

DEPARTMENT OF FORESTRY, FISHERIES AND THE ENVIRONMENT

NO. 2321

29 July 2022

CONSULTATION ON THE DRAFT 8th NATIONAL GREENHOUSE GAS INVENTORY REPORT FOR THE REPUBLIC OF SOUTH AFRICA

I, Barbara Dallas Creecy, Minister of Forestry, Fisheries and the Environment, hereby consult on the draft 8th National Greenhouse Gas Inventory Report, for public comment, as set out in the Schedule hereto.

The National Greenhouse Gas Inventory Report will eventually form part of the Fifth Biennial Update Report to the United Nations Framework Convention on Climate Change (UNFCCC). South Africa is required by the UNFCCC to provide in its national inventory, on gas-by-gas basis, and its units' mass, estimates of anthropogenic emissions of carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), by sources and removals by sinks. An accurate, complete and updated greenhouse gas emissions inventory is a good foundation for effective mitigation responses.

Members of the public are invited to submit to the Minister, within 30 days from the date of the publication of this Notice, 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 email to: GHGreporting@environment.gov.za

By hand at: Environment House, 473 Steve Biko Road, Arcadia, Pretoria, 0083.

Any inquiries in connection with the draft notice can be directed to Mr Jongikhaya Witi at Tel: 012 399 9151 or by email at Jwiti@dfre.gov.za

The draft 8th National Greenhouse Gas Inventory Report is also available at the following website
https://www.dffe.gov.za/legislation/gazetted_notices

Comments received after the closing date may not be considered.


BARBARA DALLAS CREECY
MINISTER OF FORESTRY, FISHERIES AND THE ENVIRONMENT

NATIONAL GHG INVENTORY REPORT

SOUTH AFRICA

2000 - 2020

2022



Acknowledgements

Many people and institutes were involved in the compilation of this National Greenhouse Gas Inventory Report for 2020 (NIR). We greatly appreciate all the contributions from organizations and individuals who were involved in the process of completing this NIR. Special thanks to Gesellschaft für Internationale Zusammenarbeit ((GIZ) GmbH) for providing funding for the compilation of the AFOLU sector inventory and the overall NIR. We would also like to thank all reviewers of the various sector sections as well as the reviewers of the completed NIR.



Report compilation details

Report compilation: Luanne Stevens

Internal Report Reviewers: Jongikhaya Witi, Sindisiwe Mashele, Rumbidzai Zireva, Hendrik Louw

External report reviewers:

Lead sector compilers and technical contributors

Energy sector

Mamahloko Senatla Jaane (DFFE)

IPPU sector

Farryn Moodley (DFFE)

AFOLU sector

Luanne Stevens (Gondwana Environmental Solutions)

Jared Lodder (Gondwana Environmental Solutions)

Elanie van Staden (Gondwana Environmental Solutions)

Sewela Malaka (DFFE)

Waste sector

Phindile Mangwana (DFFE)



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
CFC	Chlorofluorocarbons
CH ₄	Methane
CO	Carbon monoxide
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
CRF	Common reporting format
DALRRD	Department of Agriculture, Land Reform and Rural Development
DFFE	Department of Forestry, Fisheries and the Environment
DFID	Department for International Development
DM	Dry matter
DMD	Dry matter digestibility
DMRE	Department of Mineral Resources and Energy
DoE	Department of Energy
DOM	Dead organic matter
DTIC	Department of Trade, Industry and Competition
DWAS	Department of Water Affairs and Sanitation
DWAF	Department of Water Affairs and Forestry
EF	Emission factor
F-gases	Flourinated gases: e.g., HFC, PFC, SF ₆ and NF ₃
FOD	First order decay
FOLU	Forestry and Other Land Use
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
ISWC	Institute of Soil, Water and Climate
KCA	Key category analysis
LC	Land cover
LPG	Liquefied petroleum gas
LTO	Landing/take off
MCF	Methane conversion factor
MEF	Manure emission factor
MW	Megawatt
MWH	Megawatt hours
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
NE	Not estimated
NERSA	National Energy Regulator of South Africa
NGHGIS	National Greenhouse Gas Inventory System
NIR	National Greenhouse Gas Inventory Report
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
SAGERS	South African GHG Emissions Reporting System
SAISA	South African Iron and Steel Institute
SAMI	South African Minerals Industry
SAPIA	South African Petroleum Industry Association
SAR	Second Assessment Report
SASQF	South African Statistical Quality Assurance Framework
SADC	Southern African Development Community
SF ₆	Sulphur hexafluoride
SNE	Single National Entity
SOC	Soil organic carbon
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

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 (DFFE, 2009), a decision was made to use the recently published 2006 IPCC Guidelines (IPCC, 2006) to enhance accuracy and transparency, and to familiarise researchers with the latest inventory preparation guidelines. Following these guidelines, in 2014 the GHG inventory for the years 2000 to 2010 were compiled (DFFE, 2014). An update was completed for 2011 and 2012 in 2016 (DFFE, 2016), for 2013 to 2015 in 2019 (DFFE, 2019), and 2017 in 2020 (DFFE, 2020).

This report documents South Africa's submission of its national greenhouse gas inventory for the year 2020. It also reports on the GHG trends for the period 2000 to 2020. It is in accordance with the guidelines provided by the UNFCCC and follows the 2006 IPCC Guidelines (IPCC, 2006) and IPCC Good Practice Guidance (GPG) (IPCC, 2000; IPCC, 2003; IPCC, 2014). 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. Quality assurance for this GHG inventory was undertaken by independent reviewers.

E.S.1.2. Institutional arrangements for inventory preparation

The 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 2000 – 2020 GHG emissions inventory.

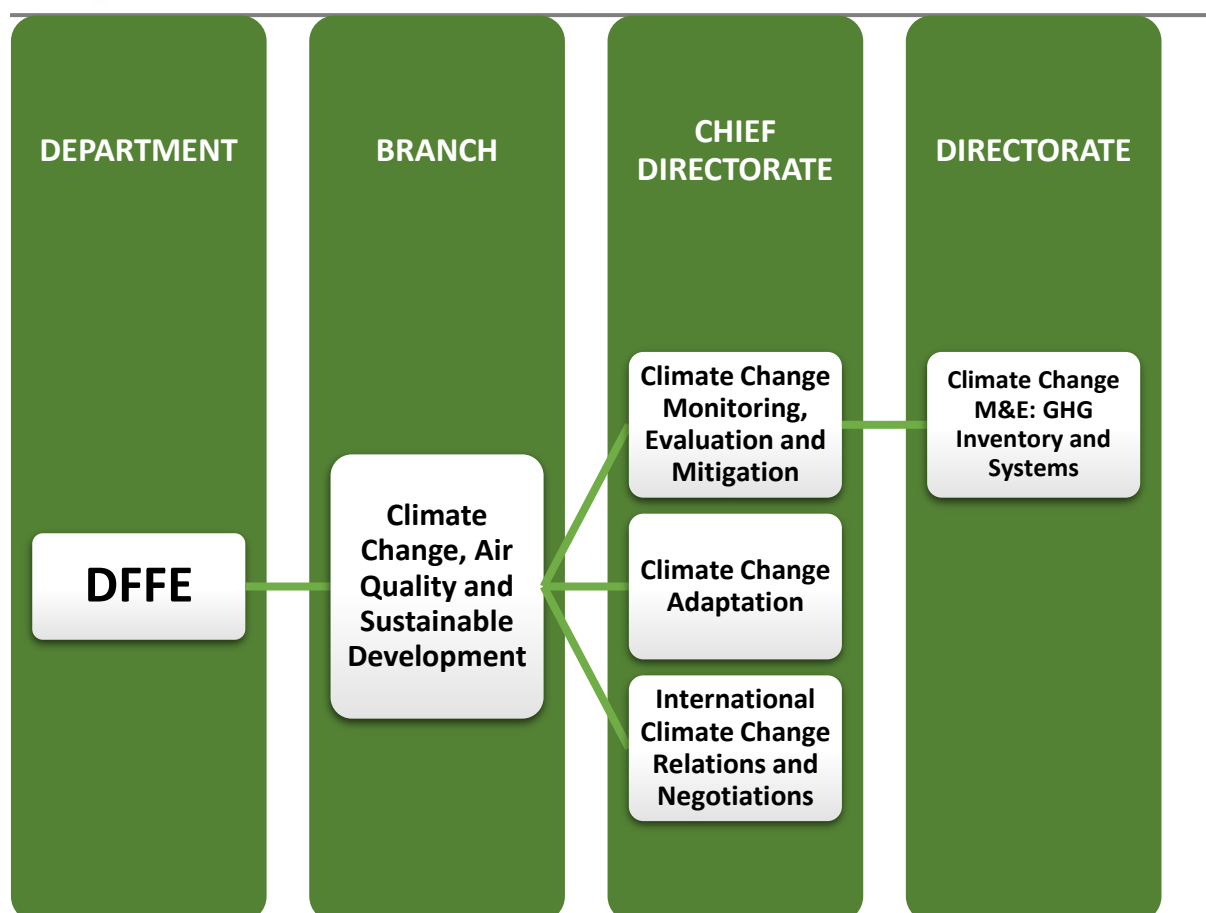


Figure ES 1: Institutional arrangements for the compilation of the 2000 – 2020 inventory for South Africa.

E.S.1.3. Organisation of report

This report follows a standard NIR format in line with the UNFCCC Reporting Guidelines (UNFCCC, 2013). 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 6 deal with detailed explanations of the emissions in the energy, IPPU, AFOLU 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.



E.S.2. Summary of national emission and removal trends

GWP

In this inventory the Second Assessment Report (SAR) (IPCC, 1996) GWP's were applied. This is consistent with the previous inventory for 2017 (DFFE, 2020) and is compliant with UNFCCC reporting requirements. For purposes of comparison with past inventories, and due to the use of the Third Assessment Report (TAR) (IPCC, 2011) GWP's in other national regulations, the emissions based on TAR GWP's are also provided (Table ES 1) in this section (National trends) of the executive summary. All text references, tables and graphs throughout the report refer to the SAR GWP estimates, unless it is otherwise stated to be a TAR GWP estimate.

Table ES 1: Trends in national GHG emissions (excluding and including FOLU) between 2000 and 2020.

	SAR GWP		TAR GWP	
	Emissions (excl. FOLU)	Emissions (incl. FOLU)	Emissions (excl. FOLU)	Emissions (incl. FOLU)
	Gg CO ₂ e			
2000	473 832.0	446 275.1	478 152.9	450 720.9
2001	477 829.9	459 267.7	482 143.7	463 704.9
2002	490 217.2	474 804.4	494 512.3	479 221.4
2003	509 430.2	484 580.7	513 753.8	489 024.6
2004	524 219.1	508 618.9	528 527.5	513 046.0
2005	521 031.4	523 147.3	525 378.7	527 611.7
2006	516 757.5	516 075.9	521 103.5	520 537.5
2007	549 009.1	544 506.3	553 426.6	549 037.9
2008	546 098.9	552 774.2	550 584.7	557 372.6
2009	572 564.3	559 066.0	577 006.7	563 619.3
2010	534 371.9	528 151.2	538 896.3	532 785.0
2011	532 753.5	519 674.2	537 144.3	524 173.0
2012	544 986.3	532 244.6	549 515.5	536 880.1
2013	543 858.5	521 372.8	548 514.2	526 133.2
2014	522 711.2	505 406.7	527 382.8	510 181.5
2015	524 105.8	497 766.3	528 805.9	502 568.1
2016	521 212.5	481 348.5	525 879.6	486 115.7
2017	519 378.9	494 461.0	524 061.4	499 242.1
2018	515 053.3	492 198.6	519 692.8	496 935.0
2019	511 780.4	483 542.5	516 980.3	488 837.8



2020

478 634.1

445 565.6

483 672.7

450 698.0

E.S.3. Overview of source and sink category emission estimates and trends

E.S.3.1. Gas trends

Carbon dioxide

The gas contributing the most to South Africa's emissions (excl. FOLU) was CO₂, and this contribution has decreased from 83.3% to 81.7% between 2000 and 2020 (Figure ES 2). The CO₂ emissions totalled 391 021 Gg CO₂ (excl. FOLU) and 356 324 Gg CO₂ (incl. FOLU) in 2020 (Table ES 2). The *Energy* sector is by far the largest contributor to CO₂ emissions in South Africa, contributing an average of 92.0% between 2000 and 2020, and 95.2% in 2020. The categories *1A1 energy industries* (60.2%), and *1A3 Transport* (12.1%) were the major contributors to the CO₂ emissions in 2020. The *IPPU* sector contribution an average of 7.7% between 2000 and 2020, while the *AFOLU* sector (excl. FOLU) contributed an average of 0.3%.

Methane

The contribution from methane has increased from 11.9% to 12.7% between 2000 and 2020 (Figure ES 2). National CH₄ emissions (excl. FOLU) increased from 56 460 Gg CO₂e (2 689 Gg CH₄) in 2000 to 60 632 Gg CO₂e (2 887 Gg CH₄) in 2020. In the *Land* sector wetlands contributed an additional 1 193 Gg CO₂e (56.8 Gg CH₄) to the total CH₄, pushing the total CH₄ (incl. FOLU) to 61 825 Gg CO₂e. The *AFOLU livestock* category and *Waste* sectors were the major contributors, providing 48.8% and 36.5%, respectively, to the total CH₄ emissions in 2020.

Nitrous oxide

Nitrous oxide contribution to the emissions (excl. FOLU) increased from 4.6% in 2000 to 4.6% in 2020 (Figure ES 2). The emissions (excl. FOLU) were 21 927 Gg CO₂e (70.7 Gg N₂O) in 2020 and 22 364 Gg CO₂e (72.1 Gg N₂O) including FOLU (Table ES 2). The categories *3C Aggregated and non-CO₂ sources on land* (which includes emissions from managed soils and biomass burning) and *3A Livestock* are the main contributors to N₂O. Livestock manure, urine and dung inputs to managed soils provided the largest N₂O contribution in the *AFOLU* sector therefore the trend follows a similar pattern to the



livestock population. N₂O emissions from IPPU declined by 82.2% between 2000 and 2017, but then increased again in 2018. The increase between 2018 and 2020 is due to improved data through the GHG Reporting Regulation.

