)

Mineral production emissions are process related GHG emissions resulting from the use of carbonate raw materials. The *Mineral production* category is divided into five subcategories: *Cement production*, *Lime production*, *Glass production*, *Process uses of carbonates*, and *Other mineral products processes*. For this inventory report, emissions are reported for four subcategories: *Cement production (2A1)*, *Lime production (2A2)*, *Glass production (2A3)* and *Other process uses of carbonates (2A4)*. *Other mineral products processes (2A5)* are not included due to a lack of data.



4.2.1 Cement production (CRT 2.A.1)

4.2.1.1 Category description

The South African cement industry's plants vary widely in age, ranging from five to over 70 years (DMR, 2009). The most common materials used for cement production are limestone, shells, and chalk or marl combined with shale, clay, slate or blast-furnace slag, silica sand, iron ore and gypsum. For certain cement plants, low-grade limestone appears to be the only raw material feedstock for clinker production (DMR, 2009). Portland cement, which has a clinker content of >95%, is described by the class CEM I, CEM II cements can be grouped depending on their clinker content into categories A (80 – 94%) and B (65 – 79%). Portland cement contains other pozzolanic components such as blast-furnace slag, micro silica, fly ash and ground limestone. CEM III cements have a lower clinker content and are also split into subgroups: A (35 – 64% clinker) and B (20 – 34% clinker). South Africa's cement production plants produce Portland cement and blended cement products, such as CEM I, and more recently CEM II and CEM III. Cement produced in South Africa is sold locally and to other countries in the Southern Africa region, such as Namibia, Botswana, Lesotho, and Swaziland.

The main GHG emission in *Cement production* is CO₂ emitted through the production of clinker, an intermediate stage in the cement production process. Non-carbonate materials may also be used in cement production, which reduce the amount of CO₂ emitted. However, the amounts of non-carbonate materials used are generally very small and not reported in cement production processes in South Africa. An example of non-carbonate materials would be impurities in primary limestone raw materials. It is estimated that 50% of the cement produced goes to the residential building market (DMR, 2009); therefore, any changes in the interest rates that affect the residential market will affect cement sales. COVID-19 effected the local market in the sense that lower strength cement was more in demand verses high strength cement during the 2020 period.

4.2.1.2 Methodological issues

From 2022, most cement producers used Tier 2 and 3 methodologies. Previously a Tier 1 approach was used to determine emissions from clinker produced in the *Cement production* category as per the IPCC 2006 Guidelines. From 2008 to 2015 imports of clinker were included in the calculations as the information was available for these years.



4.2.1.2.1 Activity data

Data on cement production in South Africa was obtained from the SAMI Annual Reports produced by the DMRE for 2000 to 2017. Clinker production for the years 2018 and 2019 were provided by the cement industries via South Africa's GHG Reporting Programme. Clinker fraction for the years 2000 to 2012 were obtained from cement industries but was not available for the period between 2013 and 2017, therefore it was assumed to remain unchanged between 2012 and 2017. The clinker fraction for the years 2018 and 2019 were not provided by all cement industries, however the clinker produced was provided, from the 2020 -2024 reporting period through South Africa's GHG Reporting Programme.

4.2.1.2.2 Emission factors

For the calculation of GHG emissions in *Cement production*, CO₂ emission factors were sourced from the IPCC 2006 Guidelines. It was assumed that the Calcium Oxide (CaO) composition (one tonne of clinker) contains 0.65 tonnes of CaO from Calcium Carbonate (CaCO₃). This carbonate is 56.03% of CaO and 43.97% of CO₂ by weight (IPCC, 2006, p. 2.11). The emission factor for CO₂, provided by IPCC 2006 Guidelines, is 0.52 tonnes of CO₂ per tonne clinker. The country-specific clinker fraction for the period 2000 to 2021 ranged between 69% - 76%. From 2022 a Tier 2 calculation was done by production plants. The implied emission factor of 0.526 is very close that of the IPCC.

4.2.1.3 **Uncertainties and time-series consistency**

4.2.1.3.1 Activity data uncertainty

The largest uncertainty in this sub-category is the import/export data. According to IPCC 2006 Guidelines the uncertainties are: 1% for chemical analysis of clinker to determine CaO; 10% for country production data; 30% for the Cement Kiln Dust (CKD) correction factor default assumption; and 10% on the trade data. From 2022, these uncertainties will be much less due to the Tier 2 and Tier 3 reporting protocols but will only be updated once enough data is available to determine these.

4.2.1.3.2 Emission factor uncertainty

Since this submission moved back to a Tier 1 method uncertainty has increased. According to the IPCC 2006 Guidelines, uncertainty with a Tier 1 approach could be as much as 35% in terms of estimation of % of calcination of CKD (IPCC, 2006, Table 2.3).

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From 2022 Tier 2 and Tier 3 methods are used. Uncertainty should be much less but is not quantified yet.

4.2.1.3.3 *Time-series consistency*

The time-series for this sub-category is not consistent. A Tier 1 method has been used from 1990 to 2021 to estimate emissions from this category. Tier 2 and Tier 3 methodologies have been used for 2022-2024. Import data was available and used for estimations from 2008 to 2015. Emissions were estimated throughout the time-series by using clinker production, which was calculated by multiplying cement production, obtained from the SAMI Report, by clinker fraction from 2000 to 2017. Company specific clinker production was provided from 2018 onwards.

4.2.1.4 *Category specific QA/QC and verification*

External verification of 2022/23/ and 24 emissions were requested for most of the cement producers.

For verification of cement production data, the facility-level clinker production submitted by cement industries via the SAGERS for the inventory was compared with estimated clinker production from previous inventories. The clinker production however for 2020 showed a decrease compared to previous years. This decrease could be due to the COVID-19 pandemic which saw stringent lockdown measures being implemented in South Africa during 2020.

In previous years (2000 -2017) comparisons against the SAMI reports produced by DMR was also conducted although the information with the report is not clinker production but rather the total amount of lime and dolomite sold to the cement industry however using a clinker fraction of 69% - 76% indicates that clinker production follows the same trend as that from the facility level data from cement industries. It is important to note that the numbers in the SAMI Report may produce slightly overestimated values if not all lime is converted to cement in that year.

In addition, the estimates of clinker production from the DMR data do not include clinker exports due to a lack of data. It is not clear if the industry level clinker data within the report takes imports and exports into account. These differences lead to increased uncertainty and the reasons for the discrepancies need to be further investigated. Direct reporting and verification by data providers have limited these uncertainties.



4.2.1.5 Category specific recalculations

Recalculations were not performed for this category.

4.2.1.6 Category specific planned improvements

It is evident that there are discrepancies between the cement production data from industry and the cement production data published by the DMR (2000 – 2017), however further data collected by SAGERS could assist in reducing this uncertainty and aid in more consistent reporting in future.

4.2.2 Lime production (CRT 2.A.2)

4.2.2.1 Category description

Lime is the most widely used chemical alkali in the world. Calcium oxide (CaO or quicklime or slaked lime) is sourced from CaCO_3 which occurs naturally as limestone (CaCO_3) or dolomite ($\text{CaMg}(\text{CO}_3)_2$). CaO is formed by heating limestone at high temperatures to decompose the carbonates (IPCC, 2006 pg 2.19) and produce CaO. This calcination reaction produces CO_2 emissions. Lime kilns are typically rotary-type kilns, which are long, cylindrical, slightly inclined and lined with refractory material. At some facilities, the lime may be subsequently reacted (slaked) with water to produce hydrated lime.

In South Africa the market for lime is divided into pyrometallurgical and chemical components. Hydrated lime is divided into three sectors: chemical, water purification and other sectors (DMR, 2019). Lime has wide applications, e.g., it is used as a neutralizing and coagulating agent in chemical, hydrometallurgical and water treatment processes and a fluxing agent in pyrometallurgical processes. Quicklime sales for both pyrometallurgical uses and chemical uses both increased in 2017 (DMR, 2019). Demand for hydrated lime for water purification purposes decreased from 2016 to 2017, while demand for sales for chemical applications increased during the same period (DMR, 2019).

4.2.2.2 Methodological issues

A Tier 1 and Tier 2 approach was used to estimate emissions from this category as per the IPCC 2006 Guidelines. The production of lime involves various steps, which include the quarrying of raw materials, crushing and sizing, calcining the raw materials to produce lime, and (if required) hydrating the lime to calcium hydroxide. The Tier 2

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approach was used for the calculation of GHG emissions from *Lime production* (Equation 2.6, IPCC 2006 Guidelines). This report estimated the total *Lime production* based on the quantity of quicklime, hydrated lime and dolomitic lime produced.

For 2024 a Tier 2 methodology is used for the calculation of emissions.

4.2.2.2.1 Activity data

The DMRE publishes data on lime products that is divided into quicklime which includes pyrometallurgical and chemical components; and hydrated lime that includes water purification, chemical and other uses (DMR, 2019). In the previous submissions only pyrometallurgical quicklime and water purification hydrated lime was incorporated from the SAMI Reports (DMR, 2019) were used (8). It was assumed that all quicklime is high calcium lime. From the 2020 inventory included activity data provided by the lime industries reported via South Africa's GHG Reporting Programme. The types of lime reported were quicklime, hydrated lime and dolomitic lime. Quicklime activity data for 2018 and 2019 were extrapolated due to lack of data received for these years. Activity data for hydrated lime during 2018 and 2019 was not provided by industry through South Africa's GHG Reporting Programme and the updated SAMI report was not available for use.

4.2.2.2.2 Emission factors

Quicklime is indicated to be high-calcium lime. The IPCC 2006 Guidelines default emission factor for high-calcium lime (0.75 tonnes CO₂ per tonne lime) was applied. The IPCC 2006 Guidelines default emission factor of 0.77 tonnes CO₂ per tonne lime was applied to dolomitic lime. The IPCC 2006 Guidelines default emission factor of 0.59 tonnes CO₂ per tonne lime was applied to hydrated lime.

From 2022, a Tier 3 methodology was used with implied emission factors of 0.78 and 0.57 tonnes CO₂ per ton lime for quicklime and hydrated lime respectively.

4.2.2.3 **Uncertainties and time-series consistency**

4.2.2.3.1 Activity data uncertainty

According to the IPCC 2006 Guidelines, uncertainty of the Lime Kiln Dust (LKD) correction factor for hydrated lime adds to the uncertainty of the activity data due to not knowing the amount of LKD produced and what percentage is calcined, as with the CKD



correction factor used for estimating emissions from cement production. Therefore, it can be assumed that the uncertainty for LKD is equal to the uncertainty of CKD which is 30%.

For 2022 a Tier 3 methodology is used, but even though uncertainty would be much less, it has not been calculated.

4.2.2.3.2 *Emission factor uncertainty*

According to the IPCC 2006 Guidelines, the uncertainty on *Lime production* emissions is: 6% for assuming an average CaO in lime; 2% for high-calcium EF; 5% for correction for hydrated lime.

4.2.2.3.3 *Time-series consistency*

A Tier 1 and Tier 2 method was used to estimate emissions from 1990 to 2021. The time series was updated to include the IPCC 2006 Guidelines default emission factor of 0.59 for hydrated lime in 2017. Dolomitic lime was added to the time series in 2019. From 2022 a Tier 3 methodology is used.

4.2.2.4 *Category specific QA/QC and verification*

No category specific QC checks were completed for this sub-category.

The only available data for *Lime production* was sourced from the SAMI report for the 2000 to 2017 inventories, however, from the 2020 inventory, data was sourced from the lime production industry: therefore, there was no comparison of data across different plants previously. The numbers in the DMR report are the total amount of lime (quicklime and hydrated lime) sold locally so may produce slightly overestimated values if not all lime is produced in South Africa or during that year. Reporting is currently not consistent between plants, and verification will be undertaken as consistency is achieved in the future. The SAGERS which became active in 2020, will allow for consistency to be achieved going forward.

4.2.2.5 *Category specific recalculations*

Recalculations were not undertaken for this category.

4.2.2.6 *Category specific planned improvements*

The inclusion of Tier 3 emission estimates and external verification of emissions data is set to continue to the future.

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4.2.3 Glass production (CRT 2.A.3)

4.2.3.1 *Category description*

There are many types of glass and compositions used commercially, however the glass industry is divided into four categories: containers, flat (window) glass, fibre glass and speciality glass. When other materials (including metal) solidify, they become crystalline, whereas glass (a super cool liquid) is non-crystalline. The raw materials used in glass production are sand, limestone, soda ash, dolomite, feldspar and saltcake. The major glass raw materials which emit CO₂ during the melting process are limestone (CaCO₃), dolomite CaMg (CO₃)₂ and soda ash (Na₂CO₃). Glass makers do not produce glass only from raw materials, they also use a certain amount of recycled scrap glass (cullet). The chemical composition of most glass is silica (72%), iron oxide (0.075%), alumina (0.75%), magnesium oxide (2.5%), sodium oxide (14.5%), potassium oxide (0.5%), sulphur trioxide (0.25%) and calcium oxide (7.5%) (PFG glass, 2010).

4.2.3.2 *Methodological issues*

A Tier 3 approach was used to determine estimates of the GHG emissions from *Glass production* by the glass production industries for the 2024 inventory. Data providers used a mass balance approach to estimate emissions providing inputs and outputs of their process and carbon content factors specific to their materials. External verification is done on the 2024 data.

4.2.3.2.1 Activity data

Production data was provided by the glass production industries (PG Group, Consol Glass and Isanti Glass), via the manual reporting.

4.2.3.2.2 Emission factors

All glass production industries determined their own emissions using a Tier 3 approach and provided these emission estimates to DFFE. In most cases the activity data and emission factors used are not supplied due to confidentiality issues. External verification is however done on the 2024 data.



4.2.3.3 *Uncertainties and time-series consistency*

4.2.3.3.1 *Activity data uncertainty*

As per the IPCC 2006 Guidelines, uncertainty related to activity data using a Tier 3 approach is between 1 – 3% (IPCC 2006 Guidelines, Chapter 2.4.2.2). Carbonates lost as dust is negligible under the Tier 3 method.

4.2.3.3.2 *Emission factor uncertainty*

As per the IPCC 2006 Guidelines, uncertainty related to emission factors developed using a Tier 3 approach is between 1 – 3% (IPCC 2006 Guidelines, p. 2.31). There is some uncertainty when assuming that all carbonates are calcined, but this is minimal.

4.2.3.3.3 *Time-series consistency*

A Tier 1 method was used to estimate emissions from 2000 to 2017, using the cullet ratio and the default emission factor of 0.2. From 2018 onwards after the promulgation of the NGER, glass production industries began using the Tier 2 and Tier 3 methods to estimate emissions, using a mass balance approach.

4.2.3.4 *Category specific QA/QC and verification*

External verification of emissions was done for the 2023 and 2024 data from individual companies.

4.2.3.5 *Category specific recalculations*

No recalculations were performed for this category.

4.2.3.6 *Category specific planned improvements*

There is an improvement project planned to investigate the inclusion separation of cullet ratio reported per facility.



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4.2.4 Other process uses of carbonates (CRT 2.A.4)

4.2.4.1 Category description

Limestone (CaCO_3), dolomite ($\text{CaMg}(\text{CO}_3)_2$) and other carbonates (e.g., MgCO_3 and FeCO_3) are basic raw materials having commercial applications in a number of industries. The calcination of carbonates at high temperatures yields CO_2 . In addition to those industries already discussed individually above, carbonates are also consumed in metallurgy, agriculture, construction and environmental pollution control (IPCC, 2006). The use of lime in the following specific source categories are reported within the mineral category, such as ceramics, other soda ash usage and non-metallurgical magnesia production.

Ceramics include the production of bricks and roof tiles, vitrified clay pipes, refractory products, expanded clay products, wall and floor tiles, table and ornamental ware (household ceramics), sanitary ware, technical ceramics, and inorganic bonded abrasives. Emissions from the ceramic production industry are process related and are emitted when calcination of clay occurs and when additives are added to the process (IPCC, 2006). Within South Africa it has been shown that carbonates are very low in raw materials.

Soda ash is used in a variety of applications, including, glass production, soaps and detergents, flue gas desulphurisation, chemicals, pulp and paper and other common consumer products. Soda ash production and consumption results in the release of CO_2 emissions (IPCC, 2006).

Magnesite (MgCO_3) is one of the key inputs into the production of magnesia, and ultimately fused magnesia. There are three major categories of magnesia products: calcined magnesia, dead burned magnesia (periclase) and fused magnesia. Magnesia is produced by calcining MgCO_3 which results in the release of CO_2 (IPCC, 2006). Emissions may result from several other source categories that are not included above.

4.2.4.2 Methodological issues

A Tier 1 and 3 approach was adopted to estimate emissions from the *Ceramics* and *Soda ash usage* subcategories. The Tier 3 approach included data providers undertaking analysis of their raw materials used within the process to determine the carbon content and then applying this value to their production data. A Tier 1 approach was used to estimate emissions from other uses of carbonates. *Other uses of carbonates* included the use of dolomite and calcite within separate processes.



4.2.4.2.1 Activity data

Activity data were obtained from industries operating under the relevant sector. Activity data was reported via South Africa's GHG Reporting Programme. This is a new category added to the inventory from 2018 and all activity data has been reported via the GHG reporting Programme in 2023/24.

4.2.4.2.2 Emission factors

The IPCC 2006 Guidelines default emission factors for calcite (0.43971 tonnes CO₂ per tonne carbonate), magnesite (0.52197 tonnes CO₂ per tonne carbonate) and for soda ash usage (0.41492 tonnes CO₂ per tonne carbonate) was applied where a Tier 1 approach was used. The IPCC 2006 Guidelines default emission factor for other usage of carbonates (0.47732 tonnes CO₂ per tonne lime) was applied to dolomite usage. Most industrial operators have however switched to a Tier 3 methodology.

4.2.4.3 **Uncertainties and time-series consistency**

4.2.4.3.1 Activity data uncertainty

According to the IPCC 2006 Guidelines, uncertainty arising from a Tier 3 approach is between 1-3%, and where a Tier 1 approach has been used uncertainty rises to between 15-85%. As both approaches were used to estimate emissions in 2020 activity data for subcategories *Ceramics* and *Soda Ash Usage* uncertainty will fall between the range of 1 - 85%.

4.2.4.3.2 Emission factor uncertainty

As per the IPCC 2006 Guidelines, emission factors used correctly to activity data that has been collected correctly uncertainty is negligible. However, should there be an error in the assumption of carbonates an uncertainty of between 1-5% should apply.

4.2.4.3.3 Time-series consistency

The *Other Process Uses of Carbonates* is a new category introduced to the inventory in 2018. This has resulted in an inconsistent time series as historical data is unavailable currently. The time series consistency will be updated as industry continues to report in future via the SAGERS Portal. More data providers are also switching to Tier 3 methodologies over time.

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4.2.4.4 Category specific QA/QC and verification

No category specific QC checks were completed for this sub-category.

4.2.4.5 Category specific recalculations

Recalculations were not undertaken for this category.

4.2.4.6 Category specific planned improvements

There are no subcategory specific planned improvements, but any updated information from SAGERS will be included.

4.3 Chemical industry (CRT 2.B)

This category estimates GHG emissions from the production of both organic and inorganic chemicals in South Africa. The chemical industry in South Africa is mainly developed through the gasification of coal because the country has no significant oil reserves. GHG emissions from the following chemical production processes were reported: *Ammonia production, Nitric acid production, Carbide production, Soda ash production, Titanium dioxide production, Carbon black, Hydrogen production and Other chemical processes*. The chemical industry in South Africa contributes approximately 3.0% to the GDP and 23% of its manufacturing. The chemical products in South Africa can be divided into four categories: base chemicals, intermediate chemicals, chemical end-products, and speciality end-products. Chemical products include ammonia, waxes, solvents, plastics, paints, explosives and fertilizers.

The chemical industries subsector contains confidential information, so, following the IPCC 2006 Guidelines for reporting confidential information, no disaggregated source-category level emission data are reported; only the emissions at the sector scale are discussed. Emission estimates are, however, based on bottom-up activity data and methodologies.

4.3.1 Ammonia production (CRT 2.B.1)**4.3.1.1 Category description**

Ammonia production is the most important nitrogenous material produced and is a major industrial chemical. According to the IPCC 2006 Guidelines (p.3.11), ammonia gas can be



used directly as a fertilizer, in heat treating, paper pulping, nitric acid and nitrates manufacture, nitric acid ester and nitro compound manufacture, in explosives of various types and as a refrigerant.

4.3.1.2 Methodological issues

Emission estimates from *Ammonia production* were obtained through the Tier 3 approach. Emissions were calculated based on actual process balance analysis. Total emission estimates were obtained from the ammonia production plants. 2022/23/ and 24 data was verified externally.

4.3.1.2.1 Activity data

Consumption data is not provided within this report due to confidentiality. It is however reported via the SAGERS system.

4.3.1.2.2 Emission factors

The emission factors are not provided within this report due to confidentiality reasons.

4.3.1.3 Uncertainties and time-series consistency

4.3.1.3.1 Activity data uncertainty

According to the IPCC 2006 Guidelines (p.3.16), the plant-level activity data required for the Tier 3 approach are the total fuel requirement classified by fuel type; CO₂ recovered for downstream use or other applications; and *Ammonia production*. Uncertainty of $\pm 2\%$ was applied to activity data as advised in the IPCC 2006 Guidelines (p.3.17) should activity data be obtained from producers. The uncertainty was assumed to be the same for both CO₂ and CH₄ emissions.

4.3.1.3.2 Emission factor uncertainty

The IPCC 2006 Guidelines default uncertainty for Tier 1 is 6% (IPCC 2006 Guidelines, Table 3.1) therefore it is expected that for a Tier 3 approach the uncertainty would be less, therefore an assumption of $\pm 2\%$ is made as per information provided in the IPCC 2006 Guidelines (p. 3.17) for activity data obtained from plants. The uncertainty was assumed to be the same for both CO₂ and CH₄ emission estimates as guidance was not provided per GHG.

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4.3.1.3.3 *Time-series consistency*

A Tier 3 method was used from the 2022 reporting onwards, emissions prior to 2022 were estimated using tier 1.

4.3.1.4 ***Category specific QA/QC and verification***

Internal QA/QC for the inventory compilation was completed, and the 2024 reported emissions data was verified externally.

4.3.1.5 ***Category specific recalculations***

No recalculations were performed for this category.

4.3.1.6 ***Category specific planned improvements***

There are no subcategory specific planned improvements, but any updated information from SAGERS will be included.

4.3.2 Nitric acid production (CRT 2.B.2)**4.3.2.1** ***Category description***

Nitric acid is a raw material used mainly in the production of nitrogenous-based fertilizer. According to the IPCC 2006 Guidelines (p.3.19), during the production of nitric acid, nitrous oxide is generated as an unintended by-product of high-temperature catalytic oxidation of ammonia.

4.3.2.2 ***Methodological issues***

The emissions from *Nitric acid production* were calculated based on continuous monitoring (Tier 3 approach) and approved country specific emission factors.

4.3.2.2.1 *Activity data*

Consumption data is not provided within this report due to confidentiality. It is however reported via SAGERS.

4.3.2.2.2 *Emission factors*

The emission factors are not provided as the information is confidential.



4.3.2.3 Uncertainties and time-series consistency

4.3.2.3.1 Activity data uncertainty

According to the IPCC 2006 Guidelines (p. 3.24) the plant-level activity data required for the Tier 3 approach includes production data disaggregated by technology and abatement system type. The IPCC 2006 Guidelines suggest that where uncertainty values are not available from other sources, as is the case for this inventory, this default value of ± 2 percent should be applied to the activity data (IPCC 2006 Guidelines, p.3.25).

4.3.2.3.2 Emission factor uncertainty

According to the IPCC 2006 Guidelines (p. 3.24), default emission factors have very high uncertainties for two reasons: a) N_2O may be generated in the gauze reactor section of nitric acid production as an unintended reaction by-product; and b) the exhaust gas may or may not be treated for NO_x control and the NO_x abatement system may or may not reduce the N_2O concentration of the treated gas. Since a Tier 3 approach was applied in this inventory it was assumed that the uncertainty value was ± 2 as per Tier 3 approach (IPCC 2006 Guidelines, p.3.24).

4.3.2.3.3 Time-series consistency

A Tier 3 method was used throughout the time-series, with emission data being provided by industry.

4.3.2.4 Category specific QA/QC and verification

The 2024 data were verified externally.

4.3.2.5 Category specific recalculations

No recalculations were performed on this category.

4.3.2.6 Category specific planned improvements

There are no subcategory specific planned improvements, but any updated information from SAGERS will be included.

4.3.3 Adipic acid production (CRT 2.B.3)

There is no *Adipic acid production* occurring in South Africa.

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4.3.4 Caprolactum, glyoxal and glyoxylic acid production (CRT 2.B.4)

There is no *Caprolactum, glyoxal and glyoxylic acid production* occurring in South Africa.

4.3.5 Carbide production (CRT 2.B.5)

4.3.5.1 Category description

Carbide production can result in GHG emissions such as CO₂ and CH₄. According to the IPCC 2006 Guidelines (p.3.39), calcium carbide is manufactured by heating calcium carbonate (limestone) and subsequently reducing CaO with carbon (e.g., petroleum coke) while silicon carbide is produced from silica sand or quartz and petroleum coke.

4.3.5.2 Methodological issues

Emissions from *Carbide production* were calculated based on a Tier 1 approach as per the IPCC 2006 Guidelines. From 2022 emissions are reported based on Tier 3 methodologies.

4.3.5.2.1 Activity data

Calcium carbide and silicon carbide consumption values were sourced from the carbide production plants but are not shown due to confidentiality issues. Calcium carbide is not estimated for 2019 and the production plant is no longer operational. Silicon carbide emission estimates have been included since 2019 through South Africa's GHG Reporting Programme.

4.3.5.2.2 Emission factors

An IPCC 2006 Guidelines default emission factor was applied historically. Since 2022 Tier 3 methodologies are used.

4.3.5.3 Uncertainties and time-series consistency

4.3.5.3.1 Activity data uncertainty

According to the IPCC 2006 Guidelines (p. 3.45), the uncertainty of the activity data that accompanies the method used here is approximately $\pm 5\%$. The uncertainty was assumed



to be the same for both CO₂ and CH₄ emission estimates as guidance was not provided per GHG.

4.3.5.3.2 *Emission factor uncertainty*

The default emission factors are generally uncertain because industrial-scale carbide production processes differ from the stoichiometry of theoretical chemical reactions (IPCC 2006 Guidelines; p. 3.45). Emission factor uncertainty for Tier 1 is $\pm 10\%$. The uncertainty was assumed to be the same for both CO₂ and CH₄ emission estimates as guidance was not provided per GHG. From 2022 Tier 3 methodologies are used with indicated uncertainty of $\pm 2\%$.

4.3.5.3.3 *Time-series uncertainty*

The emissions from *Carbide production* were sourced from the specific carbide production plants therefore there was no comparison of data across different plants. A Tier 1 method was used across the time series, with the addition of silicon carbide in 2019. From 2022 a Tier 3 method is used.

4.3.5.4 *Category specific QA/QC and verification*

No category specific QC checks were carried out.

4.3.5.5 *Category specific recalculations*

No recalculations were performed on this category.

4.3.5.6 *Category specific planned improvements*

There are no subcategory specific planned improvements, but any updated information from SAGERS will be included.

4.3.6 **Titanium dioxide production (CRT 2.B.6)**

4.3.6.1 *Category description*

Titanium dioxide (TiO₂) is a white pigment used mainly in paint manufacture, paper, plastics, rubber, ceramics, fabrics, floor coverings, printing ink, among others. According IPCC 2006 Guidelines (p. 3.47), there are three processes in TiO₂ production that result in GHG emissions, namely, a) titanium slag production in electric furnaces; b) synthetic

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rutile production using the Becher Process and c) rutile TiO₂ production through the chloride route.

4.3.6.2 Methodological issues

A Tier 3 approach was used for calculating GHG emissions from titanium dioxide production. Data providers used a mass balance approach to estimate emissions.

4.3.6.2.1 Activity data

The *Titanium dioxide production* emissions data were sourced from the titanium dioxide production plants and activity data was not supplied in this report due to confidentiality issues.

4.3.6.2.2 Emission factors

The emission factors are not provided in this report as the information is confidential. Tier 3 calculations are done for this sector.

4.3.6.3 Uncertainties and time-series consistency**4.3.6.3.1 Activity data uncertainty**

According to the IPCC 2006 Guidelines (p. 3.50), the uncertainty of the activity data when using a Tier 2 approach is $\pm 2\%$ for activity data collected at plant level. It is therefore assumed that the uncertainty is ± 2 as data was provided at a plant level.

4.3.6.3.2 Emission factor uncertainty

The IPCC 2006 Guidelines state that uncertainty for titanium slag is unavailable due to confidentiality and lack of production plants. However, an assumption of ± 2 was made as per the uncertainty of the activity data (IPCC 2006 Guidelines, p.3.50)

4.3.6.3.3 Time-series consistency

The total GHG emissions were sourced from the specific titanium dioxide production plants therefore, no comparison of data across different plants was made. A Tier 3 approach was used across the time series.



4.3.6.4 Category specific QA/QC and verification

No category specific QC checks were completed for this sub-category.

4.3.6.5 Category specific recalculations

No recalculations were performed on this category.

4.3.6.6 Category specific planned improvements

There are no subcategory specific planned improvements, but any updated information from South Africa's GHG Reporting Programme will be included.

4.3.7 Soda ash production (CRT 2.B.7)

4.3.7.1 Category description

Soda ash (sodium carbonate, Na_2CO_3) is a white crystalline solid that is used as a raw material in many industries including glass manufacture, soap and detergents, pulp and paper production and water treatment. CO_2 is emitted during production with the quantity emitted dependent on the industrial process used to manufacture soda ash (IPCC, 2006).

Emissions of CO_2 from the production of soda ash vary substantially with the manufacturing process. Four different processes may be used commercially to produce soda ash. Three of these processes, monohydrate, sodium sesquicarbonate (trona) and direct carbonation, are referred to as natural processes. The fourth, the Solvay process, is classified as a synthetic process. Calcium carbonate (limestone) is used as a source of CO_2 in the Solvay process.

4.3.7.2 Methodological issues

A Tier 3 approach was used for calculating GHG emissions from *soda production*. Data providers used a mass balance approach to estimate emissions from 2020 onwards.

4.3.7.2.1 Activity data

The *Soda ash production* emissions data were sourced from the production plants and activity data was not supplied in this report due to confidentiality issues.

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4.3.7.2.2 Emission factors

The emission factors are not provided in this report as the information is confidential. It is however reported via SAGERS and manually for the 2023/24 period.

4.3.7.3 *Uncertainties and time-series consistency***4.3.7.3.1 Activity data uncertainty**

According to the IPCC 2006 Guidelines (p. 3.54), the uncertainty of the activity data when uncertainty is unavailable is $\pm 5\%$ for activity data collected at plant level.

4.3.7.3.2 Emission factor uncertainty

The IPCC 2006 Guidelines state that the uncertainty of the default emission factor is negligible as an assumption of 100% purity of input and output materials is made (IPCC 2006 Guidelines, p.3.54).

4.3.7.3.3 Time-series consistency

The time series is not consistent as soda ash production is a new category added in 2019. Historical data is not available. The time series will be built on in future as more data becomes available.

4.3.7.4 *Category specific QA/QC and verification*

No category specific QC checks were completed for this sub-category.

4.3.7.5 *Category specific recalculations*

No recalculations were performed on this category.

4.3.7.6 *Category specific planned improvements*

There are no subcategory specific planned improvements, but any updated information from SAGERS and manually for the 2023/24 period.



4.3.8 Petrochemical and carbon black production (CRT 2.B.8)

4.3.8.1 Category description

Carbon black is produced from petroleum-based or coal-based feed stocks using the furnace black process (IPCC, 2006). Primary fossil fuels in carbon black production include natural gas, petroleum and coal. The use of these fossil fuels may involve the combustion of hydrocarbon content for heat rising and the production of secondary fuels (IPCC 2006 Guidelines, p.3.56).

GHG emissions from the combustion of fuels obtained from feed stocks should be allocated to the source category in the IPPU sector, however, where the fuels are not used within the source category but are transferred out of the process for combustion elsewhere, these emissions should be reported in the appropriate energy sector source category (IPCC 2006 Guidelines, p. 3.56). Commonly, the largest percentage of carbon black is used in the tyre and rubber industry, and the rest is used as pigment in applications such as ink and carbon dry-cell batteries.

4.3.8.2 Methodological issues

Tier 1 was the main approach used in estimating emissions from *Carbon black production*, using production data and relevant emission factors.

4.3.8.2.1 Activity data

Carbon black activity data was sourced directly from industry but is not shown due to confidentiality issues.

4.3.8.2.2 Emission factors

For the calculation of emissions from *Carbon black production*, the IPCC 2006 Guidelines default CO₂ and CH₄ emission factors were applied (Table 4.7). Carbon black is mainly produced through the furnace black process; however, a small portion of carbon black production is known to be produced through the acetylene black process.



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Table 4.7: Emission factors applied for carbon black production emission estimates

Sub-category	CO ₂ EF	CH ₄ EF	Source
	(tonnes CO ₂ /tonne product)	(kg CH ₄ /tonne product)	
Carbon black production (Furnace Black Process)	2.62	0.06	IPCC 2006
Carbon black production (Acetylene Black Process)	0.12		IPCC 2006

4.3.8.3 *Uncertainties and time-series consistency*

4.3.8.3.1 *Activity data uncertainty*

According to the IPCC 2006 Guidelines, the uncertainty of the activity data that accompanies the method used here is in the range of $\pm 15\%$ for CO₂ and $\pm 85\%$ for CH₄ as per the IPCC 2006 Guidelines, Table 3.27.

4.3.8.3.2 *Emission factor uncertainty*

According to the IPCC 2006 Guidelines, the uncertainty of the emission factors that accompanies the method used here is in the range of $\pm 15\%$ for CO₂ and $\pm 85\%$ for CH₄ as per the IPCC 2006 Guidelines, Table 3.27.

4.3.8.3.3 *Time-series consistency*

A Tier 1 approach was used throughout the time series with activity data being collected from industry. Carbon black produced via the acetylene black process was reported for the years 2016 to 2018 when the company shut down.

4.3.8.4 *Category specific QA/QC and verification*

No category specific QC checks were completed for this sub-category.

4.3.8.5 *Category specific recalculations*

No recalculations were performed on this category.



4.3.8.6 Category specific planned improvements

There are no subcategory specific planned improvements, but any updated information from SAGERS and manually for the 2023/24 period.

4.3.9 Hydrogen Production (2.B.8.g)

4.3.9.1 Category description

Hydrogen (H₂) is a gas with flammable properties like natural gas and gasoline. Currently hydrogen is used as raw material in refineries and in the production of ammonia, methanol and various chemicals (IPCC, 2019). Hydrogen can also be used as an energy carrier in the transport sector, as energy storage and buffer systems in renewable electricity production, as a main constituent in coal gas used for heating and cooking, as well as in semiconductor industry processing and welding (IPCC, 2019). Hydrogen can be produced through various processes, the most common being steam reforming (95%), which uses fossil fuels or renewable fuels as a feedstock. The use of fossil fuels results in GHGs being emitted (Zohuri, 2018).

4.3.9.2 Methodological issues

A Tier 3 approach was used for calculating GHG emissions from *hydrogen production*. Data Providers used a mass balance approach to estimate emissions from 2020 onwards.

4.3.9.2.1 Activity data

The *hydrogen production* emissions data were sourced from the production plants and activity data was not supplied in this report due to confidentiality issues.

4.3.9.2.2 Emission factors

The emission factors are not provided in this report as the information is confidential.

4.3.9.3 Uncertainties and time-series consistency

4.3.9.3.1 Activity data uncertainty

According to the IPCC 2019 Refinement (p. 3.50), the uncertainty of the activity data when plant level data is available is $\pm 2\%$.

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4.3.9.3.2 *Emission factor uncertainty*

Uncertainty is not provided in the IPCC 2019 Refinement for emission factors; therefore, it was assumed to be the same as with activity data, $\pm 2\%$.

4.3.9.3.3 *Time-series consistency*

The time series is not consistent as hydrogen production is a new category added in 2018. Historical data is not available. The time series will be built on in future as more data becomes available.

4.3.9.4 *Category specific QA/QC and verification*

No category specific QC checks were completed for this sub-category.

4.3.9.5 *Category specific recalculations*

No recalculations were performed on this category.

4.3.9.6 *Category specific planned improvements*

There are no subcategory specific planned improvements, but any updated information from SAGERS and manually for the 2023/24 period.

4.3.10 Other (CRT 2.B.10)**4.3.10.1 *Category description***

This category includes emissions from chemicals manufacturing industries that are not covered elsewhere in the IPCC 2006 Guidelines. Emissions of CO₂ and CH₄ are reported within this category. Process emission from the Phthalic Anhydride process and partial oxidation of Butane and Ortho-Xylene are included in this category.

4.3.10.2 *Methodological issues*

A Tier 3 approach was used for calculating GHG emissions from this subcategory. Data Providers used stack monitoring reports to estimate emissions from 2020 onwards.



4.3.10.2.1 Activity data

The emissions data were sourced from the production plants and activity data was not supplied in this report due to confidentiality issues.

4.3.10.2.2 Emission factors

The emission factors are not provided in this report as the information is confidential. Tier 3 calculations are used for reporting in this sectors.

4.3.10.3 *Uncertainties and time-series consistency*

4.3.10.3.1 Activity data uncertainty

The IPCC 2006 Guidelines have not provided guidance on the uncertainty from activity data therefore an assumption of $\pm 5\%$ was made based on the default uncertainty from Carbide production for both CO₂ and CH₄.

4.3.10.3.2 Emission factor uncertainty

The IPCC 2006 Guidelines have not provided guidance on the uncertainty from emission factors therefore an assumption of $\pm 5\%$ was made based on the default uncertainty from Carbide production for both CO₂ and CH₄.

4.3.10.3.3 Time-series consistency

The time series is not consistent as this is a new category added in 2020. Historical data is not available. The time series will be built on in future as more data becomes available.

4.3.10.4 *Category specific QA/QC and verification*

No category specific QC checks were completed for this sub-category.

4.3.10.5 *Category specific recalculations*

No recalculations were performed on this category.

4.3.10.6 *Category specific planned improvements*

There are no subcategory specific planned improvements, but any updated information from SAGERS and manually for the 2023/24 period.



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4.4 Metal industry (CRT 2.C)

This subcategory relates to emissions resulting from the production of metals. Processes covered for this inventory report include the production of iron and steel, ferroalloys, aluminium, lead, and zinc. Estimates were made for emissions of CO₂ from the manufacture of all the metals and emissions of CH₄ were estimated from *Iron and steel production* and *Ferroalloy production*, and perfluorocarbons (CF₄ and C₂F₆) from *aluminium production*. Due to the moving towards Tier 3 calculations and estimation methodologies, CH₄ emissions are not estimated for all entities and uncertainties might be higher than stated.

4.4.1 Iron and steel production (CRT 2.C.1)

4.4.1.1 Category description

Iron and steel production results in the emission of CO₂, CH₄ and N₂O. According to the IPCC 2006 Guidelines (p. 4.9), the iron and steel industry broadly consists of primary facilities that produce both iron and steel; secondary steel-making facilities; iron production facilities; and offsite production of metallurgical coke. According to the World Steel Association (2010), South Africa is the 21st-largest crude steel producer in the world. The range of primary steel products and semi-finished products manufactured in South Africa includes billets; blooms; slabs; forgings; light-, medium- and heavy sections and bars; reinforcing bar; railway track material; wire rod; seamless tubes; plates; hot- and cold-rolled coils and sheets; electrolytic galvanised coils and sheets; tinplate; and pre-painted coils and sheets. The range of primary stainless-steel products and semi-finished products manufactured in South Africa include slabs, plates, and hot- and cold-rolled coils and sheets. COVID-19 had a negative effect on iron and steel production, but the market recovered to a large extent afterwards. The negative market effect was however used to shut down certain plants or areas for major maintenance.

4.4.1.2 Methodological issues

Historically a Tier 1 approach was applied to calculation emissions from *Iron and steel production*. A Tier 1 and 3 approach was applied for the different process types in 2020 and Tier 3 was used from 2022. Default IPCC emission factors were used for the calculation of GHG emissions from basic oxygen furnace, electric arc furnace, pig iron production, direct reduced iron production and sinter production. Industry also used a Tier 3 approach to estimate emissions from electric arc furnaces using raw material input and output.



Energy-related emissions from *Iron and steel production* have been accounted for under the Energy Sector.

4.4.1.2.1 Activity data

Activity data was provided by the *Iron and steel production* plants via South Africa's GHG Reporting Programme.

4.4.1.2.2 Emission factors

Historically IPCC default emission factors were applied for the calculation of emissions from *Iron and steel production*. From 2022 all reporting was done using a Tier 3 approach based on mass balance.

4.4.1.3 *Uncertainties and time-series consistency*

4.4.1.3.1 Activity data uncertainty

As historically both a Tier 1 and Tier 3 approach was used to estimate emissions from this category it was assumed that the uncertainty ranged from $\pm 5\%$ to $\pm 10\%$ as per the IPCC 2006 Guidelines (Table 4.4). From 2022 a Tier 3 approach is used, and uncertainty is estimated as $\pm 5\%$.

4.4.1.3.2 Emission factor uncertainty

The IPCC 2006 Guidelines indicate that applying Tier 1 to default emission factors for iron and steel production may have an uncertainty of $\pm 25\%$ (IPCC 2006 Guidelines, Table 4.4). As both a Tier 1 and Tier 3 approach was used historically to estimate emissions an uncertainty range of $\pm 5\%$ and $\pm 25\%$ was used for the EF. From 2022 a Tier 3 approach is used, and uncertainty is estimated as $\pm 5\%$.

4.4.1.3.3 Time-series consistency

Data was not consistent throughout the time series as the data was provided by different sources for the 2019 inventory. From 2020 the inventory included activity data directly from industry via the SAGERS through South Africa's GHG Reporting Programme. Prior to 2017 sinter production was not reported, however, since the promulgation of the NGER there has been disaggregation between direct reduced iron and sinter processes. Due to the effects of COVID-19, steel production values also differ with regards to production methodology for the past few years.



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4.4.1.4 *Category specific QA/QC and verification*

External verification of 2024 data was done.

4.4.1.5 *Category specific recalculations*

No recalculations were performed on the emissions from this subcategory.

4.4.1.6 *Category specific planned improvements*

There are no subcategory specific planned improvements, but any updated information from South Africa's GHG Reporting Programme will be included. An improvement to consider in the future is the estimation of CH₄ emissions.

4.4.2 Ferrous alloys production (CRT 2.C.2)

4.4.2.1 *Category description*

Ferrous alloy refers to concentrated alloys of iron and one or more metals such as silicon, manganese, chromium, molybdenum, vanadium and tungsten. Ferrous alloy plants manufacture concentrated compounds that are delivered to steel production plants to be incorporated in alloy steels. Ferrous alloy production involves a metallurgical reduction process that results in significant CO₂ emissions (IPCC 2006 Guidelines, p. 4.32). South Africa is the world's largest producer of chromium and vanadium ores, and the leading supplier of these alloys (DMR, 2015). South Africa is also the largest producer of iron and manganese ores and an important supplier of ferromanganese, ferrosilicon and silicon metal (DMR, 2013). COVID-19 had a negative effect on ferrous alloys production, but the market recovered to a large extent afterwards. The negative market effect was however used to shut down certain plants or areas for major maintenance.

4.4.2.2 *Methodological issues*

Historically a Tier 1 and 3 approach was applied across the different ferrous alloy production plants for different types of ferrous alloys. From 2022 only a Tier 3 approach is applied.

4.4.2.2.1 *Activity data*

Ferrous alloy production data for 2000 to 2012 were obtained from ferrous alloy production plants. Activity data from 2013 to 2017 were obtained from the SAMI Annual Reports (DMR, 2019), however, from 2018 activity data was again supplied by the ferrous alloy



production plants due to the implementation of the GHG Reporting Regulations. For ferromanganese production the 7% C values were taken to be the high and medium carbon ferro-manganese, and the 1% C values were the other manganese alloys (DMR, 2013, 2015). For 2014 and 2017 the split between 7% and 1% was not provided (only a total manganese value) therefore the split from 2013 was applied. A drop in silicon metal production was observed in 2017 due to the closure of most furnaces because of low demand and high electricity tariffs (DMR, 2019).

Most plants provided a split between ferromanganese 1% and 7%, however, where the split was not made, the split from 2013 was applied. This inconsistency was overcome from 2018 as South Africa's GHG Reporting Programme requires the split to be made.

4.4.2.2.2 *Emission factors*

Historically Tier 1 emission factors were used. Over the past 3 years it moved more towards a Tier 3 approach to the point that 2022 is purely Tier 3. Due to certain assumptions for the Tier 3 approach, there is still higher uncertainty with CH₄ emissions and Tier 1 is used in some instances.

4.4.2.3 *Uncertainties and time-series consistency*

4.4.2.3.1 *Activity data uncertainty*

An uncertainty of $\pm 5\%$ on activity data was assumed as per the IPCC 2006 Guidelines (IPCC, 2006, Table 4.9). The uncertainty was assumed to be the same for both CO₂ and CH₄.

4.4.2.3.2 *Emission factor uncertainty*

IPCC 2006 Guidelines indicates that for Tier 1, the default emission factors may have an uncertainty of $\pm 25\%$ (IPCC, 2006). For this inventory, as both a Tier 1 and Tier 3 approach was used for CH₄ the uncertainty range was assumed to be between $\pm 5\%$ and $\pm 25\%$ for and CH₄. CO₂ uncertainty is assumed to be $\pm 5\%$.

4.4.2.3.3 *Time-series consistency*

The time series is not consistent due to a change in data sources in 2018 and 2019. From 2020 industry reported via the brought better consistency.



4.4.2.4 Category specific QA/QC and verification

The 2024 data was verified externally by the respective companies.

4.4.2.5 Category specific recalculations

No recalculations were performed for the category.

4.4.2.6 Category specific planned improvements

There are no subcategory specific planned improvements, but any updated information from South Africa's GHG Reporting Programme will be included.

4.4.3 Aluminium production (CRT 2.C.3)

4.4.3.1 Category description

Aluminium production takes place via the Hall-Heroult electrolytic process. In this process, electrolytic reduction cells differ in the form and configuration of the carbon anode and alumina feed system.

The most significant process emissions are (IPCC, 2006, p. 4.43):

- CO₂ emissions from the consumption of carbon anodes in the reaction to convert aluminium oxide to aluminium metal;
- PFC emissions of CF₄ and C₂F₆ during anode effects. Also emitted are smaller amounts of process emissions, CO, Sulphur dioxide (SO₂), and NMVOCs.

4.4.3.2 Methodological issues

A Tier 1 approach was used for CO₂ emission estimation, while a Tier 3 methodology was applied to the PFCs between 2000 and 2012. In the Tier 3 approach the amount of CF₄ and C₂F₆ produced were tracked and used to determine emissions in this category. The Tier 3 method was then extrapolated for the 2013-15 period (using activity data and an implied emission factor). It is considered that the extrapolation of a Tier 3 method might overestimate or underestimate the emissions. Therefore, in the 2000-2017 inventory this was corrected so that actual plant-performance data is used to quantify emissions for the 2013-2017 period. A Tier 3 method was used to estimate emissions for both CO₂ and PFCs from 2018.



4.4.3.2.1 Activity data

The source of activity data for *Aluminium production* were the aluminium production plants. Data is not shown in this report due to confidentiality.

4.4.3.2.2 Emission factors

The emission factors are not provided in this report as the information is confidential.

4.4.3.3 **Uncertainties and time-series consistency**

4.4.3.3.1 Activity data uncertainty

As per the IPCC 2006 Guidelines, uncertainty is minimal regarding aluminium production data. A default uncertainty of $\pm 1\%$ is used (IPCC, 2006, Page 4.57).

4.4.3.3.2 Emission factor uncertainty

The uncertainty on the Tier 3 CO₂ emission factors for aluminium production is $\pm 5\%$ (IPCC 2006 Guidelines, Page 4.56) for estimating CO₂ emissions. Even though a Tier 3 approach was used for *aluminium production* PFC emissions, no data was collected on uncertainty. The Tier 3 default uncertainty for CF₄ and C₂F₆ are indicated to be $\pm 15\%$ (IPCC 2006 Guidelines, page 4.56).

4.4.3.3.3 Time-series uncertainty

Emissions were estimated using a Tier 1 approach for Prebake and Soderberg processes from 2000 to 2013 and 2000 to 2008, respectively. A Tier 3 approach was used to estimate emissions from Centre-Worked Prebake (CWPB), Side Worked Prebake (SWPB), Vertical Stud Soderberg (VSS) and Horizontal Stud Soderberg (HSS) processes from 2000 to 2008.

The Soderberg, SWPB, VSS and HSS processes were stopped in 2008. A Tier 3 approach was used to estimate emissions for CWPB from 2012 onwards.

4.4.3.4 **Category specific QA/QC and verification**

The 2024 data has been externally verified.



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4.4.3.5 Category specific recalculations

No recalculations were performed for this category.

4.4.3.6 Category specific planned improvements

There are no subcategory specific planned improvements, but any updated information from SAGERS will be included.

4.4.4 Magnesium production (CRT 2.C.4)

There is no *Magnesium production* occurring in South Africa.

4.4.5 Lead production (CRT 2.C.5)

4.4.5.1 Category description

According to the IPCC 2006 Guidelines, there are two primary processes to produce lead bullion from lead concentrates:

- Sintering/smeltering, which consists of sequential sintering and smelting steps and constitutes approximately 7% of the primary production; and
- Direct smelting, which eliminates the sintering step and constitutes 22% of primary lead production.

Secondary lead processing, according to the IPCC 2006 Guidelines, involves the recycling of lead acid batteries. Recycling occurs through the following processes:

- crushed using a hammer mill and entered the smelting process with or without desulphurization; or
- smelted whole

4.4.5.2 Methodological issues

Emissions from *Lead production* were estimated using a Tier 1 approach.

4.4.5.2.1 Activity data

Lead production data for 2000 to 2017 were obtained from the SAMI Annual Reports (DMR, 2019), however from 2018 activity data was supplied by the lead production plants through South Africa's GHG Reporting Programme, via the SAGERS.



4.4.5.2.2 Emission factors

IPCC 2006 default emission factor of 0.2 t CO₂ per tonne of lead produced was applied (IPCC, 2006, Table 4.21).

4.4.5.3 **Uncertainties and time-series consistency**

4.4.5.3.1 Activity data uncertainty

For lead production emissions using the Tier 1 method there is a $\pm 10\%$ uncertainty on the activity data (IPCC 2006 Guidelines, Table 4.23).

4.4.5.3.2 Emission factor uncertainty

Uncertainty for default lead production emission factors has an uncertainty of $\pm 50\%$ (IPCC 2006 Guidelines, Table 4.23).

4.4.5.3.3 Time-series consistency

The time series is not consistent as the source of activity data changed in 2018 from the SAMI Report (DMR, 2019) to industry reporting via the SAGERS Portal, and then manually reported in 2023/24.

4.4.5.4 **Category specific QA/QC and verification**

No specific QC checks were completed for this sub-category.

4.4.5.5 **Category specific recalculations**

A recalculation was undertaken for the 1990 – 2019 where initially emissions were estimated using the emissions factor 0.52 tonnes CO₂/tonne product. In 2020 DFFE was made aware that the production was not primary but secondary and the emission factor was adjusted to 0.2 tonnes CO₂/tonne product.

4.4.5.6 **Category specific planned improvements**

There is currently no planned improvement projects.

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4.4.6 Zinc production (CRT 2.C.6)

4.4.6.1 Category description

According to the IPCC 2006 Guidelines, there are three primary processes to produce zinc:

- Electro-thermic distillation: this is a metallurgical process that combines roasted concentrate and secondary zinc products into sinter that is combusted to remove zinc. Halides, cadmium, and other impurities. The reduction results in the release of non-energy CO₂ emissions.
- The pyrometallurgical process: this involves the utilization of an Imperial Smelting Furnace. Which allows for the simultaneous treatment of zinc and zinc concentrates. The process results in the simultaneous production of lead and zinc and the release of non-energy CO₂ emissions.
- Electrolytic: this is a hydrometallurgical technique. During which zinc sulphide is calcinated. Resulting in the production of zinc oxide. The process does not result in non-energy CO₂ emissions.

4.4.6.2 Methodological issues

Emissions from *Zinc production* were estimated using a Tier 1 approach.

4.4.6.2.1 Activity data

In the previous submission the *Zinc production* data was supplied by industry, however this was not available for the period 2018 to 2021 and an extrapolation was applied. The 2022 to 2024 data was sourced from industry.

4.4.6.2.2 Emission factors

The IPCC 2006 Guidelines default emission factor of 1.72 t CO₂ per tonne zinc produced was applied. It was assumed that for *Zinc production* it was 60% imperial smelting and 40% Waelz Kiln (IPCC, 2006).



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4.4.6.3 *Uncertainties and time-series consistency*

4.4.6.3.1 *Activity data uncertainty*

For *Zinc production* emissions there is a $\pm 10\%$ uncertainty on the activity data (IPCC 2006 Guidelines, Table 4.25).

4.4.6.3.2 *Emission factor uncertainty*

Uncertainty for default *Zinc production* emission factors has an uncertainty of $\pm 50\%$ (IPCC 2006 Guidelines, Page 4.25).

Time-series consistency

The time series is inconsistent as activity data has not been available consistently since 2017 and an extrapolation was undertaken to obtain data values where necessary.

4.4.6.4 *Category specific QA/QC and verification*

No specific QC checks were completed for this sub-category.

4.4.6.5 *Category specific recalculations*

No recalculations were performed for this category.

4.4.6.6 *Category specific planned improvements*

There is currently no planned improvement projects.

4.4.7 Other (CRT 2.C.7)

No activities were included under this sub-category.

4.5 Non-Energy Products from Fuels and Solvent Use (CRT 2.D)

Non-energy use of fuels and solvents includes lubricants. Paraffin wax and solvents. Lubricants are divided into two types, namely, motor and industrial oils, and greases that differ in physical characteristics. Paraffin wax is used in products such as petroleum jelly,

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paraffin waxes and other waxes (saturated hydrocarbons). Paraffin waxes are used in applications such as candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others (IPCC, 2006, p.5.11). The use of solvents can result in evaporative emissions of various NMVOCs. Which can be oxidized and released into the atmosphere. According to the IPCC 2006 Guidelines (p. 5.16). white spirit is used as an extraction solvent. Cleaning solvent. Degreasing solvent and as a solvent in aerosols, paints, wood preservatives, varnishes and asphalt products. Lubricants are used in industrial and transport applications. Emissions from solvents are not estimated due to a lack of data.

4.5.1 Lubricant use (CRT 2.D.1)

4.5.1.1 Category description

According to the IPCC 2006 Guidelines Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities.

4.5.1.2 Methodological issues

A Tier 1 method was applied to this subcategory.

4.5.1.2.1 Activity data

The source of activity data for solvents was the energy balance tables published annually by the DoE. Activity data was interpolated for 2007 to 2010 using 2006 and 2011 data as the data was unreliable for this period. An extrapolation was applied from 2020 activity data, as the updated energy balance tables are currently unavailable.

4.5.1.2.2 Emission factors

The IPCC 2006 Guidelines default carbon content (20 tC/TJ) and oxidised fraction factor (0.2) applied to this subsector.

4.5.1.3 Uncertainties and time-series consistency

4.5.1.3.1 Activity data uncertainty

According to the IPCC 2006 Guidelines much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used in individual countries. For this a default of 5% may be used in countries with well-



developed energy statistics and 10 to 20 % in other countries. Based on expert judgement of the accuracy of energy statistics (IPCC 2006 Guidelines, Page 5.10). Therefore, an uncertainty range of $\pm 10\%$ to $\pm 20\%$ was used.

4.5.1.3.2 *Emission factor uncertainty*

The default oxidised during use (ODU) factors available in the IPCC 2006 Guidelines are uncertain, as they are based on limited knowledge of typical lubricant oxidation rates. Expert judgment suggests using a default uncertainty of 50% (IPCC, 2006, Page 5.10).

4.5.1.3.3 *Time-series consistency*

The time series is inconsistent as activity data has not been available for 2020 to 2024 and an extrapolation was undertaken to obtain data values.

4.5.1.4 *Category specific QA/QC and verification*

No specific QC checks were completed for this sub-category.

4.5.1.5 *Category specific recalculations*

No recalculations were performed for this category.

4.5.1.6 *Category specific planned improvements*

There is a planned improvement project to determine the use of blended lubricant in two-stroke engines.

4.5.2 Paraffin wax use (CRT 2.D.2)

4.5.2.1 *Category description*

According to the IPCC 2006 Guidelines this category includes petroleum jelly, paraffin waxes and other waxes, including ozokerite (mixtures of saturated hydrocarbons, solid at ambient temperature). Paraffin waxes are separated from crude oil during the production of light lubricating oils.

4.5.2.2 *Methodological issues*

A Tier 1 method was applied to this subcategory.

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4.5.2.2.1 Activity data

The source of activity data for solvents was the energy balance tables published annually by the DMRE. An extrapolation was applied to the activity data from 2020, as the updated energy balance tables are currently unavailable.

4.5.2.2.2 Emission factors

The IPCC 2006 Guidelines default carbon content (20 tC/TJ) and oxidised fraction factor (0.2) applied to this subsector.

4.5.2.3 *Uncertainties and time-series consistency***4.5.2.3.1 Activity data uncertainty**

According to the IPCC 2006 Guidelines much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used in individual countries. For this a default of 5% may be used in countries with well-developed energy statistics and 10 to 20 % in other countries, based on expert judgement of the accuracy of energy statistics (IPCC, 2006, Page 5.13).

4.5.2.3.2 Emission factor uncertainty

The default ODU factors available in the IPCC 2006 Guidelines are very uncertain, as they are based on limited knowledge of typical lubricant oxidation rates. Expert judgment suggests using a default uncertainty of 50%. The carbon content coefficients are based on two studies of the carbon content and heating value of lubricants from which an uncertainty range of about ± 3 % was estimated (IPCC, 2006, Page 5.13).

4.5.2.3.3 Time-series consistency

The time series is inconsistent as activity data has not been available from 2020 and an extrapolation was undertaken to obtain data values.

4.5.2.4 *Category specific QA/QC and verification*

No specific QC checks were completed for this sub-category.

4.5.2.5 *Category specific recalculations*

No recalculations were performed for this category.



4.5.2.6 Category specific planned improvements

There are no subcategory specific planned improvements, but any updated information from South Africa's GHG Reporting Programme.

4.5.3 Other (CRT 2.D.3)

No activities were included under this sub-category, due to the lack of data.

4.6 Electronics industry (CRT 2.E)

Emissions from the *Electronics industry* in South Africa are not estimated due to a lack of data. DFFE will undertake a survey to estimate GHG emissions for this category and assess the significance of this sector and report progress in its future GHG inventory submissions.

4.7 Product Uses as Substitutes for Ozone Depleting Substances (ODS) (CRT 2.F)

The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer) is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone depletion. HFCs and, to a limited extent, PFCs are ODS being phased out under this protocol.

According to the IPCC 2006 Guidelines, current application areas of HFCs and PFCs include refrigeration and air conditioning; fire suppression and explosion protection; aerosols; solvent cleaning; foam blowing; and other applications (equipment sterilisation, tobacco expansion applications, and as solvents in the manufacture of adhesives, coatings, and inks).

Emissions were only estimated from 2005 onwards due to a lack of data prior to that. The 2012 inventory only estimated emissions from refrigeration, but due to recent studies, this inventory includes emissions from air conditioning, foam blowing agents, fire protection and aerosols. Emissions from solvents are not estimated due to a lack of data.

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4.7.1 Refrigeration and air conditioning (CRT 2.F.1)

4.7.1.1 Category description

According to the IPCC 2006 Guidelines, refrigeration, and air-conditioning (RAC) systems may be classified in up to six sub-application categories:

- Domestic refrigeration;
- Commercial refrigeration including different types of equipment, from vending machines to centralised refrigeration systems in supermarkets;
- Industrial processes including chillers, cold storage, and industrial heat pumps used in the food, petrochemical and other industries;
- Transport refrigeration including equipment and systems used in refrigerated trucks, containers, reefers, and wagons;
- Stationary air conditioning including air-to-air systems, heat pumps, and chillers for building and residential applications; and
- Mobile air-conditioning systems used in passenger cars, truck cabins, buses, and trains

4.7.1.2 Methodological issues

The IPCC 2006 Guidelines (IPCC, 2006) propose either an emissions factor approach at the sub-application level (Tier 2a) or a mass balance approach at the sub-application level (Tier 2b) to calculate emissions from RAC applications.

In the HFC Emissions Database the emissions factor approach (Tier 2a) is primarily applied, with the mass balance approach applied for uncertainty purposes/checking. There was insufficient data to follow this approach for Commercial Refrigeration and Industrial Processes. Thus, a hybrid approach is applied for these sub-applications, which were combined into one application. Table 4.8 summarises the approach used for each sub-application in the RAC sector.



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Table 4.8: Methodology and data sources used for each RAC sub-application

Sub-application	Method	Motivation
Domestic Refrigeration	Tier 2a (2b)	Estimated the yearly data on existing, new and retired domestic refrigerators in South Africa based on data from Stats SA. Emission factors based on IPCC (2006) and other international studies. Estimated yearly sales of R134a for servicing and/or new equipment into domestic refrigeration from survey for cross checking.
Commercial Refrigeration and Industrial Processes	Tier 2b	Estimated early sales of refrigerants into commercial refrigeration. Assumed share of refrigerant taken up into charging of new equipment. Emission factors based on IPCC (2006) and other international studies.
Stationary Air Conditioning	Tier 2a	Yearly data on stationary air conditioning units (BSRIA) Emission factors based on IPCC (2006) and other international studies. Estimated yearly sales of refrigerants into stationary air conditioning for servicing and/or new equipment from survey for cross checking.
Transport Refrigeration	Tier 2a (2b)	Yearly data on existing, new and retired refrigerated trucks based on previous studies (GIZ, 2014) and expert knowledge (SARDA). Emission factors based on IPCC (2006) and other international studies. Estimated yearly sales of R134a and R404a into transport refrigeration for servicing and/or new equipment from survey for cross checking.
Mobile Air Conditioning	Tier 2a (2b)	Yearly data on existing, new and retired vehicles from eNaTIS and NAAMSA. Emission factors based on IPCC (2006) and other international studies. Estimated yearly sales of R-134a into mobile air conditioning for servicing and/or new equipment from survey for cross checking.

4.7.1.2.1 Activity data

Stakeholders in the refrigeration and air conditioning sector in South Africa were identified by means of desktop research and the membership lists of the various industry associates in the refrigeration and air conditioning sector, such as the South African Institute of Refrigeration and Air Conditioning (SAIRAC), the South African Refrigeration & Air Conditioning Contractors' Association (SARACCA) and SARDA.

Other sources included the members of the DFFE's Chemical Management Hydrochlorofluorocarbons (HCFC) working group, and importers and exporters listed in the International Trade Centre (ITC) website (Market Analysis and Research). Other literature and statistical data sources provided the activity data for other sub-applications, e.g., eNaTIS for vehicle data for mobile air conditioning and transport refrigeration and Stats SA for data on the number of households with refrigerators.

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Activity data from 2016 onwards was extrapolated due to inconsistent data availability.

4.7.1.2.2 Emission factors

It was assumed that the equipment lifespan was 15 years and the emission factor from the installed base was 15% (IPCC, 2006). The percentage of HFC destroyed at the end-of-life was assumed to be 25% (IPCC, 2006).

4.7.1.3 *Uncertainties and time-series consistency***4.7.1.3.1 Activity data uncertainty**

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

4.7.1.3.2 Emission factor uncertainty

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

4.7.1.3.3 Time-series consistency

Time series is not consistent over the full 20-year period as emission data is only available from 2005, with an enhanced data set (including mobile air conditioning) from 2011. Activity data from 2016 onwards was extrapolated due to inconsistent data availability.

4.7.1.4 *Category specific QA/QC and verification*

No specific QC checks were completed for this sub-category.

4.7.1.5 *Category specific recalculations*

No recalculations were performed for this category.

4.7.1.6 *Category specific planned improvements*

It is planned that the HFC survey will be updated and will focus mostly on the refrigeration and air conditioning sector to improve emissions estimates from this category.



4.7.2 Foam blowing agents (CRT 2.F.2)

4.7.2.1 Category description

HFCs are being used as replacements for Chlorofluorocarbons (CFCs) and HCFCs in foams and particularly in insulation applications according to the IPCC 2006 Guidelines. Compounds that are being used include HFC-245fa, HFC-365mfc, HFC-227ea, HFC-134a, and HFC-152a. The division of foams into open-cell or closed-cell relates to the way in which blowing agent is lost from the products.

For open-cell foam, emissions of HFCs used as blowing agents are likely to occur during the manufacturing process and shortly thereafter. In closed-cell foam, only a minority of emissions occur during the manufacturing phase. Emissions therefore extend into the in-use phase, with often the majority of emissions not occurring until end-of-life (decommissioning losses).

4.7.2.2 Methodological issues

HFC emissions from foam blowing applications are calculated in the HFC Emissions Database following the approach in the IPCC 2006 Guidelines (Chapter 7: Emissions of Fluorinated Substitutes for Ozone Depleting Substances), as given in Equation 3 (IPCC, 2006). This formula calculates the emissions based on the amount of HFC lost during manufacture and the first year of foam use, the annual amount lost from HFC-containing foams in use (banks), and the amount lost at the end of the foams' life when products are decommissioned, less the amount of HFC recovered or destroyed from decommissioned foam products.

4.7.2.2.1 Activity data

Where data is difficult to obtain in the country the IPCC 2006 Guidelines suggest obtaining historic regional usage to account for HFC banks and emissions factors from the UNEP Foams Technical Options Committee (FTOC). The latest United Nations Environmental Programme (UNEP) FTOC report suggests that in 2008 only 0.15% of the foam bank within developing nations contained HFCs and that sub-Saharan Africa had not utilised any HFC for foam manufacture at this time (UNEP, 2010). This suggests that the HFC-containing foam bank in South Africa is limited and the foam bank in the HFC Emissions are therefore estimated by simply extrapolating the annual net consumption data for 2010-2020 back to the date HFC blowing agent was introduced into South Africa (2005). Activity data was assumed to be stable from 2016.



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4.7.2.2.2 *Emission factors*

It was assumed that the equipment lifespan was 15 years and the emission factor from the installed base was 15% (IPCC, 2006). The percentage of HFC destroyed at the end-of-life was assumed to be 25% (IPCC, 2006). Other factors applied are shown in Table 4.9.

Table 4.9: Emission factors and defaults applied in the foam blowing agents emission estimates

Sub-category	Value	Units	Source
Product life	34	Years	(UNEP, 2005; IPCC, 2006)
First year loss	14	%	
Annual loss	0.66	%	
Landfilling loss	16	%	
Landfill annual loss	0.75	%	

4.7.2.3 *Uncertainties and time-series consistency*

4.7.2.3.1 *Activity data uncertainty*

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

4.7.2.3.2 *Emission factor uncertainty*

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

4.7.2.3.3 *Time-series consistency*

Time series is not consistent over the full 20-year period as emission data for this sub-category is only available from 2011. Due to a lack of consistency in data availability, activity data was assumed to be the same from 2016.

4.7.2.4 *Category specific QA/QC and verification*

No specific QC checks were completed for this sub-category.

4.7.2.5 *Category specific recalculations*

No recalculations were performed for this category.



4.7.2.6 Category specific planned improvements

No improvements are planned currently.

4.7.3 Fire protection (CRT 2.F.3)

4.7.3.1 Category description

According to the IPCC 2006 Guidelines there are two general types of fire protection (fire suppression) equipment that use HFCs and/or PFCs as partial replacements for halons: portable (streaming) equipment, and fixed (flooding) equipment. While actual emissions from the fire protection sub-sector are expected to be quite small, the use is normally non-emissive in provision of stand-by fire protection and is growing.

4.7.3.2 Methodological issues

Emissions from fire protection applications are expected to be small because their use is non-emissive, that is, they are used in the provision of stand-by fire protection equipment. However, this does result in an accumulating bank of gas that has the potential to be released in the future when equipment is decommissioned (IPCC, 2006). The emissions from the fire protection sector are calculated in accordance with the approach suggested by the IPCC 2006 Guidelines, Equation 12 and Equation 13.

4.7.3.2.1 Activity data

Emissions from fire protection equipment are estimated using local sales data from eight importers/distributors of fire protection equipment and gases. This yielded very similar results to those calculated from net consumption (imports minus exports) of ten companies importing fire suppression agents. Activity data from 2016 onwards was extrapolated due to inconsistent data availability.

4.7.3.2.2 Emission factors

Emissions from Fire Protection were calculated in accordance with the IPCC 2006 Guidelines and an emission factor was calculated based on the fraction of agent in equipment emitted each year (excluding emissions from retired equipment or otherwise removed from service), dimensionless. However, none of the contractors or wholesalers of the agents interviewed could provide an estimation of the fraction of agent emitted each year the emissions of agent during recovery, recycling or disposal at the time of removal from service. However, experience gained with the emissions patterns of halon

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substances has yielded valuable lessons in terms of emissions factors for fire suppression agents. A proposed emissions factor of 4% of in-use quantities is assumed. as proposed by the IPCC (IPCC, 2006).

4.7.3.3 *Uncertainties and time-series consistency***4.7.3.3.1 *Activity data uncertainty***

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

4.7.3.3.2 *Emission factor uncertainty*

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

4.7.3.3.3 *Time-series consistency*

Time series is not consistent over the full 20-year period as emission data for this sub-category is only available from 2011. Activity data from 2016 onwards was extrapolated due to inconsistent data availability.

4.7.3.4 *Category specific QA/QC and verification*

No specific QC checks were completed for this sub-category.

4.7.3.5 *Category specific recalculations*

No recalculations were undertaken for this category as they were not previously estimated.

4.7.3.6 *Category specific planned improvements*

No further improvements are planned for this sub-category.

4.7.4 Aerosols (CRT 2.F.4)**4.7.4.1 *Category description***

Most aerosol packages contain hydrocarbon (HC) as propellants but, in a small fraction of the total. HFCs and PFCs may be used as propellants or solvents. Emissions from



aerosols usually occur shortly after production. on average six months after sale. During the use of aerosols, 100 percent of the chemical is emitted. The 5 main sub-applications are as follows:

- Metered dose inhalers (MDIs)
- Personal care products (e.g., hair care. deodorant. shaving cream)
- Household products (e.g., air-fresheners. oven and fabric cleaners)
- Industrial products (e.g., special cleaning sprays such as those for operating electrical contact. lubricants. pipe-freezers)
- Other general products (e.g., silly string. tyre inflators. klaxons)

4.7.4.2 Methodological issues

An emission factor approach on a sub-application level (Tier 2a) was applied to calculate emissions from aerosols. However, data from gas suppliers could not be disaggregated into sub-applications, resulting in a Tier 1a approach being applied in addition to the Tier 2a approach.

4.7.4.2.1 Activity data

Data on the number of aerosol products sold locally at the sub-application level (e.g. number of individual metered dose inhalers, hair care products, and tyre inflators. etc.), as well as the average charge of propellant per container, is required. In the HFC emissions database aerosols are grouped into the following sub-applications:

- MDIs;
- Personal care products;
- Household products;
- Industrial products; and
- Other general products.

Data on aerosol imports and exports had to be obtained directly from the companies/distributors, as trade data could not be used because official import statistics for aerosol products do not differentiate HFC-containing aerosols from other alternatives. Furthermore, import/export figures are typically reported in million units with no indication of the mass of the product or the type or loading of propellant, rendering them unusable for HFC emissions estimation. Due to a lack of consistency in data availability, activity data was assumed to be the same from 2016.

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4.7.4.2.2 Emission factors

The simplified default approach in Equation 2 assumes that all emissions associated with aerosols and metered dose inhalers occur during the use phase, that there are zero losses on the initial charge of the product during manufacture, zero leakages during the life of the product and zero emissions from the disposal of the product. A product life span of two years translates to a default EF of 50% of the initial charge per year (IPCC, 2006).

4.7.4.3 *Uncertainties and time-series consistency***4.7.4.3.1 Activity data uncertainty**

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

4.7.4.3.2 Emission factor uncertainty

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

4.7.4.3.3 Time-series consistency

Time series is not consistent over the full 20-year period as emission data for this sub-category is only available from 2011. Due to a lack of consistency in data availability, activity data was assumed to be the same from 2016.

4.7.4.4 *Category specific QA/QC and verification*

No specific QC checks were completed for this sub-category.

4.7.4.5 *Category specific recalculations*

No recalculations were performed for this category as they were not previously estimated.

4.7.4.6 *Category specific planned improvements*

No improvements are currently planned.

4.7.5 Solvents (CRT 2.F.5)

No activities were included under this sub-category, due to the lack of data.

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4.8 Other product manufacture and use (CRT 2.G)

Emissions from this category were not estimated for South Africa due to a lack of data.

4.9 Other (CRT 2.H)

Emissions from this category were not estimated for South Africa due to a lack of data from the Pulp and Paper Industry and the Food and Beverages Industry.



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Chapter 5: Agriculture (CRT sector 3)

5.1 Sector overview

This chapter includes GHG emissions from Agriculture sector. Agriculture in South Africa is a vital sector of the economy, contributing significantly to employment and GDP. The country has diverse agricultural activities, including crop farming, livestock production, and horticulture. Major crops include maize, wheat, sugarcane, and citrus fruits, while livestock farming focuses on cattle, sheep, and poultry.

Table 5.1 presents the IPCC categories considered in estimating GHG emissions from the Agriculture sector. The inventory includes emissions from Enteric Fermentation (3A), Manure Management (3B), Direct and Indirect N₂O emissions from managed soils (3D1 and 3D2), Field Burning of Agricultural Residues (3F), Liming (3G), and Urea Application (3H). These categories represent the primary sources of emissions within the sector. Certain categories, such as Rice Cultivation (3C) and Other Carbon-Containing Fertilizers (3I), are classified as “Not Estimated (NE)” due to their negligible contribution or lack of activity data. Prescribed Burning of Savannahs (3E) is reported under a the LULUCF sector and therefore marked as “Included Elsewhere (IE),” while the category labelled “Other” (3J) is identified as “Not Occurring (NO)” within the national context. This classification ensures transparency in reporting and highlights the main emission sources considered under the Agriculture sector in line with IPCC 2006 Guidelines.

Table 5.1: Main IPCC categories included in the Agriculture sector emission estimates

IPCC Category	Category name	Included
3A	Enteric fermentation	✓
3B	Manure management	✓
3C	Rice cultivation	NE
3D1	Direct N ₂ O emissions from managed soils	✓
3D2	Indirect N ₂ O from managed soils	✓
3E	Prescribed burning of savannahs	IE
3F	Field burning of agricultural residues	✓
3G	Liming	✓



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3H	Urea application	✓
3I	Other carbon containing fertilisers	NE
3J	Other	NO

Livestock included are dairy cattle, other cattle, sheep, goats, horses, mules and asses, swine and poultry. Emissions from ruminants in privately owned game parks were excluded due to comments made during the UNFCCC review.

Rice cultivation is not included, as it is regarded as insignificant. Prescribed burning of savannahs is included in the land sector. Other carbon containing fertilisers (3I) and Other (3J) are not estimated. More research needs to be done on other carbon containing fertilisers (3I).

Emissions from fuel combustion in this sector are not included here as these falls under Transport (category 1A4c *Agriculture/forestry/fisheries*) in the Energy sector subsector (see Section 3.2.8).

5.1.1 Shares and trends in emissions

Agricultural emissions have remained relatively stable between 1990 and 2024, fluctuating around 55 000–60 000 Gg CO₂e, with a slight overall decline. *Enteric fermentation* is the dominant source, consistently contributing about 70–75% of total emissions, while agricultural soils are the second-largest contributor, followed by manure management. Other sources such as field burning, liming, and urea application have minimal and nearly constant contributions. Emissions peaked slightly between 2010 and 2015 before gradually declining, with recent years (2020–2024) showing a downward trend compared to the peak.

In 2024, the Agriculture sector produced approximately 52 744 Gg CO₂e, accounting for 11% of South Africa's total emissions (excl. LULUCF). *Enteric fermentation* remained the dominant source category, contributing close to 36 048 Gg CO₂e in 2024, which is about 68% of the sector's emissions (Figure 5.1). The overall trend continues to show a gradual decline compared to earlier years, with total emissions in 2024 being roughly 12% lower than 2000 levels. This reduction is largely attributed to a sustained decrease in livestock population numbers and improved manure and soil management practices.

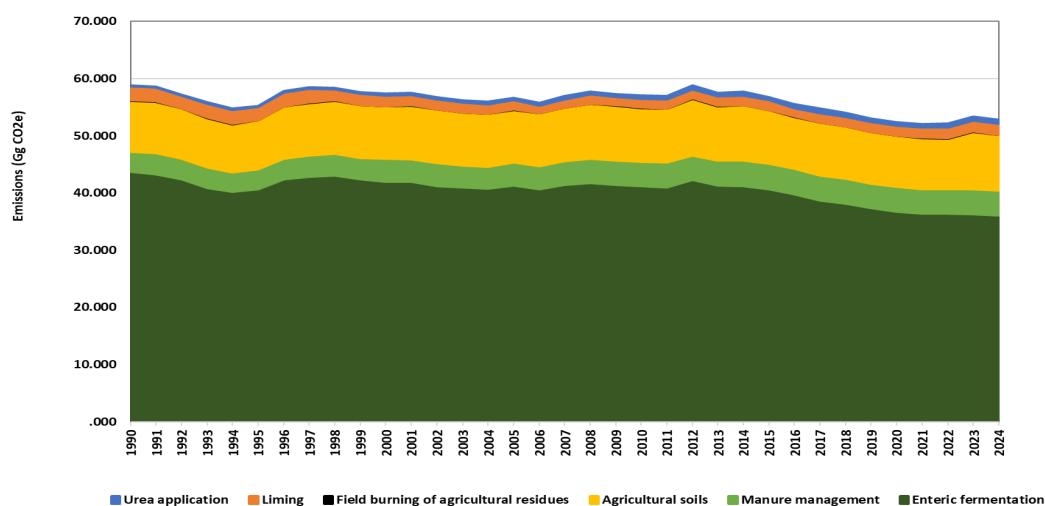


Figure 5.1: Trend in emissions from Agriculture sector, 1990-2024

5.1.1.1 Enteric fermentation

Figure 5.2 illustrates the trend in enteric fermentation emissions from 1990 to 2024, showing contributions from various livestock categories. Overall emissions declined from 43 687 Gg CO₂e in 1990 to 36 048 Gg CO₂e in 2024, indicating a gradual downward trend over the period. Non-dairy cattle consistently remained the dominant source, followed by sheep and dairy cattle, while minor contributors such as goats, horses, mules and asses, and swine exhibited negligible and stable emissions throughout the time series. A slight peak occurred between 2010 and 2013, after which emissions decreased significantly, particularly from 2015 onwards, largely due to reductions in livestock populations and improved management practices.

In 2022 the *Enteric Fermentation* category contributed 36 351 Gg CO₂e, with non-dairy cattle and sheep being the largest contributors (Table 5.2). By 2024, emissions further declined to 36 048 Gg CO₂e, representing a 5.1% decrease compared to 2022. Emissions from horses, which showed a slight increase between 2000 and 2022, stabilized in 2024, while emissions from all other livestock types continued to decline. This sustained reduction reflects ongoing structural changes in the agricultural sector, including herd size adjustments and improved feeding and manure management practices.



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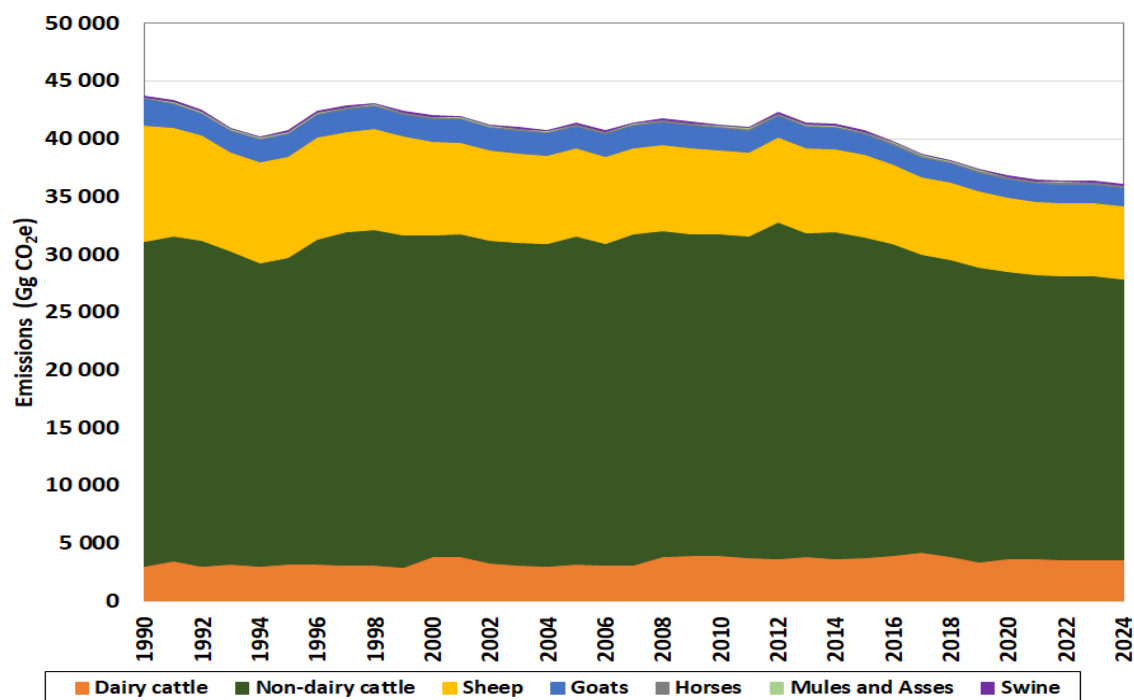


Figure 5.2: Enteric fermentation emission trends, 1990-2024

Table 5.2: Enteric fermentation emission trends, 1990-2024

	Dairy cattle	Non-dairy cattle	Sheep	Swine	Goats	Horses	Mules & asses	Total
	(Gg CO ₂ e)							
1990	3 021	28 133	10 020	49	2 285	116	63	43 687
1991	3 492	28 063	9 467	54	2 021	116	63	43 275
1992	3 021	28 199	9 117	53	1 883	116	63	42 451
1993	3 217	27 076	8 603	53	1 779	118	63	40 909
1994	3 021	26 263	8 744	51	1 925	121	63	40 188
1995	3 217	26 510	8 762	51	1 952	123	63	40 678
1996	3 217	28 098	8 825	55	1 982	126	63	42 365
1997	3 099	28 833	8 680	55	1 975	129	63	42 833
1998	3 099	29 050	8 725	56	1 948	131	63	43 072
1999	2 982	28 685	8 546	57	1 915	130	63	42 378



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	Dairy cattle	Non-dairy cattle	Sheep	Swine	Goats	Horses	Mules & asses	Total
	(Gg CO ₂ e)							
2000	3 884	27 776	8 121	53	1 990	136	46	42 006
2001	3 884	27 877	7 930	54	2 022	136	46	41 949
2002	3 335	27 888	7 772	55	1 982	136	46	41 214
2003	3 099	27 901	7 787	54	1 952	136	46	40 975
2004	3 021	27 919	7 620	54	1 956	136	46	40 752
2005	3 217	28 386	7 579	53	1 950	136	46	41 367
2006	3 139	27 848	7 508	52	1 965	141	46	40 699
2007	3 099	28 674	7 470	53	1 923	146	46	41 411
2008	3 845	28 172	7 450	52	1 997	150	46	41 713
2009	3 923	27 892	7 445	52	1 946	151	46	41 455
2010	3 923	27 823	7 282	51	1 920	151	47	41 197
2011	3 806	27 794	7 270	51	1 888	154	47	41 009
2012	3 649	29 198	7 317	51	1 881	155	47	42 297
2013	3 884	28 023	7 314	51	1 847	156	48	41 323
2014	3 727	28 269	7 149	50	1 830	157	48	41 230
2015	3 806	27 741	7 076	49	1 800	159	47	40 678
2016	3 963	26 948	6 892	49	1 731	161	47	39 789
2017	4 237	25 777	6 726	48	1 679	163	46	38 676
2018	3 884	25 634	6 703	47	1 658	164	46	38 135
2019	3 453	25 436	6 609	45	1 612	165	46	37 365
2020	3 727	24 814	6 395	44	1 586	164	46	36 776
2021	3 649	24 560	6 375	43	1 580	165	46	36 418
2022	3 640	24 499	6 378	43	1 578	168	46	36 351
2023	3 639	24 493	6 339	43	1 577	169	46	36 306
2024	3 609	24 291	6 313	43	1 577	170	45	36 048

Note: Numbers may not add exactly due to rounding off.

Figure 5.3 presents livestock population trends in South Africa from 1990 to 2024, based on DALRRD data. The population of other cattle remained relatively stable between 12 and 13 million until around 2015, after which it declined to approximately 11 million by 2024, representing a decrease of about 8% compared to 1990 levels. Sheep numbers exhibited a significant upward trend, increasing from about 100 million in 1990 to nearly 170 million in 2024, which is an approximate 70% increase over the period. Poultry populations also grew steadily, rising from around 120 million to 160 million, an increase of roughly 33%. In contrast, dairy cattle numbers remained relatively constant at around 1.2–1.6 million, with a slight decline after 2010, amounting to an overall reduction of about 10% since 1990. Goat populations decreased from roughly 3 million in 1990 to



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below 2 million by 2024, a decline of approximately 33%, while swine populations remained stable at around 1.5 million. Horses, mules, and asses maintained very small and nearly constant populations throughout the time series. These trends indicate structural changes in livestock production systems, with notable growth in sheep and poultry and gradual reductions in cattle and goats, which align with observed declines in enteric fermentation emissions.

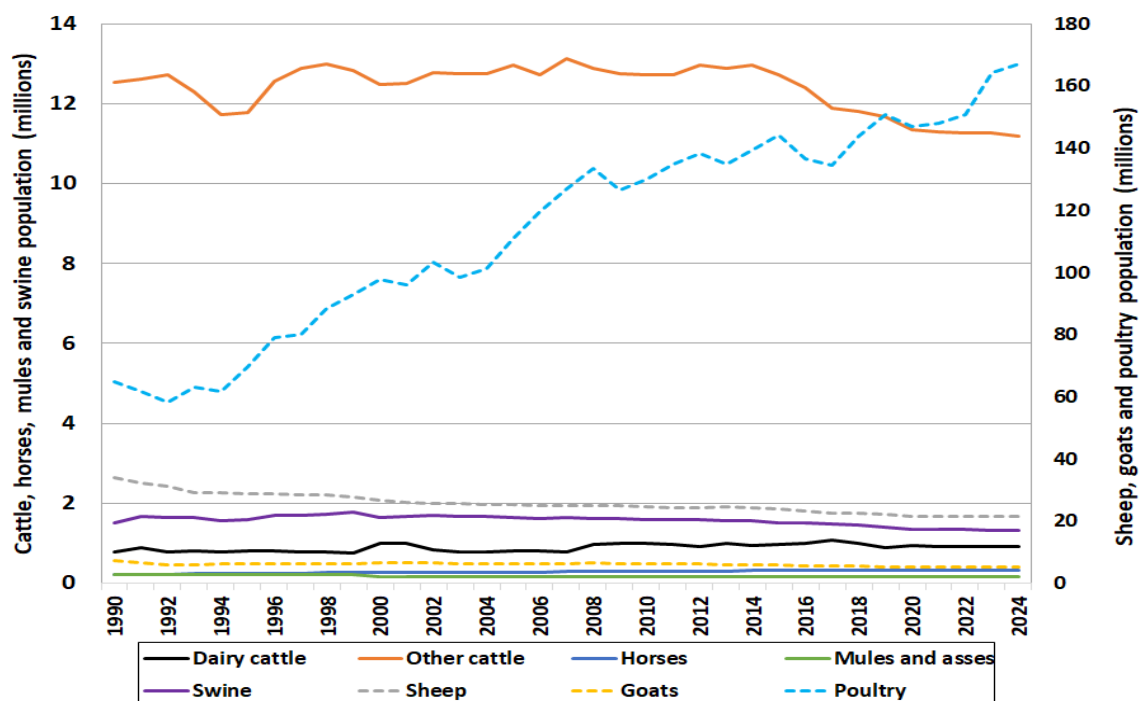


Figure 5.3: Livestock population trends, 1990-2024 (Data source: DALRRD, 2024)

Table 5.3 presents the changes in enteric fermentation emissions between 1990 and 2024, along with the relative contributions of different livestock categories. Overall, total emissions declined by 17.5%, from 43 687 Gg CO₂e in 1990 to 36 048 Gg CO₂e in 2024, indicating a downward trend over the long term. Despite this reduction, the distribution of emissions among species remained dominated by non-dairy cattle, which accounted for 67.4% of total enteric fermentation emissions in 2024, slightly higher than its 64.4% share in 1990.



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Sheep showed a significant decrease in emissions, dropping by 37%, and their share declined from 22.9% to 17.5%, reflecting changes in population or management practices. Dairy cattle, in contrast, experienced a 19.5% increase, raising their share from 6.9% to 10%, suggesting growth in dairy production systems. Other species such as goats, horses, and swine contributed marginally, with goats decreasing by 31% and horses increasing by 46.9%, though their overall shares remained below 1%.

Table 5.3: Change in *Enteric fermentation* emissions (1990-2024) and relative contribution of the various livestock categories to the total emissions

	Emissions		Change		Share of enteric fermentation (%)	
	(Gg CO ₂ e)		(1990-2024)			
	1990	2024	Diff	%	1990	2024
Dairy cattle	3 021	3 609	588.1	19.5	6.9	10.0
Non-dairy cattle	28 133	24 291	-3 842.0	-13.7	64.4	67.4
Buffalo	NO	NO				
Sheep	10 020	6 313	-3 706.8	-37.0	22.9	17.5
Goats	2 286	1 577	-708.4	-31.0	5.2	4.4
Camels	NO	NO				
Horses	116	170	54.4	46.9	0.3	0.5
Mules and asses	63	45	-17.6	-28.0	0.1	0.1
Swine	49	43	-6.5	-13.3	0.1	0.1
Other	NO	NO				
Total	43 687	36 048	-7 638.8	-17.5	100	100

Note: Numbers may not add exactly due to rounding off.

5.1.1.2 Manure management

As shown in Table 5.4, emissions from manure management increased from 3 573 Gg CO₂e in 1990 to 4 067 Gg CO₂e in 2024, representing a 13.8% rise over the period. This growth is primarily driven by nitrous oxide (N₂O) emissions, which increased by 406 Gg CO₂e (21.2%), while methane (CH₄) emissions grew modestly by 88 Gg CO₂e (5.3%).

The composition of emissions has shifted slightly. In 1990, methane contributed 46.4% of total manure management emissions, while nitrous oxide accounted for 53.6%. By

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2024, methane's share declined to 42.9%, whereas nitrous oxide increased to 57.1%, reinforcing its dominant role in this category.


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Table 5.4: Trends and changes in *Manure management* emissions, 1990-2024

	Emissions		Change		Share of manure management	
	(Gg CO ₂ e)		(1990 – 2024)			
	1990	2024	Diff	%	1990	2024
					%	%
Methane	1 659	1 746	87.5	5.3	46.4	42.9
Nitrous oxide	1 914	2 321	406.2	21.2	53.6	57.1
Total manure management	3 573	4 067	493.7	13.8	100	100

Most of South Africa's livestock (cattle, sheep, goats, horses, mules and asses) are kept on pasture, range and paddock, therefore the *Manure management* category emissions were relatively small in 2022. Figure 5.4 shows that methane emissions from manure management remained relatively stable over the period 1990–2024, fluctuating between approximately 600 and 750 Gg CO₂e. Dairy cattle and non-dairy cattle are the dominant contributors, with dairy cattle accounting for the largest share, while swine provides a smaller but consistent contribution. Emissions from other species, including sheep, goats, horses, mules and asses, and poultry, are negligible. A slight increase in emissions occurred between 2010 and 2018, followed by a gradual decline toward 2024.

These emission trends closely reflect livestock population dynamics presented in Figure 5.4. The relatively stable manure management emissions correspond to the limited changes in dairy cattle and swine populations, which remained largely constant throughout the time series. The slight increase in emissions around 2010–2018 aligns with a period of marginal growth in cattle numbers, while the subsequent decline toward 2024 coincides with reductions in other cattle populations after 2015. In contrast, significant increases in sheep and poultry populations did not substantially affect manure management emissions, as these species contribute minimally to methane generation from manure. Overall, the stability of manure management emissions underscores the influence of cattle and swine populations and suggests that mitigation efforts should focus on improving manure handling practices for these species.



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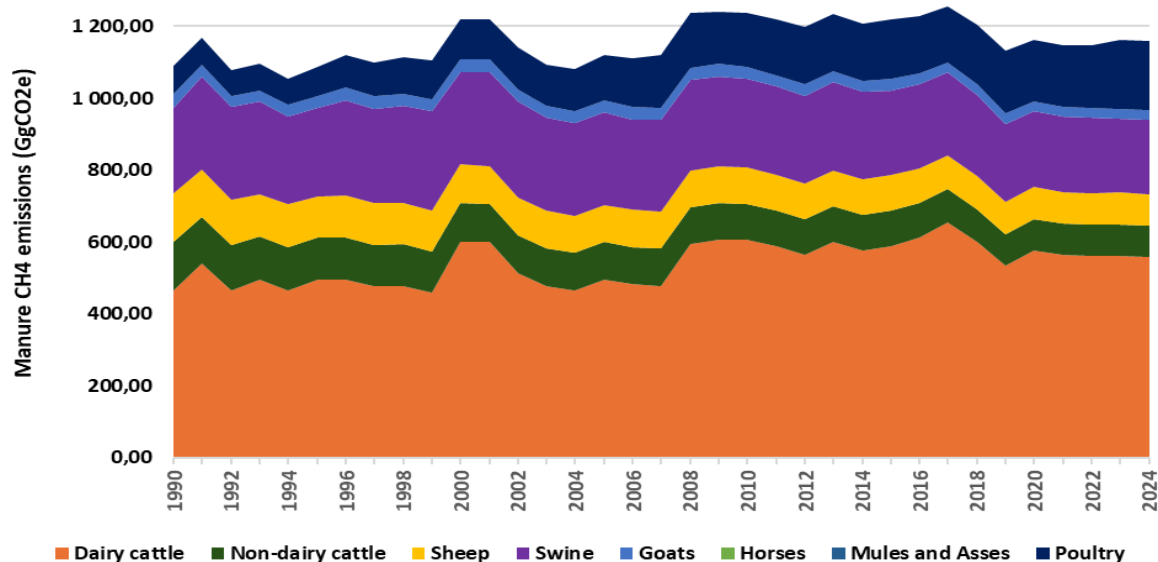


Figure 5.4: Trend in manure management CH₄ emissions from livestock, 1990-2024

Figure 5.5 illustrates the trend in nitrous oxide (N₂O) emissions from manure management in the livestock sector between 1990 and 2024. Overall emissions show a steady upward trajectory, increasing from 1 914 Gg CO₂e in 1990 to 2 654 Gg CO₂e in 2024, representing an increase of 38.6% over the period. Non-dairy cattle and dairy cattle are the dominant contributors, with non-dairy cattle accounting for the largest share, followed by dairy cattle. Sheep and swine contribute smaller but noticeable portions, while emissions from goats, horses, mules and asses, and poultry remain minimal. The growth in N₂O emissions correlates with the expansion of sheep and poultry populations observed in Figure 5.3, as well as changes in manure management practices. This upward trend contrasts with the relatively stable methane emissions from manure management (Figure 5.4), highlighting the increasing significance of N₂O emissions within the agricultural sector.



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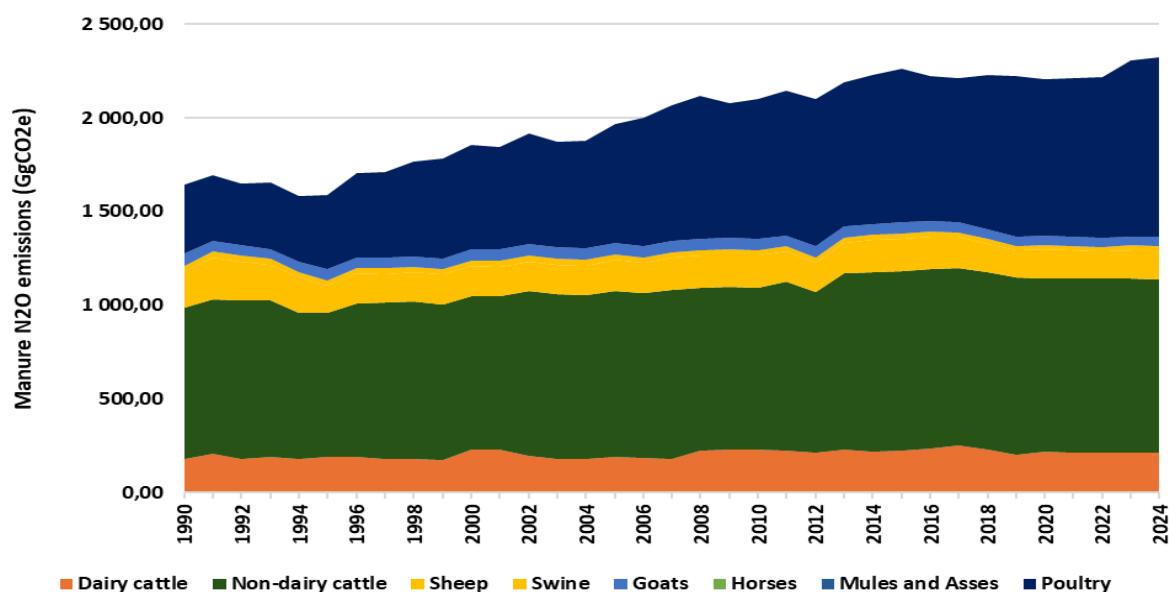


Figure 5.5: Trend in manure management N₂O emissions from livestock, 1990-2024

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Table 5.5 presents the time series of indirect N₂O emissions from manure management (IPCC category 3B5) for 1990–2024, expressed in Gg CO₂e. These emissions occur through two pathways: volatilization and leaching/runoff. Overall, emissions increased from 268 Gg CO₂e in 1990 to 333 Gg CO₂e in 2024, an approximate 24% rise. Between 2000 and 2024, emissions grew by 14.1%, with volatilization remaining the dominant pathway. Poultry manure shows the most significant growth across both pathways, increasing by 71% for volatilization and leaching, while other cattle manure rose moderately, contrasting with declines in dairy, swine, and goat manure. Recent changes between 2022 and 2024 indicate that poultry manure continues to drive increases, rising by 10.5% for volatilization and 10.9% for leaching, while emissions from cattle remain stable or slightly declining. These trends highlight the growing influence of poultry production and shifts in livestock management practices.