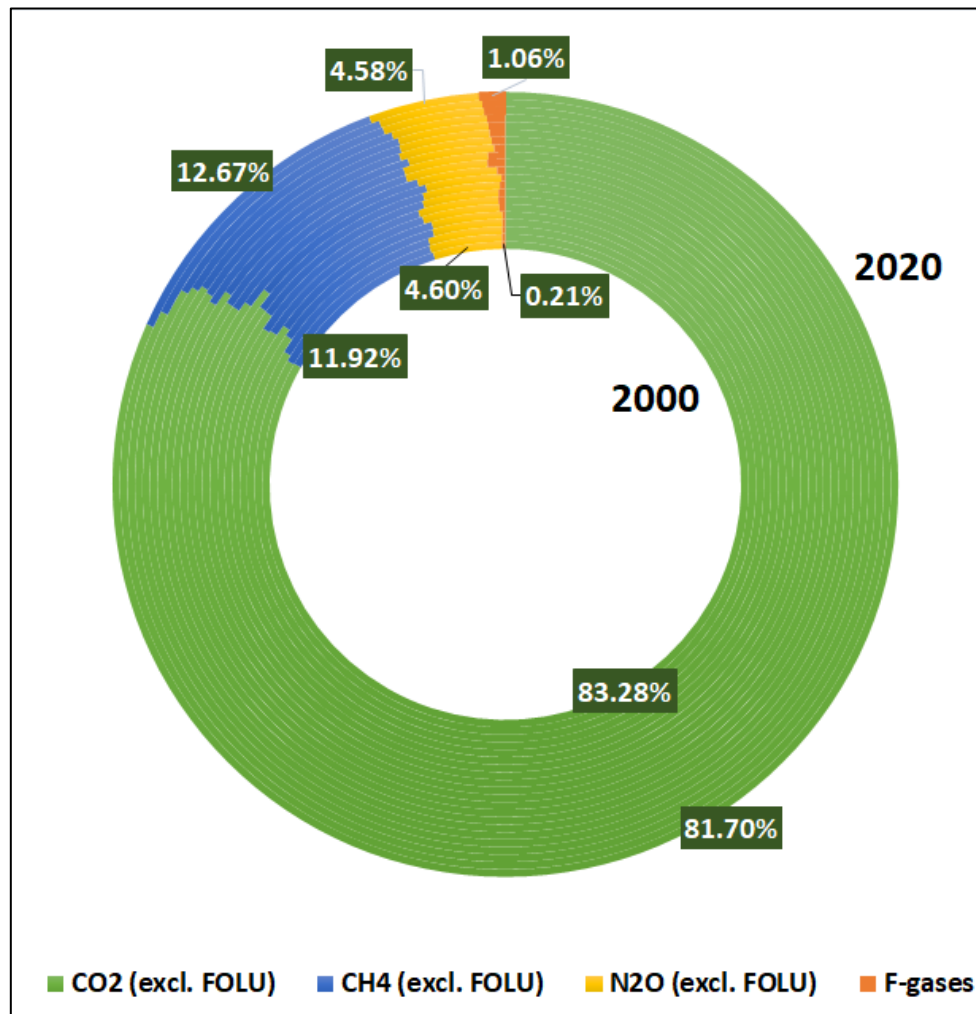


Figure ES 2: Gas contribution to South Africa's emissions (excl. FOLU) between 2000 and 2020.

F-gases

F-gas emission estimates varied annually and contributed 1.1% to overall emissions (excl. FOLU) in 2020 (Figure ES 2). 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.



PFC emissions were estimated at 983 Gg CO₂e in 2000. This increased to 1 979 Gg CO₂e in 2012, then declined to 120 Gg CO₂e in 2020. This increase is, however, due mostly to the incorporation of new sources at intervals across this time series as opposed to a true increase. PFCs are produced during the production of aluminium. In 2000 only PFC's were estimated, and in 2005 HFC emissions from ODS were included. From 2011 onwards the HFC emissions from *mobile air conditioning, fire protection, foam blowing agents* and *aerosols* were also incorporated. In 2020 HFCs contributed 97.6% to the total F-gas emissions. HFCs increased from 1 713 Gg CO₂e in 2005 to 4 933 Gg CO₂e in 2020, and the largest contributor is HFC-134a.

Table ES 2: Trend in gas emissions between 2000 and 2020 including FOLU.

	Emissions					
	CO ₂ (incl. FOLU)	CH ₄ (incl. FOLU)		N ₂ O (incl. FOLU)		F-gases
	Gg CO ₂	Gg CO ₂ e	Gg CH ₄	Gg CO ₂ e	Gg N ₂ O	Gg CO ₂ e
2000	364 858.9	58 047.6	2 764.2	22 385.5	72.2	983.2
2001	376 948.2	58 279.2	2 775.2	23 032.6	74.3	1 007.7
2002	392 325.6	58 171.7	2 770.1	23 410.0	75.5	897.1
2003	403 529.2	57 906.3	2 757.4	22 249.0	71.8	896.2
2004	427 324.2	57 864.7	2 755.5	22 540.6	72.7	889.4
2005	438 886.6	58 805.0	2 800.2	23 742.3	76.6	1 713.4
2006	431 975.9	58 239.1	2 773.3	23 880.0	77.0	1 980.9
2007	459 869.3	59 250.7	2 821.5	23 352.3	75.3	2 034.1
2008	468 780.6	59 450.1	2 831.0	22 969.9	74.1	1 573.6
2009	475 982.1	58 823.2	2 801.1	23 160.5	74.7	1 100.3
2010	444 619.3	59 008.7	2 809.9	22 319.5	72.0	2 203.7
2011	433 657.9	59 019.1	2 810.4	22 311.9	72.0	4 685.2
2012	444 380.7	60 320.1	2 872.4	23 037.0	74.3	4 506.8
2013	435 866.7	59 822.3	2 848.7	22 831.3	73.6	2 852.5
2014	419 087.0	59 984.7	2 856.4	23 046.8	74.3	3 288.2
2015	412 604.8	59 428.3	2 829.9	22 030.5	71.1	3 702.7
2016	397 328.9	58 599.7	2 790.5	21 534.2	69.5	3 885.7
2017	409 373.2	58 771.6	2 798.6	22 168.3	71.5	4 148.0
2018	406 098.5	58 517.6	2 786.6	23 126.6	74.6	4 455.9
2019	391 892.3	64 022.3	3 048.7	22 857.1	73.7	4 770.8
2020	356 323.5	61 824.6	2 944.0	22 364.0	72.1	5 053.5

E.S.3.2. GHG precursors



Carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic carbons (NMVOCs) were estimated from biomass burning only. CO emissions varied between 545 Gg CO to 1 680 Gg CO between 2000 and 2020. The NO_x emissions were between 25 Gg NO_x and 77 Gg NO_x, while NMVOCs were between 30 Gg NMVOCs and 85 Gg NMVOCs over the period 2000 to 2020. There is annual variability because the emissions include wildfires as well as controlled fires.

E.S.3.3. Sectoral trends

Energy

2020

Total emissions from the *Energy* sector for 2020 were estimated to be 380 033 Gg CO_{2e} (Table ES 3) which is 79.4% of the total emissions (excl. FOLU) for South Africa (Figure ES 2). *Energy industries* were the main contributor, accounting for 62.3% of emissions from the *Energy* sector. This was followed by *Transport* (12.7%) and *Manufacturing industries and construction* (8.7%).

Table ES 3: Sectoral trends in emissions for South Africa between 2000 and 2020.

	Energy	IPPU	AFOLU (excl. FOLU)	AFOLU (incl. FOLU)	Waste
	Emissions (Gg CO _{2e})				
2000	371 261.2	32 955.2	51 374.3	23 817.5	18 241.2
2001	374 055.3	33 220.9	52 210.1	33 648.0	18 343.6
2002	384 221.8	35 204.1	52 224.8	36 812.0	18 566.4
2003	405 081.0	34 506.9	51 039.1	26 189.6	18 803.2
2004	419 944.6	34 617.1	50 798.5	35 198.3	18 858.8
2005	412 391.2	37 825.5	51 729.2	53 845.0	19 085.5
2006	406 869.6	38 900.2	51 691.7	51 010.1	19 295.9
2007	434 275.9	42 498.8	52 732.7	48 229.9	19 501.8
2008	432 693.7	40 354.6	53 308.5	59 983.8	19 742.1
2009	460 985.8	38 815.7	53 030.5	39 532.2	19 732.3
2010	426 365.1	35 452.1	52 547.7	46 326.9	20 007.0
2011	420 629.7	39 510.4	52 499.4	39 420.2	20 113.9
2012	431 952.8	38 654.1	54 072.4	41 330.7	20 306.9
2013	432 419.5	38 213.3	52 734.6	30 248.9	20 491.1



2014	409 393.8	39 097.3	53 559.7	36 255.2	20 660.4
2015	410 108.9	41 402.0	51 698.6	25 359.1	20 896.3
2016	409 324.7	40 120.7	50 643.7	10 779.7	21 123.4
2017	414 409.6	32 266.3	51 003.7	26 085.8	21 699.3
2018	413 007.7	29 792.9	50 263.6	27 408.9	21 989.0
2019	407 769.1	32 392.4	49 319.5	21 081.6	22 299.3
2020	380 032.6	26 594.8	48 960.9	15 892.4	23 045.8

2000 - 2020

Energy sector emissions increased by 2.4% between 2000 and 2020. The emissions increased between 2000 and 2009, then declined to 2014 after which total emissions were stable until 2019. Emissions declined by 6.8% in 2020. The main contributor to the decline is a 19.7% reduction in emissions from *Other sectors* and a 13.7% reduction in *Transport* emissions. *Commercial/institutional* emissions declined by 19.7% in 2020, along with a 13.7% reduction in *road transport* and 54.28% reduction in *civil aviation* emissions during this year. These reductions can be attributed to the reduced travel and trading during the COVID-19 lockdown restrictions.

2017 - 2020

Energy emissions declined by 8.3% since 2017 (Table ES 4). The main contributors to decrease were the *energy industries and transport* which decreased by 5.7% (12 679 Gg CO₂e) and 13.9% (5 590 Gg CO₂e) respectively. The other sectors and *Non-specified* sectors collectively increased by 60% while the *Fugitive emissions* sector emissions decreased by 6.4%. The decrease in *Other sectors* is due to the change in allocation of fuel.

Table ES 4: Change in sector emissions since 2000 and 2017.

	Emissions (Gg CO ₂ e) [#]			Change 2000 to 2020		Change 2017 to 2020	
	2000	2017	2020	Gg CO ₂ e [#]	%	Gg CO ₂ e [#]	%
Energy	371 261.2	414 409.6	380 032.6	8 771.4	2.4	-34 377.0	-8.3
IPPU	32 955.2	32 266.3	26 594.8	-6 360.4	-19.3	-5 671.5	-17.6
AFOLU (excl. FOLU)	51 374.3	51 003.7	48 960.9	-2 413.4	-4.7	-2 042.8	-4.0
AFOLU (incl. FOLU)	23 817.5	26 085.8	15 892.4	-7 925.0	-33.3	-10 193.4	-39.1
Waste	18 241.2	21 699.3	23 045.8	4 804.6	26.3	1 346.5	6.2

[#] Calculated with SAR GWP

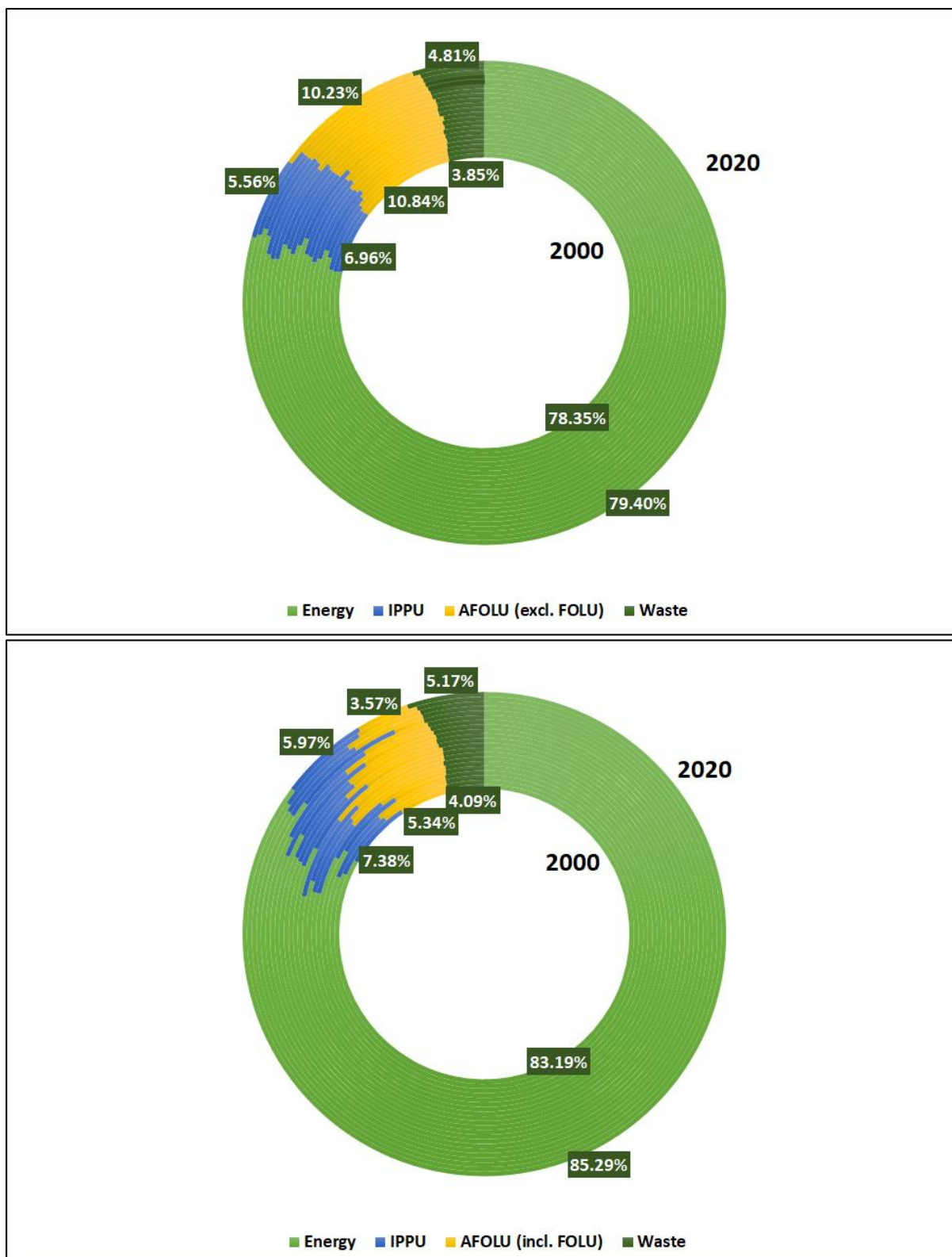


Figure ES 3: Sector contribution to total emissions excluding FOLU (top) and including FOLU (bottom) in South Africa between 2000 and 2020.



Industrial processes and product use (IPPU)

2020

In 2020 the IPPU sector produced 26 595 Gg CO₂e, which is 5.6% of South Africa's emission (excluding FOLU) (Table ES 4, Figure ES 3). The largest source category is the *metal industry* category, which contributes 41.8% to the total IPPU sector emissions. *Iron and steel production* and *Ferroalloys production* are the biggest CO₂ contributors to the metal industry subsector, producing 3 856 Gg CO₂e (34.7%) and 5 954 Gg CO₂e (53.6%) respectively to the total metal industry CO₂ emissions. The *mineral industry* and the *chemical industry* subsectors contribute 16.2% and 18.7%, respectively, to the IPPU sector emissions. *Carbide production*, *carbon black production*, *iron and steel production*, *ferroalloy production* and *ammonia production* produce 3 320 Gg CO₂e of CH₄, while chemical industries are estimated to produce 837 Gg CO₂e of N₂O.

2000 - 2020

Estimated emissions from the *IPPU* sector are 6360 Gg CO₂e (-19.3%) lower than the emissions in 2000. This was mainly due to the decline in production in the iron and steel as well as carbide production categories in 2020. The overall decrease in the IPPU sector emissions is due to 24.9% decline in Mineral industry emissions and a 56.6% decline in metal industry emissions. The Cement industry and Iron and steel industries were the main contributors to these declines.

IPPU emissions increased by 17.9% between 2000 and 2006, after which there was a -0.2% decline to 2009. This decrease was mainly due to the global economic recession and the electricity crisis that occurred in South Africa during that period. In 2010 emissions decreased by -8.7% due to a decrease in the non-energy products from fuels and solvent use category. Emissions decreased by -9.0% between 2010 and 2017. Emissions within the sector decreased further from 2017 to 2020 by -17.6 % due to lower production demands in the mineral, chemical and metal industry.

2017 – 2020

IPPU emissions showed a decrease of -17.6% (5 671.5 Gg CO₂e) between 2017 and 2020. The main contributor to this decrease was the *iron and steel and ferroalloy* production categories which decreased by -50.1% (3 871.2 Gg CO₂e) and -47.5% (5 376 Gg CO₂e), respectively, over this period. The *mineral industry* emissions decreased by -30.9% (1 936.2 Gg CO₂e) between 2017 and 2020, and the *metal industry* showed an overall decrease of - 45.5% (9 267.7 Gg CO₂e).

Agriculture, forestry and land use change (AFOLU)



2020

The overall AFOLU emissions totalled 15 892 Gg CO₂e (incl. FOLU) in 2020, and 48 961 Gg CO₂e excluding FOLU (Table ES 4). Livestock contributed 31 372 Gg CO₂e (64.1% of total excl. FOLU). *Aggregated and non-CO₂ emissions on land* contributed 35.9% to the AFOLU (excl. FOLU) emissions in 2020, and the largest contributor to this category is *Direct N₂O from managed soils* (72.9%). Nitrogen inputs from urine and dung contribute 49.4% to direct N₂O emissions, followed by 23.7% from crop residues and 15.6% from inorganic fertilisers. For the Land category the largest contributor to the sink is the *Forest land*, followed by *Grasslands*. *Other land* is the main contributor to the source in the Land category.

2000 - 2020

There was a 4.7% decline in emissions (excl. FOLU) and a 33.3% decline in emissions including FOLU between 2000 and 2020. *Enteric fermentation* emissions have been fairly constant between 2000 and 2012, with a slight decline in 2006 and a slight increase in 2012. After 2012 emissions declined to 2020. This trend follows the livestock population trend. The other cattle population has declined by 12.5% since 2014 which contributes to the decline in emissions. Other cattle and sheep were the largest contributors to the *Enteric fermentation* emissions. Emissions from manure management increased by 11.8% between 2000 and 2020 and this is because most managed manure is on dairy, pig and poultry farms and these livestock have been increasing in numbers over this period. Emissions from *Aggregated and non-CO₂ emissions on land* have remained fairly constant except for a decline in 2003-2004 and 2015 and 2016, which are attributed to changes in biomass burning. The Land sector sink declined between 2000 and 2008, after which it increased to 2020. The sink was largest in 2016 due to increasing forest land and reduced losses through fuelwood collection and biomass burning. The sink declined in 2017 and 2018 but increased again thereafter.

2017 - 2020

AFOLU emissions (excl. FOLU) declined by 4.0% between 2017 and 2020 (Table ES 4), due to a 4.6% and 3.0% decline in *Livestock* and *Aggregated and non-CO₂ emissions on land*. On the other hand, AFOLU emissions (incl. FOLU) declined by 39.1% over the same period due to a 38.5% increase in the land sink over this time.

Waste

2020



In South Africa the total *Waste* sector emissions for 2020 were 23 046 Gg CO₂e (Table ES 4) of total net national emissions. The majority of these emissions are from *Solid waste disposal* contributing 18 253 Gg CO₂e (79.2%) of the total *Waste* sector emissions. *Wastewater treatment and discharge* contributed a further 4 458 Gg CO₂e (19.3%) of waste emissions while *open burning* of waste contributed 335 Gg CO₂e (1.5%). Emissions from *biological treatment of solid waste* were estimated to be insignificant (0.0019) Gg CO₂e.

2000 - 2020

Solid waste disposal increased its contribution to the total *Waste* sector emissions by 4.6% since 2000. *Incineration and open burning of waste* increased its contribution since 2000 by 0.5%, while the contribution from *Wastewater treatment and discharge* remained stable throughout the time series. This is largely driven by increases of 0.4% in *Domestic wastewater treatment*, whilst there was a -0.5% decline in *Industrial wastewater treatment and discharge*.

2017 - 2020

The *Waste* sector emissions increased by 6.2% between 2017 and 2020 (Table ES 3) due to a 6.2% increase in *Solid waste disposal* emissions, 33.6% increase in *Open burning of waste* and a 4.5% increase in *Wastewater treatment and discharge*.

E.S.4. Improvements and recalculations

Improvements introduced in the current inventory

Energy

Updated consumption data in the *Road transport*, *Manufacturing industries and construction*, *Other sectors* and *Non-specified emissions from energy production* categories was included, particularly for coal, diesel, natural gas and gas works gas. This was because the energy balance data from DMRE updated the fuel allocation in these sectors. In addition, new data became available from a fuel consumption study done by DFFE under the GHG improvement programme. This was completed for the transport sector which provided consumption data based on vehicle kilometres travelled (VKT). In this inventory the petrol, diesel and natural gas consumption data for *Road transport* was updated. Lastly the Department of Mineral Resources and Energy had updated coal statistics in its South Africa's Mineral Industry (SAMI) report series.



IPPU

Through the introduction of the SAGERS Portal, the GHG reporting tool, there have been various additions to the inventory. In the Mineral industry the category Other process uses of carbonates was added from 2018, and dolomitic lime was added from 2019. In the Chemical industry silicon carbide production was added in 2019 and an error was corrected in the Titanium dioxide production category. Emissions from two new categories were added, namely the production of Soda Ash (from 2019) and Hydrogen production from 2018. Lastly, the Metal industry saw the addition of treatment of secondary raw material under Lead production.

AFOLU

In the livestock category Tier 2 data for enteric fermentation and manure management emission factor calculations for cattle, goats and sheep were incorporated based on a recent study by ARC (2020). This also led to changes in the livestock categorisation and an update of manure management data.

In the *Land* category various updates were made which include the incorporation of the 1990-2018 land change matrix, inclusion of updated biomass and DOM data from the National Terrestrial Carbon sinks assessment (DEFF, 2020) and various scientific publications, incorporation of new BCEF for plantations, inclusion of country specific SOC reference and stock change data, inclusion of mortality, inclusion of charcoal production and finally the inclusion of CO₂, CH₄ and N₂O from mineral inlands wetlands.

Aggregated and non-CO₂ emissions on land category were improved through the updated livestock category data as these have nitrogen inputs to this category. In addition, MODIS burnt area data was updated to Collection 6 data.

Country specific data was included in the Harvested Wood Products calculations.

Waste

In the Waste sector the population, waste per capita and the percentage of waste going to solid waste disposal sites was corrected in the FOD model for the years 1950 to 2000. Waste generation rate per person was adjusted to bring it in to alignment with data in IPCC 2019 refinement values. Waste generation rate per GDP value was also adjusted along with the amount of waste sent to SWDS as MSW and Industrial waste. Lastly the fraction of methane in developed gas was updated.

Recalculations



Recalculations due to improvements led to a 1.3% and a 2.6% increase in emission estimates excluding and including FOLU, respectively, for 2017 (Figure ES 4). Recalculated emission estimates were higher than previous estimates in the period 2000 to 2013, after which the estimates were similar to previous estimates. Recalculated estimates were 0.9% and 0.6% higher than the previous estimates for the *Energy* and *IPPU* sectors, while the estimates for *AFOLU* (excl. FOLU) were 4.9% higher. For *AFOLU* (incl. FOLU) there was a 44.9% increase in the 2017 estimates although in other years the change was less than 30.0%. For the Waste sector emission estimates were 2.1% higher than previous estimates for 2017.

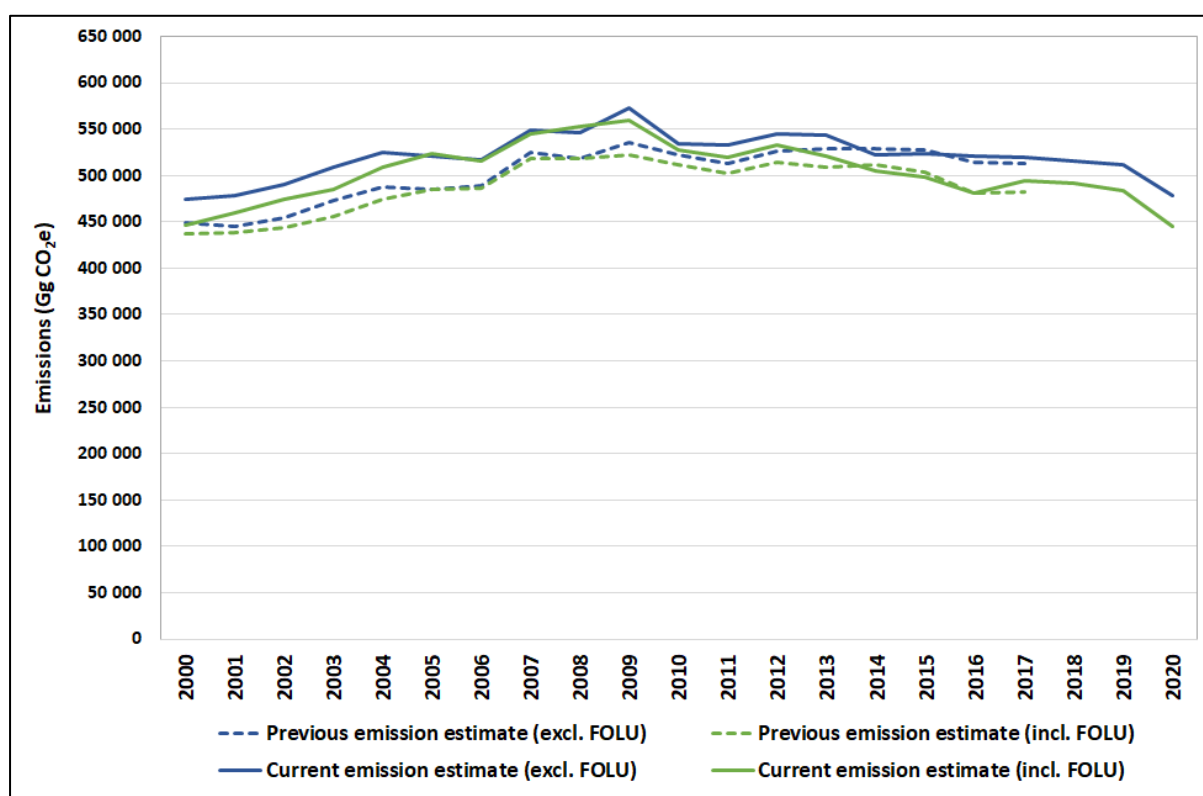


Figure ES 4: Changes in overall emission estimates due to recalculations.

E.S.5. Key category analysis

A key category is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of GHG's in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions or removals. This includes both source and sink categories.

A Tier 1 level and trend assessment were conducted, following Approach 1 (IPCC, 2006), on both the emissions including and excluding FOLU to determine the key categories for



South Africa. The key categories were then ranked according to their combined contribution to the level and trend assessments. In the previous inventory there were 44 key categories, while in this inventory there are 55. Table ES 5 shows the top 30 key categories.

Electricity and heat production moved from the second place in the previous inventory to the number one key category over Road transport. In the previous inventory solid fuels from Commercial/Institutional category was third, whereas in 2020 this has moved down to 19th place. Its contribution has reduced significantly, and this could be a result of COVID-19 lockdown restrictions. Solid waste disposal has moved up from 7th place to 4th place, followed by Forest land remaining forest land which remains in the same place as last year.

Table ES 5: Key categories for South Africa for 2020 (including FOLU) and their ranking.

Rank	IPCC Category code	IPCC Category	GHG [#]
1	1A1a	Electricity and Heat Production (Solid fuel)	CO ₂
2	1A3b	Road Transport (Liquid fuel)	CO ₂
3	3B1a	Forest land remaining forest land	CO ₂
4	4A	Solid Waste Disposal	CH ₄
5	1A5a	Stationary (Solid fuel)	CO ₂
6	1B3	Other Emissions from Energy Production	CO ₂
7	1A4c	Agriculture/Forestry/Fishing/Fish Farms (Liquid fuel)	CO ₂
8	2C1	Iron and Steel Production	CO ₂
9	3A1a	Enteric fermentation - cattle	CH ₄
10	2F1	Refrigeration and Air Conditioning	HFCs
11	1A1c	Manufacture of Solid Fuels and Other Energy Industries (Liquid fuel)	CO ₂
12	1A2	Manufacturing Industries and Construction (Solid fuel)	CO ₂
13	3B1b	Land converted to forest land	CO ₂
14	2C2	Ferroalloys Production	CO ₂
15	1A2	Manufacturing Industries and Construction (Liquid fuel)	CO ₂
16	1A1a	Electricity and Heat Production (Liquid fuel)	CO ₂
17	3C4	Direct N ₂ O emissions from managed soils	N ₂ O
18	3A1c	Enteric fermentation - sheep	CH ₄
19	1A4a	Commercial/Institutional (Solid fuel)	CO ₂
20	1A3d	Water-Borne Navigation (Liquid fuel)	CO ₂
21	1A4b	Residential (Solid fuel)	CO ₂
22	4D1	Wastewater Treatment and Discharge	CH ₄
23	1A4b	Residential (Liquid fuel)	CO ₂
24	1A1b	Petroleum Refining (Gas fuel)	CO ₂



25	3D1	Harvested wood products	CO ₂
26	3B4	Wetland	CH ₄
27	3B5a	Settlements remaining settlements	CO ₂
28	4D2	Industrial Wastewater Treatment and Discharge	CH ₄
29	1A3a	Civil Aviation (Liquid fuel)	CO ₂
30	3C2	Liming	CO ₂

#C=Confidential

E.S.6. Indicator trends

The carbon intensity of the population (i.e. total net emissions per capita) increased between 2000 and 2007 to a peak of 11.1 t CO₂e per capita, after which it declined to 8.0 t CO₂e per capita in 2020 (Figure ES 5). The carbon intensity of the economy has shown a declining trend and declined by 8.6% between 2000 and 2009. After this there was a sharp decline, but the carbon intensity stabilised between 2015 and 2020. The carbon intensity of the energy supply (i.e. total net emissions per energy unit) shows a steady decline between 2000 and 2020. This declined by 31.3% during this time.