Table 5.5: Indirect N₂O emissions from manure management (3B5), 1990-2024

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Gg CO ₂ e															
Emissions due to volatilization															
Dairy cattle	41.80	44.52	53.75	44.52	54.29	52.66	54.83	58.63	53.75	47.78	51.58	50.49	50.37	50.35	49.94
Other cattle	127.97	122.28	129.79	140.27	136.23	152.44	153.72	152.43	151.94	151.69	148.16	149.32	149.11	149.09	148.41
Sheep	30.34	22.29	24.28	24.80	26.16	26.89	25.89	24.79	23.30	21.68	23.89	22.65	21.90	23.37	24.15
Swine	22.55	23.45	24.37	24.43	23.59	22.54	22.37	21.92	21.52	20.57	20.08	19.89	19.87	19.55	19.55
Goat	0.91	0.77	0.79	0.78	0.77	0.72	0.69	0.67	0.66	0.64	0.63	0.63	0.63	0.63	0.63
Poultry	23.36	24.86	34.55	39.04	45.94	50.85	48.38	47.46	50.82	53.58	52.17	52.53	53.51	58.33	59.11
Horses	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Mules and asses	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions due to leaching/runoff															
Dairy cattle	2.26	2.41	2.91	2.41	2.93	2.85	2.96	3.17	2.91	2.58	2.79	2.73	2.72	2.72	2.70
Other cattle	10.61	10.11	10.77	11.69	11.36	12.59	12.66	12.51	12.47	12.44	12.13	12.23	12.21	12.21	12.15
Sheep	2.61	1.92	2.09	2.13	2.25	2.31	2.23	2.13	2.00	1.87	2.05	1.95	1.88	2.01	2.08
Swine	0.35	0.37	0.38	0.38	0.37	0.35	0.35	0.34	0.33	0.32	0.31	0.31	0.31	0.30	0.30
Goat	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Poultry	5.43	5.83	8.16	9.25	10.85	12.03	11.41	11.22	11.99	12.59	12.26	12.37	12.58	13.72	13.95
Horses	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Mules and asses	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total Indirect N ₂ O emissions	268.28	258.88	291.89	299.77	314.81	336.28	335.55	335.34	331.75	325.80	325.14	325.16	332.34	333.03	

Note: Numbers may not sum exactly due to rounding off.



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5.1.1.3 *Agricultural soils*

Table 5.6 summarizes changes in emissions related to agricultural soils between 1990 and 2024. Overall emissions in this category increased by 6.5%, from 11 544 Gg CO₂e in 1990 to 12 296 Gg CO₂e in 2024, indicating a relatively stable trend with moderate growth over the long term.

The largest contributor remains Direct N₂O emissions from managed soils (3D1), which rose slightly by 3.2% to 8 167 Gg CO₂e in 2024. Indirect N₂O emissions (3D2) increased significantly by 50%, reaching 1 514 Gg CO₂e, while urea application (3H) recorded the most dramatic growth of 637.1%, reflecting change of activity data source in the year 2024.

Conversely, liming (3G) declined by 23.5%, and field burning of agricultural residue (3F) decreased by 7.4%, suggesting progress in reducing emissions from these sources. These trends indicate that while some mitigation measures have been effective, increased nitrogen inputs through fertilizers remain a key driver of emissions growth.

Table 5.6: Changes in emissions related to agricultural soils between 1990 and 2024

Category	Emissions (Gg CO ₂ e)		Change (1990 – 2024)	
	1990	2024	Diff	%
3D1 Direct N ₂ O from managed soils	7 914	8 167	252.3	3.2
3D2 Indirect N ₂ O from managed soils	1 009	1 514	504.7	50.0
3F Field burning of agricultural residue	59	55	-4.4	-7.4
3G Liming	2 471	1 891	-579.9	-23.5
3H Urea application	91	671	579.8	637.1
Total	11 544	12 296	752.6	6.5

Note: Numbers may not sum exactly due to rounding off.

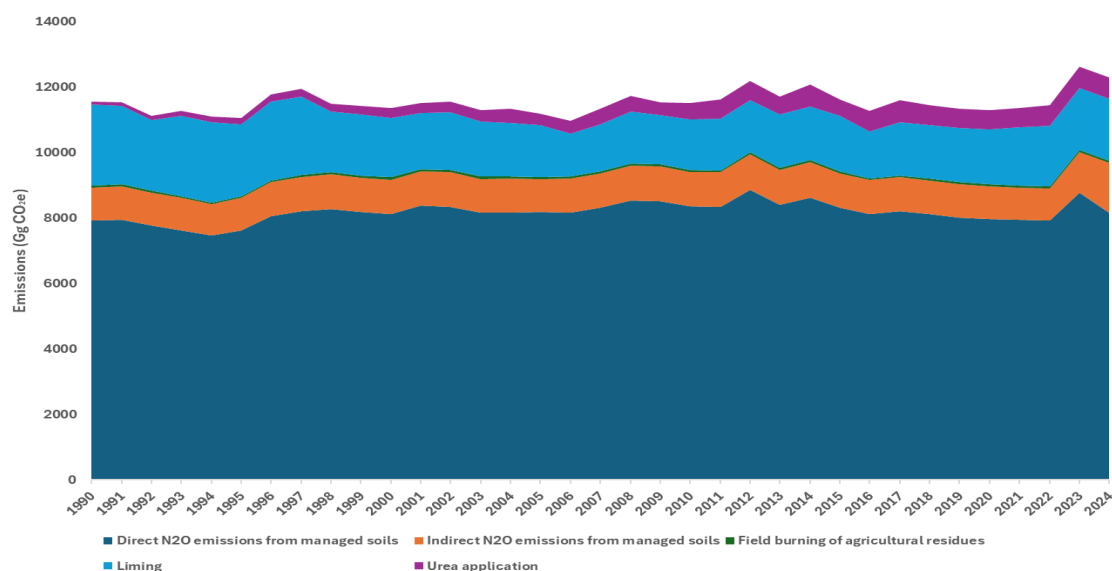


Figure 5.6: Trends in emissions related to agricultural soils, 1990-2024

Figure 5.6 illustrates trends in emissions related to agricultural soils from 1990 to 2024. Overall emissions fluctuated between 8 424 Gg CO₂e and 10 012 Gg CO₂e, with a slight increase toward 2024. *Direct N₂O emissions from managed soils* (Figure 5.6) consistently represent the largest share, increasing by about 15% over the period. Indirect N₂O emissions show a moderate rise of approximately 20%, while emissions from *Liming* grew by roughly 10%. *Urea application* increased significantly, by nearly 30%, reflecting greater use of nitrogen-based fertilizers. *Field burning of agricultural residues* remained negligible throughout the time series. A modest peak occurred around 2013–2015, followed by stabilization and a slight rise in recent years. These trends underscore the dominance of nitrogen-related processes in agricultural soils as a key driver of emissions, with notable growth in fertilizer-related sources.

5.1.2 Overview of methodology and completeness

The IPCC 2006 Guidelines (IPCC, 2006) is applied in this sector, with a few updated methodologies being taken from the IPCC 2019 Refinement (IPCC, 2019). Default constants and emission factors are also sourced from these two guideline documents, with details being provided in the methodology sections within each category section. Table 5.6 shows the methods and types of EF used in the Agriculture inventory.

Table 5.6: Summary of methods, emission factors and completeness of the Agriculture sector emissions.

GHG Source and sink category	CO ₂		CH ₄		N ₂ O		NO _x	CO	NMVOC	NH ₃
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
3.A Enteric fermentation										
3.A.1- Cattle										
3.A.1.a - Dairy cows	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
3.A.1.b - Other cattle	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
3.A.2 - Sheep	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
3.A.3 - Swine	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
3.A.4 - Other										
3.A.4.a - Buffalo	NA	NA	NO	NO	NA	NA	NA	NA	NA	NA
3.A.4.b - Camels	NA	NA	NO	NO	NA	NA	NA	NA	NA	NA
3.A.4.d - Goats	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
3.A.4.e - Horses	NA	NA	T1	DF	NA	NA	NA	NA	NA	NA
3.A.4.f – Mules and Asses	NA	NA	T1	DF	NA	NA	NA	NA	NA	NA
3.B Manure management										
3.B.1- Cattle										
3.B.1.a - Dairy cows	NA	NA	T2	CS	T2	CS	NE	NA	NA	NE
3.B.1.b - Other cattle	NA	NA	T2	CS	T2	CS	NE	NA	NA	NE
3.B.2 - Sheep	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE
3.B.3 - Swine	NA	NA	T2	CS	T2	CS	NE	NA	NA	NE
3.B.4 - Other										
3.B.4.a - Buffalo	NA	NA	NO	NO	NO	NO	NE	NA	NA	NE
3.B.4.b - Camels	NA	NA	NO	NO	NO	NO	NE	NA	NA	NE
3.B.4.d - Goats	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE
3.B.4.e - Horses	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE
3.B.4.f – Mules and Asses	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE

GHG Source and sink category	CO ₂		CH ₄		N ₂ O		NO _x	CO	NMVOC	NH ₃
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
3.B.4.g - Poultry	NA	NA	T2	CS	T2	CS	NE	NA	NA	NE
3.B.5-Indirect N ₂ O emissions										
3.C - Rice cultivation	NE		NE		NE					
3.D - Agricultural soils										
3.D.1 - Direct N₂O Emissions from managed soils										
Synthetic fertilizers	NA		NA		T1	DF		NA	NA	
Animal waste added to soils	NA		NA		T2	CS		NA	NA	
Other organic fertilizers	NA		NA		T1	DF		NA	NA	
Urine and dung deposited by grazing livestock	NA		NA		T2	CS		NA	NA	
Crop residues	NA		NA		T1	DF		NA	NA	
3.D.2 - Indirect N₂O Emissions from managed soils										
Atmospheric deposition	NA		NA		T1	DF				
Nitrogen leaching and runoff	NA		NA		T1	DF				
3.E - Prescribed burning of savannas										
Prescribed burning of savannas	NE		NE		NE					
3.F - Field burning of Agricultural residues										
Field burning of Agricultural residues	T2	DF, CS	T2	DF, CS	T2	DF, CS				
3.G - Liming										
Liming	T1	DF	NA		NA		NA	NA	NA	NA

GHG Source and sink category	CO ₂		CH ₄		N ₂ O		NO _x	CO	NMVOC	NH ₃
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
3. H - Urea application										
Urea application	T1	DF	NA		NA		NA	NA	NA	NA
3.1 – Other carbon containing fertilisers										
Other carbon containing fertilisers	NE		NE		NE					
3.2 - Other										
Other	NO		NO		NO					

NA = Not applicable; NO = Not occurring; NE = Not estimated; IE = Included elsewhere; T1 = Tier 1; T2 = Tier 2; DF = IPCC default factor; CS = Country specific factor.

5.1.3 Improvements and recalculations

The agriculture sector is under continual improvement which leads to recalculations. The main inventory improvements that were carried out and which led to recalculations were:

- Included Organic soils for cropland and Grassland under agriculture sector
- Area of drained organic soils for cropland is 4 173 and 4 173 ha for 2023 and 2024 respectively.
- Area of drained organic soils for Grassland is 15 678 and 15 678 ha for 2023 and 2024 respectively.
- Included the IPCC 2019 Refinement EFs for soil management categories since it is disaggregated into wet and dry climate.
- Time-series (historical) data were included for the early years (1990–1999), and the dataset has now been extended to cover the period from 1990 to 2024.

The specific details of these improvements are discussed in the relevant category or sub-category sections within this report. The recalculations indicated a consistent trend; however, they also indicated a shift in the trend across the entire time series (Figure 5.7). After the recalculations, emissions are higher than those recorded in the previous inventory (Figure 5.7).



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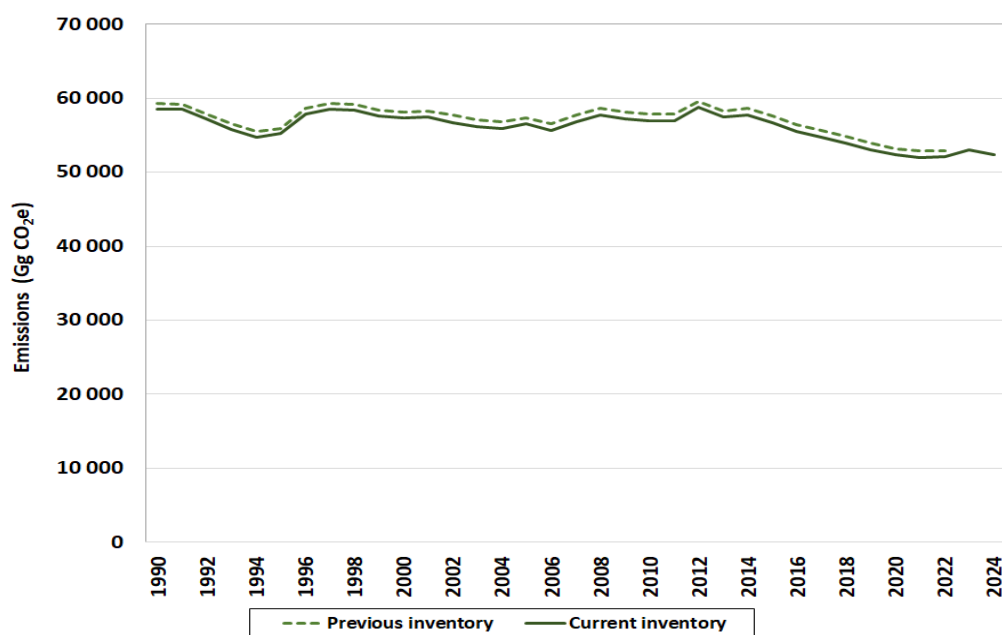


Figure 5.7: Change in Agriculture emission estimates due to recalculations since 2022 submission

5.1.4 Key categories in the Agriculture sector

The key categories for the Agriculture sector as determined by the level (L) and trend (T) assessment are shown in Table 5.7. The key categories identified for the Agriculture sector in 2024 are *Enteric fermentation* (CH₄) from non-dairy cattle, dairy cattle, sheep and goats. These were followed by poultry manure management (N₂O), and emissions from *Liming* and *Urea application* (CO₂).

Table 5.7: Key categories in the Agriculture sector in 2024

Key category rank	IPCC code	IPCC Category	GHG	Criteria
15	3.A.1.a.ii	Non-dairy Cattle	CH ₄	L, T
16	3.A.2	Sheep	CH ₄	L, T
37	3.A.4	Goats	CH ₄	L, T



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Key category rank	IPCC code	IPCC Category	GHG	Criteria
39	3.A.1.a.i	Dairy Cattle	CH ₄	L, T
40	3.B.4	Poultry	N ₂ O	T
41	3.G	Liming	CO ₂	L, T
42	3.H	Urea Application	CO ₂	T

#L = Level Assessment; T = Trend Assessment

5.1.5 QA/QC process and verification

The QA/QC processes implemented are described in detail in the sections for each category below. Furthermore, the QA/QC measures outlined in Table 5.8 were used for the agriculture sector calculation files.

Table 5.8: General QA/QC checks completed for the agriculture sector

QA/QC principle	Check
Accuracy	Activity data source
Accuracy	Correct units
Accuracy	Unit carry through
Accuracy	Method validity
Accuracy	Calculations check
Accuracy	Uncertainties
Accuracy	Double counting
Accuracy	Correct GWP
Accuracy	Notation keys
Accuracy, Completeness, Consistency, Transparency	Trend check
Accuracy, Transparency	Emission factor applicability
Accuracy, Transparency, Consistency, Completeness	Recalculations
Completeness, Comparability	Sub-category completeness
Consistency	Time series consistency
Transparency	Documentation
Transparency, Completeness, Consistency, Accuracy	Colour coding
Accuracy, Comparability	Cross check data
Accuracy	Spot checks
Transparency, Consistency	Data source referencing
Transparency	Links to source data



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QA/QC principle	Check
Transparency	Raw primary data
Accuracy	QA review

5.1.6 Planned improvements and recommendations

The following are planned improvements and recommendations for agriculture sector to improve estimates in the future:

- a) Improving livestock population data has become increasingly important, as recent studies have refined emission factors, leaving population figures as the largest source of uncertainty. Establishing a Livestock Estimates Committee could help address this gap. The DFFE has begun discussions with the Department of Agriculture and the Agricultural Research Council, which hosts a dedicated livestock division, to explore potential collaboration on this matter.
- b) National data set on manure management systems: This data seems to be highly variable depending on where the information comes from. In addition, data on the amount of manure being diverted to biogas needs to be included as this is a mitigation option and has been highlighted in previous inventory reviews. It is recommended to find a mechanism to track manure management practices or systems used in South Africa, as this could allow for incorporation of dynamics driven by changes in management regimes, and thus improve the accuracy of manure related emissions.
- c) A detailed study on the herd composition of the various livestock and the number of days each livestock sub-category is alive in a year would contribute to a reduction in uncertainty.
- d) Use appropriate MCFs depending on the average temperature for each year of the time series. Stratify the estimates depending on the average temperature in different regions in South Africa.
- e) Collect data for Tier 2 approach on soil management category since as a key category.

5.2 Enteric Fermentation (CRT 3.A)

5.2.1 Category description

Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which plant material consumed by an animal is broken down by bacteria in the gut under anaerobic conditions. A portion of the plant material is fermented in the rumen to simple fatty acids, CO₂ and CH₄. The fatty acids are absorbed into the bloodstream, and the gases vented by eructation and exhalation by the animal. Unfermented feed and microbial cells pass to the intestines.

According to IPCC 2006 Guidelines the method for estimating CH₄ emissions from enteric fermentation requires three basic steps:

- Divide livestock population into animal subgroups based on sex, age, and production level.
- Estimate the emission factors for each subgroup in terms of kilograms of CH₄ per animal per year.
- Multiply the subgroup emission factors by the subgroup populations to estimate subgroup emissions and sum across the subgroups to estimate total emission.

Enteric fermentation emissions decreased by 14.2% in the period 2000–2024. Enteric fermentation contributed 36 048 Gg CO₂e in 2024, which is 68.8% of the agriculture sector emissions. South Africa identified, through Tier 1 level and trend assessments, *Enteric fermentation* as a key source category. In accordance with IPCC good practice requirements Tier 2 methods are therefore used, to estimate *Enteric fermentation* emissions from the major livestock sub-categories.

5.2.2 Methodological issues

A Tier 1 methodology is used to calculate CH₄ emissions from enteric fermentation in horses, mules and asses by multiplying the population data by IPCC 2019 Refinement default emissions factors (IPCC Equation 10.19, IPCC 2019 Refinement).

For all other livestock a Tier 2 methodology was applied by following the basic IPCC equations:



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$$CH_4 \text{ emissions} = EF * Population$$

and

$$EF = (GE * (Ym/100) * 365 \text{ days}) / 55.65 \text{ MJ (kg CH}_4\text{)}^{-1}$$

Where:

EF = emission factor (kg CH₄ head⁻¹ yr⁻¹)

GE = gross energy intake (MJ head⁻¹ day⁻¹)

Ym = methane conversion factor (percentage gross energy in feed converted to methane) (Table 5.9)

These equations assume that the emission factors are for an entire year. Since the population data is census data it is assumed that the population data is representative of a typical population on any one day of the year.

Table 5.9: Methane conversion factors and their sources.

Livestock category	Sub-category	Breed	Methane conversion factor (Ym)
Dairy cattle	Mature female cows	Holstein	6 ¹
		Jersey	6.3 ¹
	Heifers (6 - 24 months)		7 ¹
Other cattle	Commercial	All breeds	7 ¹
	Subsistence		6.5 ²
	Feedlot		3 ¹
Sheep	Commercial	All breeds	6.7 ¹
	Subsistence		6.7 ¹
	Feedlot		6.7 ¹
Goats	Commercial	All breeds	5.5 ¹
	Subsistence		5.5 ¹
Swine	Commercial		0.7 ³
	Subsistence		0.7 ³

¹IPCC 2019 Refinement, ²IPCC 2006 Guidelines, ³Du Toit et al. (2013c).



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5.2.2.1 Activity data: Livestock population

The data sources for the livestock population estimates are shown in Table 5.10. The main data source is the Abstracts of Agricultural Statistics (DALRRD, 2024a) which is a sustainable data source released every year. The livestock population data is collected 4 times in a year (every 3 months). For the year 2022, the data was initially collected in February, the second datasets were collected in May, the 3rd in August and the 4th in November. In addition, the total livestock numbers for cattle, sheep, goats and pigs are obtained from data provided by the DALRRD (2024b). The same data for number of animals of the various animal groups is used in all the different calculations of emissions.

Table 5.10: Livestock population data sources.

Livestock category		Data source
Cattle	Total cattle	DALRRD (2024b)
	Commercial dairy cows (>2yrs)	DALRRD (2024a)
	Commercial dairy heifers (1-2 yrs)	DALRRD (2024a)
	Feedlot cattle	Feedlot SA (2024)
	Commercial other cattle total	DALRRD (2024a)
	Subsistence cattle	Calculated (see text)
Sheep	Total sheep	DALRRD (2024b)
	Commercial sheep total	DALRRD (2024a)
	Feedlot sheep	Calculated from DALRRD (2024a) slaughter data (see text)
	Subsistence sheep	Calculated (see text)
Goats	Total goats	DALRRD (2024b)
	Commercial goats total	DALRRD (2024a)
	Subsistence goats	Calculated (see text)
Horses, mules and asses		FAOSTAT (2024)
Swine	Total swine	DALRRD (2024b)
	Commercial swine	Calculated (see text)
	Subsistence swine	Calculated (see text)
Poultry	Commercial broilers	Extrapolated based on the data from Leading edge Poultry Software CC (2024)
	Commercial broiler parents	Extrapolated based on the data from Leadingedge Poultry Software CC (2024)
	Commercial layers	Extrapolated based on the data from Leadingedge Poultry Software CC (2024)
	Commercial pullets	Extrapolated based on the data from Leadingedge Poultry Software CC (2024)



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Livestock category		Data source
	Subsistence broilers	Calculated (see text)
	Subsistence layers	Calculated (see text)

5.2.2.1.1 Other cattle calves and subsistence cattle

The total number of calves is obtained from the Abstracts of Agricultural Statistics (DALRRD, 2024a), but the feedlot cattle are all assumed to be calves, so these are subtracted from the total calves to obtain the estimate of commercial calves in the other cattle category.

The total number of cattle is provided by DALRRD (2024b). The number of dairy heifers and cows is subtracted from the total number of cattle to obtain the total number of other cattle. The Abstracts of Agricultural Statistics (2024a) provides the total commercial other cattle; therefore, this is subtracted from the total other cattle to obtain an estimate of the subsistence cattle population.

5.2.2.1.2 Subsistence and feedlot sheep

There is limited data on feedlot sheep, so several assumptions were applied. The number of sheep slaughtered is obtained from the Abstracts of Agricultural Statistics (DALRRD, 2024a). It was assumed that 70% of the slaughtered animals come from feedlots. Feedlot sheep are estimated to be in the feedlots on average for 35 days (pers. comm. Mokhele Moeletsi, 2021) and are weaned or sold at about 120 days which means the feedlot sheep are alive for 155 days. This data was applied to equation 10.1 of the IPCC 2006 Guidelines to determine the annual average population. The feedlot total is assumed to be included in the total commercial sheep numbers provided by Abstracts of Agricultural Statistics (DALRRD, 2024a).

The subsistence sheep population is estimated by subtracting the total commercial sheep (DALRRD, 2024a) from the total sheep (DALRRD, 2024b).

5.2.2.1.3 Subsistence goats

The subsistence goat population is estimated by subtracting the total commercial goats (DALRRD, 2024a) from the total goats (DALRRD, 2024b).

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5.2.2.1.4 Commercial and subsistence swine

The total swine population provided by DALRRD (2024b) is almost the same as that provided in the Abstracts of Agricultural Statistics (DALRRD, 2024a), suggesting that there are no subsistence swine. Du Toit et al (2013c) noted that there was a large discrepancy between DALRRD (2024a) data and data from industry with industry suggesting a much lower population. Du Toit et al. (2013c) indicated that 26% of the population was subsistence, so based on this it is assumed that the total swine population is as given in the DALRRD (2024b) data, but that this data is split into commercial and subsistence using the 0.26 ratio provided by Du Toit et al. (2013c).

5.2.2.1.5 Poultry

Commercial – Broilers and Commercial – Layers data was obtained from SAPA-Board-Report- 2023¹⁸ and 2024.¹⁹ South African Poultry Association (SAPA) is provided data by Leadingedge Poultry Software CC (2024). The data is modelled data. In this inventory the total broiler parents and pullets are also included. Data for parents and pullets are only available for 2018 onwards for these categories. A ratio between the parents and the broilers, as well as the pullets and the layers, is determined and this ratio is extrapolated (linear) backwards to 1990 to complete the time-series for the parent population.

Leading Poultry Software CC (2021) reports that in 2015, subsistence populations accounted for 4-5% of commercial poultry populations. The percentage (4%) is assumed to be constant between 2000 and 2015. In 2024, the projected number of subsistence poultry is 4-5% of commercial poultry, therefore, 5% was applied in 2024 and linear extrapolation was used to estimate the percentage of poultry subsistence poultry in other years.

5.2.2.2 **Activity data: Population characterisation and herd composition**

The previous inventory included more detailed characterization of livestock. This is based on a study conducted in 2010 (Du Toit et al., 2013a, b, c) which provided country-specific emission factors for all livestock types. The population data for the detailed livestock characterisation in the previous inventory utilised the same national data as provided in this inventory but applied the population and herd composition data provided in Du Toit et al. (2013a, b, c) to split the population into the more detailed categories. Subsequent to this there have been further studies on livestock emissions

¹⁸ <https://www.sapoultry.co.za/wp-content/uploads/2024/07/SAPA-AR-2023.pdf>

¹⁹ <https://www.sapoultry.co.za/wp-content/uploads/2025/06/SAPA-Board-Report-2024.pdf>



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which made use of fewer herd composition categories but added more detailed breed classes. To accommodate new data and improve consistency, the list of categories has been revised (Table 5.11) and some of the herd classes were aggregated. In addition, instead of incorporating the detailed category information into the population break down, the detail is incorporated into the emission factors. Thus, the national statistics population data categories are kept, and the detailed breed and herd composition data is used to calculate a weighted average emission factor (based on the composition and assumptions provided in Table 5.11) for each class. This way the national population data categories can be kept constant for reporting purposes, and any detailed data gathered in the future can be incorporated into the emission factors.

Table 5.11: Livestock characterization and herd composition data sources and assumptions

Main category	Production category	Subcategory	Herd composition data and assumptions
Dairy cattle	- High production (Holstein) - Medium production (Jersey)	- Mature female cows - Heifers (12-18 months) - Heifers (6-12 months) - Heifers (3-6 months)	Herd composition based on DALRRD (2021a) data; 57% Holstein and 43% Jersey; even distribution of heifer categories
Other cattle	Commercial (Afrikaner; Angus; Beefmaster; Bonsmara; Boran; Brahams; Brangus; Braunvich; Charolais; Drakensburger; Hereford; Hugenoot; Limousin; Bradford; Santa Gertrudis; Simbra; Simmentaler; Susses; Wagyu; Tuli)	- Mature cows - Bulls - Young bulls - Heifers (12-18 months) - Heifers (6-12 months) - Heifers (3-6 months) - Ox - Young ox - Calves	Commercial herd composition based on ARC Report (2021) data; even distribution of heifer categories; herd composition assumed to be the same for all breeds; even distribution of breeds
	Subsistence	- Mature cows - Bulls - Heifers (12-18 months) - Heifers (6-12 months) - Heifers (3-6 months) - Ox - Young ox - Calves	Subsistence herd composition based on ARC Report (2021) data; even distribution of heifer categories
	Feedlot		All calves
Sheep	- Commercial wool (Merino) - Commercial meat (Dorper)	- Mature ewe - Replacement ewe - Mature ram - Young ram	Commercial sheep herd composition based on ARC Report (2021) data; even distribution of mature and replacement ewes;



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Main category	Production category	Subcategory	Herd composition data and assumptions
	Commercial dual-purpose (Mutton Merino, Dohne merino)	- Female lamb - Male lamb	even distribution of mature and young rams; even distribution of male and female lambs; species distribution taken from ARC Report (2021a)
	Subsistence	- Mature ewe - Replacement ewe - Mature ram - Young ram - Female lamb - Male lamb	Subsistence sheep herd composition based on ARC Report (2021) data; even distribution of mature and replacement ewes; even distribution of mature and young rams; even distribution of male and female lambs; all species assumed to be dual purpose
	Feedlot		All weaned sheep
Goats	- Commercial (Angora; Boer) - Commercial dairy goat (Saanen; Toggenburg; British Alpine)	- Mature doe - Replacement doe - Mature buck - Young buck - Female kid - Male kid	Commercial goat herd composition based on ARC Report (2021) data; even distribution of mature and replacement does; even distribution of mature and replacement buck; even distribution of male and female kids; distribution of commercial and dairy goats taken from ARC Report (2021a); even distribution of dairy goats and also commercial goats
	Subsistence	- Mature doe - Replacement doe - Mature buck - Young buck - Female kid - Male kid	Subsistence goat herd composition based on ARC Report (2021) data; even distribution of mature and replacement does; even distribution of mature and replacement buck; even distribution of male and female kids)
Horses, mules, asses	All breeds		
Swine	Commercial	- Boars - Cull boars - Replacement boars - Cull sows - Replacement sows - Dry gestating sows - Lactating sows - Pre-wean-piglets	Commercial swine herd composition based on Du Toit et al. (2013c) data
	Subsistence	- Boars - Cull boars - Replacement boars - Cull sows - Replacement sows - Dry gestating sows	Commercial swine herd composition based on Du Toit et al. (2013c) data



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Main category	Production category	Subcategory	Herd composition data and assumptions
		- Lactating sows - Pre-wean-piglets	
Poultry	- Commercial - Subsistence	- Broilers - Broiler parents - Layers - Pullets	Composition determined from population data

5.2.2.3 Emission factors

Tier 1 IPCC 2019 Refinement default emission factors of 18 kg CH₄ head⁻¹ yr⁻¹ and 10 kg CH₄ head⁻¹ yr⁻¹ are applied to horses, and mules/asses, respectively (IPCC Table 10.10, IPCC 2019 Refinement). Emission factors for all other livestock are determined using the IPCC Tier 2 methodology. The emission factors for the detailed livestock categories are used to determine weighted averages (Table 5) for the livestock categories with population data. The weighting is based on the herd and breed composition assumptions provided in Table 5.

Table 5.12: Enteric fermentation emission factors and their sources per livestock category

Livestock category	Sub-category	Enteric EF (kg CH ₄ head ⁻¹ yr ⁻¹)	Reference
Dairy cattle	Mature cows	141.07	Calculated (see text)
	Heifers	70.91	Calculated (see text)
Other cattle	Commercial bulls	113.00	Du Toit et al. (2013a)
	Commercial young bulls	51.6	Assumed the same as young ox
	Commercial cows	118.41	Calculated (see text)
	Commercial heifers	65.23	Calculated (see text)
	Commercial ox	89.40	Du Toit et al. (2013a)
	Commercial young ox	51.60	Du Toit et al. (2013a)
	Commercial calves	51.60	Du Toit et al. (2013a)
	Feedlot	41.61	Calculated (see text)
	Subsistence cattle	61.47	Calculated (see text)
	Commercial wool	9.95	Calculated (see text)
Sheep	Commercial dual-purpose	10.89	Calculated (see text)
	Commercial meat	13.80	Calculated (see text)
	Feedlot	7.22	Calculated (see text)
	Subsistence sheep	5.61	Calculated (see text)
	Commercial mohair	6.64	Calculated (see text)



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Livestock category	Sub-category	Enteric EF (kg CH ₄ head ⁻¹ yr ⁻¹)	Reference
Goats	Commercial meat	14.38	Calculated (see text)
	Commercial dairy	19.99	Calculated (see text)
	Subsistence goats	9.33	Calculated (see text)
Swine	Commercial swine	1.09	Calculated (see text)
	Subsistence swine	1.33	Calculated (see text)
Horses		18	IPCC 2019 Refinement, Table 10.10
Mules/asses		10	IPCC 2019 Refinement, Table 10.10

5.2.2.3.1 Cattle (3.A.1)

Emission factors for commercial and subsistence bulls, young bulls, ox, young ox and calves are taken directly from Du Toit et al. (2013a) where the methods are described in detail. For the other, more dominant livestock categories, all the background data is included in the calculation files to enable the direct calculation of the emission factors using the IPCC Tier 2 equations (Table 5.13).

5.2.2.3.2 Sheep (3.A.2) and goats (3.A.4.d)

Emission factors for sheep and goats are calculated using a Tier 2 methodology (Table 5.14). The net energy for growth and lactation for goats is determined in the same way as for sheep as the IPCC 2019 Refinement indicates that this is the updated approach for goats and Swine (3.A.3).

Gross energy intake data for swine is taken from Du Toit et al. (2013c) and applied in the IPCC Equation 10.21 to determine the emission factors.

Table 5.13: Equations for the calculation of emissions factors for cattle using the Tier 2 approach

IPCC Equation	IPCC 2006 equations	Variables/constants/assumptions
10.3	$NE_m = C_f \times (weight)^{0.75}$	NE_m = net energy for maintenance (MJ day⁻¹) C_f = maintenance coefficient (MJ day⁻¹ kg⁻¹) [IPCC 2019 Refinement, Table 10.4: Lactating dairy cows = 0.386, Non-lactating cattle = 0.322, Bulls = 0.37] Weight = live weight of animal (kg)
10.4	$NE_a = C_a \times NE_m$	NE_a = net energy for activity (MJ day⁻¹) C_a = coefficient corresponding to animal's feeding situation [Dairy cattle assumed to feed in pastures¹, other cattle assume to graze on large grazing areas¹; IPCC 2019 Refinement, Table 10.5: Dairy cattle = 0.17, Other cattle = 0.36]
10.6	$NE_g = 22.02 \times \left(\frac{BW}{C \times MW}\right)^{0.75} \times (WG)^{1.097}$	NE_g = net energy for growth (MJ day⁻¹) BW = average live body weight of animals in the population (kg) C = growth coefficient [IPCC 2019 Refinement, Equation 10.6: Females = 0.8, Castrates = 1.0, Bulls = 1.2] MW = mature live body weight of an adult animal in moderate condition (kg) WG = average daily weight gain of animals in the population (kg day⁻¹)
10.8	$NE_l = Milk \times (1.47 + 0.40 \times Fat)$	NE_l = net energy for lactation (MJ day⁻¹) Milk = amount of milk produced (kg milk day⁻¹) Fat = milk fat content (% by weight)
10.11	$NE_{work} = 0.10 \times NE_m \times Hours$	NE_{work} = net energy for work (MJ day ⁻¹)

IPCC Equation	IPCC 2006 equations	Variables/constants/assumptions
		Hours = number of hours of work daily
10.13	$NE_p = C_{preg} \times NE_m$	NE _m = net energy for pregnancy (MJ day ⁻¹) C _{preg} = pregnancy coefficient [IPCC 2019 Refinement, Table 10.7: Cattle = 0.1]
10.14	$REM = \left[1.123 - (4.092 \times 10^{-3} \times DE\%) + [1.126 \times 10^{-5} \times (DE\%)^2] - \left(\frac{25.4}{DE\%} \right) \right]$	REM = ratio of net energy available in a diet for maintenance to digestible energy consumed DE% = digestible energy as a percentage of gross energy [ARC (2021): Mature dairy cows = 70%, Dairy heifers = 60%, Other commercial cattle in grazing land = 60%, Cattle feedlot = 75%, Other subsistence cattle in grazing land = 50%]
10.15	$REG = \left[1.164 - (5.160 \times 10^{-3} \times DE\%) + [1.308 \times 10^{-5} \times (DE\%)^2] - \left(\frac{37.4}{DE\%} \right) \right]$	REG = ratio of net energy available for growth in a diet to digestible energy consumed DE% = digestible energy as a percentage of gross energy [see above]
10.16	$GE = \left[\frac{(NE_m + NE_a + NE_l + NE_{work} + NE_p)}{REM} + \left(\frac{NE_g}{REG} \right) \right] \times \frac{DE\%}{100}$	GE = gross energy intake (MJ head ⁻¹ day ⁻¹) DE% = digestible energy as a percentage of gross energy [see above]
10.21	$EF = \left[\frac{GE \times \left(\frac{Y_m}{100} \right) \times 365}{55.65} \right]$	EF = emissions factor (kg CH ₄ head ⁻¹ yr ⁻¹) Y _m = methane conversion factor (percent of gross energy in feed converted to methane) [IPCC 2019 Refinement, Table 10.12: Holstein high milk producing dairy cows = 6%, Jersey medium milk producing dairy cows = 6.3%, Dairy heifers = 7%, Non-dairy commercial cattle = 7%, Non-dairy subsistence cattle = 6.5, Feedlot cattle = 3%] 55.65 (MJ kg ⁻¹ CH ₄) is the energy content of CH ₄ constant

¹ARC (2021)

Table 5.14: Equations for the calculation of emissions factors for sheep and goats using the Tier 2 approach

IPCC Equation	IPCC 2006 equation	Variables/constants/assumptions
10.3	$NE_m = C_f \times (weight)^{0.75}$	NE_m = net energy for maintenance (MJ day ⁻¹) C_f = maintenance coefficient (MJ day ⁻¹ kg ⁻¹) [IPCC 2019 Refinement, Table 10.4: Mature and replacement ewes = 0.217, Mature ram = 0.250, Young ram and male lamb = 0.271, Female lamb = 0.236] Weight = live weight of animal (kg)
10.5	$NE_a = C_a \times (weight)$	NE_a = net energy for activity (MJ day ⁻¹) C_a = coefficient corresponding to animal's feeding situation (MJ day ⁻¹) [Sheep grazing assumed to occur on flat pastures ¹ , IPCC 2019 Refinement, Table 10.5: all sheep = 0.0107] Weight = live weight of animal (kg)
10.7	$NE_g = \frac{WG_{lamb/kid} \times (a + 0.5b(BW_l + BW_f))}{365}$	NE_g = net energy for growth (MJ day ⁻¹) $WG_{lamb/kid}$ = weight gain (BW _f – BW _i) (kg yr ⁻¹) BW_i = the live bodyweight at weaning (kg) BW_f = the live bodyweight at 1-year old or at slaughter (kg) a = constant (MJ kg ⁻¹) [IPCC 2019 Refinement, Table 10.6: Female sheep = 2.1; Male sheep = 2.5 as it is assumed all male sheep are intact ¹] b = constant (MJ kg ⁻¹) [IPCC 2019 Refinement, Table 10.6: Female sheep = 0.45; Male sheep = 0.35 as it is assumed all male sheep are intact ¹]
10.10	$NE_l = \left[\frac{5 \times WG_{wean}}{365} \right] \times EV_{milk}$	NE_l = net energy for lactation (MJ day ⁻¹) WG_{wean} = the weight gain of the lamb/kid between birth and weaning (kg)

IPCC Equation	IPCC 2006 equation	Variables/constants/assumptions
		EV_{milk} = the energy required to produce 1 kg of milk (MJ kg⁻¹) [IPCC 2019 Refinement, Equation 10.10: sheep = 4.6, goats = 3] NE_{wool} = net energy required to produce wool (MJ day⁻¹) EV_{wool} = the energy value of each kg of wool produced (weighed after drying but before scouring) (MJ kg⁻¹) [IPCC 2019 Refinement, Equation 10.12: sheep = 24, for goats this energy value is not considered] Production_{wool} = annual wool production per sheep (kg yr⁻¹) NE_m = net energy for pregnancy (MJ day⁻¹) C_{preg} = pregnancy coefficient [The number of lambs/kids born in a year divided by the number of ewes that are pregnant in a year yields a value less than 1¹, therefore single birth coefficient is applied²; IPCC 2019 Refinement, Table 10.7: single births for sheep and goats = 0.077] REM = ratio of net energy available in a diet for maintenance to digestible energy consumed DE% = digestible energy as a percentage of gross energy [ARC (2021): Sheep in grazing land = 60%, Sheep in feedlots = 75%, Subsistence sheep = 50%, Goats in grazing land = 60%, Dairy goats = 70%, Subsistence goats = 50%] REG = ratio of net energy available for growth in a diet to digestible energy consumed DE% = digestible energy as a percentage of gross energy [see above]
10.12	$NE_{wool} = \frac{EV_{wool} \times Production_{wool}}{365}$	
10.13	$NE_p = C_{preg} \times NE_m$	
10.14	$REM = \left[1.123 - (4.092 \times 10^{-3} \times DE\%) + [1.126 \times 10^{-5} \times (DE\%)^2] - \left(\frac{25.4}{DE\%} \right) \right]$	
10.15	$REG = \left[1.164 - (5.160 \times 10^{-3} \times DE\%) + [1.308 \times 10^{-5} \times (DE\%)^2] - \left(\frac{37.4}{DE\%} \right) \right]$	

IPCC Equation	IPCC 2006 equation	Variables/constants/assumptions
10.16	$GE = \left[\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM} + \frac{NE_g}{REG} \right] \frac{DE\%}{100}$	GE = gross energy intake (MJ head ⁻¹ day ⁻¹) DE% = digestible energy as a percentage of gross energy [see above]
10.21	$EF = \left[\frac{GE \times \left(\frac{Y_m}{100} \right) \times 365}{55.65} \right]$	EF = emissions factor (kg CH ₄ head ⁻¹ yr ⁻¹) Y _m = methane conversion factor (percent of gross energy in feed converted to methane) [IPCC 2019 Refinement, Table 10.13: Sheep = 6.7%, Goats = 5.5%] 55.65 (MJ kg ⁻¹ CH ₄) is the energy content of CH ₄ constant

¹ARC (2021); ²IPCC 2019 Refinement

5.2.3 Uncertainty and time-series consistency

5.2.3.1 Activity data uncertainty

5.2.3.1.1 *Population data*

Uncertainty data is provided in Moeletsi et al. (2015a), although it is not clear how the uncertainty was derived. In this report dairy population data is indicated to have an uncertainty of $\pm 10\%$. Considering the comparisons above this uncertainty value appears reasonable. A $\pm 10\%$ uncertainty is also assigned to commercial beef cattle categories, except calves which has an uncertainty of $\pm 5\%$. The comparisons with Du Toit et al. (2013a) suggest that the uncertainty could be around $\pm 20\%$. The comparison is only for one year, therefore an uncertainty of $\pm 20\%$ is applied to all commercial beef cattle categories except calves (which remains at $\pm 5\%$). Moeletsi et al. (2015a) indicate a $\pm 10\%$ uncertainty on commercial sheep and goat population data. The comparisons with Du Toit et al. (2013b) suggest that this uncertainty is reasonable for sheep but may be too low for goats. The goat uncertainty is therefore increased to $\pm 20\%$. The $\pm 10\text{-}20\%$ uncertainty provided in Moeletsi et al. (2015a) for swine appears to be low with Du Toit et al. (2013c) reporting values 60% lower. The uncertainty for swine population is therefore increased to $\pm 50\%$. Moeletsi et al. (2015a) does not provide uncertainty data for poultry but considering the comparisons with FAO and Du Toit et al. (2013c) an uncertainty of $\pm 20\%$ is assigned to poultry population data.

5.2.3.2 Emission factor uncertainty

The uncertainties on the emission factors are provided by ARC (2021) for mature cows, heifers, feedlot cattle, all sheep and all goat sub-categories (Table 5.15). No uncertainty data is provided by Du Toit et al. (2013c) for bulls, oxen, young oxen, calves, or swine emission factors. For the bulls, young bulls, oxen, young oxen, and calf sub-categories the uncertainty was assumed to be an average of those for mature cows and heifers in each sub-category. For swine IPCC 2006 Guidelines indicates that a Tier 2 approach is likely to have an uncertainty of around $\pm 20\%$. Tier 1 default factors for horses, and mules/asses have an uncertainty of between $\pm 30\%$ - 50% , hence an average of $\pm 40\%$ is applied.



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Table 5.15: Enteric fermentation emission factor uncertainties

Animal categories	Animal subcategories	Emission Factor uncertainty	Reference
3.A.1.a - Dairy cattle	Mature cows	± 23	ARC (2021)
	Heifer (12 – 18 months)	± 21	ARC (2021)
	Heifer (6 – 12 months)	± 17	ARC (2021)
	Heifer (3 – 6 months)	± 13	ARC (2021)
3.A.1.b - Commercial beef cattle	Bulls	± 10	Average of uncertainty estimates for cows and heifers
	Young bulls	± 10	
	Mature cows	± 7	ARC (2021)
	Heifer (12 – 18 months)	± 9	ARC (2021)
	Heifer (6 – 12 months)	± 9	ARC (2021)
	Heifer (3 – 6 months)	± 13	ARC (2021)
	Oxen	± 10	Average of uncertainty estimates for cows and heifers
	Young oxen	± 10	
	Calves	± 10	
	Feedlot cattle	± 15	ARC (2021)
3.A.1.b - Subsistence cattle	Bulls	± 26	Average of uncertainty estimates for cows and heifers
	Young bulls	± 26	
	Mature cows	± 24	ARC (2021)
	Heifer (12 – 18 months)	± 28	ARC (2021)
	Heifer (6 – 12 months)	± 27	ARC (2021)
	Heifer (3 – 6 months)	± 27	ARC (2021)
	Oxen	± 26	Average of uncertainty estimates for cows and heifers
	Young oxen	± 26	
	Calves	± 26	
3.B.2 - Sheep	Mature ewes	± 30	ARC (2021)
	Replacement ewes	± 22	ARC (2021)
	Female lambs	± 36	ARC (2021)
	Male lambs	± 27	ARC (2021)
	Young rams	± 33	ARC (2021)
	Rams	± 24	ARC (2021)
	Feedlot sheep	± 29	ARC (2021)
3.A.4.d - Goats	Mature does	± 35	ARC (2021)
	Replacement does	± 31	ARC (2021)
	Female kids	± 34	ARC (2021)
	Male kids	± 34	ARC (2021)
	Young buck	± 39	ARC (2021)
	Buck	± 40	ARC (2021)
3.A.4.e - Horses		± 40	IPCC 2006



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Animal categories	Animal subcategories	Emission Factor uncertainty	Reference
3.A.4.f - Mules & asses		± 40	IPCC 2006
3.A.3 - Swine		± 20	IPCC 2006

5.2.3.3 Time-series consistency

The time-series for enteric fermentation is consistent.

5.2.4 Category specific QA/QC and verification

5.2.4.1 Livestock population data

Livestock data were compared with FAO data and other studies. For all livestock except poultry, the national statistics data (DALRRD, 2022a) used in this inventory correspond to those in the FAO database. There were small differences in the early years (1990 – 2002), but the data were then adjusted accordingly. Regarding poultry data, the data applied in this inventory are on average 33% lower than the FAO data. However, it should be noted that the majority of FAO poultry data are estimates and do not come from official data sources. In 2005 and 2006 official data is indicated to be reported and, in these years, the current data is 9% and 5% lower, respectively. Official data is also indicated to be used between 2013 and 2015, and in these years the data is 12% to 19% lower than the reported data in the FAO database.

In another study by Moeletsi and Tongwane (2015) the same national statistics data was applied for all livestock except poultry. Moeletsi and Tongwane (2015) reported broiler data that is 4% higher and layer data that is 24% lower for the year 2004.

A study by Du Toit et al. (2013a, b, c) made use of population data from the livestock industry associations for the year 2010. This study provides a total dairy population that is 7% higher than the DALRRD (2024a) data. The commercial and subsistence other cattle numbers provided by Du Toit et al. (2013a) are 22% and 4% higher than the DALRRD (2024a) data, respectively.

For sheep Du Toit et al. (2013b) utilized national statistics from Statistics SA and these numbers are within 0.5% of the data from DALRRD (2024a). Goat population data from Du Toit et al. (2013b) were obtained from the industry associations and are 34% higher for commercial goats, while subsistence numbers are only 1% higher.

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Swine population data from industry (Du Toit et al., 2013c) are 60% lower than that provided in DALRRD (2024a). Broiler and layer commercial population data is 19% and 15% lower than the Du Toit et al. (2013c) data for 2010.

All of this data shows that there is still a gap between the national statistics and data from livestock associations. As has been mentioned in previous inventories, it would be beneficial to set up a Livestock Estimates Committee which brings together government and livestock association representatives on an annual basis to discuss livestock population data to obtain consensus. The committee could also be used for discussions on ways to improve livestock population estimates and the reporting thereof.

5.2.4.2 Emission factors

For the emission factor data, a literature search was conducted, and the results are shown in the calculation files.

Data was also compared to the IPCC default data. The *Dairy cattle* Implied Emission Factor (IEF) is higher than the Africa default and is slightly higher than the default values for Oceania and Western Europe. The weight and milk production of SA dairy cattle are closer to those in Oceania and Western Europe than those in Africa, hence the closer alignment of the emission factors with these regions. This is the same for *Non-dairy cattle*. The sheep, goat and swine IEFs are generally consistent with the IPCC defaults.

5.2.5 Category-specific recalculations

No recalculations are performed for this category.

5.2.6 Category-specific planned improvements

In this inventory all the background calculations to complete the Tier 2 calculations has been included, however average activity data (i.e., livestock weights, milk production, fat content) are applied in many cases. However, it is recommended that in future inventories annual activity data be collected and incorporated. This means that the emission factor will vary annually and may better reflect any emission changes due to implemented changes (or mitigation actions) in livestock population management, feeding situations and pasture management. South Africa would then be able to track the impacts of possible mitigation actions through the inventory. This issue was noted in the previous inventory, and there has been no progress on the planned improvements.



Improving livestock population data has become increasingly important, as recent studies have refined emission factors, leaving population figures as the largest source of uncertainty. Establishing a Livestock Estimates Committee could help address this gap. The DFFE has begun discussions with the Department of Agriculture and the Agricultural Research Council, which hosts a dedicated livestock division, to explore potential collaboration on this matter.

A detailed study on the herd composition of the various livestock and the number of days each livestock sub-category is alive in a year would contribute to a reduction in uncertainty. Use appropriate MCFs depending on the average temperature for each year of the time series. Stratify the estimates depending on the average temperature in different regions in South Africa.

5.3 Manure Management (CRT 3.B)

5.3.1 CH₄ emissions from manure management (CRT 3.B(a))

5.3.1.1 *Category description*

Livestock manure is composed principally of organic material. When the manure decomposes in the absence of oxygen, methanogenic bacteria produce CH₄. The amount of CH₄ emissions is related to the amount of manure produced and the amount that decomposes anaerobically.

According to IPCC 2006 Guidelines the method for estimating CH₄ emissions from manure management requires the following steps:

- Divide livestock population into animal subgroups based on sex, age, and production level.
- For CH₄ emissions:
 - i. Estimate the emission factors for each subgroup in terms of kilograms of CH₄ per animal per year.
 - ii. Multiply the subgroup emission factors by the subgroup populations to estimate subgroup emissions and sum across the subgroups to estimate total emission.

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Manure management emissions increased by 11.2 % in the period 2000–2024. Manure management contributed 4 399.8 Gg CO₂e in 2024, which is 8.3% of the agriculture sector emissions. Methane emissions from manure management contributed 40% to the total manure emissions. N₂O emissions from manure management contributed 60% to the total manure emissions.

5.3.1.2 Methodological issues**5.3.1.2.1 Activity data**

Livestock population data is described in section 5.2.2.1.

The manure management data for cattle, sheep and goats was sourced from the ARC Report (2021) and there were various sources for this data as indicated in Table 5.16 Data for horses, swine and poultry is sourced from Moeletsi and Tongwane (2015) and Du Toit et al. (2013c).

Table 5.16: Manure management systems for the various livestock types and their data sources

Livestock	Lagoon	Liquid/ slurry	Dry lot/ Kraals	Solid storage	Daily spread	Compost	Manure with litter	Manure without litter	Pasture, range, paddock (PRP)
Dairy cattle									
Mature female cows	5 ¹	5 ¹	20 ¹	5	5				60 ³
Heifers (6 - 24 months)			2						98 ⁴
Other cattle									
Commercial			3						97 ⁴
Subsistence			35						65 ⁴
Feedlot	5		85 ²	10					
Sheep									
Commercial ⁴			2						98
Subsistence			35 ⁶						65 ⁴
Feedlot ⁶	2		98						
Goats									
Commercial			2 ²						98 ⁴
Subsistence ⁴			35						65
Dairy goats ⁴			10						90
Horses, mules, asses ²									100
Swine									
Commercial ^{2,5}	71	11	13		3	2			
Subsistence ⁵	25	10	35						30
Poultry									
Commercial ²			80			5	15		
Subsistence ²		5	70		5	10		10	

¹ DEA (2014); ² Moelesi and Tongwane (2015); ³ Malaka (2017); ^{4,6}Expert opinion, ⁵Du Toit et al. (2013c);

Table 5.17: Verification of livestock manure management systems

Livestock	DAFF (2010)	Du Toit et al. (2013a, b, c)	Moeletsi et al. (2015)	Moeletsi and Tongwane (2015)	ARC Report (2021)	IPCC 2019 Refinement (Sub-Saharan Africa (SSA) default)
Dairy cattle	Cows and heifers: 45% lagoon, 10% liquid slurry, 15% dry lot, 10% compost, 20% PRP	TMR: 10% lagoon, 0.5% liquid slurry, 1% daily spread, 88.5% PRP; Pasture: 3% lagoon, 7% daily spread, 90% PRP	TMR: 95% lagoon, 5% manure with bedding; Pasture: 11% lagoon, 8% dry lot, 10% solid storage, 3% daily spread, 60% PRP	Cows: 20% lagoon, 5% liquid slurry, 25% dry lot, 45% PRP, 5% manure with bedding; Heifers: 5% dry lot, 2% compost, 93% PRP	Cows: 5% lagoon, 5% liquid slurry, 20% dry lot, 5% solid storage, 5% daily spread, 60% PRP; Heifers: 2% dry lot, 98% PRP	20% solid storage, 29% dry lot, 45% PRP, 6% burned for fuel
Other cattle	Commercial: 25% dry lot, 5% compost, 70% PRP; Feedlot: 1.5% lagoon, 1.5% liquid slurry, 20% dry lot, 2% daily spread, 10% compost, 65% PRP; Subistence: 10% dry lot, 90% PRP	Commercial: 100% PRP; Feedlot: 80% dry lot, 20% solid storage; Subistence: 100% PRP	Commercial: 2% solid storage, 1% daily spread, 95% PRP, 2% manure with bedding; Feedlot: 20% solid storage, 80% manure with bedding; Subistence: 10% dry lot, 30% PRP, 60% manure with bedding	Commercial: 5% dry lot, 5% compost, 90% PRP; Feedlot: 5% lagoon, 5% liquid slurry, 75% dry lot, 5% daily spread, 10% compost; Subistence: 10% dry lot, 80% PRP, 10% manure with bedding	Commercial: 3% dry lot, 97% PRP; Feedlot: 5% lagoon, 85% dry lot, 10% solid storage; Subistence: 35% dry lot, 65% PRP	15% solid storage, 30% dry lot, 50% PRP, 5% burned for fuel
Sheep	Commercial: 2% dry lot, 98% PRP; Subistence: 5% dry lot, 95% PRP	Commercial and subsistence: 100% PRP	Commercial and subsistence: 100% PRP	Commercial: 2% dry lot, 98% PRP; Subistence: 5% dry lot, 95% PRP	Commercial: 2% dry lot, 98% PRP; Subistence: 35% dry lot, 65% PRP; Feedlot: 2% lagoon, 98% dry lot	17% solid storage, 3% dry lot, 80% PRP

Livestock	DAFF (2010)	Du Toit et al. (2013a, b, c)	Moeletsi et al. (2015)	Moeletsi and Tongwane (2015)	ARC Report (2021)	IPCC 2019 Refinement (Sub-Saharan Africa (SSA) default)
Goats	Commercial: 2% dry lot, 98% PRP; Subsistence: 5% dry lot, 95% PRP	Commercial and subsistence: 100% PRP	Commercial and subsistence: 100% PRP	Commercial: 2% dry lot, 98% PRP; Subsistence: 5% dry lot, 95% PRP	Commercial: 2% dry lot, 98% PRP; Subsistence: 35% dry lot, 65% PRP	17% solid storage, 3% dry lot, 80% PRP
Horses	100% PRP	40% dry lot, 60% PRP	100% PRP	100% PRP		
Mules/asses	100% PRP	100% PRP	100% PRP	100% PRP		
Swine	Commercial: 50% lagoon, 20% liquid slurry, 20% dry lot, 5% daily spread, 5% compost	Commercial: 92% lagoon, 1.5% liquid slurry, 5% dry lot, 1.5% daily spread; Subsistence: 50% dry lot, 50% daily spread	Commercial: 50% lagoon, 20% liquid slurry, 20% dry lot, 10% solid storage	Commercial: 50% lagoon, 20% liquid slurry, 20% dry lot, 5% daily spread, 5% compost		High productivity: 7% liquid slurry, 6% solid storage, 86% dry lot, 1% pit<1; Low productivity: 5% lagoon, 30% liquid slurry, 15% solid storage, 15% dry lot, 15% pit<1, 5% pit>1, 5% daily spread, 5% digester, 5% PRP
Poultry	Layers and broilers: 80% dry lot, 20% compost	Layers: 100% poultry manure without litter; Broilers: 100% poultry manure with litter	Layers and broilers: 10% dry lot, 5% daily spread, 2% compost, 5% poultry manure without litter, 78% poultry manure with litter	Layers: 5% liquid slurry, 70% dry lot, 5% daily spread, 10% compost, 10% poultry manure without litter; Broilers: 80% dry lot, 5% compost, 15% poultry manure with litter		Layers: 90% pit>1 month, 10% poultry manure with litter; Broilers: 100% poultry manure with litter



5.3.1.2.2 *Emission factors*

Annual volatile solid (VS) excretion from horses and mules/asses is determined with a Tier 1 methodology (IPCC 2006 Guidelines, Equation 10.22) by using a default VS excretion rate of 7.2 kg VS (1000 kg animal mass)⁻¹ day⁻¹ (IPCC 2019 Refinement, Table 10.13A).

The annual VS excretion for all other livestock is determined with the IPCC 2006 Guidelines Equation

10.24. IPCC 2006 suggests a value of 0.04 for the fraction of urinary energy (UE) for all livestock except swine where a value of 0.02 is applied (IPCC 2006 Guidelines, Equation 10.24). The fraction of ash content of feed (ASH) is set at 0.08 for all livestock (IPCC 2006 Guidelines, Equation 10.24), except for swine where a value of 0.17 is applied (Du Toit et al., 2013c).

5.3.1.3 *Uncertainty*

5.3.1.3.1 *Activity data uncertainty*

The population data uncertainties are discussed in section 5.2.3.1

For manure management data Moeletsi et al. (2015) reported a $\pm 20\%$ uncertainty on mixed diet dairy cattle manure management, and a $\pm 25\%$ and $\pm 10\%$ uncertainty on pasture and Total Mixed Ratio (TMR) manure management systems, respectively. Considering the variation in the reported data (Table 5.17) the uncertainty seems to be much higher, therefore an uncertainty of $\pm 50\%$ is assigned to dairy cattle manure management. For non-dairy cattle an uncertainty of $\pm 15\%$ is provided, and considering the variation shown in this is not unreasonable, although it might be slightly on the low side. The uncertainty is therefore adjusted to $\pm 20\%$. The $\pm 5\%$ uncertainty assigned by Moeletsi et al. (2015) to goats and horses, and the $\pm 2\%$ assigned to horses, mules/asses and sheep appears to be reasonable, but it is unclear why the uncertainty for sheep is lower than goats when the manure management data is the same in all studies for these two livestock categories. Based on this, and the data in Table 5.17, the uncertainty for goats is adjusted to $\pm 2\%$. Poultry and swine manure management data has an uncertainty of $\pm 15\%$ (Moeletsi et al., 2015). The variation in the data reported in Table 5.17 is low for swine but is high for poultry, therefore the uncertainty is adjusted to $\pm 10\%$ and $\pm 25\%$ for swine and poultry, respectively.

The IPCC 2006 Guidelines default uncertainty for N excretion is $\pm 50\%$, but this is for a Tier 1 method. It is therefore assumed that the Tier 2 method reduces uncertainty to $\pm 30\%$.

5.3.1.3.2 *Emission factor uncertainty*

The data on uncertainty for CH₄ emission factors from livestock manure is presented in Table 5.18. Uncertainty on the CH₄ manure emission factors is provided by ARC (2021) for mature cows, heifers, feedlot cattle, all sheep and all goat sub-categories. No uncertainty data is provided by Du Toit et al. (2013c) for bulls, oxen, young oxen, calves, or swine emission factors. For the bulls, young bulls, oxen, young oxen, and calf sub-categories the uncertainty was assumed to be an average of those for mature cows and heifers in each sub-category. For swine IPCC 2006 Guidelines indicate that a Tier 2 approach is likely to have an uncertainty of around $\pm 20\%$. The same applies to poultry. Tier 1 default factors for horses, and mules/asses have an uncertainty of between $\pm 30\%$ - 50% , that an average of $\pm 40\%$ is applied.

Table 5.18: Uncertainty data for livestock manure CH₄ emission factors

Animal categories	Animal subcategories	Emission Factor uncertainty	Reference
3.B.1.a - Dairy cattle	Mature female	± 24	ARC (2021)
	Heifer (12 – 18 months)	± 21	ARC (2021)
	Heifer (6 – 12 months)	± 18	ARC (2021)
	Heifer (3 – 6 months)	± 13	ARC (2021)
3.B.1.b - Commercial beef cattle	Bulls	± 10	Average of uncertainty estimates for cows and heifers
	Young bulls	± 10	
	Mature female	± 7	ARC (2021)
	Heifer (12 – 18 months)	± 11	ARC (2021)
	Heifer (6 – 12 months)	± 9	ARC (2021)
	Heifer (3 – 6 months)	± 9	ARC (2021)
	Oxen	± 10	Average of uncertainty estimates for cows and heifers
	Young oxen	± 10	
	Calves	± 9	
3.B.1.b - Subsistence cattle	Feedlot cattle	± 6	ARC (2021)
	Bulls	± 17	Average of uncertainty estimates for cows and heifers
	Young bulls	± 17	
	Mature female	± 16	ARC (2021)
	Heifer (12 – 18 months)	± 19	ARC (2021)
	Heifer (6 – 12 months)	± 18	ARC (2021)
	Heifer (3 – 6 months)	± 19	ARC (2021)
	Oxen	± 17	Average of uncertainty estimates for cows and heifers
	Young oxen	± 17	
3.B.2 - Sheep	Calves	± 17	
	Mature ewes	± 15	ARC (2021)
	Replacement ewes	± 8	ARC (2021)



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Animal categories	Animal subcategories	Emission Factor uncertainty	Reference
	Female lambs	±15	ARC (2021)
	Male lambs	±16	ARC (2021)
	Young rams	±11	ARC (2021)
	Rams	±9	ARC (2021)
	Feedlot sheep	±15	ARC (2021)
3.B.4.d - Goats	Mature does	±46	ARC (2021)
	Replacement does	±42	ARC (2021)
	Female kids	±46	ARC (2021)
	Male kids	±46	ARC (2021)
	Young buck	±50	ARC (2021)
	Buck	±50	ARC (2021)
3.B.4.e - Horses		± 30	IPCC 2006
Mules & asses		± 30	IPCC 2006
3.B.3 - Swine		± 20	IPCC 2006
3.B.4.g - Poultry		± 20	IPCC 2006

5.3.1.4 Time-series consistency

The time-series is consistent throughout the period 2000 – 2024.

5.3.1.5 Category specific QA/QC and verification

Livestock data verification is provided in section 5.2.4.1.

Manure management data is compared to data from various studies and Table 5.17 shows that there is high variation in the results for cattle and poultry. The data variability is much less for sheep, goats, horses, mules/asses and swine. The percentage allocation differs significantly from the IPCC 2019 Refinement Sub-Saharan Africa (SSA) default value, but this is not unexpected as the default is for the whole SSA region while the numbers from the other studies are more specific to SA which has some high productivity systems. There is some agreement on the types of manure management systems utilised, except that SA does not mention pit storage systems. In addition, no manure is allocated to burning or digesters since there is no data and it is not significant. There are some cattle feedlots and piggeries which make use of digesters, but the data is limited, and it is thought to be minimal. This should, however, be monitored in future, particularly because of the energy production benefits of the digesters.

For the emission factor data, a literature search was conducted, and the results are shown in the calculation files.



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Data was also compared to the IPCC default data. The dairy cattle emission factor is higher than the default for Africa. The differences are due to the different manure management systems in these regions which impacts the MCF. The situation is similar for the emission factor for swine. The Other cattle emission factor is much lower than that in other countries and is even lower than the default value for Africa. Sheep and goat emission factors are lower than IPCC default values.

5.3.1.6 *Category-specific recalculations*

There have been no recalculations performed for this source category this year.

5.3.1.7 *Category-specific planned improvements*

There are no planned improvements for this category in the next year.

5.3.2 N₂O emissions from manure management (CRT 3.B(b))

5.3.2.1 *Category description*

The *Manure management* category also includes N₂O emissions related to manure handling before it is added to agricultural soil. The amount of N₂O emissions depends on the system of waste management and the duration of storage. N₂O emissions from manure management occur both directly and indirectly. Direct emissions occur during the handling, storage, and application of manure. When manure is stored in anaerobic conditions (without oxygen), microbes break down nitrogen compounds, leading to the release of N₂O. Indirect emissions of N₂O-N can take place in two ways: i) volatilization of N as NH₃ and oxides of N, and ii) through runoff and leaching from land where N was applied (IPCC, 2006).

Ammonia (NH₃) and NO_x volatilise from manure storage; however, these emissions are not estimated due to a lack of data.

According to IPCC 2006 Guidelines the method for estimating direct N₂O emissions from manure management requires the following steps:

- Divide livestock population into animal subgroups based on sex, age, and production level.
- For N₂O emissions:
 - i. Determine average annual nitrogen excretion rate per head for each livestock subcategory.



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- ii. Determine the fraction of total annual nitrogen excretion for each livestock category that is managed in each manure management system.
- iii. Determine N₂O emission factors for each manure management system.
- iv. Multiply the emission factor by the total nitrogen managed in the system and sum over all manure management systems.

Direct N₂O emissions from manure management contributed 53% of the total Manure management emissions in 2024. Indirect N₂O emissions from manure management contributed 8% of the total Manure management emissions in 2024.

5.3.2.2 *Methodological issues*

Direct manure N₂O emissions are calculated following the IPCC 2006 Guidelines equation 10.25 (IPCC, 2006, volume 4, chapter 10).

A Tier 1 method is used to determine N₂O emissions from deposition of volatilized N. Indirect N₂O losses due to volatilization are calculated using the Tier 1 method as described by equation 10.26 in the IPCC 2019 Refinement. This is followed by equation 10.28. Data on biogas plants and co-digestion is limited, therefore this term was excluded from the calculation and can be updated in future when more data becomes available.

Indirect N₂O losses due to leaching and runoff are calculated using the Tier 1 method as described by equation 10.27 in the IPCC 2019 Refinement, which is followed by equation 10.29. As with the emissions due to volatilisation the amount of N from co-digestates added to biogas plants was excluded from the calculation and can be updated in future when more data becomes available.

5.3.2.2.1 *Activity data*

Direct N₂O emissions require information on livestock population (section 5.2.2.1), manure management (section 5.3.1.2) and annual average nitrogen (N) excretion per head of livestock (N_{ex(T)}).

Annual N excretion for horses and mules/asses is calculated with a Tier 1 methodology, based on the IPCC default N excretion rate of 0.46 kg N (1000 kg animal mass)⁻¹ day⁻¹, and typical animal mass. ARC (2021) provides a typical animal mass of 595 kg for horses and 250 kg for mules and asses.

A Tier 2 methodology (following IPCC 2006 Guidelines Equation 10.31 and 10.32) is utilised to calculate annual N excretion rates for cattle, sheep, and goats (Table 5.19). The updated IPCC 2019 Refinement Tier 2 methodology (Equation 10.32A) is applied to swine and poultry to determine N intake rates. The dry matter intake (DMI) data for



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swine and poultry is taken from Du Toit et al. (2013c). In all cases the N retention values are sourced from IPCC 2006 Guidelines, Table 10.2.

Both indirect N₂O emission equations require data on livestock population, N excretion, and manure management which are described in section 5.2.2.1, section 5.3.2.2 and section 5.3.1.2, respectively. The fraction of managed manure that volatilises and that is leached are taken from the IPCC 2019 Refinement (volume 4, chapter 11, Table 10.22).

Table 5.19: Nitrogen excretion rate for different livestock categories

Livestock category	Subcategories	Nitrogen excretion rate (kgN/animal/year)
3.A.1.a - Dairy cattle	Mature female cows	113.71
	Heifer 12 - 18 months	27.06
	Heifer 6 - 12 months	21.87
	Calves 0 - 6 months	12.09
3.A.1.b - Commercial beef cattle	Mature female cows	44.60
	Heifers 12 - 18 months	25.74
	Heifers 6 - 12 months	19.86
	Calves 3 - 6 months	13.34
	Feedlot cattle	59.00
3.A.1.b - Subsistence cattle	Mature female cows	46.05
	Heifers 12 - 18 months	26.09
	Heifers 6 - 12 months	24.00
	Calves 0 - 6 months	16.46
3.A.2 - Commercial sheep	Mature ewes	4.00
	Replacement ewes	2.93
	Female lambs	3.28
	Male lambs	4.06
	Replacement rams	3.82
	Mature rams	5.11
	Feedlot sheep	4.33
3.A.2 - Subsistence sheep	Mature ewes	4.47
	Replacement ewes	3.27
	Female lambs	2.42
	Male lambs	2.63
	Replacement rams	2.84
	Mature rams	5.77
3.A.4.d - Goats	Mature does	6.33
	Replacement does	2.99
	Female kids	2.51



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Livestock category	Subcategories	Nitrogen excretion rate (kgN/animal/year)
	Male kids	3.31
	Replacement bucks	3.51
	Bucks	5.59
	Dairy goats	-

5.3.2.2.2 *Emission factors*

Emission factors for all livestock are obtained from IPCC 2019 Refinement (Table 10.21).

IPCC default emission factors for N₂O from atmospheric deposition of N on soils and water surfaces, and from leaching and runoff are taken from the IPCC 2019 Refinement (volume 4, chapter 11, Table 11.3). The dry climate factors are applied.

5.3.2.3 *Uncertainty*

5.3.2.3.1 *Activity data uncertainty*

The population data uncertainties are discussed in section 5.2.3.1. Uncertainty on manure management systems is provided in section 5.3.1.3. The IPCC 2006 Guidelines default uncertainty for N excretion is $\pm 50\%$, but this is for a Tier 1 method. It is therefore assumed that the Tier 2 method reduces uncertainty to $\pm 30\%$.

Uncertainty on activity data for livestock population and N excretion are discussed in sections 5.2.3.1 and 5.3.2.2. Frac_{GASMS} and Frac_{LeachMS} uncertainties are provided in IPCC 2019 Refinement (volume 4, chapter 10, Table 10.22).

5.3.2.3.2 *Emission factor uncertainty*

Uncertainty on the IPCC 2019 Refinement default N₂O manure emission factors is -50% to +100%. The uncertainty on EF₄ is -100% and +120%, and for EF₅ it is -100% and +82% (IPCC 2019 Refinement, Table 11.3).

5.3.2.4 *Time-series consistency*

The time-series is consistent throughout the period 1990 – 2024.

5.3.2.5 *Category specific QA/QC and verification*

Category specific QA/QC and verification is provided in section 5.3.1.5. Additionally, general QA/QC measures in Table 5.8 were used for this category.



5.3.2.6 Category-specific recalculations

No recalculations are performed for this category.

5.3.2.7 Category-specific planned improvements

Improvements include collecting the national data set on manure management systems. This data seems to be highly variable depending on where the information comes from. In addition, data on the amount of manure being diverted to biogas needs to be included as this is a mitigation option and has been highlighted in previous inventory reviews. It is recommended to find a mechanism to track manure management practices or systems used in South Africa, as this could allow for incorporation of dynamics driven by changes in management regimes, and thus improve the accuracy of manure related emissions. It is recommended that data be collected on manure inputs to biogas plants so the data can be incorporated into the equation in future. Investigate if there are studies available about the burning of manure in South Africa. This issue was noted in the previous inventory, and there has been no progress on the planned improvements.

5.4 Rice cultivation (CRT 3.C)

Rice cultivation is excluded from this inventory because, in accordance with IPCC 2006 Guidelines, it is not identified as a key category and its contribution to total GHG emissions is considered insignificant. The previous inventory included estimations for rice cultivation, which demonstrated and confirmed that its emissions were negligible. Therefore, its exclusion does not materially affect the completeness or accuracy of the inventory results.

5.5 Agricultural soils (CRT 3.D)

5.5.1 Direct N₂O emissions from managed soils (CRT 3.D.1)

5.5.1.1 Category description

Agricultural soils contribute to GHGs in three ways:

- CO₂ through the loss of soil organic matter. This is a result of land-use change, and is, therefore, dealt with in the land sector, not in this section. CH₄ from anaerobic soils. Anaerobic cultivation, such as rice paddies, is not practised in



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South Africa, and therefore CH₄ emissions from agricultural soils are not included in this inventory; and

- N₂O from fertilizer use and intensive cultivation. This is a significant fraction of non-carbon emissions from agriculture and is the focus of this section of the inventory.

The IPCC 2006 Guidelines identifies several pathways of nitrogen inputs to agricultural soils that can result in direct N₂O emissions:

- Nitrogen inputs:
 - Synthetic nitrogen fertilizers.
 - Organic fertilizers (including animal manure, compost, and sewage sludge); and
 - Crop residue (including nitrogen fixing crops).
- Soil organic matter lost from mineral soils through land-use change.
- Organic soil that is drained or managed for agricultural purposes; and
- Animal manure deposited on pastures, rangelands, and paddocks.

In this inventory, sewage sludge emissions are included under waste (IE). In South Africa, sewage sludge is often not applied to agricultural crops due to concerns about contamination. Sewage sludge can contain pathogens, heavy metals, and other pollutants that could pose risks to human health and the environment if not properly treated. Regulations and guidelines are in place to manage its use, but many farmers and regulatory bodies remain cautious. Some areas may use treated sludge for non-food crops or in controlled applications, but the widespread use of untreated or inadequately treated sludge on food crops is typically avoided.

In 2024, direct N₂O emissions from managed soils were estimated at 8167 Gg CO₂e, accounting for 84% of total emissions from agricultural soils. Indirect N₂O emissions from managed soils were estimated at 1514 Gg CO₂e, representing the remaining 16% of agricultural soil emissions. The emission contribution of the various types of N inputs is shown in Table 5.20. Total direct N₂O emissions increased between 1990 and 2000, followed by a period of relative stabilisation, with emissions in 2024 remaining close to 2000 levels despite shifts among individual source categories (Table 5.20).

Between 1990 and 2024, emissions from inorganic and organic nitrogen fertilisers increased, with organic fertilisers showing the larger relative growth. Emissions from urine and dung of grazing animals declined over the period but remained the largest



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source of direct N₂O emissions. In contrast, emissions from crop residues increased substantially, becoming a more significant contributor by 2024. Emissions associated with soil organic matter mineralisation and immobilisation remained negligible throughout, while emissions from the cultivation of organic soils increased modestly, with their share of total agricultural emissions remaining constant.

Direct N₂O emissions from managed soils is a key category based on the level and trend assessments.

Table 5.20: Emission trends for the various sub-categories of direct N₂O emissions from managed soils

		1990	2000	2024	Change (%)	
					1990-2024	2000-2024
Inorganic N fertiliser	Emissions (Gg CO ₂ e)	715.6	866.0	864.0	20.7	-0.2
	% Agriculture	1.2	1.5	1.6		
Organic N fertiliser	Emissions (Gg CO ₂ e)	544.2	645.7	783.2	43.9	21.3
	% Agriculture	0.9	1.1	1.5		
Urine and dung from grazing animals	Emissions (Gg CO ₂ e)	6 302.6	6 179.8	5 256.5	-16.6	-14.9
	% Agriculture	10.7	10.8	10.0		
Crop residues	Emissions (Gg CO ₂ e)	350.7	426.9	1 261.7	259.7	195.5
	% Agriculture	0.6	0.7	2.4		
Mineralization/immobilization associated with loss/gain of soil organic matter	Emissions (Gg CO ₂ e)	0.9	0.9	1.1	19.1	18.4
	% Agriculture	0.0	0.0	0.0		
Cultivation of organic soils	Emissions (Gg CO ₂ e)	42.0	46.5	50.7	20.7	9.0
	% Agriculture	0.1	0.1	0.1		

5.5.1.2 Methodological issues

Tier 1 and Tier 2 approaches were used to calculate Direct N₂O emission from managed soils. Some of the sub-categories under managed soils utilized Tier 1 method, while



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others employed Tier 2 method. Tier 1 followed the IPCC 2006 Guidelines Equation 11.1 (IPCC, 2006, Volume 4, Chapter 11).

5.5.1.2.1 Inorganic fertiliser N inputs (F_N) (CRT 3.D.1.a)

IPCC Tier 1 methodologies and default emission factors (IPCC 2006) are used for estimating direct N_2O emissions from managed soils. The amount of inorganic N applied to soils is multiplied with the IPCC 2006 Guidelines default emission factor (IPCC 2006).

5.5.1.2.2 Organic fertiliser N inputs (F_{ON}) (CRT 3.D.1.b)

The amount of N (kg N yr⁻¹) from organic N additions applied to soil is calculated using IPCC 2006 Guidelines Equation 11.3 (IPCC, 2006; Volume 4, chapter 11).

A Tier 2 approach was used to calculate N from animal manure applied to soils (IPCC 2006 Guidelines, Equation 11.4, vol 4, chapt 11). The amount of animal manure applied is equal to the amount of managed manure N available for soil application minus that used for feed and construction. The amount of managed manure N available for soil application is calculated from IPCC 2006 Guidelines Equation 10.34 (IPCC, 2006, volume 4, chapter 10).

N_2O emissions from sludge are included in the Waste sector and are therefore excluded here to avoid double counting.

The amount of compost N applied on managed soils each year is estimated from the synthetic fertilizer consumption data. The synthetic fertilizer input changed each year, while the rest of the factors were assumed to remain unchanged over the 20-year period. It is estimated that a total of 5% of all farmers use compost (DAFF, 2010). Compost is seldom, if ever, used as the only nutrient source for crops or vegetables. It is used as a supplement for synthetic fertilizers, and it is estimated that farmers would supply about 33% of nutrient needs through compost. All of this is considered when estimating N inputs from compost (details provided in DAFF (2010) and Otter (2011)).

5.5.1.2.3 Urine and dung N deposited by grazing animals (F_{PRP}) (CRT 3.D.1.c)

Manure N deposited in pastures, rangelands and paddocks include all the open areas where animal excretions are not removed or managed. It also includes emissions from daily spread. This manure remains on the land, where it is returned to the soil, and contributes to GHG emissions. In South Africa, the majority of animals spend most of their lives on pastures and rangelands. The annual amount of urine and dung N deposited on pastures, ranges, or paddocks by grazing animals (F_{PRP} ; kg N yr⁻¹) is calculated using Equation 11.5 in the IPCC 2006 Guidelines (Chapter 11, Volume 4).



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5.5.1.2.4 Crop residues N inputs (F_{CR}) (CRT 3.D.1.d)

The amount of N in crop residues is estimated using the updated IPCC Tier 1 approach for the IPCC 2019 Refinement (Equation 11.6) but with some national factors. Some country specific factors are given for fraction of dry matter, fraction of residue burnt, fraction of residue removed, and ratio of above-ground and below ground residues to harvested yield (Tongwane et al., 2016). IPCC default factors are applied for combustion factors. IPCC 2019 Refinement default values for N content of above-ground residue, N content of below ground residue, and ratio of below-ground biomass to above-ground biomass (IPCC 2019 Refinement, Table 11.1A) are applied.

5.5.1.2.5 Mineralisation/immobilisation associated with loss/gain of soil organic matter (F_{SOM}) (CRT 3.D.1.e)

The mineralised N resulting from loss of soil organic carbon stocks in mineral soils through land-use change (F_{SOM}) was estimated following the equation 11.8 from the IPCC 2006 Guidelines. IPCC recommended defaults for C:N ratio (IPCC 2006, Equation 11.8) are used in the calculation.

5.5.1.2.6 Activity data

Inorganic fertiliser N inputs

For nitrogen emissions the Fertilizer Association of South Africa (Fertasa) reports total N consumption.²⁰ This value is the total nitrogen consumed in all fertilizer types and it accounts for the different N content of urea, ammonia, etc. It should be noted that the N consumption data between 2000 and 2009 was based on actual data, but thereafter the numbers are estimates.

Organic fertiliser N inputs

Animal manure inputs

IPCC 2006 Guidelines Equation 10.34 (IPCC, 2006; volume 4, chapter 10) requires the following data:

- Livestock population data (section 5.2.2.1)
- N excretion data (section 5.3.2.2)
- Manure management system usage data (Table 5.30)
- Amount of managed manure nitrogen that is lost in each manure

²⁰ <http://www.fertasa.co.za/fertilizer-information/historic-sales-data/content/uploads/2021/03/Fertilizer-Usage-2020-and-2021-RSA.pdf>

and

<http://www.fertasa.co.za/wp-content/uploads/2021/03/Fertilizer-Usage-2020-and-2021-RSA.pdf>



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management system (Frac_{LOSSMS}). IPCC 2006 Guidelines default values were used here (Table 10.23, Chapter 10, Volume 4, IPCC 2006).

- Amount of nitrogen from bedding. There were no data available for this, so the values provided by IPCC (IPCC, 2006; pg. 10.66) are utilized and
- The fraction of managed manure used for feed, fuel, or construction. Again, there were insufficient data and thus F_{AM} was not adjusted for these fractions (IPCC 2006 Guidelines, p. 11.13).

Compost inputs

The activity data to calculate compost is inorganic N fertiliser data which is described above.

Urine and dung deposited by grazing animals

Activity data for this sub-category are livestock population (section 5.2.2.1) and manure management (section 5.3.1.2) data.

Crop residue N inputs

Planted area and production data is obtained from Abstracts of Agricultural Statistics (DALRRD, 2022) and FAO (FAOSTat). Production data is used to calculate yield and this is usually dry mass (as indicated in FAOSTAT) so these values are not multiplied by the dry matter content to get dry yield.

Mineralised N due to land use change

The average annual loss of soil carbon from the various land types is the activity data for this subcategory and this data comes from the land conversions data discussed in the Land sector.

5.5.1.2.7 Emission factors

Inorganic and organic N fertiliser, crop residues and F_{SOM}

The IPCC default emission factor of 0.005 kg N₂O-N/kg N applied (IPCC 2019 Refinement, Table 11.1, dry climate).

Urine and dung deposited by grazing animals

The IPCC default emission factor of 0.002 kg N₂O-N (kg N)⁻¹ for cattle, poultry and pigs and 0.003 kg N₂O-N (kg N)⁻¹ for sheep and other animals is applied (IPCC 2019 Refinement, Table 11.1, dry climate).



5.5.1.3 **Uncertainty**

5.5.1.3.1 Activity data uncertainty

For *Inorganic N fertiliser*, Expert opinion (Corne Louw, corne@grainsa.co.za) suggests that the N consumption would likely be within 15% of the number.

For animal manure inputs the uncertainty is estimated at $\pm 41\%$ based on the uncertainty on livestock population, manure management and N excretion data. No uncertainty data was provided for compost, so a $\pm 25\%$ uncertainty is assumed. This is based on the 15% uncertainty on N consumption, with additional uncertainty on the percentage nitrogen, percentage of compost in total fertiliser application and amount of animal manure in compost.

For *Urine and dung deposited by grazing animals*, the uncertainty estimate for this activity data is 53.6% based on the uncertainty on livestock population data, manure management data and the 50% uncertainty on the F_{LossMS} factor (IPCC 2006 Guidelines, Table 10.23).

For *Crop residues*, the uncertainty on crop residue input data is high (average of 91.2%) which is estimated from a $\pm 10\%$ uncertainty on crop production data, a $\pm 75\%$ uncertainty on N content, a $\pm 50\%$ uncertainty on above and below ground ratios (IPCC 2019 Refinement, Table 11.1A) and a $\pm 10\%$ uncertainty on residue management data.

For *FSOM*, Uncertainty is estimated at $\pm 33\%$ due to a $\pm 13\%$ uncertainty on land area data, $\pm 30\%$ uncertainty on SOC data and $\pm 5\%$ uncertainty on the C:N ratio.

5.5.1.3.2 Emission factor uncertainty

Inorganic and organic N fertiliser, crop residues and F_{SOM}

Uncertainty on the default emission factor applied to these sub-categories is -100% and +200% (IPCC 2019 Refinement, Table 11.1).

Urine and dung deposited by grazing animals

Uncertainty on the default emission factor for cattle, poultry and pigs is -100% to +200% and for the sheep and other animals it is -100% to +230% (IPCC 2019 Refinement, Table 11.1).

5.5.1.4 **Time-series consistency**

The time-series for direct N_2O emissions is complete and consistent.



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5.5.1.5 *Category specific QA/QC and verification*

Synthetic N fertiliser consumption data was compared to the FAO data (FAOSTAT) and there was no difference in the data between 2000 and 2014, but after that data varied by up to 23%. It was noted in the FAO data that the last few years were indicated to be unofficial data so this could account for the discrepancy. Additionally, the general QA/QC measures in Table 5.8 were used for this category.

5.5.1.6 *Category-specific recalculations*

Recalculations were performed for the entire time-series and the updated data is lower than provided in the previous inventory. The difference seen is because of the updated emission factors in this category. The emission factors provided in the IPCC 2019 Refinement are half of what was used in the previous inventory. This is because the 2019 Refinement disaggregates the data into wet and dry climates and the dry climate data, (which is applied in this inventory) are much lower.

5.5.1.7 *Category-specific planned improvements*

No category-specific improvements are currently planned. However, data collection is required to support a Tier 2 approach for the soil management category, as it is a key category. This need was identified in the previous inventory, but no progress has been made.

5.5.2 Indirect nitrous oxide emissions from managed soils (CRT 3.D.2)

5.5.2.1 *Category description*

Indirect emissions of N₂O-N from managed soils can take place in two ways: i) volatilization of N as NH₃ and oxides of N, and the deposition of these gases onto water surfaces, and ii) through runoff and leaching from land where N was applied (IPCC, 2006). Indirect emissions due to atmospheric deposition/volatilisation occur from inorganic and organic N application and urine and dung N inputs, while indirect runoff/leaching emissions can also occur from crop residue application and N losses due to changes in land management practices and land use (see Figure 11.1 of the IPCC 2006 Guidelines).

Indirect N₂O emissions from managed soils contributed 1 514 Gg CO₂e in 2024, accounting for 16% of total emissions from agricultural soils.



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5.5.2.2 *Methodological issues*

Due to limited data a Tier 1 approach was used to calculate the indirect N₂O emissions in this category.

5.5.2.2.1 *Indirect N₂O from atmospheric deposition of volatilized N*

The annual amount of N₂O-N produced from atmospheric deposition of N volatilized from managed soils (N₂O_{(ATD)-N}) was calculated with IPCC 2006 Guidelines Equation 11.9.

5.5.2.2.2 *Indirect N₂O from leaching/runoff*

The annual amount of N₂O-N produced from leaching and runoff of N additions to managed soils (N₂O_{(L)-N}) is determined by IPCC 2006 Guidelines Equation 11.10. IPCC 2019 Refinement (Chapter 11, Vol. 4, Table 11.3) indicates that the term Frac_{LEACH-(H)} only applies to wet climates, while for dry climates Frac_{LEACH-(H)} is taken as zero. South Africa has a dry climate, therefore zero was applied to urine and dung deposits. The fraction of all N added to/mineralised in cultivated lands that is lost through leaching and runoff (Frac_{LEACH-(H)}) was determined by using a weighted average as leaching was assumed to occur on irrigated lands. WRI (2018) indicated that 10% of cultivated land is irrigated, therefore a Frac_{LEACH-(H)} value of 0.02 kg N (kg N additions)⁻¹ was applied to cultivated lands.

5.5.2.2.3 *Activity data*

The calculations of F_{SN}, F_{ON}, and F_{PRP} are described above.

5.5.2.2.4 *Emission factors*

Indirect N₂O from atmospheric deposition of volatilized N

The emission factor (EF₄), and the volatilization fractions (Frac_{GASF} and Frac_{GASM}) were all taken from the IPCC 2019 Refinement default table (Table 11.3, Chapter 11, Volume 4).

Indirect N₂O from leaching/runoff

The emission factor (EF₅) was taken from the IPCC 2019 Refinement (Table 11.3, Chapter 11, Volume 4).



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5.5.2.3 *Uncertainty*

5.5.2.3.1 *Activity data uncertainty*

Uncertainty on activity data for F_{SN} , F_{ON} , and F_{PRP} are provided in section 5.5.1.3. $Frac_{GASF}$ has an uncertainty of -82% and +200%, while $Frac_{GASM}$ has an uncertainty of -100% + 48% (IPCC 2019 Refinement, Table 11.3).

5.5.2.3.2 *Emission factor uncertainty*

The uncertainty on EF_4 is -100% and +120%, and for EF_5 it is -100% and +82% (IPCC 2019 Refinement, Table 11.3).

5.5.2.4 *Time-series consistency*

The time-series is consistent throughout the inventory time period.

5.5.2.5 *Category specific QA/QC and verification*

There were no category specific quality control checks. The general QA/QC measures in Table 5.8 were used for this category.

5.5.2.6 *Category-specific recalculations*

Recalculations across the entire time-series produced slightly lower emissions. The reduction in emissions is due mostly to the updated emission factors from the IPCC 2019 Refinement, but also due to the Inclusion of Organic soils for cropland and Grassland.

5.5.2.7 *Category-specific planned improvements*

There are no planned improvements for this category.

5.6 Prescribed burning of savannahs (CRT 3.E)

In this inventory, the prescribed burning of savannahs is included within the land sector. This technique is commonly employed for land management, enhancing ecological health and biodiversity.



5.7 Field burning of agricultural residues (CRT 3.F)

5.7.1 Category description

Agricultural burning is the intentional use of fire for residue management in agricultural fields. Agricultural burning helps farmers remove crop residues left in the field after harvesting grains. This section reports emissions of non-CO₂ gases (CH₄, CO, N₂O and NO_x) from cropland while other Land use categories are discussed in the LULUCF section.

In this inventory this category includes biomass burning of sugarcane residues only since the burning of other crop residues is not significant in South Africa. Sugarcane is the only crop which utilises pre-harvest burning to expose the cane stalks removing the outer leaves, driving away insects, snakes and other wild animals making easy not only manual, but also mechanical harvesting additionally, after harvesting, sugarcane residues are burned releasing to the atmosphere GHGs. In addition to CO₂, the burning of biomass results in the release of other GHGs or precursors of GHGs that originate from incomplete combustion of the fuel. The key GHGs are CO₂, CH₄, and N₂O; however, NO_x, NH₃, NMVOC and CO are also produced, and these are precursors for the formation of GHG in the atmosphere (IPCC, 2006).

The CO₂ emissions from burning are not included in this category as they are accounted under the disturbance losses in the Land (3B) category. All non-CO₂ emissions, on the other hand, are included in this category.

Field burning of sugarcane residues before harvesting, a common agricultural practice, contributed 54.5 Gg CO₂e in 2024, which is 0.10% of the agriculture sector emissions. Emissions decreased by 21.08% in the period 2000–2024. This pre-harvesting burning is primarily employed to clear the fields of dry leaves and debris, making it easier to harvest the cane itself. However, while it offers immediate benefits in terms of labour efficiency and reduced harvesting challenges, the environmental consequences can be significant. South Africa has 14 cane-producing areas, extending from Northern Pondoland in the Eastern Cape Province through the coastal belt and KwaZulu-Natal midlands to the Mpumalanga Lowveld.

5.7.2 Methodological issues

The Tier 1 methodology was applied, with the emissions from biomass burning being calculated using the following equation (Equation 2.27 from IPCC 2006 Guidelines):

$$L_{fire} = A * M_B * C_f * G_{ef} * 10^{-3}$$



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Where:

L_{fire} = mass of GHG emissions from the fire (t GHG)

A = area burnt (ha)

M_B = mass of fuel available for combustion (t dm ha⁻¹)

C_f = combustion factor (dimensionless)

G_{ef} = emission factor (g kg⁻¹ dm burnt)

This equation calculates the mass of emissions (L_{fire}) produced by a fire based on several key factors. The area burned (A) in hectares is multiplied by the mass of fuel available for combustion (M_B), expressed in tons per dry matter per hectare. Additionally, the combustion factor (C_f), which is dimensionless, accounts for the efficiency of combustion, while the emission factor (G_{ef}), measured in grams per kilogram of dry matter burned, quantifies the specific emissions produced during the burning process. By combining these variables, the equation provides a comprehensive estimate of the GHG emissions resulting from the burning of biomass.

5.7.2.1 Activity data

5.7.2.1.1 Burnt area data

The report utilized crop data on sugarcane planted areas from the Abstracts of Agricultural Statistics (DALRRD, 2022), which is a reliable and sustainable data source published annually.

The research conducted by Shikwambana et al. (2021) indicates that the sugarcane industry in South Africa burns 90% of its crop at harvest while 10% is harvested green; therefore, this assumption was applied for this inventory. A 90% assumption was applied to estimate the burned area for sugarcane.

5.7.2.1.2 Mass of fuel available for combustion (M_B) and the combustion factor (C_f)

The country specific parameters such as Fuel density of 7 t/ha was used for cropland and it was sourced from DAFF (2010), and the combustion factor of 1 was used and sourced from DAFF (2010). The IPCC value of fuel combustion (t/ha) of 4-10 was used for cropland (IPCC, 2006).

5.7.2.2 Emission factors

IPCC 2006 Guidelines default emission factors (IPCC, 2006, vol 4, chapter 2, Table 2.5, page 2.47) are applied.



5.7.3 Uncertainty

5.7.3.1 Activity data uncertainty

Based on uncertainties in IPCC 2006 Guidelines (IPCC, 2006; Table 2.4) and van Leeuwen et al. (2014) fuel consumption uncertainty was determined to be 20% for croplands.

5.7.3.2 Emission factor uncertainty

IPCC 2006 Guidelines default uncertainties for emission factors are provided in the guidelines (IPCC, 2006; Table 2.5).

5.7.4 Time-series consistency

Time series is consistent.

5.7.5 Category specific QA/QC and verification

Burnt area data that was estimated from the crop data on sugarcane planted areas from the Abstracts of Agricultural Statistics was compared to those from MODIS collection 6 data. Additionally, the general QA/QC measures in Table 5.8 were used for this category.

5.7.6 Category-specific recalculations

No recalculations are performed for this category.

5.7.7 Category-specific planned improvements

There are no specific planned improvements for this category.

5.8 Liming (CRT 3.G)

5.8.1 Category description

Liming is used to reduce soil acidity and improve plant growth in managed systems. Adding carbonates to soils in the form of lime (limestone or dolomite) leads to CO₂ emissions as the carbonate limes dissolve and release bicarbonate. Lime is commonly applied to agricultural lands where nitrogenous fertilisers are continuously used and where precipitation exceeds evapotranspiration.



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Liming emissions increased by 3.9% in the period 2000–2024. Liming contributed 1 891 Gg CO₂e in 2024, which is 3.6% of the agriculture sector emissions.

5.8.2 Methodological issues

A Tier 1 approach of the IPCC 2006 Guidelines was used to calculate annual CO₂ emissions from lime application (Equation 11.12, IPCC 2006). Tier 2 approach is not available for this category.

5.8.2.1 Activity data

The crop area data was sourced from the Abstracts of Agricultural Statistics (DALRRD, 2022), which is a reliable and sustainable data source published annually. Emissions from lime application was estimated per crop type using crop area data and application rates. The calculation was derived from crop areas and application rates, employing estimates from Tongwane et al. (2016). However, this resulted in a figure exceeding 3 million tons of lime in 2008, contrasting with the 1.5 million tons reported by the Fertiliser Association of South Africa.

5.8.2.2 Emission factors

The IPCC 2006 Guidelines default emission factors of 0.12 t C (t limestone)-1 and 0.13 t C (t dolomite)-1 were used to calculate the CO₂ emissions from *Liming*.

5.8.3 Uncertainty

5.8.3.1 Activity data uncertainty

Uncertainty is determined from the difference between the SAMI (DMR, 2018) report data and the Fertilizer Association data. For limestone it is -90% to 25% and for dolomite it was determined to be -75% to 15%.

5.8.3.2 Emission factor uncertainty

The dolomite and limestone default emission factors have an uncertainty of -50% (IPCC 2006 Guidelines, p. 11.27).

5.8.4 Time-series consistency

The time-series is consistent and complete.



5.8.5 Category specific QA/QC and verification

Previous inventories reviews highlighted the need to enhance this information and explore alternative methods for calculating potential lime use. In 2020 inventory, this was attempted by using crop area estimates along with application rates from Tongwane et al. (2016), which resulted in a figure exceeding 3 million tons of lime in 2008, in contrast to the 1.5 million tons reported by the Fertiliser Association of SA. This highlighted a discrepancy between the two data sources. As a result, this data was excluded from the 2020 inventory, but it has now been included in this report. Additionally, there is a need to seek alternative data sources for future analyses. Additionally, the general QA/QC measures in Table 5.8 were used for this category.

5.8.6 Category-specific recalculations

No recalculations are performed for this category.

5.8.7 Category-specific planned improvements

There is a need for alternate data sources for lime data.

5.9 Urea application (CRT 3.H)

5.9.1 Category description

Adding urea to soils during fertilization leads to a loss of CO₂ that was fixed in the industrial production process.

Urea application emissions increased by 126% in the period 2000–2024. Urea application contributed 671 Gg CO₂e in 2024, which is 1.3% of the agriculture sector emissions.

Urea application emissions increased from 297.3 Gg CO₂e in 2000 to 670.8 Gg CO₂e in 2024, representing more than a twofold rise. The increase in urea application emissions from 2000 to 2024 does not represent a real rise in fertilizer use or associated emissions. Instead, it results from a change in the data source used for the inventory, which has produced higher reported values. The increase is interpreted as an improvement in data quality rather than a true emissions surge.