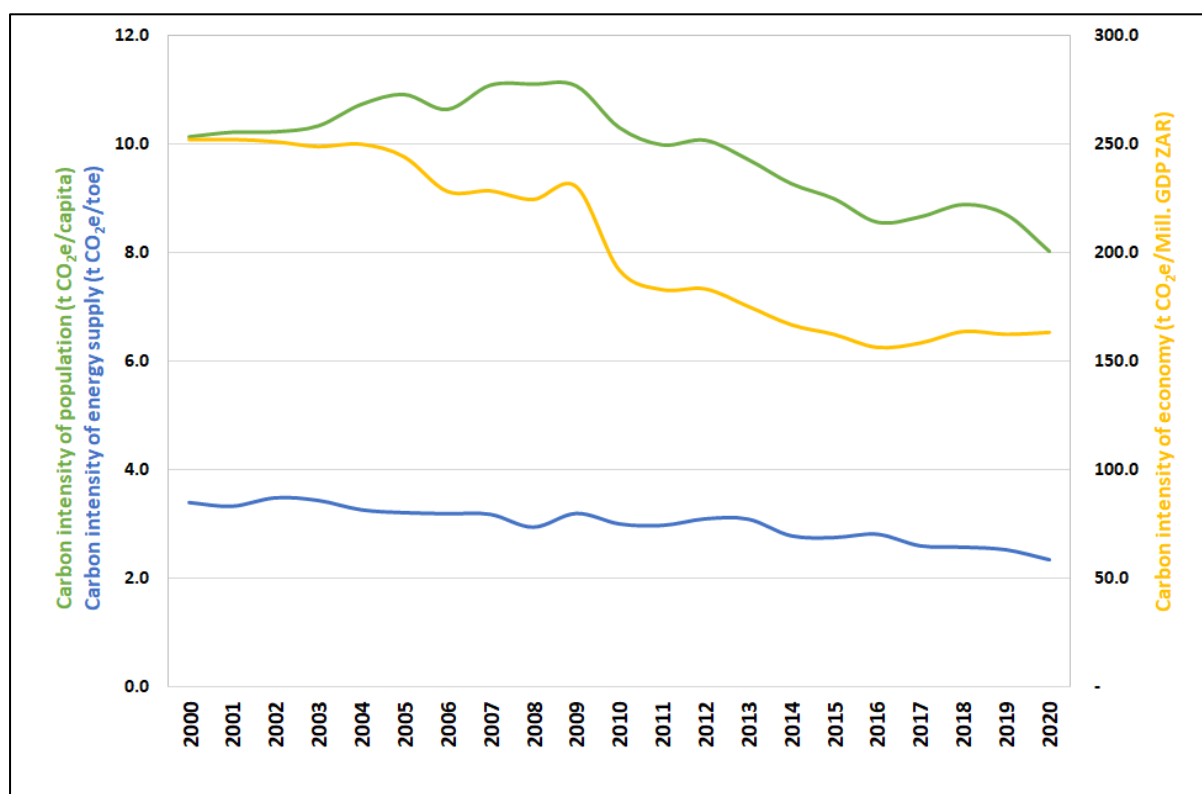


Figure ES 5: Trend in carbon intensity indicators for South Africa between 2000 and 2020.



E.S.7. Other information

General uncertainty evaluation

Uncertainty analysis is regarded by the IPCC Guidelines as an essential element of any complete inventory. The reporting of uncertainties requires a complete understanding of the processes of compiling the inventory, so that potential sources of inaccuracy can be qualified and possibly quantified. South Africa still makes use of numerous IPCC default uncertainties, but as data becomes available on uncertainties these values are improved. A trend uncertainty between the base year and 2020, as well as a combined uncertainty of activity data and emission factor uncertainty was determined using an Approach 1. The total uncertainty for the inventory was determined to be 9.11%, with a trend uncertainty of 7.54%. Excluding FOLU reduced the overall uncertainty to 7.64%, with the trend uncertainty dropping to 6.78%.

Quality control and quality assurance

In accordance with IPCC requirements, the national GHG inventory preparation process must include quality control and quality assurance (QC/QA) procedures. The objective of quality checking is to improve the transparency, consistency, comparability, completeness, and accuracy of the national greenhouse gas inventory. QC procedures, performed by the compilers, were carried out at various stages throughout the inventory compilation process. Quality checks were completed at four different levels, namely (a) inventory data (activity data, EF data, uncertainty, and recalculations), (b) database (data transcriptions and aggregations), (c) metadata (documentation of data, experts and supporting data), and (d) inventory report. Quality assurance was completed through a public review process as well as an independent review. The inventory was finalized once comments from the quality assurance process were addressed.

Completeness of the national inventory

The South African GHG emission inventory for the period 2000 – 2020 is not complete, mainly due to the lack of sufficient data. Table ES 6 identifies some of the sources in the 2006 IPCC Guidelines which were not included in this inventory and the reason for their omission. Some emissions are included under other categories of the inventory due to insufficient granularity in the activity data. Lastly, there are a few activities which do not occur in South Africa and these are also highlighted in the table. Further detail on completeness is provided in the various sector tables (see Appendix C). It is also noted that precursor gases and SF₆ have not yet been included in the inventory.



Table ES 6: Activities in the 2020 inventory which are not estimated (NE), included elsewhere (IE) or not occurring (NO).

NE, IE or NO	IPCC Category	Activity	Comments
NE	1B2	CO ₂ and CH ₄ fugitive emissions from oil and natural gas operations	CO ₂ emissions from Oil are included, but CH ₄ emissions need to be included along with natural gas emissions. To be included in the next inventory submission.
	1B1b	CO ₂ , CH ₄ and N ₂ O from spontaneous combustion of coal seams	New research work on sources of emissions from this category will be used to report emissions in the next inventory submission
	1B1ai2	CH ₄ emissions from abandoned mines	New research work on sources of emissions from this category will be used to report emissions in the next inventory submission
	1C1	CO ₂ transport	Insufficient data to include
	1C2	Injection and storage	Insufficient data to include
	2B7	CH ₄ and N ₂ O emissions from Soda Ash Production	CO ₂ included in this inventory so CH ₄ and N ₂ O will be included in the next inventory
	2C1	N ₂ O emissions from iron and steel production	Insufficient data to include
	2C2	N ₂ O emissions from ferroalloy production	Insufficient data to include
	2D2	CH ₄ and N ₂ O emissions from paraffin wax use	Insufficient data to include
	2E	Electronics industry	A study needs to be undertaken to understand emissions from this source category
	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
	3B	CO ₂ from organic soils	Due to priority this will only be included in the next inventory.
	3C4	N ₂ O from organic soils	Insufficient data to include
	4B	CH ₄ , N ₂ O emissions from biological treatment of waste	Insufficient data to include, but will be considered for inclusion in next inventory
	4C1	CO ₂ , CH ₄ and N ₂ O from waste incineration	Insufficient data to include
	2	SF ₆ emissions in the IPPU sector	Insufficient data. It is planned to include these by the 2021 inventory.
	All sectors	NO _x , CO, NMVOC emissions	These have only been included for biomass burning due to a lack of data in other sectors



	All sectors	SO ₂ emissions	Insufficient data. It is planned to include these by the 2021 inventory.
IE	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.
	3B	Precursor emissions from controlled burning	Emissions from controlled burning are not separated from biomass burning and so are included under Biomass burning (3C1)
	3B	SOC changes for converted lands	These changes are included under the land remaining land categories as a Formulation A of the SOC equation was applied.
	3C1	CO ₂ emissions from biomass burning	These are not included under biomass burning, but rather under disturbance losses in the Land sector (3B).
NO	2B3	CO ₂ , CH ₄ and N ₂ O emissions from Adipic acid production	
	2B4	CO ₂ , CH ₄ and N ₂ O Caprolactam, Glyoxal and Glyoxylic acid production	
	3C7	Rice cultivation	

Planned improvements

GHG improvement programme

The main challenge in the compilation of South Africa's GHG inventory remains the availability of accurate activity data. The DFFE is in the process of implementing a project that will ensure easy accessibility of activity data. It has initiated a programme called the National Greenhouse Gas Improvement Programme (GHGIP), which comprises a series of sector-specific projects that are targeting improvements in activity data, country-specific methodologies and emission factors used in the most significant sectors. **Error! Reference source not found.** and summarize some of the projects that are under implementation as part of the GHGIP.

DFFE has also identified the following private sectors for engagement on the GHGIP:

- Cement industry – development of country specific emission factors;
- CTL-GTCs and GTLs – development of T3 methodologies; and
- Petrochemical industry – development of EFs, carbon content of fuels, and NCVs of liquid fuels.



TableA: Donor funded GHGIP projects

Project	Partner	Objective	Outcome	Timelines	Status
Liquid Fuel Study	GIZ SAPIA	Development of CO2 Emission Factors for Liquid and Gaseous Fuels in South Africa	Country Specific CO2 emission factors developed to enable reporting of liquid fuels emissions using a tier 2 approach.	2022	In Progress
Cement Sector Study	GIZ ACMP	Development of Country-Specific CO2 Emission Factors for Alternative Fuels used in the cement sector in South Africa	Country Specific CO2 emission factors developed to enable reporting of alternative fuels emissions using a tier 2 approach.	2022	In Progress
Transport Sector Study	GIZ DOT	Development of Country-Specific Emission Factors (Methane and Nitrous Oxides) for transport sector	Shift towards an IPCC Tier 2 approach	2023	Not Started
Refrigeration and Conditioning Sector Study.	GIZ	HFC Survey in the Refrigeration Sector and Air Conditioning Sector.	Improvement of activity data for the sector.	2023	Not Started

GHG regulation reporting

DFFE has modified the National Atmospheric Emissions Inventory System (NAEIS) to meet the requirements of the National Greenhouse Gas Reporting Regulations, 2016 (NGERs). The South African GHG Emission Reporting System (SAGERS) portal has been developed under this project and this will serve as a tool for the implementation of the online registration and reporting by industry in fulfilment of mandatory NGERs. The key benefits of the portal to South Africa include the institutionalization of the preparation of the National GHG Inventory. In particular, the system enables the country to enhance the data collection process, therefore improving the quality of the national GHG inventories consistent with the requisite principles of completeness, consistency, accuracy, comparability, and transparency credentials.



This inventory has started to incorporate information from the SAGERS system, however further data will be included in the next inventory. The inclusion of this data has led to some time-series inconsistencies, but these will be addressed as further data is collected.

E.S.8. Conclusions and recommendations

The 2000 to 2020 GHG emissions results revealed emissions have increased since 2000 from the *Energy* and *Waste* sectors, with a decrease in the *IPPU* and *AFOLU* sector. These declines are due to improved data in the *IPPU* sector, as well as a reduction in emissions in 2020 partly due to the impacts of COVID on industry and transport. In the *AFOLU* sector the decline is due to an increasing Land sink. There was an annual average increase of 2.6% in the total net emissions between 2000 and 2009, and then emissions stabilised and declined with an average annual decline of 2.0% between 2010 and 2020.

The *Energy* sector in South Africa continued to be the main contributor of GHG emissions and was found to be a key category each year. It is therefore important that activity data from this sector always be available to ensure that the results are accurate. The accurate reporting of GHG emissions in this sector is also important for mitigation purposes.

The *IPPU* data was sourced from publicly available data as well as from data submitted by companies. Increasing the amount of company level data will enhance the accuracy of emission estimates and help reduce uncertainty associated with the estimates. The mandatory reporting regime which is driven by the NGERs will provide enhanced data for this sector. This data has been included in the recent years of the inventory but does pose some issues in terms of time-series consistency due to the data not being available prior to 2015 in most cases. These are issues which will be improved over the next two inventory cycles and as more data becomes available.

The *AFOLU* sector was highlighted as an important sector as it (excl. FOLU) has a contribution greater than the *IPPU* sector, and enteric fermentation is one of the top-10 key categories each year. The land subsector was also an important component of the *AFOLU* emissions (incl. FOLU) because of its increasing land sink. South Africa continues to require a more complete picture of this subsector. There is a need for more land change data and a system for integrating various maps irrespective of the technologies used to develop the maps. An updated land mapping system is currently being developed and this will lead to improvements over the next two inventory cycles. It is recommended that carbon density maps be developed for multiple years and that these maps be integrated with the land mapping system so that South Africa can move towards a Tier 3 approach. A national forest inventory would also assist in providing some of this data. This



subsector also has important mitigation options for the future and understanding the sinks and sources will assist in determining its mitigation potential.

In the *Waste* sector the emission estimates from both the solid waste and wastewater sources were largely computed using default values suggested in the IPCC 2006 Guidelines, which could lead to large margins of error for South Africa. South Africa needs to improve the data capture of the quantities of waste disposed into managed and unmanaged landfills, as well as update waste composition information and the mapping of all the wastewater discharge pathways. This sector would also benefit from the inclusion of more detailed economic data (e.g. annual growth) broken down by the different population groups. The assumption that GDP growth is evenly distributed across the different populations groups is highly misleading and exacerbates the margins of error.



Contents

E.S.1.	Background	vi
E.S.2.	Summary of national emission and removal trends.....	viii
E.S.3.	Overview of source and sink category emission estimates and trends ix	
E.S.4.	Improvements and recalculations	xvii
E.S.5.	Key category analysis	xix
E.S.6.	Indicator trends.....	xxi
E.S.7.	Other information.....	xxii
E.S.8.	Conclusions and recommendations.....	xxvi
Chapter 1:	Introduction	1
1.1	Background information	1
1.1.1	Background information on climate change	1
1.1.2	Background information on GHG inventories	1
1.1.3	Global warming potentials	2
1.2	Structure of the report.....	3
1.2.1	Overall structure	3
1.2.2	Structure of sectoral chapters.....	4
1.3	National inventory arrangements.....	5
1.3.1	Overview of institutional, legal, and procedural arrangements	5
1.3.2	Overview of inventory planning, preparation and management.....	7
1.4	Inventory preparation	10
1.4.1	GHG inventory.....	10
1.4.2	Data collection, processing and storage.....	12
1.5	Brief general description of methodologies and data sources.....	17
1.5.1	Data sources.....	17
1.5.2	General description of methods	21
1.6	Brief description of key categories	23
1.6.1	Changes in key categories since the 2017 submission.....	25
1.7	Quality assurance, quality control and verification plans and procedures	29
1.7.1	Quality assurance and quality control procedures.....	29
1.7.2	Verification activities.....	35
1.8	General uncertainty evaluation.....	35
1.8.1	Procedures for determining uncertainty.....	35
1.8.2	Results of uncertainty assessment.....	35
1.9	General assessment of completeness	36
1.10	Improvements introduced	38



1.1.1	Energy	38
1.1.2	IPPU.....	38
1.1.3	AFOLU	39
1.1.4	Waste	40
1.11	Improvement plan.....	40
1.12	References	51
Chapter 2:	Trends in GHG emissions.....	53
2.1	Description and interpretation of trends for aggregated GHG emissions.....	53
2.1.1	National trends	53
2.1.2	Indicator trends.....	56
2.2	Description and interpretation of emission trends by greenhouse gas	59
2.2.1	Carbon dioxide (CO ₂).....	61
2.2.2	Methane (CH ₄).....	63
2.2.3	Nitrous oxide (N ₂ O)	64
2.2.4	F gases	65
2.3	Description and interpretation of emission trends by category	67
2.3.1	Energy	67
2.3.2	IPPU.....	68
2.3.3	AFOLU	70
2.3.4	Waste	71
2.4	Description and interpretation of emission trends for indirect GHG	71
2.5	References	72
Chapter 3:	Energy.....	73
3.1	Sector overview.....	73
3.1.1	Shares and trends in emissions.....	75
3.1.2	Overview of methodology and completeness.....	89
3.1.3	Improvements and recalculations since the 2017 submission.....	92
3.1.4	Key categories in the energy sector	93
3.1.5	Planned improvements and recommendations.....	94
3.2	Fuel combustion (1.A)	95
3.2.1	Category description	95
3.2.2	Methodological issues	95
3.2.3	Comparison between sectoral and reference approach.....	100
3.2.4	International bunker fuels	102
3.2.5	Feedstock and non-energy use of fuels	103
3.2.6	Energy industries (1.A.1).....	103
3.2.7	Manufacturing industries and construction (1.A.2).....	108