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5.9.2 Methodological issues

A Tier 1 approach of the IPCC 2006 Guidelines is used to calculate CO₂ emissions from urea fertilization (Equation 11.13, IPCC 2006).

5.9.2.1 Activity data

Import and export data for urea was obtained from South African Revenue Service (SARS) (downloaded from <http://www.sagis.org.za/sars.html> on 13/07/2022).

5.9.2.2 Emission factors

The IPCC 2006 Guidelines default emission factor of 0.2 t C (t urea)⁻¹ is applied in the equation to calculate the CO₂ emissions.

5.9.3 Uncertainty

5.9.3.1 Activity data uncertainty

In terms of urea application, it is assumed that all urea imported is applied to agricultural soils and this approach may lead to an over- or under-estimate if the total imported urea is not applied in that particular year. However, over the long-term this bias should be negligible (IPCC, 2006). Urea data is based on import data, which is well controlled, so a nominal 5% uncertainty was assumed. There is also some uncertainty with regards to the use and distribution of this urea. Again, there are no uncertainty estimates provided for this so an additional 5% was assumed.

5.9.3.2 Emission factor uncertainty

As for the liming emission factors, the urea emission factor also has an uncertainty of - 50% (IPCC 2006 Guidelines, p. 11.32).

5.9.4 Time-series consistency

The time-series is consistent.

5.9.5 Category specific QA/QC and verification

Urea data is checked against the FAOStat dataset and found to be very similar. Additionally, the general QA/QC measures in Table 5.8 were used for this category.



5.9.6 Category-specific recalculations

No recalculations are performed for this category.

5.9.7 Category-specific planned improvements

No improvements are planned for this category in the next year.

5.10 Other carbon-containing fertilizers (CRT 3.I)

Other carbon-containing fertilizers are not included in the inventory, as there has been no progress since the previous inventory in terms of data availability or research regarding their presence and use in South Africa. Relevant activity data and parameters required to define and quantify this category remain unavailable. In the absence of sufficient evidence on application rates, associated carbon emissions, and overall environmental impacts, it is not possible to reliably estimate their contribution to GHG emissions. Consequently, the inventory continues to focus on well-documented fertilizer categories to ensure methodological robustness and transparency. Further research and data development would be required before these fertilizers can be considered for inclusion in future inventories.

5.11 Other (CRT 3.J)

The "Other" category is excluded from the inventory because it is not applicable.



5.12 Chapter 5 References

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Chapter 6: Land use, Land Use Change and Forestry (LULUCF) (CRT sector 4)

6.1 Sector overview

In the LULUCF sector South Africa reports on the emissions (positive) and removals (negative) of CO₂, CH₄ and N₂O from the entire land area (122 008 kha) of South Africa as all lands are considered managed. The national territory of South Africa includes two subantarctic islands, namely Marion Island (46° 54' S, 37° 45' E; 29 300 ha) and Prince Edward Island (46° 38' S, 37° 57' E; 4 500 ha) and together they are known as The Prince Edward Islands (Nel, et al., 2020; Smith & Mucina, 2006). These overseas territories are included in the total land area.

The following land categories are included in this inventory:

- *Forest land* (4.A.)
- *Cropland* (4.B.)
- *Grassland* (4.C.)
- *Wetlands* (4.D.)
- *Settlements* (4.E.)
- *Other land* (4.F.)

In all these land categories a distinction is made between areas which, during the reporting period:

- undergo no land-use changes, and thus remain, in unchanged form, in the land-use category they are in ("land remaining" categories 4.A.1. – 4.F.1.)
- undergo land-use changes:
 - From the time of conversion onward, these areas are reported in the category to which they were converted. Within those land-use categories, the converted areas are then reported in conversion categories ("land conversion" categories 4.A.2. – 4.F.2.) for a total of 20 years. After 20 years in a conversion category, the areas are reported under the relevant remaining categories.



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The following pools are included under each of the land categories:

- Above-ground biomass:
 - Includes all living biomass above the soil including stem, stump, branches, bark, seeds, and foliage.
 - Included for all land categories.
- Below-ground biomass:
 - Includes all biomass of live roots.
 - Included for all land categories.
- Litter:
 - Included all non-living biomass, lying dead, in various states of decomposition above the mineral or organic soil.
 - Included for all land categories.
- Dead wood:
 - Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil.
 - Only separated out from litter in the *Forest land* category.
- Mineral soils:
 - Includes organic carbon in mineral soils to a depth of 30cm.
 - Included for all land categories.
- Organic soils:
 - Drainage and rewetting (see below).
- Harvested wood products (4.G.).

Within each land categories the following non-CO₂ emissions are also included:

- Direct and indirect N₂O emissions from nitrogen inputs into managed lands (4(I)):
 - There is insufficient data to include all these emissions under each land category, but a start is made by including N input to forest plantations (*Forest land*) and golf courses (*Settlements*).
 - N inputs to Croplands are included under Agriculture (3.D. Agricultural soils) and not in the LULUCF sector.
- Emissions and removals from drainage, rewetting and other management of soils (4(II)):
 - N₂O emissions from drained organic soils only included for *Grasslands remaining grasslands*. Estimates for *Croplands remaining croplands* are reported under Agriculture (CRT 3.D.1).



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- CH₄ emissions from rewetting of mineral and organic soils are included for *Wetlands*.
- Direct and indirect N₂O emissions from N mineralisation/mobilisation associated with loss/gain soil organic matter resulting from change of land use or management (4(III)):
 - These emissions are included in all land categories except Cropland remaining croplands which are included under Agriculture (CRT 3.D.1).
- Biomass burning (4(IV)):
 - Included for all land categories except *Other land* as it is assumed there is no burning on *Other lands* due to the lack of vegetation.
 - Emission estimates of the precursor gases CO, NO_x and NMVOC are reported here, but the indirect emissions of CO₂ and N₂O associated with these are reported in Chapter 8 of this NID and Table 6 of the CRT. These emissions are not included in the LULUCF sector total.

6.1.1 Shares and trends in emissions 1990-2024

The LULUCF sector is a sink in 2024 (Table 6.1) with *Forest lands* being the largest contributor to the sink. All other land categories, except for a small sequestration from *Settlements*, are a source of emissions in 2024, with *Other lands* being the largest.

Table 6.1: Summary of emissions from the LULUCF sector in 2024

GHG source and sink categories	CO ₂	CH ₄		N ₂ O		Total
	Gg CO ₂	Gg	Gg CO ₂ e	Gg	Gg CO ₂ e	Gg CO ₂ e
4. LULUCF	-37 584	105	2 941	5	1 231	-33 412
4.A. Forest land	-55 744	14	399	1	309	-55 037
4.B. Cropland	8 084	3	71	1	156	8 311
4.C. Grassland	3 048	19	519	1	351	3 918
4.D. Wetlands	107	69	1 932	0	67	2 105
4.E. Settlements	-1 453	1	21	0	106	-1 326
4.F. Other land	10 093	0	0	1	241	10 334
4.G. Harvested wood products	-1 718	NA	NA	NA	NA	-1 718

Figure 6.1 provides an overview of the LULUCF emission trends for South Africa over the time-series 1990-2024. The time-series reflects the trends in land-use changes (Figure 6.2). The land-use changes have been determined based on South African National Land Cover (SANLC) data sets for the reference years 1990, 2014, 2018, 2020 and 2022.



Between the reference years, the land-use changes have been linearly interpolated, hence the larger changes after each reference year and the stable emissions and removals between reference periods. A map is being developed for 2024 but it was not finalised before the preparation of this inventory and so the data could not be included. Data for the period 2022-2024 was extrapolated as per the methodology described in section 6.3.6.

Forest lands are the largest contributor to the sink across the time-series. The dominant *Forest land* sinks are thickets and woodlands. Between 1990 and 2000 the *Forest land* sink is smaller than the later years and this is attributed to the burnt area data that was extrapolated over this period. The data is very uncertain and appears to be much higher than for the years from 2001 onwards (see further details in section 6.4.7). The increased annual variability, particularly in *Forest lands*, from 2001 onwards is due to changes in burnt area and the associated losses, as well as fuelwood and harvest losses. The increasing *Forest land* sink between 2018 and 2024 is attributed to an increasing conversion of *Grasslands* to *Forest land* (Figure 6.2).

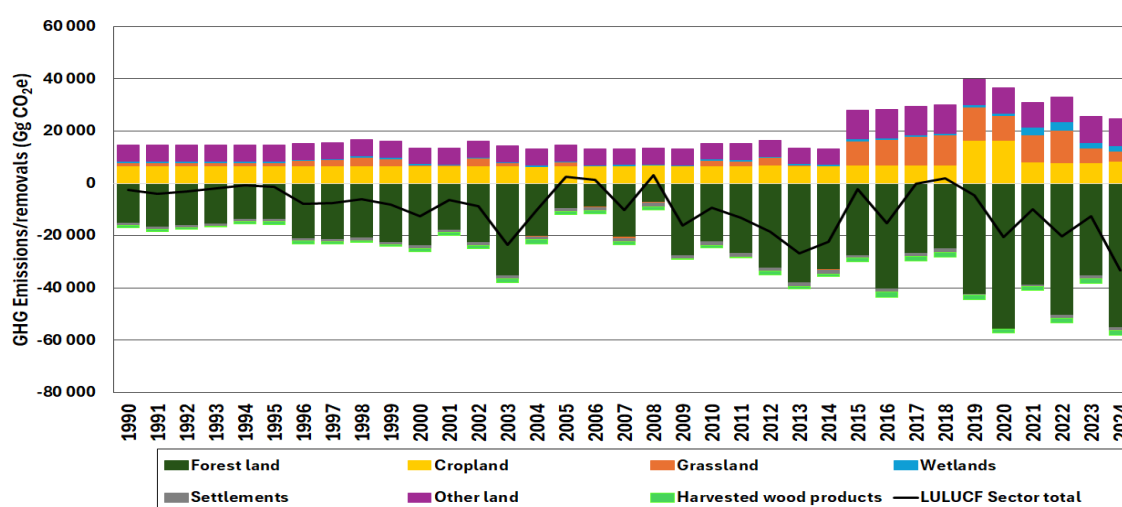


Figure 6.1: Time series for GHG emissions and removals by land type in the LULUCF sector, 1990-2024

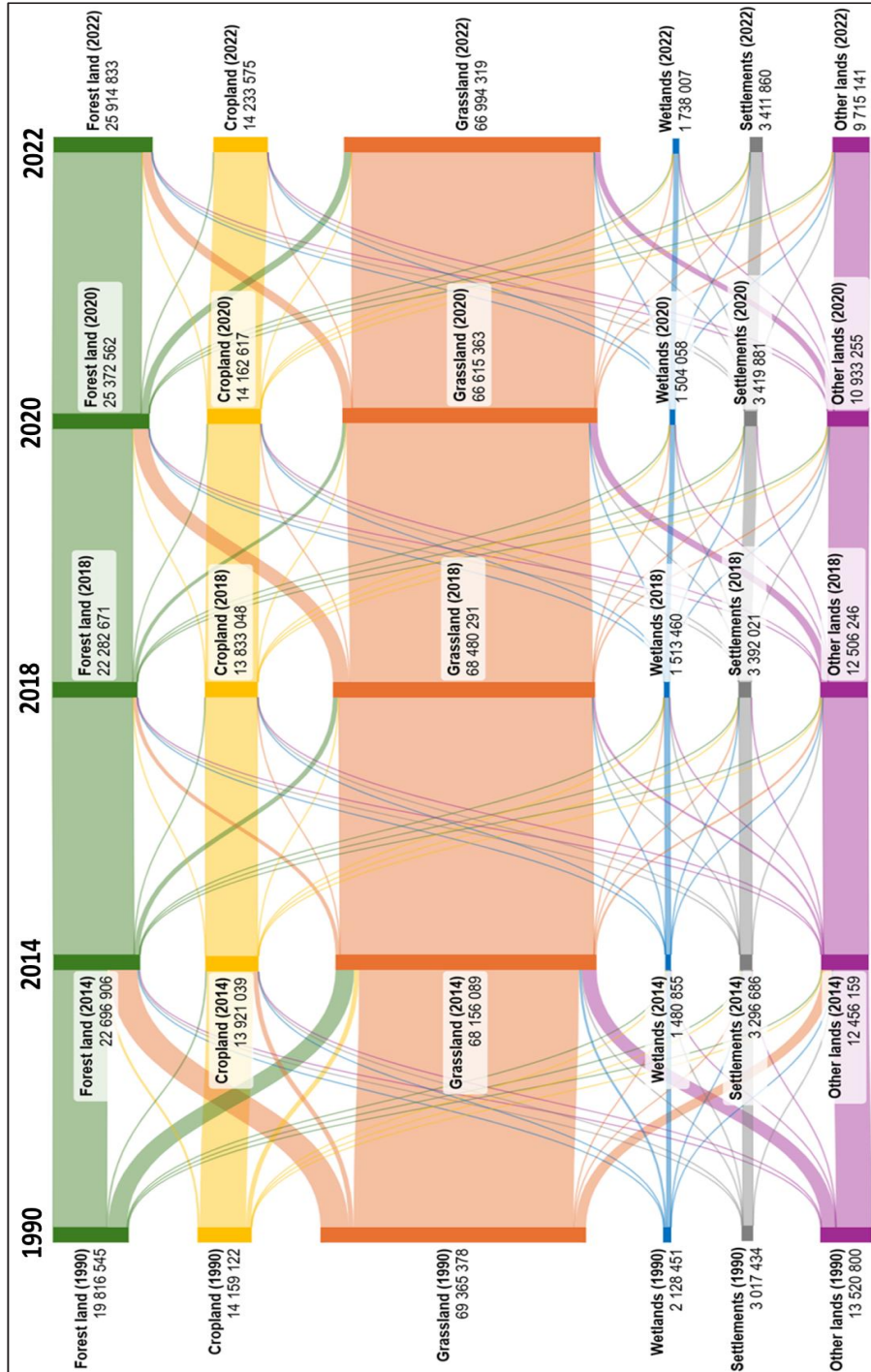


Figure 6.2: Land conversions between 1990 and 2022



In terms of emission sources, *Other lands* contribute the most and the emissions increase between 2014 and 2024. Between 2014 and 2018 there is an increase in conversion of *Forest land* to *Other land*, while from 2018 onwards there is an increase in conversion of *Grasslands* to *Other lands*. Much of these conversions are, however, thought to be related to seasonal variation rather than actual change. *Croplands* are a consistent source across the time-series except for an increase in emissions between 2019 and 2020. This increase is related to an increase in conversion from *Forest land* to *Croplands*. There is also a slight increase between 2018 and 2024 due to a slow increase in subsistence crop area. *Grasslands* are an emission source and shows increased emissions from 2014 onwards. This is mainly due to the conversion of *Forest lands* to *Grasslands* (Figure 6.2). The *Wetland* source is small but increases from 1990 to 2024 as there is an increase in conversion of all other land types to *Wetlands*.

Converted lands are the largest contributors to all land categories except *Settlements* (Table 6.2). Overall, the LULUCF sector increased its sink by 30 954 Gg CO₂e between 1990 and 2024. Of this change, 67.1% occurred between 2000 and 2024. The sink increased by 13 107 Gg CO₂e since 2022. Between 1990 and 2024 the greatest percentage increases were seen in the *Forest land*, while for the periods 2000 to 2024, and 2022 to 2024 the *Grassland* and *Wetland* categories showed the largest changes.

Biomass is the dominant carbon pool (Figure 6.3). Overall the SOC is a small source throughout the time-series. The DOM pool is slightly larger than the SOC pool and seems to vary between a source and a sink depending on the land changes.

CO₂ is the dominant gas in the LULUCF sector and is responsible for the sink (Figure 6.4). CH₄ and N₂O are emission sources and are produced through activities such as biomass burning, nitrogen additions to soil, loss of soil organic carbon due to land use change, and drainage and rewetting of soils.

Table 6.2: Summary of the change in emissions from the LULUCF sector over the time-series 1990-2024 and since the last inventory in 2022.

GHG source and sink categories	Emissions (Gg CO ₂ e)				Difference (Gg CO ₂ e)				Change (%)			
	1990	2000	2022	2024	1990-2024	2000-2024	2022-2024	1990-2024	2000-2024	2022-2024	1990-2024	2022-2024
4. LULUCF	-2 458	-12 643	-20 305	-33 412	-30 954	-20 769	-13 107	1 259.2	164.3	64.6		
4.A. Forest land	-15 260	-23 838	-50 456	-55 037	-39 776	-31 199	-4 580	260.7	130.9	9.1		
4.A.1. Forest land remaining forest land	20 235	11 788	4 444	8 486	-11 749	-3 302	4 043	-58.1	-28.0	91.0		
4.A.2. Land converted to forest land	-35 495	-35 626	-54 900	-63 523	-28 027	-27 896	-8 623	79.0	78.3	15.7		
4.B. Cropland	6 531	6 570	7 939	8 311	1 780	1 741	372	27.3	26.5	4.7		
4.B.1. Cropland remaining cropland	747	710	29	336	-410	-373	307	-55.0	-52.6	1 049.1		
4.B.2. Land converted to cropland	5 784	5 860	7 910	7 975	2 190	2 115	64	37.9	36.1	0.8		
4.C. Grassland	1 404	430	10 369	3 918	2 514	3 488	-6 451	179.0	810.6	-62.2		
4.C.1. Grassland remaining grassland	-5 963	-6 816	-41 542	-14 683	-8 720	-7 867	26 859	146.2	115.4	-64.7		
4.C.2. Land converted to grassland	7 368	7 246	51 911	18 601	11 233	11 354	-33 311	152.5	156.7	-64.2		
4.D. Wetlands	503	426	3 188	2 105	1 602	1 679	-1 083	318.4	394.5	-34.0		
4.D.1. Wetlands remaining wetlands	217	165	474	309	92	144	-165	42.6	87.7	-34.8		
4.D.2. Land converted to wetlands	286	261	2 714	1 796	1 510	1 535	-918	527.4	588.2	-33.8		
4.E. Settlements	-760	-1 040	-1 285	-1 326	-566	-286	-41	74.5	27.5	3.2		
4.E.1. Settlements remaining settlements	-1 287	-1 513	-3 050	-2 981	-1 695	-1 469	68	131.7	97.1	-2.2		
4.E.2. Land converted to settlements	527	473	1 765	1 656	1 128	1 183	-110	214.0	250.3	-6.2		
4.F. Other land	6 159	6 159	9 516	10 334	4 176	4 176	818	67.8	67.8	8.6		
4.F.1. Other land remaining other land	0	0	0	0	0	0	0	0.0	0.0	0.0		
4.F.2. Land converted to other land	6 159	6 159	9 516	10 334	4 176	4 176	818	67.8	67.8	8.6		
4.G. Harvested wood products	-1 036	-1 350	-1 675	-1 718	-683	-369	-43	65.9	27.3	2.6		

Note: Columns may not add up exactly due to rounding off



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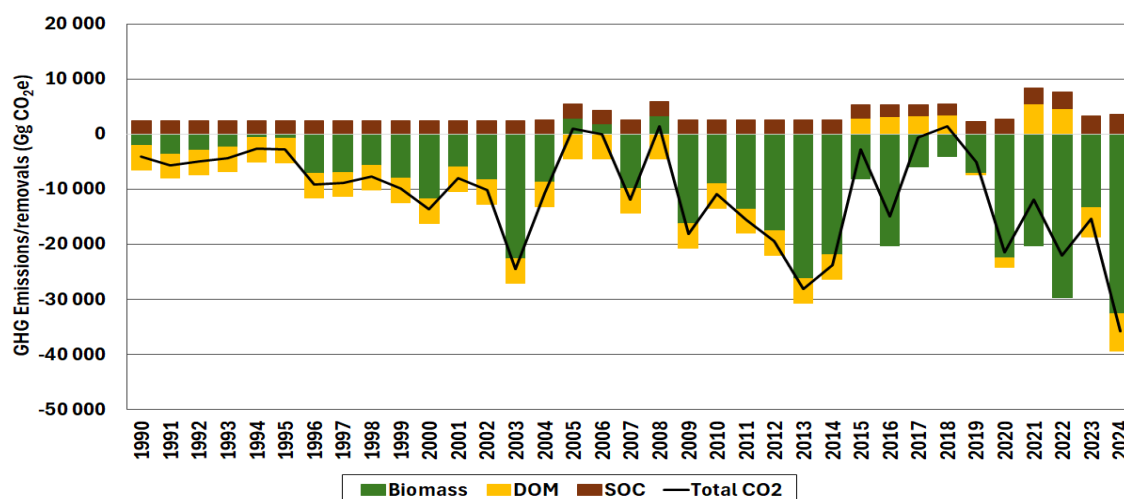


Figure 6.3: Time-series of GHG emission and removals by carbon pool for the LULUCF sector, 1990-2024

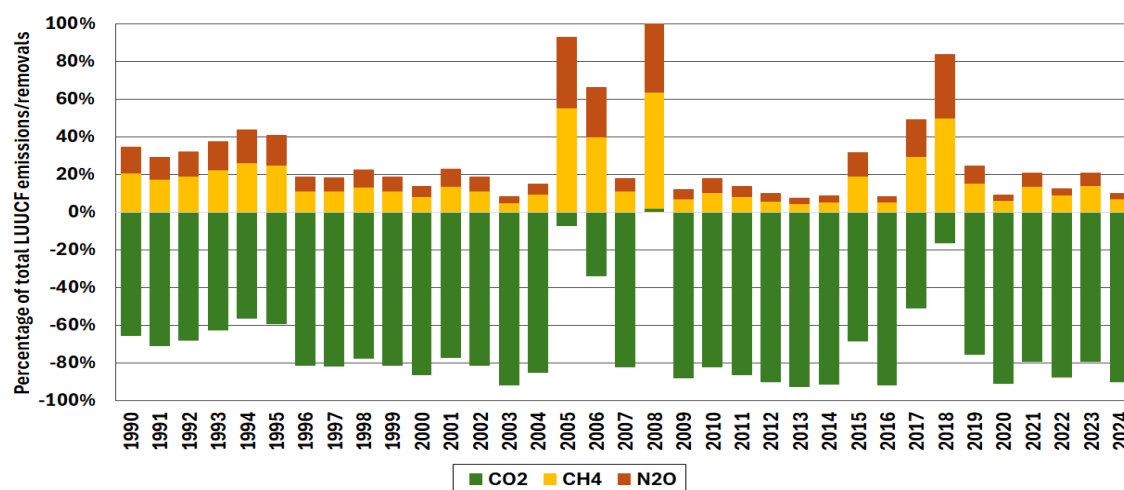


Figure 6.4: Time-series of percentage contribution of gases to the total LULUCF sector emissions/removals, 1990-2024



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6.1.2 Methodological issues

The emissions and removals in the LULUCF sector were estimated by following the guidance provided in the IPCC 2006 Guidelines (IPCC, 2006), parts of the IPCC 2019 Refinement (IPCC, 2019) and parts of the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014a) (hereinafter referred to as IPCC 2013 Wetland Supplement).

6.1.2.1 Overview of methodological approach (CRT 4.A to 4.F) and completeness

The following basic elements and processes were required to prepare the LULUCF inventory:

1. Land cover/use maps: SANLC maps, containing 73 land classes, were obtained for 1990, 2014, 2018, 2020 and 2022 (section 6.3.1 and Annex V.1). The relevant land uses, and the specific areas assigned to them, were explicitly determined for these years, while the areas applying to the periods between those years were obtained by linearly interpolating the calculated areas. It is assumed that the annual change between 1970 and 1990 was the same as for 1990-2014.
2. Land change matrix: The 73 classes from the SANLC maps were aggregated into 20 classes for land change determination. The classes were indigenous forests, thicket/dense bush, woodlands/open bush, forest plantations, vineyards, orchards, annual pivot crops, annual non-pivot crops, subsistence crops, grasslands, low shrublands, eroded land, wetlands, waterbodies, residential areas, commercial areas, industrial areas, small-holdings, mines, and bare ground. The annual land change areas were determined from the change matrix for 1990-2014, 2014-2018, 2018-2020 and 2020-2022 for the above-mentioned land categories (section 6.3.3) to assist in the calculation of "land remaining" and "land converted" categories.
3. Soil type stratification: A detailed soil map for South Africa is aggregated into the IPCC 2006 Guidelines soil types. The 20 class land conversion maps are clipped by soil type using this soil map and a land change matrix for each conversion period for each soil type is developed (section 6.3.4.1).
4. Burnt area: Monthly MODIS burnt area data is summed to obtain an annual burnt area data set. The SANLC data (aggregated to 20 classes) for 1990, 2014, 2018, 2020 and 2022 are intersected with the annual burnt area data for these years to obtain burnt area per land class for these base years. For the in-between years the annual burnt area data for 2001-2014 is intersected with the 2014 land cover



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map, 2015-2016 with 2014 land cover, 2017-2019 were intersected with 2018 land cover, 2020-2021 with 2020 land cover and 2022-2024 with 2022 land cover. Since MODIS data is only available from 2001 the annual burnt area for the years 1990-2000 is extrapolated using FAO data, Forestry SA data and averaging assumptions.

5. Adjustments applied to land change matrixes: Corrections for the coastal buffer, Landsat and Sentinel data impacts between 2014-2018, unlikely changes, Forestry South Africa plantation data, and wet and dry seasonal variation are implemented (see detail in section 6.3.3.2.1).
6. Addition of overseas territories: The overseas territories are not included in the SANLC maps so these were added to the land conversion matrixes as discussed in section 6.1.2.2 below.
7. 20-year default transition period: The land-use-matrix calculation is referenced to the year 1970, to make it possible to determine land-use-change areas for years prior to the actual reporting period. Identified conversion areas were assigned to the relevant land-use-change category, in the year in which the land-use change took place, and they remained in that category for a maximum of 20 years. At the end of the 20-year period, the areas were assigned to the remaining category within the final use category. The "land remaining" was calculated from the land area converted to that land category and the area converted to another land category. The "land converted" was calculated from the annual converted area accumulated over the period in which it remains in the "land converted" up to the default 20-year conversion period. Since land parcels were not tracked the annual converted area was always removed from the "land remaining" category as indicated in the IPCC 2006 Guidelines.
8. Annual increase in carbon stocks due to biomass growth: Estimated the annual increase in biomass carbon stocks for each land class with perennial vegetation by applying the IPCC 2006 Guidelines equations 2.9-2.10. Parameters obtained from scientific literature and weighted averages (based on area) applied. Forestry SA data provides additional data for forest plantations.
9. Annual decrease in biomass carbon stocks due to losses: Losses due to harvest, fuelwood collection, and disturbances are estimated using IPCC 2006 Guidelines equations 2.11 to 2.14. The disturbance losses are only for fires except for forest plantations where other disturbance losses (such as insects, wind) were also included. Activity data is obtained from Forestry SA, StasSA, and MODIS burnt area.
10. Biomass change due to land conversions: Estimated annual change in biomass carbon stocks due to land changes by applying the IPCC 2006 Guidelines equation 2.15 and 2.16 (Tier 2).



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11. Annual change in carbon stocks in biomass in land remaining categories: Outputs from points 7-10 above were incorporated into the IPCC Gain-loss equation (IPCC 2006 Guideline equation 2.7) to determine the annual change in biomass carbon stocks.
12. Annual change in carbon stocks in deadwood and litter (DOM): For “land remaining” the DOM was assumed not to change (Tier 1 assumption) so a value of zero is applied. The “converted land” categories the annual change in stocks in DOM were estimated using IPCC 2006 Guideline equation 2.23. Parameters obtained from scientific literature and weighted averages (based on area) applied.
13. Soil organic carbon reference values: Soils were classified into the 6 soil classes identified in the IPCC 2006 Guidelines and this was intersected with the land cover data to extract the “land remaining” areas of the natural (land cover) classes. The “land remaining” area under each soil class was then intersected with the ISRIC soils dataset to obtain SOC values for these areas. An average SOC reference value was determined from this for each soil type (section 6.4.3.1).
14. Soil carbon stock change factors: The IPCC 2006 Guidelines stock change factors were applied for *Forest land, Grassland, Wetlands and Settlements*, while detailed data on cropland management provided estimates of the stock change factors for *Croplands*.
15. Annual change in carbon stocks in mineral soils: This was estimated by applying the IPCC 2006 Guideline equation 2.25 (Approach B).
16. CO₂ emissions from drained organic soils: Organic soil area was determined from ISRIC data (section 6.4.3.2). The area of drained organic soils for *Grasslands remaining grasslands* and *Croplands remaining Croplands* were obtained from FAOSTAT. These datasets were used, together with IPCC default factors, in IPCC 2019 Refinement equation 2.2 to estimate CO₂ emissions from drained organic soils. These emissions were reported in CRT 4.B to 4.C.
17. Calculation of CO₂ emissions on the basis of the carbon-stocks values for the NID, via multiplication of carbon-stock changes by the factor -44/12.
18. N₂O emissions from nitrogen input: Nitrogen input to the various land categories was sourced and direct emissions estimated by applying IPCC 2006 Guideline equations 11.1-11.6, while indirect emissions are estimated using equations 11.9-11.11. N input data is very limited and only data for forest plantations and golf courses were included in this inventory. N inputs to agriculture are accounted for under Agriculture (CRT 3.D.1).
19. N₂O emissions and removals from drainage of organic soils (section 6.4.5). Organic soil area was determined from ISRIC data (section 6.4.3.2). The area of drained organic soils for *Grasslands remaining grasslands* and *Croplands remaining croplands* are obtained from FAOSTAT. These datasets were combined into IPCC



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2013 Wetland Supplement (IPCC, 2014a) equation 2.4 to estimate CH₄ emissions and IPCC 2006 Guidelines equation 11.1 to estimate N₂O emissions. The N₂O emissions from *Croplands remaining croplands* were included in Agriculture (CRT 3.D.1) and excluded from the LULUCF sector.

20. CH₄ emissions from rewetting of wetland mineral and organic soils (section 6.4.5): These were estimated for *Wetlands* as all areas, according to the land change matrixes, that were converted from any land type to a wetland were considered rewetted. Mineral and organic soils were included. Rewetted area was combined with IPCC default emission factors into equation 5.1 of the IPCC 2013 Wetland Supplement.
21. Direct and indirect N₂O emissions from N mineralisation/immobilisation associated with soil organic matter and management changes (section 6.4.6): Loss of soil carbon is already determined through the methods mentioned above, so this data is incorporated into IPCC 2006 Guidelines equations 11.1/2 and 11.8 along with IPCC default emission factors to estimate direct N₂O emissions. Indirect N₂O emissions are estimated with IPCC 2006 Guidelines equations 11.9-11.11.
22. Non-CO₂ emissions from biomass burning (section 6.4.7): CH₄ and N₂O emissions from each land class was determined from burnt area data (MODIS Collection 6), fuel loads, combustion factors and emission factors using IPCC 2006 Guidelines equation 2.27. Data was sourced from scientific literature and IPCC 2006 Guidelines and IPCC 2019 Refinement.
23. Indirect emissions: Emissions of CO, NO_x and NMVOC are estimated from biomass burning as indicated in point 22 above. These emissions are converted to indirect emissions of CO₂ and N₂O but these emissions are not reported under the LULUCF sector but rather Chapter 8 of this report and are report in Table 6 in the CRT.
24. Calculation of N₂O emissions from nitrogen values, via multiplication of the nitrogen-stock changes by the factor -44/28; the N₂O values are converted into CO₂ equivalents using the factor 265 (GWP 100 pursuant to IPCC AR5 (IPCC, 2014b)).
25. The CH₄ emissions are converted into CO₂ equivalents using the factor 28 (GWP 100 pursuant to IPCC AR5).
26. The data from the 20 classes were aggregated into the 6 IPCC 2006 Guidelines categories (section 6.2) for reporting purposes.

A summary of the tier level of the methods and types of emission factors incorporated into the inventory, along with completeness, are provided in Table 6.3.

Table 6.3: Summary of methods, emission factors and completeness for the LULUCF sector

GHG source and sink categories	Sub-category	CO ₂		CH ₄		N ₂ O		NO _x		CO		NMVOC	
		Method	EF	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF
4.A. Forest land													
Forest land remaining forest land	4.A.1. Biomass	T2	CS										
	4.A.1. DOM	T1	CS										
	4.A.1. SOC	T2	CS										
	4(I).A.1.					T1	D						
	4(II).A.1.	NE	NA	NE	NA	NE	NA						
	4(III).A.1.					T1	D						
	4(IV).A.1.			T1/T2	D	T1/T2	D	T1/T2	D	T1/T2	D	T1/T2	CS
Land converted to forest land	4.A.2. Biomass	T2	CS										
	4.A.2. DOM	T2	CS										
	4.A.2. SOC	T2	CS										
	4(I).A.2.					T1	D						
	4(II).A.2.	NE	NA	NE	NA	NE	NA						
	4(III).A.2.					T1	D						
	4(IV).A.2.			T1/T2	D	T1/T2	D	T1/T2	D	T1/T2	D	T1/T2	CS
4.B. Cropland													
Cropland remaining cropland	4.B.1. Biomass	T1/T2	CS										
	4.B.1. DOM	T1/T2	CS										
	4.B.1. SOC	T2	CS										

	4(IV).C.2.			T1/T2	D	T1/T2	D	T1/T2	D	T1/T2	D	T1/T2	CS
4.D. Wetlands	4.D.1.b. Biomass	T2	CS										
	4.D.1.b. DOM	NA	NA										
	4.D.1.b. SOC	NA	NA										
	4(II).D.1.b.					NO	NA						
	4(II).D.1.b.	NA	NA	T1	D	NA	NA						
	4(III).D.1.b.					NA	NA						
	4(IV).D.1.b.			NA	NA	NA	NA				NA	NA	NA
Other wetlands remaining other wetlands	4.D.1.c. Biomass	T1/T2	D/C S										
	4.D.1.c. DOM	T1	CS										
	4.D.1.c. SOC	T2	CS										
	4(II).D.1.c.					NO	NA						
	4(II).D.1.c.	T1	D	T1	D	NA	NA						
	4(III).D.1.c.					T1	D						
	4(IV).D.1.c.			T1/T2	D	T1/T2	D					T1/T2	CS
Land converted to flooded land	4.D.2.b. Biomass	T1/T2	CS										
	4.D.2.b. DOM	NA	NA										
	4.D.2.b. SOC	NA	NA										
	4(II).D.2.b.					NO	NA						
	4(II).D.2.b.			T1	D	NA	NA						
	4(III).D.2.b.					T1	D						
	4(IV).D.2.b.			NA	NA	NA	NA				NA	NA	NA
	4.D.2.c. Biomass	T1/T2	CS										



	4(I).F.1.							NO	NA					
	4(II).F.1.	NE	NA	NE	NA			NE	NA					
	4(III).F.1.							T1	D					
	4(IV).F.1.			NO	NA			NO	NA	NO	NA	NO	NO	NA
<i>Land converted to other land</i>	4.F.2. Biomass	T2	CS											
	4.F.2. DOM	T2	CS											
	4.F.2. SOC	T2	CS											
	4(I).F.2.							NO	NA					
	4(II).F.2.	NE	NA	NE	NA			NE	NA					
	4(III).F.2.							T1	D					
	4(IV).F.2.			NO	NA			NO	NA	NO	NA	NO	NO	NA
4.G. Harvested wood products														
<i>Harvested wood products</i>	4.G.	T1	D											

NA = Not applicable; NO = Not occurring; NE = Included elsewhere; T1 = Tier 1; T2 = Tier 2; D = IPCC default factor; CS = Country specific factor.

NA = Not applicable; NO = Not occurring; NE = Not estimated; IE = Included elsewhere; T1 = Tier 1; T2 = Tier 2; D = IPCC default factor; CS = Country specific factor.



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6.1.2.2 *Inclusion of overseas territories*

At the recommendation of the TERT (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L.1) the overseas territories were included in the total area and emission estimates. It was noted that in the previous inventory this was not done correctly and so this has been addressed in this inventory. There is still a lack of land cover/use data related to these overseas territories so some assumptions have been made, but this inventory has worked to include the areas correctly into the methodology and any assumptions will be updated in future as more data becomes available.

6.1.2.2.1 *Methodology for inclusion of overseas territories*

The Prince Edward Islands are South Africa's overseas territories, and these consist of Marion Island (29 000ha) and Prince Edward Island (4 500 ha) (Smith & Mucina, 2006). This area has been included in the total land area for South Africa. Marion Island has 10 876.5 ha of polar desert (Smith, et al., 2001) and looking at the map of Prince Edward Island in Smith and Mucina (2006) it is assumed to be 2% of Prince Edward Island. The total Polar desert area for the overseas territories is therefore 10 966.4 ha. The rest of the area of these islands consists of various vegetation types, such as herbfields, mires, tussock grasslands, fernbrakes and fellfield (Smith, et al., 2001; Smith & Mucina, 2006) which are all grouped under the land category of subantarctic tundra. In tern the polar desert was considered under the *Other land* IPCC class, while the subantarctic tundra was included under *Grasslands*.

There are no land change maps or data for these overseas territories and there is very little human management of the land, so for the purposes of this inventory the land cover was assumed not to change over the time series. As data becomes available this assumption can be updated to reflect the situation.

Vegetation was also stratified by soil type. The spatial map for the Prince Edward Islands were not available at the time of the inventory but a map and data for Marion Island soils is provided in Lubbe (2010). The soil types on the Prince Edwards Islands are based on this. It appears that the polar desert consists of Regosols which are classified as HAC soils (IPCC 2006 Guidelines, Table 2.3). Lubbe indicates that Regosols cover 58km² of Marion Island and, based on the soil map, this is under the polar desert. It is also indicated there is 7km² of rock and this is assumed to be allocated to polar desert. Based on the map it is then assumed the rest of the polar desert is on Andosol (Volcanic soil). As the polar desert is 109km² it means that Andosols cover 44km². Lubbe indicates that Andosols cover 98km² which means 54km² are allocated to tundra vegetation. Histosols (organic soils) and Histic Andosols (Volcanic soils) cover 62 and 64km² respectively. All of this means



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that 53.2% of polar desert is HAC, 6.4% is rock and 40.4% is Volcanic, while tundra is estimated to be on 65.5% (30%+35.5%) Volcanic and 34.5% Organic soils. These same ratios were applied to the Prince Edward Island area.

6.1.3 Improvements and recalculations

Detailed improvements are discussed in each section land category section of this report, but the main inventory improvements that were carried out and which led to recalculation impacts in the different periods were:

- 1990 – 1999:
 - This part of the time-series was not included in the previous inventory so was not recalculated but rather estimated for the first time.
 - HWP data for this period was improved by updating activity data.
- 2000 – 2024:
 - Incorporation of 2020-2022 land change matrix data.
 - Updated land use change assumptions for technology corrections between 2014 and 2018.
 - Removal of “land remaining land” error that was identified in the previous inventory.
 - Incorporation of updated method and assumptions for removing seasonal variation changes in land use/cover.
 - Inclusion of initial estimates of organic soils in *Croplands* and *Grasslands*.
 - Improved soil data through the inclusion of land change matrix per soil type for each change period (1990-2014, 2014-2018, 2018-2020, 2020-2022).
 - Updated biomass, carbon stock and emission factor data.
 - Improved burnt area methodology.
 - Updated fuelwood consumption data.
 - Methodological improvements, particularly to *Wetland* category, to improve alignment with IPCC methodologies and CRT's.

The recalculations showed the same trend between 2000 and 2014 as the previous data except that the sink was reduced by an average of 13.1% compared to the previous inventory (Figure 6.5). These differences were mainly due to updates in soil data, biomass data, burnt area and fuelwood estimates. After 2014 there is a change with recalculated estimates for 2014-2018 being very similar to the previous inventory, while estimates for 2018-2022 had an increased sink. The changes that lead to additional impacts during this period were the introduction of the 2020-2022 land use maps and the correction of the

“land remaining” error. Recalculations led to an average reduction of 51.3% in the sink between 2014 and 2022. In the previous inventory the 2022 estimated sink for LULUCF was 43 181 Gg CO₂e, and in this inventory it is estimated at 20 305 Gg CO₂e which is a 53.0% decrease in the sink.

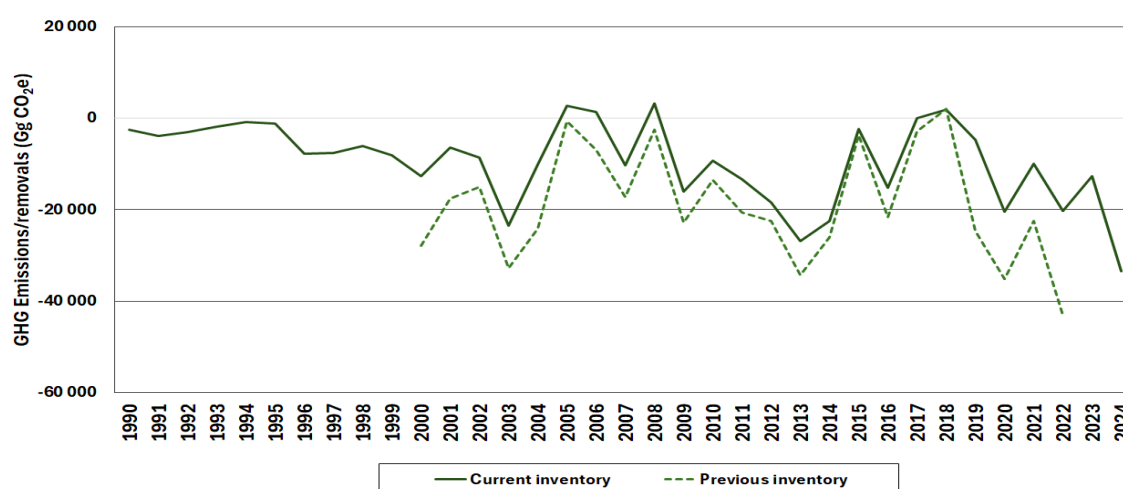


Figure 6.5: Change in LULUCF emission estimates due to recalculations since 2022 submission

6.1.4 Key categories in the LULUCF sector

The key categories in the LULUCF sector and their ranking are shown in Table 6.4. These show that the two most important categories are *Forest lands* and *Grasslands*, both remaining (4.A.1, 4.C.1) and converted lands (4.A.2, 4.C.2). Following this would be land converted to *Croplands* (4.B.2) and *Other lands* (4.F.2). In the previous submission *Grassland converted to forest land* was ranked at the main key category for LULUCF (1 overall) and *Forest land remaining forest land* as the second (3rd overall). In this submission these two have switched positions in the LULUCF key categories and moved down the overall ranking to 3rd and 6th position. There have been some shifts in the LULUCF rankings but generally the *Forest lands* and *Grasslands* are still the main categories. CH₄ emissions from Wetlands were on the key category list in the previous submission, but with the improved methodologies these have now dropped off the key



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category list. Biomass burning is also no longer on the key category list but has been replaced by CH₄ from drainage and rewetting (trend only).

Table 6.4: Key categories in the LULUCF sector in 2024.

Rank	IPCC code	IPCC Category	GHG	Criteria [#]
6	4.A.1.a	Forest land remaining forest land – biomass (above and below)	CO ₂	L,T
3	4.A.2.b	Grassland converted to forest land – all pools	CO ₂	L,T
19	4.B.2.a	Forest land converted to Cropland – all pools	CO ₂	L,T
9	4.C.1.a	Grassland remaining Grassland – biomass (above and below)	CO ₂	L,T
4	4.C.2.a	Forest land converted to Grassland – all pools	CO ₂	L,T
33	4.C.2.b	Cropland converted to Grassland – all pools	CO ₂	L,T
32	4.C.2.c	Wetland converted to Grassland – all pools	CO ₂	T
7	4.C.2.e	Other land converted to Grassland – all pools	CO ₂	L,T
22	4.E.1.a	Settlements remaining Settlements – biomass (above and below)	CO ₂	L,T
34	4.E.2.b	Cropland converted to settlements – all pools	CO ₂	T
28	4.F.2.a	Forest land converted to other land – all pools	CO ₂	T
18	4.F.2.c	Grassland converted to other land – all pools	CO ₂	L,T
24	4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH ₄	T
38	4.G	Harvested Wood Products	CO ₂	T

[#]L = Level Assessment; T = Trend Assessment

6.1.5 Quality assurance and quality control

General quality control (QC), category specific quality control and quality assurance (QA) has been carried out in conformance with the QA/QC Plan for South Africa. This was developed in accordance with the IPCC 2006 Guidelines.

In the previous inventory the quality control process was identified as needing improvement and therefore several additional checks were completed for the LULUCF sector in this inventory. This is also based on the TERT recommendations (FCCC/ETF/TERR.1/2024/ZAF/Add.1/ID# 6.L.2) to improve the QC process for the LULUCF sector. There have been three major changes introduced to improve the QC process and estimates:

- a) Redesign and recreation of the LULUCF sector calculation file. This was done to improve transparency and reduce errors. Previous files had been added to over the years and were becoming less transparent. In addition, the new files were

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setup to align with the new UNFCCC online reporting tool and CRT's. Numerous additional automatic checks were included in the new file. Outputs were compared to those in the previous inventory file and where there were discrepancies the calculations were assessed to understand the reasons for the differences.

- b) Training of officials on the compilation of the LULUCF sector inventory to increase the number of eyes on the calculation files. DFFE had brought in a new team member during the compilation of the previous inventory to assist with the LULUCF compilation. The development of a new calculation file provided a good opportunity to train the LULUCF team members, so they were included from the start of the process. In addition, the person joining the team was involved in the development of the land use maps and so has a good understanding of the use of spatial data. This enabled the team to make more detailed assessments of the land cover data and provided someone who could do the checks on the land areas. Training is still ongoing so the ability to do more quality checks in future will improve in the next inventory.
- c) Training on the latest version of the IPCC software was completed by the team. Even though the software is not being used to compile the inventory understanding how the software works enabled some of the methods and calculation done in the calculation file to be checked against the IPCC software. The software also shows where all the data fits into the CRT tables so this will improve the team's ability to complete and check the CRTs.

The general QC/QA process is described here with additional category specific checks being highlighted in the category specific sections below. All calculation checks were documented in the calculation file, with external reports being stored on the National GHG Inventory Management System (NGHGIMS).

6.1.5.1 General QC procedure

Automatic quality control checks are included in the calculation file, but a quality reviewer also completes checks on the calculation file. The QC reviewer incorporates comments into the calculation file by making use of the QA Analyst programme. For this all comments must start with a hashtag and include the initials of the QC reviewer, the date and the comment (see further details in the QA/QC Plan). After running QA Analyst, all comments are pulled out and listed in the QA log page at the front of the calculation file. The following steps are carried out during the QC of the calculation files:

- (a) LULUCF compiler completes the inventory estimates;
- (b) LULUCF compiler sends calculation file to QC reviewer;

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- (c) QC reviewer checks the calculation file, makes comments, completes the QC reviewer sheets at the top of each worksheet and runs the QA Analyst programme to produce the QA log sheet;
- (d) QC reviewer sends the checked calculation file back to the LULUCF compiler;
- (e) Compiler responds to the QC reviewer comments, updates the QA log page by running QA Analyst and send the calculation file back to the QC reviewer;
- (f) QC reviewer checks and signs off the QC comments and completes the review by updating the QA log file;
- (g) QC reviewer exports log file and uploads it to the NGHIGMS under QA/QC Procedures/ QAQC Logs.

6.1.5.2 QC of input data, emission factors and calculation procedures

The land change data is the main driving activity data for the inventory and there were several checks that were conducted on this data. The following checks were completed on all land area data (including those for different soil types and for the full time-series):

- The national area is constant across the time series.
- The national area is the same for all land use change matrixes.
- The total area for each soil type is constant across the time-series.
- The total area of all soil types adds to the national total in all years.
- Addition calculations for “land remaining” and “land converted” are applied correctly and to the correct data.
- Adjustments to land change matrixes are applied correctly.
- The 20-year correction has been applied correctly.

In terms of other input data the following checks were conducted:

- The original data is transcribed correctly into the calculation file.
- If there are any sharp changes in the time-series data these are checked and explanations sought.
- Correct units are applied.
- All data sources are references in the calculation file.
- All data sources are uploaded and available on the NGHIGMS.
- IPCC extrapolation techniques to fill gaps are correctly applied.
- Assumptions are documented and explained.

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Emission factor checks included:

- Transcription errors.
- Differences from the previous inventory. If there are differences the reason for the change has been explained and documented.
- Consistency across time-series.
- Calculation of implied emission factors are correct.
- Provision of uncertainty data.

Calculation methodology and procedures were checked by comparing the methodology in the calculation file against the methodology applied in the IPCC software (ver 2.98). This was done by conducting spot checks on the different components of the various land categories and doing a complete re-run of the HWP data in the IPCC software. The following checks were also completed on calculations in the calculation file:

- Data in summary sections are added or combined correctly.
- Correct units and conversion factors have been applied.
- Data is consistent with that in CRT tables.

The final quality check was to compare the resulting emission estimates to any estimates calculated outside of the inventory calculation file.

6.1.5.3 QA process

A public commenting process took place whereby the inventory was published for public comment and issues arising were addressed where necessary.

6.1.5.4 Verification

The LULUCF sector inventory was prepared primarily from land use maps and data that was specific to South Africa which means that there was not often comparable data that could be used for verification. Land use and cover were also difficult to verify due to the different data sources using different classifications. If there were any reports that assessed the quality of the land use/cover maps through the use of other tools such as aerial photography, then these were utilised but these were often for small areas. The country specific classification of soils into the IPCC classes was compared to the ISRIC global dataset. The values obviously vary as the country specific map is more detailed, however similarities were looked for.

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Where possible country specific data was compared to international datasets such as FAOSTAT data and all emission factors or reference data were compared to IPCC default values. Parameters were also compared to neighbouring countries where available.

6.1.6 Planned improvements

There are four main improvements to be focussed on in the next inventory cycle, of which some, as indicated) were highlighted in the UNFCCC TERT Review report:

- Development of a land mapping system to move towards approach 3 (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L_CBN.4):
 - The major uncertainty in the LULUCF sector is still related to the land conversion areas. Currently there are various corrections that are being applied to distinguish seasonal and technology changes from actual change. As mentioned in the previous inventory, a detailed plan is being setup to improve the land change data in a systematic manner and to incorporate all corrections spatially to insure more consistency in the overlays. The aim is to obtain a better understanding of actual change. The UNFCCC TERT review also highlighted the need to develop a land mapping system that will allow for the tracking of land parcels. This tracking would also assist with improving the challenges with removal of seasonal variation, identifying conversions from already converted land and tracking burnt area.
 - The planned land change mapping system will also incorporate additional spatial data (soils, climate, peatlands, ecozones, etc) to improve the alignment of the overlay data. The overall improvement would mean a reduction in the uncertainty on LULUCF activity data.
 - Additional data, such as CHIRPS data, can also be included to assist with the development of a more consistent method for adjusting for seasonal variations.
 - To date a basic system design has been developed and costed out and so the focus in the next inventory cycle is implementation.
- Update the SOC Reference data:
 - Currently the SOC reference data relies on an older ISRIC data set and was based on the 2014 SANLC data. This needs to be updated with the improved data and more recent land use maps. There are some discrepancies between the SA SOC Reference values and the IPCC values, and this update might lead to an improvement in the comparability.



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- This would be incorporated as part of the land mapping system discussed in the point above, but if the system is not fully functional by the next inventory this improvement could be done separately and incorporated into the current system.
- Source data to complete the implementation of Tier 2 DOM methodology in *Forest lands*.
 - The Tier 2 equations and available data have been incorporated into the calculation files, however mortality rates and rates of transfer out of the DOM pools in *Forest land* need to be sourced and results verified before inclusion in the inventory outputs.
- Improve data collection on controlled fires (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L_CBN.3):
 - There is a need to separate out controlled fires and wildfires so that natural disturbances can be reported separately. Currently there is no system for collecting this data. In the next inventory cycle additional data sources will be explored and discussion will be started around developing a means to collect and report such data.

There is also still a need for a forest inventory (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L_CBN.1), and this will continue to be explored with the Department of Forestry.

6.2 Land use and cover definitions

The land-cover legend and associated information content within the SANLC 2018 (DEA, 2019), SANLC 2020 (DFFE, 2021) and SANLC 2022 (DFFE, 2024) dataset was based primarily on the new gazetted land-cover classification standard (SANS 19144-2)²¹, but with modifications to ensure, as far as possible, comparability and compatibility with the legend and information content associated with the previous 1990 and 2013-14 South African National Land-Cover (SANLC) datasets (DEA, 2015a). The SANLC maps have 73 land classes (definitions are included in each of the relevant sections below) which were aggregated firstly into 20 classes for land change assessment, and then further aggregated into the 6 IPCC classes for reporting. The relationship between the IPCC classes, the change classes and the various SANLC datasets are shown in Table 6.5.

²¹ South African Land Cover Classes and Definitions (SDI Act No. 54 of 2003).



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Table 6.5: Relationship between the IPCC categories, land change categories and the SANLC datasets in the 2024 inventory

SANLC 1990 and 2013/14 Class		Change class		IPCC category	SANLC 2018 - 2022 Class	
4	Indigenous forest	1	Indigenous forest	Forest land	1	Contiguous forest
5	Thicket/ dense bush	2	Thicket/dense bush	Forest land	2	Contiguous low forest & thicket
					24	Mangrove wetlands
6	Woodland/open bush	3	Natural woodland	Forest land	3	Dense forest and woodland
					4	Open woodland
					42	Fallow lands (trees)
					43	Fallow lands (bushes)
32 33 34	Plantations and woodlots	4	Planted forest	Forest land	5	Contiguous and dense plantation forest
					6	Open and sparse plantation forest
					7	Temporary unplanted plantation
8 9	Shrublands fynbos Low shrubland	5	Shrubland	Grassland	8	Low shrubland (other, fynbos, succulent karoo, nama karoo)
					9	Fallow lands (low shrub)
					10	
					11	
7	Grassland	6	Grassland	Grassland	12	Sparsely wooded grassland
					13	Natural grassland
					44	Fallow land (grass)
1 2 37 38	Water seasonal/permanent Mine water seasonal/permanent	7	Waterbodies	Wetland	14	Rivers
					15	Estuaries and lagoons
					16	Ocean and coastal
					17	Lakes
					18	Pans
					19	Artificial dams
					20	Artificial sewage ponds
					21	Artificial flooded mine pits
3	Wetlands	8	Wetlands	Wetlands	22	Herbaceous wetlands
					23	
					73	Fallow land (wetlands)
41	Bare non vegetated	9	Barren land	Other land	25	Rock surfaces
					26	Dry pans
					28	Sand dunes
					29	Coastal sand dunes
					30	Bare riverbed
					31	Other bare
					45	Fallow land bare
40	Erosion (donga)	10	Eroded land	Grassland	27	Eroded land
16 17	Cultivated orchards	11	Permanent orchards	Cropland	32	Permanent orchards
					35	Permanent pineapples



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SANLC 1990 and 2013/14 Class		Change class		IPCC category	SANLC 2018 - 2022 Class	
18 22	Cultivated pineapples					
19 20 21	Cultivated vines	12	Permanent vines	Cropland	33	Permanent vines
13 14 15 26 27	Commercial pivot crops Cane pivots Cane pivot - fallow	13	Annual pivot irrigated	Cropland	34 38	Sugarcane pivot irrigated Annual crops pivot irrigated
10 11 12 28 29 30 31	Commercial non-pivot crops Cane crop Cane fallow Cane emerging crop Cane emerging fallow	14	Annual non-pivot crops	Cropland	36 37 39 40	Sugarcane non-pivot Sugarcane emerging non-pivot Non-pivot irrigated Rainfed dryland
23 24 25	Cultivated subsistence	15	Cultivated subsistence	Cropland	41	Subsistence annual crops
44- 52, 57- 72	Various types of urban classes (informal, residential, sport, township, village, built-up)	16	Built-up residential	Settlements	47-56, 61-64	Various types of residential (formal, informal, village, recreational, urban)
53 54 55 56 42	Various urban small holdings	17	Built-up smallholdings	Settlements	57 58 59 60	Various smallholdings
42	Urban commercial	18	Built-up commercial	Settlements	65	Commercial
43	Urban industrial	19	Built-up industrial	Settlements	66	Industrial
35 36 39	Mine bare Mine semi-bare Mine buildings	20	Mines	Settlements	68 69 70 71 72	Mines Land-fills



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6.2.1 Forest land

The National Forest Act (Act 84 of 1998) (NFA) (RSA, 1998) states that:

- “forest” includes a natural forest, a woodland and a plantation (Section 1(2)(x) of NFA);
- “natural forest” means a group of trees whose crowns are largely contiguous, or which have been declared by the Minister to be a natural forest (Section 1(2)(xx) of NFA);
- “plantation” means a group of trees cultivated for exploitation of the wood, bark, leaves or essential oils (Section 1(2)(xxii) of NFA); and
- “woodland” means a group of indigenous trees which are not a natural forest, but whose crowns cover more than five percent of the area bounded by the trees forming the perimeter of the group (Section 1(2)(xxxix) of NFA).

The definition of Forests in South Africa’s National Forest Act relates to international definitions and corresponds with the FAO definition of forests except that the FAO regards 10% as the lower boundary for woodland canopy cover. South Africa’s NFA definition is lower (5%) and thus also includes degraded woodland into that definition so that other provisions of the statute would still remain applicable even to degraded woodlands.

Taking guidance from the Marrakesh Accord (2011) and adjusting the specific thresholds so as to be consistent with the NFA, the forest definition is given as “a minimum area of land of 0.05 hectares with tree crown cover of more than 10 per cent with trees with the potential to reach a minimum height of 2.5 metres at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high portion of the ground open forest. Young natural stands and all forest plantations which have yet to reach a crown density of 10 per cent or tree height of 2.5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes, but which are expected to revert to forest.”

The *Forest land* category therefore includes indigenous forests, plantation/woodlots (hereinafter referred to as forest plantations), thicket/dense bush (hereinafter referred to as thickets) and woodland/open bush (hereinafter referred to as woodlands) as defined in Table 6.6. Note that Mangroves are included under *Forest land* as they are currently aggregated with thickets for the change analysis.



Table 6.6: Definitions of the land classes, as given in the SANLC reports for 2018 onwards, that are included in the Forest land category (DEA, 2019; DFFE, 2021)

SANLC class number	Aggregated change class	Class name	Class definition
1	Indigenous forest	Contiguous Forest (combined very high, high, medium)	Natural tall woody vegetation communities, with 75% or more canopy cover, and canopy heights exceeding 6 metres. Typically representative of tall, indigenous forests.
2	Thicket/Dense bush	Contiguous Low Forest & Thicket	Natural tall woody vegetation communities, with 75% or more canopy cover, and canopy heights ranging between 2.5 - 6 metres. Typically representative of low, indigenous forests and dense thicket communities.
3	Woodland	Dense Forest & Woodland	Natural tall woody vegetation communities, with canopy cover ranging between 35 - 75%, and canopy heights exceeding 2.5 metres. Typically represented by dense bush, dense woodland and thicket communities.
4	Woodland	Open Woodland	Natural tall woody vegetation communities, with canopy cover ranging between 10 - 35%, and canopy heights exceeding 2.5 metres. Typically represented by open bush and woodland communities.
5	Plantation	Contiguous & Dense Planted Forest	Dense to contiguous cover, planted tree forests, consisting primarily of exotic timber species, with canopy cover exceeding 35%, and canopy heights exceeding 2.5 metres. Typically represented by mature commercial plantation tree stands. This class also includes smaller woodlots and windbreaks
6	Plantation	Open & Sparse Planted Forest	Open to sparse cover, planted tree forests, consisting primarily of exotic timber species, with canopy cover ranging between 5 - 35%, and canopy heights exceeding 2.5 metres. Typically represented by young or recently planted commercial plantation tree stands. This class also include smaller woodlots and windbreaks
7	Plantation	Temporary Unplanted Forest	Temporarily unplanted stands within commercial forest plantations that have recently been harvested, and/or re-planted but the tree saplings are undetectable on the imagery.
24	Thicket/Dense bush	Mangrove Wetlands	Naturally occurring mangrove community wetlands.
42	Woodland	Fallow Land & Old Fields (Trees)	Long-term, non-active, previously cultivated lands that are <i>now</i> overgrown with tree-dominated woody vegetation. Typically the cultivated land unit boundary is no longer image detectable.
43	Woodland	Fallow Land & Old Fields (Bush)	Long-term, non-active, previously cultivated lands that are <i>now</i> overgrown with bush dominated woody vegetation.

6.2.2 Cropland

The SANLC 2018 report defines *Croplands* as active or recently cultivated lands used for the production of agricultural crops (DEA, 2019). *Croplands* include annual commercial croplands (pivot and non-pivot), permanent perennial orchards, permanent perennial vines, and semi-commercial or subsistence croplands. The SANLC classes that are included under croplands, along with their definitions, are provided in Table 6.7.



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Table 6.7: Definitions of the land classes, as given in the SANLC reports for 2018 onwards, that are included in the Cropland category (DEA, 2019; DFFE, 2021)

SANLC class number	Aggregated change class	Class name	Class definition
32	Perennial orchards	Cultivated Commercial Permanent Orchards	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with commercial orchards consisting of tree and/or bush based plants.
33	Perennial vines	Cultivated Commercial Permanent Vines	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with commercial viticulture.
34	Annual pivot irrigated	Cultivated Commercial Sugarcane Pivot Irrigated	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with commercial sugarcane. Grown in pivot irrigated fields.
35	Perennial orchards	Commercial Permanent (Pineapples)	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with pineapples.
36	Annual non-pivot crops	Cultivated Commercial Sugarcane Non-Pivot (all other)	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with commercial sugarcane. Grown in rainfed or non-pivot irrigation fields.
37	Annual non-pivot crops	Cultivated Emerging Farmer Sugarcane Non-Pivot (all other)	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with small-scale / emerging farmer sugarcane.
38	Annual pivot irrigated	Cultivated Commercial Annuals Pivot Irrigated	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with commercial annual crops. Pivot irrigation.
39	Annual non-pivot crops	Cultivated Commercial Annuals Non-Pivot Irrigated	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with commercial annual crops. Non-pivot irrigation.
40	Annual non-pivot crops	Cultivated Commercial Annuals Non-Pivot / Non-Irrigated	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with commercial annual crops.
41	Cultivated subsistence crops	Subsistence Annual Crops	Active or recently active cultivated lands used for the production of agricultural crops, in this case specifically associated with small-scale commercial or subsistence-level annual crops.

6.2.3 Grassland

Grassland comprises of areas dominated by grasses and herbaceous vegetation, with woody cover generally less than 10%. In South Africa, *Grassland* includes natural and semi-natural grasslands, low shrublands and eroded land. It also includes range and pasture lands that were not considered cropland. The category covers all grasslands from



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wild lands to recreational areas as well as agricultural and silvi-pastoral systems, consistent with national definitions. With the addition of the overseas territories the subantarctic tundra class was also included under *Grasslands*. Definitions of land areas included in the *Grassland* category are given in Table 6.8.

Table 6.8: Definitions of the land classes, as given in the SANLC reports for 2018 onwards, that are included in the Grassland category (DEA, 2019; DFFE, 2021)

SANLC class number	Aggregated change class	Class name	Class definition
8	Low shrubland	Low Shrubland (other regions)	Natural, low woody shrubland communities, where the total plant canopy cover is typically both dominant over any adjacent bare ground exposure, and the canopy height ranges between 0.2 – 2 metres. Typically representative of low, indigenous karoo-type vegetation communities, which have been identified using image-based spectral models, but which fall spatially <i>outside</i> the SANBI defined boundaries for Fynbos, Succulent and Nama-Karoo vegetation communities.
9	Low shrubland	Low Shrubland (Fynbos)	This is the same as class 8, Low Shrubland, but now represents low, indigenous karoo-type vegetation communities, which have been identified using image-based spectral models, but which fall spatially <i>inside</i> the SANBI defined boundaries for Fynbos vegetation communities.
10	Low shrubland	Low Shrubland (Succulent Karoo)	This is the same as class 8, Low Shrubland, but now represents low, indigenous karoo-type vegetation communities, which have been identified using image-based spectral models, but which fall spatially <i>inside</i> the SANBI defined boundaries for Succulent Karoo vegetation communities.
11	Low shrubland	Low Shrubland (Nama Karoo)	This is the same as class 8, Low Shrubland, but now represents low, indigenous karoo-type vegetation communities, which have been identified using image-based spectral models, but which fall spatially <i>inside</i> the SANBI defined boundaries for Nama Karoo vegetation communities.
12	Grassland	Sparsely Wooded Grassland	Natural woody vegetation, with a woody canopy cover ranging between only 5 - 10%, and canopy heights exceeding 2.5 metres, in a grass-dominated environment. Typically represented by very sparse woodland or lightly wooded grassland communities.
13	Grassland	Natural Grassland	Natural and/or semi-natural indigenous grasslands, typically devoid of any significant tree or bush cover, and where the grassland component is typically dominant over any adjacent bare ground exposure.
27	Eroded land	Eroded Lands	Permanent or semi-permanent, non-vegetated erosion surfaces, typically represented by gullies, dongas, and/or sheet erosion areas.
44	Grassland	Fallow Land & Old Fields (Grass)	Long-term, non-active, previously cultivated lands that are now overgrown with grass dominated woody vegetation.
	Subantarctic tundra		Includes subantarctic coastal vegetation, biotic herbfields and grasslands, mire, drainage lines and spring vegetation, fernbrake vegetation, fellfield, and cinder cone vegetation.



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6.2.4 Wetlands

Wetlands are lands saturated with water permanently or seasonally, supporting vegetation adapted to wet conditions. *Wetlands* include natural rivers, lakes, estuaries, lagoons, pans, and herbaceous wetlands, as well as artificial water bodies such as dams, sewage ponds, and flooded mine pits as defined in Table 6.9. Waterbodies are considered as the flooded lands and hereinafter are referred to as flooded lands. Mangroves are classified in the *Forest land* category so do not fall under *Wetlands*.

Table 6.9: Definitions of the land classes, as given in the SANLC 2018, that are included in the Wetland category (DEA, 2019; DFFE, 2021)

SANLC class number	Aggregated change class	Class name	Class definition
14	Waterbodies	Natural Rivers	Naturally occurring waterbodies associated with perennial and non-perennial rivers and associated tributaries.
15	Waterbodies	Natural Estuaries & Lagoons	Naturally occurring coastal region water bodies that are located at river mouths or are replenished by coastal tidal flows.
16	Waterbodies	Natural Ocean	Naturally occurring saltwater coastal and ocean waterbodies.
17	Waterbodies	Natural Lakes	Naturally occurring, large inland waterbodies containing freshwater.
18	Waterbodies	Natural Pans (flooded)	Naturally occurring inland waterbodies within pans, where the water extent is both spatially and temporally sufficient to be image-detectable.
19	Waterbodies	Artificial Dams	Man-constructed artificial inland waterbodies, ranging from small farm dams to large reservoirs, and if image-detectable, large irrigation canals.
20	Waterbodies	Artificial Sewage Ponds	Man-constructed artificial inland waterbodies, specifically associated with water and effluent treatment activities.
21	Waterbodies	Artificial Flooded Mine Pits	Man-generated artificial inland waterbodies, specifically associated with flooded mine pits, tailings ponds, or other surface-based mining activities.
22	Wetlands	Herbaceous Wetlands (currently mapped)	Natural or semi-natural wetlands covered in permanent or seasonal herbaceous vegetation. The class represents primarily riparian wetland areas, but can also include emergent aquatic vegetation in pans.
23	Wetlands	Herbaceous Wetlands (previous mapped extent)	Natural or semi-natural wetlands covered in permanent or seasonal herbaceous vegetation. The class represents primarily riparian wetland areas, but can also include emergent aquatic vegetation in pans.
73	Wetlands	Fallow Land & Old Fields (wetlands)	Long-term, non-active, previously cultivated lands that are currently classified as wetland vegetation.

6.2.5 Settlements

The *Settlement* category covers transportation infrastructure and human settlements. This includes formal built-up areas in which people reside on a permanent or near-permanent basis identifiable by the high density of residential and associated infrastructure, as well as towns and villages, smallholdings, commercial, residential and industrial areas. These areas are characterized by built-up surfaces and limited natural vegetation. Mines are also included. Definitions are provided in Table 6.10.

Table 6.10: Definitions of the land classes, as given in the SANLC report for 2018 onwards, that are included in the Settlement category (DEA, 2019; DFFE, 2021).

SANLC class number	Aggregated change class	Class name	Class definition
47	Built-up residential	Residential Formal (Tree)	Built-up areas primarily containing formally planned and constructed residential structures and associated utilities. The dominant vegetation (in gardens etc) is tree-based.
48	Built-up residential	Residential Formal (Bush)	Built-up areas primarily containing formally planned and constructed residential structures and associated utilities. The dominant vegetation (in gardens etc) is bush-based.
49	Built-up residential	Residential Formal (low veg / grass)	Built-up areas primarily containing formally planned and constructed residential structures and associated utilities. The dominant vegetation (in gardens etc) is grass and/or low shrub based.
50	Built-up residential	Residential Formal (Bare)	Built-up areas primarily containing formally planned and constructed residential structures and associated utilities. The surface is predominantly non-vegetated.
51	Built-up residential	Residential Informal (Tree)	Built-up areas primarily containing informal, often unplanned residential structures and associated utilities. The dominant vegetation (in surrounding areas etc) is tree-based.
52	Built-up residential	Residential Informal (Bush)	Built-up areas primarily containing informal, often unplanned residential structures and associated utilities. The dominant vegetation (in surrounding areas etc) is bush-based.
53	Built-up residential	Residential Informal (low veg / grass)	Built-up areas primarily containing informal, often unplanned residential structures and associated utilities. The dominant vegetation (in surrounding areas etc) is grass and/or low shrub-based.
54	Built-up residential	Residential Informal (Bare)	Built-up areas primarily containing informal, often unplanned residential structures and associated utilities. The surface is predominantly non-vegetated.
55	Built-up residential	Village Scattered	Built-up areas primarily associated with scattered rural settlements and associated utilities. <i>Scattered villages</i> are defined as those represented by contiguous / adjacent village-classified cells which collectively <i>do not form the majority cover</i> in a surrounding 1 ha window.
56	Built-up residential	Village Dense	Built-up areas primarily associated with scattered rural settlements and associated utilities. <i>Dense villages</i> are defined as those represented by contiguous / adjacent village-classified



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			cells which collectively <i>do form the majority cover</i> in a surrounding 1 ha window.
57	Built-up smallholdings	Smallholdings (Tree)	Agricultural holdings typically located in peri-urban environments, where the dominant vegetation is tree-based.
58	Built-up smallholdings	Smallholdings (Bush)	Agricultural holdings typically located in peri-urban environments, where the dominant vegetation is bush-based.
59	Built-up smallholdings	Smallholdings (low veg / grass)	Agricultural holdings typically located in peri-urban environments, where the dominant vegetation is low shrub or grass based.
60	Built-up smallholdings	Smallholdings (Bare)	Agricultural holdings typically located in peri-urban environments, where the dominant cover is non-vegetation is bush-based.
61	Built-up residential	Urban Recreational Fields (Tree)	Non-built-up, vegetated urban areas primarily associated with formally planned and established parks, sports fields, and golf courses.
62	Built-up residential	Urban Recreational Fields (Bush)	Non-built-up, vegetated urban areas primarily associated with formally planned and established parks, sports fields, and golf courses.
63	Built-up residential	Urban Recreational Fields (Grass)	Non-built-up, vegetated urban areas primarily associated with formally planned and established parks, sports fields, and golf courses.
64	Built-up residential	Urban Recreational Fields (Bare)	Non-built-up, open urban areas primarily associated with formally planned and established parks, sports fields, and golf courses.
65	Built-up commercial	Commercial	Built-up areas primarily containing formally planned and constructed commercial structures and associated utilities. Includes shops, offices, schools, hospitals, and administration structures.
66	Built-up industrial	Industrial	Built-up areas primarily containing formally planned and constructed industrial structures and associated utilities. Includes both light and heavy industry, power generation, airports, rail terminals and ports.
67	Built-up commercial	Roads & Rail (Major Linear)	Built-up features represented by primary road and rail networks that are image-detectable (i.e. networks are non-contiguous), as well as smaller airfields and airstrips.
68	Mines	Mines: Surface Infrastructure	Built-up structures associated with the administration and/or industrial processing and extraction of mined resources.
69	Mines	Mines: Extraction Sites: Open Cast & Quarries combined	Non-vegetated, active and/or non-active extraction pits associated with surface-based mining activities, including open-cast mines, quarries, and road-side borrow pits etc.
70	Mines	Mines: Extraction Sites: Salt Mines	Non-vegetated, active or non-active extraction pits associated with evaporative salt-mining activities, typically associated with coastal or inland saline pan localities.
71	Mines	Mines: Waste (Tailings) & Resource Dumps	Non-vegetated, active or non-active mine generated material dumps or stockpiles, associated with both mine waste material (i.e. tailings dams) or mine generated resource stockpiles (i.e. coal stockpiles).
72	Mines	Land-fills	Primarily non-vegetated, active or non-active land-fill sites used for the large scale disposal of urban waste.



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6.2.6 Other land

Other Land is predominantly bare ground areas, typically barren or sparsely vegetated. This includes natural rock outcrops, dry pans, sand dunes (coastal and terrestrial), bare riverbeds, and other bare surfaces. It also covers fallow lands that have become predominantly bare ground. These areas generally have low productivity and limited vegetation cover. With the addition of the overseas territories the polar desert class was also included under *Other lands*. The definitions of the land classes included in *Other lands* are provided in Table 6.11.

Table 6.11: Definitions of the land classes, as given in the SANLC report for 2018 onwards, that are included in the Other land category (DEA, 2019; DFFE, 2021)

SANLC class number	Aggregated change class	Class name	Class definition
25	Barren land	Natural Rock Surfaces	Naturally occurring areas of non-vegetated, exposed rock and consolidated substrate.
26	Barren land	Dry Pans	Naturally occurring areas of non-vegetated, consolidated substrate, associated with permanent or long-term dry pans.
28	Barren land	Sand Dunes (terrestrial)	<i>Non-vegetated</i> , naturally occurring inland (non-coastal) sand dunes, which are typically associated with arid, desert-like environments.
29	Barren land	Coastal Dunes & Beach Sand	Non-vegetated, naturally occurring coastal sands, typically associated with both coastal dunes and beach environments.
30	Barren land	Bare Riverbed Material	Natural or semi-natural, non-vegetated, consolidated or unnaturally occurring coastal sands, typically associated with both coastal dunes and beach environments.
31	Barren land	Other Bare	Other natural, semi-natural or man-created non-vegetated areas.
45	Barren land	Fallow Land & Old Fields (Bare)	Long-term, non-active, previously cultivated lands that are now predominately non-vegetated bare ground surfaces.
	Polar desert		Areas that consist of black lava, thin layers of volcanic ash or unconsolidated deposits of pebble-sized scoria with the occasional rock or boulder. Moss can be present but usually covers less than 2% of the area.

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6.3 Land representation approaches and data processing

South Africa covers an area of 122 008 kha, which includes the Prince Edward Islands (Marion Island – 29 kha and Prince Edward Island – 4.5 kha). Land-cover²² maps were developed for 1990 (DEA, 2016), 2013-14 (DEA, 2015a), 2018 (DEA, 2019), 2020 (DFFE, 2021) and 2022 (DFFE, 2024). These land cover maps exclude the Prince Edward Islands. There is no land change data for the islands and so for the purposes of this inventory the islands are assumed not to have any vegetation change. This assumption can be updated in future when more data becomes available.

The details of the processing and development of the land cover and change maps are provided in the relevant reports and are summarised below. In addition, further details are provided in Annex V.

A map for 2024 is currently being developed but was not completed by the time this inventory was compiled and therefore was not included. Data was extrapolated for 2023 and 2024 as outlined in section 6.3.6.

6.3.1 Land use and cover database and data processing

6.3.1.1 SANLC 1990

The 1990 72 x class South African National Land-cover dataset was generated primarily from digital, multi-seasonal Landsat 5 multispectral imagery, acquired mainly between 1990 and 1991. An excess of 600 Landsat images were used to generate the land-cover information, based on an average of 8 different seasonal image acquisition dates, within each of the 76 x image frames required to cover South Africa. The land-cover dataset, which covered the whole of South Africa, was presented in a map-corrected, raster format, based on 30x30m cells equivalent to the image resolution of the source Landsat 8 multi-spectral imagery. Each data cell contains a single code representing the dominant land-cover class (by area) within that 30x30m unit, as determined from analysis of the multi-date imagery acquired over that image frame. The original land-cover dataset was processed in UTM (north) / WGS84 map projection format based on the standard Landsat map projection format provided by the USGS2. The final product is available in

²² The term 'land cover' is used loosely here as the classes are a combination of land cover and land use.



UTM35(north) and (south), WGS84 map projections and Geographic Coordinates, WGS84.

6.3.1.2 SANLC 2013-14

The primary imagery source used in the generation of the 2013-14 SA National Land-cover dataset (referred to as SANLC 2014 in this report) was 30m resolution Landsat 8 imagery, acquired between April 2013 and March 2014. Unfortunately, due to localised, prolonged cloud cover problems in some regions during this April 2013 - March 2014 period, there were gaps in the data. In these cases, Landsat 5 imagery was used as a substitute, but only if it was from a suitable seasonal period to compliment the Landsat 8 data and was $\pm 100\%$ cloud free.

All Landsat 8 and 5 imagery was standardised to 16-bit, Top-of-Atmosphere (ToA) reflectance values prior to land-cover modelling using a generic modelling approach. The original USGS generated UTM (north), WGS84 map projection format was retained without change or modification throughout all image-frame based modelling procedures. As far as possible only cloud free or image dates with limited cloud cover were used in the land-cover modelling (i.e. maximum $\pm 20\%$ terrestrial cloud cover in any one date). Any cloud affected regions were corrected by merging cloud affected ToA corrected imagery with cloud free ToA corrected data from preferably the preceding or following overpass date; so that as far as possible, the final cloud-free merged imagery composite only represented a maximum difference of ± 16 days. Cloud masks were created using either conventional pixel classification procedures (within analyst defined sub-image areas), or spectral based modelling using generic thermal and blue light reflectance thresholds; depending on cloud characteristics. This was deemed acceptable in terms of minimising any changes in local vegetation cover growth changes. Approximately 35% of the 616 x images used in the landcover modelling were cloud-masked composites. No external atmospheric correction was applied to the image data.

Derived spectral indices, generated from the ToA corrected imagery were used as the only inputs into the land-cover models. No original spectral (i.e. ToA reflectance) data was used as an input, although collectively, 5 out of the 8 available non-thermal spectral bands were used in the various spectral indices.

The same two-step process as outlined below for the SANLC 2018 map was then followed to generate the land-cover dataset.



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6.3.1.3 SANLC 2018

The 20m resolution, raster format SANLC 2018 dataset was generated from automated mapping models (as opposed to conventional image classification procedures), using multi-seasonal 20m resolution Sentinel 2 satellite imagery. The imagery used represents the full temporal range of available imagery acquired by Sentinel 2 during the period 01 January 2018 to 31 December 2018.

The automated land-cover mapping models and associated procedures utilise both cloud-based image archives and cloud-based geo-data computing capabilities; although the final compilation and merging of the different land-cover and land-use information components (i.e. water, mining extent, forest plantations etc.), were completed in a conventional desk-top environment, using automated modelling capabilities within commercial mapping software.

The generation of the automated land-cover data in the new, Sentinel 2 based procedure involved two separate, but sequential processing steps:

- **Step 1:** Fully automated image modelling procedures were used to generate what is referred to as the “spectrally-defined” base land-cover characteristics. These ‘base’ land-cover characteristics were the primary ‘building blocks’ which were used to describe the entire landscape in terms of primary cover characteristics such as woody vegetation, grass, bare or water dominated surfaces. A standardised set of spectral indices were identified from which the required foundation cover classes, namely (1) tree dominated, (2) bush dominated, (3) grass dominated, (4) water and (5) bare ground could be modelled, using pre-determined, generic spectral threshold values. The generic threshold values associated with each indices and cover type were tested over several landscapes and seasons before being confirmed and accepted as such. The spectral indices included both existing algorithms such as the Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index (NDWI), as well as algorithms developed in-house specifically for the GTI land-cover modelling requirements. No attempt was made at this stage to define additional detail such as whether the tree cover is a natural forest, or a managed forest plantation.
- **Step 2:** Ancillary spatial datasets, referred to as ‘geographical masks’ (such as “Mines & Quarries”, “Built-up”), were used to convert the base land-cover classes into more detailed sub-classes. The geographical masks define specific, pre-determined areas-of-interest within the South African landscape, within which the primary, spectrally-defined base classes were de-constructed into more specific land-cover and/or land-use sub-classes. In each case, a specific set of modification

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rules were used to either amalgamate, sub-divide or re-allocate the primary, base-level class(es) to the required sub-class detail. The primary objective and reason behind the use of these geographical masks is to facilitate the delineation of sub-classes that cannot be achieved using spectral data alone, since many unrelated sub-classes can often share similar spectral characteristics, e.g. river water versus water-in-pans, or non-vegetated mine dumps and some natural rock exposures, or coastal dunes and sand-roads etc. The 'geographical masks' are described in detail in the SANLC 2018 report (DEA, 2019).

The automated land-cover mapping models and associated procedures used in the production of the SANLC 2018 dataset utilise both cloud-based image archives and cloud-based geo-data computing capabilities; although the final compilation and merging of the different land-cover and land-use information components (i.e. water, mining extent, forest plantations etc), has been completed in a conventional desk-top environment, using automated modelling capabilities within proprietary, i.e. commercial mapping software.

6.3.1.4 SANLC 2020 and 2022

The SANLC 2020 and 2022 datasets were produced using the same automated mapping approach developed for SANLC 2018, which was migrated to a cloud-based environment and fully automated under the Computer Automated Land-Cover (CALC) workflow. This process uses multi-seasonal Sentinel-2 imagery at 20m resolution, covering the full temporal range of 01 January to 31 December of the target year. CALC integrates cloud-based image archives and geospatial computing capabilities to generate land-cover maps, while final compilation and merging of thematic components (e.g. water bodies, mining extent, forest plantations) are completed in a desktop environment using automated modelling tools. All future SANLC products will be generated using this cloud-based automated workflow.

6.3.1.5 Computer Automated Land Cover (CALC) System Methodology

The Computer Automated Land Cover (CALC) is a DFFE automated system that generates land cover and land use change datasets. CALC is designed and operationally implemented as an automated, cloud-based solution for the future production of South African National Land-Cover datasets. The system produces national land-cover data for South Africa, based on the new Gazetted land-cover classes (SANS 19144-2), associated map accuracy and change detection analysis datasets and reports.

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Each CALC generated SANLC dataset represents a 20m resolution, raster format, land-cover and land-use (LCLU) automated classification of the entire South African landscape, including a 100-metre buffer into neighbouring countries, and 10 km buffer into coastal waters. The buffer area is then excluded during analysis. Each SANLC dataset represents a particular assessment year, not a specific date nor season. The CALC classification process used all available Sentinel-2 image acquisitions acquired between and including January and December in the assessment year. The automated land-cover mapping models and associated rules utilise both cloud-based image archives and cloud-based geo-data computing capabilities.

The land-cover / land-use (LCLU) legend and associated information content used with all CALC generated SANLC datasets is based primarily on the new gazetted land-cover classification standard (SANS 19144-2), but with modifications to ensure, as far as possible, comparability and compatibility with the legend and information content associated with the previous 1990 and 2013-14 South African National Land-Cover (SANLC) datasets. These modifications have been made in order to facilitate more representative change detection and reporting between the SANLC 1990 and SANLC 2013-14, 2018, 2020 and 2022 datasets.

CALC generated SANLC datasets are generated using only European Space Agencies (ESA) free-to-access Sentinel-2 satellite imagery. No other satellite image sources have been used. Sentinel-2 imagery has been chosen over Landsat as the preferred source of imagery due to its improved spatial, spectral and temporal (i.e. re-visit) capabilities, compared to Landsat. Sentinel-2A and 2B satellites are collectively able to provide 20 metre resolution imagery, containing 12 spectral bands, every 5 days, anywhere across the globe.

This system enables the DFFE to generate single-year-representative, full legend content, national land-cover datasets over South Africa that are compatible with both the new Gazetted land-cover classes (SANS 19144-2), and the information content in the existing 1990 and 2013/14 South African National Land-Cover datasets. The CALC system also supports the calculation and reporting of land-cover mapping accuracies against independently obtained validation points; and land-cover change assessments with statistical reporting based on a simplified legend (20 classes) and reduced spatial resolution (30 m). CALC also generates RGB false-colour image tiles from Sentinel-2 imagery that is used as a visual reference to update 12 dynamic geographical masks before classification takes place. These visual backdrops are only used for on-screen updating within a GIS environment and should not be used for spectral classification of the imagery.



The CALC system is a fully functional, operational system capable of generating SANLC datasets for DFFE, enabling the Department to maintain and expand its inventory of SANLC content into the future.

6.3.2 Land mapping accuracy

6.3.2.1 SANLC 1990 and 2014

No accuracy assessment was undertaken on the historical 1990 South African National Land-Cover dataset, because no suitable historical reference data was available in the same format as that used for the verification of the 2013-14 dataset. However, since exactly the same mapping and modelling procedures and image formats have been used in the generation of the 1990 land-cover data, the map accuracies determined for the 2013-14 dataset can be used as a reliable indication of the likely mapping accuracies achieved for the 1990 dataset.

The overall map accuracy for the 2013-14 South African National Land-Cover, modelled from multi-seasonal Landsat 8 imagery is 82.53%, with a mean land-cover / land-use class accuracy of 88.36 %. This was determined from 6415 sample points. The associated Kappa Index value of 80.87 indicates that these results are very unlikely to be the result of chance occurrence.

6.3.2.2 SANLC 2018, 2020 and 2022

The land-cover mapping accuracy assessments for the 2018, 2020 and 2022 South African National Land Cover (SANLC) datasets were conducted using a consistent and established methodology to ensure comparability across years. In all three assessments, map accuracy was evaluated by comparing image-classified land-cover outputs with independently generated and/or sourced reference data, with results reported using conventional spatial accuracy statistics.

To minimise potential misclassification arising from short-term or transitional land-cover changes (such as recently clear-felled plantation areas), the accuracy evaluations were undertaken using a simplified, content-reduced 47-class legend rather than the full 73-class mapping legend. Reference sample points were primarily captured and spatially interpreted using Sentinel-2 imagery at 20 m spatial resolution corresponding to each respective year (2018, 2020 and 2022).

Table 6.12 details the map accuracy for the 2018, 2020 and 2022 SANLC datasets. The 2018 map achieved the highest overall accuracy, while a gradual decline in overall and



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mean class accuracies was observed in the subsequent 2020 and 2022 maps. Despite this trend, all three datasets demonstrate robust classification performance, with high overall accuracies, strong class-level agreement, and kappa indices indicating high agreement between mapped land-cover classes and reference data.

Table 6.12: Comparison of mapping accuracies for SANLC 2018, 2020 and 2022

SANLC Year	Overall Accuracy (%)	Mean Class Accuracy (%)	90% Confidence Limits (%)	Kappa Index
2018	90.14	89.63	89.65 – 90.62	89.91
2020	85.47	84.66	84.91 – 96.03	85.13
2022	84.22	83.55	83.67 – 84.77	83.81

6.3.2.3 Comparison between Landsat and Sentinel maps

One of the key intentions behind the production of the new Sentinel land cover datasets was to expand the timeline of available South African National Land Cover datasets in support of long-term environmental monitoring and change detection. To that end, the SANLC 2018, 2020 and 2022 datasets have been generated to provide as close as possible a repeat of the SANLC 1990 and SANLC 2014 data contents, format and landscape representations. However, improvements in landscape interpretation and mapping resulting from the improved spatial, spectral and temporal characteristics of Sentinel 2 imagery have resulted in changes between SANLC 2018 and the previous SANLC 1990 and SANLC 2014 datasets, which are not necessarily associated with true landscape changes, but rather improved interpretation and thus mapping quality. There has been no attempt to perpetuate both known and unknown errors from the SANLC 1990 and SANLC 2014 datasets into the SANLC 2018, 2020 and 2022 datasets if more accurate mapping could be achieved from the Sentinel 2 image interpretations, whilst retaining as far as possible the same class-based information content.

Generally, it can be assumed that comparisons between the current SANLC 2018 and both historical SANLCs will be more accurate in terms of documenting true land-use related changes, compared to land-cover related changes, as land-use features are typically associated with easily (image) detectable boundaries and/or unique (image) spectral characteristics. Mapping, and by association, change detection in natural landscapes, such as woodland, grassland and shrublands etc. are typically more challenging; since these landscape features typically do not have 'hard' boundaries, but rather gradients, within which a class boundary must be defined. This challenge is often compounded as a result



of inter-annual seasonal differences, and associated differences in interpretable spectral/spatial image characteristics.

The end-result is that, if a user compares the current and historical SANLC datasets, many landscape differences will be correct, it is also likely that some of these differences, especially in natural vegetation landscape can be attributed to mapping errors in one or both land-cover input datasets. Although these are most likely to be associated with the historical Landsat generated SANLCs as a result of Landsat's poorer spatial, spectral and temporal characteristics, compared to Sentinel 2 imagery. The enhanced spectral, spatial and temporal characteristics associated with Sentinel 2 imagery, as well as enhancements to the content and integration of the geographical masks used in the latest SANLC 2018 and 2020 landcover modelling, are considered to have resulted in a more accurate SANLC 2018 landscape interpretation. This assumption is supported by the significantly higher woody class mapping accuracies reported for SANLC 2018 compared to those reported in the SANLC 2014 dataset (see Table 6.13).

Table 6.13: Comparison of mapping accuracies between SANLC 2014 and SANLC 2018

SANLC 2014 Class Mapping Accuracies	User/Producer Accuracy (2014)	User/Producer Accuracy (2018)	SANLC 2018 Class Mapping Accuracies
Indigenous forest	72.60/94.64	98.90/84.11	Contiguous (indigenous) forest
		80.60/92.31	Contiguous low forest & thicket
Dense bush/Thicket	53.74/83.64	76.44/93.59	Dense forest & woodland
Woodland/Open bush	60.84/54.13	78.79/92.86	Open woodland
Grassland	84.56/69.82	85.90/87.58	Grassland
Shrubland (non-fynbos)	70.59/61.82	66.67/86.25	Shrubland (non-fynbos)

6.3.3 Land use change map processing and refinement

6.3.3.1 Data processing for developing land change maps

Land-use changes were mapped using an Approach 2 method as described in IPCC 2006 Guidelines. The 1990-2014, 2014-2018, 2018-2020 and 2020-2022 land use change maps were utilized in this inventory and data was extrapolated to 2024 as described in

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section 6.3.6. The key data processing steps used in Computer Automated Land Cover (CALC) system to generate any two-date SANLC change assessment are:

- Generate the 73-class SANLC datasets for the target years.
- Convert all SANLC datasets to the new 20-class, simplified land-cover change legend format and content.
- Re-project the 20-class Geographic Coordinate format SANLC datasets to a standardised Albers Equal Area map projection.
- Spatially resample (using nearest-neighbour class code allocation) the Sentinel 2 derived 20 x 20 m SANLC datasets to the standardised 30 x 30 m resolution required for land use change maps.
- Ensure pixel-to-pixel registration between all 30 m resolution Albers Equal Area map projection outputs using the CALC 2018 SANLC as the generic reference dataset against which all other CALC generated SANLC datasets are registered. This approach has been taken as the ortho-precision of the source Sentinel 2 imagery from which all SANLC datasets are generated and is considered superior to the Landsat imagery used in the compilation of the 1990 and 2013/14 SANLC datasets.
- Ensure pixel-level equivalent land-cover geographic coverage between all SANLC datasets, so that the change assessment results do not include a null class values as a result of differences in total mapped extent resulting from different boundary delineations and associated buffer zones.
- Generate a national 30 x 30 m resolution land-cover class-pair based change-reporting matrix for each two-year land-cover change assessment.

6.3.3.2 Land change map refinements

The land change matrixes required further processing and refining before being incorporated into the inventory. At this stage these adjustments could only be made to the matrixes in excel and could not be included spatially. It is noted that this does lead to some misalignment with the soil and burnt area overlays but this issue will be addressed in the land mapping system which is planned to be developed (see planned improvements in section 6.1.6).

6.3.3.2.1 Coastal buffer adjustments

The SANLC land-cover datasets are initially generated with a 10 km buffer extending into coastal waters to ensure complete coverage of coastal features. However, this buffer artificially increases the total land area of South Africa and must be removed for accurate



reporting. To address this, all land change maps were clipped to the official national boundary, excluding the coastal buffer. This adjustment eliminated an excess area of approximately 1 590 kha, which was originally attributed to the flooded land class. Consequently, the land change matrixes were recalculated to reflect the actual terrestrial land area of South Africa, which is 122 008 kha. This correction was done to ensure consistency with IPCC land representation requirements and maintain the integrity of national land-use statistics.

6.3.3.2.2 2014-2018 change map adjustments

As part of the SANLC 2018 land-cover mapping project, a comprehensive South African National Land Cover Change Assessment (DEA, 2019a) was undertaken to verify natural land class changes between 1990, 2014, and 2018. The assessment revealed that most apparent changes between natural land classes during 2014–2018 were not actual land conversions but were artifacts introduced by technological improvements, specifically the transition from Landsat imagery to higher-resolution Sentinel-2 imagery (see section 6.3.2.3). These sensor differences resulted in classification inconsistencies rather than real land-use changes.

A blanket correction factor of 80% was applied to all conversions identified as spurious, effectively reducing the reported change areas. The 80% adjustment was adopted as a conservative measure based on expert review and findings from the DEA assessment, which indicated that the majority of observed changes were classification errors rather than real land-use transitions. Applying this correction minimizes the risk of overestimating land-use change and associated emissions or removals in GHG inventories. Where no genuine conversion was considered to have occurred, the affected areas were reverted to their 2018 land class, as the 2018 dataset was deemed more accurate due to improved resolution and classification methods.

6.3.3.2.3 Unlikely change adjustments

Adjustments for highly unlikely land conversions were implemented across all four change periods: 1990–2014, 2014–2018, 2018–2020, and 2020–2022. Transitions such as indigenous forest converting to plantation, settlements converting to mines or cropland, and flooded land converting to settlements were deemed highly unlikely based on ecological, socio-economic, and practical considerations. These conversions typically result from classification errors rather than actual land-use dynamics. These areas flagged with these improbable transitions were reverted to their original land class prior to the reported change. This approach ensures that the land-change matrices reflect



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realistic land-use dynamics and prevents the inclusion of spurious changes that could distort activity data.

6.3.3.2.4 *Forest plantation adjustments*

Forest plantation corrections were applied across all the change periods (1990–2014, 2014–2018, 2018–2020, and 2020–2022) to address classification inconsistencies and align plantation areas with Forestry South Africa (FSA) statistics. The following specific adjustments were implemented:

- Unlikely conversions to forest plantations: Changes from flooded lands, wetlands, croplands, and settlements to forest plantations were considered highly improbable and were reverted to their original land classes. This correction prevents overestimation of forest plantation expansion in areas where such conversions are assumed not to occur.
- Unlikely conversions from forest plantations: Similarly, conversions from forest plantations to flooded lands or wetlands were assumed not to occur and were reverted to the original forest plantation class.
- Partial adjustment for remaining conversions: The total forest plantation area was compared with the FSA area data and the remaining land conversions were adjusted to occur at half the rate indicated in the matrixes. This conservative adjustment was applied to better align with observed forest plantation trends and FSA data.

6.3.3.2.5 *Adjustments for impacts of seasonal (wet/dry) variation on land use change*

In the previous inventory adjustments for seasonal changes were implemented for natural land areas that overlapped and showed interchanging conversions between two change periods. For example, the area of woodland converted to grassland in 2014–2018 was intersected with the area of grassland that was converted back to woodland in 2018–2020. The overlap area was assumed to therefore be non-permanent, and the area was reverted to the woodland class.

In this inventory a new approach for seasonal change adjustments was implemented for natural land classes where climate data was utilised to determine if the change periods were from a wet to a dry year or *vice versa*. If the change period was a “wetting” cycle, then different land category changes were expected to be affected compared to a “drying” change period. The following change categories were determined to be affected (i.e. show increased conversion area) if the change was from a wetter to a drier year (“drying” change period):

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- Thickets to woodlands
- Woodlands to grasslands
- Woodlands to bare ground
- Low shrublands to bare ground
- Grasslands to bare ground
- Low shrublands to eroded land
- Low shrublands to grasslands

On the other hand, in a conversion from a drier to wetter year (“wetting” change period) the conversions in the opposite direction to those indicated above are expected to increase. For example, there would be an increase in conversion of grasslands to woodlands and bare ground to shrublands.

To implement this correction, the first step was to identify if a change period was a “wetting” or “drying” change. The Annual State of the Climate in South Africa Report (SAWS, 2025) was the first data source used to complete this assessment. In addition, the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data (CHIRPS, 2025) was also accessed to provide spatial climate data. In this case data for 2018 and 2020 was obtained and the difference between the two showed the regions of significant reduction of rainfall in this period. These areas anecdotally match the changes in woody vegetation for example. Unfortunately, due to time constraints, the assessment of CHIRPS data could not be completed for all the years, but this will be included into the improvement plan. The rainfall data will be incorporated into the land mapping system that is being developed. This will significantly improve the ability to correct for the seasonal changes due to rainfall impacts in future.

The second step in the process was to apply the correction factor to the change categories as provided above. It was assumed that 75% of these land changes are not real changes but are rather due to these seasonal fluctuations brought about by rainfall changes. This means that 75% of the change associated with that change class was reverted back to the original land class. For example, in a “drying” change period 75% of the change from low shrubland to bare ground was reverted back to low shrubland. If, however, it was a “wetting” change period then 75% of the change from bare ground to low shrubland would be reverted back to bare ground. It is noted that for now the approach applies some broad assumptions which could be improved in future with the use of spatial data and through the tracking of land parcels in the developing land mapping system.

This correction was not applied to the 1990-2014 change period as the 24-year period is long enough to include actual changes that are not seasonal. It was also not applied to the 2014-2018 period as this change map already has a correction applied to it due to the

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change from Landsat to Sentinel data so this correction would include seasonal change corrections. The correction was applied to 2018-2020 (“drying”), 2020-2022 (“wetting”) and the 2022-2024 extrapolations (“drying”).

6.3.3.2.6 Addition of overseas territory area

The SANLC data does not include the overseas territories in its area so these need to be added to the land change matrix for each change period. These territories include subantarctic tundra and polar desert. As indicated in section 6.1.2.2, there is assumed to be no land change data on these overseas territories. This assumption will be updated in future when further data becomes available.

6.3.3.2.7 Land change results

The resulting corrected annual change areas used as the basis for the calculations to determine land remaining and converted land areas as discussed in the next section are provided in Table 6.14 to Table 6.17. The original (uncorrected) annual areas are provided in Annex V.



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Table 6.14: Annual land change areas (ha) for 1990-2014 used as a basis for inventory calculations (20-year transition period)

Land categories	1990																					
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annuals Pivot Irrigated	Annuals Non-Pivot	Cultivated Subistence	Residential						
2014	Indigenous Forest		672	1 308	344	1 462	29	270	22	0	8	0	0	55	35	73	3	3	1	0	0	
	Thicket / Dense Bush	1 725	62 647	5 319	26 423	72 094	1 209	6 047	3 560	233	563	175	97	3 423	3 591	2 725	162	120	133	305	0	
	Natural woodland	446		1 968	68 524	128 942	674	3 203	8 787	1 030	350	22	245	9 159	7 572	1 126	242	37	68	777	0	
	Planted Forest	0	239	749		281	5 984	0	9	1	0	0	0	0	0	0	0	0	0	0	0	
	Shrubland	88	16 780	62 477	1 052		176 234	1 221	5 444	148 400	7 478	234	190	139	16 664	737	49	49	69	584	0	
	Grassland	436	36 78	5 765	184 838			1 602	16 522	8 422	3 517	393	49	216 291	3 471	3 904	290	79	142	2 091	0	
	Waterbodies	5	519	540	66	592	1 102		528	1 185	10	8	10	2	139	45	24	7	2	3	110	0
	Wetlands	73	1 419	833	673	1 396	5 961	2 312		276	77	35	25	17	1 395	64	134	36	7	11	63	0
	Barren Land	38	989	6 436	43	105 562	7 688	3 761	378		1 456	6	8	5	293	27	62	4	9	22	171	0
	Eroded Land	0	101	613	1	1 451	1 981	11	27	31		1	0	2	116	226	46	0	1	1	13	0
	Permanent Orchards	33	955	474	258	535	433	15	89	10	0		143	144	1 295	114	0	0	0	0	0	0
	Permanent Vines	0	144	67	29	557	67	7	86	109	0	401		38	343	11	0	0	0	0	0	0
	Annuals Pivot Irrigated	1	370	1 439	25	2 875	2 852	8	251	75	9	148	24		16 209	75	0	0	0	0	5	0
	Annuals Non-Pivot	67	3 994	3 870	1 002	8 904	24 381	163	1 709	112	25	703	110	949		1 865	0	0	0	0	49	0
	Cultivated Subistence	67	2 261	3 002	106	2 646	10 053	37	617	16	146	167	0	15	719		0	0	0	0	19	0
	Residential	112	1 915	3 170	796	2 445	7 874	0	137	171	45	33	11	15	785	423		408	165	192	29	0



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Land categories	1990														
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annuals Pivot Irrigated	Annuals Non-Pivot	Cultivated Subistence
Smallholdings	0	48	238	346	97	366	0	8	1	6	7	10	1	349	38
Commercial	1	65	30	20	51	121	0	8	5	0	1	0	0	11	1
Industrial	1	77	33	19	97	189	0	8	17	0	5	2	0	34	0
Mines	12	357	649	149	545	2 198	234	75	112	13	2	0	27	1 527	59
Subantarctic tundra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polar desert	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.15: Annual land change areas (ha) for 2014-2018 used as a basis for inventory calculations (20-year transition period)

Land categories	2014														
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annuals Pivot Irrigated	Annuals Non-Pivot	Cultivated Subistence
Indigenous Forest	4 693	426	551	1 505	133	475	7	327	132	0	9	0	0	65	39
Thicket / Dense Bush	2 063	204	6 568	1 673	1 740	7 177	142	621	280	1	331	35	69	1 657	1 014
Natural woodland	0	2 939	1 507	1 981	67	179	837	2 573	1 414	1 027	1 516	249	994	9 164	6 778
Planted Forest	46	26	54	391	382	4 765	0	0	25	2	0	0	0	0	0
Shrubland	994	78	169	4 996	591	81	919	2 161	144	615	491	794	377	8 641	46
Grassland		222	371		484		1 010	7 454	5 900	3 395	308	128	905	30	11
														030	650

Land categories	2014															
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annuals Pivot Irrigated	Annuals Non-Pivot	Cultivated Subistence	Residential
Waterbodies	21	1 802	1 064	54	945	2 186		1 901	2 024	26	13	11	14	172	45	60
Wetlands	49	3 553	1 771	354	1 152	12 332	299		114	26	24	19	29	821	189	165
Barren Land	30	6 735	14 724	173	120 767	21 973	1 494	1 392		337	54	59	39	1 100	604	91
Eroded Land	3	398	1 121	9	7 778	5 937	8	63	1 336		0	0	2	48	233	15
Permanent Orchards	6	619	157	125	283	173	10	55	7	0		829	121	1 162	28	0
Permanent Vines	0	235	38	7	244	55	11	31	32	0	63		13	269	0	0
Annuals Pivot Irrigated	1	280	626	13	797	1 065	5	92	12	4	135	20		5 105	19	0
Annuals Non-Pivot	60	3 301	2 571	633	9 532	21 694	83	1 365	173	76	2 937	1 085	1 635		408	0
Cultivated Subistence	101	3 341	8 228	135	500	4 132	8	198	9	355	123	0	31	1 760		0
Residential	52	4 950	3 340	845	3 206	10 944	0	219	368	145	63	65	18	1 234	2 107	
Smallholdings	1	108	345	250	57	301	0	18	3	1	3	1	1	372	15	241
Commercial	1	157	67	14	130	147	0	6	21	1	2	2	0	16	2	1 783
Industrial	1	209	188	19	429	395	0	13	191	2	191	9	30	183	4	834
Mines	10	326	710	58	1 192	1 434	130	56	706	38	1	2	18	447	49	223
Subantarctic tundra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polar desert	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.16: Annual land change areas (ha) for 2018-2020 used as a basis for inventory calculations (20-year transition period)

Land categories	2018															
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annuals Pivot Irrigated	Annuals Non-Pivot	Cultivated Subistence	Residential
Indigenous Forest	2	887	489	71	2 073	27	79	33	0	0	0	0	0	2	0	96
Thicket / Dense Bush	1	129 657	10	5 671	724	11	248	162	1	118	0	58	158	219	339	0
Natural woodland	755	84 677	94	130 694	624	1 868	6 224	474	29 944	4 445	2 121	6	989	15 656	70 530	11 313
Planted Forest	0	1 017	1 853	1 557	15	863	0	0	365	15	0	0	0	0	0	0
Shrubland	60	4 927	47 688	1 595	1 103 458	3 910	224	887 743	2 579	19	19	94	1 194	7	10	0
Grassland	2 410	77 871	327 855	31 151	322 349	14 734	5 248	119 831	6 223	121	7	496	7 038	7 750	170	0
Waterbodies	16	156	4 461	207	6 742	8 511	3 299	9 445	189	18	6	25	615	54	196	0
Wetlands	154	206	613	1 367	1 549	7 725	4 058	1 398	0	3	0	10	89	27	67	0
Barren Land	84	1 280	17 473	212 160	27 355	27 265	13 377	15	0	5	0	8	78	54	17	0
Eroded Land	0	2	1 732	43	2 622	28 023	230	1	389	0	0	0	1	33	0	0
Permanent Orchards	7	759	6 339	1 282	742	1 376	9	83	237	0	23	2 327	8 555	249	0	0
Permanent Vines	0	43	596	14	1 171	161	3	9	92	0	11	16	57	0	0	0
Annuals Pivot Irrigated	0	715	5 525	105	1 241	6 946	20	194	169	24	151	47	20 528	116	0	0
Annuals Non-Pivot	48	2 140	56 466	2 528	13 428	119 605	344	2 760	5 550	137	4 107	63	9 922	6 105	0	0
Cultivated Subistence	48	462	16 598	84	138	23 656	162	186	2 606	1 545	181	0	154	1 205	0	0
Residential	308	1 986	17 786	990	609	8 020	0	75	823	63	6	0	22	479	2 015	48
Commercial	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mine	24	18	2 042	0	0	0	0	0	0	0	0	0	0	0	0	0
Subantarctic tundra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polar desert	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Land categories	2018																					
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annals Pivot Irrigated	Annals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine	Subantarctic tundra	Polar desert
Smallholdings	2	0	16	19	0	5	0	25	0	0	10	0	3	36	157	125		46	82	29	0	0
Commercial	0	11	445	7	10	1 762	0	6	29	0	2	0	0	0	1	34	26		1	38	0	0
Industrial	0	19	467	20	437	1 902	0	15	183	1	30	1	9	166	8	74	75	1		305	0	0
Mines	37	9	955	413	5 031	9 787	1 347	185	738	57	4	2	106	2 220	221	369	13	25	203		0	0
Subantarctic tundra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Polar desert	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 6.17: Annual land change areas (ha) for 2020-2022 used as a basis for inventory calculations (20-year transition period)

Land categories	2020																					
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annals Pivot Irrigated	Annals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine	Subantarctic tundra	Polar desert
Indigenous Forest		6	780	440	78	2 730	9	149	70	0	0	0	0	0	0	262	2	0	0	19	0	0
Thicket / Dense Bush	63		110 629	1	3 795	115 156	128	184	341	1	0	0	0	1	5	3 513	0	11	7	7	0	0
Natural woodland	841	110 037		56	347 782	755 661	2 979	742 519	59 519	5 255	22	7	93	223	6 720	27 519	0	802	548	2 390	0	0
Planted Forest	0	1 344	2 068		1 632	26 286	0	0	423	31	0	0	0	0	0	0	0	0	0	0	0	0
Shrubland	40	4 749	44 263	1 888		34 107	2 434	291 734	734 586	727	16	18	2	133	0	52	0	9	6	4 704	0	0

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Land categories	2020																					
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annuals Pivot Irrigated	Annuals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine	Subantarctic tundra	Polar desert
Grassland	1 057	7 582	914 627	16 831	4 010 564		4 310	5 079	62 471	17 991	30	6	125	1 951	225	465	1	2 502	3 113	20 906	0	0
Waterbodies	79	886	20 145	611 875	15 875	42		13 607	37 257	505	24	16	183	3 213	446	434	149	9	46	2 703	0	0
Wetlands	113	235	797	765	397	10 956	1 774		590	1	1	0	1	7	7	133	42	7	15	126	0	0
Barren land	30	231	14 163	281 295	221 462	49	3 150	882		5	0	0	6	35	17	18	0	2	1	940	0	0
Eroded land	0	0	1 030	15 399	13 399	5 975	61	0	112		0	0	0	0	1	1	0	0	0	151	0	0
Permanent Orchards	0	3	214	21	151	301	7	6	23	0		0	0	115	0	0	0	0	0	5	0	0
Permanent Vines	0	0	10	0	87	32	3	1	13	0	0		0	33	0	0	0	0	0	3	0	0
Annuals Pivot Irrigated	0	81	2 282	57	460	2 745	19	104	21	6	42	0		4 017	207	0	0	0	0	59	0	0
Annuals Non-Pivot	0	297	3 253	959	1 382	7 418	291	216	196	2	2	1	361		2	0	0	0	0	1 139	0	0
Cultivated Subistence	0	38	37 764	1	2	644	47	13	8	3	0	0	0	22		0	0	0	0	168	0	0
Residential	117	379	14 881	571	1 305	16 193	0	69	2 081	290	10	6	13	461	2 311		33	802	46	870	0	0
Smallholdings	2	0	36	19	0	39	0	31	7	0	0	0	0	0	1	205		29	72	27	0	0
Commercial	1	19	573	9	35	1 673	0	6	115	1	1	0	0	12	8	722	28		20	40	0	0
Industrial	0	13	542	29	388	1 958	0	18	543	3	3 748	1 567	174	1 498	19	640	105	86		386	0	0
Mines	25	3	1 074	275	4 082	7 411	1 206	158	1 198	59	2	1	52	1 574	84	375	13	22	294		0	0
Subantarctic tundra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Polar desert	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	



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6.3.4 Land stratification

6.3.4.1 Soils

South Africa's detailed soils map was reclassified into the 7 soil classes provided by IPCC 2006 Guidelines (DEA, 2015) (Figure 6.6). The map was derived from the 1:250 000-scale Land-type Survey of South Africa. This survey mapped over 7 000 unique land types, each of which has a specific combination of soil, terrain form and macroclimate. Within each land-type mapping unit, a number of different soil forms, as well as other land classes, such as rock, stream beds and pans, are recorded, and their percentage within the land type is used to allocate the land type to a specific broad soil pattern. Table 6.18 indicates the soil categories and what criteria was used for their classification. This map does not show organic soils and the inclusion of these is discussed in the section below.

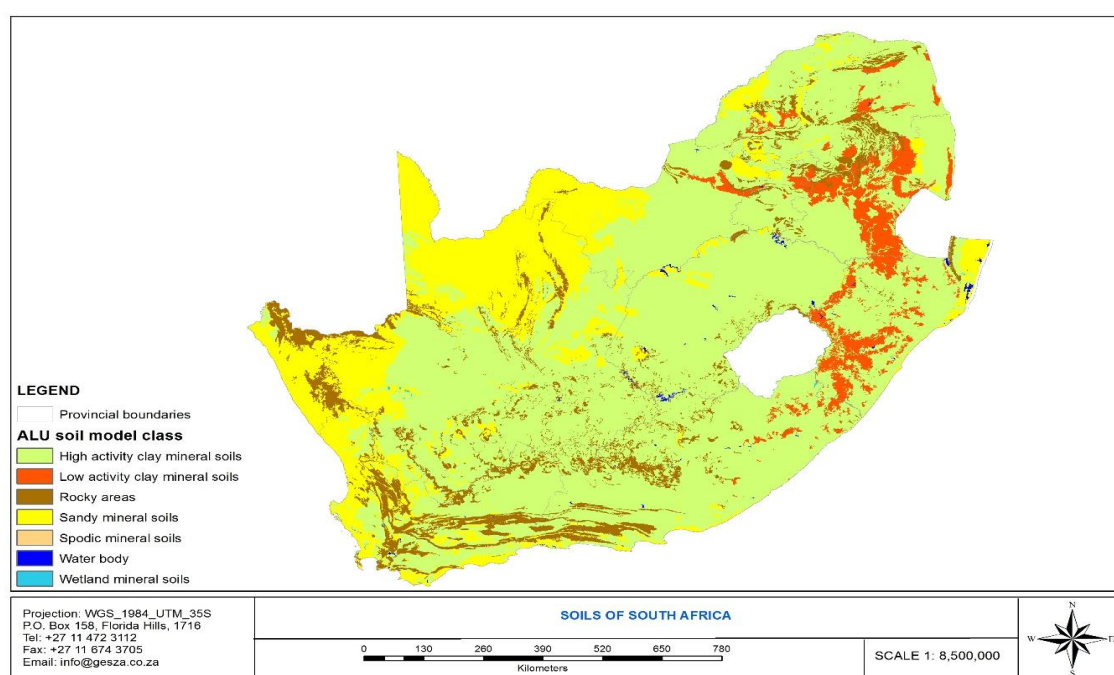


Figure 6.6: South African soils classified into the IPCC classes (DEA, 2015)



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Table 6.18: Soil types and their description (DEA, 2015)

	Description	Criteria
Sandy mineral soils	Sandy mineral soils comprise all soils where the texture class is sandy (<i>irrespective of taxonomy</i>). These areas generally have either sandy parent materials or have been subject to aeolian (wind-blown) deposition (such as the Kalahari sands of the Northern Cape).	Land types where soils with an average topsoil clay content less than 8% comprise more than 40%.
Wetland mineral soils	This map unit comprises all land types where soils with wetland characteristics are dominant. Most land types will have wetland soils in the lower parts of the landscape, but only a few land types have these soils as dominant, mainly in the north-east of KwaZulu-Natal.	Land types where Katspruit and Fernwood (series 30-42) soil forms, along with streambeds and pans, comprise more than 40%.
Organic soils	This map unit comprises all land types dominated by 'peat' soils. These soils typically occur in cool, often upland areas, so their distribution is limited to small zones in KwaZulu-Natal.	Land types where champagne soil forms comprise more than 40%.
Spodic mineral soils	This map unit comprises all land types where podzols (where leaching of iron/aluminium and organic matter has occurred) predominate. These areas are restricted to small zones in the south and south-west of the Western Cape.	Land types where Houwhoek and Lamotte soil forms comprise more than 30%.
Rocky areas		All I _b and I _c land types (rock outcrops more than 60%).
Low activity clay mineral soils	This map unit comprises all land types dominated by highly weathered, apedal (structureless) soils dominated by low activity (1:1) clay minerals such as kaolinite. Only soils where the base status is defined as part of the soil classification could be used, so it is very probable that the extent of such soils is larger than that shown on the map. These soils are found mainly in the warmer, higher rainfall areas, such as KwaZulu-Natal and Mpumalanga.	Land types where Kranskop, Magwa, Inanda, Nomanci, Avalon (series 10-17), Glencoe (series 10-17), Pinedene (series 10-17), Griffin (10-13), Clovelly (series 10-18), Bainsvlei (series 10-17), Hutton (series 10-18) and Shortlands (all series) comprise more than 40%, and where average topsoil clay percentage is more than 8%.
High activity clay mineral soils	This map unit comprises all land types dominated by lightly to moderately weathered soils, dominated by 2:1 silicate clay minerals, including vertisols, mollisols, calcareous soils, shallow soils and various others. This group covers most of South Africa.	Land types not falling into one of the categories given above.

To determine the area of each land class in a particular soil type, the soil type map was combined with the land cover data. The data was processed using a combination of QGIS and an Anaconda Python environment with NumPy and Rasterio packages installed to process the geospatial data. The data processing flow was as follows:



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- Soil type dataset:
 - Geo-reference the soils file (.ovr pyramid structure) to corresponding raster outline of South Africa (EPSG 4326 (WGS84)).
 - Resample the resolution of the soil type raster (50 m) to the highest resolution necessary for the analysis. i.e., the dataset with the smallest resolution (28.986m, SANLC Change Raster).
- Overlay and counts:
 - Convert the raster datasets into arrays for processing. The data sets were set to an equal extent to ensure the layers fit on top of one another.
 - Index spatial extent to assign each pixel in the spatial dataset a value (location) in the array.
 - Code instructed to loop through each array and counts the number of unique pixels that correspond to the unique cells of the other raster data (np.unique = Counts the unique values in the array).
 - A code loop finds the soil type for each corresponding Landcover change class and then counts the number of pixels that occurred.
 - Determine the counts of pixels for each LC Change class corresponding to the unique 7 soil classes of the soil dataset.
 - Export results to excel file and multiply the pixel count by the pixel area (resolution 28.986m x 28.986m = 840.19m²) to give the landcover change class per soil type.
 - Convert m² to ha.
- Reformat data into land change matrix per soil type (i.e. 7 land change matrixes per change period).
- Add in the soil data for overseas territories (see section 6.1.2.2 for soil details).

These overlays use the original SANLC change data, however adjustments were made to these matrixes in excel. These then lead to some misalignments in the overlay data. This will be corrected in future, with the improved land mapping system, so that the original maps are adjusted before the overlays are done. In the meantime, the soil matrix data were normalised to the area of the adjusted matrix areas by dividing the change area by the total change in overlay data and then multiplying this by the change area in the adjusted matrix.

6.3.4.2 Climate

Long term climate maps were developed for South Africa (DEA, 2015) which categorize the climate into the classes provided by IPCC 2006 Guidelines. Four climate types (Figure 6.7) are present for the mainland in South Africa, with the dominant climate being the



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warm, temperate dry climate (99.6% of the area). This was followed by warm, temperate moist (0.2%), cool temperate dry (0.08%) and lastly cool, temperate moist (0.02%). The climate classification is used to select the appropriate emission factors, however South Africa uses country specific data and so incorporating the climate classification has little impact on the emission results. It is however useful to know the classification so that verification can be done with the IPCC default values.

It should be noted that the Prince Edward Islands have their own climate classification. According to the IPCC 2006 Guidelines decision tree in Figure 3A.5.2 and Smith and Mucina (2006) the Prince Edward Islands would fall into the cool, temperate dry category so emission factors in this climate zone were selected for the subantarctic tundra land category.

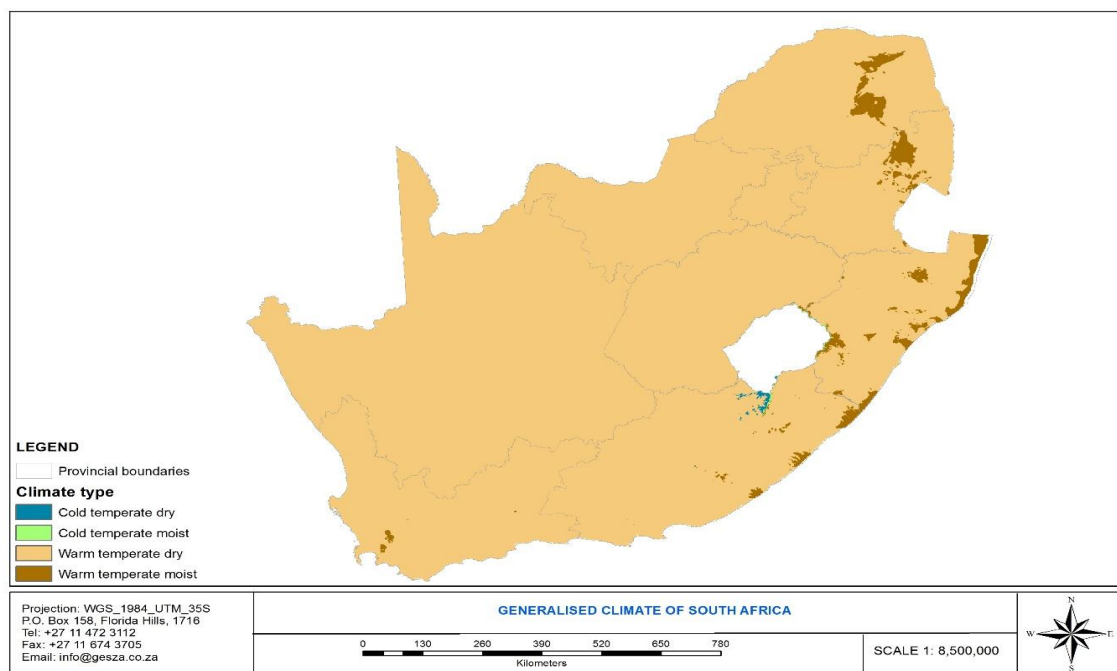


Figure 6.7: South Africa's long term climate map classified into the IPCC climate classes (DEA, 2015)



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6.3.4.3 Ecological zones

IPCC default values are provided based on the climate and ecological zone (ecozone). This is particularly relevant for the *Forest land* category. To enable the selection of the appropriate factor or for purposes of verification the relevant ecozone for each land class was determined. This was done by intersecting the FAO ecozones (Table 6.19), which are those used in the IPCC 2006 Guidelines (see Table 4.1, Volume 4, Chapter 4), with the 2014 land cover map. Results for *Forest land* categories are shown in Table 6.20. In this inventory country specific parameters and emission factors were applied in most cases for *Forest land* so the main purpose of this data was for verification. For other land categories there were some cases where IPCC default values were required and this ecozone data was utilised to create area based weighted averages for the land categories (see details in category specific sections below).

Table 6.19: FAO Global Ecological Zoning framework for 2000 (Simons, 2001; IPCC, 2006)

EZ Level 1 – Domain		EZ Level 2 – Global Ecological Zone		
Name	Criteria (Equivalent to Köppen-Trewartha Climatic groups)	Name (reflecting dominant zonal ^a vegetation)	Code	Criteria (approximate equivalent of Köppen – Trewartha Climatic types, in combination with vegetation physiognomy and one orographic zone within each domain)
Tropical	All months without frost: in marine areas over 18°C	Tropical rain forest	TAr	Wet: 0 – 3 months dry ^b . When dry period, during winter
		Tropical moist deciduous forest	TAwa	Wet/dry: 3 – 5 months dry, during winter
		Tropical dry forest	TAwb	Dry/wet: 5 – 8 months dry, during winter
		Tropical shrubland	TBSh	Semi-Arid: Evaporation > Precipitation
		Tropical desert	TBWh	Arid: All months dry
		Tropical mountain systems	TM	Approximate > 1000 m altitude (local variations)
Subtropical	Eight months or more over 10°C	Subtropical humid forest	SCf	Humid: No dry season
		Subtropical dry forest	SCs	Seasonally Dry: Winter rains, dry summer
		Subtropical steppe	SBSH	Semi-Arid: Evaporation > Precipitation
		Subtropical desert	SBWh	Arid All months dry
		Subtropical mountain systems	SM	Approximate > 800-1000 m altitude
Temperate	Four to eight months over 10°C	Temperate oceanic forest	TeDo	Oceanic climate: coldest month over 0°C
		Temperate continental forest	TeDc	Continental climate: coldest month under 0°C
		Temperate steppe	TeBSk	Semi-Arid: Evaporation > Precipitation
		Temperate desert	TeBWk	Arid: All months dry
		Temperate mountain systems	TeM	Approximate > 800 m altitude
Boreal	Up to 3 months over 10°C	Boreal coniferous forest	Ba	Vegetation physiognomy: coniferous dense forest dominant
		Boreal tundra woodland	Bb	Vegetation physiognomy: woodland and sparse forest dominant
		Boreal mountain systems	BM	Approximate > 600 m altitude
Polar	All months below 10°C	Polar	P	Same as domain level

^a Zonal vegetation: resulting from the variation in environmental, i.e. climatic, conditions in a north south direction.

^b A dry month is defined as the month in which the total of precipitation P expressed in millimeters is equal to or less than twice the mean Temperature in degrees Centigrade.



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In the next inventory the overlay will be updated by intersecting the updated ecozone map (FAO, 2012) with the more recent sentinel derived land cover maps (2018 onwards). In future it is proposed that the spatial ecozone map be incorporated into the developing land mapping system so the zones can be associated with specific pixels and land areas. This could assist in providing further stratification of country specific data and improve the accuracy of the estimates.

Table 6.20: Ecozone classification for each of South Africa's Forest land categories

IPCC ecozone type	Fraction within each ecozone ^a			
	Indigenous forest	Thickets	Woodlands	Forest plantations
Subtropical humid forest	0.49	0.29	0.04	0.15
Subtropical dry forest	0.03	0.09	0.03	0.03
Subtropical mountain system	0.19	0.12	0.08	0.54
Tropical moist deciduous forest	0.07	0.02	0.01	0.01
Tropical dry forest	0.12	0.37	0.52	0.22
Tropical shrubland	0.00	0.01	0.16	0.00
Tropical desert	0.00	0.06	0.13	0.00
Tropical mountain system	0.10	0.04	0.03	0.05

^a Dominant category shown in red; secondary category shown in orange.

6.3.5 Incorporating the 20-year transition period

Each land type is divided into "land remaining land" and "land converted to" that land class. IPCC states that land remains in the land converted to category for the default 20-yr period. After 20 years the converted land moves to the land remaining land category. In this inventory the 20-year transition period was included for each land category. It was assumed that the same annual rate of change occurred prior to 1990, therefore the area of land converted to and land remaining land for each land type in 1990 was calculated as:

$$LC_{i\ 1990} = ALC_{i\ 1990} * 20\ \text{yrs}$$

$$LRL_{i\ 1990} = A_{i\ 1990} - LC_{i\ 1990}$$

Where:



$LC_{i\ 1990}$ = area (ha) of land in land converted to land category i in 1990;

$ALC_{i\ 1990}$ = annual total area (ha) converted to land category i in 1990;

$LRL_{i\ 1990}$ = area (ha) of land in the land remaining in the land category i in 1990;

$A_{i\ 1990}$ = total area of land in category i in 1990.

For subsequent years these categories were calculated as follows:

$LC_{i\ t} = LC_{i\ t-1} + ALC_{i\ t} - ALC_{i\ (t-20)}$

$LRL_{i\ t} = LRL_{i\ t-1} + ALC_{i\ t} - ACF_{i\ t}$

Where:

$LC_{i\ t}$ = area (ha) of land in land converted to land category i in year t ;

$LC_{i\ t-1}$ = area (ha) of land in land converted to land category i in year $t-1$;

$ALC_{i\ t}$ = annual total area (ha) converted to land category i in year t ;

$ALC_{i\ (t-20)}$ = annual total area (ha) converted to land category i in year $t-20$;

$LRL_{i\ t}$ = area (ha) of land in the land remaining in the land category i in year t ;

$LRL_{i\ t-1}$ = area (ha) of land in the land remaining in the land category i in year $t-1$;

$ACF_{i\ t}$ = annual total area (ha) converted from land category i to another land category in year t .

In accordance with the IPCC Approach 2, all land conversions occur from the “land remaining land” categories. In the previous inventory this led to some negative land areas and therefore a correction was added which assumed that some of the conversions occurred from “converted land”. Unfortunately, there were errors in the way this correction was applied. The assumption is true but tracking of land parcels is required to fully implement this approach (Approach 3). Due to the error and the lack of parcel tracking the correction approach was removed in this inventory and the focus shifted to refining the land conversion matrixes (see section 6.3.3.2) prior to applying the 20-year correction. This meant the land conversion areas were smaller and the application of the Approach 2 assumption of all lands being converted from “land remaining land” did not lead to negative land areas. This assumption was therefore reinstated as it aligns more accurately with the IPCC Approach 2 methodology.



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It is acknowledged that land conversions do occur on “converted land” but land parcels need to be tracked to be able to apply the Approach 3 correctly. With the land area challenges, along with requirements to track burnt area, there is a need to shift towards tracking land parcels and moving to Approach 3. This was highlighted as a capacity building need in the UNFCCC TERT review (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L_CBN.4) and has been incorporated into the improvement plan.

This process was applied to each land change matrix (per soil type) to produce a complete time-series of land area per soil type since 1990.

6.3.6 Extrapolation to 2024

It was assumed that the annual change between 2020 and 2022 continued to 2024. In addition, the data from the Annual State of the Climate South Africa (SAWS, 2025) indicates that 2024 was a drier year than 2022. The seasonal variation corrections for a drying year were therefore applied to the 2020-2022 change matrix data to project data to 2024.

6.3.7 Resulting land areas for 1990 - 2024

The time-series of the resulting land areas per land class, which form the activity data for the emission estimates, are provided in the relevant land category sections below. Table 6.21 provides the land change matrix (including the 20-year transition period) for 2024. The diagonal shaded cells represent the land remaining areas while the conversions show the total converted area over the 20-year transition period.

Table 6.21: Land change (ha) matrix for South Africa for 2024 (including 20-year conversion periods)

Land categories	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Permanent Orchards	Permanent Vines	Annuals Pivotal	Annuals Non-Pivotal	Cultivated Subistence	Low shrubland	Grassland	Eroded land	Subantarctic tundra	Waterbodies	Wetlands	Residential	Smallholdings	Commercial	Industrial	Mines	Barren land	Polar desert	Sum of reductions	Additions - reductions
Indigenous Forest	420 517	17 891	14 032	21 933	117	0	3	816	502	4 415	30 268	1	0	440	4 624	3 026	83	40	17	154	1 021	0	99 384	-15 966
Thicket / Dense bush	36 147	4 320 502	1 392 623	59 928	7 195	1 891	1 360	41 180	40 428	301 460	1 026 860	2 340	0	13 904	63 831	44 059	1 724	1 409	1 467	3 121	38 052	0	3 078 978	444 419
Natural woodland	17 411	1 914 375	3 667 349	28 093	13 888	1 253	8 778	160 450	270 780	2 173 282	10 046	42 697	0	40 944	45 705	153 023	3 116	6 457	5 075	23 073	332 344	0	16 235 790	-8 104 309
Planted Forest	0	20 900	25 067	905 186	0	0	0	0	0	13 831	194 930	140	0	0	0	0	0	0	0	0	2 490	0	257 358	187 547
Permanent Orchards	366	13 552	18 906	5 727	246 405	4 787	6 579	35 170	1 753	8 567	8 977	5	0	230	1 300	0	0	0	0	33	689	0	106 641	-21 509
Permanent Vines	0	2 472	2 061	346	4 284	147 814	465	4 746	109	9 240	1 337	0	0	130	1 002	0	0	0	0	19	1 454	0	27 666	188
Annuals Pivotal	11	6 573	37 077	737	2 489	412	486 730	239 638	1 887	36 260	57 648	175	0	215	3 684	0	0	0	0	429	1 215	0	388 451	-319 630
Annuals Non-Pivotal	1 011	58 611	174 925	21 437	26 998	5 567	314 314	9 704 630	32 506	159 550	599 468	831	0	3 816	28 941	0	0	0	0	8 192	13 689	0	1 172 858	83 554
Cultivated Subistence	1 172	37 051	247 185	1 770	2 529	0	579	16 736	1 499 724	28 746	166 943	5 979	0	913	7 388	0	0	0	0	1 189	5 436	0	523 615	-26 896
Low shrubland	1 383	303 977	1 120 844	22 244	4 410	5 189	3 096	204 127	12 514	22 298	6 570 987	89 008	0	36 400	64 561	7 950	539	546	762	37 367	7 081 782	0	15 567 686	3 787 130
Grassland	20 088	1 005 158	4 602 868	235 899	5 524	1 037	7 265	454 905	97 709	13 5863 937	5 863 937	109 629	0	87 621	226 186	47 872	3 227	17 809	21 550	152 280	712 084	0	21 333 590	-526 851
Eroded land	11	2 608	19 599	250	15	1	28	1 354	3 263	82 909	167 607	41 014	0	1 187	522	530	4	7	6	814	7 435	0	288 150	-15 462
Subantarctic tundra	0	0	0	0	0	0	0	0	0	0	0	0	22 534	0	0	0	0	0	0	0	0	0	0	0
Waterbodies	357	14 789	67 791	2 928	260	216	860	16 165	2 526	68 415	139 400	1 970	0	175 262	53 298	2 605	799	72	320	16 563	132 240	0	521 578	-178 369
Wetlands	1 772	29 701	19 465	15 141	459	325	313	17 439	1 478	25 561	755	874	0	44 092	713 203	2 670	662	130	228	1 778	9 991	0	333 836	185 176



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Land categories	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Permanent Orchards	Permanent Vines	Annals Pivot Irrigated	Annals Non-Pivot	Cultivated Subistence	Low shrubland	Grassland	Eroded land	Subantarctic tundra	Waterbodies	Wetlands	Residential	Smallholdings	Commercial	Industrial	Mines	Barren land	Polar desert	Sum of reductions	Additions - reductions
Residential	2 406	44 437	140 153	15 603	636	394	315	15 593	25 931	43 708	203 326	2 321	0	0	2 676	2 232 963	5 194	5 853	2 211	5 325	13 155	0	529 237	-239 741
Smallholdings	21	915	3 937	4 575	101	111	18	5 053	757	1 195	5 027	66	0	0	323	2 238	232 550	257	561	185	50	0	25 391	-8 356
Commercial	19	1 371	3 751	305	31	12	3	223	50	1 195	12 014	11	0	0	140	14 418	15 471	15 650	540	284	655	0	35 493	-2 061
Industrial	13	1 700	4 184	423	15 863	6 326	833	7 393	107	5 118	105	24	0	0	239	6 535	1 017	514	21 837	2 666	3 473	0	71 532	-36 268
Mines	333	4 907	15 536	3 654	45	16	762	792	1 561	36 605	76 928	637	0	10 373	1 979	3 479	142	220	2 191	41 811	10 212	0	197 374	62 920
Barren land	895	42 408	221 477	3 911	286	316	250	7 632	2 855	2 829 920	373 111	15 979	0	102 945	12 615	1 091	57	118	295	6 822	4 521 323	0	3 622 985	4 744 485
Polar desert	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10 966	0	0	
Sum of additions	83 418	3 523 397	8 131 482	444 905	85 131	27 854	68 821	1 256 412	496 719	19 354 816	20 806 740	272 688	0	343 209	519 012	289 496	17 035	33 432	35 264	260 293	8 367 470	0		
Sum for land category	503 935	7 843 899	11 798 831	1 350 091	331 536	175 668	555 551	10 961 042	1 996 442	41 653 048	26 670 676	313 702	22 534	518 471	1 232 215	2 522 459	249 585	49 082	57 100	302 104	12 888 793	10 966		
Total land area	122 007 731																							



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6.4 General emission/removal methodologies and data preparation

This section describes the general methodologies, along with stratification and data preparation processes, required to prepare the LULUCF emission estimates. Further category specific details are provided in sections 6.6 to 6.11.

6.4.1 Carbon emissions from biomass (CRT 4.A to 4.F)

South Africa used a combination of Tier 1, and Tier 2 methods for estimating emissions for the LULUCF sector. There are two methods for estimating carbon stock changes in biomass, namely the Gain-loss method and the Stock-difference method. The Stock-difference method requires carbon stock inventories for a given land area, at two points in time. This method is applicable in countries that have national inventory systems for forests and other land-use categories where the stocks of different biomass pools are measured at periodic intervals (IPCC, 2006). South Africa does not have a forest inventory and so the Gain-loss method was applied.

For the “land remaining” category in *Forest land*, *Cropland*, *Grasslands* and *Wetlands* the annual increases in biomass carbon stocks were estimated using equation 2.9 of the IPCC 2006 Guidelines, where the mean annual biomass growth was estimated using equation 2.10 (Tier 1 approach) but with country specific data. For forest plantations the Tier 2 approach of this equation was applied. For *Settlements* equation 8.2 was applied. For pure grasslands the assumption of equivalence was applied (Tier 1), however the *Grassland* category also incorporates low shrublands which has a small shrub element that was included. For *Wetlands* and *Other lands* the Tier 1 assumption of equivalence was applied. The above-ground biomass and biomass gains for all woody or perennial land categories were sourced from the scientific literature. Literature was also relied on for root to shoot ratios so that below-ground biomass could be determined. Data on MAI for estimating growth in forest plantations were obtained from collected forestry data.

The annual decrease in carbon stocks due to disturbance losses were estimated from IPCC 2006 Guidelines equations 2.11 to 2.14 (IPCC, 2006). Fire disturbance losses (from both wildfires and controlled fires) were incorporated for *Forest land*, *Croplands*, *Grassland*, *Wetlands*, and *Settlements*. *Other lands* were assumed not to burn due to the lack of biomass on these lands. The burnt area estimation is discussed under section 6.4.7.1.



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Harvest losses were included for forest plantations and perennial crops, while the woodland/open bush category included fuelwood collection losses. Forest plantations were the only category where other losses (such as losses due to insects and climate) were included due to a lack of data in other land categories.

The IPCC 2006 Guidelines equations 2.15 and 20.16 were utilised for estimating emissions from biomass changes on converted land. A Tier 2 approach was applied as country specific biomass stocks were utilised and natural land classes²³ were not assumed to be cleared but rather transition slowly from initial to final biomass levels. Land was only assumed to be cleared for forest plantations, croplands and settlements, so carbon stocks immediately after conversion were set to zero. For land transitions to land categories with woody components the carbon growth values were used and carbon was gained over the 20-default transition period. Woody losses were assumed to be immediate and were accounted for in the year of conversion. Growth in converted lands was estimated using the growth rates for the various land categories.

6.4.2 Carbon emissions from litter and deadwood (CRT 4.A to 4.F)

The dead organic matter (DOM) pool includes litter and deadwood for *Forest lands* and wooded *Grasslands*, while only litter is included for all other land classes. It is assumed that there are no DOM changes in “land remaining” categories (Tier 1) unless otherwise state in the category specific sections, and it is assumed that in “converted land” all litter pool carbon losses occur entirely in the year of transition (Tier 1). The IPCC 2006 Guidelines equation 2.23 was used to estimate changes in litter in converted land. Litter and deadwood estimates for the various land categories were determined from literature or from intersecting the SANLC data with the National Terrestrial Carbon Sinks Atlas (NTCSA) carbon density maps (DEFF, 2020) and are provided in the relevant land category sections below.

²³ This refers to land cover classes rather than land use classes, such as indigenous forests, thickets, woodlands, grasslands, low shrublands, wetlands and other lands.



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6.4.3 Emissions from soils (CRT 4.A to 4.F)

6.4.3.1 Mineral soils

Annual SOC change for each land use category was determined by applying IPCC 2006 Guidelines equation 2.25 (Formulation B). This combines the SOC reference data for each soil type with the stock change factor for each vegetation type.

The land cover/use maps were stratified by soil type (see section 6.3.4.1) to obtain a land change matrix per soil type.

SOC reference data was determined from the ISRIC dataset. The ISRIC (2017) soil organic carbon stock at 30 cm depth²⁴, which is based on many data points in South Africa, was used as the SOC reference data. A soil carbon value for each soil type was determined by extracting the ISRIC SOC to fit the South African boundary (South African Boundary shapefile (2018)) obtained from the Municipal Demarcation Board²⁵. This was then re-projected to match the same co-ordinates as the land cover dataset (UTM 35 S). The SOC data set was re-sampled to change the cell size from 250 x 250 m to 100 x 100m to match the soil map. The soil data was sub-divided to create a stand-alone file for each soil type, and the SOC data was extracted for each soil type to determine a SOC reference value for each soil type (weighted average SOC per soil type using the 'Value' (t/ha) and counts or number of cells that match the value). Only data for "land remaining land" categories were used as the reference values is a SOC value without any land conversions. Since the Prince Edward Islands were not included in this analysis due to a lack of spatial data, no value was determined for volcanic soils. In this case the IPCC 2019 Refinement value for cool, temperate dry climate was applied. The resulting SOC reference values are shown in Table 6.22.

Table 6.22: Soil carbon reference data per soil type as obtained from ISRIC database

	SOC reference value (t C/ha)	IPCC 2006 default ²⁶	IPCC 2019 Refinement
Sandy mineral soils	20.85	19	10 ±5%
Wetland soils	40.53	88	74 ±17%

²⁴

<https://data.isric.org/geonetwork/srv/enq/catalogue.search?sessionId=D59E70CBD401A199C806783D11B4B656#/metadata/ea80098c-bb18-44d8-84dc-a8a1fbadc061>

²⁵ <https://dataportal-mdb-sa.opendata.arcgis.com/search?tags=2018>

²⁶ Defaults are for warm, temperate climates



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	SOC reference value (t C/ha)	IPCC 2006 default ²⁶	IPCC 2019 Refinement
Spodic soils	71.65	115 ²⁷	143 ±30%
Rocky soils	47.03	NA	NA
Low activity clay	65.54	24	19 ±16%
High activity clay	35.21	38	24 ±5%
Volcanic	20.00		20 ±90%

Comparisons were made with the IPCC data (Table 6.22) and this shows that the country specific values for wetlands mineral soils and spodic soils are lower than the IPCC default values, but for low activity clay the value is much higher. The values for sandy soil and high activity clay are within the IPCC default range, and these two soils cover the majority of the land area (19.8% and 66.4% respectively). The differences, particularly with the IPCC 2019 Refinement defaults, could be because the data is outdated as the soil data was from 2017, and the overlay was with the lower resolution 2014 land cover map. An update of the SOC reference data has been put on the improvement list (section 6.1.6) for updating in the next inventory cycle. The impact of changing to the IPCC 2019 Refinement default values is a 0.5% decrease in the sink in 2024 so improving this data set would have a small impact on the overall emissions.

IPCC 2006 Guidelines default values are the main source of the stock change factors, although some country specific values (particularly for croplands) are applied and these are all described in the various land category sections below.

6.4.3.2 Organic soils

Inclusion of estimates for organic soils in *Croplands* and *Grasslands* is an improvement that has been incorporated in the 1990-2024 inventory. Literature indicates that high organic soils are in Kwa-Zulu Natal (KZN) Province (Schutte, et al., 2019; Moeletsi, et al., 2015) therefore this inventory focussed on identifying and incorporating organic soils in this province. In the next inventory a more complete assessment of organic soils will be included.

The initial mapping of organic soils for KZN province involved raster data processing and analysis using the soil type map, ISRIC 20m Total Soil Organic Carbon for 2018, SANLC datasets and the SANBI Vegmap bioregions layer. A threshold of >200 t/ha in the Total Soil Organic Carbon 2018 raster dataset was used to extract areas with higher organic

²⁷ This is the default value for cold, temperate climates as there is no value for warm, temperate environments.



soil values and used as an initial mask. This Total Soil Organic Carbon 2018 high organic soils mask was then used to intersect areas within the grassland biome of the SANBI vegmap, as well as with the cropland and wetland areas in the SANLC maps. The focus on these biomes was because the FAOSTAT data provided drained organic soil areas for these land categories. Again, a more extensive organic soil assessment going beyond these land categories will be completed in the next inventory.

As the organic soils have not yet been incorporated into the overall soil type map the next step was to identify what soil types these organic soils were associated with in the soil type map. An overlay of the soil type and organic soil map for KZN showed that organic soils were classified as high and low activity clays (with a close to 50% split) in the soil type map. To maintain the consistent land area the organic soil area was subtracted equally from the high and low activity clay soils in *Croplands* and *Grasslands* thereby incorporating organic soils into the matrix. The *Cropland* organic soil area was determined to be 59 041 ha, while for *Grasslands* it was 427 410 ha.

6.4.4 Direct and indirect N₂O emissions from nitrogen inputs to managed lands (CRT 4(I))

Direct N₂O from nitrogen inputs to managed soils were estimated using IPCC 2006 Guidelines equations 11.1-11.6, while indirect emissions were estimated from equations 11.9 -11.11. These emissions were only included for Forest lands and Croplands due to a lack of data in other land categories. Emissions for Croplands were not included in the LULUCF sector but are rather reported in the Agriculture sector under 3.D.1.

6.4.5 Emissions and removals from drainage, rewetting and other management of soils (CRT 4(II))

The area of drained organic soils for *Grasslands* and *Croplands* was obtained from FAOSTAT and CH₄ emissions were estimated using Equation 2.4 of the IPCC 2013 Wetland Supplement (IPCC, 2014). There was insufficient data on drained organic soils in the other land categories so these were not estimated in this inventory.

Methane from rewetted inland wetland mineral soils were estimated for the wetland category. Rewetted areas were considered to be those that were converted from other lands to wetlands. Emissions were estimated with equation 5.1 from the IPCC 2013 Wetland Supplement (IPCC, 2014a).

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6.4.6 Direct and indirect N₂O emissions from N mineralisation/immobilisation associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (CRT 4(III))

Direct N₂O emissions in this category were estimated based on IPCC 2006 Guidelines equations 11.1, 11.2 and 11.8. Indirect N₂O emission estimates were determined by applying IPCC 2006 Guidelines equations 11.9 and 11.10. Direct and indirect emissions for *Croplands remaining croplands* are included under the Agriculture sector (3.D.1.e).

6.4.7 Biomass burning (CRT 4(IV))

6.4.7.1 Burnt area data processing

Burnt area data for the time-series has been developing over time and as technology has evolved. The MODIS Collection 5 Burnt Area data was utilised for the 2017 inventory (2000-2017). At the time of the 2017 inventory the land cover maps had 17 land categories. In the following inventory (2000-2019) land cover maps were updated to include more disaggregated settlement classes bringing the total number of land categories to 20. An updated 1990 and 2014 land cover map, as well as the 2018 map, were released. During this inventory the burnt area was also updated to utilise the MODIS Collection 6 Burned Area Product Geotiff version (<http://modis-fire.umd.edu/pages/BurnedArea.php?target=GeoTIFF>). This product is a level 3 gridded 500 m product, and the quality of the information is described in Giglio et al. (2018). Monthly data was combined to obtain annual burnt area maps for each year. Each year's dataset was clipped (extract by mask) to the actual South African boundary. The burnt area maps were intersected with the SANLC data to obtain burnt area per land class. Land cover maps are not available for every year, so the 2014 map was intersected with the burnt areas for 2000 to 2014, the 2018 intersected with the years 2015-2020.

Due to time limitations not all the past years could be reanalysed using the Collection 6 data. The years 2001, 2005, 2010 and 2014 – 2020 were analysed and for the in between years the previous Collection 5 data was used as a proxy and the IPCC splicing technique was applied to adjust the years in between. As the updated data made use of the 20 category maps it could be used to include the additional settlement categories in the in between years. This was done by applying the average fraction of the total settlements allocated to each disaggregated class. This produced a consistent time series between

2000 and 2020 for all 20 land categories. There was very little difference in the two data sets for the years since 2010 (<1%), but there was a 15% difference for the 2001 dataset (Figure 6.8).

For the 2000-2022 inventory land cover and burnt area data overlays were not completed. The total burnt area from MODIS for 2021 was obtained and disaggregated by land class by using the same ratio to the total as found in 2020. The 2022 burnt area data was not yet available, so this data was estimated based on average burnt area for the previous 5 years.

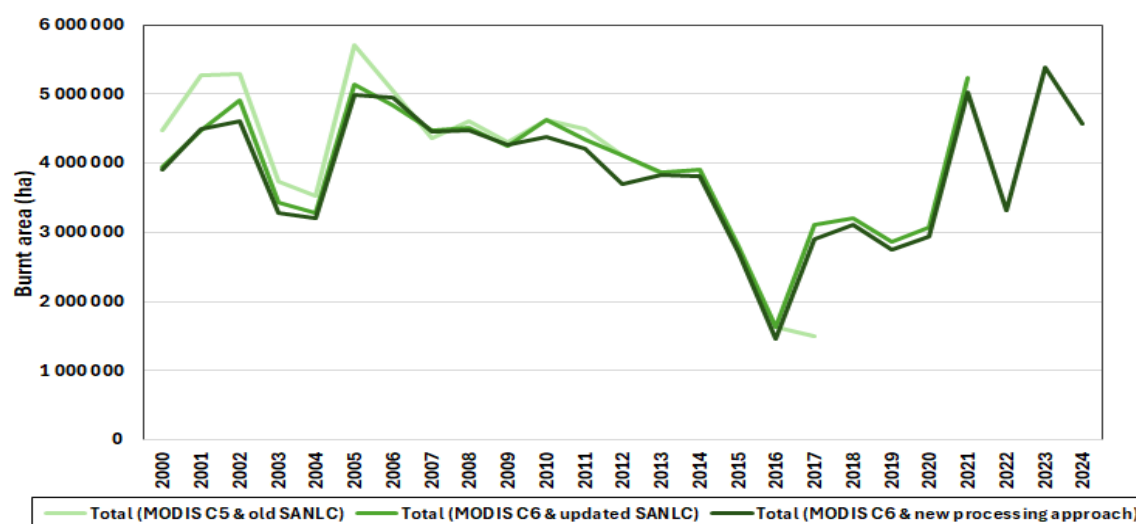


Figure 6.8: Progression and comparison of the burnt area data estimates from the application of updated approaches over time

In this current inventory for 2024 a change in processing methodology was applied. Tracking land parcels is becoming more important and there are plans to develop an improved mapping system for the LULUCF sector. This is to reduce small inconsistencies in all the base maps and overlay processes and to increase automation so all corrections are applied consistently through the time series and in future updates. One way to do this is through georeferencing of all input maps. In this inventory the land cover, soil and burnt area maps were georeferenced, and a programme developed to automate the overlay system. The MCD64A1 Burned Area Product (hereafter the MCD64A1) is a



monthly, Level-3 gridded 500-m product containing per-pixel burning and quality information, and tile-level metadata. The MCD64A1 files (window 13 files) were downloaded directly from the USGS servers for the 2018 to 2024 annual periods. (Window 13 of the MCD64A1 contains southern Africa). The original soil map from previous inventories (Moeletsi et al., 2015) was utilised along with the 2018, 2020 and 2022 SANLC maps (downloaded from <https://www.dffe.gov.za/egis>). The data was processed using a combination of QGIS and an Anaconda Python environment with NumPy and Rasterio packages installed to process the geospatial data (see Annex V for Burnt Area Data Processing Workflow).

This new processing approach was used to determine burnt area for the years 2018 to 2024. The 2018 and 2019 burnt area was overlaid with the 2018 SANLC, 2020 and 2021 against the 2020 SANLC and 2022-2024 against the 2022 SANLC. As it is a new approach the years 2018-2020 were completed to ensure there is an overlap for comparison. The total burnt area for both methods was very similar (Figure ??), however there was found to be some differences in the area burnt per land category. The largest changes being a reduction in burnt area in thickets, low shrublands and indigenous forests (83%, 43% and 14% respectively) and an increase in burnt area in grasslands and woodlands (235 and 4% respectively). These updates do appear to be an improvement as thickets and indigenous forests are not fire-prone vegetation types (DEAT, 2009; Forsyth & Le Maitre, 2019; Van Wilgen, 2025) and fires are classed as rare. The updated values, therefore, bring the data more into alignment with this concept. For this reason, the IPCC overlap splicing technique was applied to years 2000 – 2017 using 2018-2020 data to ensure time series-consistency. In future the new processing approach will be applied to years prior to 2018 and data will replace the spliced dataset.

In the previous inventory it was assumed that flooded lands and *Other lands* (barren land) do not burn due to the lack of vegetation. This assumption is carried through for barren land, but for flooded land it is assumed that the burning occurs on the converted land. Lastly, the MODIS burnt area data for forest plantations is replaced by ground based data on fires in forest plantations obtained from Forestry SA (<https://forestry.co.za/industry-info/statistical-data/>).

To estimate the burnt area per land conversion category, the fraction of the land class that was burnt was assumed to occur evenly across all conversions, so the fraction was applied to each land conversion area.

6.4.7.2 Back extrapolation of burnt area data from 2000 to 1990

MODIS burnt area data is only available from 2001, therefore extrapolation is needed to extent the time series back to 1990. FAO provides data on burnt area for forests, savannas and grasslands from 1990 to 2023 (<https://www.fao.org/faostat/en/#data/GI>). The exact definitions of the various land categories may differ from FAO, however the total burnt area data for forest, savannas and grasslands shows a similar trend to that of forests, savannas and grasslands in this inventory (Figure 6.9). This data was therefore used as proxy data to extend the timeline for forests, savannas and grasslands back to 1990.

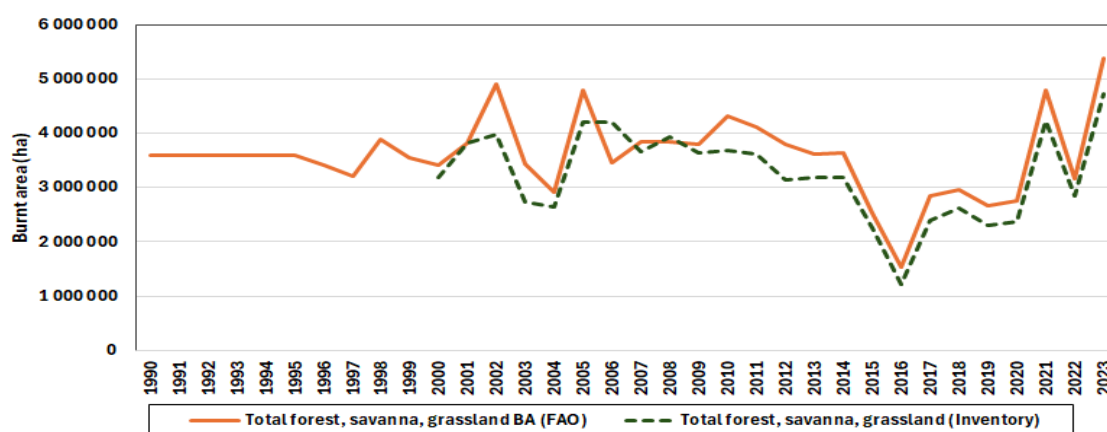


Figure 6.9: A comparison of MODIS and FAO burnt area data for forests, savannas and grasslands

As the category definitions are different between FAO and the SANLC data it was difficult to match the data for the specific categories. It was found that FAO forest burnt area trends were the same as burnt area trends for Indigenous forests and forest plantations combined. FAO shrubland burnt area had the same trends as the inventory low shrubland category. Comparing the savanna and grassland categories the differences were larger due to the different classifications, however the total savanna and grassland burnt area from FAO corresponded well to the savanna and grassland burnt inventory for the inventory. These groupings were therefore used with the IPCC overlap splicing technique to extend the timeseries to 1990. Splitting this aggregated data into the specific land categories was done by applying the average (2001-2005) ratio of the burnt area of that



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category to the total for the grouping by the total FAO burnt area total for that grouping. For forest plantations, ground-based data is available back to 1990, so this actual data is applied. Indigenous forest data was therefore the total FAO burnt area for forests and forest plantations minus the actual plantation burnt area data²⁸. This was the approach for indigenous forests, forest plantations, thickets, woodlands, grasslands, low shrublands and eroded land. For all other land categories and average burnt area for the period 2001 to 2010 was applied to the years 1990-1999.

The resulting burnt area activity data for all land categories across the full time series (1990 – 2024) are provided in the relevant land category sections below.

6.4.7.3 Verification

Burnt area data was compared to those from the Meraka Institute (Meraka Institute, 2019) for 2014-2018 who also used the MODIS collection 6 data. The Meraka Institute dataset shows the same trend but the inventory burnt area estimates are about 20% higher than the Meraka Institute data. Data was also compared to the SASSCAL data²⁹ and again the annual burnt area trends are the same, with the inventory data being 3.2% lower than the SASSCAL burnt area data. Also discussed above, the burnt area for forests, savannas and grasslands was compared to the FAO data and the inventory data is on average 10.2% lower than the FAO data. Differences between the dataset are likely due to different processing methods and because the inventory data includes an overlay with soil and land cover data. The overlay process can lead to a small loss of burnt area due to the different resolutions of the input data sets. The inventory data is, however, within the ranges provided in the literature.

6.5 Country specific approaches

6.5.1 Approach for natural disturbance

The total emissions and removals reported for South Africa in this NID **include** natural disturbance. This is being clarified due to a recommendation made by the TERT (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L.5). The NDC on the other hand, sets out emission targets based on the emissions excluding natural disturbance. It is stipulated

²⁸ It was found that the indigenous forest burnt area data for 1996-2000 was very high and was uncharacteristic as indigenous forests mostly do not burn. For this reason, the FAO proxy data for these years was replaced by an average burnt area for 2001-2010 as done for other categories. The FAO data for 1990-1996 was still higher than usual but left this data as is. This could perhaps be improved in future if other data becomes available.

²⁹ <https://sasscal.org/wp-content/uploads/2024/06/SASSCAL-Burnt-area-20240603.pdf>



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that this separation is to be reported in the NID so this section explains the methodology used for separating out natural disturbance (for NDC purposes) and provides the relevant data for the NDC in Annex VII. The explanation of the methodology is also in response to the TERT recommendation (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L.5).

Natural disturbance includes all the emissions and removals associated with wildfires and any other non-anthropogenic events affecting forest plantations (such as losses due to storms, windthrow, animals and disease). There is insufficient data on other disturbances (besides fire) in the other land classes and so these are not included in the inventory or this natural disturbance.

Estimating the overall impact of natural disturbance involves estimating the biomass losses (which usually occur immediately) and subsequent gains (which usually occur over time) related to natural disturbance events. There is insufficient disaggregation at this stage to include DOM and SOC. The gains and losses are summed to obtain the overall impact of disturbances. This can then be subtracted from the overall LULUCF emissions (including natural disturbance).

The losses (emissions) due to natural disturbance include:

- Emissions of CH₄, N₂O, NO_x, CO and NMVOC from wildfires.
- Woody vegetation biomass losses (as CO₂) due to wildfires and other disturbances.

The gains are all the vegetation growth that occurs on the disturbed areas. The IPCC 2006 Guidelines indicates that the gains on that disturbed area are to be removed as part of natural disturbance until such time as the carbon returns to the original level. As South Africa does not track land parcels this becomes a bit more challenging, as some areas may burn more than once in the time that it takes to gain the carbon back. A land system to track land change and disturbance is included in the improvement plan (a recommendation from the TERT) but for now the gains have been estimated using a more simplistic approach. The following steps were followed:

- Estimate the amount of carbon lost on the burnt area per land class.
- Using the growth rates estimate the number of years it would take for the carbon to return to original levels.
- Allow the carbon to grow on the annual disturbed areas at the given growth rate for the determined number of years.
- After this any further gains are not included under natural disturbance but rather move to the main inventory of anthropogenic emissions and removals.



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This basic method uses the assumption that no burning occurs on a disturbed area that is recovering before it has reached the original carbon level. This assumption is most likely not realistic, and probably leads to an overestimation of the gains, but these assumptions will be improved once South Africa is able to track the fires and land use changes.

The inclusion of the removal of the subsequent gains on disturbed lands was not done in the previous inventory, therefore the overall LULUCF sink (excluding natural disturbance) (Figure 6.10) is reduced compared to that reporting the previous NID.

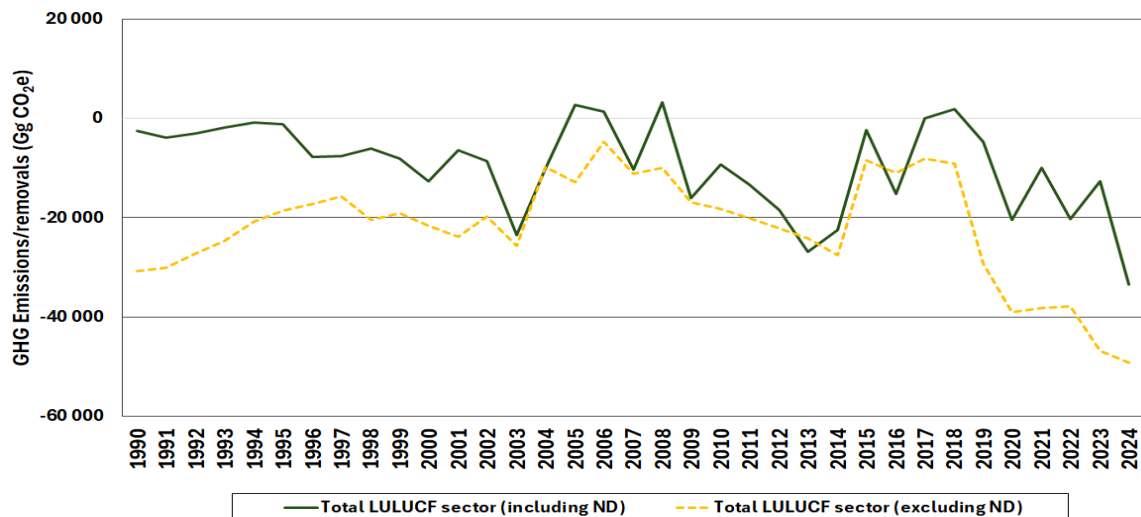


Figure 6.10: LULUCF sector sink with and without natural disturbance

6.5.2 Approach for harvested wood products

In this inventory the production approach was applied to estimate HWP emissions, but this was also compared to the other approaches (Atmospheric flow, Simple decay, Stock difference). The IPCC 2019 Refinement methodology was applied, which is largely the same as the IPCC 2006 Guidelines methodology, but it gives better guidance on the calculation of the initial carbon stock in the HWP pool. HWP in SWDS are not included in this inventory. The HWP estimates were compared to the emission estimates using the



IPCC software which applies the IPCC 2006 Guidelines methodology. Details are provided in section 6.12.

6.6 Forest land (CRT 4.A.)

6.6.1 Category description

The *Forest land* category is subdivided into *Forest land remaining Forest land* (4.A.1) and *Land converted to Forest land* (4.A.2). Calculations were carried out based on a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years. Both sub-categories are key categories for CO₂ emissions and removals in terms of the level and trend assessment.

Emissions in *Forest land* include CO₂ emissions/removals from above- and below-ground biomass, litter, deadwood and mineral soils. Organic soil area in *Forest land* was not separated out due to a lack of data so all soils were treated as mineral soils. It also covers direct and indirect N₂O emissions from nitrogen inputs and mineralisation in mineral soils. Finally, it includes CH₄ and N₂O emissions from wildfires. Indirect emissions from wildfires were also estimated but these are reported under indirect CO₂ and N₂O in Chapter 8 of this report.

The *Forest land* category covers indigenous forests, forest plantations, thickets (including mangroves), and woodlands.

The *Forest land* is a sink of 55 037 Gg CO₂e in 2024, which is more than a 2-fold increase since 1990 (Table 6.23). Biomass is the dominant pool in 2024, followed by DOM. *Grasslands converted to Forest land* contributed the most towards the *Forest land* sink (Figure 6.11). The larger *Forest land remaining Forest land* emissions between 1990 and 2000 are related to the much higher burnt area estimates for this period. These values were extrapolated from FAO data and so another data source may need to be found to update or verify this data.



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Table 6.23: Forest land emissions for 1990 and 2024

Category	Pool	Gas	1990	2024	Change between 1990-2024 (%)
			Emissions (Gg CO ₂ e)	Emissions (Gg CO ₂ e)	
Forest land	All	All	-15 260	-55 037	260.7
Forest land	All	CO ₂	-16 075	-55 744	246.8
Forest land	All	CH ₄	487	399	-18.1
Forest land	All	N ₂ O	328	309	-5.9
Forest land remaining	All	All	20 235	8 487	-58.1
Land converted to Forest land	All	All	-35 495	-63 523	79.0
Forest land	Biomass	All	-7 645	-42 129	451.0
Forest land	DOM	All	-8 084	-12 508	54.7
Forest land	Mineral soil	All	-346	-1 107	220.1

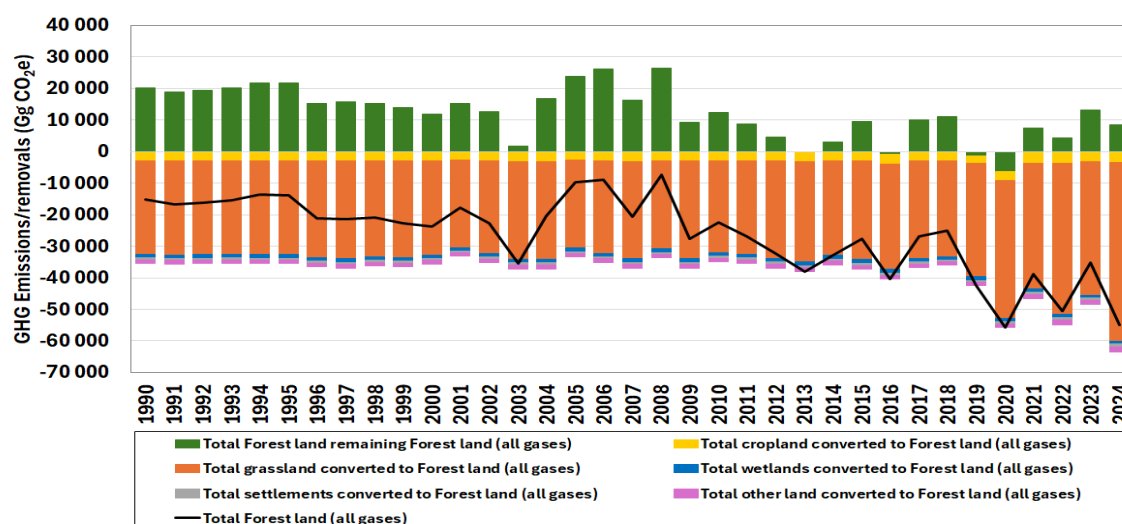


Figure 6.11: Forest land emission trends between 1990 and 2024



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6.6.2 Methodological issues

The methodologies and emission factors applied to *Forest lands* are provided in Table 6.24. In the previous inventory both *Forest land remaining Forest land* and *Land converted to Forest Land* were identified as key categories and, based on the IPCC decision tree, the Tier 2 approach is suitable for this category.

Table 6.24: Methodologies and EF applied for estimating emissions from *Forest land*

Category	Gas	Method used	Source of activity data	Emission factor used
Forest land remaining Forest land	CO ₂	Tier 2	CS	CS
Forest land remaining Forest land	CH ₄	Tier 1/Tier 2	CS	D
Forest land remaining Forest land	N ₂ O	Tier 1/Tier 2	CS	D
Land converted to Forest land	CO ₂	Tier 2	CS	D/CS
Land converted to Forest land	CH ₄	Tier 1/Tier 2	CS	D
Land converted to Forest land	N ₂ O	Tier 1/Tier 2	CS	D

(NO = Not occurring; NA = Not applicable; CS = Country specific; D = IPCC default)

The Stock-Difference approach was considered for forest plantations, but due to the fact that (a) detailed age-class population data from DFFE was only available from 2001 (therefore stock change data from 2002 only) and (b) land conversion losses were not fully incorporated into this methodology at this stage the Stock-Difference approach was used as verification and is discussed in more detail in section 6.6.5.

6.6.2.1 Land area activity data

The activity data was country specific land area data determined as outlined in section 6.3 with an Approach 2 methodology and included areas for both *Forest land remaining Forest land* and *Land converted to Forest land* (Table 6.25).



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Table 6.25: Country specific land areas (kha) (including 20-year transition period) for Forest land

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Forest land remaining Forest land</i>	12 613	12 733	12 853	12 973	13 093	13 213	13 333	13 453	13 573
<i>Land converted to Forest land</i>	7 204	7 204	7 204	7 204	7 204	7 204	7 204	7 204	7 204
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Forest land remaining Forest land</i>	13 693	13 813	13 933	14 053	14 173	14 293	14 413	14 533	14 653
<i>Land converted to Forest land</i>	7 204	7 204	7 204	7 204	7 204	7 204	7 204	7 204	7 204
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Forest land remaining Forest land</i>	14 773	14 893	15 013	15 133	15 253	15 373	15 493	15 454	15 415
<i>Land converted to Forest land</i>	7 204	7 204	7 204	7 204	7 204	7 204	7 204	7 139	7 074
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Forest land remaining Forest land</i>	15 377	15 338	15 059	14 780	14 046	13 312	13 087	12 862	
<i>Land converted to Forest land</i>	7 010	6 945	8 769	10 593	11 597	12 602	14 363	16 123	

6.6.2.2 Biomass gains

6.6.2.2.1 *Indigenous forests, thickets and woodlands*

In *Forest land remaining Forest land* the biomass gains were determined using the IPCC 2006 Guidelines gain-loss equations 2.9 and 2.10 with country specific data. Indigenous forests were divided into primary and secondary forest so that different growth rates and biomass data could be applied. There was no data on the area of primary forests and so in the last inventory protected area was used as a proxy for primary forests. On further investigation, this was likely an overestimate. Widespread logging was practiced during the mid-1800s to early 1900s (Fisher, 2024; Lawes, et al., 2007) and as a result these areas are classified as secondary forests. Very few primary forests remain in South Africa and protected areas include both primary and secondary forests (Fisher, 2024). Primary forest area was therefore assumed to be 10% of the indigenous forest area which is less than the protected area. All thickets and woodlands were assumed to be secondary forests.



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Parameters for estimating carbon gains were obtained from scientific literature. Indigenous forests were divided into the forest types provided in the 2006 SANBI Vegmap (Mucina, et al., 2007) and area weighted averages of the various factors were calculated for Indigenous forests in general. For thickets a similar weighting process was followed except that there was insufficient data for the numerous thicket types indicated in the Vegmap. There was data on Albany thickets, other thickets (areas obtained from SANLC map intersected with Vegmap) as well as Mangroves (as these are included within the Thicket/Dense bush class). Albany thickets were further divided into intact and degraded thickets assuming 52% of the area was degraded based on information from Carvalho, et al. (2022). The weighting for thickets was therefore based on these categories. For woodlands the two divisions provided in the SANLC maps, namely Dense forest and woodland, and Open woodland, were utilised. The resultant weighted averages are provided in Table 6.26 with additional background data in Annex V. Values are within the range of the IPCC 2019 Refinement default factors. The IPCC 2006 Guidelines default carbon fraction of 0.47 t C/t dm for all tree parts in tropical and subtropical vegetation (IPCC 2006, Volume 4, Chapter 4, Table 4.3) was applied.

Table 6.26: Forest land biomass growth parameters

Forest class	Forest age	Annual AGB growth (G _w) (t dm/ha/yr)		Ratio of BGB to AGB (t dm BGB/t dm AGB)	
		Factor applied	IPCC 2019 Refinement	Factor applied	IPCC 2019 Refinement
Indigenous forest	Primary	0.0	0.15 ^a	0.25	0.23
	Secondary (>20yrs)	0.92	1.08 ^a		
	Secondary (<20 yrs)	2.86	2.98 ^a		
Thickets	Secondary (>20yrs)	1.18	1.08 ^a	0.22	
	Secondary (<20 yrs)	2.92	2.98 ^a		
Woodlands	Secondary (>20yrs)	0.77	1.08 ^a	0.32	
	Secondary (<20 yrs)	1.31	2.98 ^a		
		Herbaceous	NA	NA	

^a Weighted average based on climate zone areas



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6.6.2.2.2 Forest plantations

As in the previous inventory the forest plantations were sub-divided into *Eucalyptus* sp., softwood sp., *Acacia* (wattle) and other plantation species. Softwoods were further divided into sawlogs, pulp and other as the growth and expansion factors of these forest plantations differed. *Eucalyptus grandis* and *Other Eucalyptus* species were separated.

For forest plantations a Tier 2 method as applied to calculate biomass gains. The plantation area provided in the land cover datasets is overestimated according to the Forestry SA data (FSA, 2019)³⁰, therefore in the calculation files a correction was made to the SANLC matrix data (section 6.3.3.2.4) to align the areas with the Forestry SA data (Table 6.27). At the time of completing this inventory forest plantation data was not available for 2020 onwards as there was no service provider to collect the data over this period. The years 2020 to 2024 were extrapolated using the IPCC extrapolation splicing technique and this was done per species. It is noted that this is a long extrapolation, however the data source (DFFE) has indicated that a service provider has been appointed, and data collection has resumed. It is therefore expected that in the next inventory there will be data that can be used to update this extrapolated period.

Table 6.27: Forest plantation area (kha) comparison

Plantation data	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>FSA Plantation area</i>	1 241	1 296	1 301	1 307	1 366	1 429	1 487	1 518	1 384
<i>Applied forest plantation area</i>	1 514	1 502	1 490	1 479	1 467	1 455	1 444	1 432	1 420
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>FSA Plantation area</i>	1 402	1 331	1 352	1 351	1 372	1 339	1 334	1 282	1 266
<i>Applied forest plantation area</i>	1 409	1 397	1 385	1 373	1 362	1 350	1 338	1 327	1 315
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>FSA Plantation area</i>	1 257	1 275	1 271	1 273	1 268	1 266	1 233	1 224	1 221
<i>Applied forest plantation area</i>	1 303	1 292	1 280	1 268	1 257	1 245	1 233	1 230	1 226
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>FSA Plantation area</i>	1 212	1 192	1 195	1 183	1 174	1 165	1 157	1 148	
<i>Applied forest plantation area</i>	1 222	1 219	1 199	1 178	1 187	1 196	1 179	1 163	

³⁰ *Statistical Data - Forestry in South Africa*



MAI curves were obtained from Forestry SA (FSA, 2019). The MAI at rotation age for each of the products (sawlogs, pulp, mining timber, poles and other uses) per each of the 5 plantations species (Pines, *E. grandis*, other *Eucalyptus* species, Wattle and other hardwood species) were weighted based on the area under production for each species and product. The overall MAI therefore varied slightly each year but data for 2024 is shown in Table 6.28.

The $BCEF_s$ values were calculated by using the equations given in Dovey et al. (2021) which estimates the $BCEF_s$ from the volume data. Stock volumes (m^3/ha) were determined from the MAI for each age class multiplied by the age of the stand. Age class data was obtained from DFFE Timber Statistics reports (DFFE, 2020). The $BCEF_i$ values were derived from the $BCEF_s$ data by analysing the IPCC 2006 Guidelines default values and applying a ratio for $BCER_i$ to $BCEF_s$. For softwood the $BCEF_i$ was determined to be 78% of the $BCEF_s$, while for the other species it was 60%. The age class area weighted $BCEF_s$ and $BCEF_i$ for 2024 are provided in Table 6.28 but the values did vary slightly from year to year due to the changes in the areas of the different species and the areas of each age class. The root to shoot ratios (du Toit, et al., 2016) were then applied to include the below-ground biomass.

The above-ground biomass data for forest plantations was determined from the age class and MAI data provided by Department of Forestry (DFFE, 2020). This data was utilised with the equations provided in (Dovey, et al., 2021) to determine the $BCEF_s$ values and the biomass (Table 6.28). Age class area weighted $BCEF_s$ and biomass values were calculated and these varied slightly across the years due to changes in species composition and age structure. The $BCEF_i$ values were determined by looking at the relationship between the $BCEF_s$ and $BCEF_i$ values in Table 4.5 of the IPCC 2006 Guidelines. The $BCEF_R$ were determined from the relationship between $BCEF_R$ and $BCEF_i$ provided in IPCC 2006 Guidelines (Vol. 4, Chapter 4, page 4.14).

Table 6.28: Factors applied for forest plantations in 2024 with IPCC default values for comparison

		Softwoods (e.g. Pines)	<i>Eucalyptus</i> <i>grandis</i>	Other <i>Eucalyptus</i> sp.	<i>Acacia</i> sp. (Wattles)	Other hardwood sp.
Mean annual increment ($m^3/ha/yr$)	Weighted average applied	15.6	17.9	18.3	9.9	18.5
	IPCC 2019 Refinement	12 - 18	18 - 24	12-14 (general) 22-28 (<i>E. nitens</i>)	10 - 12	
$BCEF_s$	Weighted average applied	0.90	0.60	1.09	0.71	0.98



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		Softwoods (e.g. Pines)	Eucalyptus grandis	Other Eucalyptus sp.	Acacia sp. (Wattles)	Other hardwood sp.
	IPCC 2006 default (temperate)	0.6 – 1.0	0.8 – 2.6	0.8 – 2.6	0.7 – 1.9	0.7 – 1.9
BCEF _i	Weighted average applied	0.71	0.63	0.65	0.64	0.66
	IPCC 2006 default (temperate)	0.6	1.3	1.3	0.9	0.9
BCEF _R	Weighted average applied	0.60	0.71	0.71	0.99	0.68
	IPCC 2006 default (temperate)	0.83	1.89	1.89	1.55	1.55
Ratio of BGB to AGB (t dm/t dm)	Weighted average applied	0.28	0.24	0.24	0.28	0.26
Above- ground biomass (t dm/har)	Weighted average applied	100.10	62.39	58.59	52.46	119.44
	IPCC 2019 Refinement	10-100 (SMS) 20 - 194 (TDF)	40 - 150 (SMS) 30 - 70 (TDF)			

SMS = Subtropical mountain system; TDF = Tropical dry forest

6.6.2.3 Biomass losses

Carbon losses in *Forest land* included wood removal, fuelwood collection, and losses due to other disturbances. Harvested wood was included for forest plantations, while fuelwood collection was estimated for all forest land and included under Woodlands as it was not possible to disaggregate it by forest type. All emissions from the burning of fuelwood for energy or heating purposes were reported as part of the energy sector. In forest plantations, disturbance from fires and other disturbances were included, while for all other subcategories only disturbance from fire was included due to a lack of data on other disturbances.

6.6.2.3.1 Indigenous forests and thickets

Biomass losses for indigenous forests and thickets only include losses from fires. These losses are determined using IPCC 2006 Guidelines equation 2.14, with the burnt area data (Table 6.29) coming from MODIS (see section 6.4.7). There is insufficient data to separate controlled fires from wildfires so all losses are included under wildfires.



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Table 6.29: Burnt area (ha) data for natural forests

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Indigenous forest</i>	53 523	62 766	57 977	55 522	49 531	43 309	16 933	16 596	30 561
<i>Thicket/Dense bush</i>	60 340	60 340	60 340	60 340	60 340	60 340	53 183	48 475	56 736
<i>Woodlands</i>	707 939	707 939	707 939	707 939	707 939	707 939	623 972	568 733	665 659
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Indigenous forest</i>	19 362	10 681	11 889	10 951	13 809	10 796	14 195	14 426	18 868
<i>Thicket/Dense bush</i>	53 442	49 732	63 125	78 341	47 082	48 442	83 196	64 895	75 769
<i>Woodlands</i>	627 009	746 504	1 073 551	937 745	359 586	672 691	1 135 776	986 575	567 677
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Indigenous forest</i>	15 789	15 569	12 766	9 966	14 633	14 299	12 648	8 981	7 142
<i>Thicket/Dense bush</i>	83 361	60 618	74 075	58 397	74 911	60 485	76 478	42 118	25 405
<i>Woodlands</i>	1 025 122	675 485	951 624	869 381	700 735	546 601	835 283	551 254	148 941
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Indigenous forest</i>	9 610	16 687	13 869	11 690	12 051	7 499	11 587	18 769	
<i>Thicket/Dense bush</i>	45 281	56 167	65 277	31 371	34 880	28 260	51 916	109 925	
<i>Woodlands</i>	437 810	432 481	518 064	388 709	1 030 627	641 708	1 729 159	1 026 898	

Above-ground biomass data (Table 6.30) was determined from scientific literature (Annex V.3) and weighted averages determined as outlined for biomass growth in section 6.6.2.2.1. The values for thickets are similar to the IPCC 2019 Refinement default values, whereas the indigenous forest values are higher and woodland values are lower. It is expected that the woodland value is lower as this includes open woodlands (savannas) which are not always included under *Forest land*. The indigenous forest values were, however, quite a bit higher than the IPCC 2019 Refinement default values. This value has been checked, and information comes from more than one study (see Annex V) so it is assumed to be more accurate than the default value. The data will continue to be updated as more data becomes available. Indigenous forests make up around 2% of the *Forest land* area. Root losses were also included (Table 6.30).

There is no country specific data on the fraction of biomass lost (*fd*) during the fire disturbance, so the combustion fractions provided by 2019 Refinements of the IPCC 2006 Guidelines were used as a proxy. For indigenous forests and thickets the value of 0.45 for all other temperate forests was applied and this was combined with the IPCC default carbon fraction of 0.47.



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Table 6.30: Above-ground biomass data for natural forests

Forest class	Forest age	AGB (B_w) (t dm/ha/yr)	
		Factor applied	IPCC 2019 default
Indigenous forest	Primary	497.7	78.60 ^a
	Secondary (>20yrs)	239.8	67.32 ^a
	Secondary (<20 yrs)	29.8	
Thickets/ Dense bush	Secondary (>20yrs)	58.02	
	Secondary (<20 yrs)	14.93	
Woodlands	Secondary (>20yrs)	35.83	
	Secondary (<20 yrs)	18.2	
	Herbaceous	4.8	

6.6.2.3.2 Woodlands

Biomass losses for woodlands include disturbances losses from fires and losses due to fuelwood collection.

Fire disturbance losses are estimated as for indigenous forests and tickets/dense bush by combining burnt area (section 6.4.7; Table 6.29), above-ground biomass (Table 6.30), root ratio (Table 6.30), an fd value of 0.45 and carbon fraction of 0.47. An improvement in this inventory was the separation of controlled fires. This was based on a recommendation from the TERT (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L.5). Controlled burns are carried out in the Kruger National Park (KNP) for veld management purposes, and these were the controlled fires included in this inventory. There may be other sources however there is no sustainable data for controlled fire data, so this is a first attempt at including these estimates. Setting up a system for the collection of controlled fire data has been included in the improvement list. Annual area of controlled fires burnt in the KNP were determined from literature which indicates 16-22% of the park (1 948.5 kha) burns and 25-50% of this is due to natural causes (van Wilgen, et al., 2000; van Wilgen, et al., 2008; van Wilgen, 2025), while the rest is due to management.



This area was subtracted from the total woodland wildfire burnt area (Table 6.29) and allocated to controlled fires.

Fuelwood losses are estimated using IPCC 2006 Guidelines equation 2.13 where all wood is removed as tree parts. The amount of fuelwood removed is estimated from the number of households and an average annual household fuelwood consumption rate. There is insufficient data to distribute the fuelwood removal to the different forest land classes, so it is all allocated to woodlands as these are the dominant areas where wood is sourced from. All losses due to fuelwood collection are allocated to the *Forest land remaining forest land* as there was insufficient data to provide a split on the losses between remaining and converted lands.

The amount of fuelwood collected was determined from the number of households using fuelwood for cooking and heating (StatsSA, 2025). It was assumed that there is overlap between the houses that use wood for heating and cooking and so the higher value (households for heating) was taken to be the total number of households using wood. An average household fuel wood consumption rate of 3.5 t per household per year (Twine & Holdo, 2016; Shackleton, et al., 2022) and an average wood density of 0.65 t dm/m³ was applied to estimate the volume of fuelwood used (Table 6.31).

Table 6.31: Estimated volume (m³) of fuelwood extracted from Woodlands

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Fuelwood volume	12 736 068	12 526 428	12 316 788	12 107 149	11 897 509	11 687 869	11 478 229	11 268 590	11 058 950
	1999	2000	2001	2002	2003	2004	2005	2006	2007
Fuelwood volume	10 849 310	10 639 670	10 430 030	10 206 000	10 510 500	10 500 000	9 145 500	9 208 500	9 117 500
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fuelwood volume	10 230 500	9 443 000	10 024 000	7 738 063	8 025 500	6 433 000	6 121 500	5 999 000	6 083 000
	2017	2018	2019	2020	2021	2022	2023	2024	
Fuelwood volume	6 881 000	6 299 776	6 569 927	6 667 540	6 870 039	7 072 921	7 275 037	7 196 812	

The number of households using wood was only available from 2002 onwards. The FAOSTAT fuelwood bioenergy consumption data was converted to volume of fuelwood consumed by applying a conversion factor (NCV for wood) of 17 MJ/kg (DEA, 2017) to get the mass of wood and then applied the average wood density value to obtain volume of wood. These derived fuelwood consumption values were very similar to the fuelwood



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determined from household number and showed the same trend. This data extended back to 1990 and therefore the IPCC overlap splicing techniques was used with this data set to extrapolate the data back to 1990.

6.6.2.3.3 *Forest plantations*

Losses from forest plantations include both harvest losses and disturbance losses. Disturbance losses include losses from fires (both natural and human-induced fires such as arson and accidental fires) and other disturbances such as insect and animal disturbance losses. Emissions from *Harvested wood products* were included under 4.G.

Loss of carbon from harvested wood was estimated from the IPCC 2006 Guidelines equation 2.12. Harvested wood data (Table 6.32) was obtained from Timber Statistics report from the Department of Forestry at DFFE (DFFE, 2020) and from Forestry SA (Oberholzer, 2021). The industry conversion factors provided by Forestry SA³¹ were used to convert between tonnes and m³. Biomass data, BCEF_R and root ratios are provided in Table 6.28. The harvested wood included the wood used for fuelwood and charcoal as it is all removed as whole trees. All losses due to harvesting were allocated to *Forest land remaining forest land* as it was assumed that recently converted land would not be harvested due to the longer harvest cycle. As indicated in the gains section above, plantation data was only available up to 2019, and a linear extrapolation technique was used (per species and wood use) for the remaining years. Once the new data becomes available these values will be updated and this is on the improvement list for the next inventory.

Table 6.32: Forest plantation carbon loss activity data

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Harvested wood volume (m3)</i>	15 962 700	15 766 983	15 982 226	15 919 850	17 163 207	17 037 252	18 191 221	18 559 363	15 553 778
<i>Fire disturbance area (ha)</i>	15 923	6 680	11 469	13 924	19 915	26 137	11 733	13 901	8 276
<i>Other disturbance area (ha)</i>	8 855	4 068	15 233	22 527	10 532	10 773	6 387	8 738	5 029
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Harvested wood volume (m3)</i>	15 839 028	16 680 299	16 606 874	16 619 310	19 205 509	20 311 189	21 979 338	22 827 192	20 330 501

³¹ South African Forestry & Forestry Products Industry Facts 1980-2019 (*Statistical Data - Forestry in South Africa*)



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Fire disturbance area (ha)	16 455	20 221	17 266	16 727	28 983	28 326	22 445	28 895	70 697
Other disturbance area (ha)	5 488	2 925	2 776	2 022	3 766	12 904	19 498	23 827	26 896
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Harvested wood volume (m3)	20 137 591	18 887 579	17 514 015	18 517 492	18 196 071	17 846 463	16 865 916	17 897 483	16 442 017
Fire disturbance area (ha)	70 812	19 805	15 812	15 348	9 599	21 297	16 486	11 962	14 222
Other disturbance area (ha)	6 338	3 003	7 445	24 830	8 516	5 230	3 301	19 233	13 580
	2017	2018	2019	2020	2021	2022	2023	2024	
Harvested wood volume (m3)	18 332 661	18 683 137	16 599 681	14 271 073	16 128 115	17 129 211	16 393 525	16 393 525	
Fire disturbance area (ha)	16 145	17 266	12 195	15 033	15 033	15 033	15 033	15 033	
Other disturbance area (ha)	9 537	12 177	6 208	11 006	11 006	11 006	11 006	11 006	

Disturbance losses are estimated using IPCC 2006 Guidelines equation 2.14. Fire and other disturbance losses were included separately. The forest plantation area that was burnt by fires or was disturbed by other disturbances was obtained from Forestry SA³² (Table 6.32) and this was split by hardwoods and softwood. For the years 2020 to 2024 a 10-year average was applied for disturbances, and these are expected to be updated in future once new data becomes available. Disturbed area is provided for the total area of each species and in order to split this into land remaining land and land converted to forests the fraction of disturbed area was calculated and applied to the land remaining and the converted land areas.

Fire disturbance included both controlled and wildfire estimates. In Forestry SA annual presentations for 2012 to 2019 (Oberholzer, 2021) the source of the fires is indicated to be arson, accidental, natural and unknow with percentages being provided. Natural fires constitute 10%-32% of the fires, however the source of a large portion (39-47%) of fires is not known. If it is assumed that maybe half of this is natural fires, then natural fires would account for 25%-50% (average of 36%) of the planted forest burnt area provided by Forestry SA. The rest of the area is allocated to controlled burns.

The BCEF_R, root ratios and biomass values are provided in Table 6.28.

³² South African Forestry & Forestry Products Industry Facts 1980-2019 (*Statistical Data - Forestry in South Africa*)



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Forestry SA data reports on the severity of the disturbance, therefore disturbance matrices were developed for disturbances where there was (a) slight damage, (b) serious damage but where wood was salvaged and (c) severe damage where all biomass was lost. For slight damage it was assumed that half of the non-utilisable biomass would be burnt. The non-utilisable component was determined from the Dovey et al. (2021) equation for hardwoods and softwoods. In the case where there was serious damage but wood was salvaged it was assumed that all the non-utilisable biomass and an additional 10% was lost, while for severe damage with no recovery it was assumed all biomass was lost. The overall average fraction (fd) of plantation biomass lost to fires and other disturbances was 0.661 and 0.363, respectively. Losses due to disturbance were calculated for both the *Forest land remaining forest land* and *land converted to forest land* by applying the percentage disturbance area to each of the land sub-categories.

6.6.2.4 Gains and losses due to land conversions

The same methodology was applied to all forest categories. The IPCC 2006 Guidelines equations 2.15 and 20.16 were utilised for estimating emissions from biomass changes on converted land. The conversions also included conversions between forest types but then these losses were included under the “land remaining” category. The biomass changes in *Land converted to Forest lands* involves the determination of gains and losses, but also initial biomass changes due to the conversion. Biomass gains and losses for land converted from other land types to forest lands are calculated as for *Forest lands remaining forest lands* (described above). These gains and losses were incorporated into IPCC 2006 Guidelines equation 2.15 along with the initial change in biomass carbon stocks on the converted land determined with IPCC 2006 Guidelines equation 2.16.

The carbon stocks on the land before conversion were determined from above- and below-ground biomass data provided in the relevant land category sections. Land being converted to forest plantations is assumed to be cleared and therefore the biomass values immediately after conversion were assumed to be zero. For land being converted to the natural forest land classes (indigenous forests, thickets and woodlands) it was assumed that there was no abrupt change, unless it was a conversion from a higher biomass category.

6.6.2.5 Deadwood and litter

The DOM pool for *Forest lands* includes both deadwood and litter. In the previous inventory the DOM category for *Forest land remaining Forest land* was determined to be a key category. According to the IPCC decision tree, a Tier 2 approach should be used for this category. In this Tier 2 Gain-loss approach the change in carbon stocks are estimated

from the average annual transfer of biomass into and out of the DOM pool due to annual processes and disturbances (IPCC 2006 Guidelines equation 2.18). This approach was investigated during this inventory. Most of the data is available for determining biomass transfer into the DOM pool (IPCC 2006 Guidelines equations 2.20 – 2.22), but mortality rate data is very limited for the various forest categories (particularly for natural forest classes). In addition, there was a lack of data on the decay and disturbance losses out of the DOM pool. For these reasons the Tier 2 approach could not be fully implemented, and further data collection would be required to implement this approach. A Tier 1 approach was therefore applied in this inventory, and the Tier 2 approach was incorporated into the improvement plan.

The Tier 1 approach assumes there is no change in DOM in *Forest land remaining forest land*. Change, however, does occur where one forest type is converted to another and these changes are included under “land remaining” but are estimated as described for land conversions.

Changes in the DOM pool in converted land was estimated using IPCC 2006 Guidelines equation 2.23. The initial DOM is given in the relevant land category section, and the final DOM for the forest land types is shown in Table 6.33. Litter and deadwood data was obtained from scientific literature and the weighted average approach described for biomass was again applied to get an average litter and deadwood value for each forest category. If there is a gain in DOM this is assumed to occur over the 20-year default period, while losses are assumed to occur within the year of conversion (Tier 1).

The deadwood and litter data is generally in range of the IPCC 2019 Refinement default values, however the deadwood value for woodlands is very low. The Woodland category does include open woodlands which would have a lower value than is provided by IPCC. It is also considered that a lot of the deadwood in this forest category gets collected for fuelwood and could therefore be the reason for the lower value. If the Tier 2 approach is applied, which accounts for DOM inflow and outflow then this estimate may improve. Data comparison with the National Terrestrial Carbon Sinks Assessment (NTCSA) data, does however shows a lower value for Woodlands which supports the data used in this inventory.



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Table 6.33: Deadwood and litter data for the various forest land categories

	Average value applied		Comparison with other data			
			NTCSA	IPCC 2019 Refinement		
	Deadwood (t C/ha)	Litter (t C/ha)	DOM (t C/ha)	Deadwood (t C/ha)	Litter (t C/ha)	Forest type [#]
Indigenous forests	6.12	3.82	9.93	13.2 (0.2 - 43.8)	8.7 (1.2 - 24.0)	Subtropical humid forest
				10.67	4.95	Weighted average
Thickets	7.71	3.54	4.99	9.0 (1.3 - 17.3)	2.4 (2.1 - 2.7)	Tropical dry forest
				8.88	3.53	Weighted average
Woodlands	0.59	1.36	2.16	9.0 (1.3 - 17.3)	2.4 (2.1 - 2.7)	Tropical dry forest
				6.26	1.65	Weighted average
Forest plantations	9.00	2.40	4.81	11.8 (7.2 - 16.3)	NA	Subtropical mountain system
				10.54	1.91	Weighted average

[#] Plantations The first forest type is the dominant ecozone for each forest category (see section 6.3.4.3) while the weighted average is the IPCC default average weighted by ecozone area in each forest type.

6.6.2.6 Soil carbon

6.6.2.6.1 Mineral soils

Soil carbon changes were estimated for all forest categories as described in sections 6.3.4.1 and 6.4.3.1. The IPCC 2006 Guidelines default stock change factor of 1 was applied for indigenous forests, woodlands and forest plantations, while for thickets (which are shown to be degraded) a value of 0.95 (moderately degraded) was applied for management regime.

6.6.2.6.2 Organic soils

Organic soils were not separated from mineral soils for *Forest lands*, therefore all soils were included under mineral soils.

6.6.2.7 Direct and indirect N₂O from N inputs

Nitrogen is not applied to the natural forest classes (indigenous forests, thickets, woodlands), however it is known that forest plantations are fertilised when they are



planted. Through the GHG Reporting Regulations (DFFE, 2016) some forest plantation companies are required to report data to the SAGERS system, and this includes information on fertiliser use. This system has, however, only been operating since 2021 so data is only available for 3 years. This data was extracted and an average application rate per ha per year was obtained and applied to the area of forest plantations. It is assumed that it is a once off application when trees are planted. This value will be improved once more data becomes available, but it is not a high priority as fertiliser use in forest plantations is very small.

Direct N₂O emissions were estimated by combining the amount of nitrogen applied was combined with the IPCC 2019 Refinement default average emission factor for synthetic fertilisers (0.01 kg N₂O-N/kg N) in IPCC 2006 Guidelines equation 11.1. Indirect emissions from atmospheric deposition of N volatilised from managed soils were determined with equation 11.9, a $Frac_{GASF}$ of 0.11 kg N volatilised/kg N applied (IPCC 2019 Refinement, Chapter 11, Table 11.3) and an emission factor of 0.01 kg N₂O-N/(kg NH₃-N + NO_x-N volatilised) (IPCC 2019 Refinement, Chapter 11, Table 11.3). Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines equation 11.10 with a $Frac_{LEACH}$ of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).

6.6.2.8 Emissions and removals from drainage and rewetting

There is no data on the area of drained or rewetted *Forest land* soils, therefore these emissions were not estimated.

6.6.2.9 Direct and indirect N₂O from N mineralisation/immobilisation

Direct N₂O from N mineralisation/immobilisation associated with loss of soil carbon from soil organic matter as a result of changes to land use were incorporated through the application of the IPCC 2006 Guidelines equations 11.1 and 11.8. The annual loss of carbon due to land use change comes from analysis described in section 6.6.2.6.1 and the C:N ratio of 12.5 was obtained from IPCC 2006 Guidelines (average of 10 and 15). The IPCC 2019 Refinement emission factor was 0.01 kg N₂O-N/kg N.

Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines equation 11.10 with a $Frac_{LEACH}$ of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).

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6.6.2.10 Non-CO₂ emissions from biomass burning

Biomass burning emissions were identified as a key category in the previous inventory and therefore a Tier 2 approach is, according to IPCC decision tree, recommended. In this inventory, even though the emission factors were taken from the IPCC 2006 Guidelines, more specific fuel loads and combustion factors were applied (Tier 2). The CO₂ emissions from biomass burning were incorporated as disturbance losses in the gain-loss method described above. This category therefore only includes the emissions of CH₄ and N₂O emissions. Emissions were also estimated for CO, NO_x and NMVOCs but these are not reported here but rather under the section on Indirect emissions (Chapter 8).

Emissions were estimated with IPCC 2006 Guidelines equation 2.27. Burnt areas are provided in Table 6.29 and Table 6.32, and the division of data into controlled and wildfires in woodlands is described in section 6.6.2.3.2. Emission factors from IPCC 2006 Guidelines Table 2.5 were applied (Extra tropical forest values for indigenous forests, thickets and forest plantations; Savana values for woodlands). A NMVOC emission factor of 30 g/kg dm burnt for indigenous forests, thickets and forest plantations, and 3.4 g/kg dm burnt for savannas was taken from the literature (Andreae, 2019).