3.2.8	Transport (1.A.3)	112
3.2.9	Other sectors (1.A.4).....	118
3.2.10	Non-specified sectors (1.A.5).....	124
3.3	Fugitive emissions from fuels (1.B).....	126
3.3.1	Solid fuels (1.B.1)	126
3.3.2	Oil and natural gas (1.B.2).....	130
3.3.3	Other emissions from energy production (1.B.3)	132
3.4	References	133
Chapter 4:	Industrial Processes and Product Use (IPPU)	136
4.1	Sector overview.....	136
4.1.1	Shares and trends in emissions.....	137
4.1.2	Overview of methodology and completeness.....	150
4.1.3	Improvements and recalculations since 2017 submission	154
4.1.4	Key categories in the IPPU sector.....	154
4.1.5	Planned improvements and recommendations.....	154
4.2	Mineral industry (2.A)	155
4.2.1	Cement production (2.A.1).....	155
4.2.2	Lime production (2.A.2)	159
4.2.3	Glass production (2.A.3).....	161
4.2.4	Other process uses of carbonates (2.A.4).....	163
4.3	Chemical industry (2.B)	165
4.3.1	Ammonia production (2.B.1).....	165
4.3.2	Nitric acid production (2.B.2)	167
4.3.3	Adipic acid production (2.B.3).....	169
4.3.4	Caprolactum, glyoxal and glyoxylic acid production (2.B.4)	169
4.3.5	Carbide production (2.B.5)	169
4.3.6	Titanium dioxide production (2.B.6)	171
4.3.7	Soda ash production (2.B.7)	172
4.3.8	Carbon black production (2.B.8.f)	174
4.3.9	Flourochemical production (2.B.9).....	175
4.4	Metal industry (2.C).....	176
4.4.1	Iron and steel production (2.C.1)	176
4.4.2	Ferroalloys production (2.C.2)	179
4.4.3	Aluminium production (2.C.3).....	181
4.4.4	Magnesium production (2.C.4)	183
4.4.5	Lead production (2.C.5).....	183



4.4.6	Zinc production (2.C.6).....	186
4.4.7	Other (2.C.7).....	187
4.5	Non-Energy Products from Fuels and Solvent Use (2.D)	188
4.5.1	Lubricant use (2.D.1).....	188
4.5.2	Paraffin wax use (2.D.2)	190
4.5.3	Solvent use (2.D.3)	192
4.6	Electronics industry (2.E)	192
4.7	Product Uses as Substitutes for Ozone Depleting Substances (ODS) (2.F)	192
4.7.1	Refrigeration and air conditioning (2.F.1)	193
4.7.2	Foam blowing agents (2.F.2)	195
4.7.3	Fire protection (2.F.3).....	198
4.7.4	Aerosols (2.F.4).....	199
4.8	Other product manufacture and use (2.G).....	201
4.9	Other (2.H)	202
4.10	References	202
Chapter 5: Agriculture, Forestry and Other Land Use (AFOLU)		203
5.1	Sector overview.....	203
5.1.1	Shares and trends in emissions.....	204
5.1.2	Overview of methodology and completeness.....	226
5.1.3	Improvements and recalculations since the 2017 submission.....	231
5.1.4	Key categories in the AFOLU sector	233
5.1.5	Planned improvements and recommendations.....	233
5.2	Livestock (3.A).....	234
5.2.1	Livestock population and characterisation	234
5.2.2	Manure management	241
5.2.3	Enteric Fermentation (3.A.1)	247
5.2.4	Manure Management (3.A.2).....	258
5.3	Aggregated and non-CO ₂ emissions on land (3.C)	263
5.3.1	Category description	263
5.3.2	Emissions from biomass burning (3.C.1)	263
5.3.3	Liming (3.C.2)	269
5.3.4	Urea application (3.C.3).....	271
5.3.5	Direct nitrous oxide emissions from managed soils (3.C.4).....	273
5.3.6	Indirect nitrous oxide emissions from managed soils (3.C.5).....	279
5.3.7	Indirect nitrous oxide emissions from manure management (3.C.6)	281
5.4	Land (3.B).....	283
5.4.1	Category description	283



5.4.2	Land representation	286
5.4.3	Methodological issues	300
5.4.4	Recalculations since the 2017 inventory	315
5.4.5	Uncertainties and time-series consistency	316
5.4.6	Forest land (3.B.1)	319
5.4.7	Croplands (3.B.2)	329
5.4.8	Grasslands (3.B.3)	333
5.4.9	Wetlands (3.B.4)	336
5.4.10	Settlements (3.B.5)	338
5.4.11	Other lands (3.B.6)	341
5.5	Other (3.D)	343
5.5.1	Category description	343
5.5.2	Harvested wood products (3.D.1)	343
5.6	References	347
Chapter 6: Waste		353
6.1	Sector overview	353
6.1.1	Overview of shares and trends in emissions	354
6.1.2	Overview of methodology and completeness	358
6.1.3	Key categories in the Waste sector	360
6.1.4	Recalculations and improvements since the 2017 submission	360
6.1.5	Planned improvements and recommendations	361
6.2	Solid Waste Disposal (4.A)	361
6.2.1	Category information	361
6.2.2	Methodology	363
6.2.3	Uncertainty and time series consistency	365
6.2.4	Planned improvements	366
6.3	Biological Treatment of Solid Waste (4.B)	366
6.3.1	Category information	366
6.3.2	Methodology	367
6.4	Incineration and open burning of waste (4.C)	369
6.4.1	Category information	369
6.4.2	Methodology	370
6.4.3	Uncertainty and time series consistency	371
6.4.4	Planned improvements	372
6.5	Wastewater Treatment and Discharge (4.D)	372
6.5.1	Domestic wastewater treatments and discharge (4.D.1)	372



6.5.2	Industrial wastewater treatment and discharge (4.D.2).....	376
6.6	References.....	376
Appendix A:	Key category analysis	378
Appendix B:	Uncertainty analysis.....	416
Appendix C:	Summary emission tables for 2020	422
Appendix D:	Reference and sectoral fuel consumption	441
Appendix E:	Soil carbon validation methodology	444
Appendix F:	External review of inventory.....	449



Tables

Table 1.1: Global warming potential (GWP) of greenhouse gases used in this report and taken from IPCC SAR (Source: IPCC, 1996).	3
Table 1.2: Principal data sources for the Energy sector inventory.....	17
Table 1.3: Principal data sources for the IPPU sector inventory.....	18
Table 1.4: Principal data sources for the AFOLU sector inventory.....	19
Table 1.5: Principal data sources for the Waste sector inventory.	20
Table 1.6: Key categories for South Africa for 2020 (including FOLU) and their ranking	24
Table 1.7: Quality control checks carried out on South Africa's 2020 GHG inventory.....	30
Table 1.8: Activities in the 2020 inventory which are not estimated (NE), included elsewhere (IE) or not occurring (NO).....	36
Table 1.9: List of planned improvements for South Africa's GHG inventory.....	41
Table 2.1: Changes in South Africa's emissions excluding and including FOLU between 2000, 2017 and 2020.....	53
Table 2.2: Trends and annual change in emissions (excluding and including FOLU), 2000 – 2020.	55
Table 2.3: Trend in CO ₂ , CH ₄ , N ₂ O and F-gases between 2000 and 2020.....	62
Table 2.4: Trends in PFC and HFC emissions (Gg) by gas type.....	66
Table 2.5: Trend in emissions and removals by sector for 2000 to 2020.....	70
Table 2.6: Trends in indirect GHG emissions between 2000 and 2020.....	72
Table 3.1: Summary of emissions from the Energy sector in 2020.....	75
Table 3.2: Summary of the change in emissions from the Energy sector between 2000 and 2020.	77
Table 3.3: Emission trends for the public electricity producer, 2000 - 2020.....	81
Table 3.4: Trend in emissions from the auto electricity producers, 2000 – 2020.	83
Table 3.5: Trend in emissions from other sectors, 2000 – 2020.....	87
Table 3.6: Trend in fugitive emissions, 2000 – 2020.....	88
Table 3.7: Summary of methods and emission factors for the energy sector and an assessment of the completeness of the energy sector emissions.....	90
Table 3.8: Key categories identified in the Energy sector.	93
Table 3.9: Data sources for the fuel combustion subcategory.....	96
Table 3.10: Net calorific values for solid, liquid and gaseous fuels as provided by the South African Petroleum Industry Association.	97
Table 3.11: Emission factors for stationary combustion (solid, liquid, gaseous and other fuels).	98
Table 3.12: Trend in fuel consumption for the various categories in the energy industry sector, 2000 – 2020.....	105
Table 3.13: Uncertainty for South Africa's fuel combustion emission estimates.	107
Table 3.14: Fuel consumption (TJ) in the manufacturing industries and construction category, 2000 – 2020.....	110



Table 3.15: Uncertainty for South Africa's Manufacturing industries and construction emission estimates.....	111
Table 3.16: Uncertainty for South Africa's transport emission estimates.....	117
Table 3.17: Uncertainty for South Africa's Other sectors emission estimates.....	123
Table 3.18: Amount of coal produced from opencast and underground mining, 2000 – 2020..	128
Table 3. 19: Emission factors for coal mining and handling.....	129
Table 3.20: Uncertainty for South Africa's fugitive emissions estimates.....	129
Table 4.1: Summary of the estimated emissions from the IPPU sector in 2020 for South Africa.	138
Table 4.2: Summary of the change in emissions from the IPPU sector between 2000 and 2020.	140
Table 4.3: Summary of methods and emission factors (EF) for the IPPU sector and an assessment of the completeness of the IPPU sector emissions.	151
Table 4. 4: Key categories identified in the IPPU sector.....	154
Table 4.5: Production data for the mineral industries, 2000 – 2020.....	156
Table 4.6: Emission factors applied in the chemical industry emission estimates.....	169
Table 4.7: Emission factors applied in the chemical industry emission estimates.....	174
Table 4.8: Production data for the iron and steel industry, 2000 – 2020.....	177
Table 4.9: Emission factors applied in the metal industry emission estimates.....	178
Table 4.10: Production data for the ferroalloy industry, 2000 – 2017.....	180
Table 4.11: Production data for the lead and zinc industries, 2000 – 2020.....	184
Table 4.12: Lubricant and paraffin wax consumption, 2000 – 2020.....	188
Table 4.13: Methodology and data sources used for each RAC sub-application.....	193
Table 4. 14: Emission factors and defaults applied in the foam blowing agents emission estimates.....	197
Table 5.1: Main IPCC categories included in the AFOLU sector emission estimates.....	203
Table 5.2: <i>Enteric fermentation</i> emission trends between 2000 and 2020.....	207
Table 5.3: Change in <i>Enteric fermentation</i> emissions (2000 – 2020) and relative contribution of the various livestock categories to the total emissions.....	208
Table 5.4: Trends and changes in manure management emissions (2000 to 2020).	208
Table 5.5: <i>Manure management</i> CH ₄ emission trends between 2000 and 2020.	209
Table 5.6: <i>Manure management</i> N ₂ O emission trends between 2000 and 2020.....	210
Table 5.7: Changes in aggregated and non-CO ₂ emission sources on land between 2000 and 2020.....	211
Table 5.8: South Africa's net carbon stock change (Gg CO ₂) by carbon pool for the Forest land, 2000 – 2020.....	215
Table 5.9: South Africa's net carbon stock change (Gg CO ₂) by carbon pool for Croplands, 2000 – 2020.....	217
Table 5.10: South Africa's net carbon stock change (Gg CO ₂) by carbon pool for Grasslands, 2000 – 2020.....	219
Table 5.11: South Africa's net carbon stock change (Gg CO ₂) by carbon pool for Settlements, 2000 – 2020.....	222



Table 5.12: South Africa's net carbon stock change (Gg CO ₂) by carbon pool for Other lands, 2000 – 2020.....	224
Table 5.13: Trends in HWP net emissions and removals between 2000 and 2020.	225
Table 5.14: Summary of methods and emission factors for the AFOLU sector and an assessment of the completeness of the AFOLU sector emissions.....	227
Table 5.15: Key categories in the AFOLU sector in 2020.....	233
Table 5.16: Livestock population data sources.....	235
Table 5.17: Livestock characterization and herd composition data sources and assumptions.	237
Table 5.18: Manure management systems for the various livestock types and their data sources.	243
Table 5.19: Verification of livestock manure management systems.....	244
Table 5.20: Methane conversion factors and their sources.	248
Table 5.21: Enteric fermentation emission factors (kg CH ₄ head ⁻¹ yr ⁻¹) and their sources per livestock category.	249
Table 5.22: Equations for the calculation of emissions factors for cattle using the Tier 2 approach.....	251
Table 5.23: Equations for the calculation of emissions factors for sheep and goats using the Tier 2 approach.	253
Table 5.24: Enteric fermentation emission factor uncertainties.....	256
Table 5.25: Uncertainty data for livestock manure CH ₄ emission factors.	261
Table 5.26: Fuel density and combustion fractions for the various vegetation classes.....	267
Table 5.27: Emission trends for the various sub-categories of direct N ₂ O emissions from managed soils.	274
Table 5.28: Land cover change between 1990 and 2014 (Source: GTI, 2015; DEFF, 2020).....	284
Table 5.29: Trends in emissions and removals between 2000 and 2020 from the Land sector in South Africa.	286
Table 5.30: Relationship between SANLC, land change and IPCC categories in the 2020 inventory.	290
Table 5.31: Annual land conversion areas (ha) for South Africa between 1990 and 2014.....	295
Table 5.32: Soil types and their description (Source: Moeletsi et al., 2015).....	298
Table 5.33: Above ground biomass factors for the various vegetation classes.	306
Table 5.34: Root:shoot ratios for each of the land classes.....	308
Table 5.35: DOM data applied in the inventory for each of the land classes.	310
Table 5.36: Biomass growth or accumulation rates for the various woody land categories.	312
Table 5.37: Comparison between annual SOC change per land class using the NTCSA data and a Tier 1 approach.....	314
Table 5.38: Factors applied for plantation data.....	322
Table 6.1: Summary of the estimated emissions from the Waste sector in 2020.....	354
Table 6.2: GHG emissions from South Africa's Waste sector between 2000 and 2020.....	356
Table 6.3: Trend in Waste sector category emissions between 2000 and 2020.....	358
Table 6.4: Summary of methods and emission factors for the Waste sector and an assessment of the completeness of the Waste sector emissions.	359
Table 6.5: Main data sources for the Waste sector emission calculations.....	359



Table 6.6: IPCC default factors utilized in the FOD Model to determine emissions from solid waste disposal.	363
Table 6.7: Uncertainties associated with emissions from South Africa's solid waste disposal. .	366
Table 6.8: Activity data for biological treatment systems.	367
Table 6.9: Emission Factors for Biological Treatment of Solid Waste.....	369
Table 6.10: Emission factors for estimating emissions from open burning of waste.....	370
Table 6.11: Emission factors for different wastewater treatment and discharge systems	374
Table 6.12: Distribution and utilization of different treatment and discharge systems.....	374