Indigenous forests were estimated with a fuel load of 76 t dm/ha which was derived from IPCC 2006 Guidelines fuel density and combustion factors for “All secondary tropical forests” in Tables 2.4 and 2.6. A combustion fraction of 0.4 was taken from an earlier inventory (DEA, 1999). The thicket fuel load (1.4 t dm/ha) was derived from the literature, along with a combustion factor of 0.95 (DEA, 1999). Fuel load (6.69 t dm/ha) and combustion factor (0.75) for woodlands were derived from literature data using a weighting approach based on the area of the different woodland types as described in the biomass section (data shown in Annex V). These values were found to be comparable to the IPCC 2006 Guidelines default values. For forest plantations the fuel loads were equivalent to the biomass data for the various species, with a combustion factor of 0.63 (IPCC 2006 Guidelines, Table 2.6, Eucalyptus forest).

6.6.3 Uncertainty

Uncertainties were provided for individual factors, based on literature and the IPCC 2006/2019 Refinement Guideline default values, and are combined using equations 3.1 and 3.2 of the IPCC 2006 Guidelines.

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6.6.3.1 Activity data uncertainty

Uncertainty for the land areas were provided by the SANLC data accuracy assessments (DFFE, 2021). The mapped areas of indigenous forests, thickets, woodlands and forest plantations have uncertainties of $\pm 16\%$, $\pm 21\%$, $\pm 26\%$ and $\pm 12\%$, respectively. An additional 5% was added to this for indigenous forests and forest plantations, and 10% for woodlands and thickets to account for uncertainty on the corrections. The uncertainty for converted areas was taken to be the combined uncertainty (applying the propagation of errors as indicated in IPCC 2006 Guidelines) for the two land areas. The results of this approach indicate the converted lands had a higher uncertainty than the individual land types as was to be expected. Mapped areas for land converted to Forest land had an estimated uncertainty of 57.3%.

Harvested wood uncertainty is around $\pm 2\%$ (expert opinion) as the forestry companies measure the harvested wood so it is fairly accurate data. The uncertainty lies in whether all the harvested wood is accounted for as not all small growers report to Forestry SA. The fuelwood removal data is very uncertain as it was determined from household statistics on number of households using wood ($\pm 5.6\%$ uncertainty for rural households and $\pm 3.2\%$ for urban households based on Shackelton et al., 2022), a single wood density value ($\pm 5\%$ based on data from IPCC 2006 Guidelines) and an average household wood consumption value ($\pm 40\%$ based on Shackelton et al., 2022). The burnt area data determined from MODIS collection 6 has an uncertainty of $< 6\%$ (Boschetti et al., 2021) and the soil maps are estimated to have an uncertainty of $\pm 10\%$. The overall activity data uncertainty for forest land remaining forest land was estimated at $\pm 42.3\%$ and $\pm 58.7\%$ for land converted to forest land.

6.6.3.2 Emission factor uncertainty

The uncertainty on biomass gains was estimated from uncertainties and data ranges provided in the scientific literature and IPCC 2006 Guidelines and 2019 Refinement. The BCEF and root to shoot ratios had uncertainties of $\pm 20\%$ and $\pm 30\%$ respectively. Carbon fraction uncertainty is $\pm 6\%$ (IPCC, 2006). In terms of carbon losses, the wood density value is estimated to have an uncertainty of around 5% based on data provided in IPCC 2006 Guidelines. Since the DOM and SOC data have greater uncertainty than the biomass data an uncertainty of $\pm 20\%$ is assigned to these categories. The CO₂ emission factor uncertainty for Forest lands was estimated at $\pm 57\%$, while for land converted to forest lands it was $\pm 62\%$.

For CH₄ and N₂O biomass burning emission factors have uncertainties of $\pm 40\%$ and $\pm 47\%$ respectively for forest lands. Direct emission factors for inputs (of N and FSOM) to



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managed soils have, based on defaults from IPCC 2019 Refinement, uncertainties of -90% and +80%, while indirect emissions for volatilisation and leaching are $\pm 80\%$ and -100% to +82% respectively.

6.6.4 Time-series consistency

The land change maps had some inconsistency in that there was a switch from Landsat to Sentinel data between 2014 and 2018, however some corrections were made to bring these two datasets into alignment. All other datasets were consistent through the time-series, using the same methodology and data sources. The calculations are consistent over time and complete for the entire reporting period (1990-2024).

6.6.5 Category specific QA/QC and verification

Forest plantation area and harvest data is compared to FAO data.

Forest plantation emissions were estimated with the Stock-Difference approach for verification. Age class data for the 5 plantation species groups (Pines, Eucalyptus grandis, Other Eucalyptus species, Acia species, and Other hardwood species) was obtained from DFFE Timber Statistics reports (DFFE, 2020). Data was available for 2001 to 2019. MAI curves for each species (obtained from Forestry SA) were used to determine MAI at each age. Stock volume was estimated from the MAI and age of the trees. The stock volume was combined with the BCEFs value (determine for each species and age class using the equation provided by Dovey et al., 2021) to estimate carbon biomass stock per age class. These were then added to determine the total carbon stock per year.

As the carbon stock is determined from area, it does not actually account for losses due to damage (fire or other disturbances). Disturbances losses, as determined for the Gain-Loss method, were therefore subtracted from the total carbon stock to get the overall carbon stock per species per year.

The change in carbon stock was then determined by subtracting the initial year carbon stock from the final year carbon stock. The area of forest plantations changes from year to year therefore an area correction³³, as described by IPCC, was applied. Ideally the area should be the same and then the carbon gains or losses due to land conversions in that area are accounted for. The area correction means that only the plantation area is being considered and so the gains and losses due to land conversion to/from other land classes

³³ Area corrected carbon stock difference = ((Final carbon stock/Final plantation area) - (Initial carbon stock/Initial plantation area)) x Final plantation area.



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is not accounted for. This is one area where the Gain-loss and Stock-difference approach applied in this inventory differ and is one of the reasons why the Gain-loss method was included in the inventory instead of the Stock-difference.

The carbon change determined by the Stock-Difference method had a similar trend to the estimates based on the Gain-Loss method, except that there were some variations between years (Figure 6.12). It is noted that between 2008 and 2016 there seems to be a mismatch in the years but there is no clear explanation for this. The Stock-difference method shows a sharp decline in carbon in 2012 and increase in 2013 which is not seen in the Gain-loss data. These peaks are due to large changes in temporarily unplanted (TUP) area. Effectively the carbon losses in the Stock-difference method are based on the area of TUP, whereas in the Gain-loss method the amount of wood harvested is taken into account. The harvested wood and the TUP area show differing patterns which causes much of the variation between the Gain-loss and Stock-difference method.

Overall, the two methods produce values in a similar range, but the differences will be explored further in the next inventory.

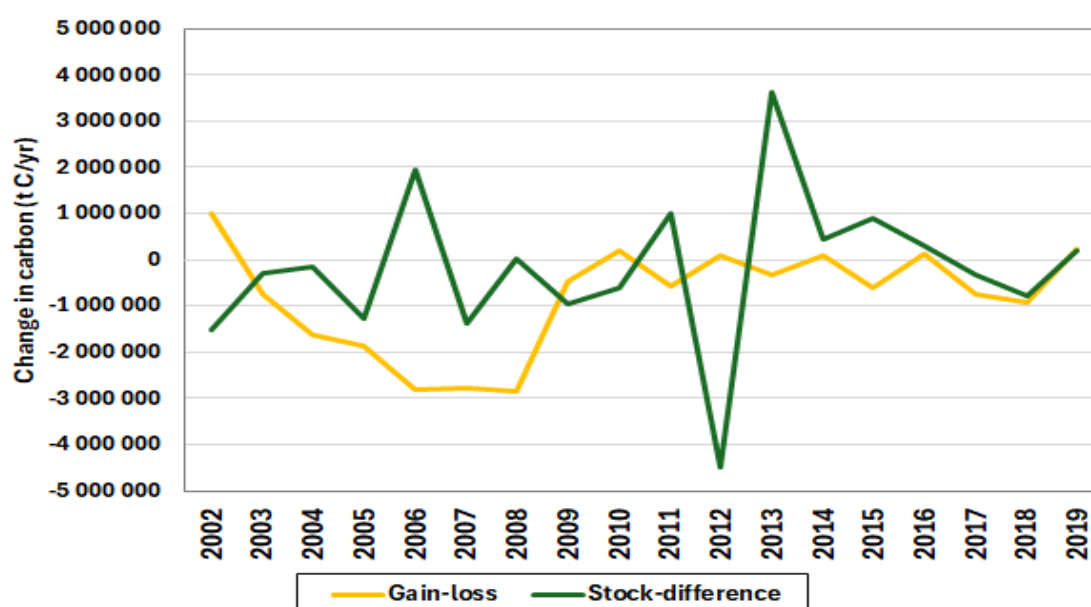


Figure 6.12: Carbon change for plantations estimated by the Gain-loss and Stock-difference methods

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6.6.6 Category-specific recalculations

The following main improvements led to a recalculation of the *Forest land* emission estimates:

- Inclusion of 2020-2022 land change maps.
- Updated land change matrix corrections for change in technology between 2014 and 2018, and wet and dry season variations.
- Removal of error from 2014 onwards (mentioned in last inventory) relating to a correction for land conversions on already converted land.
- Updated methodology for estimating burnt area per land class.
- Incorporation of soil type map overlay with 2014-2018, 2018-2020 and 2020-2022 land cover maps.
- Updated biomass, deadwood and litter carbon data.
- Updated assumption for primary and secondary forest division.
- Updated household fuelwood consumption data.
- Inclusion of direct and indirect N₂O emissions from N inputs and N mineralisation.

The recalculated emission estimates for *Forest land* show an average sink reduction of 42.3% between 2000 and 2022, with this percentage varying from year to year. The 2021 and 2022 estimates were reduced by 39.2% (25 095 Gg CO₂e) and 38.7% (31 884 Gg CO₂e) respectively compared to the previous submission.

6.6.7 Category-specific planned improvements

There are no additional category specific improvements beyond those mentioned in section 6.1.6.

6.7 Croplands (CRT 4.B)

6.7.1 Category description

The *Cropland* category is subdivided into *Cropland remaining Cropland* (4.B.1) and *Land converted to Cropland* (4.B.2). Calculations are carried out based on a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years.



Emissions in *Croplands* include CO₂ emissions/removals from above- and below-ground biomass, litter, and mineral soils. It also includes CH₄ emissions from drained organic soils. In keeping with the IPCC 2006 Guidelines (IPCC, 2006) direct and indirect N₂O emissions from nitrogen inputs, mineralisation in mineral soils and drained organic soils are reported under Agriculture (CRT 3.D.1) and are listed as “IE” in the LULUCF sector. Finally, it includes CH₄ and N₂O emissions from wildfires. Indirect emissions from wildfires are also estimated but these are reported under indirect CO₂ and N₂O in Chapter 8.

The *Cropland* category covers perennial crops (orchards and vineyards) and annual crops (pivot irrigation, non-pivot and subsistence crops).

The *Cropland* category is an overall source of 8 311 Gg CO₂e in 2024, which is a 27.3% increase since 1990 (Table 6.34). Most of the emissions come from land conversions and biomass is the dominant pool in 2024. *Grasslands converted to Cropland* and *Forest land converted to Cropland* are the largest contributors to the emissions (Figure 6.13). There was a doubling of emissions between 2018 and 2019. This was due to an increased conversion of woodlands to annual croplands during this period. These emissions drop back down in 2021.

Table 6.34: *Cropland* emissions for 1990 and 2024

Category	Pool	Gas	1990	2024	Change between 1990-2024 (%)
			Emissions (Gg CO ₂ e)	Emissions (Gg CO ₂ e)	
Cropland	All	All	6 531	8 311	27.3
Cropland	All	CO ₂	6 352	8 084	27.3
Cropland	All	CH ₄	57	71	24.6
Cropland	All	N ₂ O	122	157	28.0
Cropland remaining Cropland	All	All	747	336	-55.0
Land converted to Cropland	All	All	5 784	7 975	37.9
Cropland	Biomass	All	3 013	4 118	36.7
Cropland	DOM	All	386	148	-61.7
Cropland	Mineral soil	All	2 953	3 818	29.3



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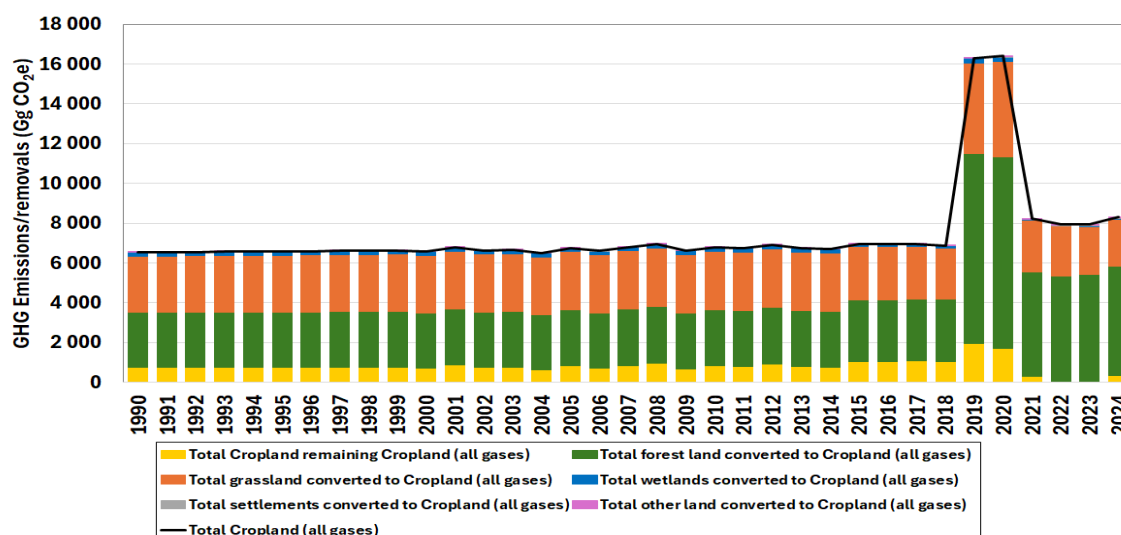


Figure 6.13: *Cropland* emission trends, 1990-2024

6.7.2 Methodological issues

The methodologies and emission factors utilised for *Croplands* are shown in Table 6.35. In the previous inventory *Grassland converted to Cropland* was identified as a key category for all carbon pools and these are calculated using a Tier 2 methodology. This is consistent with IPCC decision tree on the appropriate methods to apply.

Table 6.35: Methodologies and EF applied for estimating emissions from *Cropland*

Category	Gas	Method used	Source of activity data	Emission factor used
Cropland remaining Cropland	CO ₂	Tier 1/Tier 2	CS	D/CS
Cropland remaining Cropland	CH ₄	Tier 1/Tier 2	CS	D
Cropland remaining Cropland	N ₂ O	Tier 1/Tier 2	CS	D/CS
Land converted to Cropland	CO ₂	Tier 2	CS	D/CS
Land converted to Cropland	CH ₄	Tier 1/Tier 2	CS	D
Land converted to Cropland	N ₂ O	Tier 1/Tier 2	CS	D

(NO = Not occurring; NA = Not applicable; CS = Country specific; D = IPCC default)

6.7.2.1 Land area activity data

The activity data was country specific land area data determined as outlined in section 6.3 with an Approach 2 methodology and included areas for both *Cropland remaining Cropland* and *Land converted to Cropland* (Table 6.36).

Table 6.36: Country specific land areas (kha) (including 20-year transition period) for Croplands

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Cropland remaining Cropland</i>	12 759	12 744	12 728	12 713	12 698	12 683	12 668	12 653	12 637
<i>Land converted to Cropland</i>	1 400	1 406	1 411	1 416	1 421	1 427	1 432	1 437	1 442
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Cropland remaining Cropland</i>	12 622	12 607	12 592	12 577	12 561	12 546	12 531	12 516	12 501
<i>Land converted to Cropland</i>	1 448	1 453	1 458	1 464	1 469	1 474	1 479	1 485	1 490
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Cropland remaining Cropland</i>	12 485	12 470	12 460	12 450	12 440	12 431	12 421	12 412	12 403
<i>Land converted to Cropland</i>	1 495	1 500	1 500	1 500	1 500	1 500	1 500	1 487	1 474
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Cropland remaining Cropland</i>	12 395	12 386	12 348	12 310	12 360	12 410	12 460	12 510	
<i>Land converted to Cropland</i>	1 460	1 447	1 650	1 853	1 838	1 824	1 809	1 795	

6.7.2.2 Biomass gains

6.7.2.2.1 Annual crops (pivot, non-pivot and subsistence crops)

A Tier 1 approach was applied for annual crops where the increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year. A Tier 1 approach is appropriate as *Croplands remaining croplands* were not identified as a key category in the previous inventory. Where there was conversion



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between the *Cropland* categories these biomass changes were calculated as described for land conversions, but the emissions were reported under *Croplands remaining croplands*.

6.7.2.2.2 Perennial crops (orchards and vines)

Biomass gains for perennial crops were estimated with IPCC 2006 Guidelines equation 2.9 and 2.10. Above-ground biomass growth rates were determined by dividing the above-ground biomass (DEA, 2015) by the maturity cycle (30 years). Root to shoot ratios are provided in Table 6.37.

6.7.2.3 **Biomass losses**

6.7.2.3.1 Annual crops (pivot, non-pivot and subsistence crops)

As there were no gains in these classes, no losses were accounted for either. If there were conversions between different cropland categories, then these losses were determined as described for converted lands and included here.

6.7.2.3.2 Perennial crops (orchards and vines)

Losses accounted were those from biomass burning and harvest losses. For harvest losses the maturity cycle was 30 years and so the area was divided by 30 to divide the crops into age classes. Every year it was assumed then that the oldest age class was harvested. All harvest losses were allocated to *Cropland remaining cropland*.

Biomass losses for perennial crops were determined using IPCC 2006 Guidelines equation 2.14, with the burnt area data (Table 6.38) coming from MODIS (see section 6.4.7), biomass data provided in Table 6.37, an *fd* value of 0.85 (IPCC 2006 Guidelines, Table 2.6, Other crops) and a carbon fraction of 0.5. Annual crop burning losses are not included due to the assumption of equivalence, in addition any burning in annual crops are assumed to be due to residue burning which falls under the Agriculture sector (3.F).

Table 6.37: Biomass and growth factors for the various cropland categories

	Inventory biomass data					IPCC 2019 Refinement	
	AGB (t dm/ha)	Data source	Root to shoot ratio	Data source	Total biomass (t dm/ha)	Biomass growth rate (t dm/ha/yr)	Biomass accumulation rate (t dm/ha/yr)
Orchards	76.0	(DEA, 2015)	0.42	(Scandellari, et al., 2016)	107.9	2.53	1.9 – 5.0 (Table 5.1, temperature)
Vineyards	28.0	(DEA, 2015)	0.42	(Zhang, et al., 2021)	39.8	0.93	55.5 – 148.7 (AGB, Table 5.1, temperature)
Annual non- pivot crops	8.1	Area weighted average calculated from production, yield and harvest index data (DLRRD, 2022; Stats SA, 2021; DEA, 2015)	0.20	Varies slightly for each crop type (IPCC 2019 Refinement) and this was an area weighted average	9.72	NA	9.4 (Total biomass, Table 5.9, annual crops)
Annual pivot crops							
Subsistence crops	4.1	Assumed to be 50% of commercial			7.8		NA



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Table 6.38: Burnt area (ha) data for perennial crops

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Orchards</i>	2 263	2 274	2 284	2 295	2 305	2 315	2 326	2 336	2 347
<i>Vineyards</i>	486	489	493	496	499	503	506	509	512
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Orchards</i>	2 357	1 503	2 890	2 196	2 248	1 237	2 788	1 722	2 993
<i>Vineyards</i>	516	2 541	1 674	405	634	159	440	616	296
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Orchards</i>	3 815	1 629	2 737	2 137	3 501	2 437	2 175	1 989	1 949
<i>Vineyards</i>	222	333	552	1 891	449	537	204	953	921
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Orchards</i>	2 096	1 852	3 649	2 367	3 833	1 919	1 955	4 060	
<i>Vineyards</i>	1 137	560	742	433	2 230	1 254	182	967	

6.7.2.4 Gains and losses due to land conversions

The same methodology was applied to all cropland categories. The IPCC 2006 Guidelines equations 2.15 and 2.16 were utilised for estimating emissions from biomass changes on converted land. The conversions also included conversions between cropland types but then these losses were included under the “land remaining” category.

A tier 2 approach was adopted where the initial change in biomass carbon stocks on the converted land was added to the equation. Carbon gains and losses were calculated as for *Cropland remaining cropland* (described above) with only the woody perennial crops being included. Losses were also only for fire disturbance. The carbon stock change due to the removal of biomass from the initial land use (i.e. $\Delta C_{CONVERSION}$) was only calculated for the area of lands undergoing a conversion in a given year, and in subsequent years it was zero.

The carbon stocks on the land before conversion were determined from above- and below-ground biomass data provided in the relevant land category sections. The biomass stocks immediately after conversion were assumed to be zero, as it is assumed all land is cleared before being converted to cropland. A default period of 20 years is applied to carbon stock increases for perennial crops (i.e. it was assumed the carbon stock will increase from the initial carbon stock to the final carbon stock over a period of 20 years). For annual crops, in the previous inventory 1 years' worth of growth was included for the converted area, but this growth was removed due to the assumption of equivalence. This was checked against the IPCC 2006 software. This was also the case for losses in annual crops.



All carbon losses were assumed to occur within the year of conversion. For perennial crop the loss occurred across the total converted land area instead of the annual converted area.

6.7.2.5 Litter

The DOM pool for *Croplands* was not identified as a key category in the previous inventory, so a Tier 1 methodology was applied. The Tier 1 assumption for the litter pool in *Cropland remaining cropland* was that the stocks are not changing over time, therefore litter changes are reported to be zero. This was applied to areas where the crop type did not change, however, there were conversions between the various crops and these were treated as converted land areas.

Changes in the DOM pool in converted land was estimated using IPCC 2006 Guidelines equation 2.23. The initial DOM is given in the relevant land category section, and the final DOM for the cropland types is shown in Table 6.39. The litter data was sourced from the NTCSA (DEA, 2015) which provides spatial carbon density maps. These maps were intersected with the SANLC data to provide an area averaged estimate of the litter for each crop type. If there was a gain in DOM this was assumed to occur over the 20-year default period, while losses were assumed to occur within the year of conversion (Tier 1).

Table 6.39: Litter data for *Croplands*

Crop category	Litter (t C/ha)	Reference
Annual non-pivot crops	1.36	NTCSA (DEA, 2015)
Annual pivot crops	1.09	
Subsistence crops	0.54	
Orchards	3.20	
Vineyards	4.60	

6.7.2.6 Soil carbon

6.7.2.6.1 Mineral soils

Soil carbon changes were estimated for all *Cropland* categories as described in sections 6.3.4.1 and 6.4.3.

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For perennial crops (orchards and vines) the IPCC 2019 Refinement default stock change factors of 0.72, 1 (full till) and 1 (medium input) were applied for land use, management and input respectively. This was based on information provided in Moeletsi et al. (2015).

For annual crops (pivot, non-pivot) the land use stock change factor of 0.76 was applied (IPCC 2019 Refinement, Table 5.5, Long-term cultivation in warm temperate dry conditions). There was also a small area of cropland on inland wetland mineral soil and for this area the land use stock change factor was 0.71 (IPCC 2013 Wetland Supplement, Chapter 5, Table 5.3). The stock change factors for management, input and land use were determined from data reported in literature (Moeletsi, et al., 2015; Tongwane, et al., 2016). The management and input data for each crop type was combined with the IPCC 2019 Refinement default stock change factors and climate data to determine the stock change factors for each crop type. The IPCC 2019 Refinement data was selected as it has greater disaggregation than the 2006 Guidelines. These factors were assumed to remain constant throughout the time-period due to a lack of annual management data. A weighted average based on crop area was then determined for annual crops. Crop areas were obtained from DALRRD, national statistics (Statistics SA), Crop Estimates Committee, and FAO. The weighted average did not vary significantly across the years and the values in 2024 were 0.76, 1 and 0.96 for land use, management and input respectively.

The combined stock change factor of 0.58 was utilised for subsistence crops (DEFF, 2020).

6.7.2.6.2 Organic soils

The determination of the organic soil area in *Croplands* is described in section 6.4.3.2. The CO₂ emissions from drained organic soils is however not reported in this category (4.B) but under emissions from drainage and rewetting of mineral and organic soils in croplands (4(II).B). This category is therefore reported as included elsewhere (IE).

6.7.2.7 **Direct and indirect N₂O from N inputs**

All direct and indirect emissions of N₂O from nitrogen fertiliser inputs to *Croplands* are not included in the LULUCF sector, but rather in the Agriculture sector (3.D.1 & 3.D.2). These are therefore reported as IE in this section.

6.7.2.8 Emissions and removals from drainage and rewetting

Drained organic soil area for *Croplands* was obtained from FAOSTAT (Table 6.40). The IPCC 2013 Wetland Supplement methodology for CO₂ emissions (equations 2.3 – 2.5) and CH₄ emissions (equation 2.6) were utilised to estimate emissions from drained soils.

Table 6.40: Drained organic soil area (ha) for *Croplands*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Cropland drained organic soil</i>	3 391	3 391	3 391	3 391	3 391	3 382	3 385	3 390	3 456
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Cropland drained organic soil</i>	3 582	3 645	3 667	3 883	4 205	4 272	4 281	4 281	4 276
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Cropland drained organic soil</i>	4 283	4 286	4 290	4 290	4 290	4 296	4 317	4 317	4 317
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Cropland drained organic soil</i>	4 317	4 323	4 175	4 175	4 173	4 173	4 173	4 173	

CO₂ emissions from drained soil included on-site and off-site emissions on drained soils (IPCC 2013 Wetland Supplement, equation 2.2). A Tier 1 approach for on-site CO₂ emissions (equation 2.3) involved combining the drained organic soil area with an emission factor of 5.3 t C/ha/yr (IPCC 2013 Wetland Supplement, Table 2.1). Off-site emissions (equation 2.4) used an emission factor of 0.31 t C/ha/yr (IPCC 2013 Wetland Supplement, Table 2.2). CO₂ emissions from fires on drained soils were not included as burnt area for drained soils could not be separated from the total cropland burnt. The CO₂ emissions will therefore be slightly underestimated. Emission factors were selected based on a temperate, dry climate.

CH₄ emissions from drained soils were estimated with IPCC 2013 Wetland Supplement equation 2.6. The area of ditches is not known so an average fraction of 0.5 is assumed for ditches (IPCC 2013 Wetland Supplement, Table 2.4). The drained area was combined with this fraction and default emission factors for drained organic soils (0 kg CH₄/ha/yr) and drained ditches (1 165 kg CH₄/ha/yr) from the IPCC 2013 Wetland Supplement Tables 2.3 and 2.4 respectively. Emission factors were selected based on a temperate, dry climate.

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N₂O emissions from drained organic soils were not included in this sector but rather in the Agriculture sector (3.D.1.f).

6.7.2.9 Direct and indirect N₂O from N mineralisation/immobilisation

Direct N₂O from N mineralisation/immobilisation associated with loss of soil carbon from soil organic matter as a result of changes to land use were incorporated through the application of the IPCC 2006 Guidelines equations 11.1 and 11.8. The annual loss of carbon due to land use change comes from analysis described in section 6.6.2.6.1 and C:N ratios were obtained from IPCC 2006 Guidelines. The C:N ratio of 15 was applied for *Forest land* or *Grassland* to *Cropland* conversions and 12.5 for all other land use changes. The IPCC 2019 Refinement emission factor was 0.01 kg N₂O-N/kg N.

Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines equation 11.10 with a F_{leach} of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).

6.7.2.10 Non-CO₂ emissions from biomass burning

Biomass burning emissions were identified as a key category in the previous inventory and therefore a Tier 2 approach is, according to IPCC decision tree, recommended. In this inventory, even though the emission factors were taken from the IPCC 2006 Guidelines, more specific fuel loads and combustion factors were applied (Tier 2). This section only includes emissions for perennial crops (orchards and vines) as the burning that occurs in annual crops is assumed to be due to crop residue burning and these emissions are included in the Agriculture sector (3.F). The CO₂ emissions from biomass burning were incorporated as disturbance losses in the gain-loss method described above. This category therefore only includes the emissions of CH₄ and N₂O emissions. Emissions were also estimated for CO, NO_x and NMVOCs but these are not reported here but rather under the section on Indirect emissions (Chapter 8).

Emissions were estimated with IPCC 2006 Guidelines equation 2.27. Burnt areas are provided in Table 6.38. Emission factors from IPCC 2006 Guidelines Table 2.5 were applied (Agricultural residues) along with a NMVOC emission factor of 7.6 g/kg dm burnt (Andreae, 2019). The biomass consumption for perennial crops was 7 t dm/ha (DAFF, 2010).



6.7.3 Uncertainty

Uncertainties were provided for individual factors, based on literature and the IPCC 2006/2019 Refinement Guideline default values, and are combined using equations 3.1 and 3.2 of the IPCC 2006 Guidelines.

6.7.3.1 Activity data uncertainty

Uncertainty for the land areas were provided by the SANLC data accuracy assessments (DFFE, 2021). Cropland areas are determined from crop boundary data so uncertainty is low ($\pm 2-9\%$). An additional 2% was added to this for uncertainty on the mapped area corrections. This uncertainty is lower than *Forest lands* and *Grasslands* as minimal corrections were made to land use areas. The uncertainty for converted areas was taken to be the combined uncertainty (applying the propagation of errors as indicated in IPCC 2006 Guidelines) for the two land areas. The results of this approach indicate the converted lands had a higher uncertainty than the individual land types as was to be expected. Mapped areas for land converted to Cropland had an estimated uncertainty of 39.2%.

The burnt area data determined from MODIS collection 6 has an uncertainty of $<6\%$ (Boschetti et al., 2021) and the soil maps were estimated to have an uncertainty of $\pm 10\%$. The overall activity data uncertainty for cropland remaining cropland was estimated at $\pm 21.7\%$. For land converted to cropland the uncertainty was estimated at $\pm 40.9\%$.

6.7.3.2 Emission factor uncertainty

Biomass data was determined from actual yield and production data from commercial crops so has a small uncertainty for the individual crops (estimates at $\pm 5\%$) but the average value over all crops had a slightly higher uncertainty ($\pm 10\%$). Disturbance losses in industrialised countries have a default uncertainty of $\pm 15\%$, so a $\pm 20\%$ uncertainty was assumed. Root to shoot ratios have a $\pm 30\%$ uncertainty and carbon fraction uncertainty is $\pm 6\%$ (IPCC, 2006). Litter and SOC data have greater uncertainty than the biomass data, particularly since they were derived from the NTCSA overlay, and therefore an uncertainty of $\pm 20\%$ was assumed for these categories. The CO₂ emission factor uncertainty for *Croplands* was estimated at $\pm 40.3\%$, while for land converted to grasslands it was $\pm 53.2\%$.

For CH₄ and N₂O biomass burning emission factors have uncertainties of $\pm 40\%$ and $\pm 47\%$ respectively for Croplands. Direct emission factors for inputs (of N and FSOM) to managed soils have, based on defaults from 2019 Refinement, uncertainties of -90% and

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+80%, while indirect emissions for volatilisation and leaching are $\pm 80\%$ and -100% to $+82\%$ respectively. Drainage and rewetting CH_4 and N_2O emission factors have an uncertainty of $+71.2\%$ and $+58.1\%$.

6.7.4 Time-series consistency

The land change maps had some inconsistency in that there was a switch from Landsat to Sentinel data between 2014 and 2018, however some corrections were made to bring these two datasets into alignment. All other datasets were consistent through the time-series, using the same methodology and data sources. The calculations are consistent over time and complete for the entire reporting period (1990-2024).

6.7.5 Category specific QA/QC and verification

There were no category specific QA/QC checks over and above what was described in section 6.1.5.

6.7.6 Category-specific recalculations

The following main improvements led to a recalculation of the *Cropland* emission estimates:

- Inclusion 2020-2022 land change map.
- Updated land change matrix corrections for change in technology between 2014 and 2018, and wet and dry season variations.
- Removal of error from 2014 onwards (mentioned in last inventory) relating to a correction for land conversions on already converted land.
- Updated methodology for estimating burnt area per land class.
- Incorporation of soil type map overlay with 2014-2018, 2018-2020 and 2020-2022 land cover maps.
- Updated biomass, deadwood and litter carbon data.
- Inclusion of drained organic soils and their emissions.
- Removal of one years' worth of growth and losses for converted annual crops.

The recalculated emission estimates for *Croplands* show an increase in the emissions across the time-series. The 2021 and 2022 estimates have doubled (increased by 4 626 Gg CO_2e and 4 163 Gg CO_2e respectively) compared to the previous submission.



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6.7.7 Category-specific planned improvements

There are no planned improvements for *Croplands* beside the improvements that will come through the development of the overarching land mapping system (see section 6.1.6).

6.8 Grasslands (CRT 4.C)

6.8.1 Category description

The *Grassland* category is subdivided into *Grassland remaining Grassland* (4.C.1) and *Land converted to Grassland* (4.C.2). Calculations are carried out based on a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years. Both sub-categories are key categories for CO₂ emissions and removals in terms of the level and trend assessment.

Emissions in *Grasslands* include CO₂ emissions/removals from above- and below-ground biomass, litter, mineral and organic soils. It also includes CH₄ emissions from drained organic soils and direct and indirect N₂O emissions from mineralisation in mineral soils. In keeping with the IPCC 2006 Guidelines (IPCC, 2006) direct and indirect N₂O emissions from drained organic soils are reported under Agriculture (CRT 3.D.1) and are listed as "IE" in the LULUCF sector. There was insufficient data to include N₂O emissions from nitrogen inputs. Finally, it includes CH₄ and N₂O emissions from wildfires. Indirect emissions from wildfires are also estimated but these are reported under indirect CO₂ and N₂O in Chapter 8 of this report.

The *Grassland* category covers grasslands (which includes pastures and rangelands), low shrublands, eroded land as well as the newly added subantarctic tundra.

The *Grassland* category emitted 3 918 Gg CO₂e in 2024, which is up from the 1 404 Gg CO₂e in 1990 (Table 6.41). DOM is the dominant pool but soils are also an important sink. *Grasslands remaining grasslands* are a large sink while the *Land converted to Grasslands* is an almost equal source. *Forest land converted to Grasslands* is responsible for the source, while conversions of *Croplands* and *Other lands to Grasslands* are sinks (Figure 6.14). The annual variation across the times-series is relatively small because of the Tier 1 assumption of equivalence in grasslands remaining grasslands. This reduces the annual variation which is usually brought about by biomass burning. There are large increases



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in the sources and sinks between the land change mapping periods and this is due to changes in the annual land conversions.

Table 6.41: Grassland emissions for 1990 and 2024

Category	Pool	Gas	1990	2024	Change between 1990-2024 (%)
			Emissions (Gg CO ₂ e)	Emissions (Gg CO ₂ e)	
Grassland	All	All	1 404	3 918	179.0
Grassland	All	CO ₂	575	3 048	430.1
Grassland	All	CH ₄	489	519	6.1
Grassland	All	N ₂ O	340	351	3.3
Grassland remaining Grassland	All	All	-5 963	-14 683	146.2
Land converted to Grassland	All	All	7 368	18 601	152.5
Grassland	Biomass	All	619	978	58.0
Grassland	DOM	All	2 869	4 492	56.6
Grassland	Mineral soil	All	-2 913	-2 423	-16.8

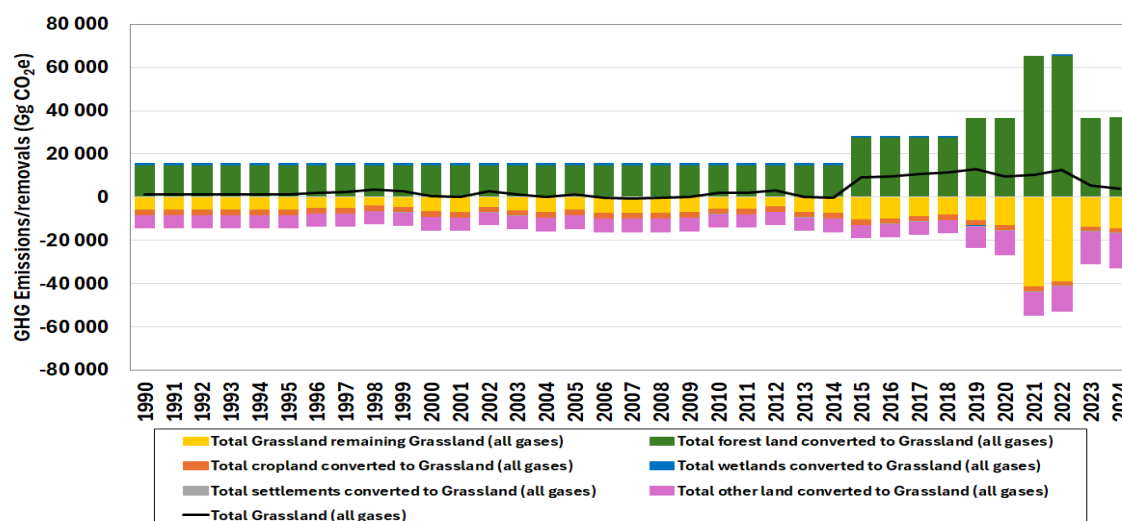


Figure 6.14: Grassland emission trends, 1990-2024



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6.8.2 Methodological issues

The methodologies and emission factors applied for *Grasslands* are provided in Table 6.42. In the previous inventory *Grassland remaining Grassland* (biomass) and *Land converted to Grasslands* (all carbon pools) were identified as key categories. Land conversions were calculated with a Tier 2 approach which is consistent with the IPCC decision tree (IPCC 2006 Guidelines, Figure 2.2), however only Tier 1 approach could be used for *Grassland remaining Grassland* due to a lack of data. As the land map data gets improved sources of additional data for disaggregation of *Grasslands* will be considered.

Table 6.42: Methodologies and EF applied for estimating emissions from *Grasslands*

Category	Gas	Method used	Source of activity data	Emission factor used
Grassland remaining Grassland	CO ₂	Tier 1/Tier 2	CS	D/CS
Grassland remaining Grassland	CH ₄	Tier 1/Tier 2	CS	D
Grassland remaining Grassland	N ₂ O	Tier 1/Tier 2	CS	D
Land converted to Grassland	CO ₂	Tier 2	CS	D/CS
Land converted to Grassland	CH ₄	Tier 1/Tier 2	CS	D
Land converted to Grassland	N ₂ O	Tier 1/Tier 2	CS	D

(NO = Not occurring; NA = Not applicable; CS = Country specific; D = IPCC default)

6.8.2.1 Land area activity data

The activity data was country specific land area data determined as outlined in section 6.3 with an Approach 2 methodology and included areas for both *Grassland remaining Grassland* and *Land converted to Grassland* (Table 6.43).

Table 6.43: Country specific land areas (kha) (including 20-year transition period) for *Grasslands*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Grassland remaining Grassland</i>	60 439	60 389	60 338	60 288	60 238	60 187	60 137	60 087	60 036
<i>Land converted to Grassland</i>	8 926	8 926	8 926	8 926	8 926	8 926	8 926	8 926	8 926



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	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Grassland remaining Grassland</i>	59 986	59 935	59 885	59 835	59 784	59 734	59 683	59 633	59 583
<i>Land converted to Grassland</i>	8 926	8 926	8 926	8 926	8 926	8 926	8 926	8 926	8 926
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Grassland remaining Grassland</i>	59 532	59 482	59 432	59 381	59 331	59 280	59 230	59 196	59 162
<i>Land converted to Grassland</i>	8 926	8 926	8 926	8 926	8 926	8 926	8 926	9 041	9 156
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Grassland remaining Grassland</i>	59 128	59 095	57 038	54 982	53 781	52 581	50 676	48 771	
<i>Land converted to Grassland</i>	9 271	9 386	10 510	11 634	13 023	14 413	15 529	16 644	

6.8.2.2 Biomass gains

6.8.2.2.1 Grasslands, Eroded land and Subantarctic tundra

A Tier 1 assumption of equivalence was applied to the grassland, eroded land and subantarctic tundra classes within the *Grassland* category as these have no woody components. Where there was conversion between the *Grassland* categories these biomass changes were calculated as described for land conversions, but the emissions were reported under *Grasslands remaining grasslands*.

6.8.2.2.2 Low shrublands

The low shrubland class includes a woody component as it includes the fynbos and karoo vegetation. The karoo vegetation has very small growth rates and so it was suggested in a UNFCCC review that these could be considered in equilibrium but the fynbos has a higher growth rate. As *Grasslands remaining grasslands* were identified as a key category in the previous inventory more data was sought for this vegetation class. The SANLC data showed the area of fynbos, succulent karoo and nama karoo in this low shrubland category. The fraction of the total low shrubland area covered by these classes was determined from the SANLC maps (1990, 2014, 2018, 2020, 2022) and then linearly extrapolated between these points to complete the time series. This was used to estimate the area of each subclass.



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Using scientific literature as a source, biomass data was split into woody and herbaceous component and area weighted biomass, root to shoot ratios, growth rates, etc were determined for the low shrubland class (Table 6.44). Biomass gains for low shrublands were estimated with IPCC 2006 Guidelines equation 2.9 and 2.10.

Table 6.44: Biomass factors for grassland categories

	Woody AGB (t dm/ha)	Herbaceous biomass (t dm/ha)	Woody AGB growth (t dm/ha)	Ratio of BGB to AGB (woody)	Ratio of BGB to AGB (herbaceous)	Litter (t C/ha)	Deadwood (t C/ha)
<i>Low shrubland[#]</i>	7.07 (18.22)	0.35 (0.18)	0.72 (2.5)	0.26	1.19 (1.68)	0.35	2.1
<i>IPCC 2019 Refinement (Shrubland)</i>	48.4	NA	0.2-1.6	NA	2.8	NA	NA
<i>Grasslands</i>	NA	2.0	NA	NA	2.6	0.73	NA
<i>IPCC 2006 (Semi-arid grasslands)</i>	NA	1.6	NA	NA	2.8	NA	NA

[#] The weighted average is shown with the Fynbos value in brackets.

6.8.2.3 Biomass losses

6.8.2.3.1 Grasslands, eroded lands and subantarctic tundra

As no gains were included for *Grasslands remaining grasslands* no losses were included either. If there were conversions between different grassland categories, then these losses were determined as described for converted lands and included here.

6.8.2.3.2 Low shrublands

Biomass losses for low shrublands are determined using IPCC 2006 Guidelines equation 2.14, with the burnt area data (Table 6.45) coming from MODIS (see section 6.4.7). No burnt area data was available for the Subantarctic tundra as there are no land cover maps for the overseas territories. Burnt area and biomass data was combined with a *fd* of 0.91 and a carbon fraction of 0.47.



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Table 6.45: Burnt area (ha) data for Grasslands

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Grasslands</i>	2 260 677	2 260 677	2 260 677	2 260 677	2 260 677	2 260 677	1 992 544	1 816 147	2 125 663
<i>Eroded land</i>	3 435	3 435	3 435	3 435	3 435	3 435	3 027	2 759	3 229
<i>Low shrublands</i>	207 219	207 219	207 219	207 219	207 219	207 219	264 832	284 092	359 112
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Grasslands</i>	2 002 241	2 211 087	2 531 164	2 611 302	2 097 613	1 777 414	2 762 240	3 039 324	2 871 773
<i>Eroded land</i>	3 042	4 767	4 315	4 969	1 462	4 391	5 379	6 504	989
<i>Low shrublands</i>	317 429	135 861	108 708	308 469	188 215	110 258	185 802	65 620	57 571
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Grasslands</i>	2 667 606	2 761 543	2 375 424	2 413 849	2 013 447	2 427 910	2 153 523	1 525 175	855 746
<i>Eroded land</i>	4 629	3 005	4 044	6 822	2 899	2 891	2 513	1 766	387
<i>Low shrublands</i>	70 038	97 548	244 729	234 960	332 804	120 579	83 302	116 318	157 802
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Grasslands</i>	1 659 196	1 857 947	1 583 629	1 870 800	2 907 928	1 709 207	2 869 169	2 394 056	
<i>Eroded land</i>	2 241	2 507	2 228	2 730	7 984	1 785	4 437	4 266	
<i>Low shrublands</i>	216 942	246 259	99 491	46 956	222 887	453 421	48 284	145 389	

6.8.2.4 Gains and losses due to land conversions

Land converted to grassland was identified as a key category in the previous inventory with the level and trend assessment and therefore a Tier 2 approach (IPCC 2006 Guidelines equations 2.15 and 2.16) was applied. For *land converted to grasslands* carbon gains and losses were only calculated for the woody low shrubland component, while in annual grasslands carbon stocks were assumed to be in balance and not included in the annual gain calculation.

The carbon stock change due to the removal of biomass from the initial land use (i.e. $\Delta C_{CONVERSION}$) was only calculated for the area of lands undergoing a conversion in a given year, and in subsequent years it was zero. The biomass values for the initial land types are given in the relevant land category sections, while biomass data for the grassland categories are provided in Table 6.44. It was assumed that only croplands and forest

plantations were cleared before being converted to a grassland, while all other conversions were slow transitions and not abrupt changes. Converted lands remain in the converted category for a period of 20 years.

6.8.2.5 Litter and deadwood

The DOM pool for *Grasslands remaining grasslands* was identified as a key category in the previous inventory, however there is a lack of data to allow for movement to a Tier 2. A Tier 1 methodology was therefore applied and the collection of DOM data for Grasslands was included in the improvement list.

The Tier 1 assumption for the DOM pool was that the stocks in *Grasslands remaining grasslands* were not changing over time, therefore litter changes were reported to be zero. This was applied to areas where the grassland category did not change, however, there were conversions between the various grassland categories, and these were treated as converted lands.

Changes in the DOM pool in converted land was estimated using IPCC 2006 Guidelines equation 2.23. The initial DOM is given in the relevant land category section, and the final DOM for the grassland types is shown in Table 6.46. The litter data for grasslands was sourced from the NTCSA (DEA, 2015) which provides spatial carbon density maps. These maps were intersected with the SANLC data to provide an area averaged estimate of the litter for the grassland category. The Low shrubland category included fynbos which has a woody component, therefore deadwood was included in this DOM pool. Litter and deadwood values for Low shrublands were derived from IPCC 2019 refinement data for the various ecozones and an area based weighted average was determined based on the percentage area in each ecozone (methodology described in section 6.3.4.3. If there was a gain in DOM this is assumed to occur over the 20-year default period, while losses are assumed to occur within the year of conversion (Tier 1).

Table 6.46: DOM data for *Grasslands*

Grassland category	Litter (t C/ha)	Deadwood (t C/ha)	Reference
Grasslands	0.73		NTCSA (DEA, 2015)
Low shrublands	0.35	2.10	Weighted average IPCC 2019 Refinement values
Eroded land	0		Assumed to be zero



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6.8.2.6 Soil carbon

6.8.2.6.1 Mineral soils

Soil carbon changes were estimated for all grassland categories as described in sections 6.3.4.1 and 6.4.3. The IPCC 2006 Guidelines default stock change factor of 1 for grasslands and low shrublands, and 0.7 (IPCC 2006 Guidelines, Chapter 6, Table 6.2) for eroded lands were applied.

6.8.2.6.2 Organic soils

The determination of the organic soil area in *Grasslands* is described in section 6.4.3.2. The CO₂ emissions from drained organic soils is however not reported in this category (4.C) but under emissions from drainage and rewetting of mineral and organic soils in *Grasslands* (4(II).C). This category is therefore reported as included elsewhere (IE).

6.8.2.7 Direct and indirect N₂O from N inputs

All direct and indirect emissions of N₂O from nitrogen fertiliser inputs to *Grasslands* are not included in the LULUCF sector, but rather in the Agriculture sector (3.D.1 & 3.D.2). It should be noted that there is no known data source for nitrogen inputs to *Grasslands*. There may be some inputs to pastures and rangelands, but there is no input to natural grasslands, low shrublands or eroded lands. These emissions are therefore not estimated.

6.8.2.8 Emissions and removals from drainage and rewetting

Drained organic soil area for *Grasslands* was obtained from FAOSTAT (Table 6.47). The IPCC 2013 Wetland Supplement methodology for CO₂ emissions (equations 2.3 – 2.5) and CH₄ emissions (equation 2.6) were utilised to estimate emissions from drained soils.

Table 6.47: Drained organic soil area (ha) for *Grasslands*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Grassland drained organic soil</i>	13 198	13 198	13 198	13 198	13 198	13 348	13 484	13 666	14 112
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Grassland drained organic soil</i>	14 823	14 947	15 001	15 216	15 696	15 737	15 772	15 784	15 801
	2008	2009	2010	2011	2012	2013	2014	2015	2016



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<i>Grassland drained organic soil</i>	15 830	15 832	15 830	15 835	15 835	15 835	15 809	15 807	15 795
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Grassland drained organic soil</i>	15 795	15 796	15 691	15 680	15 670	15 678	15 678	15 678	

CO₂ emissions from drained soil includes on-site and off-site emissions (IPCC 2013 Wetland Supplement, equation 2.2). A Tier 1 approach for on-site CO₂ emissions (equation 2.3) included combining the drained organic soil area with an emission factor of 5.3 t C/ha/yr (IPCC 2013 Wetland Supplement, Table 2.1). Off-site emissions (equation 2.4) used an emission factor of 0.31 t C/ha/yr (2013 WS, Table 2.2). CO₂ emissions from fires on drained soils were not included as burnt area for drained soils could not be separated from the total grassland burnt area. The CO₂ emissions will therefore be slightly underestimated. Emission factors were selected based on a temperate, dry climate and nutrient poor grasslands. The nutrient status of the drained soil is not known so the nutrient poor value was chosen as it is an average value for grasslands in temperate climates.

CH₄ emissions from drained soils are estimated with the IPCC 2013 Wetland Supplement equation 2.6. The area of ditches is not known so an average fraction of 0.5 is assumed for ditches (IPCC 2013 Wetland Supplement, Table 2.4). The drained area was combined with this fraction and default emission factors for drained organic soils (1.8 kg CH₄/ha/yr) and drained ditches (527 kg CH₄/ha/yr) from the IPCC 2013 Wetland Supplement Tables 2.3 and 2.4 respectively.

N₂O emissions from drained organic soils were not included in this sector but rather in the Agriculture sector (3.D.1.f).

6.8.2.9 Direct and indirect N₂O from N mineralisation/immobilisation

Direct N₂O from N mineralisation/immobilisation associated with loss of soil carbon from soil organic matter as a result of changes to land use were incorporated through the application of the IPCC 2006 Guidelines equations 11.1 and 11.8. The annual loss of carbon due to land use change comes from analysis described in section 6.6.2.6.1 and the C:N ratio of 12.5 was obtained from IPCC 2006 Guidelines (average of 10 and 15). The IPCC 2019 Refinement emission factor was 0.01 kg N₂O-N/kg N.

Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines equation 11.10 with a F_{leach} of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).



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6.8.2.10 *Non-CO₂ emissions from biomass burning*

Biomass burning emissions were identified as a key category in the previous inventory and therefore a Tier 2 approach is, according to IPCC decision tree, recommended. In this inventory, even though the emission factors were taken from the IPCC 2006 Guidelines, more specific fuel loads and combustion factors were applied (Tier 2). This section only included emissions for grasslands and low shrublands as there was no burnt area available for the small subantarctic area. The CO₂ emissions from biomass burning were incorporated as disturbance losses in the gain-loss method described above. This category therefore only includes the emissions of CH₄ and N₂O emissions. Emissions were also estimated for CO, NO_x and NMVOCs but these are not reported here but rather under the section on Indirect emissions (Chapter 8).

Emissions were estimated with IPCC 2006 Guidelines equation 2.27. Burnt areas are provided in Table 6.45. Emission factors from IPCC 2006 Guidelines Table 2.5 were applied (Savanna and grassland) along with a NMVOC emission factor of 3.4 g/kg dm burnt (Sinha, et al., 2003). An area weighted average fuel consumption value of 2.72 t dm/ha was determined for low shrublands based on the fuel consumption values for the different low shrubland (fynbos, succulent karoo, nama karoo) classes. These varied from 0.6 t dm/ha for Succulent karoo to 12.9 t dm/ha for fynbos (IPCC, 2006; DEAT, 2009; DEA, 1999). The grassland fuel load was 2.8 t dm/ha. Combustion factors for grasslands and low shrublands were 0.88 and 0.91 respectively (IPCC, 2006; Hely, et al., 2003).

6.8.3 Uncertainty

Uncertainties were provided for individual factors, based on literature and the IPCC 2006/2019 Refinement Guideline default values, and were combined using equations 3.1 and 3.2 of the IPCC 2006 Guidelines.

6.8.3.1 *Activity data uncertainty*

Uncertainty for the land areas were provided by the SANLC data accuracy assessments (DFFE, 2021). Grasslands have the highest uncertainty (52%) followed by shrublands (36%) and eroded land (16%). An additional 15% for land remaining and 20% for land conversions was added to this for uncertainty on the mapped area corrections. The uncertainty for converted areas was taken to be the combined uncertainty (applying the propagation of errors as indicated in IPCC 2006 Guidelines) for the two land areas. The results of this approach indicate the converted lands have a higher uncertainty than the individual land types as is to be expected. Mapped areas for land converted to Grasslands had an estimated uncertainty of $\pm 60.7\%$.



The burnt area data determined from MODIS collection 6 has an uncertainty of <6% (Boschetti et al., 2021) and the soil maps are estimated to have an uncertainty of $\pm 10\%$. The overall activity data uncertainty for grassland remaining grassland was estimated at $\pm 41.2\%$. For land converted to cropland the uncertainty was estimated at $\pm 61.8\%$.

6.8.3.2 Emission factor uncertainty

The uncertainty on biomass gains was estimated from uncertainties and data ranges provided in the scientific literature, IPCC 2006 Guidelines and IPCC 2019 Refinement. Uncertainty on growing stock ($\pm 12\%$) was taken from the literature. Disturbance losses in industrialised countries have a default uncertainty of $\pm 15\%$, so a $\pm 20\%$ uncertainty is assumed. Root to shoot ratios have a $\pm 30\%$ uncertainty and carbon fraction uncertainty is $\pm 6\%$ (IPCC, 2006). Since the DOM and SOC data have greater uncertainty than the biomass data an uncertainty of $\pm 20\%$ is assigned to these categories. The CO₂ emission factor uncertainty for *Grasslands* was estimated at $\pm 40.3\%$, while for land converted to grasslands it was $\pm 53.2\%$.

For CH₄ and N₂O biomass burning emission factors have uncertainties of $\pm 40\%$ and $\pm 47\%$ respectively for *Grasslands*. Direct emission factors for inputs (of N and FSOM) to managed soils have, based on defaults from 2019 Refinement, uncertainties of -90% and +80%, while indirect emissions for volatilisation and leaching are $\pm 80\%$ and -100% to +82% respectively. Drainage and rewetting CH₄ and N₂O emission factors have an uncertainty of +71.2% and +58.1%.

6.8.4 Time-series consistency

The land change maps had some inconsistency in that there was a switch from Landsat to Sentinel data between 2014 and 2018, however some corrections were made to bring these two datasets into alignment. All other datasets were consistent through the time-series, using the same methodology and data sources. The calculations are consistent over time and complete for the entire reporting period (1990-2024).

6.8.5 Category specific QA/QC and verification

There were no category specific QA/QC checks over and above the checks described in section 6.1.5.



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6.8.6 Category-specific recalculations

The following main improvements led to a recalculation of the *Grassland* emissions:

- Inclusion of 2020-2022 land change maps
- Updated land change matrix corrections for change in technology between 2014 and 2018, and wet and dry season variations.
- Removal of error from 2014 onwards (mentioned in last inventory) relating to a correction for land conversions on already converted land.
- Updated methodology for estimating burnt area per land class.
- Incorporation of soil type map overlay with 2014-2018, 2018-2020 and 2020-2022 land cover maps.
- Updated biomass, deadwood and litter carbon data.
- Inclusion of drained organic soils and their emissions.

The improvements led to an increase in emissions in the *Grasslands* category. The 2021 emission estimates were reduced by 2 279 Gg CO₂e (18.1%) and the 2022 estimates increased by 1 166 Gg CO₂e (10.3%) since the previous submission.

6.8.7 Category-specific planned improvements

The only planned improvement for *Grasslands* is the collection of more DOM data as this was listed as a key category in the previous inventory.

6.9 Wetlands (CRT 4.D)

6.9.1 Category description

The *Wetlands* category is split into *Wetlands remaining Wetlands* (4.D.1) and *Land converted to Wetlands* (4.D.2). These two divisions are, in the IPCC guidelines, further divided into 3 types of wetlands, namely peat extraction, flooded land and other wetlands. There is a “land remaining” and a “land converted” category for each of these wetland types. In this inventory flooded lands are what are classified as waterbodies in the SANLC and the class called wetlands is incorporated into the CRTs under “other wetlands”. The SANLC does not separate out coastal wetlands, so these are included under “other wetlands” and are listed as “IE” in the CRTs. South Africa does have peatlands, but the area is very small (Grundling & Grobler, 2005; Grundling, et al., 2017; Grundling, et al.,



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2021). These are also not separated out from “other wetlands” in the SANLC. Due to the small peatland area peat extraction is limited and is primarily done by small-scale landowners. It is discouraged because peatlands provide vital ecosystem services. For this reason, peat extraction data is virtually non-existent and therefore emissions from this sub-category are not estimated.

All land conversion calculations are carried out based on a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years.

Emissions in *Wetlands* include CO₂ emissions/removals from above- and below-ground biomass, litter, deadwood, and mineral soils. Organic soil area is small and is not separated out from mineral soils, so for *Wetlands* all soil is treated as mineral and organic emissions from organic soils are indicated as “IE”. *Wetland* emissions also include CO₂ and CH₄ from rewetting in mineral soils, and direct and indirect N₂O emissions from mineralisation in mineral soils. N₂O emissions from nitrogen inputs do not occur. Finally, it includes CH₄ and N₂O emissions from wildfires. Indirect emissions from wildfires are also estimated but these are reported under indirect CO₂ and N₂O in Chapter 8 of this report.

The *Wetland* category increased its emissions from 503 Gg CO₂e in 1990 to 2 105 Gg CO₂e 2024 (Table 6.48). This increase is mainly due to increased CH₄ emissions from rewetting as land is converted to flooded lands. Biomass is the dominant *Wetlands* pool and this source of emissions has increased by 74.8% since 1990. DOM is the main sink with a 20.0% increase since 1990. There is a large increase in conversion to flooded land in 2021 and 2022 (Figure 6.15) but this could be related to the fact that 2022 was a wet year so there was an increase in *Wetland* area.

Table 6.48: *Wetland* emissions for 1990 and 2024

Category	Pool	Gas	1990	2024	Change between 1990-2024 (%)
			Emissions (Gg CO ₂ e)	Emissions (Gg CO ₂ e)	
Wetlands	All	All	503	2 105	318.4
Wetlands	All	CO ₂	-147	107	*
Wetlands	All	CH ₄	582	1 932	232.1
Wetlands	All	N ₂ O	68	67	-2.0
Wetlands remaining Wetlands	All	All	217	309	42.6



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Land converted to Wetlands	All	All	286	1 796	527.4
Wetlands	Biomass	All	337	629	86.5
Wetlands	DOM	All	-405	-466	15.0
Wetlands	Mineral soil	All	-78	-55	-29.3

*Cannot be calculated due to positive and negative numbers. Sink changes to a source.

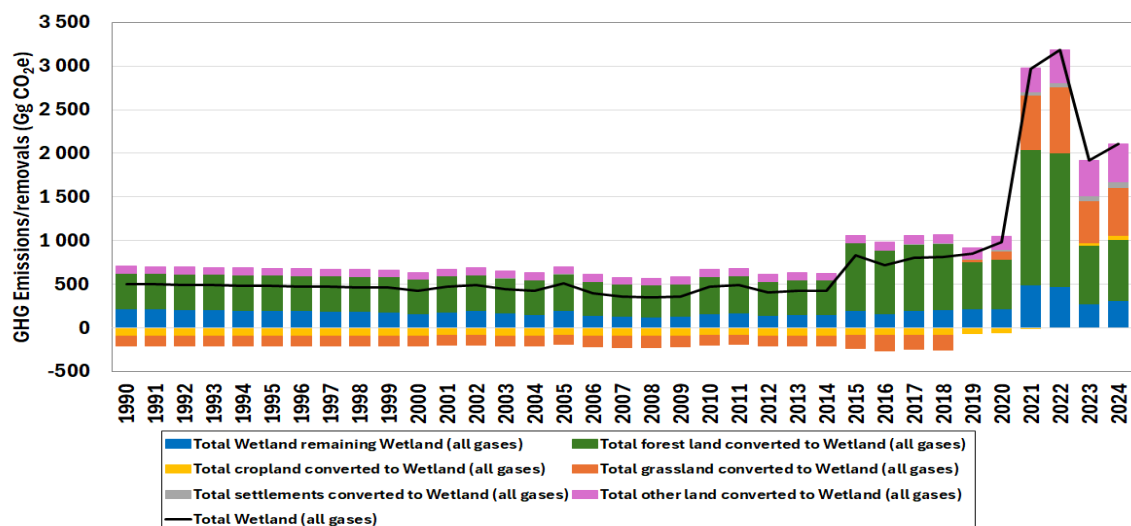


Figure 6.15: *Wetland* emission trends, 1990-2024

6.9.2 Methodological issues

Methodologies and emission factors applied for *Wetlands* are provided in Table 6.49. In the previous inventory *Wetlands remaining wetlands* and *Land converted to Wetlands* were identified as key categories for CH₄ emissions due to drainage and rewetting. In this inventory these emissions estimates were reassessed, and methodologies were revised to align with IPCC 2013 Wetland Supplement and IPCC 2019 Refinement methodologies. The *Wetlands* emissions were determined following the Inland Wetland Mineral Soils methodology provided in the IPCC 2013 Wetland Supplement. The methodology for flooded lands was taken from IPCC 2006 Guidelines, vol 4., Chapter 7 (as indicated in the decision tree in the IPCC 2013 Wetland Supplement (Chapter 1, Figure 1.1)).



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Table 6.49: Methodologies and EF applied for estimating emissions from *Wetlands*

Category	Gas	Method used	Source of activity data	Emission factor used
Wetlands remaining Wetlands	CO ₂	Tier 1/Tier 2	CS	D/CS
Wetlands remaining Wetlands	CH ₄	Tier 1/Tier 2	CS	D
Wetlands remaining Wetlands	N ₂ O	Tier 1/Tier 2	CS	D
Land converted to Wetlands	CO ₂	Tier 2	CS	D/CS
Land converted to Wetlands	CH ₄	Tier 1/Tier 2	CS	D
Land converted to Wetlands	N ₂ O	Tier 1/Tier 2	CS	D

(NO = Not occurring; NA = Not applicable; CS = Country specific; D = IPCC default)

6.9.2.1 Land area activity data

The activity data was country specific land area data determined as outlined in section 6.3 **Error! Reference source not found.** with an Approach 2 methodology and included areas for both *Wetlands remaining Wetlands* and *Land converted to Wetlands* (Table 6.50).

Table 6.50: Country specific land areas (kha) (including 20-year transition period) for Wetlands.

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Flooded land remaining flooded land</i>	520	514	508	501	495	489	482	476	469
<i>Land converted to flooded land</i>	87	87	87	87	87	87	87	87	87
<i>Other wetlands remaining other wetlands</i>	1 271	1 250	1 229	1 209	1 188	1 168	1 147	1 126	1 106
<i>Land converted to other wetlands</i>	250	250	250	250	250	250	250	250	250
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Flooded land remaining flooded land</i>	463	457	450	444	437	431	425	418	412
<i>Land converted to flooded land</i>	87	87	87	87	87	87	87	87	87
<i>Other wetlands remaining other wetlands</i>	1 085	1 065	1 044	1 023	1 003	982	962	941	920
<i>Land converted to other wetlands</i>	250	250	250	250	250	250	250	250	250



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	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Flooded land remaining flooded land</i>	406	399	393	386	380	374	367	369	370
<i>Land converted to flooded land</i>	87	87	87	87	87	87	87	92	96
<i>Other wetlands remaining other wetlands</i>	900	879	859	838	817	797	776	771	765
<i>Land converted to other wetlands</i>	250	250	250	250	250	250	250	258	266
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Flooded land remaining flooded land</i>	371	372	336	299	300	302	265	229	
<i>Land converted to flooded land</i>	101	105	133	161	282	403	436	468	
<i>Other wetlands remaining other wetlands</i>	759	753	756	760	752	745	751	757	
<i>Land converted to other wetlands</i>	275	283	284	285	286	288	289	290	

6.9.2.2 Biomass gains

6.9.2.2.1 Flooded lands (waterbodies)

There is no methodology for estimating CO₂ from *Flooded land remaining Flooded land*, but there was a small area that was converted from another wetland to flooded land. This area was treated as *Flooded land remaining flooded land* and the losses were calculated as described for land conversions.

6.9.2.2.2 Other wetlands

As the other wetlands do not contain woody vegetation they are considered annual and a Tier 1 assumption of equivalence was applied. As with flooded lands there was a small area that was converted from flooded land to wetlands and emissions from this area were estimated as described for converted land, but the emissions were reported under *Other wetlands remaining other wetlands*.



6.9.2.3 Biomass losses

6.9.2.3.1 Flooded lands (waterbodies)

As with biomass gains there is no methodology for *Flooded lands remaining flooded lands*, but losses were estimated for the area of wetlands converted to flooded lands as described under the land conversion section. These losses were included here.

6.9.2.3.2 Other wetlands

As no gains were included for *Other wetlands remaining other wetlands* no losses were included either. If there were conversions between different wetland categories, then these losses were determined as described for converted lands and included here.

6.9.2.4 Gains and losses due to land conversion

For land conversions a Tier 2 approach (IPCC 2006 Guidelines equations 2.15 and 2.16) was applied. As the vegetation in wetlands is annual the only losses that occurred were the losses due to abrupt changes (i.e. $\Delta C_{CONVERSION}$), there were no additional gains or losses due to the assumption of equivalence. The losses were estimated for the area of lands undergoing a conversion in a given year, and in subsequent years it was zero. Converted lands remained in the converted category for a period of 20 years.

The biomass values for the initial land types are given in the relevant land category sections. Wetland biomass data was sourced from the literature and a weighted average determined based on the area of the various wetland types provided in the SANLC maps (DFFE, 2021). The above ground biomass was 15.0 t dm/ha and this was combined with a root to shoot ratio of 0.96 (IPCC, 2014a). It was assumed that only croplands and forest plantations were cleared before being converted to a grassland, while all other conversions were slow transitions and not abrupt changes.

6.9.2.5 Litter

The DOM pool for *Wetlands* was not identified as a key category in the previous inventory, so a Tier 1 methodology was applied. The Tier 1 assumption for the litter pool is that the stocks in *Wetlands remaining wetlands* are not changing over time, therefore litter changes are reported to be zero. This was applied to areas where the *Wetland category* did not change, however, there were conversions between wetlands and flooded lands so changes in litter in these areas was estimated as for converted land.

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Changes in the DOM pool in converted land was estimated using IPCC 2006 Guidelines equation 2.23. The initial DOM is given in the relevant land category section, and the final DOM for the other wetlands was 9.8 t C/ha (Glenday, 2007) and assumed zero for flooded lands. If there was a gain in DOM this was assumed to occur over the 20-year default period, while losses were assumed to occur within the year of conversion (Tier 1).

6.9.2.6 Soil carbon**6.9.2.6.1 Mineral soils**

Soil carbon changes were estimated for other wetlands as described in sections 6.3.4.1 and 6.4.3. The IPCC 2006 Guidelines default stock change factor of 1 was applied. There is no methodology for *Flooded lands remaining flooded lands* or land converted to Flooded lands so these emissions were listed as not applicable.

6.9.2.6.2 Organic soils

Organic soils were not separated from mineral soils for *Wetlands*, therefore all soils were included under mineral soils.

6.9.2.7 Direct and indirect N₂O from N inputs

There are no known inputs of nitrogen to *Wetlands* so these emissions were allocated the notation key "NO".

6.9.2.8 Emissions and removals from drainage and rewetting**6.9.2.8.1 Flooded lands (waterbodies)**

There is insufficient data to include drainage and rewetting of soils under flooded lands, but the IPCC 2019 Refinement provides methods for estimating annual reservoir surface CH₄ emissions (equation 7.10 B and 7.15 B). There is no place for these emissions to be reported in the CRTs as reporting with 2019 Refinement is not a requirement. For this reason, these emissions are, for the moment, reported under drainage and rewetting.

Total CH₄ for reservoirs >20 years, i.e. flooded land remaining flooded land, were estimated using IPCC 2019 Refinement equation 7.10. The reservoir surface area was estimated from the fraction of the flooded land area occupied by artificial waterbodies (reservoirs are the dominant man-made waterbodies) in the SANLC maps. An average fraction (0.6) was applied across the time-series. A Tier 1 method was applied so the



emission factor adjustment for trophic state in the reservoirs was set at 1. The ratio of total downstream flux of CH₄ to the flux of the CH₄ from a reservoir surface to the atmosphere (0.09) and the CH₄ emission factor (150.9 kg CH₄/ha/yr) were sources from IPCC 2019 Refinement, chapter 7, Table 7.9 and 7.10.

Similarly, CH₄ emissions were estimated for land converted to reservoirs by applying the IPCC 2019 Refinement equation 7.15. All the factors were the same as the method for *Flooded land remaining flooded land* except the emission factor which was 195.6 kg CH₄/ha/yr (IPCC 2019 Refinement, chapter 7, Table 7.15).

6.9.2.8.2 Other wetlands

For *lands converted to other wetlands* it was assumed the water level increases constitutes rewetted soil. The IPCC 2013 Wetland Supplement (IPCC, 2014a) provides a methodology to estimate CH₄ emissions from rewetted wetlands on Inland Wetland Mineral Soils (IPCC 2013 Wetland Supplement, Chapter 5, equation 5.1). Section 6.3.4.1 describes the estimation of the inland wetland mineral soil areas which was combined with the emission factor of 235 kg CH₄/ha/yr (IPCC 2013 Wetland Supplement, chapter 5, Table 5.4).

IPCC does not provide a method for estimating N₂O emissions from *Wetlands* so these emissions were not included.

6.9.2.9 **Direct and indirect N₂O from N mineralisation/immobilisation**

Direct N₂O from N mineralisation/immobilisation associated with loss of soil carbon from soil organic matter as a result of changes to land use were incorporated through the application of the IPCC 2006 Guidelines equations 11.1 and 11.8. The annual loss of carbon due to land use change comes from analysis described in section 6.6.2.6.1 and the C:N ratio of 12.5 was obtained from IPCC 2006 Guidelines (average of 10 and 15). The IPCC 2019 Refinement emission factor was 0.01 kg N₂O-N/kg N.

Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines equation 11.10 with a F_{leach} of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).

6.9.2.10 **Non-CO₂ emissions from biomass burning**

This section includes only non-CO₂ emissions (CH₄, N₂O) for *Wetlands*. The CO₂ emissions from biomass burning were incorporated as disturbance losses in the gain-loss method



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described above. Emissions were also estimated for CO, NO_x and NMVOCs but these are not reported here but rather under the section on Indirect emissions.

Emissions were estimated with IPCC 2006 Guidelines equation 2.27. Burnt areas are provided in Table 6.51. Emission factors from IPCC 2006 Guidelines Table 2.5 were applied (Savanna and grassland) along with a NMVOC emission factor of 3.4 g/kg dm burnt (Sinha, et al., 2003). A fuel load and combustion factor of 2.8 t dm/ha and 0.7 (IPCC, 2006) respectively were incorporated into the equation.

Table 6.51: Burnt area (ha) data for other wetlands

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Wetlands	92 482	91 229	89 976	88 723	87 470	86 218	84 965	83 712	82 459
	1999	2000	2001	2002	2003	2004	2005	2006	2007
Wetlands	81 206	69 554	83 761	94 341	76 709	65 282	97 399	65 912	58 861
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Wetlands	53 240	59 934	77 350	85 212	69 151	81 508	77 274	73 853	39 414
	2017	2018	2019	2020	2021	2022	2023	2024	
Wetlands	64 334	62 951	65 981	67 098	72 623	41 063	59 384	90 674	

6.9.3 Uncertainty

Uncertainties were provided for individual factors, based on literature and the IPCC 2006/2019 Refinement Guideline default values, and were combined using equations 3.1 and 3.2 of the IPCC 2006 Guidelines.

6.9.3.1 Activity data uncertainty

Uncertainty for the land areas were provided by the SANLC data accuracy assessments (DFFE, 2021). Wetlands have a higher uncertainty than flooded lands. An additional 5% was added to this for uncertainty on the mapped area corrections. The uncertainty for converted areas was taken to be the combined uncertainty (applying the propagation of errors as indicated in IPCC 2006 Guidelines) for the two land areas. The results of this approach indicate the converted lands have a higher uncertainty than the individual land types as is to be expected. Mapped areas for land converted to Wetlands had an estimated uncertainty of $\pm 42.8\%$.

The burnt area data determined from MODIS collection 6 has an uncertainty of $<6\%$ (Boschetti et al., 2021) and the soil maps are estimated to have an uncertainty of $\pm 10\%$.



The overall activity data uncertainty for wetlands remaining wetlands was estimated at $\pm 17.7\%$. For land converted to cropland the uncertainty was estimated at $\pm 44.4\%$.

6.9.3.2 Emission factor uncertainty

The uncertainty on biomass gains was estimated from uncertainties and data ranges provided in the scientific literature, IPCC 2006 Guidelines and IPCC 2019 Refinement Guidelines.

The uncertainty for biomass was estimated to be similar to *Grasslands*. Disturbance losses in industrialised countries have a default uncertainty of $\pm 15\%$, so a $\pm 20\%$ uncertainty is assumed. Root to shoot ratios have a $\pm 30\%$ uncertainty and carbon fraction uncertainty is $\pm 6\%$ (IPCC, 2006). Since the DOM and SOC data have greater uncertainty than the biomass data an uncertainty of $\pm 20\%$ is assigned to these categories. The CO₂ emission factor uncertainty for *Wetlands* was estimated at $\pm 40.3\%$, while for land converted to wetlands it was $\pm 53.2\%$.

For CH₄ and N₂O biomass burning emission factors have uncertainties of $\pm 40\%$ and $\pm 47\%$ respectively for Wetlands. Direct emission factors for inputs (of N and FSOM) to managed soils have, based on defaults from 2019 Refinement, uncertainties of -90% and $+80\%$, while indirect emissions for volatilisation and leaching are $\pm 80\%$ and -100% to $+82\%$ respectively. Drainage and rewetting CH₄ and N₂O emission factors have an uncertainty of $+71.2\%$ and $+58.1\%$.

6.9.4 Time-series consistency

The land change maps had some inconsistency in that there was a switch from Landsat to Sentinel data between 2014 and 2018, however some corrections were made to bring these two datasets into alignment. All other datasets were consistent through the time-series, using the same methodology and data sources. The calculations were therefore consistent over time and complete for the entire reporting period (1990-2024).

6.9.5 Category specific QA/QC and verification

There were no category specific QA/QC checks over and above the checks described in section 6.1.5.

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6.9.6 Category-specific recalculations

Recalculations were necessary as several updates and improvements were made to the *Wetland* category. In the previous submission the estimation method for CH₄ emissions was not completely in alignment with IPCC methodologies, so this was addressed in this inventory. The following improvements were the main reasons for recalculations in the *Wetland* category:

- Inclusion of 2020-2022 land change map.
- Updated land change matrix corrections for change in technology between 2014 and 2018, and wet and dry season variations.
- Removal of error from 2014 onwards (mentioned in last inventory) relating to a correction for land conversions on already converted land.
- Updated methodology for estimating burnt area per land class.
- Incorporation of soil type map overlay with 2014-2018, 2018-2020 and 2020-2022 land cover maps.
- Updated biomass, deadwood and litter carbon data.
- Correction to the CH₄ emissions from rewetted soils methodology to bring it not alignment with IPCC 2013 Wetland Supplement and CRT tables.
 - In the previous submission the emission factor was applied to the whole wetland area, but this has been corrected to only the rewetted inland mineral soil area.

The improvements, particularly in terms of the CH₄ methodology, caused a large reduction (67% for 2022) in the *Wetland* overall emissions, with emissions being reduced by 6 490 Gg CO_{2e} (2022) compared to the last submission. The CH₄ emission estimates were reduced by 6 520 Gg CO_{2e} in this submission for 2022, CO₂ emissions were reduced by half and N₂O emissions were increased by 1 971 Gg CO_{2e}. The N₂O emissions changes were due to increased emissions from fires which were affected by land area, burnt area and biomass factor improvements.

6.9.7 Category-specific planned improvements

As the land mapping system is developed so the inclusion of organic soils (for all land categories) will be improved. It is therefore planned that organic soil emissions will be incorporated into Wetlands in the future.

During the updating of this inventory further data on peatlands was found. Peatlands are not separated out in the SANLC maps but the literature (Grundling & Grobler, 2005;



Grundling, et al., 2017; Grundling, et al., 2021) indicates that some spatial data may be available. In the next inventory the aim is to try and include some information on peatlands.

Lastly, in this inventory reservoirs were separated out in the *Flooded land* subcategory, and the IPCC 2019 Refinement provides a methodology for estimating on-site CO₂ emissions from reservoirs (IPCC 2019 Refinement, Equation 7.13). It is unclear at this stage where in the CRTs this data would be accommodated, so the inclusion of this data will be explored in the next inventory.

6.10 Settlements (CRT 4.E)

6.10.1 Category description

The *Settlement* category is subdivided into *Settlements remaining Settlements* (4.E.1) and *Land converted to Settlements* (4.E.2). Calculations are carried out based on a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years. *Settlements remaining settlements* or a key category in terms of biomass CO₂ emissions and removals.

Emissions in *Settlements* include CO₂ emissions/removals from above- and below-ground biomass, litter and mineral soils. Organic soils could not be separated out so all soils were assumed to be mineral and organic soils are reported as "IE". It also includes direct and indirect N₂O emissions from nitrogen inputs and mineralisation in mineral soils. Lastly, it includes CH₄ and N₂O emissions from wildfires. Indirect emissions from wildfires are also estimated but these are reported under indirect CO₂ and N₂O in Chapter 8.

The *Settlement* category covers residential areas, smallholdings, commercial and industrial spaces, as well as mines.

The *Settlement* category increased its sink by 74.5% to 1 326 Gg CO₂e in 2024 (Table 6.52). *Settlements remaining Settlements* were a sink due to the growth of woody areas within settlement zones, while *Land converted to Settlements* is a source of emissions. Biomass is therefore the dominant pool. From 2015 onwards there has been an increase in the conversion of *Forest Land to Settlements* which reduced the sink (Figure 6.16), and an increase in conversion of *Cropland to Settlements* between 2020 and 2024.



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Table 6.52: Settlement emissions for 1990 and 2024

Category	Pool	Gas	1990	2024	Change between 1990-2024 (%)
			Emissions (Gg CO ₂ e)	Emissions (Gg CO ₂ e)	
Settlements	All	All	-760	-1 326	74.5
Settlements	All	CO ₂	-810	-1 453	79.4
Settlements	All	CH ₄	16	21	28.0
Settlements	All	N ₂ O	34	107	213.1
Settlements remaining Settlements	All	All	-1 287	-2 981	131.7
Land converted to Settlements	All	All	527	1 656	214.0
Settlements	Biomass	All	-796	-1 327	66.7
Settlements	DOM	All	162	154	-5.1
Settlements	Mineral soil	All	-175	-279	59.3

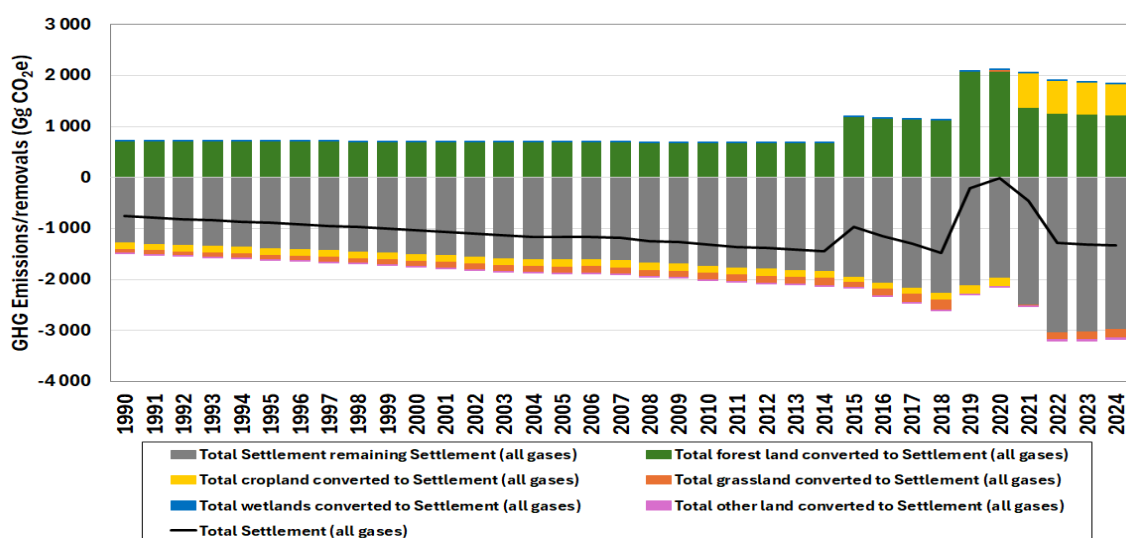


Figure 6.16: Settlement emission trends, 1990-2024

6.10.2 Methodological issues

The methodologies and emission factors applied to *Settlements* are provided in Table 6.53. In the previous inventory *Settlements remaining Settlements* (all carbon pools) and *Forest land converted to Settlements* (all carbon pools) were identified as key categories. *Settlements remaining Settlements* which contained perennial growth were identified and a Tier 2 approach applied. Land conversions were calculated with a Tier 2 approach which is consistent with the IPCC decision tree (IPCC 2006 Guidelines, Figure 2.2).

Table 6.53: Methodologies and EF applied for estimating emissions from *Settlements*

Category	Gas	Method used	Source of activity data	Emission factor used
Settlements remaining Settlements	CO ₂	Tier 1/Tier 2	CS	D/CS
Settlements remaining Settlements	CH ₄	Tier 1/Tier 2	CS	D
Settlements remaining Settlements	N ₂ O	Tier 1/Tier 2	CS	D
Land converted to Settlements	CO ₂	Tier 2	CS	D/CS
Land converted to Settlements	CH ₄	Tier 1/Tier 2	CS	D
Land converted to Settlements	N ₂ O	Tier 1/Tier 2	CS	D

(NO = Not occurring; NA = Not applicable; CS = Country specific; D = IPCC default)

6.10.2.1 Land area activity data

The activity data was country specific land area data determined as outlined in section 6.3 with an Approach 2 methodology and included areas for both *Settlements remaining Settlements* and *Land converted to Settlements* (Table 6.54).

Table 6.54: Country specific land areas (kha) (including 20-year transition period) for *Settlements*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Settlements remaining Settlements</i>	2 493	2 505	2 517	2 528	2 540	2 552	2 563	2 575	2 586
<i>Land converted to Settlements</i>	524	524	524	524	524	524	524	524	524
	1999	2000	2001	2002	2003	2004	2005	2006	2007



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Settlements remaining Settlements	2 598	2 610	2 621	2 633	2 645	2 656	2 668	2 680	2 691
Land converted to Settlements	524	524	524	524	524	524	524	524	524
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Settlements remaining Settlements	2 703	2 714	2 726	2 738	2 749	2 761	2 773	2 786	2 799
Land converted to Settlements	524	524	524	524	524	524	524	535	545
	2017	2018	2019	2020	2021	2022	2023	2024	
Settlements remaining Settlements	2 813	2 826	2 806	2 786	2 739	2 693	2 646	2 599	
Land converted to Settlements	555	566	600	634	676	719	762	805	

6.10.2.2 Biomass gains

6.10.2.2.1 Industrial, commercial and mines

The detailed SANL maps provide detailed separation of the *Settlement* category. It provides information on the area covered grass, shrubs and trees within each Settlement class. The industrial and commercial classes are not indicated to have woody vegetation and therefore no gain are included for these classes. Mines are also only shown to have infrastructure, pits and quarries, salt mines, tailings and resource dumps, therefore biomass gains were also not included for this class.

6.10.2.2.2 Residential and smallholdings

The percentage area covered by grass, shrubs and trees in each of these categories was determined from the SANLC data and the woody vegetation area estimated. For biomass gains IPCC 2006 Guidelines Equation 8.2 is applied. Only growth for perennial vegetation is included as the rest is assumed to be in equilibrium. As per the guidelines, trees over 20yrs age also assumed to be at equilibrium. Crown area was assumed to be the tree component from the SANLC residential area, but since the age of the vegetation was not known it was assumed that 50% of the tree crown cover area for "land remaining land" was >20yrs. Growth therefore was only included for half the tree area. The IPCC default accumulation rate of 2.8 t C/ha crown cover (IPCC 2019 Refinement, Chapter 8, Table 8.1) was applied.

6.10.2.3 Biomass losses

6.10.2.3.1 Industrial, commercial and mines

Since gains are not included for these classes, losses are also not included.

6.10.2.3.2 Residential and smallholdings

The carbon losses from fire disturbance in *Settlements* was estimated with IPCC 2006 Guidelines equation 2.14. Where there was land-use change between the *Settlement* categories, carbon stock changes were reported under Settlements remaining settlements. The only disturbance losses that were included are those from fires. There was insufficient data to separate out controlled and wildfire burns so all emissions were included under wildfires.

Losses were estimated from burnt area data (Table 6.55), biomass data and a fraction of vegetation that was burnt (*fd*). A weighted average biomass was determined for residential (2.77 t dm/ha) and smallholdings (3.63 t dm/ha) by using biomass data for grasslands, shrublands and woodlands and weighting it by percentage area. These were combined with a root to shoot ratio of 0.26, a *fd* value of 0.74 (which is an average of fraction lost for grasslands and woodlands) and carbon fraction of 0.47.

Table 6.55: Burnt area data (ha) for *Settlements*

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Residential</i>	42 966	43 134	43 302	43 470	43 638	43 806	43 974	44 142	44 310
<i>Smallholdings</i>	6 158	6 165	6 172	6 179	6 186	6 193	6 200	6 207	6 214
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Residential</i>	44 478	33 404	36 995	27 692	23 889	18 631	42 185	72 769	80 485
<i>Smallholdings</i>	6 221	5 738	6 355	4 379	3 778	2 946	6 671	9 127	10 094
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Residential</i>	49 688	59 795	44 716	31 968	31 133	33 475	35 002	20 882	8 569
<i>Smallholdings</i>	6 232	7 499	5 608	3 050	2 970	3 194	3 340	4 414	1 106
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Residential</i>	14 062	12 022	21 081	26 478	29 948	12 378	25 076	58 439	
<i>Smallholdings</i>	3 003	1 644	3 608	2 774	2 106	1 682	2 120	4 596	



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6.10.2.4 Carbon gains and losses for land conversions

Land converted to Settlements was estimated using a Tier 2 approach (IPCC 2006 Guidelines equations 2.15 and 2.16). For *land converted to settlements* the biomass gains and losses on total converted area were estimated as described above. The initial carbon stock change due to the removal of biomass (i.e. $\Delta C_{CONVERSION}$) was only calculated for the area of land undergoing a conversion in a given year, and in subsequent years it was zero. Converted lands remain in the converted category for a period of 20 years.

The biomass values for the initial land types are given in the relevant land category sections, while biomass data for the settlement categories are provided above (6.10.2.3). It was assumed that only croplands and forest plantations were cleared before being converted to a settlement, while all other conversions were slow transitions and not abrupt changes.

6.10.2.5 Litter

The DOM pool for *Settlements* was not identified as a key category in the previous inventory, so a Tier 1 methodology was applied. The Tier 1 assumption for the litter pool in *Settlements remaining settlements* is that the stocks are not changing over time, therefore litter changes are reported to be zero. This was applied to areas where the crop type did not change, however, there were conversions between the various settlement types, and these were treated as converted land areas.

Changes in the DOM pool in converted land was estimated using IPCC 2006 Guidelines equation 2.23. The initial DOM is given in the relevant land category section, and the final DOM for the settlement types is shown in Table 6.56. The litter data was sourced from the NTCSA (DEA, 2015) which provides spatial carbon density maps. These maps were intersected with the SANLC data to provide an area averaged estimate of the litter for each settlement type. If there is a gain in DOM this is assumed to occur over the 20-year default period, while losses are assumed to occur within the year of conversion (Tier 1).

Table 6.56: Litter data for Settlement categories

Settlement type	Litter (t C/ha)	Reference
Residential	1.39	NTCSA (DEA, 2015)
Smallholdings	1.13	
Commercial	1.11	
Industrial	2.02	



6.10.2.6 Soil carbon

6.10.2.6.1 Mineral soils

Soil carbon changes were estimated for all settlement categories as described in sections 6.3.4.1 and 6.4.3. The IPCC 2006 Guidelines default stock change factor of 1 was applied.

6.10.2.6.2 Organic soils

Organic soils were not separated from mineral soils for *Settlements*, therefore all soils were included under mineral soils.

6.10.2.7 Direct and indirect N₂O from N inputs

There are nitrogen inputs to settlements as this category includes residential gardens and recreational areas that are often fertilised. A data source for the amount of nitrogen applied to residential gardens is lacking and so these emissions still need to be estimated. As a start this inventory includes an estimate of emissions for fertilisers added to golf courses. These emissions were included under the Residential category. In the 72 class SANLC data there is class 63 which is called “Urban recreational fields (grass)” which includes grassy urban sports fields and golf courses. The fraction of this relative to the total Residential category was determined for each land map (1990, 2014, 2018, 2020, 2022). Linear extrapolation was used to extrapolate for the years in between. This enabled the determination the golf course area across the time-series. A nitrogen application rate of 263.4 kg N/ha was applied to this area to determine total N application. This rate was based on 84 kg N/ha three times a year for turf, 40 kg N/ha once a month for green, and the assumption of greens occupying 5% of the area.³⁴ This is an initial start to incorporating N input data and will be improved as more data becomes available.

Direct N₂O emissions were estimated by combining the amount of nitrogen applied was combined with the IPCC 2019 Refinement default average emission factor for synthetic fertilisers (0.01 kg N₂O-N/kg N) in IPCC 2006 Guidelines equation 11.1. Indirect emissions from atmospheric deposition of N volatilised from managed soils were determined with equation 11.9, a $Frac_{GASF}$ of 0.11 kg N volatilised/kg N applied (IPCC 2019 Refinement, Chapter 11, Table 11.3) and an emission factor of 0.01 kg N₂O-N/(kg NH₃-N + NO_x-N volatilised) (IPCC 2019 Refinement, Chapter 11, Table 11.3). Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines

³⁴ *Fertplan – Fertilizer for greens*



equation 11.10 with a $Frac_{LEACH}$ of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).

6.10.2.8 Emissions and removals from drainage and rewetting

There is no data on the area of drained or rewetted *Settlement* soils, therefore these emissions were not estimated.

6.10.2.9 Direct and indirect N₂O from N mineralisation/immobilisation

Direct N₂O from N mineralisation/immobilisation associated with loss of soil carbon from soil organic matter as a result of changes to land use were incorporated through the application of the IPCC 2006 Guidelines equations 11.1 and 11.8. The annual loss of carbon due to land use change comes from analysis described in section 6.6.2.6.1 and the C:N ratio of 12.5 was obtained from IPCC 2006 Guidelines (average of 10 and 15). The IPCC 2019 Refinement emission factor was 0.01 kg N₂O-N/kg N.

Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines equation 11.10 with a $Frac_{LEACH}$ of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).

6.10.2.10 Non-CO₂ emissions from biomass burning

Biomass burning emissions were identified as a key category in the previous inventory and therefore a Tier 2 approach is, according to IPCC decision tree, recommended. In this inventory, even though the emission factors were taken from the IPCC 2006 Guidelines, more specific fuel loads and combustion factors were applied (Tier 2). This section only included emissions for residential and small holdings as commercial, industrial and mines were assumed not to burn as there is minimal biomass at these locations. The CO₂ emissions from biomass burning were incorporated as disturbance losses in the gain-loss method described above. This category therefore only includes the emissions of CH₄ and N₂O emissions. Emissions were also estimated for CO, NO_x and NMVOCs but these are not reported here but rather under the section on Indirect emissions.

Emissions were estimated with IPCC 2006 Guidelines equation 2.27. Burnt areas are provided in Table 6.55. Emission factors from IPCC 2006 Guidelines Table 2.5 were applied (Savanna and grassland) along with a NMVOC emission factor of 3.4 g/kg dm burnt (Sinha, et al., 2003). A fuel load of 5.73 t dm/ha and 6.03 t dm/ha was determined for residential and smallholdings respectively. Combustion fraction of 0.88 from *Grasslands* (IPCC, 2006; Hely, et al., 2003) was applied.



6.10.3 Uncertainty

Uncertainties were provided for individual factors, based on literature and the IPCC 2006/2019 Refinement Guideline default values, and were combined using equations 3.1 and 3.2 of the IPCC 2006 Guidelines.

6.10.3.1 Activity data uncertainty

Uncertainty for the land areas were provided by the SANLC data accuracy assessments (DFFE, 2021). *Settlements remaining settlements* have a lower uncertainty than the other land categories as it is land use data for which there is a lot more detail and thus accuracy. An additional 2% was added to this for uncertainty on the mapped area corrections. The uncertainty for converted areas was taken to be the combined uncertainty (applying the propagation of errors as indicated in IPCC 2006 Guidelines) for the two land areas. The results of this approach indicate the converted lands have a higher uncertainty than the individual land types as is to be expected. Mapped areas for land converted to Settlements had an estimated uncertainty of $\pm 47.8\%$.

The burnt area data determined from MODIS collection 6 has an uncertainty of $<6\%$ (Boschetti et al., 2021) and the soil maps are estimated to have an uncertainty of $\pm 10\%$. The overall activity data uncertainty for *Settlements remaining settlements* was estimated at $\pm 18.3\%$. For land converted to *Settlements* the uncertainty was estimated at $\pm 49.2\%$.

6.10.3.2 Emission factor uncertainty

The uncertainty on biomass gains was estimated from uncertainties and data ranges provided in the scientific literature, IPCC 2006 Guidelines and IPCC 2019 Refinement. Growing stock or gains were indicated to have a $\pm 30\%$ uncertainty for non-industrialised countries. Disturbance losses in industrialised countries have a default uncertainty of $\pm 15\%$, so a $\pm 20\%$ uncertainty is assumed. Root to shoot ratios have a $\pm 30\%$ uncertainty and carbon fraction uncertainty is $\pm 6\%$ (IPCC, 2006). Since the DOM and SOC data have greater uncertainty than the biomass data an uncertainty of $\pm 20\%$ is assigned to these categories. The CO₂ emission factor uncertainty for *Settlements* was estimated at $\pm 40.3\%$, while for land converted to settlements it was $\pm 53.2\%$.

For CH₄ and N₂O biomass burning emission factors have uncertainties of $\pm 40\%$ and $\pm 47\%$ respectively for Settlements. Direct emission factors for inputs (of N and FSOM) to managed soils have, based on defaults from 2019 Refinement, uncertainties of -90% and $+80\%$, while indirect emissions for volatilisation and leaching are $\pm 80\%$ and -100% to $+82\%$ respectively.

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6.10.4 Time-series consistency

The land change maps had some inconsistency in that there was a switch from Landsat to Sentinel data between 2014 and 2018, however some corrections were made to bring these two datasets into alignment. All other datasets were consistent through the time-series, using the same methodology and data sources. The calculations are therefore consistent over time and complete for the entire reporting period (1990-2024).

6.10.5 Category specific QA/QC and verification

No category specific quality checks were completed for *Settlements*.

6.10.6 Category-specific recalculations

The main improvements for the *Settlement* category that led to recalculations for the time series were:

- Inclusion of 2020-2022 land change map.
- Updated land change matrix corrections for change in technology between 2014 and 2018, and wet and dry season variations.
- Removal of error from 2014 onwards (mentioned in last inventory) relating to a correction for land conversions on already converted land.
- Updated methodology for estimating burnt area per land class.
- Incorporation of soil type map overlay with 2014-2018, 2018-2020 and 2020-2022 land cover maps.
- Updated biomass, deadwood and litter carbon data.
- Update of carbon accumulation rate for tree from IPCC 2006 Guidelines default to IPCC 2019 Refinement default.

The improvements caused the *Settlements* sink to decline by 1 084 Gg CO₂e (45%) in 2022 relative to the previous submission. Most of the change is due to adjustments in the land change areas.

6.10.7 Category-specific planned improvements

There are no specific planned improvements for this category.

6.11 Other lands (CRT 4.F)

6.11.1 Category description

The *Other land* category is subdivided into *Other land remaining Other land* (4.F.1) and *Land converted to Other land* (4.F.2). Calculations are carried out based on a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years.

Emissions in *Other land* include CO₂ emissions/removals from above- and below-ground biomass, litter and mineral soils. Organic soils could not be separated out so all soils were assumed to be mineral and organic soils are reported as "IE". It also includes direct and indirect N₂O emissions from mineralisation in mineral soils. No nitrogen is input into the *Other land* category, therefore direct and indirect N₂O emissions from N input are reported as "NO". There is also no vegetation in *Other lands* so no biomass burning emissions are included.

The *Other land* category includes bare ground and the newly added polar desert.

There are no emissions from *Other land remaining Other land* so the emissions of 10 335 Gg CO₂e in 2024 are from Lands converted to Other lands (Table 6.57). These emissions have increased by 67.8% since 1990, with an almost doubling occurring from 2015 (Figure 6.17). This increase was due to an increase in the conversion of *Forest land to Other land* between 2015 and 2020 and a further increase in the conversion of *Grassland to Other land* between 2020 and 2024.

Table 6.57: Other land emissions for 1990 and 2024

Category	Pool	Gas	1990	2024	Change between 1990-2024 (%)
			Emissions (Gg CO ₂ e)	Emissions (Gg CO ₂ e)	
Other lands	All	All	6 159	10 335	67.8
Other lands	All	CO ₂	5 981	10 093	68.7
Other lands	All	CH ₄	0	0	0.0
Other lands	All	N ₂ O	178	241	35.8
Other lands remaining Other lands	All	All	0	0	0.0
Land converted to Other land	All	All	6 159	10 335	67.8



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Other lands	Biomass	All	2 393	5 176	116.3
Other lands	DOM	All	622	1 287	107.0
Other lands	Mineral soil	All	2 967	3 631	22.4

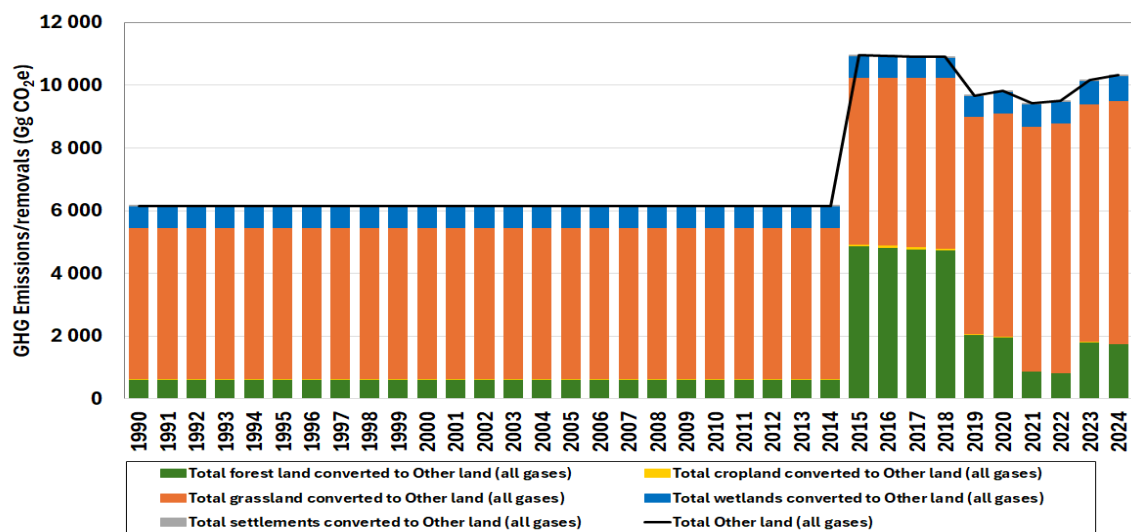


Figure 6.17: *Other land* emission trends, 1990-2024

6.11.2 Methodological issues

Methodologies and emission factors applied for *Other land* emission estimation are provided in Table 6.58. *Other lands* were not a key category in the previous inventory, so a Tier 1 approach is suitable.

Table 6.58: Methodologies and EF applied for estimating emissions from *Other land*

Category	Gas	Method used	Source of activity data	Emission factor used
Other lands remaining Other lands	CO ₂	Tier 1	CS	D/CS
Other lands remaining Other lands	CH ₄	NO	NA	NA
Other lands remaining Other lands	N ₂ O	Tier 1	CS	D



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Land converted to Other land	CO ₂	Tier 2	CS	CS
Land converted to Other land	CH ₄	NO	NA	NA
Land converted to Other land	N ₂ O	Tier 1	CS	D

(NO = Not occurring; NA = Not applicable; CS = Country specific; D = IPCC default)

6.11.2.1 Land area activity data

The activity data was country specific land area data determined as outlined in section 6.3 with an Approach 2 methodology and included areas for both *Other land remaining* and *Land converted to Other land* (Table 6.59).

**Table 6.59: Country specific land areas (kha) (including the 20-year transition period) for
*Other land***

	1990	1991	1992	1993	1994	1995	1996	1997	1998
<i>Other land remaining</i>	10 982	10 937	10 893	10 849	10 804	10 760	10 715	10 671	10 627
<i>Land converted to Other land</i>	2 539	2 539	2 539	2 539	2 539	2 539	2 539	2 539	2 539
	1999	2000	2001	2002	2003	2004	2005	2006	2007
<i>Other land remaining</i>	10 582	10 538	10 494	10 449	10 405	10 361	10 316	10 272	10 228
<i>Land converted to Other land</i>	2 539	2 539	2 539	2 539	2 539	2 539	2 539	2 539	2 539
	2008	2009	2010	2011	2012	2013	2014	2015	2016
<i>Other land remaining</i>	10 183	10 139	10 094	10 050	10 006	9 961	9 917	9 887	9 857
<i>Land converted to Other land</i>	2 539	2 539	2 539	2 539	2 539	2 539	2 539	2 582	2 625
	2017	2018	2019	2020	2021	2022	2023	2024	
<i>Other land remaining</i>	9 826	9 796	8 863	7 931	7 158	6 385	5 459	4 532	
<i>Land converted to Other land</i>	2 667	2 710	2 856	3 003	3 166	3 330	3 476	3 623	

6.11.2.2 Biomass gains

Other lands do not have vegetation, therefore there were no gains for *Other lands remaining other lands*.

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6.11.2.3 Biomass losses

No gains were included for *Other lands remaining other lands*, and therefore, due to equivalence, no losses were included either.

6.11.2.4 Carbon gains and losses for land conversions

Land converted to Other lands biomass gains were estimated using a Tier 2 approach (IPCC 2006 Guideline equations 2.15 and 2.16). For *land converted to other lands* the only biomass losses were the initial carbon losses due to the removal of biomass (i.e. $\Delta C_{CONVERSION}$). This was calculated for the area of land undergoing a conversion in a given year, and in subsequent years it was zero. Converted lands remain in the converted category for a period of 20 years.

The biomass values for the initial land types are given in the relevant land category sections, while biomass data for *Other lands* is zero. It was assumed that only croplands and forest plantations were cleared before being converted to other lands, while all other conversions were slow transitions and not abrupt changes.

6.11.2.5 Litter

The DOM pool for *Other lands* was not identified as a key category in the previous inventory, so a Tier 1 methodology was applied. As there is no vegetation there is also no litter in *Other lands remaining other lands*. Changes in the DOM pool in converted land was estimated using IPCC 2006 Guidelines equation 2.23. The initial DOM is given in the relevant land category section, and the final DOM for *Other lands* is zero. All losses are assumed to occur within the year of conversion (Tier 1).

6.11.2.6 Soil carbon**6.11.2.6.1 Mineral soils**

Soil carbon changes in *Other lands* were estimated as described in sections 6.3.4.1 and 6.4.3. The IPCC 2006 Guidelines Tier 1 methodology assumes that soil carbon stocks will decline to zero after conversion. In the inventory, however, the land conversion matrixes show large areas of conversion between bare ground (*Other land*) and other land categories such as low shrubland and grasslands. This suggests that some of the bare ground area may only be temporarily bare but can have vegetation growing on them. These conversions could be associated with seasonal variation (i.e. whether the land cover maps are for dry or wet years). In addition, this *Other land* category includes deserts and even deserts are shown to still have carbon in the soil (DEA, 2015). The soil



carbon in all the *Other land* area is therefore unlikely to have a soil carbon value of zero. For this reason, a Tier 2 approach for SOC estimation for land converted to *Other land* was applied where the reference carbon stock at the end of the 20 year default transition period was not assumed to be zero and country specific reference carbon stocks at the end of the 20 year period are applied with stock change values set at 0.7.

6.11.2.6.2 Organic soils

Organic soils were not separated from mineral soils for *Other lands*, therefore all soils were included under mineral soils.

6.11.2.7 **Direct and indirect N₂O from N inputs**

There are no nitrogen inputs to *Other lands* so these emissions were indicated to not occur (NO).

6.11.2.8 **Emissions and removals from drainage and rewetting**

This is not included in this inventory for *Other lands*.

6.11.2.9 **Direct and indirect N₂O from N mineralisation/immobilisation**

Direct N₂O from N mineralisation/immobilisation associated with loss of soil carbon from soil organic matter as a result of changes to land use were incorporated through the application of the IPCC 2006 Guidelines equations 11.1 and 11.8. The annual loss of carbon due to land use change comes from analysis described in section 6.6.2.6.1 and the C:N ratio of 12.5 was obtained from IPCC 2006 Guidelines (average of 10 and 15). The IPCC 2019 Refinement emission factor was 0.01 kg N₂O-N/kg N.

Indirect emissions from N leaching and runoff were estimated with IPCC 2006 Guidelines equation 11.10 with a F_{leach} of 0.24 kg N/kg N additions and an emission factor of 0.01 kg N₂O-N/kg N leached/runoff (IPCC 2019 Refinement, Chapter 11, Table 11.3).

6.11.2.10 **Non-CO₂ emissions from biomass burning**

As there is no biomass on bare ground it is assumed that there is no biomass burning occurring on these lands.

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6.11.3 Uncertainty

Uncertainties were provided for individual factors, based on literature and the IPCC 2006/2019 Refinement Guideline default values, and were combined using equations 3.1 and 3.2 of the IPCC 2006 Guidelines.

6.11.3.1 Activity data uncertainty

Uncertainty for the land areas were provided by the SANLC data accuracy assessments (DFFE, 2021). *Other lands* have a high uncertainty and there are numerous conversions with natural land cover classes. An additional 20% was added to this for uncertainty on the mapped area corrections. The uncertainty for converted areas was taken to be the combined uncertainty (applying the propagation of errors as indicated in IPCC 2006 Guidelines) for the two land areas. The results of this approach indicate the converted lands have a higher uncertainty than the individual land types as is to be expected. Mapped areas for land converted to *Other lands* had an estimated uncertainty of $\pm 60.6\%$.

The soil maps are estimated to have an uncertainty of $\pm 10\%$. The overall activity data uncertainty for *Other lands remaining other lands* was estimated at $\pm 30.2\%$. For land converted to *Other lands* the uncertainty was estimated at $\pm 61.8\%$.

6.11.3.2 Emission factor uncertainty

There is no growth or DOM stock on *Other lands*, but there are uncertainties associated with SOC changes. The CO₂ emission factor uncertainty for *Other lands* was estimated at $\pm 35\%$, while for land converted to settlements it was $\pm 40\%$. There is no biomass burning, nitrogen inputs or drainage and rewetting emissions.

6.11.4 Time-series consistency

The land change maps had some inconsistency in that there was a switch from Landsat to Sentinel data between 2014 and 2018, however some corrections were made to bring these two datasets into alignment. All other datasets were consistent through the time-series, using the same methodology and data sources. The calculations are consistent over time and complete for the entire reporting period (1990-2024).

6.11.5 Category specific QA/QC and verification

Part of the quality control process was to check methodologies and outputs against the IPCC software. It was noted that the final SOC reference value for conversion to *Other land*



is set at zero and cannot be changed. The IPCC software does not allow for a Tier 2 approach as used in this inventory and this was queried during an IPCC software training course. It was indicated that there may need to be a more detailed assessment of the bare ground so that the area which potentially still has soil carbon (such as deserts) can be reclassified into a vegetation class in the *Grassland* category. If the IPCC software is going to be used in the future this reclassification would be required.

6.11.6 Category specific recalculations

The main improvements that led to recalculations in this *Other land* category are:

- Inclusion of 2020-2022 land change map.
- Updated land change matrix corrections for change in technology between 2014 and 2018, and wet and dry season variations.
- Removal of error from 2014 onwards (mentioned in last inventory) relating to a correction for land conversions on already converted land.
- Incorporation of soil type map overlay with 2014-2018, 2018-2020 and 2020-2022 land cover maps.

The recalculations due to these improvements led to a 50% reduction (9 506 Gg CO₂e) in the emissions from *Other lands* in 2022 compared to the previous submission.

6.11.7 Category specific planned improvements

The soil carbon levels in *Other lands* will be investigated further in the next inventory to ensure that the most appropriate data (final soil carbon, stock change factors) and methodology is being applied correctly for lands converted to *Other lands*. The classification of *Other lands* will also be studied in more detail to determine if changes need to be made in future. The *Other land* category is very large, and it may be more appropriate to shift some of the area to another subcategory of *Grasslands*. This may improve transparency.



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6.12 Harvested wood products (CRT 4.G)

6.12.1 Category description

Much of the wood that is harvested from *Forest lands* remains in products for differing lengths of time. This section of the report estimates the contribution of these harvested wood products (HWPs) to annual CO₂ emissions or removals. *HWPs* include all wood material that leaves harvest sites from forest plantations. Wood that is collected from woodlands for household use for cooking is not included in this category. HWP in Solid Waste Disposal Sites (SWDS) are also not included.

HWP's are a net sink for the full time-series and the sink shows an increasing trend since 1990. The sink increased by 65.9% between 1990 and 2024 (Table 6.60). The trend in emissions between 1990 and 2024 are provided in Figure 6.18.

Table 6.60: HWP emissions and removals between 1990 and 2024.

Category	Gas	1990	2024	Change between 1990-2024 (%)
		Emissions (Gg CO ₂ e)	Emissions (Gg CO ₂ e)	
HWP	CO ₂	-1 036	-1 718	65.9

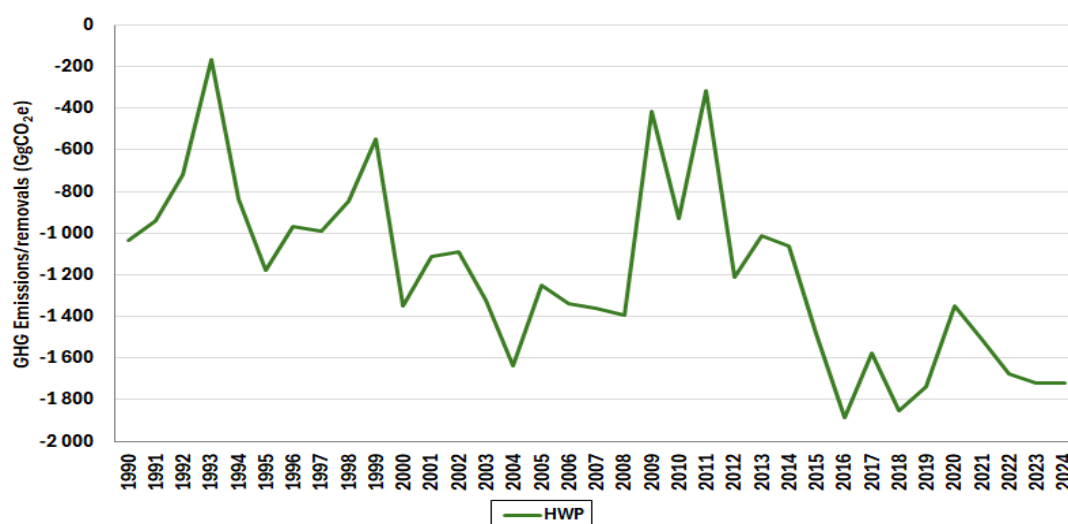


Figure 6.18: Trend in HWP CO₂ removals, 1990-2024



6.12.2 Methodological issues

Emissions and removals arising from HWP were estimated following the guidance provided in the IPCC 2019 Refinement (Chapter 12). A Tier 1 First Order Decay approach was implemented (equations 12.1-12.3), and the CO₂ inflow was determined following the Production Approach (equations 12.7-12.10). In the previous submission the IPCC 2006 Guidelines methodology was applied, but the 2019 Refinement was selected for this submission. The methodological approaches are very similar but the refinement was selected as it considers new relevant scientific information and provides clearer guidance for completing the emission estimates.

HWP from forest plantations are included in this section and it does not include fuelwood harvested from woodlands for domestic purposes. It also does not include wood disposed of in SWDS.

6.12.2.1 Activity data

Activity data is required for 1960 onwards for HWP estimation, however country specific data from Forestry SA (collected annually) is only available for 1980 onwards. FAOSTAT data was therefore used to extend the timeline back to 1960 (as well as for filling data gaps). If FAO data had gaps in the time-series the IPCC interpolation technique was used to fill these gaps. If the gaps were at the beginning of the time-series, then production data was extended with linear extrapolation and import/export data were assigned a value of zero. In addition, Forestry SA data is only available until 2019 so additional data was sought to complete the time-series to 2024. The data sources are provided in Table 6.61 and the activity data is provided in Table 6.62 and Table 6.63.

Table 6.61: HWP activity data sources

Data type		Details of data source
Industrial round wood	Production	Forestry SA statistics (South African Forestry & Forest Products Industry Facts 1980-2019); extrapolation for 2020-2024 as described in section 6.6.2.2.3). FAO data matches very well with this data set so FAO data used for 1961-1979.
	Imports and exports	FAOSTAT 1960-2024
Sawnwood	Production	Forestry SA statistics (South African Forestry & Forest Products Industry Facts 1980-2017, Sales data in table 20 (https://forestry.co.za/industry-info/statistical-data/) for 1980-2017.



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Data type		Details of data source
		FSA and FAO data match very well so FAO data used for 1961-1979 and 2018-2024.
	Imports and exports	FAOSTAT 1960-2024
Wood panels	Production	Forestry SA statistics (South African Forestry & Forest Products Industry Facts 1980-2017, Sales data in table 20 (https://forestry.co.za/industry-info/statistical-data/) for 2000-2017. FSA and FAO data match quite well so FAO data used for 1961-1979 and 2018-2024.
	Imports and exports	FAOSTAT 1960-2024
Paper and paperboard	Production	PAMSA Reports for 2001-2024. Data matches very well with FAO so FAO data applied for years 1961-2000.
	Imports and exports	FAO data was slightly lower than the FSA data so the IPCC overlap splicing technique was used to adjust the FAO data for 1961-2000 and 2019-2020.
Wood pulp	Production	Forestry SA statistics (South African Forestry & Forest Products Industry Facts 1980-2017, Sales data in table 20 (https://forestry.co.za/industry-info/statistical-data/) for 1980-2000; PAMSA Reports for 2008 onwards. FAO data matches well with FSA data therefore FAO data used for 1961-1979.
	Imports and exports	FAO data was slightly lower than the FSA data so the IPCC overlap splicing technique was used to adjust the FAO data for 1961-2000 and 2016-2020.
Recovered paper	Production	PAMSA Reports; PRASA Paper recycling statistics reports for 2010 onwards. Data the same as FAO so FAO data used for 1961-2009
	Imports and exports	FAOSTAT 1960-2024

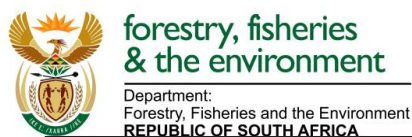


Table 6.62: Activity data for estimating HWP emissions and removals

Year	Industrial roundwood			Sawnwood			Wood panels		
	Production	Imports	Exports	Production	Imports	Exports	Production	Imports	Exports
	(m ³ /yr)								
1990	17 650 820	6 051	18 198	1 796 196	80 202	106 946	283 700	5 407	74 725
1991	17 545 290	9 921	79 762	1 793 063	80 202	106 946	274 000	5 407	74 725
1992	17 794 081	105 266	64 756	1 644 136	530 869	94 863	392 000	65 056	60 557
1993	17 645 533	66 145	419 821	1 315 022	60 943	63 801	189 000	9 456	33 192
1994	19 127 778	82 078	462 371	1 498 437	542 100	66 778	545 000	22 970	61 019
1995	19 060 473	102 830	231 311	1 574 424	413 000	57 000	618 000	93 400	42 900
1996	20 076 766	84 298	433 920	1 430 005	466 200	47 500	618 000	99 000	17 100
1997	20 504 985	10 961	277 302	1 319 902	438 000	73 600	618 000	49 100	16 100
1998	17 090 998	17 628	234 362	1 556 243	384 300	91 000	401 000	52 800	21 200
1999	17 434 523	14 690	340 130	1 378 935	510 200	134 100	401 000	52 700	24 000
2000	18 660 619	14 690	340 130	1 446 303	510 200	134 100	706 210	52 700	24 000
2001	18 494 152	13 355	156 244	1 716 031	427 000	107 800	767 058	49 584	79 500
2002	18 521 086	18 080	435 969	1 689 628	380 000	110 000	685 985	75 100	82 600
2003	21 459 013	24 502	343 280	2 006 044	480 000	123 306	733 389	119 547	67 664
2004	22 652 164	42 933	419 096	2 183 847	360 349	84 279	692 196	166 969	76 670
2005	24 537 662	42 367	285 867	2 243 209	464 350	63 971	512 802	231 514	82 249
2006	25 465 815	57 306	216 211	2 016 053	487 200	62 782	726 213	330 280	50 770
2007	22 628 073	57 306	216 211	1 892 171	535 300	78 500	820 289	319 800	35 300
2008	22 450 035	68 319	242 666	2 051 769	487 690	55 323	891 817	156 109	37 316
2009	20 990 015	39 961	237 021	1 908 347	297 000	14 726	625 228	148 192	77 678
2010	19 473 611	9 161	201 167	1 880 498	350 904	22 976	540 526	179 428	69 647
2011	20 585 783	3 102	179 446	1 568 004	302 030	18 338	551 564	277 954	99 396
2012	20 217 222	1 742	147 754	1 443 105	153 000	119 500	1 228 421	130 644	101 958
2013	19 880 460	14 593	222 935	1 588 558	341 343	123 353	1 153 878	167 659	88 912
2014	18 757 273	7 244	342 015	1 918 244	318 509	165 796	1 013 112	275 241	133 885
2015	19 941 125	43 697	301 710	2 012 515	258 620	150 720	1 227 663	208 252	169 400
2016	18 298 167	32 215	269 687	2 144 045	186 440	214 740	1 446 535	245 994	179 836
2017	20 424 180	44 353	718 414	2 141 199	267 905	264 510	1 466 502	241 688	220 796
2018	20 859 735	18 970	706 250	2 259 317	216 134	287 440	1 513 031	197 335	242 494
2019	18 510 348	49 852	514 673	2 259 317	318 225	219 000	1 513 431	254 044	276 587
2020	15 913 711	24 661	340 272	2 105 000	328 000	205 755	1 546 431	229 987	250 374
2021	17 984 503	56 418	510 915	2 105 000	250 000	301 430	1 546 431	280 314	223 163
2022	19 100 828	100 808	868 929	2 105 000	234 000	288 991	1 546 431	279 335	224 273
2023	18 280 463	53 847	955 980	2 105 000	158 000	177 470	1 546 431	241 494	323 909



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Year	Industrial roundwood			Sawnwood			Wood panels		
	Production	Imports	Exports	Production	Imports	Exports	Production	Imports	Exports
	(m ³ /yr)								
2024	18 280 463	53 847	955 980	2 105 000	158 000	177 470	1 546 431	241 494	323 909

Table 6.63: Activity data for estimating *HWP* emissions and removals

Year	Paper and paperboard			Wood pulp			Recovered paper		
	Production	Imports	Exports	Production	Imports	Exports	Production	Imports	Exports
	(t/yr)								
1990	1 904 000	178 717	146 927	1 774 494	150 807	377 177	510 000	7 984	6 396
1991	1 904 000	178 717	146 927	1 846 988	150 807	377 177	525 000	7 984	6 396
1992	1 800 000	293 890	417 128	1 866 177	55 238	465 077	598 000	19 939	6 918
1993	1 710 000	283 105	404 188	1 828 397	78 886	429 062	590 000	39 602	2 002
1994	1 684 000	311 895	698 185	2 106 973	83 993	525 171	590 000	18 264	5 970
1995	1 871 000	352 338	642 663	2 206 892	84 800	615 853	590 000	21 000	15 000
1996	1 871 000	357 132	575 709	2 902 476	131 449	886 708	590 000	6 400	1 000
1997	2 047 000	312 310	388 532	2 919 634	131 449	616 076	590 000	6 400	1 000
1998	2 105 000	303 614	680 641	2 215 322	105 878	654 261	590 000	10 000	22 000
1999	2 041 000	316 545	701 479	2 115 588	96 755	862 439	590 000	2 700	13 200
2000	2 426 000	316 545	707 631	2 126 641	96 755	862 439	690 000	2 700	13 200
2001	2 258 000	254 000	933 606	2 138 000	53 000	659 382	770 000	3 200	13 200
2002	2 332 000	265 000	784 956	2 183 000	64 000	711 259	770 000	4 800	12 900
2003	2 337 000	371 000	1 098 978	2 317 000	71 000	918 666	923 000	11 721	20 620
2004	2 522 000	399 000	1 160 892	2 073 000	71 000	1 009 721	923 000	2 803	18 555
2005	2 483 000	449 000	1 101 895	2 193 000	70 000	839 955	923 000	8 500	48 448
2006	2 610 000	670 000	921 939	2 222 000	127 000	845 794	923 000	20 519	39 300
2007	2 727 000	708 000	1 115 054	2 311 000	82 000	815 469	923 000	20 519	39 300
2008	2 726 000	645 000	1 084 000	2 572 000	114 000	849 000	1 030 000	31 800	23 893
2009	2 244 000	706 000	794 000	2 130 000	99 000	1 008 000	1 129 955	31 064	14 863
2010	2 497 000	708 000	735 000	2 307 000	77 000	985 000	1 090 198	30 752	50 572
2011	2 261 000	738 000	547 000	2 321 000	79 000	1 113 000	1 064 509	32 876	71 541
2012	2 427 000	805 000	565 000	2 259 000	88 000	998 000	1 151 315	35 156	103 092
2013	2 318 183	824 629	610 568	1 985 000	144 000	1 047 000	1 169 296	45 252	98 699
2014	2 261 790	761 128	732 474	1 967 000	230 000	1 165 000	1 063 129	72 060	55 398
2015	2 289 109	791 601	665 753	1 982 000	214 000	1 128 000	1 196 026	69 244	49 069
2016	2 352 989	747 879	719 426	2 221 547	228 758	1 151 566	1 399 039	57 645	105 620
2017	2 180 061	715 471	640 456	2 250 857	228 664	1 267 317	1 282 120	57 895	120 920


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Year	Paper and paperboard			Wood pulp			Recovered paper		
	Production	Imports	Exports	Production	Imports	Exports	Production	Imports	Exports
	(t/yr)								
2018	2 223 213	785 719	664 257	2 139 000	283 769	1 254 761	1 285 250	53 928	155 086
2019	2 159 000	791 307	529 885	1 937 000	244 035	1 269 692	1 201 909	49 312	95 472
2020	1 891 000	679 712	606 583	1 721 000	204 155	1 176 910	1 101 356	40 912	99 392
2021	1 909 000	761 000	540 000	1 591 000	199 000	1 160 000	1 149 346	53 614	144 836
2022	2 018 000	1 026 000	460 000	1 682 000	274 000	1 340 000	1 251 319	51 906	156 238
2023	2 120 000	752 302	500 777	1 700 000	168 831	1 270 000	1 200 000	40 138	167 683
2024	2 120 000	752 302	500 777	1 900 000	168 831	1 270 000	1 166 830	40 138	167 683



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6.12.2.2 Emission factors

IPCC default factors (IPCC 2019 Refinement, Table 12.2 & 12.3) incorporated into the emission calculations are shown in Table 6.64.

Table 6.64: Parameters applied in the HWP equations

	Half life	Average lifetime	Decay rate	Conversion factors (t C/m ³ or t C/adt)
Sawn Wood	35	50.5	0.02	0.229
Wood panels	25	36.1	0.028	0.269
Paper & paperboard	2	2.9	0.347	0.386

6.12.3 Uncertainty

Uncertainties for activity data and parameters associated with HWP variables are provided in the IPCC Guidelines (IPCC 2006 Guidelines, Volume 4, p. 12.22). Production and trade data have an uncertainty of $\pm 50\%$ since 1961, while the product volume to product weight factors and oven-dry product weight to carbon weight have uncertainties of $\pm 25\%$ and $\pm 10\%$, respectively. There was also a $\pm 50\%$ uncertainty on the half-life values.

6.12.4 Time-series consistency

Data from FAO and Forestry SA were combined, but splicing techniques were used to ensure the time-series is consistent. There were also some additional data sources for the country specific data between 2020 and 2024, but consistencies were checked by looking at data overlaps to ensure time-series consistency.

6.12.5 Category specific QA/QC and verification

Forestry SA production, import and export data was compared to FAOSTAT for all products (see example in Figure 6.19). The emissions from HWP were also estimated using the IPCC software (version 2.980.9306.14596) and compared (Figure 6.20). It is noted that there are some differences between the two data sets, particularly for 2003 and 2004. Some small difference may be expected since IPCC software applies IPCC 2006

Guidelines methodology, but the large differences in 2003 and 2004 will need to be investigated further.

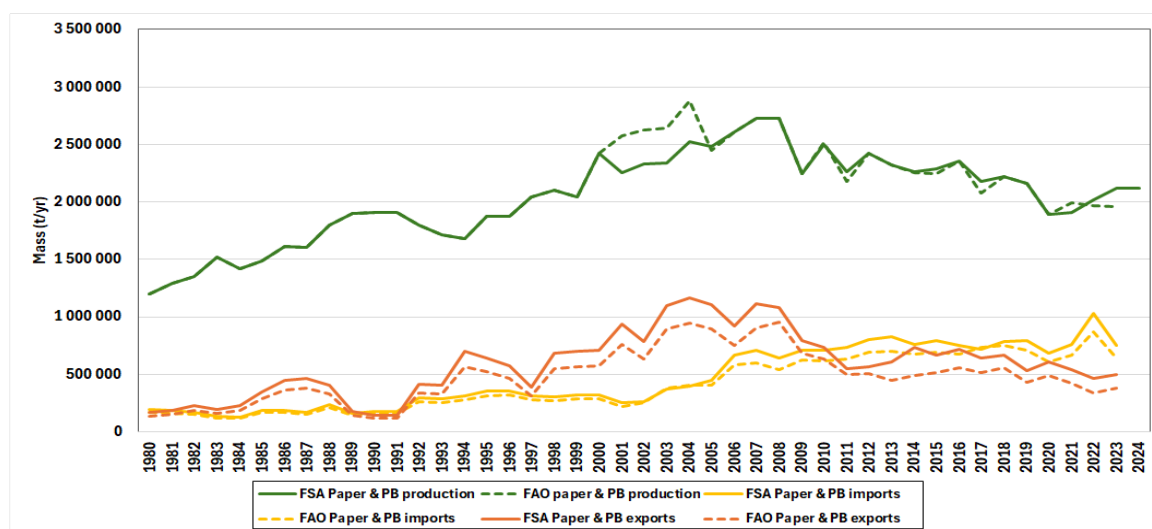


Figure 6.19: Example comparison between Forestry SA and FAO data



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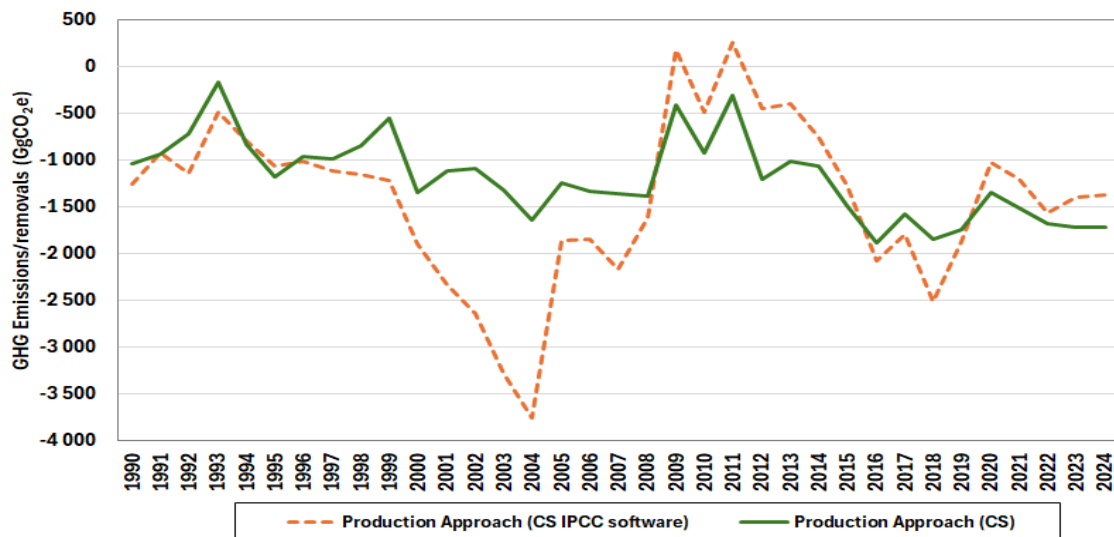


Figure 6.20: Comparison of inventory HWP emissions with emissions estimated with IPCC software

The IPCC software was used to compare the outputs from the production approach with the other IPCC 2006 Guidelines methodologies (Figure 6.21), namely Stock change, Atmospheric Flow and Simple Decay Approach. All the approaches had a similar trend, but the Atmospheric flow approach produced a much larger sink than the Production approach. The Production, Simple decay and Stock change approaches were more closely aligned. Unfortunately, due to a lack of time a comparison of the different approaches using the IPCC 2019 Refinement methodology used in this inventory was not completed. This will provide a more direct comparison, so will be completed for the next inventory.



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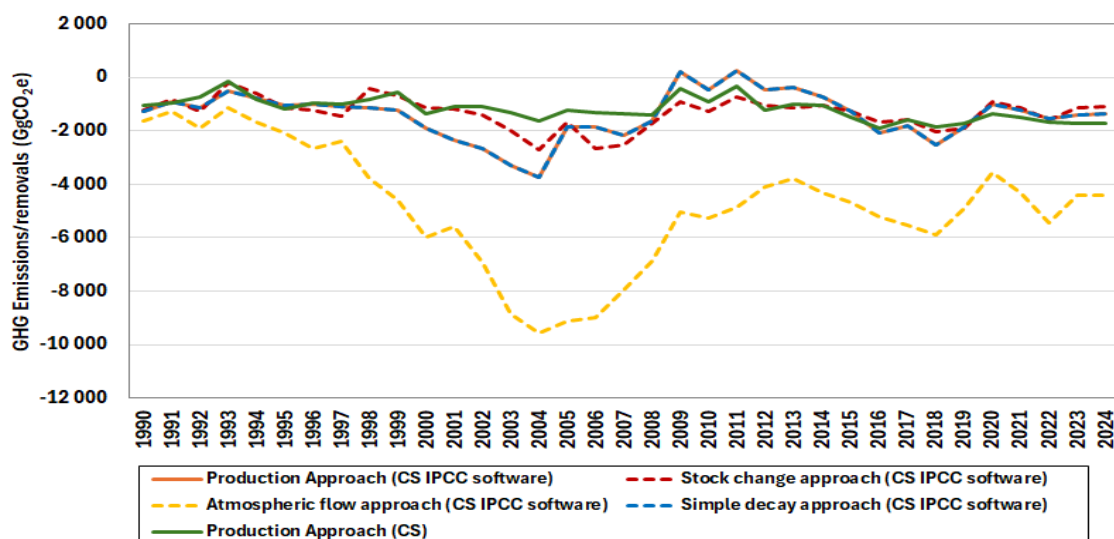


Figure 6.21: Comparison of production approach with other IPCC approaches

6.12.6 Category specific recalculations

Recalculations were performed for the full time-series due to the change in methodology and the improvement of the activity data time-series. There were only small differences (<20%) between the current inventory and the previous inventory for the years between 2009 and 2020, while the sink was reduced by about 3-fold between 1990 and 2009 (Figure 6.22). There were also slightly larger differences in 2021 and 2022 where the sink was reduced by 31% (468 Gg CO₂e) and 40% (671 Gg CO₂e) respectively compared to the previous submission. The differences are due to the use of country specific data from 1980 and the improved activity data. The resultant sink shows less variation than the previous submission.



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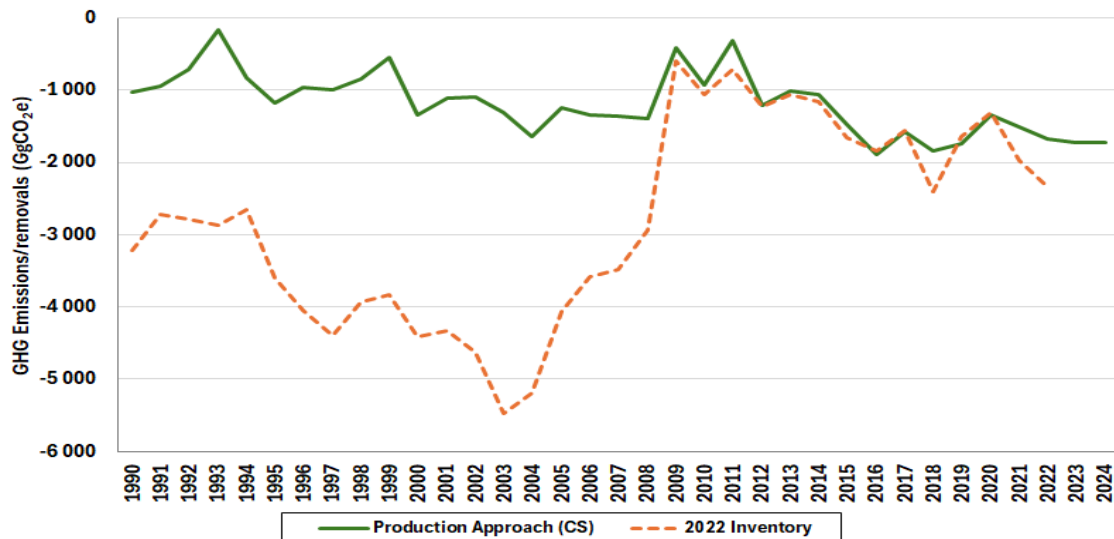


Figure 6.22: Recalculations of the *HWP* CO₂ removals compared to the previous submission

6.12.7 Category specific planned improvements

As was stated in the previous inventory a more detailed assessment of *HWP* is required to include a wider range of products and improve data collection. This was highlighted in the TERT review (FCCC/ETF/TERR.1/2024/ZAF/Add.1; ID# 6.L_CBN.2) but has not yet been done as funds would need to be made available for such a study.

6.13 Other (CRT 4.H)

South Africa does not have any additional emissions, so nothing was included under this category.



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6.14 Chapter 6 References³⁵

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³⁵ This list includes the references for Annex V.



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Chapter 7: Waste (CRT sector 5)

7.1 Sector overview

The waste sector covers GHG emissions from the following sources:

- *Solid Waste Disposal;*
- *Biological Treatment of Solid Waste;*
- *Open Burning of Waste (including pyrolysis); and*
- *Wastewater Treatment and Discharge.*

7.1.1 Overview of shares and trends in emissions

The total emissions from the Waste sector in 2024 is 19 245 Gg CO_{2e} as shown in Table 7.1. The majority of Waste sector emissions are from wastewater treatment and discharge accounting for 47% of the emissions, followed by *Solid waste disposal* accounting for 38%. Emissions from *Biological treatment of solid waste* and *Open burning of waste* only contribute 14% and 1% respectively.

An overview of the Waste emissions trends for the period 1990-2024 can be seen in Figure 7.1. Waste sector emissions have increased by 69.6% since 1990.

Table 7.1: Summary of the change in Waste sector emissions between 1990 and 2024

Source Categories	Emissions (Gg CO _{2e})		Change (%)	Contribution (%)
	1990	2024	1990-2024	
5 - Waste	11 346	19 245	69.6	
5A - Solid Waste Disposal	2 822	7 377	161.4	38.3
5B - Biological Treatment of Solid Waste	1 346	2 620	94.7	13.6
5C - Incineration and Open Burning of Waste	156	260	66.7	1.3
5C1 - Waste Incineration	NE	NE	NE	
5C2 - Open Burning of Waste	156	241	54.7	1.3
5D - Wastewater Treatment and Discharge	7 022	9 007	28.3	46.8
5D1 - Domestic Wastewater Treatment and Discharge	2 772	4 287	54.7	22.3
5D2 - Industrial Wastewater Treatment and Discharge	4 251	4 720	11.0	24.5
5E-Other (please specify)	NE	NE	NE	

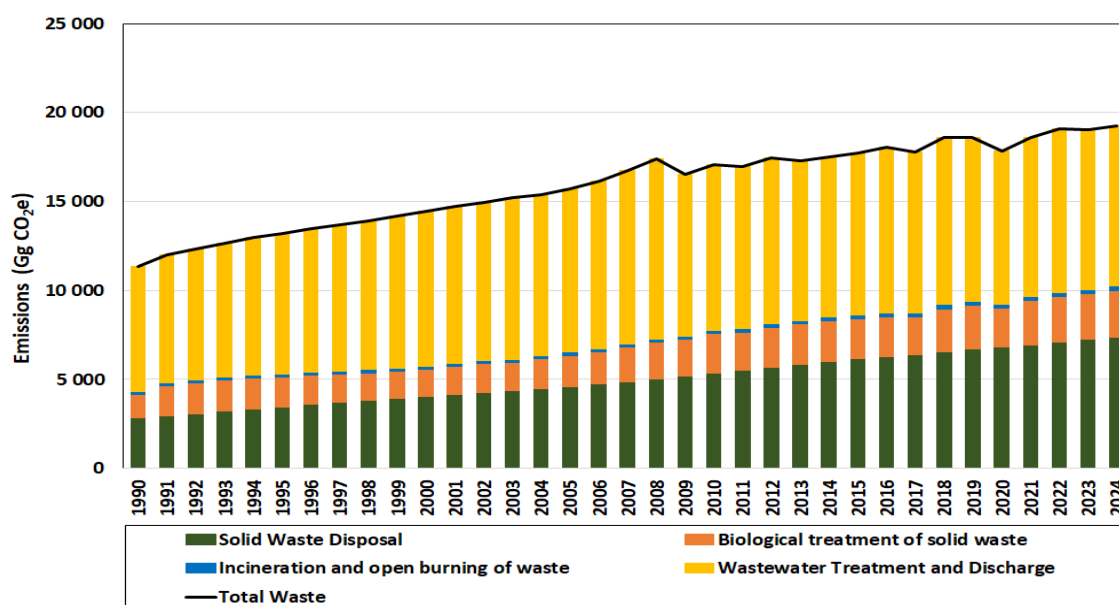


Figure 7.1: Trend in emissions from Waste sector, 1990-2024

Emissions from all waste categories have increased since 1990 (Table 7.1). However, comparing the current (2024) and the previous GHG inventory (2022) emissions from *Solid waste disposal*, *Biological treatment of solid waste*, and *Open burning of waste* have increased since 2024. The *Wastewater treatment and discharge* experienced a decreased in emissions by 2.5%, the decrease came from the industrial wastewater treatment and discharge as seen in Table 7.2.

Table 7.2: Summary of the change in emissions from South Africa's Waste sector between 2022 and 2024

Source Categories	Emissions (Gg CO ₂ e)		Change (%)
	2022	2024	2022-2024
5 - Waste	19 107	19 245	0.7
5A - Solid Waste Disposal	7 105	7 377	3.8
5B - Biological Treatment of Solid Waste	2530	2 620	3.5
5C - Incineration and Open Burning of Waste	237	241	1.6
5C1 - Waste Incineration	NE	NE	NE
5C2 - Open Burning of Waste	237	241	1.6



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5D - Wastewater Treatment and Discharge	9 235	9 007	-2.5
<i>5D1 - Domestic Wastewater Treatment and Discharge</i>	<i>4 219</i>	<i>4 287</i>	<i>1.6</i>
<i>5D2 - Industrial Wastewater Treatment and Discharge</i>	<i>5 016</i>	<i>4 720</i>	<i>-5.9</i>
5E-Other (please specify)	NE	NE	NE

7.1.2 Overview of methodology and completeness

Table 7.3 shows a summary of methods and tier levels used for the waste inventory.

Table 7.3: Summary of methods and emission factors for the Waste sector and an assessment of the completeness of the Waste sector emissions

GHG Source and sink category		CO ₂		CH ₄		N ₂ O		Details
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	
A	Solid waste disposal	NA	NA	T1	DF	NA	NA	Tier 1 FOD model was used.
B	Biological treatment of solid waste	NA	NA	T1	DF	T1	DF	IPCC 2006 Guidelines
C	Incineration and open burning of waste	T1	DF	T1	DF	T1	DF	IPCC 2006 Guidelines
D	Wastewater treatment and discharge	NA	NA	T1	DF, CS	T1	DF	IPCC 2006 Guidelines

7.1.3 Improvements and recalculations

Recalculations were performed for the Waste sector because of the following reasons:

- Updated the Methane correction factors (2019 State of waste report).
- Updated the waste generation rate (2019 State of waste report).
- Updated the waste composition (2019 State of waste report).
- Removed the Methane recovery data on the Solid waste results (reliable information gathering is ongoing to include this information in the NID).

The recalculations show a change in the trend throughout the time series (Figure 7.2). The emissions are lower after the recalculations compared to the previous inventory.

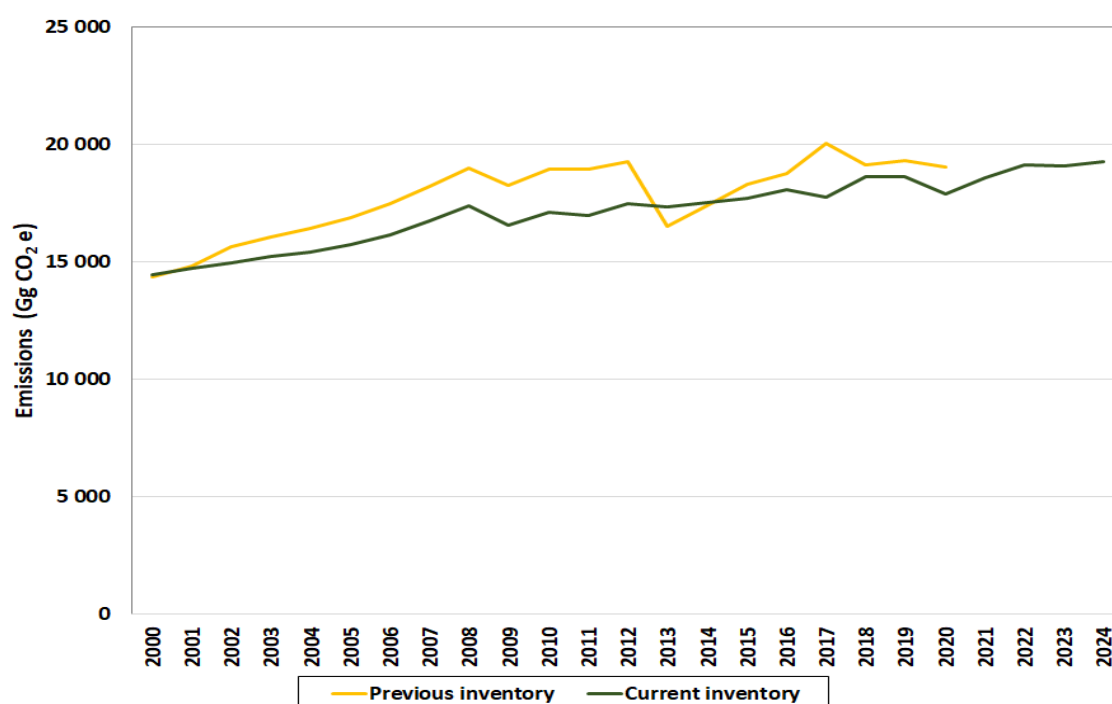


Figure 7.2: Change in Waste emission estimates due to recalculations since 2022 submission.

7.1.4 Key categories in the Waste sector

The key categories for the Waste sector as determined by level (L) and trend (T) assessment are shown in Table 7.4.

Table 7.4: Key categories in the Waste sector



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IPCC Code	Category	GHG	Criteria
5D	Wastewater Treatment and Discharge	CH ₄ , N ₂ O	L, T
5A	Solid Waste Disposal	CH ₄	L, T
5B	Biological treatment of waste	CH ₄	L,T

7.1.5 QA/QC process and verification

QA/QC measures in Table 7.5 below were used for the waste sector calculation files.

Table 7.5: General QA/QC checks completed for the Waste sector

QA/QC principle	Check
Accuracy	Activity data source
Accuracy	Correct units
Accuracy	Unit carry through
Accuracy	Method validity
Accuracy	Calculations check
Accuracy	Uncertainties
Accuracy	Double counting
Accuracy	Correct GWP
Accuracy	Notation keys
Accuracy, Completeness, Consistency, Transparency	Trend check
Accuracy, Transparency	Emission factor applicability
Accuracy, Transparency, Consistency, Completeness	Recalculations
Completeness, Comparability	Sub-category completeness
Consistency	Time series consistency
Transparency	Documentation
Transparency, Completeness, Consistency, Accuracy	Colour coding
Accuracy, Comparability	Cross check data
Accuracy	Spot checks
Transparency, Consistency	Data source referencing
Transparency	Links to source data
Transparency	Raw primary data
Accuracy	QA review



7.1.6 Planned improvements.

The most challenging task in estimating GHG emissions in South Africa was the lack of specific-activity and emissions factor data. As a result, estimations of GHG emissions from both *Solid waste* and *Wastewater* sources were largely computed using default values suggested in IPCC 2006 Guidelines and, therefore, margins of error were large. No specific improvements are planned; however, South Africa has identified the following areas to be considered in the improvement plan:

- Obtain data on the quantities of waste disposed of into managed and unmanaged landfills including its composition.
- Improve the reporting of economic data (e.g., annual growth) to include different population groups. The assumption that GDP growth is evenly distributed (using a computed mean) across all the population groups is highly misleading and leads to exacerbated margins of error.
- Obtain information on population distribution trends between rural and urban settlements as a function of income; and
- Conduct a study to trace waste streams and obtain more information on the bucket system which is still widely used in South Africa.
- Collect data on CH₄ recovery at SWDS based on metering data.

7.2 Solid Waste Disposal (CRT 5.A)

7.2.1 Category description

Waste streams deposited into managed landfills in South Africa comprise waste from households, commercial businesses, institutions, and industry. In this report only the organic fraction of the waste in solid disposal sites was considered as other waste stream components were assumed to generate insignificant quantities in landfills. The types of waste included are municipal waste, industrial waste, and sewage sludge waste. Furthermore, GHG's generated from managed and unmanaged disposal landfills in South Africa were included.

According to the IPCC 2006 Guidelines, emissions from flaring are however not significant, as the CO₂ emissions are of biogenic origin and the CH₄ and N₂O emissions are very small, so good practice in the waste sector does not require their estimation. In addition, according to the guidelines, it is good practice to only estimate and report CH₄ recovery when references documenting the amount of CH₄ recovery are available.

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Reporting based on metering of all gas recovered for energy and flaring or reporting of gas recovery based on the monitoring of produced amount of electricity from the gas (considering the availability of load factors, heating value and corresponding heat rate, and other factors impacting the amount of gas used to produce the monitored amount of electricity) is consistent with good practice.

7.2.2 Methodological issues

The methodology for calculating GHG emissions from *Solid waste* is consistent with the IPCC Tier 1 FOD Model (IPCC, 2006). This method utilizes a dynamic model driven by landfill data. It assumes that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly throughout a few decades, during which CH₄ and CO₂ are formed. If conditions are constant, the rate of CH₄ production depends solely on the amount of carbon remaining in the waste. As a result, emissions of CH₄ from waste deposited in a disposal site are highest in the first few years after deposition, then gradually decline as the degradable carbon in the waste is consumed by the bacteria responsible for the decay.

7.2.2.1 Activity data

Input data includes population data (StatsSA, 2025), waste generation rates, GDP (World bank), annual waste generation, population growth rates, emission rates, waste composition, rate constants, Methane correction factor (MCF), degradable carbon fraction (DCF), as well as other factors described in the IPCC Guidelines, Volume 5, Chapter (IPPC, 2006). Notably, due to a lack of published specific-activity data for many of these parameters in South Africa, the default values suggested in the IPCC 2006 Guidelines were applied (Table 7.6).

The FOD method requires data to be collected or estimated for historical disposals of waste over a period of 3 to 5 half-lives in order to achieve an acceptably accurate result. It is therefore good practice to use disposal data for at least 50 years as this time frame provides an acceptably accurate result for most typical disposal practices and conditions. Therefore, the activity data used comprised waste quantities disposed of into managed landfills from 1950 to 2022, covering a period of about 75 years (satisfying the condition for a period of five half-lives). Population data for the period 1950 to 2001 was sourced from United Nations population statistics (UN, 2012). Statistics South Africa population data was used for the period 2002 to 2022 (StatsSA, 2023). Waste generation rates for industrial waste were estimated using GDP values sourced from the World Bank for period 1990 to 2024.



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7.2.2.2 *Emission factors*

The emission factors for the FOD model are provided in Table 7.6.

Table 7.6: IPCC default factors utilized in the FOD Model to determine emissions from solid waste disposal.

Factor	Sub-category	Value	Unit
DOC (degradable organic carbon)	Bulk MSW	0.2	Weight fraction (wet basis)
	Industrial waste	0.15	
	Sludge waste	0.05	
DOCf (fraction of DOC dissimilated)		0.05	Fraction
Methane generation rate constant	Bulk MSW	0.05	Years ⁻¹
	Industrial waste	0.05	
	Sewage sludge	0.06	
Methane correction factor (MCF)	Unmanaged, shallow	0.4	Unitless
	Unmanaged, deep	0.8	
	Managed	1	
	Managed, semi-aerobic	0.5	
	Uncategorized	0.6	
Fraction of methane in generated landfill gas (F)		0.5	Fraction
Oxidation factor (OF)		0	Unitless

7.2.3 Uncertainty

Among the chief limitations of the FOD methodology is that even if activity data improved considerably, the limitations of the data, or lack thereof, of previous years will still introduce a considerable degree of uncertainty. On the other hand, the estimated waste generations derived from previous years, back to 1950, will remain useful in future estimations of GHGs as they will aid in taking into account half-lives.

Uncertainty in this category (Table 7.7) is due mainly to the lack of data on the characterization of landfills, as well as of the quantities of waste disposed in them over the medium to long term. An uncertainty of $\pm 30\%$ is typical for countries that collect waste-generation data on a regular basis (IPCC 2006 Guidelines, Table 3.5).



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Table 7.7: Uncertainties associated with emissions from South Africa's solid waste disposal

Gas	Activity data and emission factors	Uncertainty	
		%	Source
CH ₄	Total municipal solid waste	±30	IPCC 2006
	Fraction of MSW sent to SWDS	More than a factor of two	
	Total uncertainty of waste composition	More than a factor of two	
	DOC	±20	
	DOC _f	±20	
	MCF	±10	
	Fraction of CH ₄ in generated landfill gas	±5	
	Methane recovery	±50	

7.2.4 Time series consistency

The FOD methodology for estimating methane emissions from solid waste requires a minimum of 48 years' worth of historical waste disposal data. However, in South Africa, waste disposal statistics are not available. In addition, periodic waste baseline studies do not build time-series data. Hence, population statistics sourced from the (StatsSA; 2025) provided consistent time-series activity data for solid waste disposal.

Time series consistency is ensured by use of consistent model parameters and datasets for the calculations of emissions estimates. Where changes in datasets or model parameters occur, a full time series recalculation is undertaken.

7.2.5 Category specific QA/QC and verification

General QA/QC measures in Table 7.5 were used for this category.

7.2.6 Category specific recalculations

The population data was updated from 2002 -2024 with the latest data from Statistics South Africa. The updated data led a slight reduction in emissions.

7.2.7 Category specific planned improvements

Planned improvements include:



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- Collection of actual quantities of waste disposed into landfill sites for period 1990 – 2024.
- Conducting a detailed analysis of methane recovery from the National Climate Change Response Database, which captures valuable data from mitigation and adaptation projects for future GHG estimates from landfills.

7.3 Biological Treatment of Solid Waste (CRT 5.B)

7.3.1 Category description

Biological treatment of solid waste considers waste treated through composting and anaerobic digestion of organic waste. In this inventory only the emissions from *biological treatment of Industrial Solid Waste* have been taken into account. *Biological treatment of Municipal Solid Waste* has been excluded due to lack of information.

7.3.2 Methodological issues

A tier 1 method, with default emission factors from the IPCC 2006 Guidelines was applied to calculate emissions for this category.

7.3.2.1 Activity data

The amount of waste treated by biological treatment of solid waste was obtained from a study that was done to by DFFE (Wastewater Treatment Pathways Study;2018)). Extrapolation was used to derive data for 2018-2024.

7.3.2.2 Emission factors

The default emission factors for composting and anaerobic treatment at biogas facilities are shown in Table 7.8.



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Table 7.8: Emission Factors for Biological Treatment of Solid Waste

	CH ₄ Emission Factors (g CH ₄ /kg waste treated)	N ₂ O Emission Factors (g N ₂ O/kg waste treated)
Composting	10	0.6
Anaerobic Digestion at Biogas Facilities	2	Assumed negligible

7.3.3 Uncertainty

The estimation of the uncertainties of methane emissions from *biological treatment of solid waste* was carried out using the IPCC level 1 method (IPCC, 2006).

7.3.4 Time-series consistency

The time series for *biological treatment of solid waste* is complete and consistent from 1990-2024.

7.3.5 Category specific QA/QC and verification

General QA/QC measures in Table 7.5 were used for this category.

7.3.6 Category specific recalculations

No recalculations were performed for this category.

7.3.7 Category specific planned improvements

In future inventories, it is planned to improve data collection of waste treated by biological treatment.



7.4 Incineration and open burning of waste (CRT 5.C)

7.4.1 Category description

According to the IPCC 2006 Guidelines, *Open burning of waste* can be defined as the combustion of unwanted combustible materials such as paper, wood, plastics, textiles, rubber, waste oils and other debris in nature (open-air) or in open dumps, where smoke and other emissions are released directly into the air without passing through a chimney or stack. Open burning can also include incineration devices that do not control the combustion air to maintain an adequate temperature and do not provide sufficient residence time for complete combustion.

In South Africa *Open burning of waste* is considered in two cases:

- Where population do not have access to formal waste collection services. It is assumed that this portion of the population burn its waste openly.
- Small percentage of formal landfill sites who practice open burning to manage waste volumes at SWDS.

In this source category only the emissions from *Open burning* have been included and emissions associated with *Incineration of waste* are not yet considered.

7.4.2 Methodological issues

A Tier 1 approach, with default IPCC 2006 Guidelines emission factors, was applied in the calculation of CO₂, CH₄ and N₂O emissions from open burning. The amount of MSW open-burned was determined using Equation 5.7 of the IPCC 2006 Guidelines (IPCC, 2006; vol 5, chapter. 5; pg. 5.16).

7.4.2.1 Activity data

The activity data for the calculation of MSW are described in section 7.2.2.1 The fraction of population carrying out open-burning was assumed to be at 9% since 91% of the waste is collected. CO₂ emissions were calculated for the different waste types using the IPCC default breakdown.



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7.4.2.2 Emission factors

The emission factors for *Open burning of waste* are provided in Table 7.9.

Table 7.9: Emission factors for estimating emissions from open burning of waste.

Sub-category	Value	Unit	Source
Dry matter content			
<i>Food</i>	0.4	fraction	IPCC 2006
<i>Garden</i>	0.4		
<i>Paper</i>	0.9		
<i>Wood</i>	0.85		
<i>Textile</i>	0.8		
<i>Nappies</i>	0.4		
<i>Plastics, other inert</i>	0.9		
Fraction of carbon in dry matter			
<i>Food</i>	0.38	fraction	IPCC 2006
<i>Garden</i>	0.49		
<i>Paper</i>	0.46		
<i>Wood</i>	0.5		
<i>Textile</i>	0.5		
<i>Nappies</i>	0.7		
<i>Plastics, other inert</i>	0.03		
Fraction of fossil C in total carbon			
<i>Food</i>	0	fraction	IPCC 2006
<i>Garden</i>	0		
<i>Paper</i>	0.01		
<i>Wood</i>	0		
<i>Textile</i>	0.2		
<i>Nappies</i>	0.1		
<i>Plastics, other inert</i>	1.0		
Oxidation factor	0.58	fraction	IPCC 2006
CH₄ emission factor	6500	g/t MSW	IPCC 2006
N₂O emission factor	150	G N ₂ O/t waste	IPCC 2006

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7.4.3 Uncertainty

7.4.3.1 Activity data uncertainty

Uncertainties associated with CO₂ emission factors for *Open burning of waste* depend on uncertainties related to fraction of dry matter in waste open-burned, fraction of carbon in the dry matter, fraction of fossil carbon in the total carbon, combustion efficiency, and fraction of carbon oxidized and emitted as CO₂. A default value of $\pm 40\%$ is suggested by IPCC 2006 Guidelines.

7.4.3.2 Emission factor uncertainty

Uncertainties on default N₂O and CH₄ emission factors have been estimated to be $\pm 100\%$.

7.4.4 Time series consistency

The time series is consistent as the activity data source is the same throughout the time series.

7.4.5 Category specific QA/QC and verification

General QA/QC measures in Table 7.5 were used for this category.

7.4.6 Category specific recalculations

Recalculations for this category were done due to change in data source for the population data. The recalculations resulted in a decrease in emissions compared to the previous inventory.

7.4.7 Category specific planned improvements

An improvement planned for this category is collection of activity data on amounts of waste incinerated, by category of waste and the technologies used to incinerate waste in South Africa.

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7.5 Wastewater Treatment and Discharge (CRT 5.D)

7.5.1 Domestic wastewater treatments and discharge (CRT 5.D.1)

7.5.1.1 *Category description*

Wastewater originates from a variety of domestic, commercial and industrial sources and may be treated on site (uncollected), sewerage to a centralised plant (collected) or disposed untreated nearby or via an outfall. Domestic wastewater is defined as wastewater from household water use.

Wastewater treatment contributes to anthropogenic emissions, mainly CH₄ and N₂O. The generation of CH₄ is due to anaerobic degradation of organic matter in wastewater from domestic, commercial, and industrial sources. The organic matter can be quantified using biological oxygen demand (BOD) values.

Unlike solid waste, organic carbon in wastewater sources generates comparatively low quantities of CH₄. This is because even at very low concentrations, oxygen considerably inhibits the functioning of the anaerobic bacteria responsible for the generation of CH₄.

N₂O is produced from nitrification and denitrification of sewage nitrogen, which results from human protein consumption and discharge.

7.5.1.2 *Methodological issues*

In South Africa, most of the wastewater generated from domestic and commercial sources is treated through municipal wastewater treatment systems (MWTPs).

Domestic and commercial wastewater CH₄ emissions mainly originate from septic systems and centralised treatment systems such as MWTPs. Because of the lack of national statistics on the quantities of Biological Oxygen Demand (BOD) generated from domestic and commercial sources in South Africa annually, the yearly estimates were determined using the IPCC 2006 default Tier 1 method.

7.5.1.2.1 *Activity data*

The activity data for this category which is total amount of organically degradable material in the wastewater was calculated using population data from Statistics South Africa (Stats SA, 2023) and IPCC 2006 Guidelines default BOD.



IPCC 2006 Guidelines default correction factor of 1 was used for the factor *I*.

7.5.1.2.2 Emission factors

Methane emissions from Domestic Wastewater Treatment

Default population distribution trends between rural and urban settlements as a function of income was sourced from the IPCC 2006 Guidelines. Generally, it is good practice to express BOD product as a function of income, however, this information is not readily available in South Africa.

The emissions factors for different wastewater treatment and discharge systems were taken from the IPCC 2006 Guidelines (Table 7.10) as was the data on distribution and utilization of different treatment and discharge systems (Table 7.11).

Table 7.10: Emission factors for different wastewater treatment and discharge systems

Type of treatment or discharge	Maximum CH ₄ producing capacity (BOD)	CH ₄ correction factor for each treatment system	Emission factor
	(kg CH ₄ /kg BOD)	(MCF)	(kg CH ₄ /kg BOD)
Septic system	0.6	0.5	0.30
Latrine – rural	0.6	0.1	0.06
Latrine – urban low income	0.6	0.5	0.30
Stagnant sewer (open and warm)	0.6	0.5	0.30
Flowing sewer	0.6	0.0	0.00
Other	0.6	0.1	0.06
None	0.6	0.0	0.00

Table 7.11: Distribution and utilization of different treatment and discharge systems

Income group	Fraction of population income group	Type of treatment or discharge pathway	Degree of utilization
		(kg CH ₄ /kg BOD)	(Tij)
Rural	0.39	Septic tank	0.10
		Latrine – rural	0.28
		Sewer stagnant	0.10
		Other	0.04
		None	0.48
	0.12	Sewer closed	0.70



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Urban high-income		Septic tank	0.15
		Other	0.15
Urban low-income	0.49	Latrine – urban low income	0.24
		Septic tank	0.17
		Sewer (open and warm)	0.34
		Sewer (flowing)	0.20
		Other	0.05

Nitrous oxide emissions from Domestic Wastewater Treatment

The default values provided by the IPCC 2006 Guidelines were used in estimating the potential growing trends of N₂O emissions from the wastewater treatment systems. This was due to the lack of specific-activity data for South Africa.

For the per capita protein consumption, a value of 27.96 kg/person/yr was applied throughout the time series (FAO, 2017).

7.5.1.3 Uncertainty

An analysis of the results for methane emissions suggest that the likely sources of uncertainties may be due to the input data. These include uncertainties associated with South African population estimates provided by Statistics South Africa (StatsSA, 2023), the presumed constant country BOD production of about 37 g person⁻¹ day⁻¹ from 2001 to 2022, and the lack of data on the distribution of wastewater treatment systems in South Africa. It is recommended that, in future inventories, a detailed study on the input parameters merits careful consideration to minimize the uncertainty level. In turn, this approach would improve the reliability of the projected methane estimates from wastewater sources.

7.5.1.4 Time series consistency

The time series is complete and consistent from 2000-2022.

7.5.1.5 Category specific QA/QC and verification

General QA/QC measures in Table 7.5 were used for this category.

7.5.1.6 Category specific recalculations

Recalculations were performed for this category due to the following changes:

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- change in data source for the population data. The recalculations were done for the entire time series.
- The factor was changed from 1.25 to 1 due to industrial wastewater being estimated separately therefore there is no commercial and industrial wastewater co discharged to domestic wastewater.

The recalculations resulted in a decrease in emissions compared to the previous inventory.

7.5.1.7 Category specific planned improvements

The following improvement is planned for this category:

- Collection of wastewater related activity data for period 2000 – 2022 taking into account different wastewater treatment pathways in South Africa.

7.5.2 Industrial wastewater treatment and discharge (CRT 5.D.2)**7.5.2.1 Category description**

In South Africa, it is common practice for major industrial facilities to have comprehensive in-plant or on-site wastewater treatment systems for purposes of compliance with regulatory standards for wastewater treatment and discharge.

Industrial and commercial wastewater treated anaerobically on-site (uncollected) or sewer (co-discharged) to a centralized plant (collected) or disposed untreated nearby waterbodies, generates and is a source of methane (CH₄) (IPCC 2006).

7.5.2.2 Methodological issues

The tier 1 default IPCC 2006 Guidelines methodology was used to estimate CH₄ emissions from industrial wastewater treatment using national parameters on production tonnage per sector; wastewater generated per ton of production; average concentration of Chemical Oxygen Demand (COD); and discharge pathways for the period 2000-2017 (IPCC, 2006, equation 6.4). Emissions of methane from wastewater and their sludge generated in treatment systems were considered.

A waste improvement study implemented in the year 2019, collected actual activity data for the period 2000-2017 for all the sectors of wastewater and biological solid waste,

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followed by developing a forecasting model for the period 2018-2035 for industrial wastewater.

7.5.2.2.1 Activity data

The collected data for the industrial wastewater sectors included the following parameters:

- Production tonnage per sector.
- Wastewater generated per ton of production.
- Average concentration of COD; and
- Discharge pathways

The production tonnage per sector data for the period 2000 – 2017 was obtained from a study done by DFFE on the Sanitation Pathways for industrial wastewater.

For the period 2018-2022 the activity data was then extrapolated for the following sectors:

- Alcohol Refining;
- Starch Production;
- Beer and Malt;
- Vegetable Oils;
- Dairy Products;
- Fish Processing;
- Vegetables Fruits and Juices;
- Meat and Poultry;
- Organic Chemicals;
- Petroleum Refining;
- Plastic and Resins;
- Soap and Detergents; and
- Wine and Vinegar.

For the dairy products sector, data for the period 2018-2022 was obtained from Milk SA Lacto data report (Milk SA, 2023) which is published yearly. For the sugar industry, data for the period 2018-2022 was obtained from South Africa Sugar Association (SASA, 2023) and South African Sugar Technologists` Association (SASTA, 2023) on their production reports which are published yearly. For the Pulp and paper industry, data for the 2000-



2015 and period 2019-2022 was obtained from the Paper Manufacturers Association of South Africa (PAMSA, 2023) and for the period 2016-2018 data was interpolated.

The COD data is a combination of IPCC 2006 Guidelines defaults and country specific from the Sanitation Pathways study.

Methane recovery in the calculation was not taken into account in view of the lack of information on projects for the collection and utilization of methane in facilities for the treatment of industrial wastewater.

The maximum methane producing capacity of CH₄ (B₀)

The calculation used the value of B₀ by default 0.25 g CH₄ / g COD (IPCC, 2006).

Methane Correction Factor

The MCF values and emission factors applied are given in Table 7.12, while the COD values are provided in Table 7.13.

Table 7.12: MCF values and emission factors

Type of treatment or discharge	CH ₄ correction factor for each treatment system	Emission factor
	(MCF)	(kg CH ₄ /kg BOD)
Aerobic treatment plant	0.1	0,025
Sea River	0.1	0,025
Anaerobic Lagoon (shallow)	0.2	0,05
Aerobic Lagoon (ATP not well managed)	0.3	0,075
Sea River Untreated	0.1	0,025
Anaerobic Reactor	0.8	0,2
Anaerobic Lagoon	0.2	0,05



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Table 7.13: Average COD values used to estimate CH₄ emissions from industrial wastewater.

Industry Type	Chemical Oxygen Demand
	(COD)
Alcohol Refining	11
Starch Production	10
Beer and Malt	2.9
Vegetable Oils	1
Dairy Products	2.7
Fish Processing	2.5
Vegetables Fruits and Juices	5
Meat and Poultry	4.1
Organic Chemicals	3
Petroleum Refining	1
Plastic and Resins	1.45
Soap and Detergents	0.85
Pulp and Paper	9
Sugar	6
Wine & vinegar	1.5

7.5.2.2.2 *Emission factors*

These are given in Table 7.12.

7.5.2.3 *Uncertainty*

The estimation of the uncertainties of methane emissions from industrial wastewater was carried out using the IPCC level 1 method (IPCC, 2006).

7.5.2.4 *Time series consistency*

The time series is complete and consistent from 2000-2022.

7.5.2.5 *Category specific QA/QC and verification*

General QA/QC measures in Table 7.5 were used for this category.

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7.5.2.6 Category specific recalculations

Recalculations were done for industrial wastewater treatment due change of COD for the following industries:

- Starch Production;
- Beer and Malt;
- Pulp and Paper;
- Vegetables Fruits and Juices; and
- Wine and Vinegar.

The COD was changed to revert to IPCC 2006 Guidelines defaults due to variability in the country specific COD.

The recalculations resulted in an increase on the emissions compared to the previous inventory.

7.5.2.7 Category specific planned improvements

In future inventories, it is planned to continue collecting more detailed data on the applied technologies of wastewater treatment in various industries the use of the mandatory GHG reporting regime. Work will also continue the analysis and assessment of the data reported through the SAGERS to enhance the accuracy of the emissions from this category.

7.6 Other (CRT 5.E)

No emissions data reported under this IPCC code.



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7.7 Chapter 7 References

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Chapter 8: Indirect CO₂ and N₂O emissions

The Agriculture and LULUCF sectors report on the following indirect N₂O emissions:

- Agriculture:
 - Manure Management: Indirect N₂O emissions resulting from both volatilization and from runoff and leaching. Indirect emissions of N₂O-N from manure can take place in two ways: i) volatilization of N as NH₃ and oxides of N, and ii) through runoff and leaching from land where N was applied. Emissions reported under 3.B.
 - Agricultural soils: Indirect emissions of N₂O-N from managed soils can take place in two ways: i) volatilization of N as NH₃ and oxides of N, and the deposition of these gases onto water surfaces, and ii) through runoff and leaching from land where N was applied. These emissions included are from fertiliser application, urine and dung in grazing fields, crop residue additions to soils and N mineralisation in mineral soils due to SOC losses from land use changes. In the Agriculture sector these are emissions from Croplands and Grasslands. Emissions reported under 3.D.
- LULUCF:
 - Indirect N₂O emissions through volatilisation and leaching/runoff from N fertiliser application and N mineralisation in mineral soils due to SOC losses from land use changes. As Croplands remaining Croplands and Grasslands remaining Grasslands emissions are included under Agriculture, the indirect emissions included in LULUCF sector are from other land classes and all land conversions. Emissions reported under 4(I).A. to 4(I).F. and 4(III).A. to 4(III).F.

These indirect N₂O emissions are detailed within the Agriculture and LULUCF chapters and are included within those sector emissions and so are therefore not included in this section.

The indirect emission of N₂O that are to be included here are those produced from atmospheric deposition of nitrogen in NO_x and NH₃, and the indirect CO₂ emissions are from the atmospheric oxidation of CH₄, CO and NMVOC. This is not a category that has

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been included in the inventory before, and so South Africa is in the process of identifying the emissions that would be included here.

The indirect CO₂ and N₂O emissions produced from the precursor gases (CO, NO_x and NMVOCs) which arise from biomass burning are currently being determined. These will be included in this section in the next version of the NID.



Chapter 9: Recalculations and improvements

9.1 Explanation and justification for recalculations

A comprehensive recalculation of the Forest Land emission and removal estimates was undertaken to improve methodological consistency, data accuracy, and alignment with the most recent land representation and carbon stock information. These refinements were implemented in accordance with the principles of transparency, completeness, consistency, comparability, and accuracy as outlined in the Intergovernmental Panel on Climate Change guidelines.

The recalculation was driven by several key methodological and data improvements:

- Inclusion of updated land change maps for the period 2020–2022, enhancing temporal coverage and improving the representation of recent land-use dynamics.
- Corrections to the land-use change matrix to account for technological changes in land mapping between 2014 and 2018, as well as improved differentiation between wet and dry season classifications.
- Removal of a previously identified error (reported in the last inventory submission) affecting estimates from 2014 onwards, which related to double correction for land conversions on areas already converted.
- Revision of the methodology used to estimate burnt area per land class, improving the allocation of fire impacts across forest categories.
- Integration of soil type map overlays with the 2014–2018, 2018–2020 and 2020–2022 land cover datasets, enabling more accurate estimation of soil carbon stock changes.
- Updating of biomass, deadwood and litter carbon stock data to reflect improved emission factors and country-specific parameters.
- Refinement of assumptions used to distinguish between primary and secondary forest, improving representation of carbon density variations.

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Incorporation of updated household fuelwood consumption data to better reflect removals associated with forest degradation.

Inclusion of both direct and indirect N₂O emissions from nitrogen inputs and nitrogen mineralisation, enhancing completeness of non-CO₂ emissions reporting. Collectively, these improvements resulted in a structural revision of the Forest Land time series. The recalculated estimates indicate an average reduction in the net sink of 42.3% over the period 2000- 2022, although the magnitude of change varies by year due to interannual variability in land-use change, fire occurrence, and updated carbon parameters.

Recalculations were performed for the Energy sector due to methodological improvements, specifically the application of country-specific CO₂ emission factors for solid fuels in place of default IPCC values. These factors were derived from a Study, completed in 2022, consequently, emissions for the entire time series for where solid fuels are used were recalculated for the applicable fuel combustion activities to ensure methodological consistency and improved national representativeness.

For the most recent inventory years, the recalculated estimates show that the 2021 and 2022 net removals were reduced by 39.2% (25,095 Gg CO₂e) and 38.7% (31,884 Gg CO₂e), respectively, compared to the previous submission. These differences are primarily attributable to improved land representation, updated carbon stock data, methodological refinements in burnt area estimation, and correction of historical processing errors.

Overall, the recalculation enhances the robustness, internal consistency, and completeness of the Forest Land estimates, and ensures improved alignment with current methodological best practice and updated national datasets.



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9.2 Implications for emission and removal levels and trends

The Figure 9.1 presents a comparison between the current emission estimates and the previous submission, both excluding and including LULUCF, for the period 2000-2024.

The recalculations result in a structural downward revision of the net sink contribution from the land sector, particularly evident from 2014 onward. Consequently, total emissions including LULUCF in the current submission are higher relative to the previous submission in recent years, despite improvements in methodological accuracy.

The most significant differences occur in 2021 and 2022, where revised LULUCF estimates materially alter total national emissions. These changes are not indicative of real world emission increases but rather reflect improved data quality, methodological consistency, and correction of historical artefacts in the time series.

Overall, the recalculated time series improves consistency across the full 2000 - 2024 period, enhances transparency, and ensures alignment with updated national datasets and current good practice guidance.

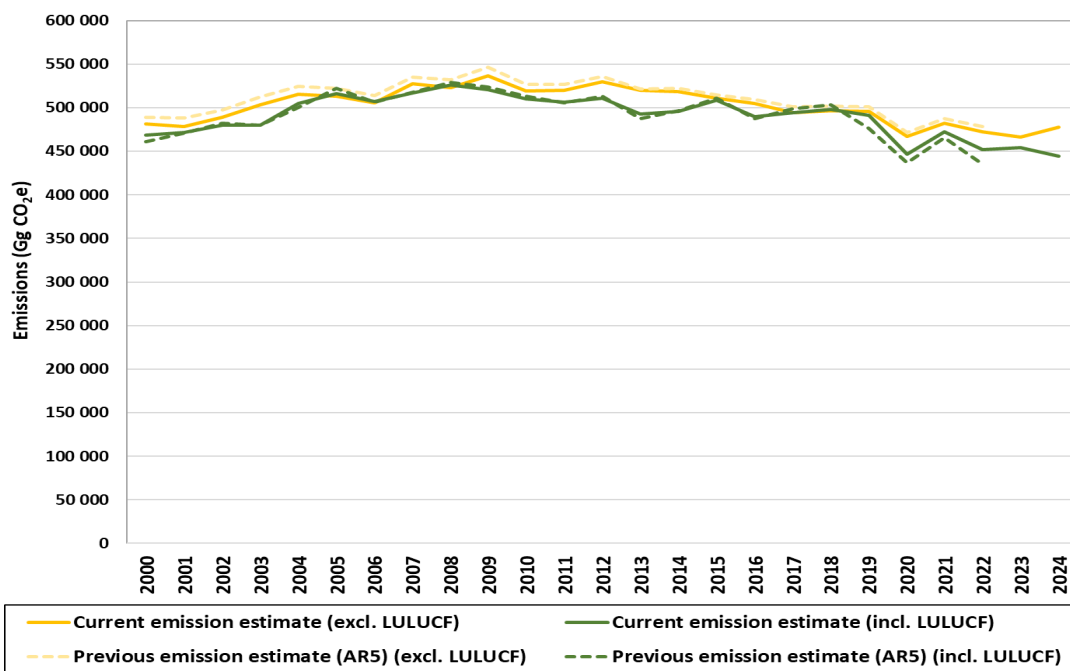


Figure 9.1: Impacts of recalculations on the overall emission estimates for South Africa.

9.3 Areas of improvement in response to review process

In response to the issues identified during the technical expert review of South Africa's first Biennial Transparency Report, a number of targeted improvements have been implemented in the current National Inventory compilation process. These include strengthened quality assurance and quality control procedures to improve consistency, systematic checks of data transfers from calculation files, and corrections to previously identified reporting inconsistencies.

Where feasible, recalculations have been undertaken to improve time-series consistency following methodological updates, while additional documentation has been provided to clarify assumptions, emission factors, activity data sources. Sector-specific enhancements were also introduced to address data gaps, improve methodological



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transparency. Collectively, these improvements enhance the transparency, accuracy, completeness, consistency, and comparability of the inventory and reflect South Africa's commitment to continuous improvement under the enhanced transparency framework.

9.4 Areas of improvement related to flexibility provisions applied

The list of improvements South Africa plans to implement in light of the flexibilities used in the 2022 inventory are as follows:

Time Series Reporting Improvements: Collect and report consistent annual data starting from 1990 to meet mandatory requirements, with completion targeted by BTR 2 in December 2026.

Assessment of Insignificant Emissions: Evaluate the significance of the following emissions sources that are not estimated in the current inventory:

- Abandoned underground mines (CH₄).
- Post-mining activities (CO₂, CH₄, N₂O).
- Various IPPU categories, including:
 - Electronics industry (N₂O, HFCs, PFCs, SF₆).
 - Solvents and electrical equipment (HFCs, PFCs, SF₆).
 - PFCs from other product use.
 - N₂O from product uses.

Incorporate these sources if emissions exceed thresholds (0.1% of total national emissions or 1,000 kt CO₂e). Assessments and updates are planned for BTR 3 in December 2028.

9.5 Improvement plan

Table 9.1 shows planned improvements and the timelines for the completion of these improvements.

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South Africa continues to strengthen its quality assurance and quality control (QA/QC) framework for the national greenhouse gas (GHG) inventory. In response to findings and recommendations arising from the external technical review process under the UNFCCC transparency framework, a structured and systematic approach has been adopted to address all identified issues.

All review comments are assessed, categorised according to significance (e.g., transparency, consistency, comparability, completeness and accuracy), and incorporated into the national inventory improvement plan. Priority is given to issues that materially affect emission estimates, methodological application, time-series consistency, or documentation. Corrective actions include recalculations where necessary, enhancement of methodological descriptions, improvement of activity data and emission factors, strengthening of institutional arrangements, and improved documentation of Tier 2 and Tier 3 methodologies.

Overall, South Africa's GHG inventory improvement plan reflects a balanced combination of completed actions, ongoing refinements and longer-term methodological developments. While significant progress has been achieved in improving transparency and sectoral detail, several improvements remain dependent on sustained funding, enhanced institutional capacity and improved collaboration with national data providers.

The inventory system will continue to apply a continuous improvement approach, prioritising actions that materially enhance transparency, accuracy and completeness in advance of future BTR submissions.

Constraints to the full and immediate resolution of all review findings include resource limitations, as well as dependency on external data providers for improved activity data and sector-specific information. Nevertheless, the continuous strengthening of the QA/QC system remains a high priority to ensure the credibility, robustness, and transparency of South Africa's national GHG inventory.

Table 9.1: List of Completed, planned and proposed improvements for South Africa's GHG inventory.

Sector	Improvement	Priority	Reason	Status	Completeness timeframe	Barriers and constraints
Cross-cutting	Tasks in progress					
	Improve uncertainty data for all sectors by incorporating more country specific uncertainty values	High	Improve transparency, accuracy and consistency in uncertainty analysis	Ongoing – more detailed uncertainty analysis included for LULUCF; further disaggregation required	Continuous improvement; phased incorporation as data becomes available (2025–2027)	Lack of uncertainty data constrains this activity. As data becomes available it will be incorporated. In this inventory a more detailed analysis of uncertainty for LULUCF sector was included but further disaggregation is required to improve the analysis.
	Improve QA/QC process by addressing all issues in external review	High	Strengthen transparency, consistency, accuracy and completeness of the national GHG inventory and ensure alignment with UNFCCC review recommendations	Ongoing- review findings are being systematically assessed and incorporated into the improvement plan	Continuous; priority issues to be addressed before next BTR submission	Resource and capacity constraints.

Agriculture	Incorporate NOx, CO, NMVOC, and SOx emissions	Medium	Improve completeness of inventory and align with reporting requirement	Partly resolved	Continuous improvement; phased incorporation as data becomes available (2025–2027)	Partly resolved.
	Update of the VKT study, including segregation of on-road/off-road	High	Improve accuracy of transport sector emissions	Planned	to be initiated before next BTR submission (2026)	Project to be initiated before next BTR
	Comparison of next VKT approach with fuel statistics	Medium	Improve QA/QC and consistency checks	Planned	to be initiated before next BTR submission (2026)	Project to be initiated before next BTR
	Incorporate all background data and equations for the Tier 2 calculations of enteric fermentation	High	Improve transparency and methodological robustness	Partially completed - equations included; some parameters rely on average data	Full completion dependent on sustainable annual data source (2027–2029)	Partially completed. All background equations are included, but some factors still rely on average data rather than annual data due to the absence of a sustainable data source; although the investigation was conducted, no sustainable data source has been identified so far
	Improve the uncertainty analysis for the Land sector to incorporate more detail.	High	Improve robustness of Land sector estimates	Partially completed - more detailed analysis included; further	2027–2029	A more detailed uncertainty analysis was included in this inventory but further disaggregation is required to improve the analysis.
LULUCF						

	Improvement of land change data through detailed assessment of maps and tracking of land parcels	High	Improve accuracy of land representation and reduce misclassification	disaggregation needed	Progressive improvement through next inventory cycles	This 2024 inventory incorporated a more detailed assessment of the land change data and identified the most important land change categories that need attention. The assessment also identified improvements that need to be done moving forward and the priority of these improvements. Removing changes due to seasonality is top priority and this will be improved as more land change maps are obtained. The 2022 SANLC map was used to make improvements. Tracking of land parcels over time still remains a critical process to undertake.
	Improve the biomass burning emissions	Medium	Improve representation of fire-related emissions	Analysis undertaken for 2024; assessment pending for replication in other years	Decision on expansion in next inventory.	An analysis of biomass burning was undertaken for 2024, and the resulting emission impacts need to be assessed to determine the value of conducting similar analyses for other years.
	Incorporate organic soils study to include emissions from organic soils	Medium	Improve completeness (CO ₂ emissions)	Initial estimates included using ISRIC, FAOSTAT and IPCC defaults	Further refinement required (2027 onwards)	Organic soil area was determined from ISRIC data. The area of drained organic soils for <i>Grasslands remaining grasslands and Croplands remaining</i>

			from drained organic soils)				Croplands were obtained from FAOSTAT. These datasets were used, together with IPCC default factors to estimate CO ₂ emissions from drained organic soils. Further organic soil studies are required to improve emission estimates.
	Move to a higher tier level for DOM in forest lands	Medium	Improve accuracy of forest carbon pool estimates	Partially addressed - disturbance matrix improved; some data gaps remain	To be completed in next inventory		This was considered in the 2022 inventory and more detailed disturbance matrix data was included to determine the amount of biomass entering the DOM pool, however there were still one or two pieces of data missing which requires further investigation. This will be completed and included in the next inventory.
Tasks outstanding							
Sector	Improvement	Priority	Reason	Status	Completeness timeframe	Barriers and constraints	
	Use IPCC Software	Medium	Improve transparency, consistency and QA/QC of calculations	Planned - migration to IPCC Software to be initiated	2027-2028 inventory cycle	Use of the IPCC software to be initiated in future.	

Improve completeness	Planned - research to be initiated	TBD	Improve completeness and accuracy of non-energy use emissions	Planned - research to be initiated	2027-2028 inventory cycle	Research to be initiated in future.
	Further disaggregation of 1A2	High	Improve sectoral resolution.	Ongoing - currently disaggregated to 1A2a, 1A2b, 1A2-ab, further breakdown required	Progressive improvement through next inventory cycles	Current inventory breaks down 1A2 into 1A2a, 1A2b and 1A2-ab. Further work is required to further disaggregate this sector and have emissions calculated per sub-sector
	Inclusion of methodology documentation/summary/approval process for tier 3 methods	Medium	Improve transparency	Planned - to be collated and included	2027-2028 inventory cycle	To be collated and included in future.
	CO ₂ , CH ₄ and N ₂ O from spontaneous combustion of coal seams	Medium	Improve completeness	Planned - research to be initiated	TBD, based on funding availability.	Funding to initiate study required
	CH ₄ emissions from abandoned mines	Medium	Improve completeness	Planned - research to be initiated	TBD, based on funding availability.	Research to be initiated in future.
	CO ₂ transport and storage	Medium	Anticipate CCS developments	Proposed	TBD	Proposed
	CO ₂ , CH ₄ and N ₂ O emissions from combined heat and power (CHP) combustion systems	Medium	Improve completeness of combustion systems	Proposed	TBD	Proposed



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IPPU	Assess significance of emissions from electronics industry	Medium	Improve completeness of IPPU sector	Proposed	TBD, Proposed; not implemented due to funding constraints	Proposed
	Update the fluorinated gases with higher accuracy figures from SARS	High	Improve accuracy of F-gas estimates	Ongoing	2027-2028 inventory cycle	Access to all data and ensuring that the data is accurate.
	Update SOC reference data	Medium	Improve soil carbon stock accuracy	Proposed	TBD, Proposed; not implemented due to funding constraints	Proposed
Agriculture	Improve manure management data, including biogas digesters as a management system	High	Improve accuracy of CH ₄ and N ₂ O estimates	Proposed	Proposed; not implemented due to funding constraints	Proposed as a project due to the high variability in the dataset; however, it was not carried out because of insufficient funding.
	Initiate data collection on controlled fires	High	Improve disaggregation biomass burning estimates	Proposed	TBD	Proposed
	Perform a more detailed assessment of HWP to include a wider range of products	Medium	Improve carbon stock change estimates	Proposed	TBD	Proposed project that could be considered under the GHGIP. For future evaluation.
LULUCF	Collect data on other disturbances besides fire in forest lands	High	Accuracy - Improve	Proposed	TBD	This would require a study so will be recommended as a project under the GHGIP.

Waste			forest carbon accounting				
	Include information on population distribution in rural and urban areas as a function of income	Medium	Improve waste generation estimates	Proposed	TBD	Insufficient data.	
	Include HWP in solid waste	Medium	Improve completeness	Proposed	TBD	Insufficient data.	
	Obtain data on waste streams and the bucket system	Medium	Improve wastewater and solid waste estimates	Proposed	TBD	Insufficient data.	
	CH ₄ , N ₂ O emissions from biological treatment of waste	Medium	Improve completeness	Proposed	TBD	Insufficient data.	
	CO ₂ , CH ₄ and N ₂ O from waste incineration	Medium	Improve completeness	Proposed	TBD	Insufficient data.	
	Data collection on quantities of waste disposed of into managed and unmanaged landfills	Medium	Improve completeness	Proposed	TBD	Funding to initiate study.	

Annex I: Key category analysis

Table A I.1: Level assessment on emissions excluding LULUCF for South Africa (1990) with the key categories highlighted in green.

Code	Category Title	GHG	1990 Estimates	Level Assessment	Cumulative Total
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	137 910.7	0.341	34%
1.A.3.b	Road Transportation	CO ₂	41 755.4	0.103	44%
1.A.4	Other Sectors - Solid Fuels	CO ₂	33 356.7	0.083	53%
3.A.1.a.ii	Non-dairy Cattle	CH ₄	28 133.1	0.070	60%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO ₂	26 631.5	0.066	66%
1.B.3	Fugitive emissions from - Other emissions from energy production	CO ₂	25 903.1	0.064	73%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO ₂	12 921.6	0.032	76%
2.C.1	Iron and Steel Production	CO ₂	12 597.0	0.031	79%
3.A.2	Sheep	CH ₄	10 019.9	0.025	81%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	9 748.0	0.024	84%
3.D.1	Direct N ₂ O Emissions From Managed Soils	N ₂ O	7 914.1	0.020	86%
1.A.4	Other Sectors - Liquid Fuels	CO ₂	5 480.3	0.014	87%
2.A.1	Cement Production	CO ₂	4 252.5	0.011	88%
5.D	Wastewater Treatment and Discharge - Industrial	CH ₄	4 250.7	0.011	89%
1.A.3.a	Domestic Aviation	CO ₂	3 408.9	0.008	90%
3.A.1.a.i	Dairy Cattle	CH ₄	3 021.0	0.007	91%
1.B.3	Fugitive emissions from - Other emissions from energy production	CH ₄	2 905.1	0.007	92%



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5.A	Solid Waste Disposal	CH4	2 821.7	0.007	92%
3.G	Liming	CO2	2 470.8	0.006	93%
5.D	Wastewater Treatment and Discharge - Domestic	CH4	2 297.1	0.006	93%
3.A.4	Goats	CH4	2 285.5	0.006	94%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO2	2 282.2	0.006	95%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	1 655.0	0.004	95%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CH4	1 495.4	0.004	95%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	1 466.1	0.004	96%
2.B.2	Nitric Acid Production	N2O	C	C	C
2.C.2	Ferroalloys Production	CO2	1 186.9	0.003	96%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	1 079.8	0.003	97%
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	1 008.9	0.002	97%
5.B	Biological Treatment of Solid Waste	CH4	858.5	0.002	97%
3.B.1.a.ii	Non-dairy Cattle	N2O	806.4	0.002	97%
1.B.2	Oil and Natural Gas	CO2	773.3	0.002	97%
3.B.1.a.ii	Non-dairy Cattle	CH4	703.2	0.002	98%
1.A.3.c	Railways	CO2	664.3	0.002	98%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	566.5	0.001	98%
1.A.3.b	Road Transportation	N2O	519.5	0.001	98%
2.A.2	Lime Production	CO2	488.0	0.001	98%
5.B	Biological Treatment of Solid Waste	N2O	487.5	0.001	98%
5.D	Wastewater Treatment and Discharge - Domestic	N2O	474.4	0.001	98%



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3.B.1.a.i	Dairy Cattle	CH4	466.0	0.001	99%
2.B.1	Ammonia Production	CO2	423.7	0.001	99%
1.A.4	Other Sectors - Solid Fuels	N2O	392.5	0.001	99%
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	389.7	0.001	99%
2.B.6	Titanium Dioxide Production	CO2	C	C	C
1.A.3.b	Road Transportation	CH4	368.5	0.001	99%
3.B.4	Poultry	N2O	367.6	0.001	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	285.8	0.001	99%
3.B.5	Indirect N2O Emissions From Manure Management	N2O	268.3	0.001	99%
2.C.3	Aluminium Production	CO2	254.0	0.001	99%
3.B.3	Swine	CH4	237.1	0.001	99%
1.A.4	Other Sectors - Solid Fuels	CH4	205.9	0.001	99%
3.B.2	Sheep	N2O	199.0	0.000	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	192.7	0.000	99%
3.B.1.a.i	Dairy Cattle	N2O	178.9	0.000	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	153.4	0.000	100%
3.B.2	Sheep	CH4	134.6	0.000	100%
2.C.6	Zinc Production	CO2	128.7	0.000	100%
2.B.8	Petrochemical and Carbon Black Production	CO2	C	C	C
3.A.4	Horses	CH4	115.9	0.000	100%
5.C	Incineration and Open Burning of Waste	CH4	108.1	0.000	100%
3.H	Urea Application	CO2	91.0	0.000	100%
2.A.3	Glass Production	CO2	85.0	0.000	100%



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3.B.4	Poultry	CH4	79.2	0.000	100%
2.B.1	Ammonia Production	CH4	76.3	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	73.2	0.000	100%
1.A.3.e	Railways	N2O	67.5	0.000	100%
3.B.4	Goats	N2O	66.8	0.000	100%
3.A.4	Mules & Asses	CH4	62.7	0.000	100%
3.A.3	Swine	CH4	49.0	0.000	100%
3.F	Field burning of agricultural residues	CH4	47.2	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	44.6	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	39.9	0.000	100%
3.B.4	Goats	CH4	38.5	0.000	100%
3.B.3	Swine	N2O	27.4	0.000	100%
1.A.3.a	Domestic Aviation	N2O	24.8	0.000	100%
5.C	Incineration and Open Burning of Waste	CO2	24.0	0.000	100%
5.C	Incineration and Open Burning of Waste	N2O	23.6	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CO2	20.4	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CH4	18.3	0.000	100%
2.C.5	Lead Production	CO2	16.0	0.000	100%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CO2	14.7	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	13.0	0.000	100%
3.F	Field burning of agricultural residues	N2O	11.6	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	N2O	11.3	0.000	100%



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1.A.4	Other Sectors - Gaseous Fuels	CO ₂	11.2	0.000	100%
1.B.2	Oil and Natural Gas	CH ₄	10.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH ₄	6.3	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	CH ₄	6.1	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N ₂ O	4.7	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	N ₂ O	3.6	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH ₄	2.6	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH ₄	2.5	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N ₂ O	2.2	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N ₂ O	2.1	0.000	100%
2.B.5	Carbide Production	CO ₂	C	C	C
2.C.2	Ferroalloys Production	CH ₄	1.6	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	CH ₄	1.0	0.000	100%
1.A.3.e	Railways	CH ₄	1.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N ₂ O	0.9	0.000	100%
1.B.2	Oil and Natural Gas	N ₂ O	0.8	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH ₄	0.7	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N ₂ O	0.7	0.000	100%
1.A.3.a	Domestic Aviation	CH ₄	0.7	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	N ₂ O	0.3	0.000	100%
2.B.8	Petrochemical and Carbon Black Production	CH ₄	C	C	C



1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	0.1	0.000	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	0.1	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	CH4	0.0	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	N2O	0.0	0.000	100%
2.A.4	Other Process Uses of Carbonates	CO2	0.0	0.000	100%
2.B.5	Carbide Production	CH4	0.0	0.000	100%
2.B.7	Soda Ash Production	CO2	0.0	0.000	100%
2.B.10	Other	CO2	0.0	0.000	100%
2.B.10	Other	CH4	0.0	0.000	100%
2.C.1	Iron and Steel Production	CH4	0.0	0.000	100%
2.C.3	Aluminium Production	Aggregate F-gases	0.0	0.000	100%
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	0.0	0.000	100%
2.G	Other Product Manufacture and Use	CO2	0.0	0.000	100%
2.B.2	Nitric Acid Production	CO2	0.0	0.000	100%
2.B.2	Nitric Acid Production	CH4	0.0	0.000	100%
2.B.8	Hydrogen Production	CO2	0.0	0.000	100%
2.C.2	Ferroalloys Production	N2O	0.0	0.000	100%
2.D.1	Non-energy Products from Fuels and Solvent Use - Lubricant use	CO2	0.0	0.000	100%
2.D.2	Non-energy Products from Fuels and Solvent Use - Paraffin wax use	CO2	0.0	0.000	100%
2.F.1.a	Refrigeration and Air conditioning - refrigeration and stationary ACs	CO2e	0.0	0.000	100%
2.F.1.b	Refrigeration and Air conditioning - mobile ACs	CO2e	0.0	0.000	100%

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Table A.I.1: Level assessment on emissions including LULUCF for South Africa (1990) with the key categories highlighted in green.