Figures

Figure 1.1: Organogram showing where the GHG Inventory compilation occurs within DFFE.....	6
Figure 1.2: Overview of the phases of the GHG inventory compilation and improvement process undertaken for South Africa's 2020 GHG inventory.....	9
Figure 1.3: The inventory compilation process is co-ordinated through a central web-based inventory management system as depicted in this illustration.	11
Figure 1.4: Data collection process for the 2020 Energy inventory.....	13
Figure 1.5: Difference in contribution to the level assessment (excl. FOLU) key category analysis between the current submission and the 2017 submission.	26
Figure 1.6: Comparison of level assessment key categories and their contribution to emissions (incl. FOLU) in the current and previous 2017 submission.	27
Figure 1.7: Difference in contribution to the trend assessment (excl. FOLU) key category analysis between the current submission and the 2017 submission.	28
Figure 1.8: Comparison of trend assessment key categories and their contribution to emissions (incl. FOLU) in the current and previous 2017 submission.	29
Figure 1.9: The independent review process for the 2000 – 2020 inventory.....	34
Figure 2.1: National GHG emissions (excluding and including FOLU) for South Africa, 2000 – 2020.....	55
Figure 2.2: Trends in overall carbon intensity of the population and of the economy of South Africa between 2000 and 2020.....	57
Figure 2.3: Trends in energy intensity indicators for South Africa between 2000 and 2020.	58
Figure 2.4: Percentage contributions from each of the gases to South Africa's emissions (excl. FOLU (top) and incl. FOLU (bottom)) between 2000 and 2020.....	60
Figure 2.5: Trend and sectoral contribution to CO ₂ emissions (excl. FOLU), 2000 – 2020.	63
Figure 2.6: Trend and sectoral contribution to the CH ₄ emissions, 2000 – 2020.....	64
Figure 2.7: Trend and sectoral contribution to N ₂ O emissions in South Africa, 2000 – 2020.....	65
Figure 2.8: Trend in F-gas emissions in South Africa, 2000 – 2020.	66
Figure 2.9: Percentage contributions from each of the sectors to South Africa's emissions (excluding (top) and including (bottom) FOLU) between 2000 and 2020.....	69
Figure 3.1: Trend in Total Primary Energy Consumption in South Africa, 2000 – 2017.....	74
Figure 3.2: Trends in South Africa's energy sector emissions, 2000 – 2020.	78
Figure 3.3: Trend in annual change in the total energy emissions in South Africa, 2000 – 2020.....	79
Figure 3.4: Trends and subcategory contributions to fuel combustion activity emissions in South Africa, 2000 – 2020.	80
Figure 3.5: Eskom's system energy availability factor (%).....	82
Figure 3.6: Renewable penetration and corresponding emissions reduction.....	83
Figure 3.7: Emissions by fuel source.....	85
Figure 3.8: Contribution of diesel and gasoline used in road transport to the total transport emissions.....	86
Figure 3.9: Recalculations for the Energy sector between 2000 and 2020.....	93



Figure 3.10: Comparisons between the reference and sectoral approach of determining the CO ₂ emissions for the energy sector for South Africa.....	102
Figure 3.11: Percentage contribution of the various fuel types to fuel consumption in the road transport category (1A3b), 2000 – 2020.	115
Figure 3.12: Fuel consumption in the commercial/institutional category, 2000 – 2020.....	120
Figure 3.13: Trend in fuel consumption in the residential category, 2000 – 2020.....	121
Figure 3.14: Trend in fuel consumption in the agriculture/forestry/fishing category, 2000 – 2020.....	122
Figure 4.1: Trend in South Africa's IPPU sector emissions, 2000 – 2020.	139
Figure 4.2: Category contribution and trend for the mineral subsector, 2000 – 2020.	143
Figure 4. 3: Trend and category contribution to emissions from the metal industries, 2000 – 2020.....	145
Figure 4. 4: Trend and category contribution in the emissions from non-energy products from fuels and solvents, 2000 – 2020.....	147
Figure 4.5: Trend and category contribution to the product uses as substitutes for ODS emissions, 2000 – 2020.....	149
Figure 5.1: The overall AFOLU emissions for South Africa between 2000 – 2020.	205
Figure 5.2: <i>Enteric fermentation</i> emission trends, 2000 – 2020.....	206
Figure 5.3: Livestock population trends, 2000 – 2020 (Data source: DALRRD, 2020).....	207
Figure 5.4: Trend in manure management CH ₄ emissions from livestock, 2000 – 2020.	209
Figure 5.5: Trend in manure management N ₂ O emissions from livestock, 2000 – 2020.....	210
Figure 5.6: Trends in aggregated and non-CO ₂ emissions on land, 2000 – 2020.	212
Figure 5.7: South Africa's carbon stock change (Gg CO ₂) for Forest land, 2000 – 2020.	214
Figure 5.8: Estimated fuelwood consumption (green) and forest burnt area (orange) between 2000 and 2020.	215
Figure 5.9: CO ₂ emissions and removals (Gg CO ₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Cropland.	217
Figure 5.10: CO ₂ emissions and removals (Gg CO ₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Grassland.	219
Figure 5.11: CO ₂ emissions and removals (Gg CO ₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Wetlands.	221
Figure 5.12: CO ₂ emissions and removals (Gg CO ₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Settlements.	222
Figure 5.13: CO ₂ emissions and removals (Gg CO ₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Other lands.....	224
Figure 5.14: Change in AFOLU emission estimates due to recalculations since 2017 submission.	232
Figure 5.15: Time series for GHG emissions and removals (Gg CO ₂) in the Land sector in South Africa, 2000 - 2020.....	285
Figure 5.16: Land cover maps for South Africa for 2014 (Source: GTI, 2015).....	288
Figure 5.17: South Africa's long term climate map classified into the IPCC climate classes (Source: Moeletsi et al., 2015).	297



Figure 5.18: South African soils classified into the IPCC classes (Moeletsi et al., 2015).....	298
Figure 5.19: Recalculated Land category emissions in 2020 compared to 2017 submission data.	316
Figure 5.20: Mapping accuracies for the 2018 SA National Land Cover dataset (Source: GTI, 2020).....	317
Figure 5.21: Class accuracies for the 2013/2014 SA National Land Cover Map (Source: GTI, 2020).....	318
Figure 5.22: Recalculations for Forest lands.....	329
Figure 6.1: Trend in emissions from Waste sector, 2000 - 2020.....	357



Chapter 1: Introduction

1.1 Background information

1.1.1 Background information on climate change

The United Nations Framework Convention on Climate Change (UNFCCC) was signed by South Africa in 1993 and ratified in 1997. All countries that ratify the Convention (the Parties) are required to address climate change, including monitoring trends in anthropogenic greenhouse gas emissions. One of the principal commitments made by the ratifying Parties under the Convention was to develop, publish and regularly update national emission inventories of greenhouse gases. Parties are also obligated to protect and enhance carbon sinks and reservoirs, for example forests, and implement measures that assist in national and/or regional climate change adaptation and mitigation.

1.1.2 Background information on GHG inventories

1.1.2.1 *South Africa's National Greenhouse Gas Inventory*

South Africa compiled its first National GHG Inventory in 1998 using activity data for the year 1990. This inventory utilised the 1996 IPCC Guidelines. Using the same methods, the second National GHG Inventory for the year 1994 was compiled and published in 2004. In 2009 the third National GHG Inventory for 2000 was completed and for this inventory the IPCC 2006 Guidelines were starting to be introduced in the Energy, IPPU and Waste sectors, but were only partially introduced in the AFOLU sector.

It was only in 2014 when South Africa started to present annual emissions and trends over a time-series instead of an individual year. The fourth National GHG Inventory included annual emission estimates for the period 2000 to 2010. The year 2000 was selected as the base year due to a lack of data, particularly in the Energy and IPPU sectors, prior to 2000. The inventory was then updated in 2016 for the period 2000 to 2012, in 2018 for the years 2000 to 2015, and again in 2021 for the period 2000 to 2017. In these inventories the IPCC 2006 Guidelines were implemented.

This 2020 National GHG Inventory Report (NIR) for South Africa provides estimates of South Africa's net greenhouse gas emissions for the period 2000 to 2020 and is South Africa's 8th inventory report. This report is to be submitted to UNFCCC to fulfil South



Africa's reporting obligations under the UNFCCC. The Report has been compiled in accordance with the *Intergovernmental Panel on Climate Change (IPCC) 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006), the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (IPCC, 2014a) and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2019). The aim is to ensure that the estimates of emissions are accurate, transparent, consistent through time and comparable with those produced in the inventories of other countries.

The NIR covers sources of greenhouse gas emissions, and removals by sinks, resulting from human (anthropogenic) activities for the major greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). The indirect greenhouse gases, carbon monoxide (CO), and oxides of nitrogen (NO_x), are also included for biomass burning. The gases are reported under four sectors: *Energy; Industrial Processes and Product Use* (IPPU); *Agriculture, Forestry and Other Land Use* (AFOLU) and *Waste*. SF₆ emissions have not yet been included due to a lack of data, however DFFE has set a threshold for SF₆ in the new GHG reporting regulation so that companies will start reporting SF₆ data. It has been noted that Eskom only started to report SF₆ in 2020 so for this inventory there was insufficient data to include it, but further data is expected to be reported by the next inventory.

In this inventory the full-time series back to 1990 was estimated for the AFOLU sector, however the results of this are not shown since the other sectors still only have data from 2000. The inventory team is planning on extending the time-series for all sectors over the next few years and it is planned that in the 6th BUR, the time-series will be starting from 1990 and going to 2021.

1.1.3 Global warming potentials

As greenhouse gases vary in their radiative activity, and in their atmospheric residence time, converting emissions into CO₂e allows the integrated effect of emissions of the various gases to be compared. To comply with international reporting obligations under the UNFCCC, South Africa has chosen to present emissions for each of the major greenhouse gases as carbon dioxide equivalents (CO₂e) using the 100-year global warming potentials (GWPs) contained in the *IPCC Second Assessment Report (SAR)* (IPCC, 1996) (Table 1.1) so as to comply with international reporting requirements.



Table 1.1: Global warming potential (GWP) of greenhouse gases used in this report and taken from IPCC SAR (Source: IPCC, 1996).

Greenhouse gas	Chemical formula	SAR GWP
Carbon dioxide	CO ₂	1
Methane	CH ₄	21
Nitrous oxide	N ₂ O	310
Hydrofluorocarbons (HFCs)		
HFC-23	CHF ₃	11 700
HFC-32	CH ₂ F ₂	650
HFC-125	CHF ₂ CF ₃	2 800
HFC-134a	CH ₂ FCF ₃	1 300
HFC-143a	CF ₃ CH ₃	3 800
HFC-227ea	C ₃ HF ₇	2 900
HFC-365mfc	C ₄ H ₅ F ₅	890
HFC-152a	CH ₃ CHF ₂	140
Perfluorocarbons (PFCs)		
PFC-14	CF ₄	6 500
PF-116	C ₂ F ₆	9 200

1.2 Structure of the report

1.2.1 Overall structure

This National Inventory Report (NIR) follows the format prescribed by the UNFCCC in the updated UNFCCC reporting guidelines on annual inventories (UNFCCC, 2013) following incorporation of the provisions of decision 14/CP.11 (FCCC/SBSTA/2006/9):

- **Chapter 1** is the introductory chapter which contains background information on climate change and GHG inventories, South Africa's inventory institutional arrangements, preparation and reporting process, key categories and uncertainty analysis, a description of the methodologies, activity data, emission factors, and the overall QA/QC process.
- **Chapter 2** provides an overview of the trends in aggregated GHG emissions and indicators, as well as an analysis and interpretation of the trends in emissions by gas (CO₂, CH₄, N₂O, F gases, indirect precursors) and by category (Energy, IPPU, AFOLU, Waste).



- **Chapters 3 to 6** deal with detailed explanations of the emissions in the Energy, IPPU, AFOLU and Waste sectors, respectively. They include an overall trend assessment, methodology, data sources, recalculations, uncertainty, time-series consistency, QA/QC process, verification and planned improvements and recommendations.
- **References** are provided at the end of each chapter.
- The **Appendices** are found at the end of the report and contain the detailed key category (Appendix A) and uncertainty analysis results (Appendix B), all summary tables in the IPCC prescribed format (Appendix C), energy sector reference approach data (Appendix D), soil organic carbon validation methodology (Appendix E) as well as details of the external review of the previous inventory (Appendix F).

1.2.2 Structure of sectoral chapters

In this submission the layout and structure of the detailed sectoral chapters (chapters 3 to 6) have been restructured slightly to improve the flow of the NIR. The following basic structure is followed in each chapter:

- **Sector overview** is at the front of each chapter, and this provides a detailed analysis of the emission trends and the drivers in the sector and the various sub-categories. In addition, this section provides an overview of the methodologies, completeness, improvements, recalculations, key categories, and planned improvements for the sector. This section in each chapter, therefore, highlights the main key points and take-home messages for each sector.
- **Category and sub-category sections** are provided below this, identified by the category name and number, and these provide the details on the methodologies, activity data, emission factors, uncertainties, time-series consistency, category specific recalculations, category specific QA/QC procedures and category specific planned improvements.

This is the overall structure followed throughout the chapters, although there are some variations in the chapters due to the different data in each sector, for example:

- In the Energy sector the Fuel combustion section has an overall, common methodology upfront with additional sections on the sectoral and reference approach, international bunkers, feedstocks, and CO₂ storage.
- The AFOLU sector has a section upfront in the Livestock category explaining the livestock population and manure management as this information is used in several sub-category sections.



- The AFOLU sector also has additional information at the beginning of the Land sub-category to provide detail on the land representation and stratification that is used throughout the section.

1.3 National inventory arrangements

1.3.1 Overview of institutional, legal, and procedural arrangements

1.3.1.1 *Single National Entity*

In South Africa the DFFE is the central co-ordinating and policy-making authority with respect to environmental conservation. Following the announcement of the sixth administration in 2019, the forestry and fisheries functions were amalgamated into the previous Department of Environmental Affairs (DEA), which then became known as the Department of Environment, Forestry and Fisheries (DEFF). On the first of April 2021 (Government Gazette 44229, Notice No. 172) the name of the DEFF changed again to the Department of Forestry, Fisheries and the Environment (DFFE).

The DFFE is mandated by the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004) (DFFE, 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 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, Air Quality and Sustainable Development 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.

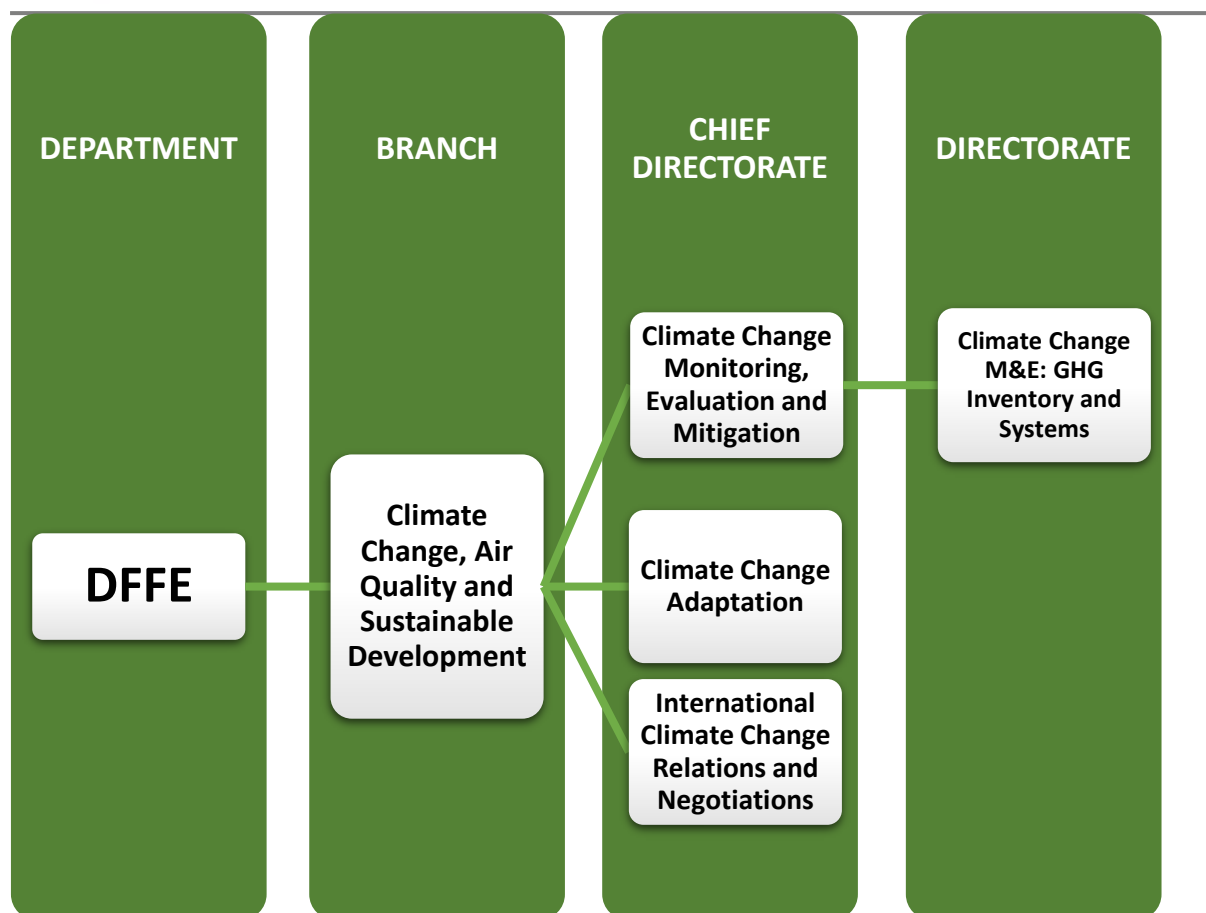


Figure 1.1: Organogram showing where the GHG Inventory compilation occurs within DFFE.