Code	Category Title	GHG	1990 Estimates	Level Assessment	Cumulative Total
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	137 910.7	0.269	27%
1.A.3.b	Road Transportation	CO ₂	41 755.4	0.082	35%
1.A.4	Other Sectors - Solid Fuels	CO ₂	33 356.7	0.065	42%
4.A.2.b	Grassland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-29 846.3	0.058	47%
3.A.1.a.ii	Non-dairy Cattle	CH ₄	28 133.1	0.055	53%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO ₂	26 631.5	0.052	58%
1.B.3	Fugitive emissions from - Other emissions from energy production	CO ₂	25 903.1	0.051	63%
4.A.1.a	Forest land remaining forest land – biomass (above and below)	CO ₂	20 674.8	0.040	67%
4.C.2.a	Forest land converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	14 927.0	0.029	70%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO ₂	12 921.6	0.025	73%
2.C.1	Iron and Steel Production	CO ₂	12 597.0	0.025	75%
3.A.2	Sheep	CH ₄	10 019.9	0.020	77%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	9 748.0	0.019	79%
3.D.1	Direct N ₂ O Emissions From Managed Soils	N ₂ O	7 914.1	0.015	81%
4.C.1.a	Grassland remaining Grassland – biomass (above and below)	CO ₂	-5 937.9	0.012	82%
4.C.2.e	Other land converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-5 730.6	0.011	83%
1.A.4	Other Sectors - Liquid Fuels	CO ₂	5 480.3	0.011	84%
4.F.2.c	Grassland converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	4 685.3	0.009	85%
2.A.1	Cement Production	CO ₂	4 252.5	0.008	86%
5.D	Wastewater Treatment and Discharge - Industrial	CH ₄	4 250.7	0.008	86%
1.A.3.a	Domestic Aviation	CO ₂	3 408.9	0.007	87%
3.A.1.a.i	Dairy Cattle	CH ₄	3 021.0	0.006	88%
4.A.2.a	Cropland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-2 955.4	0.006	88%
1.B.3	Fugitive emissions from - Other emissions from energy production	CH ₄	2 905.1	0.006	89%
5.A	Solid Waste Disposal	CH ₄	2 821.7	0.006	89%



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4.B.2.b	Grassland converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	2 737.2	0.005	90%
4.B.2.a	Forest land converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	2 736.2	0.005	90%
4.C.2.b	Cropland converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-2 520.7	0.005	91%
3.G	Liming	CO ₂	2 470.8	0.005	91%
5.D	Wastewater Treatment and Discharge - Domestic	CH ₄	2 297.1	0.004	92%
3.A.4	Goats	CH ₄	2 285.5	0.004	92%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO ₂	2 282.2	0.004	93%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO ₂	1 655.0	0.003	93%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CH ₄	1 495.4	0.003	93%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO ₂	1 466.1	0.003	94%
4.E.1.a	Settlements remaining Settlements – biomass (above and below)	CO ₂	-1 336.8	0.003	94%
2.B.2	Nitric Acid Production	N ₂ O	C	C	C
2.C.2	Ferroalloys Production	CO ₂	1 186.9	0.002	94%
4.A.1.b	Forest land remaining forest land – dead organic matter (dead wood and litter)	CO ₂	-1 135.5	0.002	95%
4.A.2.e	Other land converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-1 127.6	0.002	95%
4.A.2.c	Wetland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-1 093.7	0.002	95%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO ₂	1 079.8	0.002	95%
4.G	Harvested Wood Products	CO ₂	-1 035.6	0.002	96%
3.D.2	Indirect N ₂ O Emissions From Managed Soils	N ₂ O	1 008.9	0.002	96%
4(V)	Biomass Burning	CH ₄	974.5	0.002	96%
5.B	Biological Treatment of Solid Waste	CH ₄	858.5	0.002	96%
3.B.1.a.ii	Non-dairy Cattle	N ₂ O	806.4	0.002	96%
1.B.2	Oil and Natural Gas	CO ₂	773.3	0.002	96%
4.C.2.c	Wetland converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	720.2	0.001	97%
4.E.2.a	Forest land converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	716.6	0.001	97%



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4.B.1.a	Cropland remaining Cropland – biomass (above and below)	CO ₂	714.8	0.001	97%
3.B.1.a.ii	Non-dairy Cattle	CH ₄	703.2	0.001	97%
4.C.1.c	Grassland remaining Grassland – soil (mineral)	CO ₂	-695.6	0.001	97%
4(V)	Biomass Burning	N ₂ O	689.6	0.001	97%
1.A.3.c	Railways	CO ₂	664.3	0.001	97%
4.A.2.d	Settlements converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-662.7	0.001	97%
4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH ₄	656.2	0.001	98%
4.F.2.e	Other land converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	640.8	0.001	98%
4.F.2.a	Forest land converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	623.0	0.001	98%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N ₂ O	566.5	0.001	98%
1.A.3.b	Road Transportation	N ₂ O	519.5	0.001	98%
2.A.2	Lime Production	CO ₂	488.0	0.001	98%
5.B	Biological Treatment of Solid Waste	N ₂ O	487.5	0.001	98%
5.D	Wastewater Treatment and Discharge - Domestic	N ₂ O	474.4	0.001	98%
3.B.1.a.i	Dairy Cattle	CH ₄	466.0	0.001	98%
2.B.1	Ammonia Production	CO ₂	C	C	C
1.A.4	Other Sectors - Solid Fuels	N ₂ O	392.5	0.001	99%
1.A.3.d	Domestic Navigation - Liquid Fuels	CO ₂	389.7	0.001	99%
2.B.6	Titanium Dioxide Production	CO ₂	C	C	C
1.A.3.b	Road Transportation	CH ₄	368.5	0.001	99%
3.B.4	Poultry	N ₂ O	367.6	0.001	99%
4(III)	Direct N ₂ O emissions from N mineralization/immobilization	N ₂ O	348.6	0.001	99%
4.D.2.c.iii	Grassland converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-303.0	0.001	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N ₂ O	285.8	0.001	99%
3.B.5	Indirect N ₂ O Emissions From Manure Management	N ₂ O	268.3	0.001	99%
2.C.3	Aluminium Production	CO ₂	254.0	0.000	99%
3.B.3	Swine	CH ₄	237.1	0.000	99%
1.A.4	Other Sectors - Solid Fuels	CH ₄	205.9	0.000	99%
3.B.2	Sheep	N ₂ O	199.0	0.000	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH ₄	192.7	0.000	99%



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4.B.2.c	Wetland converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	183.8	0.000	99%
3.B.1.a.i	Dairy Cattle	N ₂ O	178.9	0.000	99%
4.D.2.c.i	Forest land converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	159.7	0.000	99%
4.D.2.b.i	Forest land converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	155.1	0.000	99%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO ₂	153.4	0.000	99%
3.B.2	Sheep	CH ₄	134.6	0.000	100%
2.C.6	Zinc Production	CO ₂	128.7	0.000	100%
4.C.2.d	Settlements converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-127.4	0.000	100%
4.E.2.b	Cropland converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-126.2	0.000	100%
2.B.8	Petrochemical and Carbon Black Production	CO ₂	121.0	0.000	100%
4.D.2.c.ii	Cropland converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-116.8	0.000	100%
3.A.4	Horses	CH ₄	115.9	0.000	100%
5.C	Incineration and Open Burning of Waste	CH ₄	108.1	0.000	100%
4.D.1.c	Other Wetlands Remaining Other Wetlands	CO ₂	-100.3	0.000	100%
3.H	Urea Application	CO ₂	91.0	0.000	100%
2.A.3	Glass Production	CO ₂	85.0	0.000	100%
3.B.4	Poultry	CH ₄	79.2	0.000	100%
2.B.1	Ammonia Production	CH ₄	C	C	C
4.E.2.c	Grassland converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-75.7	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N ₂ O	73.2	0.000	100%
4.A.1.c	Forest land remaining forest land – soil (mineral)	CO ₂	71.6	0.000	100%
1.A.3.e	Railways	N ₂ O	67.5	0.000	100%
3.B.4	Goats	N ₂ O	66.8	0.000	100%
3.A.4	Mules & Asses	CH ₄	62.7	0.000	100%
3.A.3	Swine	CH ₄	49.0	0.000	100%
3.F	Field burning of agricultural residues	CH ₄	47.2	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH ₄	44.6	0.000	100%



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4.D.2.b.iii	Grassland converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	43.2	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH ₄	39.9	0.000	100%
3.B.4	Goats	CH ₄	38.5	0.000	100%
4.C.1.b	Grassland remaining Grassland – dead organic matter (dead wood and litter)	CO ₂	-30.5	0.000	100%
4.C.1.e	Grassland remaining Grassland – drained organic soil	CO ₂	-29.6	0.000	100%
4.D.1.b	Flooded Land Remaining Flooded Land	CO ₂	28.6	0.000	100%
3.B.3	Swine	N ₂ O	27.4	0.000	100%
1.A.3.a	Domestic Aviation	N ₂ O	24.8	0.000	100%
5.C	Incineration and Open Burning of Waste	CO ₂	24.0	0.000	100%
5.C	Incineration and Open Burning of Waste	N ₂ O	23.6	0.000	100%
4.B.1.c	Cropland remaining Cropland – soil (mineral)	CO ₂	-20.8	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CO ₂	20.4	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CH ₄	18.3	0.000	100%
4(IV)	Indirect N ₂ O Emissions from Managed Soils	N ₂ O	18.1	0.000	100%
4.F.2.d	Settlements converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	16.0	0.000	100%
2.C.5	Lead Production	CO ₂	16.0	0.000	100%
4.F.2.b	Cropland converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	16.0	0.000	100%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CO ₂	14.7	0.000	100%
4(I)	Direct N ₂ O emissions from N inputs to managed soils	N ₂ O	13.6	0.000	100%
4.E.2.d	Settlements converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	13.0	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH ₄	13.0	0.000	100%
4.D.2.c.v	Other land converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-12.0	0.000	100%
3.F	Field burning of agricultural residues	N ₂ O	11.6	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	N ₂ O	11.3	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	CO ₂	11.2	0.000	100%
1.B.2	Oil and Natural Gas	CH ₄	10.0	0.000	100%
4.D.2.c.iv	Settlements converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-10.0	0.000	100%



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4.D.2.b.ii	Cropland converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	8.2	0.000	100%
4.B.1.e	Cropland remaining Cropland – drained organic soil	CO ₂	-7.6	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH ₄	6.3	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	CH ₄	6.1	0.000	100%
4.E.2.e	Other land converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-4.9	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N ₂ O	4.7	0.000	100%
4.E.1.b	Settlements remaining Settlements – dead organic matter (dead wood and litter)	CO ₂	4.2	0.000	100%
4.B.1.b	Cropland remaining Cropland – dead organic matter (dead wood and litter)	CO ₂	3.8	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	N ₂ O	3.6	0.000	100%
4.B.2.d	Settlements converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	3.4	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH ₄	2.6	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH ₄	2.5	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N ₂ O	2.2	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N ₂ O	2.1	0.000	100%
2.B.5	Carbide Production	CO ₂	C	C	C
2.C.2	Ferroalloys Production	CH ₄	1.6	0.000	100%
4.B.2.e	Other land converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	1.5	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	CH ₄	1.0	0.000	100%
1.A.3.e	Railways	CH ₄	1.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N ₂ O	0.9	0.000	100%
1.B.2	Oil and Natural Gas	N ₂ O	0.8	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH ₄	0.7	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N ₂ O	0.7	0.000	100%
1.A.3.a	Domestic Aviation	CH ₄	0.7	0.000	100%
4.D.2.b.iv	Settlements converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	0.6	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	N ₂ O	0.3	0.000	100%
2.B.8	Petrochemical and Carbon Black Production	CH ₄	0.1	0.000	100%



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1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH ₄	0.1	0.000	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N ₂ O	0.1	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	CH ₄	0.0	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	N ₂ O	0.0	0.000	100%
2.A.4	Other Process Uses of Carbonates	CO ₂	0.0	0.000	100%
2.B.5	Carbide Production	CH ₄	0.0	0.000	100%
2.B.7	Soda Ash Production	CO ₂	0.0	0.000	100%
2.B.10	Other	CO ₂	0.0	0.000	100%
2.B.10	Other	CH ₄	0.0	0.000	100%
2.C.1	Iron and Steel Production	CH ₄	0.0	0.000	100%
2.C.3	Aluminium Production	Aggregate F-gases	0.0	0.000	100%
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	0.0	0.000	100%
2.G	Other Product Manufacture and Use	CO ₂	0.0	0.000	100%
2.B.2	Nitric Acid Production	CO ₂	0.0	0.000	100%
2.B.2	Nitric Acid Production	CH ₄	0.0	0.000	100%
2.B.8	Hydrogen Production	CO ₂	0.0	0.000	100%
2.C.2	Ferroalloys Production	N ₂ O	0.0	0.000	100%
2.D.1	Non-energy Products from Fuels and Solvent Use - Lubricant use	CO ₂	0.0	0.000	100%
2.D.2	Non-energy Products from Fuels and Solvent Use - Paraffin wax use	CO ₂	0.0	0.000	100%
2.F.1.a	Refrigeration and Air conditioning - refrigeration and stationary ACs	CO ₂ e	0.0	0.000	100%
2.F.1.b	Refrigeration and Air conditioning - mobile ACs	CO ₂ e	0.0	0.000	100%
4.D.2.b.v	Other land converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	0.0	0.000	100%
4.E.1.c	Settlements remaining Settlements – soil (mineral)	CO ₂	0.0	0.000	100%
4.F.1.a	Other land remaining Other land – biomass (above and below)	CO ₂	0.0	0.000	100%
4.F.1.b	Other land remaining Other land – dead organic matter (dead wood and litter)	CO ₂	0.0	0.000	100%
4.F.1.c	Other land remaining Other land – soil (mineral)	CO ₂	0.0	0.000	100%
4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO ₂	0.0	0.000	100%

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Table A.I.2: Level assessment on emissions excluding LULUCF for South Africa (2024) with the key categories highlighted in green.

Code	Category Title	GHG	2024 Estimates	Level Assessment	Cumulative Total
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	194 648.2	0.412	41%
1.A.3.b	Road Transportation	CO ₂	56 846.0	0.120	53%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO ₂	31 538.0	0.067	60%
3.A.1.a.ii	Non-dairy Cattle	CH ₄	24 291.0	0.051	65%
1.B.3	Fugitive emissions from - Other emissions from energy production	CO ₂	23 477.0	0.050	70%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	16 682.9	0.035	74%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO ₂	14 635.7	0.031	77%
1.A.4	Other Sectors - Liquid Fuels	CO ₂	14 134.1	0.030	80%
3.D.1	Direct N ₂ O Emissions From Managed Soils	N ₂ O	8 166.5	0.017	81%
5.A	Solid Waste Disposal	CH ₄	7 376.7	0.016	83%
2.C.2	Ferroalloys Production	CO ₂	6 942.5	0.015	84%
2.C.1	Iron and Steel Production	CO ₂	6 894.0	0.015	86%
3.A.2	Sheep	CH ₄	6 313.1	0.013	87%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO ₂	5 063.6	0.011	88%
5.D	Wastewater Treatment and Discharge - Industrial	CH ₄	4 720.4	0.010	89%
2.A.1	Cement Production	CO ₂	3 846.0	0.008	90%
1.A.4	Other Sectors - Solid Fuels	CO ₂	3 842.0	0.008	91%
3.A.1.a.i	Dairy Cattle	CH ₄	3 609.0	0.008	92%
5.D	Wastewater Treatment and Discharge - Domestic	CH ₄	3 552.8	0.008	93%
1.B.3	Fugitive emissions from - Other emissions from energy production	CH ₄	2 736.7	0.006	93%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO ₂	2 228.1	0.005	94%
3.G	Liming	CO ₂	1 890.9	0.004	94%
5.B	Biological Treatment of Solid Waste	CH ₄	1 793.2	0.004	94%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CH ₄	1 754.0	0.004	95%
3.A.4	Goats	CH ₄	1 577.1	0.003	95%
3.D.2	Indirect N ₂ O Emissions From Managed Soils	N ₂ O	1 513.7	0.003	95%
2.C.3	Aluminium Production	CO ₂	1 259.2	0.003	96%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO ₂	1 115.9	0.002	96%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO ₂	986.5	0.002	96%



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3.B.4	Poultry	N ₂ O	953.0	0.002	96%
3.B.1. a.ii	Non-dairy Cattle	N ₂ O	922.6	0.002	96%
5.B	Biological Treatment of Solid Waste	N ₂ O	826.9	0.002	97%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N ₂ O	808.2	0.002	97%
2.A.2	Lime Production	CO ₂	799.1	0.002	97%
1.A.3. a	Domestic Aviation	CO ₂	775.7	0.002	97%
5.D	Wastewater Treatment and Discharge - Domestic	N ₂ O	733.8	0.002	97%
1.A.3. b	Road Transportation	N ₂ O	733.3	0.002	97%
2.D.2	Non-energy Products from Fuels and Solvent Use - Paraffin wax use	CO ₂	715.8	0.002	98%
2.B.6	Titanium Dioxide Production	CO ₂	683.3	0.001	98%
3.B.1. a.ii	Non-dairy Cattle	CH ₄	676.6	0.001	98%
3.H	Urea Application	CO ₂	670.8	0.001	98%
1.A.3. d	Domestic Navigation - Liquid Fuels	CO ₂	562.0	0.001	98%
3.B.1. a.i	Dairy Cattle	CH ₄	556.7	0.001	98%
1.A.4	Other Sectors - Gaseous Fuels	CO ₂	526.0	0.001	98%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N ₂ O	503.6	0.001	99%
2.C.6	Zinc Production	CO ₂	501.9	0.001	99%
2.D.1	Non-energy Products from Fuels and Solvent Use - Lubricant use	CO ₂	461.9	0.001	99%
1.A.3. c	Railways	CO ₂	410.1	0.001	99%
1.B.1. c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CO ₂	384.6	0.001	99%
2.B.1	Ammonia Production	CO ₂	378.7	0.001	99%
1.A.3. b	Road Transportation	CH ₄	366.1	0.001	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH ₄	341.3	0.001	99%
2.B.2	Nitric Acid Production	N ₂ O	340.4	0.001	99%
3.B.5	Indirect N ₂ O Emissions From Manure Management	N ₂ O	333.0	0.001	99%
1.B.1. c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CH ₄	250.7	0.001	99%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO ₂	227.5	0.000	99%
3.B.1. a.i	Dairy Cattle	N ₂ O	213.7	0.000	99%
1.A.4	Other Sectors - Solid Fuels	N ₂ O	207.1	0.000	99%
3.B.3	Swine	CH ₄	205.5	0.000	99%
3.B.4	Poultry	CH ₄	191.7	0.000	100%
2.A.3	Glass Production	CO ₂	177.3	0.000	100%
3.A.4	Horses	CH ₄	170.3	0.000	100%



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5.C	Incineration and Open Burning of Waste	CH4	167.2	0.000	100%
1.A.4	Other Sectors - Solid Fuels	CH4	161.8	0.000	100%
3.B.2	Sheep	N2O	158.2	0.000	100%
2.A.4	Other Process Uses of Carbonates	CO2	133.6	0.000	100%
2.B.1	Ammonia Production	CH4	113.7	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	109.3	0.000	100%
2.B.8	Petrochemical and Carbon Black Production	CO2	95.1	0.000	100%
3.B.2	Sheep	CH4	88.6	0.000	100%
2.G	Other Product Manufacture and Use	CO2	84.7	0.000	100%
2.B.8	Hydrogen Production	CO2	75.1	0.000	100%
1.B.2	Oil and Natural Gas	CO2	63.0	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	57.2	0.000	100%
3.B.4	Goats	N2O	49.3	0.000	100%
3.A.4	Mules & Asses	CH4	45.2	0.000	100%
3.F	Field burning of agricultural residues	CH4	43.7	0.000	100%
3.A.3	Swine	CH4	42.5	0.000	100%
1.A.3.e	Railways	N2O	37.8	0.000	100%
5.C	Incineration and Open Burning of Waste	CO2	37.0	0.000	100%
5.C	Incineration and Open Burning of Waste	N2O	36.5	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	32.9	0.000	100%
2.B.5	Carbide Production	CO2	31.6	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	N2O	27.3	0.000	100%
3.B.4	Goats	CH4	27.1	0.000	100%
3.B.3	Swine	N2O	23.8	0.000	100%
1.B.2	Oil and Natural Gas	CH4	22.5	0.000	100%
2.B.10	Other	CO2	20.4	0.000	100%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CO2	17.2	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	CH4	14.8	0.000	100%
2.B.10	Other	CH4	12.7	0.000	100%
3.F	Field burning of agricultural residues	N2O	10.7	0.000	100%
2.C.5	Lead Production	CO2	7.7	0.000	100%
2.B.7	Soda Ash Production	CO2	6.4	0.000	100%
1.A.3.a	Domestic Aviation	N2O	5.6	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	N2O	4.7	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	4.1	0.000	100%
2.B.5	Carbide Production	CH4	3.9	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	1.7	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	1.5	0.000	100%



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2.B.8	Petrochemical and Carbon Black Production	CH4	1.2	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	1.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	0.9	0.000	100%
1.A.3.e	Railways	CH4	0.7	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	0.5	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	0.5	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	CH4	0.3	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	N2O	0.3	0.000	100%
1.A.3.a	Domestic Aviation	CH4	0.1	0.000	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	0.1	0.000	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	0.1	0.000	100%
1.B.2	Oil and Natural Gas	N2O	0.1	0.000	100%
2.C.2	Ferroalloys Production	CH4	0.1	0.000	100%
2.C.3	Aluminium Production	Aggregate F-gases	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH4	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	0.0	0.000	100%
2.C.1	Iron and Steel Production	CH4	0.0	0.000	100%
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	0.0	0.000	100%
2.B.2	Nitric Acid Production	CO2	0.0	0.000	100%
2.B.2	Nitric Acid Production	CH4	0.0	0.000	100%
2.C.2	Ferroalloys Production	N2O	0.0	0.000	100%
2.F.1.a	Refrigeration and Air conditioning - refrigeration and stationary ACs	CO2e	0.0	0.000	100%
2.F.1.b	Refrigeration and Air conditioning - mobile ACs	CO2e	0.0	0.000	100%

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Table A.I.3: Level assessment on emissions including LULUCF for South Africa (2024) with the key categories highlighted in green.

Code	Category Title	GHG	2024 Estimates	Level Assessment	Cumulative Total
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	194 648.2	0.301	30%
4.A.2.b	Grassland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-57 097.6	0.088	39%
1.A.3.b	Road Transportation	CO ₂	56 846.0	0.088	48%
4.C.2.a	Forest land converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	36 486.2	0.056	53%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO ₂	31 538.0	0.049	58%
3.A.1.a.i	Non-dairy Cattle	CH ₄	24 291.0	0.038	62%
1.B.3	Fugitive emissions from - Other emissions from energy production	CO ₂	23 477.0	0.036	66%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	16 682.9	0.026	68%
4.C.2.e	Other land converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-15 836.5	0.024	71%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO ₂	14 635.7	0.023	73%
4.C.1.a	Grassland remaining Grassland – biomass (above and below)	CO ₂	-14 549.9	0.022	75%
1.A.4	Other Sectors - Liquid Fuels	CO ₂	14 134.1	0.022	77%
4.A.1.a	Forest land remaining forest land – biomass (above and below)	CO ₂	9 345.2	0.014	79%
3.D.1	Direct N ₂ O Emissions From Managed Soils	N ₂ O	8 166.5	0.013	80%
4.F.2.c	Grassland converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	7 549.5	0.012	81%
5.A	Solid Waste Disposal	CH ₄	7 376.7	0.011	82%
2.C.2	Ferroalloys Production	CO ₂	6 942.5	0.011	83%
2.C.1	Iron and Steel Production	CO ₂	6 894.0	0.011	84%
3.A.2	Sheep	CH ₄	6 313.1	0.010	85%
4.B.2.a	Forest land converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	5 450.4	0.008	86%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO ₂	5 063.6	0.008	87%
5.D	Wastewater Treatment and Discharge - Industrial	CH ₄	4 720.4	0.007	88%



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2.A.1	Cement Production	CO ₂	3 846.0	0.006	88%
1.A.4	Other Sectors - Solid Fuels	CO ₂	3 842.0	0.006	89%
3.A.1.a.i	Dairy Cattle	CH ₄	3 609.0	0.006	90%
5.D	Wastewater Treatment and Discharge - Domestic	CH ₄	3 552.8	0.005	90%
4.A.2.a	Cropland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-3 417.3	0.005	91%
4.E.1.a	Settlements remaining Settlements – biomass (above and below)	CO ₂	-3 103.4	0.005	91%
1.B.3	Fugitive emissions from - Other emissions from energy production	CH ₄	2 736.7	0.004	92%
4.B.2.b	Grassland converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	2 275.5	0.004	92%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO ₂	2 228.1	0.003	92%
4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH ₄	2 039.0	0.003	93%
3.G	Liming	CO ₂	1 890.9	0.003	93%
5.B	Biological Treatment of Solid Waste	CH ₄	1 793.2	0.003	93%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CH ₄	1 754.0	0.003	93%
4.F.2.a	Forest land converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	1 744.6	0.003	94%
4.G	Harvested Wood Products	CO ₂	-1 718.3	0.003	94%
4.C.2.b	Cropland converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-1 672.7	0.003	94%
3.A.4	Goats	CH ₄	1 577.1	0.002	94%
3.D.2	Indirect N ₂ O Emissions From Managed Soils	N ₂ O	1 513.7	0.002	95%
4.A.2.e	Other land converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-1 487.8	0.002	95%
2.C.3	Aluminium Production	CO ₂	1 259.2	0.002	95%
4.E.2.a	Forest land converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	1 224.3	0.002	95%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO ₂	1 115.9	0.002	95%
4.A.2.d	Settlements converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-1 008.9	0.002	96%
4.A.1.b	Forest land remaining forest land – dead organic matter (dead wood and litter)	CO ₂	-1 006.1	0.002	96%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO ₂	986.5	0.002	96%



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3.B.4	Poultry	N ₂ O	953.0	0.001	96%
3.B.1.a.i	Non-dairy Cattle	N ₂ O	922.6	0.001	96%
4(V)	Biomass Burning	CH ₄	902.0	0.001	96%
4.A.2.c	Wetland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-850.6	0.001	96%
5.B	Biological Treatment of Solid Waste	N ₂ O	826.9	0.001	97%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N ₂ O	808.2	0.001	97%
2.A.2	Lime Production	CO ₂	799.1	0.001	97%
1.A.3.a	Domestic Aviation	CO ₂	775.7	0.001	97%
4.F.2.e	Other land converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	749.9	0.001	97%
5.D	Wastewater Treatment and Discharge - Domestic	N ₂ O	733.8	0.001	97%
1.A.3.b	Road Transportation	N ₂ O	733.3	0.001	97%
2.D.2	Non-energy Products from Fuels and Solvent Use - Paraffin wax use	CO ₂	715.8	0.001	97%
4.C.1.c	Grassland remaining Grassland – soil (mineral)	CO ₂	-707.2	0.001	98%
4(V)	Biomass Burning	N ₂ O	691.9	0.001	98%
2.B.6	Titanium Dioxide Production	CO ₂	683.3	0.001	98%
3.B.1.a.i	Non-dairy Cattle	CH ₄	676.6	0.001	98%
3.H	Urea Application	CO ₂	670.8	0.001	98%
4.E.2.b	Cropland converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	606.9	0.001	98%
1.A.3.d	Domestic Navigation - Liquid Fuels	CO ₂	562.0	0.001	98%
3.B.1.a.i	Dairy Cattle	CH ₄	556.7	0.001	98%
1.A.4	Other Sectors - Gaseous Fuels	CO ₂	526.0	0.001	98%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N ₂ O	503.6	0.001	98%
2.C.6	Zinc Production	CO ₂	501.9	0.001	98%
2.D.1	Non-energy Products from Fuels and Solvent Use - Lubricant use	CO ₂	461.9	0.001	99%
4.C.2.d	Settlements converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-442.9	0.001	99%
4(III)	Direct N ₂ O emissions from N mineralization/immobilization	N ₂ O	438.0	0.001	99%
1.A.3.c	Railways	CO ₂	410.1	0.001	99%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CO ₂	384.6	0.001	99%



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4.D.2.c.i ii	Grassland converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-381.2	0.001	99%
2.B.1	Ammonia Production	CO ₂	378.7	0.001	99%
1.A.3.b	Road Transportation	CH ₄	366.1	0.001	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH ₄	341.3	0.001	99%
2.B.2	Nitric Acid Production	N ₂ O	340.4	0.001	99%
3.B.5	Indirect N ₂ O Emissions From Manure Management	N ₂ O	333.0	0.001	99%
4.D.2.b.i	Forest land converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	320.1	0.000	99%
4.B.1.a	Cropland remaining Cropland – biomass (above and below)	CO ₂	312.3	0.000	99%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CH ₄	250.7	0.000	99%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO ₂	227.5	0.000	99%
4.A.1.c	Forest land remaining forest land – soil (mineral)	CO ₂	-220.7	0.000	99%
3.B.1.a.i	Dairy Cattle	N ₂ O	213.7	0.000	99%
1.A.4	Other Sectors - Solid Fuels	N ₂ O	207.1	0.000	99%
3.B.3	Swine	CH ₄	205.5	0.000	99%
3.B.4	Poultry	CH ₄	191.7	0.000	99%
2.A.3	Glass Production	CO ₂	177.3	0.000	99%
4.D.2.b.i ii	Grassland converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	171.0	0.000	99%
3.A.4	Horses	CH ₄	170.3	0.000	100%
5.C	Incineration and Open Burning of Waste	CH ₄	167.2	0.000	100%
4.E.2.c	Grassland converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-166.9	0.000	100%
1.A.4	Other Sectors - Solid Fuels	CH ₄	161.8	0.000	100%
3.B.2	Sheep	N ₂ O	158.2	0.000	100%
4.C.2.c	Wetland converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO ₂	-144.4	0.000	100%
2.A.4	Other Process Uses of Carbonates	CO ₂	133.6	0.000	100%
2.B.1	Ammonia Production	CH ₄	113.7	0.000	100%
4.D.1.c	Other Wetlands Remaining Other Wetlands	CO ₂	-109.4	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N ₂ O	109.3	0.000	100%
2.B.8	Petrochemical and Carbon Black Production	CO ₂	95.1	0.000	100%
4.D.1.b	Flooded Land Remaining Flooded Land	CO ₂	89.4	0.000	100%
3.B.2	Sheep	CH ₄	88.6	0.000	100%



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2.G	Other Product Manufacture and Use	CO2	84.7	0.000	100%
4.D.2.c.i	Forest land converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	78.6	0.000	100%
2.B.8	Hydrogen Production	CO2	75.1	0.000	100%
4.D.2.c.i i	Cropland converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-73.7	0.000	100%
1.B.2	Oil and Natural Gas	CO2	63.0	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	57.2	0.000	100%
4(I)	Direct N2O emissions from N inputs to managed soils	N2O	54.2	0.000	100%
4.C.1.b	Grassland remaining Grassland – dead organic matter (dead wood and litter)	CO2	-49.8	0.000	100%
3.B.4	Goats	N2O	49.3	0.000	100%
4(IV)	Indirect N2O Emissions from Managed Soils	N2O	46.7	0.000	100%
4.D.2.b.i i	Cropland converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	46.3	0.000	100%
3.A.4	Mules & Asses	CH4	45.2	0.000	100%
3.F	Field burning of agricultural residues	CH4	43.7	0.000	100%
3.A.3	Swine	CH4	42.5	0.000	100%
4.B.2.e	Other land converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	38.2	0.000	100%
1.A.3.e	Railways	N2O	37.8	0.000	100%
5.C	Incineration and Open Burning of Waste	CO2	37.0	0.000	100%
5.C	Incineration and Open Burning of Waste	N2O	36.5	0.000	100%
4.E.2.e	Other land converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-35.8	0.000	100%
4.C.1.e	Grassland remaining Grassland – drained organic soil	CO2	-35.2	0.000	100%
4.B.2.c	Wetland converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	33.5	0.000	100%
4.F.2.d	Settlements converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	33.3	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	32.9	0.000	100%
2.B.5	Carbide Production	CO2	31.6	0.000	100%
4.D.2.c. v	Other land converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-28.4	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	N2O	27.3	0.000	100%



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3.B.4	Goats	CH4	27.1	0.000	100%
3.B.3	Swine	N2O	23.8	0.000	100%
1.B.2	Oil and Natural Gas	CH4	22.5	0.000	100%
4.B.1.b	Cropland remaining Cropland – dead organic matter (dead wood and litter)	CO2	-22.1	0.000	100%
4.B.2.d	Settlements converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	20.7	0.000	100%
2.B.10	Other	CO2	20.4	0.000	100%
4.E.2.d	Settlements converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	20.4	0.000	100%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CO2	17.2	0.000	100%
4.F.2.b	Cropland converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	15.7	0.000	100%
4.B.1.c	Cropland remaining Cropland – soil (mineral)	CO2	-15.2	0.000	100%
1.A.4	Other Sectors - Liquid Fuels	CH4	14.8	0.000	100%
2.B.10	Other	CH4	12.7	0.000	100%
4.D.2.c.i v	Settlements converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-11.3	0.000	100%
3.F	Field burning of agricultural residues	N2O	10.7	0.000	100%
4.B.1.e	Cropland remaining Cropland – drained organic soil	CO2	-9.4	0.000	100%
2.C.5	Lead Production	CO2	7.7	0.000	100%
2.B.7	Soda Ash Production	CO2	6.4	0.000	100%
1.A.3.a	Domestic Aviation	N2O	5.6	0.000	100%
4.D.2.b.i v	Settlements converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	5.5	0.000	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	N2O	4.7	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	4.1	0.000	100%
2.B.5	Carbide Production	CH4	3.9	0.000	100%
4.E.1.b	Settlements remaining Settlements – dead organic matter (dead wood and litter)	CO2	1.7	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	1.7	0.000	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	1.5	0.000	100%
2.B.8	Petrochemical and Carbon Black Production	CH4	1.2	0.000	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	1.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	0.9	0.000	100%
1.A.3.e	Railways	CH4	0.7	0.000	100%



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1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	0.5	0.000	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	0.5	0.000	100%
1.A.4	Other Sectors - Gaseous Fuels	N2O	0.3	0.000	100%
1.A.3.a	Domestic Aviation	CH4	0.1	0.000	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	0.1	0.000	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	0.1	0.000	100%
1.B.2	Oil and Natural Gas	N2O	0.1	0.000	100%
2.C.2	Ferroalloys Production	CH4	0.1	0.000	100%
2.C.3	Aluminium Production	Aggregate F-gases	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH4	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	0.0	0.000	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	0.0	0.000	100%
2.C.1	Iron and Steel Production	CH4	0.0	0.000	100%
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	0.0	0.000	100%
2.B.2	Nitric Acid Production	CO2	0.0	0.000	100%
2.B.2	Nitric Acid Production	CH4	0.0	0.000	100%
2.C.2	Ferroalloys Production	N2O	0.0	0.000	100%
2.F.1.a	Refrigeration and Air conditioning - refrigeration and stationary ACs	CO2e	0.0	0.000	100%
2.F.1.b	Refrigeration and Air conditioning - mobile ACs	CO2e	0.0	0.000	100%
4.D.2.b.v	Other land converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	0.0	0.000	100%
4.E.1.c	Settlements remaining Settlements – soil (mineral)	CO2	0.0	0.000	100%
4.F.1.a	Other land remaining Other land – biomass (above and below)	CO2	0.0	0.000	100%
4.F.1.b	Other land remaining Other land – dead organic matter (dead wood and litter)	CO2	0.0	0.000	100%
4.F.1.c	Other land remaining Other land – soil (mineral)	CO2	0.0	0.000	100%
4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	0.0	0.000	100%

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Table A.I.4: Trend assessment on emissions excluding LULUCF for South Africa (1990 - 2024) with the key categories highlighted in green.

Code	Category Title	GHG	1990 Estimates	2024 Estimates	Contribution to Trend	Cumulative Total
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO ₂	137 910.7	194 648.2	32%	32%
1.A.4	Other Sectors - Solid Fuels	CO ₂	33 356.7	3 842.0	17%	49%
1.A.3.b	Road Transportation	CO ₂	41 755.4	56 846.0	9%	58%
1.A.4	Other Sectors - Liquid Fuels	CO ₂	5 480.3	14 134.1	5%	63%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO ₂	9 748.0	16 682.9	4%	67%
2.C.2	Ferroalloys Production	CO ₂	1 186.9	6 942.5	3%	70%
2.C.1	Iron and Steel Production	CO ₂	12 597.0	6 894.0	3%	73%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO ₂	26 631.5	31 538.0	3%	76%
5.A	Solid Waste Disposal	CH ₄	2 821.7	7 376.7	3%	79%
3.A.1.a.ii	Non-dairy Cattle	CH ₄	28 133.1	24 291.0	2%	81%
3.A.2	Sheep	CH ₄	10 019.9	6 313.1	2%	83%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO ₂	1 655.0	5 063.6	2%	85%
1.A.3.a	Domestic Aviation	CO ₂	3 408.9	775.7	2%	86%
1.B.3	Fugitive emissions from - Other emissions from energy production	CO ₂	25 903.1	23 477.0	1%	88%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO ₂	12 921.6	14 635.7	1%	89%
5.D	Wastewater Treatment and Discharge - Domestic	CH ₄	2 297.1	3 552.8	1%	89%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO ₂	2 282.2	1 115.9	1%	90%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO ₂	1 079.8	2 228.1	1%	91%
2.C.3	Aluminium Production	CO ₂	254.0	1 259.2	1%	91%
5.B	Biological Treatment of Solid Waste	CH ₄	858.5	1 793.2	1%	92%
2.B.2	Nitric Acid Production	N ₂ O	1 227.4	340.4	1%	92%
2.D.2	Non-energy Products from Fuels and Solvent Use - Paraffin wax use	CO ₂	0.0	715.8	0%	93%
1.B.2	Oil and Natural Gas	CO ₂	773.3	63.0	0%	93%
3.A.4	Goats	CH ₄	2 285.5	1 577.1	0%	94%
3.A.1.a.i	Dairy Cattle	CH ₄	3 021.0	3 609.0	0%	94%
3.B.4	Poultry	N ₂ O	367.6	953.0	0%	94%
3.G	Liming	CO ₂	2 470.8	1 890.9	0%	95%



3.H	Urea Application	CO2	91.0	670.8	0%	95%
1.A.4	Other Sectors - Gaseous Fuels	CO2	11.2	526.0	0%	95%
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	1 008.9	1 513.7	0%	95%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	1 466.1	986.5	0%	96%
5.D	Wastewater Treatment and Discharge - Industrial	CH4	4 250.7	4 720.4	0%	96%
2.D.1	Non-energy Products from Fuels and Solvent Use - Lubricant use	CO2	0.0	461.9	0%	96%
2.A.1	Cement Production	CO2	4 252.5	3 846.0	0%	97%
2.C.6	Zinc Production	CO2	128.7	501.9	0%	97%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CO2	20.4	384.6	0%	97%
5.B	Biological Treatment of Solid Waste	N2O	487.5	826.9	0%	97%
2.A.2	Lime Production	CO2	488.0	799.1	0%	97%
2.B.6	Titanium Dioxide Production	CO2	382.1	683.3	0%	97%
5.D	Wastewater Treatment and Discharge - Domestic	N2O	474.4	733.8	0%	98%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CH4	1 495.4	1 754.0	0%	98%
1.A.3.c	Railways	CO2	664.3	410.1	0%	98%
3.D.1	Direct N2O Emissions From Managed Soils	N2O	7 914.1	8 166.5	0%	98%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	566.5	808.2	0%	98%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CH4	18.3	250.7	0%	98%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	285.8	503.6	0%	98%
1.A.3.b	Road Transportation	N2O	519.5	733.3	0%	99%
1.A.4	Other Sectors - Solid Fuels	N2O	392.5	207.1	0%	99%
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	389.7	562.0	0%	99%
1.B.3	Fugitive emissions from - Other emissions from energy production	CH4	2 905.1	2 736.7	0%	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	192.7	341.3	0%	99%
2.A.4	Other Process Uses of Carbonates	CO2	0.0	133.6	0%	99%
3.B.1.a.ii	Non-dairy Cattle	N2O	806.4	922.6	0%	99%
3.B.4	Poultry	CH4	79.2	191.7	0%	99%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	2.2	109.3	0%	99%
2.A.3	Glass Production	CO2	85.0	177.3	0%	99%
3.B.1.a.i	Dairy Cattle	CH4	466.0	556.7	0%	99%
2.G	Other Product Manufacture and Use	CO2	0.0	84.7	0%	99%
2.B.8	Hydrogen Production	CO2	0.0	75.1	0%	99%

1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	153.4	227.5	0%	99%
1.A.2	Fuel Combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	73.2	0.0	0%	99%
3.B.5	Indirect N2O Emissions From Manure Management	N2O	268.3	333.0	0%	100%
5.C	Incineration and Open Burning of Waste	CH4	108.1	167.2	0%	100%
3.A.4	Horses	CH4	115.9	170.3	0%	100%
3.B.2	Sheep	CH4	134.6	88.6	0%	100%
2.B.1	Ammonia Production	CO2	423.7	378.7	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	44.6	0.0	0%	100%
1.A.4	Other Sectors - Solid Fuels	CH4	205.9	161.8	0%	100%
3.B.2	Sheep	N2O	199.0	158.2	0%	100%
2.B.1	Ammonia Production	CH4	76.3	113.7	0%	100%
3.B.1.a.i	Dairy Cattle	N2O	178.9	213.7	0%	100%
3.B.3	Swine	CH4	237.1	205.5	0%	100%
2.B.5	Carbide Production	CO2	1.7	31.6	0%	100%
1.A.3.e	Railways	N2O	67.5	37.8	0%	100%
3.B.1.a.ii	Non-dairy Cattle	CH4	703.2	676.6	0%	100%
2.B.8	Petrochemical and Carbon Black Production	CO2	121.0	95.1	0%	100%
2.B.10	Other	CO2	0.0	20.4	0%	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	13.0	32.9	0%	100%
1.A.3.a	Domestic Aviation	N2O	24.8	5.6	0%	100%
3.A.4	Mules & Asses	CH4	62.7	45.2	0%	100%
3.B.4	Goats	N2O	66.8	49.3	0%	100%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	39.9	57.2	0%	100%
1.A.4	Other Sectors - Liquid Fuels	N2O	11.3	27.3	0%	100%
5.C	Incineration and Open Burning of Waste	CO2	24.0	37.0	0%	100%
5.C	Incineration and Open Burning of Waste	N2O	23.6	36.5	0%	100%
2.B.10	Other	CH4	0.0	12.7	0%	100%
1.B.2	Oil and Natural Gas	CH4	10.0	22.5	0%	100%
3.B.4	Goats	CH4	38.5	27.1	0%	100%
1.A.4	Other Sectors - Liquid Fuels	CH4	6.1	14.8	0%	100%
2.C.5	Lead Production	CO2	16.0	7.7	0%	100%
3.A.3	Swine	CH4	49.0	42.5	0%	100%

2.B.7	Soda Ash Production	CO ₂	0.0	6.4	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH ₄	6.3	0.0	0%	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	N ₂ O	0.3	4.7	0%	100%
2.B.5	Carbide Production	CH ₄	0.0	3.9	0%	100%
3.B.3	Swine	N ₂ O	27.4	23.8	0%	100%
3.F	Field burning of agricultural residues	CH ₄	47.2	43.7	0%	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N ₂ O	4.7	1.7	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH ₄	2.6	0.0	0%	100%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CO ₂	14.7	17.2	0%	100%
1.A.3.b	Road Transportation	CH ₄	368.5	366.1	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N ₂ O	2.1	0.0	0%	100%
2.C.2	Ferroalloys Production	CH ₄	1.6	0.1	0%	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH ₄	2.5	1.0	0%	100%
2.B.8	Petrochemical and Carbon Black Production	CH ₄	0.1	1.2	0%	100%
3.F	Field burning of agricultural residues	N ₂ O	11.6	10.7	0%	100%
1.B.2	Oil and Natural Gas	N ₂ O	0.8	0.1	0%	100%
1.A.3.a	Domestic Aviation	CH ₄	0.7	0.1	0%	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	N ₂ O	3.6	4.1	0%	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	CH ₄	1.0	1.5	0%	100%
1.A.3.e	Railways	CH ₄	1.0	0.7	0%	100%
1.A.4	Other Sectors - Gaseous Fuels	CH ₄	0.0	0.3	0%	100%
1.A.4	Other Sectors - Gaseous Fuels	N ₂ O	0.0	0.3	0%	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH ₄	0.7	0.5	0%	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N ₂ O	0.7	0.5	0%	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH ₄	0.1	0.1	0%	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N ₂ O	0.1	0.1	0%	100%
2.C.3	Aluminium Production	Aggregate F-gases	0.0	0.0	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N ₂ O	0.9	0.9	0%	100%
2.C.1	Iron and Steel Production	CH ₄	0.0	0.0	0%	100%
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	0.0	0.0	0%	100%
2.B.2	Nitric Acid Production	CO ₂	0.0	0.0	0%	100%



2.B.2	Nitric Acid Production	CH4	0.0	0.0	0.0	0%	100%
2.C.2	Ferroalloys Production	N2O	0.0	0.0	0.0	0%	100%
2.F.1.a	Refrigeration and Air conditioning - refrigeration and stationary ACs	CO2e	0.0	0.0	0.0	0%	100%
2.F.1.b	Refrigeration and Air conditioning - mobile ACs	CO2e	0.0	0.0	0.0	0%	100%

C=Confidential data

Table A.I.5: Trend assessment on emissions including LULUCF for South Africa (1990 - 2024) with the key categories highlighted in green.

Code	Category Title	GHG	1990 Estimates	2024 Estimates	Contribution to Trend	Cumulative Total
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO2	137 910.7	194 648.2	21%	21%
1.A.4	Other Sectors - Solid Fuels	CO2	33 356.7	3 842.0	11%	32%
4.A.2.b	Grassland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-29 846.3	-57 097.6	10%	42%
4.C.2.a	Forest land converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	14 927.0	36 486.2	8%	50%
1.A.3.b	Road Transportation	CO2	41 755.4	56 846.0	6%	55%
4.A.1.a	Forest land remaining forest land – biomass (above and below)	CO2	20 674.8	9 345.2	4%	59%
4.C.2.e	Other land converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-5 730.6	-15 836.5	4%	63%
1.A.4	Other Sectors - Liquid Fuels	CO2	5 480.3	14 134.1	3%	66%
4.C.1.a	Grassland remaining Grassland – biomass (above and below)	CO2	-5 937.9	-14 549.9	3%	69%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO2	9 748.0	16 682.9	3%	72%
2.C.2	Ferroalloys Production	CO2	1 186.9	6 942.5	2%	74%
2.C.1	Iron and Steel Production	CO2	12 597.0	6 894.0	2%	76%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO2	26 631.5	31 538.0	2%	78%
5.A	Solid Waste Disposal	CH4	2 821.7	7 376.7	2%	80%
3.A.1.a.ii	Non-dairy Cattle	CH4	28 133.1	24 291.0	1%	81%
3.A.2	Sheep	CH4	10 019.9	6 313.1	1%	82%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	1 655.0	5 063.6	1%	84%
4.F.2.c	Grassland converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	4 685.3	7 549.5	1%	85%
4.B.2.a	Forest land converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	2 736.2	5 450.4	1%	86%
1.A.3.a	Domestic Aviation	CO2	3 408.9	775.7	1%	87%
1.B.3	Fugitive emissions from - Other emissions from energy production	CO2	25 903.1	23 477.0	1%	88%
4.E.1.a	Settlements remaining Settlements – biomass (above and below)	CO2	-1 336.8	-3 103.4	1%	88%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	12 921.6	14 635.7	1%	89%

4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH4	656.2	2 039.0	1%	89%
5.D	Wastewater Treatment and Discharge - Domestic	CH4	2 297.1	3 552.8	0%	90%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO2	2 282.2	1 115.9	0%	90%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	1 079.8	2 228.1	0%	91%
4.F.2.a	Forest land converted to other land - all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	623.0	1 744.6	0%	91%
2.C.3	Aluminium Production	CO2	254.0	1 259.2	0%	91%
5.B	Biological Treatment of Solid Waste	CH4	858.5	1 793.2	0%	92%
2.B.2	Nitric Acid Production	N2O	1 227.4	340.4	0%	92%
4.C.2.c	Wetland converted to Grassland - all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	720.2	-144.4	0%	92%
4.C.2.b	Cropland converted to Grassland - all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-2 520.7	-1 672.7	0%	93%
4.E.2.b	Cropland converted to settlements - all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-126.2	606.9	0%	93%
2.D.2	Non-energy Products from Fuels and Solvent Use - Paraffin wax use	CO2	0.0	715.8	0%	93%
1.B.2	Oil and Natural Gas	CO2	773.3	63.0	0%	94%
3.A.4	Goats	CH4	2 285.5	1 577.1	0%	94%
4.G	Harvested Wood Products	CO2	-1 035.6	-1 718.3	0%	94%
3.A.1.a.i	Dairy Cattle	CH4	3 021.0	3 609.0	0%	94%
3.B.4	Poultry	N2O	367.6	953.0	0%	94%
3.G	Liming	CO2	2 470.8	1 890.9	0%	95%
3.H	Urea Application	CO2	91.0	670.8	0%	95%
1.A.4	Other Sectors - Gaseous Fuels	CO2	11.2	526.0	0%	95%
4.E.2.a	Forest land converted to settlements - all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	716.6	1 224.3	0%	95%
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	1 008.9	1 513.7	0%	95%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	1 466.1	986.5	0%	96%
5.D	Wastewater Treatment and Discharge - Industrial	CH4	4 250.7	4 720.4	0%	96%
2.D.1	Non-energy Products from Fuels and Solvent Use - Lubricant use	CO2	0.0	461.9	0%	96%
4.A.2.a	Cropland converted to forest land - all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-2 955.4	-3 417.3	0%	96%

4.B.2.b	Grassland converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	2 737.2	2 275.5	0%	96%
2.A.1	Cement Production	CO2	4 252.5	3 846.0	0%	96%
4.B.1.a	Cropland remaining Cropland – biomass (above and below)	CO2	714.8	312.3	0%	97%
2.C.6	Zinc Production	CO2	128.7	501.9	0%	97%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CO2	20.4	384.6	0%	97%
4.A.2.e	Other land converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-1 127.6	-1 487.8	0%	97%
4.A.2.d	Settlements converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-662.7	-1 008.9	0%	97%
5.B	Biological Treatment of Solid Waste	N2O	487.5	826.9	0%	97%
4.C.2.d	Settlements converted to Grassland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-127.4	-442.9	0%	97%
2.A.2	Lime Production	CO2	488.0	799.1	0%	98%
2.B.6	Titanium Dioxide Production	CO2	382.1	683.3	0%	98%
4.A.1.c	Forest land remaining forest land – soil (mineral)	CO2	71.6	-220.7	0%	98%
5.D	Wastewater Treatment and Discharge - Domestic	N2O	474.4	733.8	0%	98%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CH4	1 495.4	1 754.0	0%	98%
1.A.3.c	Railways	CO2	664.3	410.1	0%	98%
3.D.1	Direct N2O Emissions From Managed Soils	N2O	7 914.1	8 166.5	0%	98%
4.A.2.c	Wetland converted to forest land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-1 093.7	-850.6	0%	98%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	566.5	808.2	0%	98%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	CH4	18.3	250.7	0%	98%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	285.8	503.6	0%	98%
1.A.3.b	Road Transportation	N2O	519.5	733.3	0%	99%
1.A.4	Other Sectors - Solid Fuels	N2O	392.5	207.1	0%	99%
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	389.7	562.0	0%	99%
1.B.3	Fugitive emissions from - Other emissions from energy production	CH4	2 905.1	2 736.7	0%	99%
4.D.2.b.i	Forest land converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	155.1	320.1	0%	99%
4.B.2.c	Wetland converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	183.8	33.5	0%	99%
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	192.7	341.3	0%	99%



2.A.4	Other Process Uses of Carbonates							
4.A.1.b	Forest land remaining forest land – dead organic matter (dead wood and litter)	CO2	-1135.5	133.6	0%			99%
4.D.2.b.iii	Grassland converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	43.2	171.0	0%			99%
3.B.1.a.ii	Non-dairy Cattle	N2O	806.4	922.6	0%			99%
3.B.4	Poultry	CH4	79.2	191.7	0%			99%
4.F.2.e	Other land converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	640.8	749.9	0%			99%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	2.2	109.3	0%			99%
2.A.3	Glass Production	CO2	85.0	177.3	0%			99%
4.E.2.c	Grassland converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-75.7	-166.9	0%			99%
3.B.1.a.i	Dairy Cattle	CH4	466.0	556.7	0%			99%
4(III)	Direct N2O emissions from N mineralization/immobilization	N2O	348.6	438.0	0%			99%
2.G	Other Product Manufacture and Use	CO2	0.0	84.7	0%			99%
4.D.2.c.i	Forest land converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	159.7	78.6	0%			99%
4.D.2.c.iii	Grassland converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-303.0	-381.2	0%			99%
2.B.8	Hydrogen Production	CO2	0.0	75.1	0%			99%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	153.4	227.5	0%			99%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	73.2	0.0	0%			99%
4(V)	Biomass Burning	CH4	974.5	902.0	0%			100%
3.B.5	Indirect N2O Emissions From Manure Management	N2O	268.3	333.0	0%			100%
4.D.1.b	Flooded Land Remaining Flooded Land	CO2	28.6	89.4	0%			100%
5.C	Incineration and Open Burning of Waste	CH4	108.1	167.2	0%			100%
3.A.4	Horses	CH4	115.9	170.3	0%			100%
3.B.2	Sheep	CH4	134.6	88.6	0%			100%
2.B.1	Ammonia Production	CO2	423.7	378.7	0%			100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	44.6	0.0	0%			100%
1.A.4	Other Sectors - Solid Fuels	CH4	205.9	161.8	0%			100%
4.D.2.c.ii	Cropland converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-116.8	-73.7	0%			100%
R.2	Sheen	N2O	199.0	158.2	0%			100%

4(i)	Direct N2O emissions from N inputs to managed soils	N2O	13.6	54.2	0%	100%
4.D.2.b.ii	Cropland converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	8.2	46.3	0%	100%
2.B.1	Ammonia Production	CH4	76.3	113.7	0%	100%
4.B.2.e	Other land converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	1.5	38.2	0%	100%
3.B.1.a.i	Dairy Cattle	N2O	178.9	213.7	0%	100%
3.B.3	Swine	CH4	237.1	205.5	0%	100%
4.E.2.e	Other land converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-4.9	-35.8	0%	100%
2.B.5	Carbide Production	CO2	1.7	31.6	0%	100%
1.A.3.e	Railways	N2O	67.5	37.8	0%	100%
4(IV)	Indirect N2O Emissions from Managed Soils	N2O	18.1	46.7	0%	100%
3.B.1.a.ii	Non-dairy Cattle	CH4	703.2	676.6	0%	100%
2.B.8	Petrochemical and Carbon Black Production	CO2	121.0	95.1	0%	100%
4.B.1.b	Cropland remaining Cropland – dead organic matter (dead wood and litter)	CO2	3.8	-22.1	0%	100%
2.B.10	Other	CO2	0.0	20.4	0%	100%
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	13.0	32.9	0%	100%
4.C.1.b	Grassland remaining Grassland – dead organic matter (dead wood and litter)	CO2	-30.5	-49.8	0%	100%
1.A.3.a	Domestic Aviation	N2O	24.8	5.6	0%	100%
3.A.4	Mules & Asses	CH4	62.7	45.2	0%	100%
3.B.4	Goats	N2O	66.8	49.3	0%	100%
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	39.9	57.2	0%	100%
4.B.2.d	Settlements converted to Cropland – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	3.4	20.7	0%	100%
4.F.2.d	Settlements converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	16.0	33.3	0%	100%
4.D.2.c.v	Other land converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-12.0	-28.4	0%	100%
1.A.4	Other Sectors - Liquid Fuels	N2O	11.3	27.3	0%	100%
5.C	Incineration and Open Burning of Waste	CO2	24.0	37.0	0%	100%
5.C	Incineration and Open Burning of Waste	N2O	23.6	36.5	0%	100%
2.B.10	Other	CH4	0.0	12.7	0%	100%
1.B.2	Oil and Natural Gas	CH4	10.0	22.5	0%	100%

4.C.1.c	Grassland remaining Grassland – soil (mineral)	CO2	-695.6	-707.2	0%	100%
3.B.4	Goats	CH4	38.5	27.1	0%	100%
4.D.1.c	Other Wetlands Remaining Other Wetlands	CO2	-100.3	-109.4	0%	100%
1.A.4	Other Sectors - Liquid Fuels	CH4	6.1	14.8	0%	100%
2.C.5	Lead Production	CO2	16.0	7.7	0%	100%
4.E.2.d	Settlements converted to settlements – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	13.0	20.4	0%	100%
3.A.3	Swine	CH4	49.0	42.5	0%	100%
2.B.7	Soda Ash Production	CO2	0.0	6.4	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	6.3	0.0	0%	100%
4.B.1.c	Cropland remaining Cropland – soil (mineral)	CO2	-20.8	-15.2	0%	100%
4.C.1.e	Grassland remaining Grassland – drained organic soil	CO2	-29.6	-35.2	0%	100%
4.D.2.b.iv	Settlements converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	0.6	5.5	0%	100%
1.B.1.c	Fugitive emissions from Solid Fuels - Solid fuel transformation	N2O	0.3	4.7	0%	100%
2.B.5	Carbide Production	CH4	0.0	3.9	0%	100%
3.B.3	Swine	N2O	27.4	23.8	0%	100%
3.F	Field burning of agricultural residues	CH4	47.2	43.7	0%	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	4.7	1.7	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH4	2.6	0.0	0%	100%
1.B.1.a	Fugitive emissions from Solid Fuels - Coal mining and handling	CO2	14.7	17.2	0%	100%
4.E.1.b	Settlements remaining Settlements – dead organic matter (dead wood and litter)	CO2	4.2	1.7	0%	100%
1.A.3.b	Road Transportation	CH4	368.5	366.1	0%	100%
4(V)	Biomass Burning	N2O	689.6	691.9	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	2.1	0.0	0%	100%
4.B.1.e	Cropland remaining Cropland – drained organic soil	CO2	-7.6	-9.4	0%	100%
2.C.2	Ferroalloys Production	CH4	1.6	0.1	0%	100%
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	2.5	1.0	0%	100%
4.D.2.c.iv	Settlements converted to other wetlands – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	-10.0	-11.3	0%	100%
2.B.8	Petrochemical and Carbon Black Production	CH4	0.1	1.2	0%	100%
3.F	Field burning of agricultural residues	N2O	11.6	10.7	0%	100%
1.B.2	Oil and Natural Gas	N2O	0.8	0.1	0%	100%

1.A.3.a	Domestic Aviation	CH4	0.7	0.1	0%	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	3.6	4.1	0%	100%
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	1.0	1.5	0%	100%
1.A.3.e	Railways	CH4	1.0	0.7	0%	100%
4.F.2.b	Cropland converted to other land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	16.0	15.7	0%	100%
1.A.4	Other Sectors - Gaseous Fuels	CH4	0.0	0.3	0%	100%
1.A.4	Other Sectors - Gaseous Fuels	N2O	0.0	0.3	0%	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	0.7	0.5	0%	100%
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	0.7	0.5	0%	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	0.1	0.1	0%	100%
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	0.1	0.1	0%	100%
2.C.3	Aluminium Production	Aggregate F-gases	0.0	0.0	0%	100%
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	0.9	0.9	0%	100%
2.C.1	Iron and Steel Production	CH4	0.0	0.0	0%	100%
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	0.0	0.0	0%	100%
2.B.2	Nitric Acid Production	CO2	0.0	0.0	0%	100%
2.B.2	Nitric Acid Production	CH4	0.0	0.0	0%	100%
2.C.2	Ferroalloys Production	N2O	0.0	0.0	0%	100%
2.F.1.a	Refrigeration and Air conditioning - refrigeration and stationary ACs	CO2e	0.0	0.0	0%	100%
2.F.1.b	Refrigeration and Air conditioning - mobile ACs	CO2e	0.0	0.0	0%	100%
4.D.2.b.v	Other land converted to flooded land – all pools (i.e., biomass, dead organic matter, soil (mineral), soil (organic), drained organic soil)	CO2	0.0	0.0	0%	100%
4.E.1.c	Settlements remaining Settlements – soil (mineral)	CO2	0.0	0.0	0%	100%
4.F.1.a	Other land remaining Other land – biomass (above and below)	CO2	0.0	0.0	0%	100%
4.F.1.b	Other land remaining Other land – dead organic matter (dead wood and litter)	CO2	0.0	0.0	0%	100%
4.F.1.c	Other land remaining Other land – soil (mineral)	CO2	0.0	0.0	0%	100%
4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	0.0	0.0	0%	100%

C=Confidential data

Annex II: Uncertainty analysis

Table A II. 1: Overall uncertainty analysis including LULUCF for 1990 to 2024.

GHG Inventory for South Africa: 1990 - 2024



Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

IPCC Category	Gas	Base year emissions/ removals (1990)	Year t emissions/ removals (2024)	Activity data uncertainty		Emission factor/estimation parameter uncertainty		Combined uncertainty		Contribution to variance in Year t		Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	Lower (%)	Upper (%)	%	%
1A1a	Electricity and Heat Production	138 026,9	198 237,2	3,0%	5,0%	7,0%	7,0%	7,62%	8,60%	0,1177%	0,1502%	3,52%	0,13%
1A1b	Petroleum Refining	2 545,2	1 491,0	3,0%	5,0%	7,0%	7,0%	7,62%	8,60%	0,0000%	0,0000%	0,03%	0,00%
1A1c	Manufacture of Solid Fuels and Other Energy Industries	25 436,2	27 444,5	3,0%	5,0%	7,0%	7,0%	7,62%	8,60%	0,0023%	0,0029%	0,49%	0,00%
1A1a	Electricity and Heat Production	40,0	61,3	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%
1A1b	Petroleum Refining	1,8	0,9	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%
1A1c	Manufacture of Solid Fuels and Other Energy Industries	11,8	28,4	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%
1A1a	Electricity and Heat Production	566,7	815,9	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0002%	0,0002%	0,01%	0,00%
1A1b	Petroleum Refining	2,7	1,3	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%
1A1c	Manufacture of Solid Fuels and Other Energy Industries	0,0	100,7	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%

1A2	Manufacturing Industries and Construction	CO2	15 656,4	21 927,4	5,0%	10,0%	7,0%	7,0%	8,60%	12,21%	0,0018%	0,0037%	0,08%	0,78%	0,01%
1A2	Manufacturing Industries and Construction	CH4	53,6	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,01%	0,00%	0,00%
1A2	Manufacturing Industries and Construction	N2O	76,2	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,02%	0,00%	0,00%
1A3a	Civil Aviation	CO2	3 408,9	775,7	5,0%	5,0%	1,5%	1,5%	5,22%	5,22%	0,0000%	0,0000%	0,01%	0,01%	0,00%
1A3b	Road Transport	CO2	41 755,4	56 925,6	5,0%	5,0%	2,0%	2,0%	5,39%	5,39%	0,0049%	0,0049%	0,05%	1,01%	0,01%
1A3c	Railways	CO2	664,3	410,1	5,0%	5,0%	2,0%	2,0%	5,39%	5,39%	0,0000%	0,0000%	0,00%	0,01%	0,00%
1A3d	Water-Borne Navigation	CO2	389,7	562,0	5,0%	5,0%	3,0%	3,0%	5,83%	5,83%	0,0000%	0,0000%	0,00%	0,01%	0,00%
1A3a	Civil Aviation	CH4	0,7	0,1	5,0%	5,0%	70,0%	70,0%	70,18%	70,18%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1A3b	Road Transport	CH4	368,5	366,1	5,0%	5,0%	9,0%	9,0%	10,30%	10,30%	0,0000%	0,0000%	0,00%	0,01%	0,00%
1A3c	Railways	CH4	1,0	0,7	5,0%	5,0%	9,0%	9,0%	10,30%	10,30%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1A3d	Water-Borne Navigation	CH4	1,0	1,5	5,0%	5,0%	50,0%	50,0%	50,25%	50,25%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1A3a	Civil Aviation	N2O	24,8	5,6	5,0%	5,0%	70,0%	70,0%	70,18%	70,18%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1A3b	Road Transport	N2O	519,5	733,3	5,0%	5,0%	70,0%	70,0%	72,0%	72,17%	0,0001%	0,0001%	0,03%	0,01%	0,00%
1A3c	Railways	N2O	67,5	37,8	5,0%	5,0%	70,0%	70,0%	70,18%	72,17%	0,0000%	0,0000%	0,01%	0,00%	0,00%
1A3d	Water-Borne Navigation	N2O	2,8	4,1	5,0%	5,0%	40,0%	140,0%	40,31%	140,09%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1A4a	Commercial/Institutional	CO2	15 992,7	11 819,8	5,0%	10,0%	7,0%	7,0%	8,60%	12,21%	0,0005%	0,0011%	0,10%	0,42%	0,00%
1A4b	Residential	CO2	20 774,9	3 608,2	5,0%	10,0%	7,0%	7,0%	8,60%	12,21%	0,0000%	0,0001%	0,34%	0,13%	0,00%
1A4c	Agriculture/Forestry/Fishing/Fish Farms	CO2	2 080,6	3 074,2	5,0%	10,0%	7,0%	7,0%	8,60%	12,21%	0,0000%	0,0001%	0,01%	0,11%	0,00%
1A4a	Commercial/Institutional	CH4	6,8	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,00%	0,00%	0,00%

1A4b	Residential	CH4	202,8	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,04%	0,00%	0,00%
1A4c	Agriculture/Forestry/Fishing/Fish Farms	CH4	2,3	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1A4a	Commercial/Institutional	N2O	69,7	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,01%	0,00%	0,00%
1A4b	Residential	N2O	329,0	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,07%	0,00%	0,00%
1A4c	Agriculture/Forestry/Fishing/Fish Farms	N2O	5,0	0,0	5,0%	10,0%	75,0%	75,0%	75,17%	75,66%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1A5a	Stationary	CO2	12 183,6	18 026,3	3,0%	5,0%	7,0%	7,0%	7,62%	8,60%	0,0010%	0,0012%	0,08%	0,32%	0,00%
1A5a	Stationary	CH4	195,3	0,0	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,04%	0,00%	0,00%
1A5a	Stationary	N2O	290,5	0,0	3,0%	5,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,06%	0,00%	0,00%
1B1a	Coal mining and handling	CO2	14,7	17,2	10,0%	10,0%	63,0%	63,0%	63,79%	63,79%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1B1a	Coal mining and handling	CH4	1 495,4	1 754,0	10,0%	10,0%	63,0%	63,0%	63,79%	63,79%	0,0006%	0,0006%	0,02%	0,06%	0,00%
1B1c	Solid fuel transformation	CO2	20,4	384,6	10,0%	10,0%	63,0%	63,0%	63,79%	63,79%	0,0000%	0,0000%	0,06%	0,01%	0,00%
1B1c	Solid fuel transformation	CH4	18,3	250,7	10,0%	10,0%	63,0%	63,0%	63,79%	63,79%	0,0000%	0,0000%	0,04%	0,01%	0,00%
1B1c	Solid fuel transformation	N2O	0,3	4,7	10,0%	10,0%	63,0%	63,0%	63,79%	63,79%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1B2a	Oil	CO2	773,3	63,0	25,0%	25,0%	75,0%	75,0%	79,06%	79,06%	0,0000%	0,0000%	0,15%	0,01%	0,00%
1B2a	Oil	CH4	10,0	22,5	25,0%	25,0%	75,0%	75,0%	79,06%	79,06%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1B2a	Oil	N2O	0,8	0,1	25,0%	25,0%	75,0%	75,0%	79,06%	79,06%	0,0000%	0,0000%	0,00%	0,00%	0,00%
1B3	Other Emissions from Energy Production	CO2	25 903,1	23 477,0	25,0%	25,0%	75,0%	75,0%	79,06%	79,06%	0,1779%	0,1779%	0,97%	2,08%	0,05%
1B3	Other Emissions from Energy Production	CH4	2 905,1	2 736,7	25,0%	25,0%	75,0%	75,0%	79,06%	79,06%	0,0024%	0,0024%	0,09%	0,24%	0,00%

[illegible]

2C1	Iron and Steel Production	CO2	12 597,0	6 894,0	5,0%	10,0%	25,0%	25,0%	25,50%	26,93%	0,0016%	0,0018%	0,44%	0,24%	0,00%
2C1	Iron and Steel Production	CH4	0,0	0,0	5,0%	10,0%	25,0%	25,0%	25,50%	26,93%	0,0000%	0,0000%	0,00%	0,00%	0,00%
2C2	Ferroalloys Production	CO2	1 186,9	6 942,5	5,0%	5,0%	25,0%	25,0%	7,07%	25,50%	0,0001%	0,0016%	0,35%	0,12%	0,00%
2C2	Ferroalloys Production	CH4	0,1	0,0	5,0%	5,0%	25,0%	25,0%	25,50%	25,50%	0,0000%	0,0000%	0,00%	0,00%	0,00%
2C2	Ferroalloys Production	N2O	0,0	0,0	5,0%	5,0%	25,0%	25,0%	25,50%	25,50%	0,0000%	0,0000%	0,00%	0,00%	0,00%
2C3	Aluminium Production	CO2	C	C	C	C	C	C	C	C	C	C	C	C	C
2C3	Aluminium Production	PFCs	C	C	C	C	C	C	C	C	C	C	C	C	C
2C5	Lead Production	CO2	16,0	7,7	10,0%	10,0%	50,0%	50,0%	50,99%	50,99%	0,0000%	0,0000%	0,00%	0,00%	0,00%
2C6	Zinc Production	CO2	128,7	501,9	10,0%	10,0%	50,0%	50,0%	50,99%	50,99%	0,0000%	0,0000%	0,05%	0,02%	0,00%
2D1	Lubricant Use	CO2	0,0	461,9	10,0%	20,0%	50,0%	50,0%	50,99%	53,85%	0,0000%	0,0000%	0,06%	0,03%	0,00%
2D2	Paraffin Wax Use	CO2	0,0	715,8	10,0%	20,0%	50,0%	50,0%	50,99%	53,85%	0,0001%	0,0001%	0,09%	0,05%	0,00%
2F1	Refrigeration and Air Conditioning	HFCs	0,0	6 577,2	25,0%	25,0%	25,0%	25,0%	35,36%	35,36%	0,0028%	0,0028%	0,41%	0,58%	0,01%
2F2	Foam Blowing Agents	HFCs	0,0	2,1	50,0%	50,0%	25,0%	25,0%	55,90%	55,90%	0,0000%	0,0000%	0,00%	0,00%	0,00%
2F3	Fire Protection	HFCs	0,0	87,5	25,0%	25,0%	25,0%	25,0%	35,36%	35,36%	0,0000%	0,0000%	0,01%	0,01%	0,00%
2F4	Aerosols	HFCs	0,0	18,3	25,0%	25,0%	25,0%	25,0%	35,36%	35,36%	0,0000%	0,0000%	0,00%	0,00%	0,00%
2G1	Use of Electrical equipment	SF6	0,0	84,7	25,0%	25,0%	25,0%	25,0%	35,36%	35,36%	0,0000%	0,0000%	0,01%	0,01%	0,00%
3A1	Enteric fermentation - cattle	CH4	28 133,1	24 291,0	17,2%	17,2%	13,8%	13,8%	22,06%	22,06%	0,0148%	0,0148%	0,23%	1,48%	0,02%
3A2	Enteric fermentation - sheep	CH4	10 019,9	6 313,1	13,1%	13,1%	30,8%	30,8%	33,46%	33,46%	0,0023%	0,0023%	0,37%	0,29%	0,00%

3A3	Enteric fermentation - swine	CH4	49,0	42,5	50,2%	20,0%	20,0%	54,08%	54,08%	0,0000%	0,0000%	0,00%	0,01%	0,00%
3A4d	Enteric fermentation - goats	CH4	2 285,5	2 285,5	20,6%	35,5%	41,05%	41,05%	41,05%	0,0005%	0,0005%	0,02%	0,17%	0,00%
3A4e	Enteric fermentation - horses	CH4	115,9	170,3	7,1%	40,0%	40,0%	40,62%	40,62%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3A4f	Enteric fermentation - mules and asses	CH4	62,7	45,2	11,2%	40,0%	41,53%	41,53%	41,53%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3A4h	Enteric fermentation - other game	CH4	0,0	0,0				0,00%	0,00%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3B1	Manure management - cattle	CH4	1 169,2	1 233,2	17,2%	12,0%	20,97%	20,97%	20,97%	0,0000%	0,0000%	0,00%	0,08%	0,00%
3B2	Manure management - sheep	CH4	134,6	88,6	13,1%	16,0%	20,66%	20,66%	20,66%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3B3	Manure management - swine	CH4	237,1	205,5	50,2%	20,0%	54,08%	54,08%	54,08%	0,0000%	0,0000%	0,00%	0,04%	0,00%
3B4d	Manure management - goats	CH4	38,5	27,1	20,6%	47,8%	52,01%	52,01%	52,01%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3B4e	Manure management - horses	CH4	0,0	0,0	7,1%	30,0%	30,82%	30,82%	30,82%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3B4f	Manure management - mules and asses	CH4	0,0	0,0	11,2%	30,0%	32,02%	32,02%	32,02%	0,0000%	0,0000%	0,00%	0,00%	0,00%



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3B4g	Manure management - poultry	CH4	79,2	191,7	20,6%	20,6%	20,0%	20,0%	28,72%	28,72%	0,0000%	0,0000%	0,01%	0,01%	0,00%
3B4h	Manure management - other game	CH4	0,0	0,0					0,00%	0,00%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3A2a	Manure management - cattle	N2O	985,3	1 136,3	43,2%	43,2%	50,0%	100,0%	66,08%	108,93%	0,0003%	0,0008%	0,01%	0,17%	0,00%
3A2c	Manure management - sheep	N2O	199,0	158,2	33,0%	33,0%	50,0%	100,0%	59,88%	105,29%	0,0000%	0,0000%	0,02%	0,02%	0,00%
3B3	Manure management - swine	N2O	27,4	23,8	59,4%	59,4%	50,0%	100,0%	77,62%	116,30%	0,0000%	0,0000%	0,00%	0,01%	0,00%
3A2d	Manure management - goats	N2O	66,8	49,3	36,5%	36,5%	50,0%	100,0%	61,88%	106,44%	0,0000%	0,0000%	0,01%	0,01%	0,00%
3B4e	Manure management - horses	N2O	0,0	0,0	31,2%	31,2%	50,0%	100,0%	58,95%	104,76%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3B4f	Manure management - mules and asses	N2O	0,0	0,0	32,1%	32,1%	50,0%	100,0%	59,41%	105,02%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3B4g	Manure management - poultry	N2O	367,6	953,0	44,2%	44,2%	50,0%	100,0%	66,71%	109,32%	0,0002%	0,0006%	0,14%	0,15%	0,00%
3B4h	Manure management - other game	N2O							0,00%	0,00%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3B5	Indirect N2O from manure management	N2O	268,3	333,0	89,5%	89,5%	100,0%	101,0%	134,18 %	134,93%	0,0001%	0,0001%	0,01%	0,11%	0,00%

3D1a	Inorganic fertilisers	N2O	715,6	864,0	15,0%	15,0%	100,0 %	120,0%	101,12 %	120,93%	0,0004%	0,0006%	0,02%	0,05%	0,00%
3D1b	Organic fertilisers	N2O	544,2	783,2	41,2%	41,2%	100,0 %	120,0%	108,15 %	126,87%	0,0004%	0,0005%	0,05%	0,11%	0,00%
3D1c	Urine and dung deposited by grazing animals	N2O	6 302,6	5 256,5	53,6%	53,6%	100,0 %	230,0%	113,44 %	236,16%	0,0184%	0,0796%	0,98%	1,00%	0,02%
3D1d	Crop residues	N2O	350,7	1 261,7	91,2%	91,2%	100,0 %	120,0%	135,37 %	150,75%	0,0015%	0,0019%	0,26%	0,41%	0,00%
3D1e	FSOM	N2O	0,9	1,1	5,0%	5,0%	100,0 %	230,0%	100,12 %	230,05%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3D2a	Atmospheric deposition	N2O	969,8	920,4	203,9 %	203,9 %	100,0 %	120,0%	227,13 %	236,62%	0,0023%	0,0024%	0,05%	0,67%	0,00%
3D2b	Nitrogen leaching and runoff	N2O	39,2	593,3	58,4%	58,4%	100,0 %	82,0%	115,83 %	100,70%	0,0002%	0,0002%	0,11%	0,12%	0,00%
3F	Field burning of agricultural residues	CH4	47,2	43,7	21,2%	21,2%	40,0%	40,0%	45,28%	45,28%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3F	Field burning of agricultural residues	N2O	11,6	10,7	21,2%	21,2%	27,0%	27,0%	34,34%	34,34%	0,0000%	0,0000%	0,00%	0,00%	0,00%
3G	Liming	CO2	2 470,8	1 890,9	75,0%	75,0%	50,0%	50,0%	90,14%	90,14%	0,0015%	0,0015%	0,11%	0,50%	0,00%
3H	Urea application	CO2	91,0	670,8	10,0%	10,0%	50,0%	50,0%	50,99%	50,99%	0,0001%	0,0001%	0,07%	0,02%	0,00%
4A1	Forest land remaining forest land	CO2	19 610,9	8 118,3	42,3%	42,3%	56,9%	56,8%	70,86%	70,80%	0,0171%	0,0171%	1,93%	1,22%	0,05%
4A2	Land converted to forest land	CO2	-35 685,8	-63 862,3	58,7%	58,7%	56,9%	56,9%	81,72%	81,72%	1,4066%	1,4066%	3,49%	13,31%	1,89%
4A1	Forest land remaining forest land	CH4	690,1	265,6	21,7%	21,7%	40,3%	40,3%	45,77%	45,77%	0,0000%	0,0000%	0,05%	0,02%	0,00%
4A2	Land converted to forest land	CH4	5 662,1	7 818,3	40,9%	40,9%	53,2%	53,2%	67,09%	67,09%	0,0142%	0,0142%	0,21%	1,14%	0,01%

4A1	Forest land remaining forest land	N2O	-6 693,6	-15 342,1	41,2%	41,2%	40,3%	40,3%	57,65%	57,65%	0,0404%	0,0404%	0,80%	2,24%	0,06%
4A2	Land converted to forest land	N2O	7 268,5	18 389,6	61,8%	61,8%	53,2%	53,2%	81,48%	81,48%	0,1160%	0,1160%	1,38%	4,03%	0,18%
4B1	Cropland remaining cropland	CO2	-71,6	-20,0	17,7%	17,7%	40,3%	40,3%	44,03%	44,03%	0,0000%	0,0000%	0,01%	0,00%	0,00%
4B2	Land converted to cropland	CO2	-74,9	126,8	44,4%	44,4%	53,2%	53,2%	69,24%	69,24%	0,0000%	0,0000%	0,03%	0,02%	0,00%
4C1	Grassland remaining grassland	CO2	-1 332,6	-3 101,7	18,3%	18,3%	40,3%	40,3%	44,29%	44,29%	0,0010%	0,0010%	0,16%	0,20%	0,00%
4C2	Land converted to grassland	CO2	522,9	1 648,9	49,2%	49,2%	53,2%	53,2%	72,41%	72,41%	0,0007%	0,0007%	0,14%	0,29%	0,00%
4C1	Grassland remaining grassland	CH4	0,0	0,0	30,2%	30,2%	35,0%	35,0%	46,26%	46,26%	0,0000%	0,0000%	0,00%	0,00%	0,00%
4C2	Land converted to grassland	CH4	5 981,1	10 093,1	61,8%	61,8%	40,3%	40,3%	73,75%	73,75%	0,0286%	0,0286%	0,35%	2,21%	0,05%
4C1	Grassland remaining grassland	N2O	13,6	54,2	20,0%	20,0%	90,0%	80,0%	92,20%	92,20%	0,0000%	0,0000%	0,01%	0,00%	0,00%
4C2	Land converted to grassland	N2O	9,3	37,1	20,0%	20,0%	100,0%	82,0%	101,98%	101,98%	0,0000%	0,0000%	0,01%	0,00%	0,00%
4D1	Wetland remaining wetland	CO2	656,2	2 039,0	10,0%	10,0%	71,2%	71,2%	71,90%	71,90%	0,0011%	0,0011%	0,23%	0,07%	0,00%
4D2	Land converted to wetland	CO2	0,0	0,0	10,0%	10,0%	58,1%	58,1%							
4D1	Wetland remaining wetland	CH4	348,6	438,0	20,0%	20,0%	90,0%	80,0%	92,20%	92,20%	0,0001%	0,0001%	0,01%	0,03%	0,00%
4D2	Land converted to wetland	CH4	8,8	9,6	20,0%	20,0%	100,0%	82,0%	101,98%	101,98%	0,0000%	0,0000%	0,00%	0,00%	0,00%

4D1	Wetland remaining wetland	N2O	974,5	902,0	31,6%	31,6%	31,6%	40,4%	40,4%	51,26%	51,26%	0,0001%	0,0001%	0,02%	0,10%	0,00%
4D2	Land converted to wetland	N2O	689,6	691,9	31,6%	31,6%	31,6%	47,6%	47,6%	57,11%	57,11%	0,0001%	0,0001%	0,01%	0,08%	0,00%
4E1	Settlement remaining settlement	CO2	-1 035,6	-1 718,3	10,0%	10,0%	10,0%	10,0%	10,0%	14,14%	14,14%	0,0000%	0,0000%	0,01%	0,06%	0,00%
4E2	Land converted to settlements	CO2	2 821,7	7 376,7	50,0%	50,0%	50,0%	40,0%	40,0%	64,03%	64,03%	0,0115%	0,0115%	0,43%	1,31%	0,02%
4E1	Settlement remaining settlement	CH4	858,5	1 793,2	50,0%	50,0%	50,0%	50,0%	50,0%	70,71%	70,71%	0,0008%	0,0008%	0,11%	0,32%	0,00%
4E2	Land converted to settlements	CH4	487,5	826,9	50,0%	50,0%	50,0%	50,0%	50,0%	70,71%	70,71%	0,0002%	0,0002%	0,04%	0,15%	0,00%
4E1	Settlement remaining settlement	N2O	24,0	37,0	50,0%	50,0%	50,0%	40,0%	40,0%	64,03%	64,03%	0,0000%	0,0000%	0,00%	0,01%	0,00%
4E2	Land converted to settlements	N2O	108,1	167,2	50,0%	50,0%	50,0%	100,0%	100,0%	111,80%	111,80%	0,0000%	0,0000%	0,01%	0,03%	0,00%
4F1	Other land remaining other land	CO2	23,6	36,5	50,0%	50,0%	50,0%	100,0%	100,0%	111,80%	111,80%	0,0000%	0,0000%	0,00%	0,01%	0,00%
4F2	Land converted to other land	CO2	2 297,1	3 552,8	50,0%	50,0%	50,0%	40,0%	40,0%	64,03%	64,03%	0,0027%	0,0027%	0,10%	0,63%	0,00%
4G	Harvested wood products	CO2	474,4	733,8	50,0%	50,0%	50,0%	90,0%	90,0%	102,96%	102,96%	0,0003%	0,0003%	0,05%	0,13%	0,00%
5A	Solid Waste Disposal	CH4	4 250,7	4 720,4	50,0%	50,0%	50,0%	40,0%	40,0%	64,03%	64,03%	0,0047%	0,0047%	0,00%	0,84%	0,01%
5B	Biological Treatment of Solid Waste	CH4	138 026,9	198 237,2	3,0%	3,0%	5,0%	7,0%	7,0%	7,62%	7,62%	0,1177%	0,1502%	0,80%	3,52%	0,13%

5B	Biological Treatment of Solid Waste	N2O	2 545,2	1 491,0	3,0%	5,0%	7,0%	7,0%	7,0%	7,62%	8,60%	0,0000%	0,0000%	0,02%	0,03%	0,00%
5C2	Open Burning of Waste	CO2	25 436,2	27 444,5	3,0%	5,0%	7,0%	7,0%	7,0%	7,62%	8,60%	0,0023%	0,0029%	0,01%	0,49%	0,00%
5C2	Open Burning of Waste	CH4	40,0	61,3	3,0%	5,0%	75,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%	0,00%
5C2	Open Burning of Waste	N2O	1,8	0,9	3,0%	5,0%	75,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%	0,00%
5D1	Domestic wastewater treatment and discharge	CH4	11,8	28,4	3,0%	5,0%	75,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%	0,00%
5D1	Domestic wastewater treatment and discharge	N2O	566,7	815,9	3,0%	5,0%	75,0%	75,0%	75,0%	75,06%	75,17%	0,0002%	0,0002%	0,04%	0,01%	0,00%
5D2	Industrial wastewater treatment and discharge	CH4	2,7	1,3	3,0%	5,0%	75,0%	75,0%	75,0%	75,06%	75,17%	0,0000%	0,0000%	0,00%	0,00%	0,00%
			398 428,0	440 046,1								2,01%	2,11%			2,55%
											Uncertainty in total inventory	14,16%	14,51%		Trend uncertainty	15,98%

C = Confidential

Table A II.2: Overall uncertainty analysis excluding LULUCF for 1990 to 2024.

Gas	Base year emissions/removals (1990)	Year t emissions / removals (2024)	Activity data uncertainty		Emission factor/estimation parameter uncertainty		Combined uncertainty		Contribution to variance in Year t (lower limit)	Contribution to variance in Year t		Uncertainty in trend in national emissions introduced by EF/estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
			(-)%	(+)%	(-)%	(+)%	(-)%	(+)%		Lower (%)	Upper (%)			
1A1a Electricity and Heat Production	138 026,88	198 237,24	3,00%	5,00%	7,62%	7,00%	8,60%	0,1017%	0,1257%	0,61%		3,50%	0,13%	138 026,88
1A1b Petroleum Refining	2 545,20	1 491,00	3,00%	5,00%	7,62%	7,00%	8,60%	0,00000%	0,00000%	0,03%		0,03%	0,00%	2 545,20
1A1c Manufacture of Solid Fuels and	25 436,24	27 444,51	3,00%	5,00%	7,62%	7,00%	8,60%	0,0019%	0,0025%	0,05%		0,48%	0,00%	25 436,24

[illegible]

1A2	Manufacturing Industries and Construction	CO2	15 656,41	21 927,35	5,00%	10,00%	7,00%	7,00%	75,00%	75,00%	75,17%	75,66%	0,0000%	0,0016%	0,0032%	0,06%	0,77%	0,01%	15 656,41
1A2	Manufacturing Industries and Construction	CH4	53,55	0,00	5,00%	10,00%	75,00%	75,00%	75,00%	75,17%	75,66%	0,0000%	0,0000%	0,0000%	0,01%	0,00%	0,00%	0,00%	53,55
1A2	Manufacturing Industries and Construction	N2O	76,18	0,00	5,00%	10,00%	75,00%	75,00%	75,00%	75,17%	75,66%	0,0000%	0,0000%	0,0000%	0,02%	0,00%	0,00%	0,00%	76,18
1A3a	Civil Aviation	CO2	3 408,93	775,70	5,00%	5,00%	1,50%	1,50%	2,00%	5,22%	5,22%	5,22%	0,0000%	0,0000%	0,01%	0,01%	0,01%	0,00%	3 408,93
1A3b	Road Transport	CO2	41 755,37	56 925,56	5,00%	5,00%	2,00%	2,00%	2,00%	5,39%	5,39%	5,39%	0,0042%	0,0042%	0,04%	1,00%	0,01%	0,01%	41 755,37
1A3c	Railways	CO2	664,26	410,07	5,00%	5,00%	2,00%	2,00%	2,00%	5,39%	5,39%	5,39%	0,0000%	0,0000%	0,00%	0,01%	0,01%	0,00%	664,26
1A3d	Water-Borne Navigation	CO2	389,69	561,98	5,00%	5,00%	3,00%	3,00%	3,00%	5,83%	5,83%	5,83%	0,0000%	0,0000%	0,00%	0,01%	0,01%	0,00%	389,69

1A3a	Civil Aviation	CH4	0,65	0,15	5,00%	5,00%	70,00 %	70,18%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,65
1A3b	Road Transport	CH4	368,50	366,13	5,00%	5,00%	9,00%	10,30%	0,0000%	0,0000%	0,00%	0,01%	0,00%	368,50
1A3c	Railways	CH4	1,03	0,68	5,00%	5,00%	9,00%	10,30%	0,0000%	0,0000%	0,00%	0,00%	0,00%	1,03
1A3d	Water-Borne Navigation	CH4	1,04	1,50	5,00%	5,00%	50,00 %	50,25%	0,0000%	0,0000%	0,00%	0,00%	0,00%	1,04
1A3a	Civil Aviation	N2O	24,77	5,62	5,00%	5,00%	70,00 %	70,18%	0,0000%	0,0000%	0,00%	0,00%	0,00%	24,77
1A3b	Road Transport	N2O	519,52	733,32	5,00%	5,00%	70,00 %	70,18%	0,0001%	0,0001%	0,02%	0,01%	0,00%	519,52
1A3c	Railways	N2O	67,45	37,81	5,00%	5,00%	70,00 %	70,18%	0,0000%	0,0000%	0,01%	0,00%	0,00%	67,45
1A3d	Water-Borne Navigation	N2O	2,80	4,05	5,00%	5,00%	40,00 %	40,31%	0,0000%	0,0000%	0,00%	0,00%	0,00%	2,80
1A4a	Commercial / Institutional	CO2	15 992,75	11 819,78	5,00%	10,00 %	7,00%	8,60%	0,0005%	0,0009%	0,12%	0,42%	0,00%	15 992,75
1A4b	Residential	CO2	20 774,88	3 608,15	5,00%	10,00 %	7,00%	8,60%	0,0000%	0,0001%	0,37%	0,13%	0,00%	20 774,88



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1A4c	Agriculture/ Forestry/Fishing/Fish Farms	CO2	2 080,55	3 074,24	5,00%	10,00 %	7,00%	7,00%	75,00 %	75,17%	8,60%	12,21%	0,00000%	0,00001%	0,01%	0,11%	0,00%	2 080,55
1A4a	Commercial /Institutional	CH4	6,84	0,00	5,00%	10,00 %	75,00 %	75,00 %	75,00 %	75,17%	75,17%	75,66%	0,00000%	0,00000%	0,00%	0,00%	0,00%	6,84
1A4b	Residential	CH4	202,83	0,00	5,00%	10,00 %	75,00 %	75,00 %	75,00 %	75,17%	75,17%	75,66%	0,00000%	0,00000%	0,04%	0,00%	0,00%	202,83
1A4c	Agriculture/ Forestry/Fishing/Fish Farms	CH4	2,30	0,00	5,00%	10,00 %	75,00 %	75,00 %	75,00 %	75,17%	75,17%	75,66%	0,00000%	0,00000%	0,00%	0,00%	0,00%	2,30
1A4a	Commercial /Institutional	N2O	69,74	0,00	5,00%	10,00 %	75,00 %	75,00 %	75,00 %	75,17%	75,17%	75,66%	0,00000%	0,00000%	0,02%	0,00%	0,00%	69,74
1A4b	Residential	N2O	329,05	0,00	5,00%	10,00 %	75,00 %	75,00 %	75,00 %	75,17%	75,17%	75,66%	0,00000%	0,00000%	0,07%	0,00%	0,00%	329,05
1A4c	Agriculture/ Forestry/Fishing/Fish Farms	N2O	4,96	0,00	5,00%	10,00 %	75,00 %	75,00 %	75,00 %	75,17%	75,17%	75,66%	0,00000%	0,00000%	0,00%	0,00%	0,00%	4,96
1A5a	Stationary	CO2	12 183,63	18 026,27	3,00%	5,00%	7,00%	7,00%	7,00%	7,62%	7,62%	8,60%	0,00008%	0,00111%	0,06%	0,32%	0,00%	12 183,63
1A5a	Stationary	CH4	195,28	0,00	3,00%	5,00%	75,00 %	75,00 %	75,00 %	75,06%	75,06%	75,17%	0,00000%	0,00000%	0,04%	0,00%	0,00%	195,28

1A5a	Stationary	N2O	290,49	0,00	3,00%	75,00 %	75,00 %	75,00 %	75,06%	75,17%	0,0000%	0,0000%	0,0000%	0,06%	0,00%	0,00%	290,49
1B1a	Coal mining and handling	CO2	14,69	17,23	10,00 %	63,00 %	63,00 %	63,00 %	63,79%	63,79%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,00%	14,69
1B1a	Coal mining and handling	CH4	1 495,36	1 754,03	10,00 %	63,00 %	63,00 %	63,00 %	63,79%	63,79%	0,0006%	0,0006%	0,0006%	0,00%	0,06%	0,00%	1 495,36
1B1c	Solid fuel transformation	CO2	20,41	384,60	10,00 %	63,00 %	63,00 %	63,00 %	63,79%	63,79%	0,0000%	0,0000%	0,0000%	0,06%	0,01%	0,00%	20,41
1B1c	Solid fuel transformation	CH4	18,34	250,69	10,00 %	63,00 %	63,00 %	63,00 %	63,79%	63,79%	0,0000%	0,0000%	0,0000%	0,04%	0,01%	0,00%	18,34
1B1c	Solid fuel transformation	N2O	0,28	4,67	10,00 %	63,00 %	63,00 %	63,00 %	63,79%	63,79%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,28
1B2a	Oil	CO2	773,34	63,05	25,00 %	75,00 %	75,00 %	75,00 %	79,06%	79,06%	0,0000%	0,0000%	0,0000%	0,16%	0,01%	0,00%	773,34
1B2a	Oil	CH4	10,05	22,54	25,00 %	75,00 %	75,00 %	75,00 %	79,06%	79,06%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,00%	10,05
1B2a	Oil	N2O	0,81	0,06	25,00 %	75,00 %	75,00 %	75,00 %	79,06%	79,06%	0,0000%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,81

183	Other Emissions from Energy Production	CO ₂	25 903,05	23 477,02	25,00 %	25,00 %	25,00 %	25,00 %	75,00 %	75,00 %	75,00 %	79,06%	0,1537%	0,1537%	1,33%	2,07%	0,06%	25 903,05
183	Other Emissions from Energy Production	CH ₄	2 905,14	2 736,72	25,00 %	25,00 %	25,00 %	25,00 %	75,00 %	75,00 %	75,00 %	79,06%	0,0021%	0,0021%	0,13%	0,24%	0,00%	2 905,14
2A1	Cement Production	CO ₂	4 252,49	3 846,02	30,00 %	30,00 %	30,00 %	35,00 %	35,00 %	35,00 %	46,10%	46,10%	0,0014%	0,0014%	0,10%	0,41%	0,00%	4 252,49
2A2	Lime Production	CO ₂	488,03	799,12	30,00 %	30,00 %	30,00 %	6,00%	6,00%	6,00%	30,59%	30,59%	0,0000%	0,0000%	0,00%	0,08%	0,00%	488,03
2A3	Glass Production	CO ₂	85,01	177,32	1,00%	1,00%	3,00%	1,00%	3,00%	1,00%	1,41%	4,24%	0,0000%	0,0000%	0,00%	0,00%	0,00%	85,01
2A4a	Ceramics	CO ₂	0,00	54,48	1,00%	85,00 %	1,00%	1,00%	5,00%	1,00%	1,41%	85,15%	0,0000%	0,0000%	0,00%	0,02%	0,00%	0,00
2A4b	Other Uses of Soda Ash	CO ₂	0,00	51,92	1,00%	85,00 %	1,00%	1,00%	5,00%	1,00%	1,41%	85,15%	0,0000%	0,0000%	0,00%	0,02%	0,00%	0,00
2A4d	Other	CO ₂	0,00	27,24	15,00 %	85,00 %	1,00%	1,00%	5,00%	1,00%	15,03%	85,15%	0,0000%	0,0000%	0,00%	0,01%	0,00%	0,00
2B1	Ammonia Production	CO ₂	423,68	378,66	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%	2,83%	2,83%	0,0000%	0,0000%	0,00%	0,00%	0,00%	423,68
2B1	Ammonia Production	CH ₄	76,32	113,68	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%	2,83%	2,83%	0,0000%	0,0000%	0,00%	0,00%	0,00%	76,32

2B2	Nitric Acid Production	CO2	1 227,36	1,72	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%	2,83%	2,83%	0,00000%	0,01%	0,00%	0,00%	1 227,36
2B3	Nitric Acid Production	CH4	0,00	0,00	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%	2,83%	2,83%	0,00000%	0,00000%	0,00%	0,00%	0,00	0,00
2B2	Nitric Acid Production	N2O	4,63	1,28	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%	2,83%	2,83%	0,00000%	0,00000%	0,00%	0,00%	0,00%	4,63
2B5	Carbide Production	CO2	0,00	0,14	5,00%	10,00%	10,00%	10,00%	10,00%	11,18%	11,18%	11,18%	0,00000%	0,00000%	0,00%	0,00%	0,00%	0,00
2B5	Carbide Production	CH4	0,00	3,89	5,00%	10,00%	10,00%	10,00%	10,00%	11,18%	11,18%	11,18%	0,00000%	0,00000%	0,00%	0,00%	0,00%	0,00
2B6	Titanium Dioxide Production	CO2	0,00	0,00	2,00%	2,00%	2,00%	2,00%	2,00%	2,83%	2,83%	2,83%	0,00000%	0,00000%	0,00%	0,00%	0,00%	0,00
2B7	Soda Ash Production	CO2	0,00	0,00	5,00%	0,00%	0,00%	0,00%	0,00%	5,00%	5,00%	5,00%	0,00000%	0,00000%	0,00%	0,00%	0,00	0,00
2B8f	Carbon Black production	CO2	120,98	95,10	15,00%	15,00%	15,00%	15,00%	15,00%	21,21%	21,21%	21,21%	0,00000%	0,00000%	0,00%	0,01%	0,00%	120,98
2B8f	Carbon Black production	CH4	0,00	0,04	85,00%	85,00%	85,00%	85,00%	85,00%	120,21%	120,21%	120,21%	0,00000%	0,00000%	0,00%	0,00%	0,00%	0,00
2B8g	Hydrogen Production	CO2	0,00	75,07	2,00%	2,00%	2,00%	2,00%	2,00%	2,83%	2,83%	2,83%	0,00000%	0,00000%	0,00%	0,00%	0,00%	0,00

2B10	Other	CO ₂	0,00	20,43	5,00%	5,00%	10,00 %	10,00 %	11,18%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
2B10	Other	CH ₄	0,00	0,45	5,00%	5,00%	10,00 %	10,00 %	11,18%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
2C1	Iron and Steel Production	CO ₂	12 597,03	6 893,96	5,00%	10,00 %	25,00 %	25,00 %	25,50%	0,0014%	0,0015%	0,50%	0,24%	0,00%	12 597,03
2C1	Iron and Steel Production	CH ₄	0,00	0,00	5,00%	10,00 %	25,00 %	25,00 %	25,50%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
2C2	Ferroalloys Production	CO ₂	1 186,94	6 942,48	5,00%	5,00%	25,00 %	25,00 %	7,07%	0,0001%	0,0014%	0,35%	0,12%	0,00%	1 186,94
2C2	Ferroalloys Production	CH ₄	0,06	0,00	5,00%	5,00%	25,00 %	25,00 %	25,50%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,06
2C2	Ferroalloys Production	N ₂ O	0,00	0,00	5,00%	5,00%	25,00 %	25,00 %	25,50%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
2C3	Aluminium Production	CO ₂	254,05	1 259,24	1,00%	1,00%	5,00%	5,00%	5,10%	0,0000%	0,0000%	0,01%	0,00%	0,00%	254,05
2C3	Aluminium Production	PFCs	0,00	0,01	1,00%	1,00%	15,00 %	15,00 %	15,03%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
2C5	Lead Production	CO ₂	16,04	7,70	10,00 %	10,00 %	50,00 %	50,00 %	50,99%	0,0000%	0,0000%	0,00%	0,00%	0,00%	16,04



2C6	Zinc Production	CO2	128,66	501,87	10,00 %	10,00 %	50,00 %	50,00 %	50,99 %	50,99 %	0,00000 %	0,04 %	0,02 %	0,00 %	128,66
2D1	Lubricant Use	CO2	0,00	461,88	10,00 %	20,00 %	50,00 %	50,00 %	50,99 %	50,99 %	0,00000 %	0,06 %	0,03 %	0,00 %	0,00
2D2	Paraffin Wax Use	CO2	0,00	715,79	10,00 %	20,00 %	50,00 %	50,00 %	50,99 %	50,99 %	0,00001 %	0,09 %	0,05 %	0,00 %	0,00
2F1	Refrigeration and Air Conditioning	HFCs	0,00	6 577,21	25,00 %	25,00 %	25,00 %	25,00 %	35,36 %	35,36 %	0,0024 %	0,41 %	0,58 %	0,01 %	0,00
2F2	Foam Blowing Agents	HFCs	0,00	2,13	50,00 %	50,00 %	25,00 %	25,00 %	55,90 %	55,90 %	0,00000 %	0,00 %	0,00 %	0,00 %	0,00
2F3	Fire Protection	HFCs	0,00	87,50	25,00 %	25,00 %	25,00 %	25,00 %	35,36 %	35,36 %	0,00000 %	0,01 %	0,01 %	0,00 %	0,00
2F4	Aerosols	HFCs	0,00	18,25	25,00 %	25,00 %	25,00 %	25,00 %	35,36 %	35,36 %	0,00000 %	0,00 %	0,00 %	0,00 %	0,00
2G1	Use of Electrical equipment	SF6	0,00	84,72	25,00 %	25,00 %	25,00 %	25,00 %	35,36 %	35,36 %	0,00000 %	0,01 %	0,01 %	0,00 %	0,00
3A1	Enteric fermentation - cattle	CH4	28 133,05	24 291,03	17,19 %	17,19 %	13,82 %	13,82 %	22,06 %	22,06 %	0,0128 %	0,31 %	1,47 %	0,02 %	28 133,05

3A2	Enteric fermentation - sheep	CH4	10 019,94	6 313,14	13,07 %	13,07 %	30,80 %	30,80 %	33,46%	33,46%	0,0020%	0,0020%	0,42%	0,25%	0,00%	10 019,94
3A3	Enteric fermentation - swine	CH4	49,04	42,51	50,25 %	50,25 %	20,00 %	20,00 %	54,08%	54,08%	0,0000%	0,0000%	0,00%	0,01%	0,00%	49,04
3A4d	Enteric fermentation - goats	CH4	2 285,46	2 285,46	20,62 %	20,62 %	35,50 %	35,50 %	41,05%	41,05%	0,0004%	0,0004%	0,04%	0,17%	0,00%	2 285,46
3A4e	Enteric fermentation - horses	CH4	115,92	170,32	7,07%	7,07%	40,00 %	40,00 %	40,62%	40,62%	0,0000%	0,0000%	0,00%	0,00%	0,00%	115,92
3A4f	Enteric fermentation - mules and asses	CH4	62,72	45,16	11,18 %	11,18 %	40,00 %	40,00 %	41,53%	41,53%	0,0000%	0,0000%	0,00%	0,00%	0,00%	62,72
3A4h	Enteric fermentation - other game	CH4	0,00	0,00					0,00%	0,00%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
3B1	Manure management - cattle	CH4	1 169,19	1 233,23	17,19 %	17,19 %	12,00 %	12,00 %	20,97%	20,97%	0,0000%	0,0000%	0,00%	0,07%	0,00%	1 169,19
3B2	Manure management - sheep	CH4	134,58	88,58	13,07 %	13,07 %	16,00 %	16,00 %	20,66%	20,66%	0,0000%	0,0000%	0,00%	0,00%	0,00%	134,58

3B3	Manure management - swine	CH4	237,09	205,51	50,25 %	50,25 %	20,00 %	20,00 %	20,00 %	54,08%	0,0000%	0,0000%	0,00%	0,04%	0,00%	237,09
3B4d	Manure management - goats	CH4	38,54	27,05	20,62 %	20,62 %	47,75 %	47,75 %	47,75 %	52,01%	0,0000%	0,0000%	0,00%	0,00%	0,00%	38,54
3B4e	Manure management - horses	CH4	0,00	0,00	7,07%	7,07%	30,00 %	30,00 %	30,00 %	30,82%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
3B4f	Manure management - mules and asses	CH4	0,00	0,00	11,18 %	11,18 %	30,00 %	30,00 %	30,00 %	32,02%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
3B4g	Manure management - poultry	CH4	79,23	191,73	20,62 %	20,62 %	20,00 %	20,00 %	20,00 %	28,72%	0,0000%	0,0000%	0,00%	0,01%	0,00%	79,23
3B4h	Manure management - other game	CH4	0,00	0,00						0,00%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
3A2a	Manure management - cattle	N2O	985,27	1 136,31	43,20 %	43,20 %	50,00 %	50,00 %	100,00 %	66,08%	0,0003%	0,0007%	0,01%	0,17%	0,00%	985,27
3A2c	Manure management - sheep	N2O	198,98	158,22	32,95 %	32,95 %	50,00 %	50,00 %	100,00 %	59,88%	0,0000%	0,0000%	0,02%	0,02%	0,00%	198,98

3B3	Manure management - swine	N2O	27,43	23,77	59,37 %	59,37 %	50,00 %	100,00 %	77,62%	116,30%	0,0000%	0,0000%	0,00%	0,00%	0,00%	27,43
3A2d	Manure management - goats	N2O	66,83	49,35	36,46 %	36,46 %	50,00 %	100,00 %	61,88%	106,44%	0,0000%	0,0000%	0,01%	0,01%	0,00%	66,83
3B4e	Manure management - horses	N2O	0,00	0,00	31,22 %	31,22 %	50,00 %	100,00 %	58,95%	104,76%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
3B4f	Manure management - mules and asses	N2O	0,00	0,00	32,08 %	32,08 %	50,00 %	100,00 %	59,41%	105,02%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
3B4g	Manure management - poultry	N2O	367,62	952,97	44,16 %	44,16 %	50,00 %	100,00 %	66,71%	109,32%	0,0002%	0,0005%	0,13%	0,15%	0,00%	367,62
3B4h	Manure management - other game	N2O	0,00	0,00					0,00%	0,00%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,00
3B5	Indirect N2O from manure management	N2O	268,28	333,03	89,47 %	89,47 %	100,00 %	101,00 %	134,18%	134,93%	0,0001%	0,0001%	0,00%	0,11%	0,00%	268,28

3D1a	Inorganic fertilisers	N2O	715,61	863,97	15,00 %	15,00 %	100,00 %	120,0 0%	101,12%	120,93%	0,0003%	0,0005%	0,01%	0,05%	0,00%	715,61
3D1b	Organic fertilisers	N2O	544,24	783,20	41,18 %	41,18 %	100,00 %	120,0 0%	108,15%	126,87%	0,0003%	0,0004%	0,04%	0,11%	0,00%	544,24
3D1c	Urine and dung deposited by grazing animals	N2O	6 302,61	5 256,51	53,57 %	53,57 %	100,00 %	230,0 0%	113,44%	236,16%	0,0159%	0,0687%	1,25%	0,99%	0,03%	6 302,61
3D1d	Crop residues	N2O	350,74	1 261,69	91,24 %	91,24 %	100,00 %	120,0 0%	135,37%	150,75%	0,0013%	0,0016%	0,25%	0,41%	0,00%	350,74
3D1e	FSOM	N2O	0,94	1,12	5,00%	5,00%	100,00 %	230,0 0%	100,12%	230,05%	0,0000%	0,0000%	0,00%	0,00%	0,00%	0,94
3D2a	Atmospheric deposition	N2O	969,77	920,39	203,9 4%	203,9 4%	100,00 %	120,0 0%	227,13%	236,62%	0,0019%	0,0021%	0,07%	0,66%	0,00%	969,77
3D2b	Nitrogen leaching and runoff	N2O	39,18	593,29	58,45 %	58,45 %	100,00 %	82,00 %	115,83%	100,70%	0,0002%	0,0002%	0,11%	0,12%	0,00%	39,18
3F	Field burning of agricultural residues	CH4	47,25	43,74	21,21 %	21,21 %	40,00 %	40,00 %	45,28%	45,28%	0,0000%	0,0000%	0,00%	0,00%	0,00%	47,25
3F	Field burning of	N2O	11,59	10,73	21,21 %	21,21 %	27,00 %	27,00 %	34,34%	34,34%	0,0000%	0,0000%	0,00%	0,00%	0,00%	11,59

5D1	Domestic wastewater treatment and discharge	CH4	2 297,12	3 552,82	50,00 %	50,00 %	50,00 %	40,00 %	40,00 %	64,03%	64,03%	0,0023%	0,08%	0,63%	0,00%	2 297,12
5D1	Domestic wastewater treatment and discharge	N2O	474,42	733,76	50,00 %	50,00 %	50,00 %	90,00 %	90,00 %	102,96%	102,96%	0,0003%	0,04%	0,13%	0,00%	474,42
5D2	Industrial wastewater treatment and discharge	CH4	4 250,75	4 720,43	50,00 %	50,00 %	50,00 %	40,00 %	40,00 %	64,03%	64,03%	0,0041%	0,03%	0,83%	0,01%	4 250,75
			460 959.8	434 702.1								0.33%	0.41%			0.20%
												Uncertainty in total inventory	6.44%		Trend uncertainty	4.45%

C = Confidential

Annex III: Detailed description of reference approach

The figures below show the comparison between the Reference and Sectoral Approach for 1992-2022 this in line with the latest available data from the energy balance.

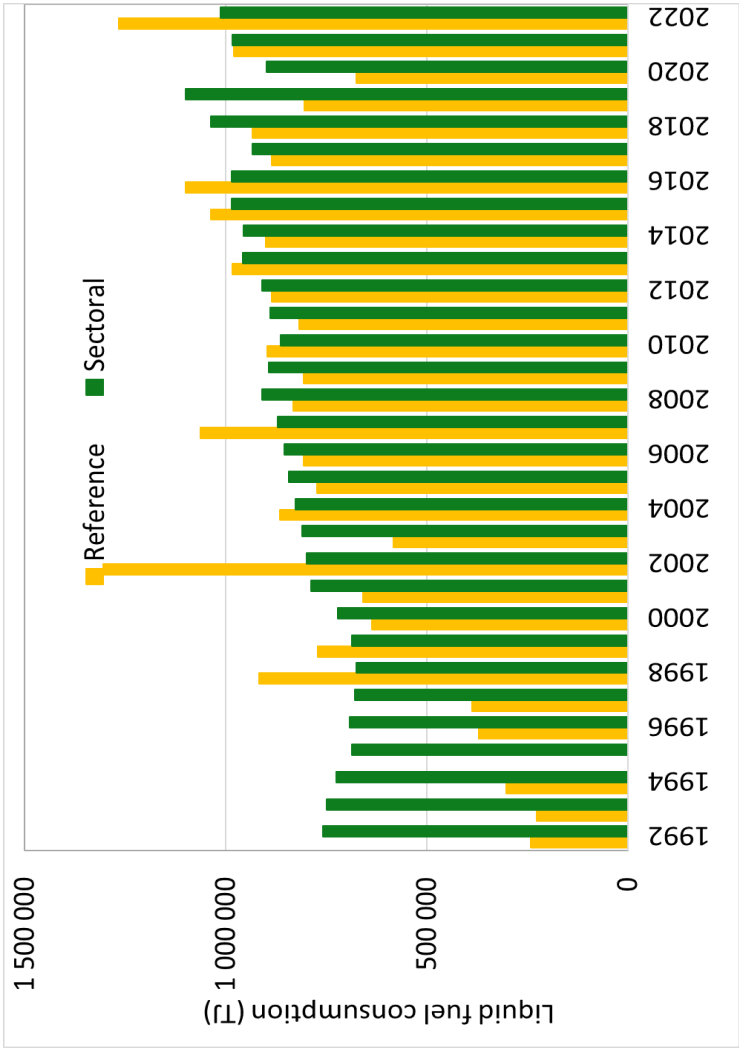


Figure D.1: Comparisons between the solid fuel consumption determined by the reference and sectoral approaches, 1992 – 2022.

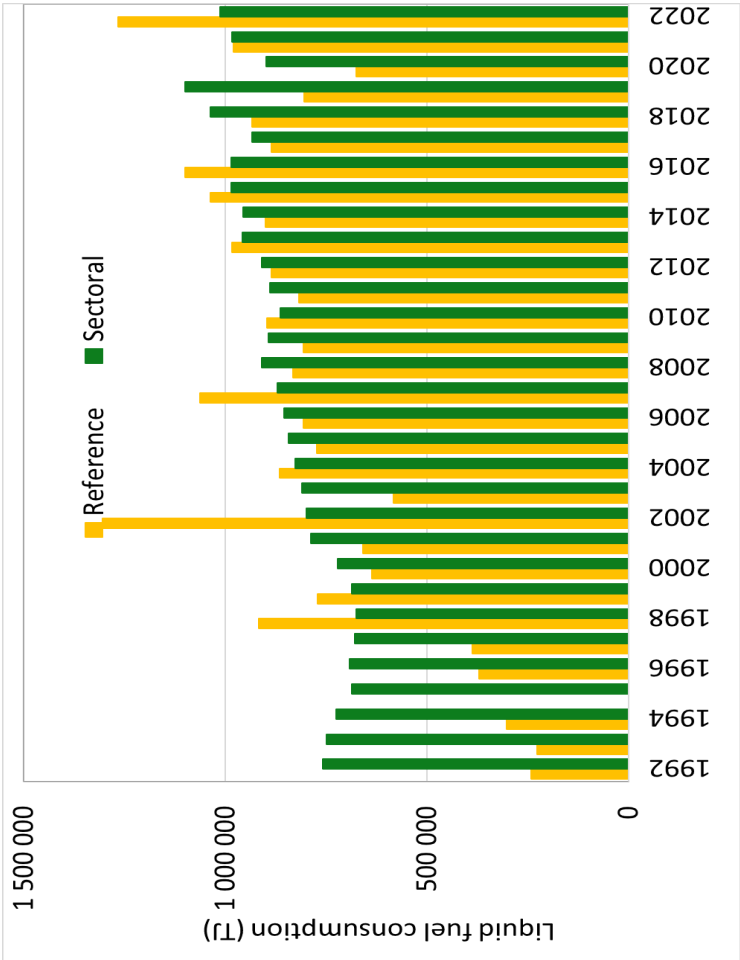


Figure D.2: Comparisons between the liquid fuel consumption determined by the reference and sectoral approaches, 1992 – 2022.

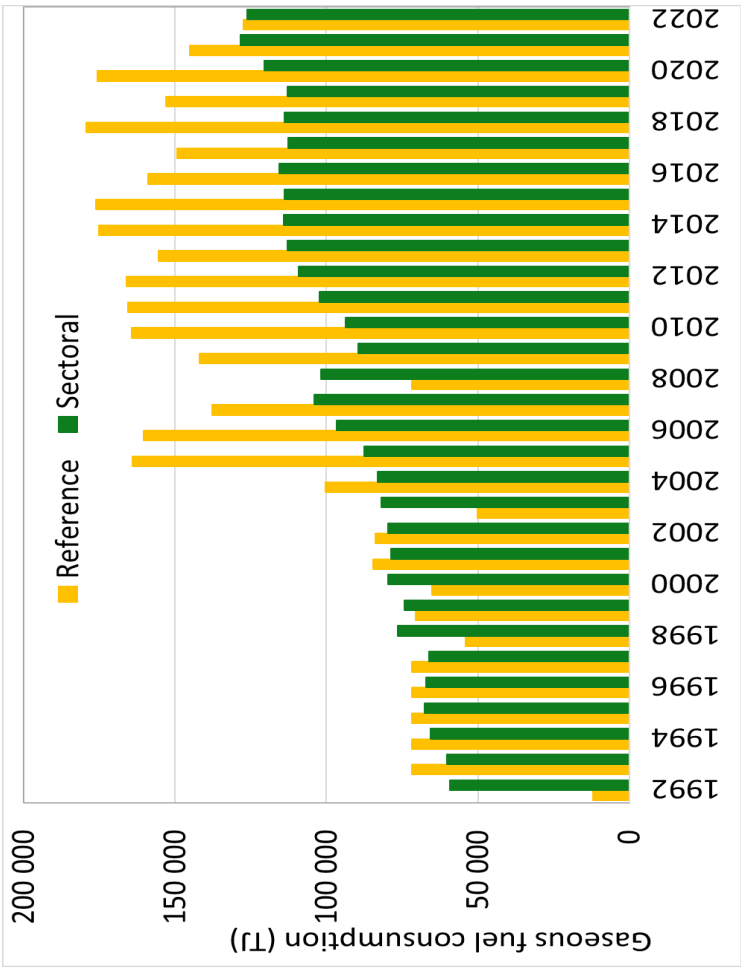


Figure D.3: Comparisons between the gaseous fuel consumption determined by the reference and sectoral approaches, 1992 – 2022.

Annex IV: QA/QC Plan

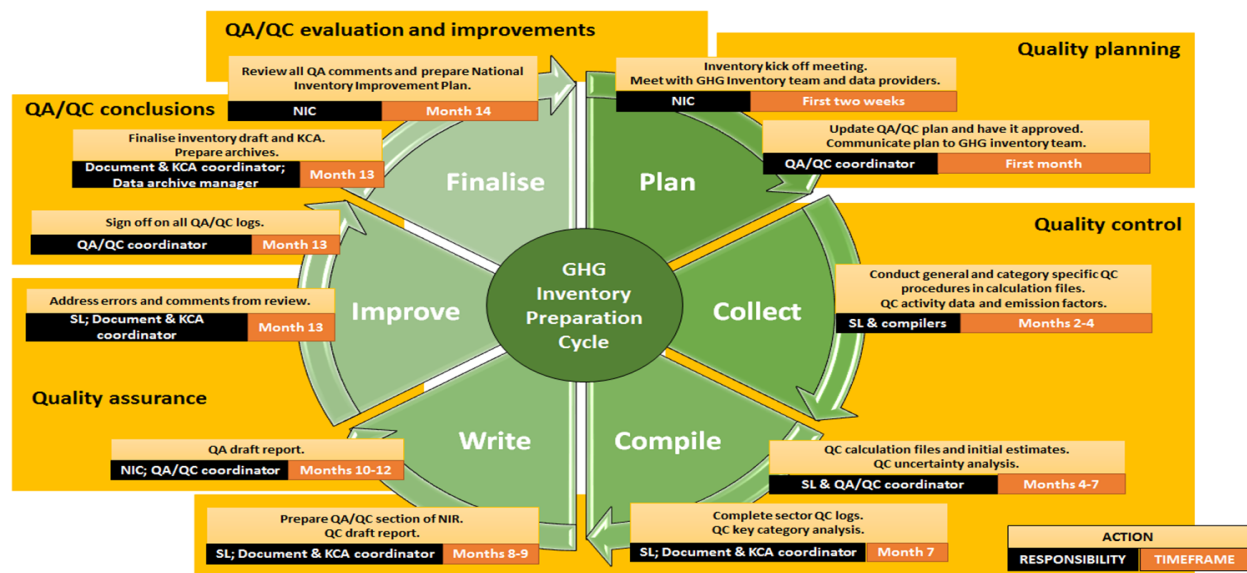
The Department of Forestry, Fisheries, and the Environment (DFFE), as the Single National Entity, oversees the centralized management, coordination, compilation, publication, and submission of the inventory. Currently, DFFE is responsible for data collection, compilation, and quality control (QC) of the Energy, IPPU, Agriculture, and Waste sector inventories as well as the quality assurance and verification. The Land Use, Land-Use Change, and Forestry (LULUCF) sector inventory, however, is compiled by external consultants Gondwana Environmental Solutions (GES).

Framework for quality

The inventory principles defined by the UNFCCC & IPCC guidelines namely, transparency, consistency, comparability, completeness and accuracy, are dimensions of quality for the inventory and form the set of criteria for assessing the output produced by South Africa's national inventory system. In addition, the principle of continuous improvement is included.

Overall QA/QC process and timeframes

The phases of the QA/QC process and their timeframes relative to the GHG Inventory Preparation Cycle is shown in Figure 1:



Quality planning

In the planning stages of the inventory a planning meeting is held to plan the work for the next inventory submission. During this meeting the review comments from the previous year's submission are considered and improvement plans are made for the upcoming submission. It is during this planning phase that the QA/QC plan is reviewed and improved. The planning stage includes the setting of quality objectives and elaboration of the QA/QC plan for the coming inventory preparation, compilation and reporting work and reviewing the quality control checks.

Quality planning process:

The steps to be followed in this stage are:

- (a) National Inventory Coordinator (NIC) designates a QA/QC coordinator;
- (b) QA/QC coordinator updates QA/QC plan and QA/QC checklists;
- (c) NIC approves it;
- (d) QA/QC coordinator makes relevant changes to QA/QC plan on the NGHGIS
- (e) QA/QC coordinator updates QA/QC checklists on the NGHGIS
- (f) QA/QC coordinator communicates QA/QC responsibilities to Sector Leads (SL) and Overall Document Manager and sets deadlines for completion.

Overall QA/QC objectives

The overall aim of the quality system is to maintain and improve the quality in all stages of the inventory work, in accordance with decision 19/CMP.1. The quality objectives of the QA/QC system and its application are an essential requirement in the GHG inventory and submission processes in order to ensure and improve the inventory principles: transparency, consistency, comparability, completeness, accuracy, timeliness and confidence in the national emissions and removals estimates. If necessary, they may be reviewed when revising the programme.

Following the definitions, guidelines and processes presented in Chapter 6 "Quality Assurance/Quality Control and Verification" of the IPCC 2006 Guidelines (IPCC, 2006) and Chapter 8 "Quality Assurance and Quality Control" of the Good Practice Guidance,

South Africa's QA/QC system objectives for the 2024 inventory are as follows:

(a) transparency

- providing transparent estimates with clear and up-to-date descriptions of the methodologies, data sources and assumptions information in the NID;
- using the notation keys as indicated in the UNFCCC guidelines;
- justifying recalculations as improvements in accuracy;
- addressing the recommendations related to transparency from independent reviewers
- providing full documentation on quality checks used in the QA/QC procedures; and
- documenting uncertainty estimates;

(b) completeness

- reporting estimates for all sources and sinks and for all gases included in the IPCC 2006 Guidelines as well as for other relevant source/sink categories;
- ensuring all data is representative of the national territory;
- addressing the recommendations related to completeness provided from previous independent review reports, during the preparation of the following inventory submission;
- ensuring the submission includes all calculations, methods and trend descriptions;
- ensuring the submission includes all mandatory sections;
- providing all CRT tables;
- providing information in the NID on completeness of NGHGI; and
- providing a summary in the NID regarding the changes related to completeness of NGHGI and the improvements of completeness from the previous submission.

(c) consistency:

- maintaining a consistent time-series of emissions and removals;
- maintaining consistency in method application;
- ensuring estimates are consistent with other related datasets or including explanations of the differences between datasets;
- ensuring consistency between common data parameters;
- addressing the recommendations related to consistency provided in the previous independent review reports, during the preparation of the following inventory submission;
- providing information in the NID on consistency and recalculations of NGHGI;
- explaining the major trends and sharp increases/decreases of time series emissions in the NGHGI; and
- ensuring there are no inconsistencies between the NID and the CRT tables.

(d) comparability:

- using the methodologies, procedures and formats agreed upon under the UNFCCC and the Kyoto Protocol for estimating and reporting the national GHG emissions and removals by sinks;
- allocating the emissions and removals to source and sink categories in accordance with the aggregation level presented in the IPCC 2006 Guidelines and IPCC-GPG;
- ensuring the most up-to-date templates are used; and
- ensuring minimal use of 'IE' and full justification of 'NE'.

(e) accuracy :

- ensuring methods, data sources and assumptions result in accurate estimates;
- ensuring all data is aggregated correctly between reporting levels;
- providing uncertainty estimates;
- providing a summary of improvements concerning uncertainties performed from the previous submission;
- ensuring there are verification activities; and
- ensuring there is continuous improvement and implementation of all review recommendations.

Quality control

This is the phase in which the quality checks, which are performed by the experts during inventory calculation and compilation, are implemented. After data collection, selection of emission factors and calculation of emissions the quality is checked (units, sources, methodology, emission factors, transcription, documentation, aggregation, etc) by performing the general and specific quality checks discussed in each sector chapter. Further uncertainty analyses and recalculations are performed.

Quality control procedures

The quality control (QC) procedures are performed by the sector experts during inventory calculation and compilation. QC measures are aimed at the attainment of the quality objectives. The QC procedures comply with the IPCC good practice guidance and the IPCC 2006 Guidelines. General inventory QC checks include routine checks of the integrity, correctness and completeness of data, identification of errors and deficiencies and documentation and archiving of inventory data and quality control actions.

In addition to general QC checks, category-specific QC checks including technical reviews of the source categories, activity data, emission factors and methods are applied on a case-by-case basis focusing on key categories and on categories where significant methodological and data revisions have taken place.

General QC procedures

The general quality checks are used routinely throughout the inventory compilation process. The general QC checks carried out on South Africa's 2024 inventory are provided in each sector chapter.

Category specific QC procedures

Category-specific QC complements general inventory QC procedures and are directed at specific types of data used in the methods for individual source or sink categories. These procedures require knowledge of the specific category, the types of data available and the parameters associated with emissions or removals and are performed in addition to the general QC checks. Category-specific QC activities include both emissions (or removals) data QC and activity data QC.

The category specific QC checks carried out on South Africa's 2024 inventory are provided in each sector chapter. These are reviewed and updated each year during the evaluation and planning phase.

QC process

Data collection and emission calculation quality control process

A number of common sense procedures govern the collection, maintenance, and use of electronic and transcribed data for all activity data, emission factors, and other primary data elements. Appropriate procedures can minimize the extent to which errors in data collection occur; various checks on the data and files can further reduce the errors that occur.

Quality checks are incorporated into the spreadsheets and checks are recorded by means of comments in the excel spreadsheets. The comments should always start with # initials of quality controller, followed by # date. After this there should be a # and a comment code.

These codes are provided in Table 1.

Tag category	QA Analyst tag	Tag name	Tag description
Problem identified	#PPE	Possible error	A possible error has been identified, which needs to be reviewed
Problem identified	#PIE	Identified error	An error has been identified in the calculations, which needs to be reviewed
Problem identified	#PT	Transparency	Documentation is needed for source referencing, assumptions, etc
Problem identified	#PCm	Completeness	Data gaps in the inventory have been identified
Problem identified	#PCs	Problem identified	A change in method or data source within a time-series has led to issues of consistency
Documentation added	#DA	Assumptions used	Information regarding the assumptions that have been applied to the calculations
Documentation added	#DM	Description of method	Information regarding the methods that have been applied to the calculations
Documentation added	#DSR	Source data reference	Information regarding the source of data used in the calculations
Documentation added	#DRfC	Reason for change	Information regarding the reasons for change in the calculations
Documentation added	#DChR	Evidence of a check	Information regarding the QC activities that have been applied to the calculations
Documentation added	#DTF	Trend feature	Information regarding the reasons for the trends that can be seen in the data
Documentation added	#Dimp	Improvement flag	Information regarding future improvement suggestions for the calculations
Comment review	#response	Response to tagged comment	Use this tab to add a response to any comment; always include #[initials] #[date] before #response
Comment review	#OK	Tagged comment sign-off	Tagged comment has been finalised and is ready for final review
Comment review	#FixChck	Tagged comment sign-off	Tagged comment has been reviewed by QA/QC expert and finalisation has been accepted

The following steps are carried out during the quality control of the calculation files:

- (a) Compilers complete the QC checks in the calculation files as they are compiling the inventory;
- (b) Sector Leads (SL) sends calculation files to QC reviewer;
- (c) QC reviewer checks the calculations files and makes any further comments;
- (d) QC reviewer sends checked calculation file to SL who reverts comments back to compilers;
- (e) Compilers respond to outstanding comments, sign off on QC checks and send final files to SL;
- (f) SL uploads final calculation files onto the “GHG estimation files” tab of the NGHGIS
- (g) SL produces the QC log for the sector and uploads the log onto the “QA/QC log” tab of the NGHGIS;
- (h) QA/QC controller gets notified of the log, checks the log file and signs off that the QC process for the sector is complete.

Cross cutting activities and National Inventory Report quality control process

The following steps are carried out during the quality control phase for cross-cutting issues and the National Inventory Report:

- (a) QA/QC coordinator compiles the QA/QC section of the NID and sends it to the Overall Document coordinator;
- (b) Overall Document coordinator compiles the draft NID;
- (c) Overall Document coordinator conducts the document quality checks and completes the Document Manager QAQC Checklist found on the “QAQC tools” tab on the NGHGIS
- (d) Completed Document Manager QAQC Checklist is uploaded by the Overall Document coordinator onto the “QAQC Log” tab of the NGHGIS
- (e) QA/QC controller gets notified of the log, checks the log file and signs off that the QC process for the NID is complete.

Quality assurance

Quality Assurance, as defined in the IPCC Good Practice Guidance, comprises a “planned system of review procedures conducted by personnel not directly involved in the inventory compilation and development process.” The quality assurance process includes both expert review and a general public review. The expert and public reviews each present opportunity to uncover technical issues related to the application of methodologies, selection of activity data, or the development and choice of emission factors. The expert and public reviews of the draft document offer a broader range of researchers and practitioners in government, industry and academia, as well as the general public, the opportunity to contribute to the final document. The comments received during these processes are reviewed and, as appropriate, incorporated into the Inventory Report or reflected in the inventory estimates. The results of the QA activities and procedures are documented and described in the QA/QC sub-chapter from the NID.

Quality assurance procedures:

There are three QA procedures in the South African GHG Inventory:

Peer reviews of specific sectors or categories which are provided by external experts or expert groups. The external experts are independent of the inventory preparation. The reviewers may also be experts in other calculation sectors of the GHG inventory system. These reviews are only conducted on selected sectors or categories, and are often dependant on in-kind contributions from experts and the availability of funding;

Public review and commenting process. A broad spectrum of groups and individuals may participate in the public review, including interested researchers, non-governmental organizations, trade associations, and other interested in the inventory process. The public review process allows parties that might not be readily identified by the expert review, an opportunity to review and comment on the inventory. For these purposes it is necessary to publish Inventory results to ensure the availability of the draft document. The public review process is dependent on Ministerial approval.

External review of the calculation files and the NID which is provided by a group of external experts. The external experts are independent of the inventory preparation. The objective of the peer review is to ensure that the inventory's results, assumptions and methods are reasonable, as judged by those knowledgeable in the specific field. This activity is dependent on funding

Quality assessment process

Peer review comments are documented separately on the “QAQC log” tab of the NGHGIS

The process for the public commenting is as follows:

- (a) NIC obtains permission from the Minister to put the draft GHG NID out for public comment;
- (b) NIC informs the QA/QC coordinator when approval has been given;
- (c) QA/QC co-ordinator initiates and manages the public commenting process;
- (d) QA/QC coordinator compiles a public comment database;
- (e) QA/QC coordinator sends comments to the SL's;
- (f) SL's send responses back to QA/QC coordinator;
- (g) QA/QC coordinator compiles a response database and logs this under the “QAQC log” tab on the NGHGIS;
- (h) QA/QC coordinator ensures all comments are incorporated into the inventory.

External reviews are organized and managed by the NIC. The external review can run simultaneously with the public commenting process. The QA/QC coordinator is responsible for logging the review on the NGHGIS and for ensuring all comments, improvements and recommendations get included in the inventory.

Verification

Emission and activity data are verified by comparing them with other available data compiled independently of the GHG inventory system. These include measurement and research projects and programmes initiated to support the inventory system, or for other purposes, but producing information relevant to the inventory preparation.

Conclusions and improvements

The ultimate aim of the QA/QC process is to ensure the quality of the inventory and to contribute to the improvement of the inventory. In the improvement stage of the QA/QC process, conclusions are made on the basis of the realised QA/QC measures and their results. The final project evaluation takes place at the next year's inventory planning meeting.

Annex V: Additional information: LULUCF sector

V.1: Additional details on the land cover maps

This annex provides detail on mapping methodologies for the LULUCF sector. The text are summaries of the SANLC maps that have been generated. The SANLC datasets, land cover reports and change assessment data can be found on the DFFE website (<https://www.dffe.gov/egis>).

1990 South African National Land Cover

The 1990 South African National Land Cover (SANLC 1990) is a 72 x class national land-cover dataset for South Africa, circa 1990, generated primarily from multi-seasonal Landsat 5 imagery, acquired mainly between 1989-1991. This is a complimentary dataset to the previous 72 x class 2013-14 South African national land-cover dataset, generated from comparable Landsat 8 imagery acquired between 2013-14. These two comparable datasets can be used to determine land-cover and land-use change over a period of ± 24 years across the South African landscape. The 1990 national land-cover dataset, is, as per the 2013-14 national land-cover dataset, based on 30x30m raster cells, and is ideally suited for $\pm 1:75,000 - 1:250,000$ scale GIS-based mapping and modelling applications. The 1990 land-cover dataset has been generated using the same operationally proven, semi-automated modelling procedures used to generate the comparable Landsat 8 derived 2013-14 South African national land-cover dataset. It is recommended that the 1990 South African National Land Cover report is read in conjunction with the 2013-14 South African National Land-Cover report associated with the 72 x class 2013-14 South African National Land-Cover Dataset.

2014 South African National Land Cover

The 2014 South African National Land Cover (SANLC 2014) is a 72 x class national land-cover dataset for South Africa, circa 2013-14, generated primarily from multi-seasonal Landsat 8 imagery, using operationally proven, semi-automated modelling procedures developed specifically for the generation of this dataset, based on repeatable and standardised modelling routines. The 2014 national land-cover dataset is, as per 1990 national land-cover dataset, based on 30x30m raster cells, and is ideally suited for $\pm 1:75,000 - 1:250,000$ scale GIS-based mapping and modelling applications. The 1990 and 2014 land-cover are two comparable datasets that can be used to determine land-cover and land-use change over a period of ± 24 years across the South African landscape.

2018 South African National Land Cover

The 2018 South African National Land Cover (SANLC 2018) is a raster format dataset generated from automated mapping models (as opposed to conventional image classification procedures), using multi-seasonal 20m resolution Sentinel 2 satellite imagery. The imagery used represents the full temporal range of available imagery

acquired by Sentinel 2 during the period 01 January 2018 to 31 December 2018. The SANLC 2018 dataset represents a new chapter in the generation of South African National Land-Cover datasets as it was generated using the CALC (Computer Automated Land-Cover) system. CALC is a DFFE fully automated land-cover production system designed to use Sentinel 2 imagery to produce standardised data-content and consistent SANLC updates in the future.

2020 South African National Land Cover

The 2020 South African National Land Cover (SANLC 2020) is a raster format dataset generated from automated mapping models (as opposed to conventional image classification procedures), using multi-seasonal 20m resolution Sentinel 2 satellite imagery. The imagery used represents the full temporal range of available imagery acquired by Sentinel 2 during the period 01 January 2020 to 31 December 2020. The automated 2020 South African National Land Cover (SANLC 2020) was generated through the CALC system using the same methodology as the SANLC 2018 dataset.

2022 South African National Land Cover

The 2022 South African National Land Cover (SANLC 2022) is a raster format dataset generated from automated mapping models (as opposed to conventional image classification procedures), using multi-seasonal 20m resolution Sentinel 2 satellite imagery. The imagery used represents the full temporal range of available imagery acquired by Sentinel 2 during the period 01 January 2022 to 31 December 2022. The automated 2022 South African National Land Cover (SANLC 2022) was generated through the CALC system using the same methodology as the SANLC 2018 and SANLC 2020 datasets.

Computer Automated Land Cover (CALC) System Methodology

The Computer Automated Land Cover (CALC) is a DFFE automated system that generates land cover and land use change datasets. CALC is designed and operationally implemented as an automated, cloud-based solution for the future production of South African National Land-Cover datasets. The system produces national land-cover data for South Africa, based on the new Gazetted land-cover classes (SANS 19144-2), associated map accuracy and change detection analyses datasets and reports.

Each CALC generated SANLC dataset represents a 20m resolution, raster format, land-cover and land-use (LCLU) automated classification of the entire South African landscape, including a 100 metre buffer into neighbouring countries, and 10 km buffer into coastal waters. Each SANLC dataset represents a particular assessment year, not a specific date nor season. The CALC classification process used all available Sentinel-2 image acquisitions acquired between and including January and December in the assessment year. The automated land-cover mapping models and associated rules utilise both cloud-based image archives and cloud-based geo-data computing capabilities.

The land-cover / land-use (LCLU) legend and associated information content used with all CALC generated SANLC datasets is based primarily on the new gazetted land-cover classification standard (SANS 19144-2), but with modifications to ensure, as far as possible, comparability and compatibility with the legend and information content associated with the previous 1990 and 2013-14 South African National Land-Cover (SANLC) datasets. These modifications have been made in order to facilitate more representative change detection and reporting between the SANLC 1990 and SANLC 2013-14 datasets, the SANLC 2018, 2020 and the new SANLC 2022 dataset.

CALC generated SANLC datasets are generated using only European Space Agencies (ESA) free-to-access Sentinel-2 satellite imagery. No other satellite image sources have been used. Sentinel-2 imagery has been chosen over Landsat as the preferred source of imagery due to its improved spatial, spectral and temporal (i.e. re-visit) capabilities, compared to Landsat. Sentinel-2A and 2B satellites are collectively able to provide 20 metre resolution imagery, containing 12 spectral bands, every 5 days, anywhere across the globe.

This system enables the DFFE to generate single-year-representative, full legend content, national land-cover datasets over South Africa that are compatible with both the new Gazetted land-cover classes (SANS 19144-2), and the information content in the existing 1990 and 2013/14 South African National Land-Cover datasets. The CALC system also supports the calculation and reporting of land-cover mapping accuracies against independently obtained validation points; and land-cover change assessments with statistical reporting based on a simplified legend (20 classes) and reduced spatial resolution (30 m). CALC also generates RGB false-colour image tiles from Sentinel-2 imagery that is used as a visual reference to update 12 dynamic geographical masks before classification takes place. These visual backdrops are only used for on-screen updating within a GIS environment and should not be used for spectral classification of the imagery.

The CALC system is a fully functional, operational system capable of generating SANLC datasets for DFFE, enabling the Department to maintain and expand its inventory of SANLC content into the future.

V.2: Annual conversion areas before corrections

This section provides the annual change areas for 1990-2014, 2014-2018, 2018-2020 and 2020-2022 before corrections discussed in section 6.3.2. were applied.

Table A V. 1: Annual land change areas (ha) for 1990-2014 before corrections.

Land categories	1990																				
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annuals Pivot Irrigated	Annuals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine	
2014	Indigenous Forest		672	1 308	344	1 462	29	270	22	0	8	0	0	55	35	73	3	3	1	0	
	Thicket / Dense Bush	1 725	62 647	5 319	26 423	72 094	1 209	6 047	3 560	233	563	175	97	3 423	3 591	2 725	162	120	133	305	
	Natural woodland	446		1 968	68 524	128 942	674	3 203	8 787	1 030	350	22	245	9 159	7 572	1 126	242	37	68	777	
	Planted Forest	61	477		562	11 969	45	377	17	2	60	7	5	1 165	89	412	187	5	8	34	
	Shrubland	88	780	62 477	1 052	176 234	1 221	5 444	148 400	7 478	234	190	139	16 664	1 232	737	49	49	69	584	
	Grassland	436	36 562	78 471	5 765	184 838	1 602	16 522	8 422	3 517	393	49	216	31 291	3 471	3 904	290	79	142	2 091	
	Waterbodies	5	519	540	66	592	1 102		528	1 185	10	8	2	139	45	24	7	2	3	110	
	Wetlands	73	1 419	833	673	1 396	5 961	2 312	276	77	35	25	17	1 395	64	134	36	7	11	63	
	Barren Land	38	989	6 436	43	105 562	7 688	3 761	378		1 456	6	8	5	293	27	62	4	9	22	171
	Eroded Land	0	101	613	1	1 451	1 981	11	27	31		1	0	2	116	226	46	0	1	1	13
	Permanent Orchards	33	955	474	258	535	433	15	89	10	0		143	144	1 295	114	28	4	0	2	0
	Permanent Vines	0	144	67	29	557	67	7	86	109	0	401		38	343	11	6	3	1	2	0
	Annuals Pivot Irrigated	1	370	1 439	25	2 875	2 852	8	251	75	9	148	24		16 209	75	4	3	0	0	5
	Annuals Non-Pivot	67	3 994	3 870	1 002	8 904	24 381	163	1 709	112	25	703	110	949		1 865	501	324	4	14	49
Cultivated Subistence	67	2 261	3 002	106	2 646	10 053	37	617	16	146	167	0	15	719		1 465	21	1	0	19	

Land categories	2014																			
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annals Pivot Irrigated	Annals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine
Permanent Orchards	28	3 094	783	627	1 415	866	49	274	35	1		4 144	605	5 810	138	68	243	0	4	2
Permanent Vines	0	1 176	192	33	1 221	274	55	157	158	0	317		63	1 343	0	25	147	1	3	1
Annals Pivot Irrigated	5	1 402	3 128	63	3 984	5 326	27	460	61	20	673	99		25 525	93	10	126	0	1	19
Annals Non-Pivot	299	16 505	12 853	3 164	47 661	108 471	417	6 827	863	381	14 686	5 426	8 176		2 042	398	3 141	3	18	578
Cultivated Subistence	506	16 41	41 673	20 2502	20 661	661	39	991	45	1 774	615	0	156	8 801		3 149	846	1	1	29
Residential	259	24 750	16 702	4 223	16 028	54 721	174	1 097	1 841	727	315	327	92	6 172	10 536		1 115	1 085	117	236
Smallholdings	4	542	1 724	1 248	286	1 504	13	90	15	3	13	7	6	1 862	74	1 203	48	113	5	
Commercial	7	784	337	70	650	734	11	32	107	6	9	9	1	78	11	8 914	41		251	25
Industrial	4	1 045	938	94	2 147	1 973	181	67	954	11	953	46	150	916	18	4 169	148	113		353
Mines	50	1 631	3 550	291	5 959	7 168	648	282	3 532	191	6	10	91	2 234	247	1 113	49	68	498	

Table A V. 3: Annual land change areas (ha) for 2018-2020 before corrections.

Land categories	2018																			
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annals Pivot Irrigated	Annals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine
Indigenous Forest		2	887	489	71	2 073	27	79	33	0	0	0	0	2	0	96	1	1	0	24
Thicket / Dense Bush	1		129 657	10	5 671	11 724	248	128	162	1	118	0	58	158	219	339	0	33	10	18
Natural woodland	755	338 706		94	130 694	1 868 624	6 224	474 944	29 944	4 445	2 121	6	989	15 656	70 530	11 313	43	1 059	847	2 042
Planted Forest	416	2 034	3 705		3 114	31 727	236	1 569	730	29	128	0	3	385	54	1 445	80	14	37	179
Shrubland	60	4 927	47 688	1 595		1 103 458	3 910	224 743	887 743	10 316	19	19	94	1 194	7	10	0	1	6	3 375

Land categories	2018																			
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annals Pivot Irrigated	Annals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine
Grassland	2 410	77 871	1 311 421	31 151	1 289 396		14 734	5 248	119 831	24 893	121	7	496	7 038	7 750	170	9	2 874	3 185	16 293
Waterbodies	16	156	4 461	207	6 742	8 511		3 299	9 445	189	18	6	25	615	54	196	41	8	49	1 723
Wetlands	154	206	613	1 367	1 549	7 725	4 058		1 398	0	3	0	10	89	27	67	26	8	16	169
Barren Land	84	1 280	17 473	557	848 638	109 418	13 265	377		15	5	0	8	78	54	17	0	2	23	490
Eroded Land	0	2	1 732	43	10 488	28 023	230	1	389		0	0	1	1	33	0	0	0	0	23
Permanent Orchards	7	759	6 339	1 282	742	1 376	9	83	237	0		23	2 327	8 555	249	48	69	0	0	3
Permanent Vines	0	43	596	14	1 171	161	3	9	92	0	11		16	57	0	30	14	0	0	3
Annals Pivot Irrigated	0	715	5 525	105	1 241	6 946	20	194	169	24	151	47		20 528	116	27	36	0	0	64
Annals Non-Pivot	48	2 140	56 466	2 528	13 428	119 605	344	2 760	5 550	137	4 107	63	9 922		6 105	557	797	0	0	1 342
Cultivated Subistence	48	462	16 598	84	138	23 656	162	186	2 606	1 545	181	0	154	1 205		915	320	0	0	150
Residential	308	1 986	17 786	990	609	8 020	245	75	823	63	6	0	22	479	2 015		48	62	7	683
Smallholdings	2	0	16	19	0	5	73	25	0	0	10	0	3	36	157	125		46	82	29
Commercial	0	11	445	7	10	1 762	7	6	29	0	2	0	0	0	1	34	26		1	38
Industrial	0	19	467	20	437	1 902	37	15	183	1	30	1	9	166	8	74	75	1		305
Mines	37	9	955	413	5 031	9 787	1 347	185	738	57	4	2	106	2 220	221	369	13	25	203	

Table A V. 4: Annual land change areas (ha) for 2020-2022 before corrections.

[illegible]

Land categories	2020																			
	Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Permanent Orchards	Permanent Vines	Annals Pivot Irrigated	Annals Non-Pivot	Cultivated Subistence	Residential	Smallholdings	Commercial	Industrial	Mine
Thicket / Dense Bush	63	442 516		1	3 795 156	115 156	128	184	341	1	0	0	0	1	5	3 513	0	11	7	7
Natural woodland	841	110 037		56	347 782 644	3 022 644	2 979	742 519	59	5 255	22	7	93	223	6 720 519	27	0	802	548	2 390
Planted Forest	277	2 687	4 135		3 263 573	52	123	2 589	846	63	3	1	1	24	1	2 118	145	11	27	258
Shrubland	40	4 749	44 263	1 888		136 426	2 434	291	2 938 345	11 633	16	18	2	133	0	52	0	9	6	4 704
Grassland	1 057	7 582	914 627	16 831	4 010 564		4 310	5 079	249 884	71 966	30	6	125	1 951	225	465	1	2 502	3 113	20 906
Waterbodies	79	886	20 145	611	15 875	42 795		13 607	37 257	505	24	16	183	3 213	446	434	149	9	46	2 703
Wetlands	113	235	797	765	397 956	10 956	1 774		590	1	1	0	1	7	7	133	42	7	15	126
Barren Land	30	231	14 163	281 295	49 462	3 150 462	3 150	882		5	0	0	6	35	17	18	0	2	1	940
Eroded Land	0	0	1 030	15	13 399	5 975	61	0	112		0	0	0	0	1	1	0	0	0	151
Permanent Orchards	0	3	214	21	151 301	7	7	6	23	0		0	0	115	0	1	0	0	0	5
Permanent Vines	0	0	10	0	87 32	3	3	1	13	0	0		0	33	0	0	0	0	0	3
Annals Pivot Irrigated	0	81	2 282	57	460 2 745	19 2 745	19	104	21	6	42	0		4 017	207	2	5	0	0	59
Annals Non-Pivot	0	297	3 253	959	1 382 7 418	291 7 418	291	216	196	2	2	1	361		2	27	19	1	0	1 139
Cultivated Subistence	0	38	37 764	1	2 644	47	47	13	8	3	0	0	0	22		53	275	0	0	168
Residential	117	379	14 881	571	1 305 193	16 193	152	69	2 081	290	10	6	13	461	2 311		33	802	46	870
Smallholdings	2	0	36	19	0 39	23 31	23	31	7	0	0	0	0	0	1	205		29	72	27
Commercial	1	19	573	9	35 1 673	5 1 673	5	6	115	1	1	0	0	12	8	722	28		20	40
Industrial	0	13	542	29	388 1 958	48 1 958	48	18	543	3	3 748	1 567	174	1 498	19	640	105	86		386
Mines	25	3	1 074	275	4 082 7 411	1 206 7 411	1 206	158	1 198	59	2	1	52	1 574	84	375	13	22	294	

V.3: Burnt area processing workflow

Data collection:

The MCD64A1 Burned Area Product (hereafter the MCD64A1) is a monthly, Level-3 gridded 500-m product containing per-pixel burning and quality information, and tile-level metadata.

The MCD64A1 files (window 13 files) were downloaded directly from the USGS servers for the 2018 to 2024 annual periods. (Window 13 of the MCD64A1 contains southern Africa.):

The soil type data set was obtained from the previous NID project files – original source was the ARC.

The National Land Cover datasets for 2018, 2020 and 2022 were downloaded from the DFFE's egis portal.

The data was processed using a combination of QGIS and an Anaconda Python environment with NumPy and Rasterio packages installed to process the geospatial data.

Data Processing:

Burned Area:

- The raw resolution of the MCD64A1 is ~500m (463.31271653m) after reprojecting it to EPSG 4326 (WGS84) [All layers were reprojected to WGS84 if they were not in that projection already].
- Each monthly active fire file was reclassified with 0 representing no burns and 1 representing the burned area (12 raster files reclassified to Boolean values (0 and 1)).
 - o For the multi burn file: Perform basic resampling where cells are summed to represent the total active burns per pixel for calendar year. Add the "1's" that overlap in an annual period together.
 - o Annual raster is the summed total of all 12 raster files and where there was a burn the value of 1 was assigned and where there were none, the value 0.
- Clip the Window 13 Modis Burnt Area (Southern Africa) to a South African boundary shapefile (sourced from Humanitarian Data Exchange SA administration boundaries <<https://data.humdata.org/dataset/cod-ab-zaf>> accessed 11 November 2024) that was later converted to raster format.
- Burnt Area product was then resampled to the highest possible resolution necessary for the analysis, in this case it was resampled to 18.535m for the South African National Land Cover (SANLC) Raster Geographic data set), i.e., the dataset with the smallest resolution.

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Soil type dataset

- Geo-reference the ALU soils file (.ovr pyramid structure) to corresponding raster outline of South Africa (EPSG 4326 (WGS84)).
- The resolution of the ALU soils raster (50 m) was then resampled to the highest resolution necessary for the analysis. i.e., the dataset with the smallest resolution (18.535m, SANLC Raster).

SANLC Raster dataset

- Reclassify the 73-class dataset to the predetermined 20 classes that were used in previous NIDs.
- No resampling the pixel/cell sizes since the SANLC was the reference resolution for the other datasets.

“Overlay” and counts:

- The next step was to convert the raster datasets into arrays for processing. The datasets were set to an equal extent to ensure the layers identically fit on top of one another.
- The spatial extent was indexed to assign each pixel in the spatial dataset a value (location) in the array.
- The Burned area was set to be a mask, i.e., only the cells that were classified to 1 (burned) will be identified in the processing.
- Next the code was instructed to Loop through each Array and count the number of unique pixels that correspond to the unique cells of the other rasters (np.unique = Counts the unique values in the array).
- To reduce the size of the output, the code was instructed to loop through the ALU soils and find the corresponding Landcover class and then count the number of unique pixels that occurred in the BA mask.
 - o i.e., what is the number of pixels that occurred within each LC/soil classification?
 - o Determine counts of pixels where a burn was recorded for each LC class corresponding to the unique 7 soil classes of the ALU dataset.
 - o The results were exported as text files.
- The pixel counts of Burned area per land cover and soil type was then copied into an excel workbook for further processing.
- The pixel count was multiplied by the pixel area (resolution 18.535m x18.535m = 343.548m²) to give the area burned per soil type and landcover class. The area burned was also converted into hectares by dividing the square meters by 10 000.

V.4: Biomass and DOM parameters

Parameter	Vegetation subdivision	Value	Range	Source
Indigenous forests				
Above ground biomass (t dm/ha)	Afrotemperate (primary)	519.8	435.5 – 622.6	(Adie, et al., 2013)
		537.7	411.5 – 722.6	(Adie, et al., 2013)
		372.2	310.6 – 434.0	(Fisher, 2024)
		498.7		(Midgley & Seydack, 2006)
	Afrotemperate (secondary)	243.2	214.5 – 270.6	(Adie, et al., 2013)
		171.7	105.1 – 245.1	(Adie, et al., 2013)
		198.9	174.5 – 217.0	(Fisher, 2024)
		226.4		(Cardoso, et al., 2017)
	Afrotemperate (degraded)	179.8	91.7 – 281.1	(Adie, et al., 2013)
	Mistbelt forest	358.1 (±31.9)	98.2 – 952.2	(Mensah, et al., 2016)
		316.7 (±21.4)		(Honold, et al., 2025)
	Coastal lowland	199.6	154.4 – 253.8	(Smithwick, 2019)
		151.6 (±16.6)		(Glenday, 2007)
	Coastal scarp	134.0 (±18) 227.4 (±29.8)		(Glenday, 2007) (Mangwale, et al., 2017)
Above ground biomass growth (t dm/ha/yr)	Coastal scarp (degraded)	27.2 (±14.2)		(Mangwale, et al., 2017)
	Coastal scarp (regrowth)	24.8 (±10.0)		(Mangwale, et al., 2017)
	Swamp forest	205.0 (±64)		(Glenday, 2007)
	Dune forest	83.6 (±13)		(Glenday, 2007)
	Transitional forest	34.8 (±15.4)		(Glenday, 2007)
	Ironwood forest	108.7 (±8.7)		(Honold, et al., 2025)
	Afromontane	4.7 (gross) 0.92 (net)		(Midgley & Seydack, 2006)
Above ground biomass growth (t dm/ha/yr)	Coastal scarp	0 (>20yrs) 3.58 (<20yrs) ³⁶		(Glenday, 2007)
	Coastal lowland	0.12 (>20yrs) 3.78 (<20yrs)		(Glenday, 2007)
	Dune	0.06 (>20yrs) 2.74 (<20yrs)		(Glenday, 2007)
	Transitional	0.16 (>20yrs)		(Glenday, 2007)

³⁶ These were post disturbance values so assumed this to be for forests <20yrs.

		2.16 (<20yrs)		
Net annual increment (m ³ /ha/yr)	Afrotemperate	1.12		(Gush, 2011)
Ratio of BGB to AGB (t dm BGB/t dm AGB)	Coastal scarp	0.27 0.13		(Glenday, 2007) (Mangwale, et al., 2017)
	Coastal scarp (degraded)	0.14		(Mangwale, et al., 2017)
	Coastal scarp (regrowth)	0.15		(Mangwale, et al., 2017)
	Swamp	0.25		(Glenday, 2007)
	Coastal lowland	0.27		(Glenday, 2007)
	Dune	0.33		(Glenday, 2007)
	Transitional	0.33		(Glenday, 2007)
Mortality rate (% of AGB)	Afrotemperate	0.8 0.6		(Midgley & Seydack, 2006) (Cardoso, et al., 2017)
Deadwood stock (t C/ha)	Coastal scarp	10.6 (±4.7) 19.4 (±3) ³⁷		(Glenday, 2007) (Mangwale, et al., 2017)
	Coastal scarp (degraded)	1.2 (±0.4)		(Mangwale, et al., 2017)
	Coastal scarp (regrowth)	0.12 (±0.8)		(Mangwale, et al., 2017)
	Swamp	3.1 (±1.8)		(Glenday, 2007)
	Coastal lowland	5.8 (±2.2)		(Glenday, 2007)
	Dune	2.6 (±0.9)		(Glenday, 2007)
	Transitional	2.2 (±1.7)		(Glenday, 2007)
	Mistbelt	5.3 (±1.3)		(Honold, et al., 2025)
	Ironwood	9.5 (±3.5)		(Honold, et al., 2025)
Litter stock (t C/ha)	Coastal scarp	3.7(±0.3) 12.8 (±1.2)		(Glenday, 2007) (Mangwale, et al., 2017)
	Coastal scarp (degraded)	1 (±0.4)		(Mangwale, et al., 2017)
	Coastal scarp (regrowth)	0.16 (±0.04)		(Mangwale, et al., 2017)
	Swamp	3.2 (±0.0)		(Glenday, 2007)
	Coastal lowland	3.8 (±0.3)		(Glenday, 2007)
	Dune	4.5 (±0.5)		(Glenday, 2007)
	Transitional	2.7 (±0.6)		(Glenday, 2007)

³⁷ These values were indicated to be large litter, and a separate litter value was provided, therefore the values were utilised as deadwood.

Litter production (% of AGB)	Forests	1 - 5		(Lechmere-Oertel, et al., 2008)
Litter decomposition rate (per year)	Afrotemperate	0.24		
Mass of fuel available for combustion (t/ha)	Forests	60		(DEA, 1999)
	Secondary tropical forests	76.7		(IPCC, 2019)
Biomass burning combustion factor	Forests	0.4		(DEA, 1999)
	Secondary tropical forests	0.55		(IPCC, 2019)
Thickets				
Above ground biomass (t dm/ha)	Dry valley thicket	61.6 (±6.8)		(Glenday, 2007)
	Alien thicket	24.2 (±7.4)		(Glenday, 2007)
	Succulent	82	67.0 -97.0	(Lechmere-Oertel, et al., 2008)
	Succulent (transformed <20yrs)	3.96 (±0.4) 11.0 (±0.4) 29.6 (±6.3)		(Mills & Cowling, 2006)
	Succulent (transformed >20yrs)	64.4 (±8.3)		(Mills & Cowling, 2006)
	Succulent (transformed)	16.7	9.5 – 23.9	(Lechmere-Oertel, et al., 2008)
	Semiarid	84 (±6)		(Mills, et al., 2005)
	Semi-arid (transformed)	14.6 (±6.3)		(Mills, et al., 2005)
	Subtropical	57.1 (±8.4) 58.08 77.41 76.02 53.68 46.25 44.1 (±5.97)		(Powell, 2009) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (Harris, et al., 2021)
	Subtropical (restored >20yrs)	94.8 (±22.1) 224.2 (±22.5)		(van der Vyver, et al., 2013)
	Subtropical (degraded)	10.3 (±1.7) 33.1 (±20.4) 13 25.8 20.36		(Powell, 2009) (van der Vyver, et al., 2013) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019)

		8.65 3.27 29 (moderate) 13.1 (severe)		(van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (Harris, et al., 2021) (Harris, et al., 2021)
Above ground biomass growth (t dm/ha/yr)	Dry valley thicket	1.0 (>20yrs) 2.3 (<20yrs)		(Glenday, 2007)
Ratio of BGB to AGB (t dm BGB/t dm AGB)	Succulent (transformed <20yrs)	0.4 0.37		(Mills & Cowling, 2006)
	Succulent (transformed >20yrs)	0.3		(Mills & Cowling, 2006)
	Semiarid	0.63		(Mills, et al., 2005)
	Semi-arid (transformed)	1.6		(Mills, et al., 2005)
	Subtropical	0.2		(Powell, 2009)
	Subtropical (degraded)	0.5		(Powell, 2009)
	Subtropical (restored >20yrs)	0.2		(van der Vyver, et al., 2013)
Deadwood stock (t C/ha)	Dry valley thicket	3 (±1)		(Glenday, 2007)
	Alien thicket	0		(Glenday, 2007)
Litter stock (t C/ha)	Dry valley thicket	5.2 (±0.6)		(Glenday, 2007)
	Alien thicket	4 (±1.2)		(Glenday, 2007)
	Succulent (transformed <20yrs)	0.1 (±0.02) 0.5 (±0.2) 0.7 (±0.1)		(Mills & Cowling, 2006)
	Succulent (>20yrs)	1.2 (±0.3)		(Mills & Cowling, 2006)
	Semi-arid	11.5 (±1.4)		(Mills, et al., 2005)
	Semi-arid (transformed)	1 (±0.4)		(Mills, et al., 2005)
	Subtropical	3.7 (±0.72) 8.04 5.81 5.81 11.49 4.12 9.18 (±3.57)		(Powell, 2009) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (Harris, et al., 2021)

	Subtropical (degraded)	1.4 (± 0.31) 0 0.56 0.6 1.86 0.31 0.95 4.0 (moderate) 1.9 (severe)		(Powell, 2009) (van der Vyver, et al., 2013) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (van der Vyver & Cowling, 2019) (Harris, et al., 2021) (Harris, et al., 2021)
	Subtropical (restored >20yrs)	12.8 (± 2.4) 25.3 (± 2.2)		(van der Vyver, et al., 2013)
Litter production (t dm/ha/yr)	Succulent (intact)	4.1		(Lechmere-Oertel, et al., 2008)
	Succulent (transformed)	2.9		(Lechmere-Oertel, et al., 2008)
Litter production (% of AGB)	Succulent (intact)	4 – 6		(Lechmere-Oertel, et al., 2008)
	Succulent (transformed)	12 - 32		(Lechmere-Oertel, et al., 2008)
Litter decomposition (t dm/ha/yr)	Succulent (intact)			(Lechmere-Oertel, et al., 2008)
	Succulent (transformed)			(Lechmere-Oertel, et al., 2008)
Mass of fuel available for combustion (t/ha)	Thickets	1.4		(DEAT, 2009)
Biomass burning combustion factor	Thickets	0.95		(DEAT, 2009)
Woodlands				
Above ground biomass (t dm/ha)	Moist woodland	81.5 (± 6.1)		(Honold, et al., 2025)
	Dry woodland	38.4 (± 8.4)		(Honold, et al., 2025)
	Lowveld woodland	33.5 (± 2.8)		(Honold, et al., 2025)
	Mopane woodland	38.7 (± 4.3)		(Honold, et al., 2025)
	Woodland (woody)	58 (± 6)		(Glenday, 2007)
	Alien woodland (woody)	28 (± 10)		(Glenday, 2007)

	Wooded grassland (woody)	9.4 (± 1.4)		(Glenday, 2007)
	Woodland – disturbed (woody)	18.2 (± 6.8)		(Glenday, 2007)
	Woodland (herbaceous)	3.6 (± 0.8)		(Glenday, 2007)
	Alien woodland (herbaceous)	4.2 (± 1)		(Glenday, 2007)
	Wooded grassland (herbaceous)	5.2 (± 1)		(Glenday, 2007)
	Woodland – disturbed (herbaceous)	5.2 (± 1)		(Glenday, 2007)
	Savanna woodland	28.3 27 (woody) 26 19.2 ³⁸ 23.4	4.7 – 41.9 9.4 – 27 22 – 25	(Colgan, 2012) (Colgan, 2012) (Lembani, 2018) (Mograbi, et al., 2015) (Nickless, et al., 2011)
	Savanna	14.4 (woody) 1.9 (herb)		(Rutherford, 1979)
	Savanna (arid)	23.1 (± 2.28)		(Shackleton & Scholes, 2011)
	Savanna (semi-arid)	18.9 (± 3.67)		(Shackleton & Scholes, 2011)
	Savanna (mesic)	41.3 (± 4.53)		(Shackleton & Scholes, 2011)
Above ground biomass growth (t dm/ha/yr)	Woodland (>20yrs)	0.06		(Glenday, 2007)
	Woodland (<20yrs)	2.3		(Glenday, 2007)
	Alien woodland (>20yrs)	0		(Glenday, 2007)
	Alien woodland (<20yrs)	1.3		(Glenday, 2007)
	Wooded grassland (>20yrs)	0		(Glenday, 2007)
	Wooded grassland (<20yrs)	0.36		(Glenday, 2007)
	Savanna (wood)	1.3		(Rutherford, 1979)

³⁸ This value is for land experiencing different levels of wood extraction.

		0.9		(Scholes & Walker, 1993)
Ratio of BGB to AGB (t dm BGB/t dm AGB)	Woodland (woody)	0.32		(Glenday, 2007)
	Savanna	1.99		(Qi, et al., 2019)
	Wooded savanna	0.5		(IPCC, 2006)
Deadwood (t C/ha)	Moist woodland	0.8 (±0.4)		(Honold, et al., 2025)
	Dry woodland	0.8 (±0.4)		(Honold, et al., 2025)
	Lowveld woodland	0.1 (±0.08)		(Honold, et al., 2025)
	Mopane woodland	0.1 (±0.08)		(Honold, et al., 2025)
	Woodland	1.5 (±0.5)		(Glenday, 2007)
	Alien woodland	1.3 (±0.8)		(Glenday, 2007)
	Wooded grassland	0.4 (±0.2)		(Glenday, 2007)
	Woodland – disturbed	1 (±1)		(Glenday, 2007)
	Savanna	0.87		(Rutherford, 1979)
Litter stock (t C/ha)	Woodland	2.6 (±0.3)		(Glenday, 2007)
	Alien woodland	4.5 (±0.8)		(Glenday, 2007)
	Wooded grassland	0.8 (±0.6)		(Glenday, 2007)
	Woodland – disturbed	3.3 (±1.2)		(Glenday, 2007)
Mass of fuel available for combustion (t/ha)	Savanna	4.3	3.5 – 5.5	(Shea, et al., 1996)
	Grassland savanna	5.3 (±2)		(van Leeuwen, et al., 2014)
	Wooded savanna	11 (±99.1)		(van Leeuwen, et al., 2014)
Combustion fraction	Savanna	0.8		(Shea, et al., 1996)
	Grassland savanna	0.81 (±0.12) 0.88		(van Leeuwen, et al., 2014) (Hely, et al., 2003)
	Wooded savanna	0.58 (±0.18)		(van Leeuwen, et al., 2014)
Low shrubland				
Above ground biomass (t dm/ha)	Succulent karoo	3.3	0.5 – 7	(Milton, 1990)
		7.6		(Rutherford, 1978)
		3.8		(Rutherford & Westfall, 1986)
		3.3		(Anderson, et al., 2010)
		19.8		(Anderson, et al., 2010)
		3.72		(Anderson, et al., 2010)

		25.7		(Anderson, et al., 2010)
	Karoo	4.0	1 – 7	(Rutherford & Westfall, 1986)
	Nama karoo	3.4		(Skowno, 2003)
	Fynbos	18.6 (±2) 15.5 18.1 14.3 4.85 (2yrs) 18.5 (mature) 35.4 (21yrs) ³⁹ 22.6 (37yrs) ⁴⁰ 6.6 (4yrs) 5.9 (4yrs)	6 – 25 2.2 – 7.5 11 – 26	(Mills, et al., 2012) (Rutherford & Westfall, 1986) (Abanda, et al., 2011) (Rutherford, 1978) (Kruger, 1977) (Kruger, 1977) (van Wilgen, 1980) (van Wilgen, 1980) (van Wilgen, 1980) (van Wilgen, 1980)
Above ground biomass growth (t dm/ha/yr)	Fynbos	2.5	1 - 4	(Kruger, 1977)
Litter stock (t C/ha)	Succulent karoo	2.1		(Rutherford, 1978)
		2.5		(Rutherford, 1978)
		0.2		(Milton, 1990)
	Fynbos	0.76 3.4 (±0.7) 1.0 5.3 (21yrs) 19.6 (37yrs) 0.2 (4yrs) 0.12 (4yrs) 6.3	0.8 – 1.4	(Rutherford, 1978) (Mills, et al., 2012) (Kruger, 1977) (van Wilgen, 1980) (van Wilgen, 1980) (van Wilgen, 1980) (van Wilgen, 1980) (Abanda, et al., 2011)
Ratio of BGB to AGB (t dm BGB/t dm AGB)	Arid shrublands	1.1		(Mokany, et al., 2006)
	Fynbos (perennial)	0.26 (±0.05)		(Higgins, et al., 1987)
	Fynbos (herbaceous)	1.68 (±0.3)		(Higgins, et al., 1987)
Litter production (t dm/ha/yr)	Fynbos	0.7		(Witkowski, 1989)
Mass of fuel available for combustion (t/ha)	Nama karoo	1		(DEA, 1999)
	Succulent karoo	0.6		(DEA, 1999)
	Fynbos	12.9		(Richardson, et al., 1994)

³⁹ This plot is 21yrs post fire.

⁴⁰ This plot was after 37yr of fire exclusion and so was excluded from totals as fires naturally occur in the fynbos

Combustion fraction	Nama karoo	0.95		(DEA, 1999)
	Succulent karoo	0.95		(DEA, 1999)
	Fynbos	0.61		(IPCC, 2006)
Mangroves				
Above ground biomass (t dm/ha)	Mangroves	94.5 (± 7.8) 157		(Steinke, et al., 1995) (Johnson, et al., 2020)
Ratio of BGB to AGB (t dm BGB/t dm AGB)	Mangroves	0.1		(Steinke, et al., 1995)
Litter production (t dm/ha/yr)	Mangroves	7.5	4.5 – 10.6	(Naidoo, 2016)
Deadwood stock (t C/ha)	Mangrove	7.63 (± 0.9)		(Steinke, et al., 1995)

Annex VI: Common Reporting Tables

Table A VI. 1: Summary emission table for South Africa for 2024.

IPCC 2006 category	Emissions and removals									
	Net CO ₂	CH ₄	N ₂ O	HFCs	PFCs	SF ₆	NO _x	CO	NMVO _C	Total GHGs
	(Gg)			(Gg CO ₂ e)			(Gg)			
Emissions (incl. LULUCF)	356 325.7	2 276.1	65.0	6 685.1	113.0	84.7	49.4	930.0	78.9	444 164.5
Emissions (excl. LULUCF)	393 909.3	2 171.1	60.3	6 685.1	113.0	84.7	1.4	53.2	0.0	477 576.4
1 - Energy	368 289.1	186.5	6.4	0.0	0.0	0.0	0.0	0.0	0.0	375 215.7
1.A - Fuel Combustion Activities	344 347.2	16.4	6.4				NE	NE	NE	346 505.1
1.B - Fugitive emissions from fuels	23 941.9	170.1	0.0				NE	NE	NE	28 710.6
1.C - Carbon dioxide Transport and Storage	NE									NE
2 - Industrial Processes and Product Use	23 029.6	4.2	1.3	6 685.1	113.0	84.7	0.0	0.0	0.0	30 371.6
2.A - Mineral Industry	4 956.1	NE								4 956.1
2.B - Chemical Industry	1 290.6	4.2	1.3							1 749.8
2.C - Metal Industry	15 605.2	0.0	0.0	NE	113.0					15 718.3
2.D - Non-Energy Products from Fuels and Solvent Use	1 177.7	NE	NE							1 177.7
2.E - Electronics Industry	NE		NE	NE	NE					NE
2.F - Product Uses as Substitutes for Ozone Depleting Substances	NE			6 685.1	NE					6 685.1
2.G - Other Product Manufacture and Use			NE	NE	NE	84.7				84.7
2.H - Other	NA	NA	NA							NA
3 - Agriculture	2 561.7	1 351.4	46.6	0.0	0.0	0.0	1.4	53.2	0.0	52 744.4
3.A – Enteric fermentation		1 287.4								36 048.3

Table A VI. 2: Summary Energy sector emission table for South Africa for 2024.

Categories	Emissions (Gg)						Emissions (Gg CO ₂ e)
	CO ₂	CH ₄	N ₂ O	NOx	CO	NMVOcs	
1 - Energy	363 767	199,3	8,331	0	0	0	371 555
1.A - Fuel Combustion Activities	339 825,0	29,2	8,3	0	0	0	342 844,6
1.A.1 - Energy Industries	227 173	3,24	3	0	0	0	228 181
1.A.1.a - Main Activity Electricity and Heat Production	198 237	2	3	NE	NE	NE	199 114
1.A.1.a.i - Electricity Generation	198 237	2	3	NE	NE	NE	199 114
1.A.1.a.ii - Combined Heat and Power Generation (CHP)				NE	NE	NE	0
1.A.1.a.iii - Heat Plants				NE	NE	NE	0
1.A.1.b - Petroleum Refining	1 491	0	0	NE	NE	NE	1 493
1.A.1.c - Manufacture of Solid Fuels and Other Energy Industries	27 445	1	0	NE	NE	NE	27 574
1.A.1.c.i - Manufacture of Solid Fuels	27 445	1	0	NE	NE	NE	27 574
1.A.1.c.ii - Other Energy Industries	NE	NE	NE	NE	NE	NE	NE
1.A.2 - Manufacturing Industries and Construction	24 141	0	0	0	0	0	24 141
1.A.2.a - Iron and Steel	1 674	0	0	NE	NE	NE	1 674
1.A.2.b - Non-Ferrous Metals	366	0	0	NE	NE	NE	367
1.A.2.-ab - 1A2 Remainder	19 887	0	0	NE	NE	NE	19 887
1.A.2.c - Chemicals	IE	IE	IE	NE	NE	NE	IE
1.A.2.d - Pulp, Paper and Print	IE	IE	IE	NE	NE	NE	IE
1.A.2.e - Food Processing, Beverages and Tobacco	IE	IE	IE	NE	NE	NE	IE
1.A.2.f - Non-Metallic Minerals	IE	IE	IE	NE	NE	NE	IE
1.A.2.g - Transport Equipment	IE	IE	IE	NE	NE	NE	IE
1.A.2.h - Machinery	IE	IE	IE	NE	NE	NE	IE
1.A.2.i - Mining (excluding fuels) and Quarrying	IE	IE	IE	NE	NE	NE	IE
1.A.2.j - Wood and wood products	IE	IE	IE	NE	NE	NE	IE
1.A.2.k - Construction	IE	IE	IE	NE	NE	NE	IE

1.A.2.l - Textile and Leather	IE	IE	IE	IE	NE	NE	NE	NE	IE
1.A.2.m - Non-specified Industry	IE	IE	IE	IE	NE	NE	NE	NE	IE
1.A.3 - Transport	51 983	13	3	0	0	0	0	0	53 133
1.A.3.a - Civil Aviation	776	0	0	NE	NE	NE	NE	NE	781
1.A.3.a.i - International Aviation (International Bunkers)	2 311	0	0	NE	NE	NE	NE	NE	2 330
1.A.3.a.ii - Domestic Aviation	776	0	0	NE	NE	NE	NE	NE	781
1.A.3.b - Road Transportation	50 190	13	3	NE	NE	NE	NE	NE	51 289
1.A.3.b.i - Cars				NE	NE	NE	NE	NE	0
1.A.3.b.i.1 - Passenger cars with 3-way catalysts				NE	NE	NE	NE	NE	0
1.A.3.b.i.2 - Passenger cars without 3-way catalysts				NE	NE	NE	NE	NE	0
1.A.3.b.ii - Light-duty trucks				NE	NE	NE	NE	NE	0
1.A.3.b.ii.1 - Light-duty trucks with 3-way catalysts				NE	NE	NE	NE	NE	0
1.A.3.b.ii.2 - Light-duty trucks without 3-way catalysts				NE	NE	NE	NE	NE	0
1.A.3.b.iii - Heavy-duty trucks and buses				NE	NE	NE	NE	NE	0
1.A.3.b.iv - Motorcycles				NE	NE	NE	NE	NE	0
1.A.3.b.v - Evaporative emissions from vehicles				NE	NE	NE	NE	NE	0
1.A.3.b.vi - Urea-based catalysts				NE	NE	NE	NE	NE	0
1.A.3.c - Railways	410	0	0	NE	NE	NE	NE	NE	444
1.A.3.d - Water-borne Navigation	562	0	0	NE	NE	NE	NE	NE	567
1.A.3.d.i - International water-borne navigation (International bunkers)	1 545	0	0	NE	NE	NE	NE	NE	1 559
1.A.3.d.ii - Domestic Water-borne Navigation	562	0	0	NE	NE	NE	NE	NE	567
1.A.3.e - Other Transportation	46	0	0	NE	NE	NE	NE	NE	51
1.A.3.e.i - Pipeline Transport	46	0	0	NE	NE	NE	NE	NE	51
1.A.3.e.ii - Off-road	IE	IE	IE	NE	NE	NE	NE	NE	NE
1.A.4 - Other Sectors	18 502	1	0	0	0	0	0	0	18 517
1.A.4.a - Commercial/Institutional	11 820	0	0	NE	NE	NE	NE	NE	11 831
1.A.4.b - Residential	3 608	0	0	NE	NE	NE	NE	NE	3 608

1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	3 074	0	0	NE	NE	NE	NE	NE	3 078
1.A.4.c.i - Stationary	3 074	0	0	NE	NE	NE	NE	NE	3 078
1.A.4.c.ii - Off-road Vehicles and Other Machinery	IE	IE	IE	NE	NE	NE	NE	NE	NE
1.A.4.c.iii - Fishing (mobile combustion)	IE	IE	IE	NE	NE	NE	NE	NE	NE
1.A.5 - Non-Specified	18 026	12	2	0	0	0	0	0	18 873
1.A.5.a - Stationary	18 026	12	2	NE	NE	NE	NE	NE	18 873
1.A.5.b - Mobile				NE	NE	NE	NE	NE	0
1.A.5.b.i - Mobile (aviation component)	NE	NE	NE	NE	NE	NE	NE	NE	NE
1.A.5.b.ii - Mobile (water-borne component)	NE	NE	NE	NE	NE	NE	NE	NE	NE
1.A.5.b.iii - Mobile (Other)	NE	NE	NE	NE	NE	NE	NE	NE	NE
1.A.5.c - Multilateral Operations									0
1.B - Fugitive emissions from fuels	23 942	170	0,0176	0	0	0	0	0	28 711
1.B.1 - Solid Fuels	402	72		0	0	0	0	0	2 407
1.B.1.a - Coal mining and handling	17	63		NE	NE	NE	NE	NE	1 771
1.B.1.a.i - Underground mines	17	63		NE	NE	NE	NE	NE	1 771
1.B.1.a.i.1 - Mining	14	51		NE	NE	NE	NE	NE	1 436
1.B.1.a.i.2 - Post-mining seam gas emissions	3	12		NE	NE	NE	NE	NE	336
1.B.1.a.i.3 - Abandoned underground mines	NE	NE		NE	NE	NE	NE	NE	NE
1.B.1.a.i.4 - Flaring of drained methane or conversion of methane to CO ₂	NE	NE		NE	NE	NE	NE	NE	NE
1.B.1.a.ii - Surface mines	0	0		NE	NE	NE	NE	NE	0
1.B.1.a.ii.1 - Mining	0	0		NE	NE	NE	NE	NE	0
1.B.1.a.ii.2 - Post-mining seam gas emissions	0	0		NE	NE	NE	NE	NE	0
1.B.1.b - Uncontrolled combustion and burning coal dumps	NE	NE	NE	NE	NE	NE	NE	NE	NE
1.B.1.c - Solid fuel transformation	385	9	0	NE	NE	NE	NE	NE	NE
1.B.2 - Oil and Natural Gas	63	1	0	0	0	0	0	0	86
1.B.2.a - Oil	63	1	0	NE	NE	NE	NE	NE	86

1.B.2.a.i - Venting					NE	NE	NE	NE	NE	NE
1.B.2.a.ii - Flaring					NE	NE	NE	NE	NE	NE
1.B.2.a.iii - All Other					NE	NE	NE	NE	NE	0
1.B.2.a.iii.1 - Exploration					NE	NE	NE	NE	NE	0
1.B.2.a.iii.2 - Production and Upgrading					NE	NE	NE	NE	NE	0
1.B.2.a.iii.3 - Transport					NE	NE	NE	NE	NE	0
1.B.2.a.iii.4 - Refining					NE	NE	NE	NE	NE	0
1.B.2.a.iii.5 - Distribution of oil products					NE	NE	NE	NE	NE	0
1.B.2.a.iii.6 - Other					NE	NE	NE	NE	NE	0
1.B.2.b - Natural Gas					NE	NE	NE	NE	NE	0
1.B.2.b.i - Venting					NE	NE	NE	NE	NE	0
1.B.2.b.ii - Flaring					NE	NE	NE	NE	NE	0
1.B.2.b.iii - All Other					NE	NE	NE	NE	NE	0
1.B.2.b.iii.1 - Exploration					NE	NE	NE	NE	NE	0
1.B.2.b.iii.2 - Production					NE	NE	NE	NE	NE	0
1.B.2.b.iii.3 - Processing					NE	NE	NE	NE	NE	0
1.B.2.b.iii.4 - Transmission and Storage					NE	NE	NE	NE	NE	0
1.B.2.b.iii.5 - Distribution					NE	NE	NE	NE	NE	0
1.B.2.b.iii.6 - Other					NE	NE	NE	NE	NE	0
1.B.3 - Other emissions from Energy Production	23 477	98	0	0	0	0	0	0	0	26 214
1.C - Carbon dioxide Transport and Storage	0				0	0	0	0	0	0
1.C.1 - Transport of CO₂	0				0	0	0	0	0	0
1.C.1.a - Pipelines	NE				NE	NE	NE	NE	NE	NE
1.C.1.b - Ships	NE				NE	NE	NE	NE	NE	NE
1.C.1.c - Other (please specify)	NE				NE	NE	NE	NE	NE	NE
1.C.2 - Injection and Storage	0				0	0	0	0	0	0

1.C.2.a - Injection	NE			NE	NE	NE	NE	NE	NE
1.C.2.b - Storage	NE			NE	NE	NE	NE	NE	NE
1.C.3 - Other	0			0	0	0	0	0	0

Table A VI. 3: Summary IPU sector emission table for South Africa for 2024

Categories	Emissions (Gg)											Emissions (Gg CO ₂ e)
	CO ₂	CH ₄	N ₂ O	HFCs	PFCs	SF ₆	NO _x	CO	NM ₂ VOC	SO ₂		
2. Industrial processes and product use	23 029.6	4.2	1.3	6 685.1	113.0	84.7	0.0	0.0	0.0	0.0		30 371.6
2A Mineral Industry	4 956.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		4 956.1
2A1 Cement production	3 846.0						NE	NE	NE	NE		3 846.0
2A2 Lime production	799.1						NE	NE	NE	NE		799.1
2A3 Glass Production	177.3						NE	NE	NE	NE		177.3
2A4 Other Process Uses of Carbonates	133.6						NE	NE	NE	NE		133.6
2A4a Ceramics							NE	NE	NE	NE		NE
2A4b Other Uses of Soda Ash							NE	NE	NE	NE		NE
2A4c Non Metallurgical Magnesia Production							NE	NE	NE	NE		NE
2A4d Other (please specify) (3)							NE	NE	NE	NE		NE
2A5 Other (please specify) (3)	NE						NE	NE	NE	NE		NE
2B Chemical Industry	1 290.6	4.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1 749.8
2B1 Ammonia Production	C	C					NE	NE	NE	NE		C
2B2 Nitric Acid Production			C				NE	NE	NE	NE		C
2B3 Adipic Acid Production			NE				NE	NE	NE	NE		NE
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production			NE				NE	NE	NE	NE		NE
2B5 Carbide Production	C	NE					NE	NE	NE	NE		C
2B6 Titanium Dioxide Production	C						NE	NE	NE	NE		C
2B7 Soda Ash Production	C						NE	NE	NE	NE		C
2B8 Petrochemical and Carbon Black Production	C	C	NE	NE	NE	NE	NE	NE	NE	NE		C
2B8a Methanol	C	C					NE	NE	NE	NE		C
2B8b Ethylene	C	C					NE	NE	NE	NE		C
2B8c Ethylene Dichloride and Vinyl Chloride Monomer	NO	NO					NO	NO	NO	NO		NO
2B8d Ethylene Oxide	C	C					NE	NE	NE	NE		C

2B8e Acrylonitrile	NO	NO						NO	NO	NO	NO	NO	NO
2B8f Carbon Black	C	C						NE	NE	NE	NE	NE	C
2B8g Hydrogen Production	C	C						NE	NE	NE	NE	NE	C
2B9 Fluorochemical Production	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2B9a By-product emissions (4)				NE				NE	NE	NE	NE	NE	NE
2B9b Fugitive Emissions (4)								NE	NE	NE	NE	NE	NE
2B10 Other (Please specify) (3)								NE	NE	NE	NE	NE	0.0
2C Metal Industry	15 605.2	0.0	0.0	0.0	113.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15 718.3
2C1 Iron and Steel Production	6 894.0	0.0						NE	NE	NE	NE	NE	6 894.0
2C2 Ferroalloys Production	6 942.5	0.0						NE	NE	NE	NE	NE	6 942.5
2C3 Aluminium production	C				C			NE	NE	NE	NE	NE	C
2C4 Magnesium production (5)	NO					NO		NO	NO	NO	NO	NO	NO
2C5 Lead Production	7.7							NE	NE	NE	NE	NE	7.7
2C6 Zinc Production	501.9							NE	NE	NE	NE	NE	501.9
2C7 Other (please specify) (3)	0.0							NE	NE	NE	NE	NE	0.0
2D Non-Energy Products from Fuels and Solvent Use (6)	1 177.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 177.7
2D1 Lubricant Use	461.9							NE	NE	NE	NE	NE	461.9
2D2 Paraffin Wax Use	715.8							NE	NE	NE	NE	NE	715.8
2D3 Solvent Use (7)								NE	NE	NE	NE	NE	0.0
2D4 Other (please specify) (3), (8)								NE	NE	NE	NE	NE	0.0
2E Electronics Industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2E1 Integrated Circuit or Semiconductor (9)				NE				NE	NE	NE	NE	NE	NE
2E2 TFT Flat Panel Display (9)					NE			NE	NE	NE	NE	NE	NE
2E3 Photovoltaics (9)								NE	NE	NE	NE	NE	NE
2E4 Heat Transfer Fluid (10)								NE	NE	NE	NE	NE	NE
2E5 Other (please specify) (3)								NE	NE	NE	NE	NE	NE
2F Product Uses as Substitutes for Ozone Depleting Substances	0.0	0.0	0.0	0.0	0.0	0.0	6 685.1	0.0	0.0	0.0	0.0	0.0	6 685.1
2F1 Refrigeration and Air Conditioning	0.0	0.0	0.0	0.0	NE	NE	6 577.2	NE	NE	NE	NE	NE	6 577.2
2F1a Refrigeration and Stationary Air Conditioning							6 577.2		NE	NE	NE	NE	6 577.2

[illegible]

Table A VI. 4: Summary Agriculture sector emission table for South Africa for 2024

	Emissions						Total emissions
	(Gg)						
	CO ₂	CH ₄	N ₂ O	NOx	CO	NMVOCs	(Gg CO ₂ e)
3 - Agriculture	2 561.7	1 380.1	11.54	1 095.3	100.9	53.4	52 744.4
3.A - Enteric Fermentation	0.0	1 287.4	0.0	0.0	0.0	0.0	36 048.3
3.A.1 - Cattle		996.4					27 900.1
3.A.1.a - Dairy Cows		128.9					3 609.0
3.A.1.b - Other Cattle		867.5					24 291.0
3.A.2 - Sheep		225.5					6 313.1
3.A.3 - Swine		1.5					42.5
3.A.4 - Other							
3.A.4.a- Buffalo		NO					NO
3.A.4.b - Camels		NO					NO
3.A.4.d - Goats		56.3					1 577.1
3.A.4.e - Horses		6.1					170.3
3.A.4.f - Mules and Asses		1.6					45.2
3.B - Manure Management	0.0	51.9	8.8	0.0	0.0	0.0	4 399.8
3.B.1 - Cattle		44.0	4.3				2 369.5
3.B.1.a - Dairy Cows		19.9	0.8				770.4
3.B.1.b - Other Cattle		24.2	3.5				1 599.2
3.B.2 - Sheep		3.2	0.6				246.8
3.B.3 - Swine		7.3	0.1				229.3
3.B.4 - Other							
3.B.4.a Buffalo		NO	NO				NO
3.B.4.b Camels		NO	NO				NO
3.B.4.d - Goats		1.0	0.2				76.4
3.B.4.e - Horses		NO	NO				NO
3.B.4.f - Mules and Asses		NO	NO				NO
3.B.4.g - Poultry		6.8	3.6				1 144.7
3.B.5 - Indirect N ₂ O emissions			1.3				333.0

3.C - Rice cultivation	NE	NE	NE	NE	NE	NE	NE	NE
3.D - Agricultural soils	0.0	39.2	2.7	1 093.9	47.7	53.4	9 680.2	NE
3.D.1-Direct N ₂ O Emissions from managed soils			30.8				8 166.5	
3.D.2-Indirect N ₂ O Emissions from managed soils			5.7				1 513.7	
3.E - Prescribed burning of savannas	IE	IE	IE				IE	
3.F-Field burning of agricultural residues	IE	1.6	0.04	1.4	53.2	NE	54.5	
3.G - Liming	1 890.95						1 890.95	
3.H - Urea application	670.8						670.8	
3.I - Other carbon containing fertilisers	NE	NE	NE				NE	
3.J - Other	NO	NO	NO				NO	

Table A VI. 5: Summary LULUCF sector emission table for South Africa for 2024

	Emissions						Total emissions (Gg CO ₂ e)
	(Gg)						
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOCs	
4 - LULUCF	-37 583.65	105.03	4.64	47.97	876.75	78.89	-33 411.95
4.A - Forest land	-55 743.95	14.24	1.16	17.56	368.24	51.58	-55 036.66
4.A.1 - Forest land Remaining Forest land	8 118.34	8.10	0.53	7.57	196.94	40.61	8 486.16
4.A.2 - Land Converted to Forest land	-63 862.29	6.14	0.63	10.00	171.30	10.97	-63 522.82
4.A.2.a - Cropland converted to Forest Land	-3 417.30	0.20	0.02	0.32	5.54	0.37	-3 407.05
4.A.2.b - Grassland converted to Forest Land	-57 097.62	5.63	0.58	9.22	157.36	9.83	-56 785.79
4.A.2.c - Wetlands converted to Forest Land	-850.65	0.07	0.01	0.08	1.75	0.26	-846.97
4.A.2.d - Settlements converted to Forest Land	-1 008.90	0.10	0.01	0.14	2.67	0.25	-1 003.14
4.A.2.e - Other Land converted to Forest Land	-1 487.82	0.14	0.01	0.23	3.98	0.25	-1 479.87
4.B - Cropland	8 083.92	2.53	0.59	0.09	3.24	0.27	8 311.11
4.B.1 - Cropland Remaining Cropland	265.59	2.51	0.00	0.07	2.74	0.23	336.46
4.B.2 - Land Converted to Cropland	7 818.33	0.01	0.59	0.01	0.50	0.04	7 974.65
4.B.2.a - Forest Land converted to Cropland	5 450.45	0.01	0.23	0.01	0.30	0.03	5 512.55
4.B.2.b - Grassland converted to Cropland	2 275.52	0.00	0.34	0.00	0.17	0.01	2 365.12
4.B.2.c - Wetlands converted to Cropland	33.47	0.00	0.00	0.00	0.02	0.00	34.59
4.B.2.d - Settlements converted to Cropland	20.66	0.00	0.00	0.00	0.00	0.00	21.72
4.B.2.e - Other Land converted to Cropland	38.24	0.00	0.01	0.00	0.01	0.00	40.68
4.C - Grassland	3 047.52	18.54	1.33	24.41	406.80	21.89	3 917.92
4.C.1 - Grassland Remaining Grassland	-15 342.11	14.55	0.95	17.65	294.14	15.85	-14 682.78
4.C.2 - Land Converted to Grassland	18 389.63	3.99	0.38	6.76	112.65	6.04	18 600.70
4.C.2.a - Forest Land converted to Grassland	36 486.15	2.96	0.28	5.01	83.56	4.39	36 642.49
4.C.2.b - Cropland converted to Grassland	-1 672.66	0.24	0.02	0.40	6.74	0.36	-1 660.21
4.C.2.c - Wetlands converted to Grassland	-144.45	0.16	0.02	0.27	4.49	0.24	-135.94
4.C.2.d - Settlements converted to Grassland	-442.87	0.12	0.01	0.21	3.45	0.18	-436.37
4.C.2.e - Other Land converted to Grassland	-15 836.54	0.51	0.05	0.86	14.41	0.87	-15 809.27
4.D - Wetlands	106.81	69.00	0.25	4.67	77.75	4.07	2 105.25

4.D.1 - Wetlands Remaining Wetlands	-20.01	10.04	0.18	3.37	56.24	2.94	309.27
4.D.2 - Land Converted to Wetlands	126.82	58.95	0.07	1.29	21.52	1.13	1 795.98
4.D.2.c.i - Forest Land converted to wetlands	398.67	10.84	0.02	0.29	4.91	0.26	706.53
4.D.2.c.ii - Cropland converted to wetlands	-27.43	2.54	0.00	0.09	1.49	0.08	45.01
4.D.2.c.iii - Grasslands converted to wetlands	-210.24	26.56	0.05	0.84	13.97	0.73	545.54
4.D.2.c.iv - Settlements converted to wetlands	-5.83	2.54	0.00	0.02	0.41	0.02	65.76
4.D.2.c.v - Other Land converted to wetlands	-28.35	16.46	0.00	0.04	0.74	0.04	433.14
4.E - Settlements	-1 452.75	0.73	0.40	1.24	20.73	1.08	-1 325.73
4.E.1 - Settlements Remaining Settlements	-3 101.65	0.60	0.39	1.02	17.05	0.89	-2 981.43
4.E.2 - Land Converted to Settlements	1 648.91	0.13	0.01	0.22	3.68	0.19	1 655.69
4.E.2.a - Forest Land converted to Settlements	1 224.27	0.05	0.00	0.09	1.46	0.08	1 226.97
4.E.2.b - Cropland converted to Settlements	606.92	0.01	0.00	0.02	0.33	0.02	607.53
4.E.2.c - Grassland converted to Settlements	-166.86	0.06	0.01	0.11	1.77	0.09	-163.60
4.E.2.d - Wetlands converted to Settlements	20.38	0.00	0.00	0.00	0.02	0.00	20.42
4.E.2.e - Other Land converted to Settlements	-35.80	0.00	0.00	0.01	0.09	0.00	-35.63
4.F - Other Land	10 093.11	0.00	0.91	0.00	0.00	0.00	10 334.48
4.F.1 - Other land Remaining Other land	NO	NO	NO	NO	NO	NO	NO
4.F.2 - Land Converted to Other land	10 093.11	NO	0.91	NO	NO	NO	10 334.48
4.F.2.a - Forest Land converted to Other Land	1 744.62	NO	0.01	NO	NO	NO	1 747.61
4.F.2.b - Cropland converted to Other Land	15.71	NO	0.00	NO	NO	NO	16.69
4.F.2.c - Grassland converted to Other Land	7 549.48	NO	0.75	NO	NO	NO	7 749.56
4.F.2.d - Wetlands converted to Other Land	749.94	NO	0.14	NO	NO	NO	786.30
4.F.2.e - Settlements converted to Other Land	33.34	NO	0.00	NO	NO	NO	34.32
4.G - Harvested wood products	-1 718.31	NA	NA	NA	NA	NA	-1 718.31

Table A VI. 6: Summary Waste sector emission table for South Africa for 2024

Categories	Emissions [Gg]							Total emissions (Gg CO ₂ e)
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOCs	SO ₂	
5 - Waste	37.05	628.95	6.03	NE	NE	NE	NE	19 244.71
5A - Solid Waste Disposal		263.46		NE	NE	NE	NE	7 376.74
5A1 - Managed Waste Disposal Sites		263.46		NE	NE	NE	NE	7 376.74
5A2 - Unmanaged Waste Disposal Sites		NE		NE	NE	NE	NE	NE
5A3 - Uncategorised Waste Disposal Sites		NE		NE	NE	NE	NE	NE
5B - Biological Treatment of Solid Waste		64.04	3.12	NE	NE	NE	NE	2 620.15
5C - Incineration and Open Burning of Waste	37.05	5.97	0.14	NE	NE	NE	NE	240.80
5C1 - Waste Incineration	NE	NE	NE	NE	NE	NE	NE	NE
5C2 - Open Burning of Waste	37.05	5.97	0.14	NE	NE	NE	NE	240.80
5D - Wastewater Treatment and Discharge	0.00	295.47	2.77	NE	NE	NE	NE	9 007.02
5D1 - Domestic Wastewater Treatment and Discharge		126.89	2.77	NE	NE	NE	NE	4 286.59
5D2 - Industrial Wastewater Treatment and Discharge		168.59		NE	NE	NE	NE	4 720.43
5E - Other (please specify)				NE	NE	NE	NE	NE



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Annex VII: Supplementary information to facilitate tracking progress on implementation and achievement of South Africa's NDC

The following information is provided to facilitate tracking progress of South Africa's NDC. South Africa's updated NDC (2025) contains Information for Clarity, Transparency and Understanding in Table 3, numbered according to Annex I of decision 4/CMA.1. entry 5(a) in Table 4, that specifies that:

"Progress and achievement will be accounted for by comparing the target ranges in 2035 with the annual emissions contained in South Africa's GHG inventory for all sectors, excluding emissions arising from natural disturbances in the land sector. Emissions arising from natural disturbances will be disaggregated in the NID for each relevant IPCC category and reported separately, and used as the basis for accounting for implementation and achievement of the NDC targets."

Natural disturbances are estimated in South Africa's national GHG inventory in the LULUCF sector. Natural disturbance includes losses/gains due to wildfires as well as losses/gains due to non-anthropogenic disturbances in forest plantations. It is included for *Forest lands* (4A), *Grasslands* (4C), *Wetlands* (4D) and *Settlements* (4E). The methodology is described in sections 6.6 to 6.11 and the approach to natural disturbance is described in section 6.5.1.

The separation of controlled fires from wildfires has started to be included in this inventory based on data that has become available. The portion of burnt area allocated to controlled fires is likely larger than currently estimated, but these numbers will be updated once more data becomes available. Note that the emissions due to fires (wildfires and controlled) includes the loss of carbon due to vegetation disturbance losses as well as the non-CO₂ emissions.

GHG emissions from natural disturbances, as well as total GHG emissions including land use, with and without natural disturbances, are contained in Table A VII. 1.

Table A VII. 1: GHG emissions from natural disturbances, and total GHG emissions (including land use) with and without natural disturbances.

	2023	2024


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GHG emissions from natural disturbances	34 136.21 Gg CO ₂ e	15 794.13 Gg CO ₂ e
Total LULUCF emissions INCLUDING emissions from natural disturbances	-12 678.94 Gg CO ₂ e	-33 411.95 Gg CO ₂ e
Total LULUCF emissions EXCLUDING emissions from natural disturbances	-46 815.15 Gg CO ₂ e	-49 794.13 Gg CO ₂ e