DFFE is currently responsible for managing all aspects of the National GHG Inventory development. The Director of the Climate Change 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 in order 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
 - Oversee consultants handling the report compilation
- Identifying, assigning, and overseeing national inventory sector leads.
- Assigning cross-cutting roles and responsibilities, including those for Quality Assurance/Quality Control (QA/QC), archiving, key category analysis (KCA),



uncertainty analysis, and compilation of the inventory section of the NC and/or BUR.

- Managing the QA (external review and public comment) process:
 - Appoint external reviewers
 - Liaise between the reviewers and the NIR authors
 - Obtain approval from Cabinet for the NIR to go for public comment
 - Manage the incoming public comments and liaise with NIR 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 NIR and submit reports (NIR, BUR, NC) to the UNFCCC; and
- Fostering and establishing links with related national projects, and other regional, international programmes as appropriate.

1.3.1.2 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 plantation industries and certain agricultural industries) the government published the National Greenhouse Gas Emission Reporting Regulations, 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 Greenhouse Gas Inventory; (b) for the Republic of South Africa to meet its reporting obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and instrument treaties to which it is bound; and (c) to inform the formulation and implementation of legislation and policy.

1.3.2 Overview of inventory planning, preparation and management

1.3.2.1 Inventory management

South Africa uses a hybrid (centralised/distributed) approach to programme management for the inventory. 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 and Waste sector inventories, while the AFOLU sector is compiled by external consultants (Gondwana Environmental Solutions (GES)) who are appointed via a formal project-based contract with the GIZ CSP programme. DFFE assists with the QC of the AFOLU sector. The consultants are also responsible for combining and compiling the overall inventory and providing the draft National Inventory Report to DFFE. External consultants are hired to conduct an external review of the inventory and the NIR.

1.3.2.2 Changes in the national inventory team since previous annual GHG inventory submission

The national arrangements have not changed but DFFE has enlarged the inventory team, by appointing additional officials, in preparation for the enhanced reporting requirements. Since the last inventory a new inventory co-ordinator was appointed, along with a new Energy, IPPU and Agriculture expert. In addition, an official proficient in statistics, was taken on board to assist with the improvement of the uncertainty analysis. All officials have undergone various IPCC training courses, including a course on uncertainty. The enlarged team also enabled a more in-depth QC process.

1.3.2.3 Inventory planning

A planning meeting was held in January 2021 to engage with the whole team and to plan the timelines for the inventory preparation process, from data collection to finalisation of the NIR. Since there were several new team members various training sessions (on inventory preparation, calculation files, QC procedures, time-series consistency and splicing techniques, uncertainty analysis) were included in the inventory compilation plan. The planning phase also involved the preparation of files and templates for the inventory compilation.

1.3.2.4 Inventory preparation

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

- Collect;
- Compile;
- Write;
- Improve and
- Finalize.



The stages and activities undertaken in the inventory update and improvement process are shown in Figure 1.2.

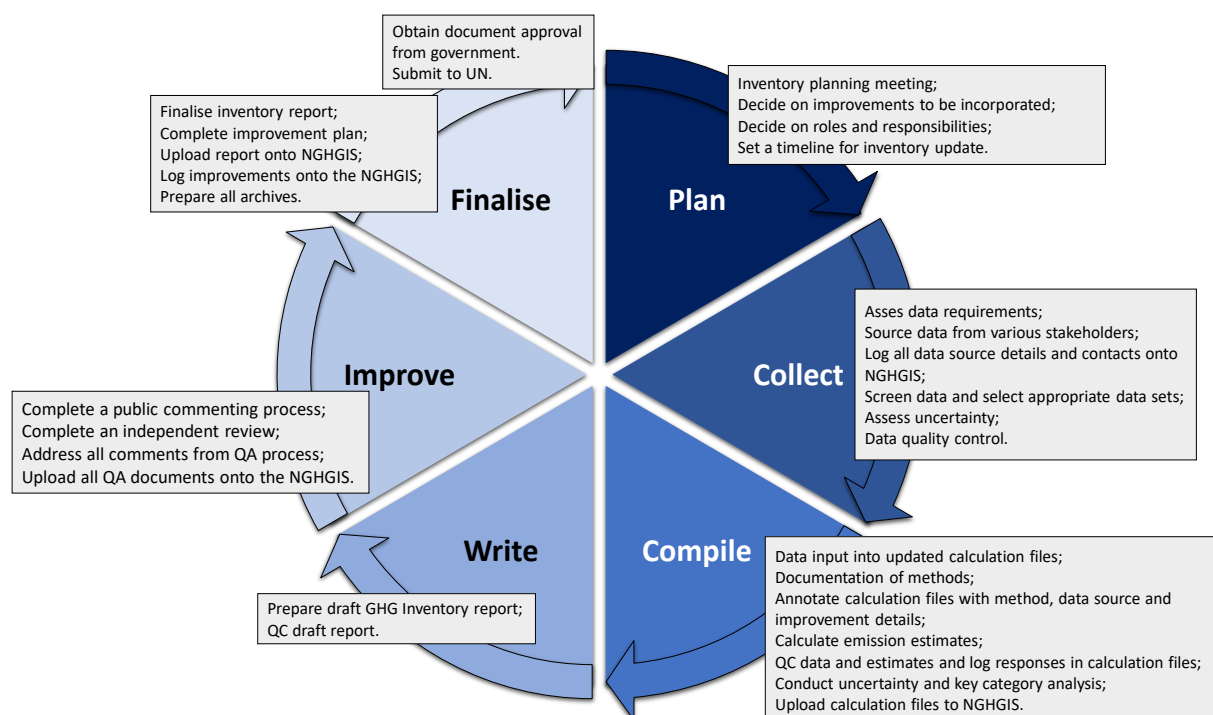


Figure 1.2: Overview of the phases of the GHG inventory compilation and improvement process undertaken for South Africa's 2020 GHG inventory.

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.

The writing phase is where the draft inventory report is prepared, including all cross-cutting 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. 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.



1.4 Inventory preparation

1.4.1 GHG inventory

1.4.1.1 *National inventory management system*

South Africa recently developed a National GHG Inventory Management System (NGHGIS) to manage and simplify its climate change obligations to the UNFCCC process (Figure 1.3). This system aims to ensure a) the sustainability of the inventory preparation in the country, b) consistency of reported emissions and c) the standard quality of results. The NGHGIS ensures that the country prepares and manages data collection and analysis, as well as all relevant information related to climate change in the most consistent, transparent, and accurate manner for both internal and external reporting. Reliable GHG emission inventories are essential for the following reasons:

- a) To fulfil the international reporting requirements such as the National Communications and Biennial Update Reports;
- b) To evaluate mitigation options;
- c) To assess the effectiveness of policies and mitigation measures;
- d) To develop long term emission projections; and
- e) To monitor and evaluate the performance of South Africa in the reduction of GHG emissions.

The NGHGIS includes:

- a) The formalization of a National Entity (the DFFE) responsible for the preparation, planning, management, review, implementation and improvement of the inventory;
- b) Legal and collaborative arrangements between the National Entity and the institutions that are custodians of key source data;
- c) A process and plan for implementing quality assurance and quality control procedures;
- d) A process to ensure that the national inventory meets the standard inventory data quality indicators of accuracy, transparency, completeness, consistency and comparability; and
- e) A process for continual improvement of the national inventory.

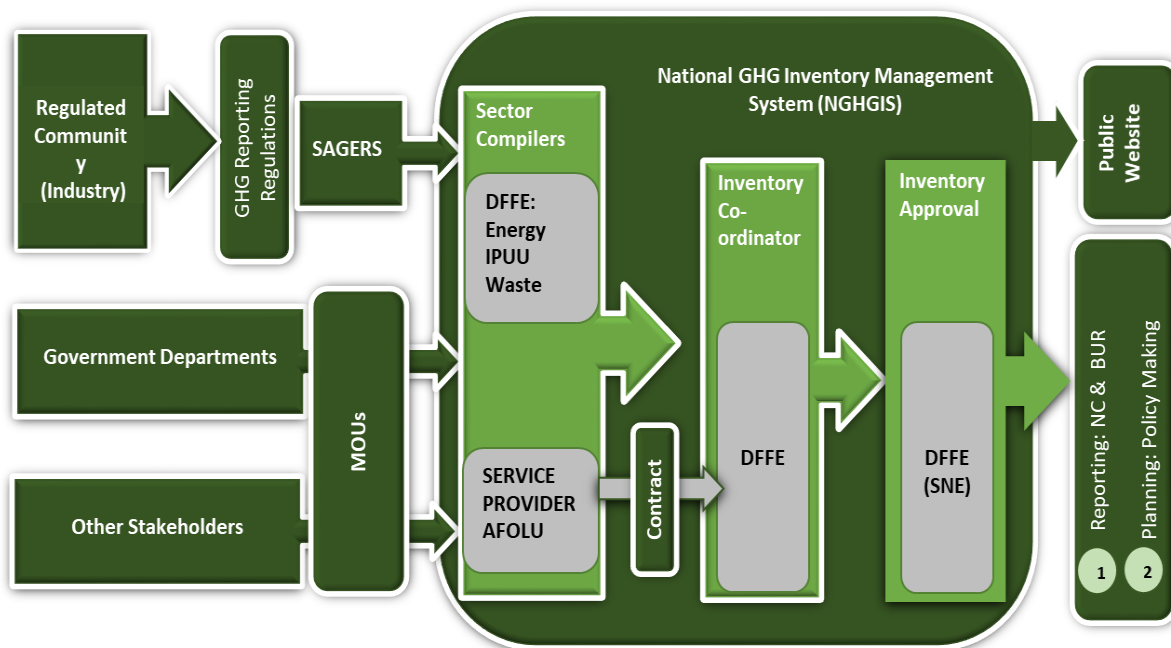


Figure 1.3: The inventory compilation process is co-ordinated through a central web-based inventory management system as depicted in this illustration.

1.4.1.2 Determination of key categories

A key category is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases 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 have been assessed using the Approach 1 level (L1) and Approach 1 trend (T1) methodologies from the 2006 IPCC Guidelines (IPCC, 2006). The key category analysis identifies key categories of emissions and removals as those that sum to 95 per cent of the gross or net level of emissions and those that are within the top 95 per cent of



the categories that contribute to the change between 2000 and 2020, or the trend of emissions.

1.4.1.3 Calculation and aggregation of uncertainties

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 as an important element of inventory preparation and development. Chapter 3 of the 2006 IPCC Guidelines 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.

The reporting of uncertainties requires a complete understanding of the processes of compiling the inventory, so that potential sources of inaccuracy can be qualified and possibly quantified. Obtaining quantitative information on uncertainty still remains a huge challenge for South Africa, and in many cases IPCC default uncertainties or expert judgement are still used. As improved uncertainty data becomes available it is included in the inventory.

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 *AFOLU* and synthetic gases. Uncertainty ranges for the various sectors (Appendix B) are largely consistent with typical uncertainty ranges expected for each sector (IPCC, 2014).

The IPCC good practice Tier 1 method was used to determine the overall aggregated uncertainty on South Africa's inventory estimate for 2020. More country specific uncertainty data will be required before South Africa can move to the Tier 2 approach.

1.4.2 Data collection, processing and storage

1.4.2.1 Data collection



Data collection and documentation take place under the responsibility of the relevant experts. One way of collecting data is to evaluate official statistics, association statistics, studies, periodicals and third-party research projects.

Collection of Energy data

The main sources of data for the *Energy* sector are the energy balance data compiled by the DMRE and data supplied by the main electricity provider, Eskom. In addition, data is also sourced from the companies PetroSA and Sasol, annual reports from South African Petroleum Industry Association (SAPIA) and Transnet. There are currently no formal processes in place for requesting or obtaining this data. The data collection process for the Energy sector is shown in Figure 1.4.

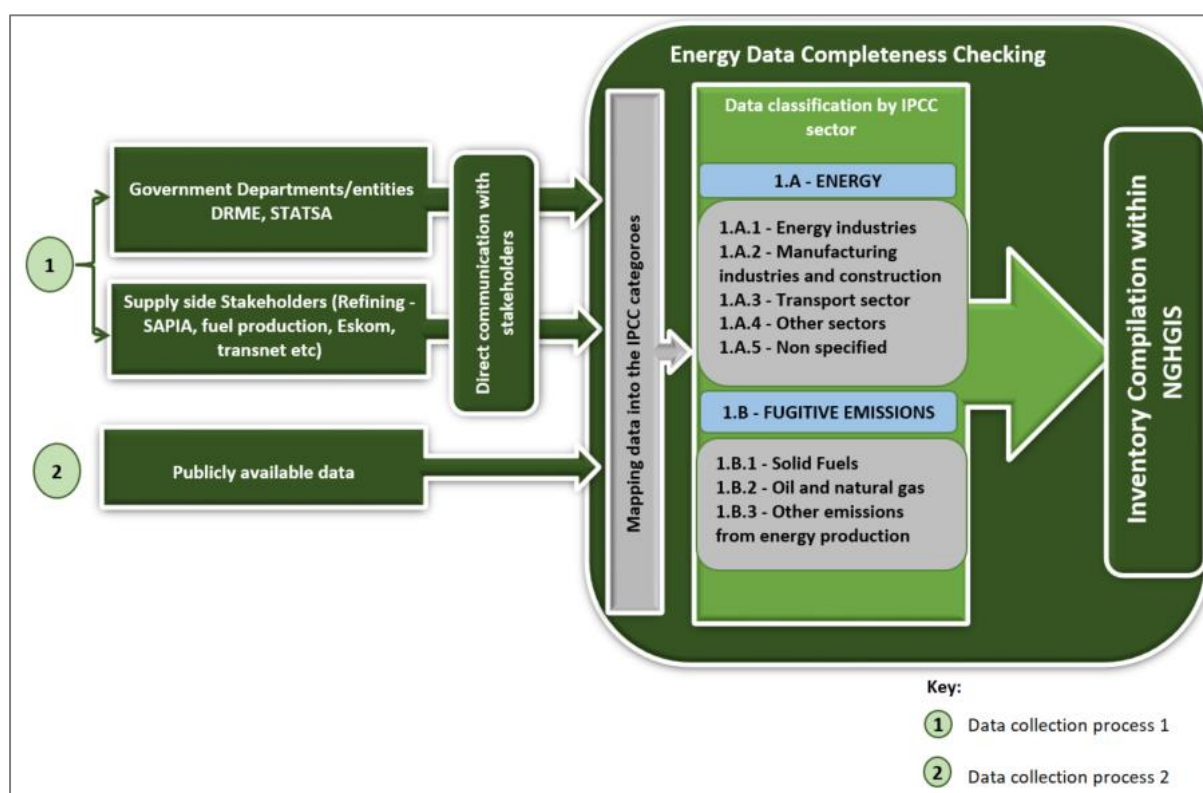


Figure 1.4: Data collection process for the 2020 Energy inventory.

NAEIS, SAGERS and industry data collection

South Africa has started to move towards a more formalised data collection system for industry. DFFE has setup the National Atmospheric Emissions Inventory System (NAEIS),



which is an online reporting platform for air quality and GHG emissions from companies to manage the mandatory reporting of GHG emissions. Emissions information including activity data from the NAEIS serves as input data during the national inventory compilation process. DFFE has modified the NAEIS to meet the requirements of the recent National Greenhouse Gas Reporting Regulations (NGER) (DFFE, 2017). This component of the portal, the South African GHG Emissions Reporting System (SAGERS), will serve as a tool for the implementation of the online registration and reporting by industry in fulfilment of mandatory NGER. The key benefit of the portal is that it will enhance the data collection process for the inventory, therefore improving the quality of the national GHG inventories consistent with the requisite principles of completeness, consistency, accuracy, comparability and transparency credentials.

HFC and PFC data collection

The HFC and PFC data was supplied by the DFFE waste branch and supplemented with the 2016 5-year periodic survey conducted by DFFE. There is no formal data collection process in place for this.

AFOLU data collection

The DFFE employs consultants to process the satellite imagery to generate land cover datasets used to determine land cover change for the *AFOLU* sector. This is usually done on a project-by-project basis. DFFE has 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 2018 onwards. The aim is to generate a map every two years. All SANLC data can be obtained from https://egis.environment.gov.za/gis_data_downloads. DFFE is also setting up a new land mapping system which will be able to incorporate and combine various types of land maps to generate a consistent time series since 1990.

Other spatial land data, such as the carbon density maps, are obtained from <https://catalogue.saeon.ac.za/>. These products are also developed on a project-by-project basis.

There are no formal data collection processes in place for all the other land and agriculture data. Data is obtained from available government reports, statistics database and the 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. Fertiliser and liming data is sourced from South African Revenue Service (SARS), DMRE and Fertilizer Association of South Africa (FertASA). Small amounts of crop statistics data is obtained from Statistics



SA. Plantation data will also be reported through the SAGERS system and so this data could be utilised in future inventories.

The main sources of data for agriculture are the Department of Agriculture, Land Reform and Rural Development (DALRRD) and Agricultural Research Council (ARC). Data from the ARC is also completed on a project-by-project basis and is not a consistent, sustainable data source. The SAGERS system has recently introduced small components of data from agriculture, such as data from poultry farms. Reporting has only just started, but the SAGERS system could be a mechanism to collect some data for the agriculture sector.

Waste data collection

As with the AFOLU sector there is no formal data collection process in this sector. The main data providers for the Waste sector are Statistics SA, DFFE, Department of Water and Sanitation (DWS) and the UN. In time it may be possible to collect some of the Waste data through the SAGERS system.

1.4.2.2 Data preparation and emission calculation

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

- a) Data entry,
- b) Data preparation (model formation, disaggregation, aggregation)
- c) Calculation of emissions,
- d) Preparation of report sections (texts), and
- e) 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 NIR 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:

$$\text{activity data} * \text{emission factor} = \text{emission}$$

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 responsible experts, and transmission of those materials to the Single National Entity, the materials are reviewed by category-specific, specialised contact persons at the Single National Entity, on the basis of a QC checklist. The results of this review are then provided to the relevant responsible experts, to enable these experts to revise their contributions (if necessary, following suitable consultation) accordingly.

1.4.2.3 Report preparation

Report preparation includes the following steps:

- a) Aggregation of emissions data for the national trend tables and reporting formats, preparation of data tables for the NIR,
- b) Compilation of submitted report texts to form a report draft (NIR), and editing of the complete NIR,
- c) Internal review of the draft (national trend tables and NIR) by DFFE,
- d) Public commenting process,
- e) External review by 3rd party,
- f) Finalisation of report,
- g) Approval by DFFE,
- h) Approval by Cabinet,
- i) Submission to UNFCCC, and
- j) Archiving.

1.4.2.4 Data storage and archiving

The National GHG Management System (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:

- (a) Stakeholder list with full contact details and responsibilities
- (b) List of input datasets which are linked to the stakeholder list
- (c) QA/QC plan
- (d) QA/QC checks
- (e) QA/QC logs which will provide details of all QA/QC activities
- (f) All method statements
- (g) 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
- (h) Calculation and supporting files
- (i) Key references



- (j) Key categories; and
- (k) All inventory reports.

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

1.5 Brief general description of methodologies and data sources

1.5.1 Data sources

The inventory is prepared using a mix of sources for activity data. The principal data sources are set out below.

1.5.1.1 Energy

Energy data sources are shown in Table 1.2.

Table 1.2: Principal data sources for the Energy sector inventory.

Sub-category	Activity data	Activity data sources
Electricity generation	Fuel consumption for public electricity generation	Eskom
	Fuel consumption for auto electricity producers	Energy balance (DMRE)
	NCVs	Eskom
Petroleum refining	Fuel consumption	Energy balance (DMRE)
Manufacture of solid fuels and other energy industries	No activity data, only emission data - based on Mass Balance Approach	PetroSA
		Sasol
Manufacturing industries and construction	Other kerosene, bitumen and natural gas consumption	Energy balance (DMRE)
	Gas/Diesel consumption	SAPIA
	Residual fuel oil consumption	Energy digest
	LPG consumption	SAMI report (DMRE)
Transport	Domestic aviation gasoline consumption	SAPIA
	Domestic aviation jet kerosene consumption	Energy balance (DMRE)
	Road transport fuel consumption	Energy balance (DMRE)



	Road transportation other kerosene consumption	SAPIA
	Railway fuel oil consumption	Energy balance (DMRE)
	Railway gas/diesel oil consumption	SAPIA
	Water-borne navigation fuel consumption	DMRE
	International aviation Jet Kerosene consumption	Energy balance (DMRE); SAPIA
Commercial/institutional	Other kerosene, gas/diesel oil, gas works gas and natural gas consumption	Energy balance (DMRE)
	Sub-bituminous coal consumption	Energy digest
	Residual fuel oil consumption	SAPIA
Residential	Coal consumption	SAMI report (DMRE)
	LPG consumption	SAPIA
	Sub-bituminous coal consumption	Energy digest
	Other fuel consumption	Energy balance (DMRE)
Agriculture/forestry/fishing/fish farms	Other kerosene consumption	SAPIA
	Gas/diesel oil consumption	Energy digest
	Other fuel consumption	Energy balance (DMRE)
Stationary non-specified	Fuel consumption	SAPIA
Mining	Coal consumption	SAMI report (DMRE)
Oil flaring	Emissions	PetroSA
Manufacturing of solid fuels and other industries	Emissions	Sasol; PetroSA
	Charcoal production	FAO

1.5.1.2 IPPU

Data for the IPPU sector is obtained mostly through the SAGERS system (Table 1.3).

Table 1.3: Principal data sources for the IPPU sector inventory.

Sub-category	Activity data	Data source
Cement production	Cement produced	SAGERS
	Clinker fraction	SAGERS
Lime production	Mass of lime produced	SAGERS
Glass production	Glass production	SAGERS
Ammonia production	Emissions from ammonia production	SAGERS
Nitric acid production	Emissions from nitric acid production	SAGERS
		SAGERS
Carbide production	Raw material (petroleum coke) consumption	SAGERS



Titanium dioxide production	Emissions from titanium dioxide production	SAGERS
Carbon black production	Amount of carbon black produced	SAGERS
Iron and steel production	Production data	SAGERS
Ferroalloys production	Production data	SAGERS
Aluminium production	Production data	SAGERS
Lead production	Production data	SAGERS
Zinc Production	Production data	Extrapolated
Lubricant use	Lubricant consumption	Extrapolated
Paraffin wax use	Paraffin wax consumption	Extrapolated
Refrigeration and air conditioning	Existing, new and retired refrigerators	HFC Survey DFFE; Stats SA
	Annual data on stationary air conditioning units	HFC Survey, DFFE; BSRIA
	Existing, new and retired refrigeration trucks	HFC study (GIZ, 2014); SARDA
	Existing. New and retired vehicles	eNaTIS; NAAMSA
Foam blowing agents	Total HFC used in foam manufacturing in a year	HFC Survey DFFE
Fire protection	Bank of agent in fire protection equipment in a year	HFC Survey DFFE
Aerosols		HFC Survey DFFE

1.5.1.3 AFOLU

AFOLU data is obtained from various sources as indicated in Table 1.4.

Table 1.4: Principal data sources for the AFOLU sector inventory.

Category	Principal data source	Principal data collection mechanism
3A Livestock	DALRRD	DFFE is in the process of developing an MOU with DALRRD
	FAO	Statistics available on FAO Stats website
	South African Poultry Association (SAPA)	Information obtained through direct contact. No formal mechanism is in place.
	ARC, TUT and University of Pretoria	Data is available through scientific publications.
3B Land	DALRRD	Statistical data is released annually and is freely available.



		DFFE is in the process of developing an MOU with DALRRD
	Forestry South Africa	Data obtained through direct request, no formal mechanism in place. Data is also freely available on their website.
	DFFE	Data and land maps are developed (usually by GTI) or funded through DFFE and are freely available on the EGIS website.
	ARC	DFFE is in the process of developing an MOU with ARC.
	SAEON/DFFE	Spatial data from the National Terrestrial Carbon Sinks Assessment is stored on the SAEON data portal and is freely accessible.
3C Aggregated and non-CO ₂ emissions from land	South African Mineral Industry Report compiled by DMRE	No formal mechanism in place but data is currently publicly available.
	MODIS burnt area data – obtained from website but processed by Gondwana Environmental Solutions	No formal process for obtaining this data but DFFE is considering compiling this data in-house.
	FAO	Statistics available on FAO Stats website
	ARC	DFFE is in the process of developing an MOU with ARC.
	Statistics SA	Agricultural census data are available from Statistics SA. No formal agreement exists between DFFE and Statistics SA.
3D Harvested wood products	FSA	Forestry SA (2018)

1.5.1.4 Waste

Waste data is collected from various data reports, statistics and global data sets (Table 1.5).

Table 1.5: Principal data sources for the Waste sector inventory.

Sub-category	Activity data	Data source
Solid waste disposal	Population data	Statistics SA (2015);
		UN (2012)
	Waste composition	IPCC 2006, and 2019 IPCC Refinement
	Waste generation rate for each component	State of Waste Report (2018)



	GDP	World bank
Open burning of waste	Population data	Statistics SA (2015);
		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 (2015);
		UN (2012)
	Split of population by income group	Statistics SA (2015)
	BOD generation rates per treatment type	IPCC 2006
	Per capita nitrogen generation rate	IPCC 2006

1.5.2 General description of methods

The guiding documents in the inventory's preparation are the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006). The methodologies are provided in a structure of three tiers that describe and connect the various levels of detail at which estimates can be made. The choice of method depends on factors such as the importance of the source category and availability of data. The tiered structure ensures that estimates calculated at a highly detailed level can be aggregated up to a common minimum level of detail for comparison with all other reporting countries. The methods for estimating emissions and/or removals are distinguished between the tiers as follows:

- Tier 1 methods apply IPCC default emission factors and use IPCC default models
- Tier 2 methods apply country-specific emission factors and use IPCC default models
- Tier 3 methods apply country-specific emission factors and use country-specific models.

Methodology for each sector in the inventory is described briefly here. Refer to each sector chapter for more detail.

1.5.2.1 Energy

Emissions for the *Energy* sector were estimated with a sectoral approach. A mix of T1, T2 and T3 methods are applied (details provided in Table 3.7 in chapter 3):

- a) Category 1A1 – T1/T2/T3
- b) Category 1A2 – T1/T2



- c) Category 1A3 – T1
- d) Category 1A4 – T1/T2/T3
- e) Category 1A5 – T1/T2
- f) Category 1B – T2
- g) Category 1B2 – T3
- h) Category 1B3 – T3

1.5.2.2 IPPU

Activity data in the *IPPU* sector are derived from a variety of sources. For this sector, South Africa uses a combination of Tier 1, Tier 2 and Tier 3 methods (details provided in Table 4.3 in chapter 4):

- a) Category 2A – T1/T2/T3
- b) Category 2B – T1/T3
- c) Category 2C – T1/T2/T3
- d) Category 2D – T1
- e) Category 2F – T1/T2

1.5.2.3 AFOLU

Livestock population data is obtained from DALRRD Agricultural Abstracts and herd composition from various livestock associations. A Tier 2 approach (IPCC, 2006) is used to estimate CH₄ emissions, with country-specific emission factors, from all livestock. Dry matter intake is estimated for these calculations. The same dry-matter intake data are used to calculate N₂O emissions from animal excreta.

Lime and urea application emissions are determined with a Tier 1 approach, with activity data being obtained from South African Fertilizer Association, DMRE and South African Revenue Service (SARS). A mix of Tier 1 and Tier 2 methods are applied for *Direct N₂O emissions*, while a Tier 1 approach is utilized for *Indirect N₂O emissions*. Biomass burning emissions are estimated with a Tier 1 method. Burnt area data are obtained from MODIS.

The *Land* category in South Africa applies a mix of Tier 1 and Tier 2 approaches. A Tier 2 approach is used for all biomass and DOM changes. SOC changes are also determined with a Tier 2 approach, using country specific SOC reference and stock change values. A wall-to-wall map, based on Landsat images, forms the main input for the *Land* sector. *Harvested wood products* emissions were estimated with a Tier 2 approach.

1.5.2.4 Waste



Solid waste is determined with the IPCC first order decay model. Tier 1 methods are used to estimate all emissions in the *Waste* sector.

1.6 Brief description of 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 have been assessed using the Approach 1 level (L1) and Approach 1 trend (T1) methodologies from the 2006 IPCC 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 per cent of the gross or net level of emissions and those that are within the top 95 per cent of the categories that contribute to the change between 2000 and 2020, or the trend of emissions. This includes both source and sink categories. The level assessment was conducted on the base year (2000) and the current year (2020), while the trend assessment utilised the base year 2000 and 2020.

Identifying key categories will allow resources to be allocated to the appropriate activities to improve those specific subcategory emissions in future submissions. In this inventory a ranking system was added to allow the key categories to be ranked in order of prioritisation based on the findings from both the level and trend assessment. The ranking system works by allocating a score based on how high categories rank in the current year level assessment and the trend assessment. The top-ranking category gets a score of 1 and the second a score of 2, etc. The ranking score from both approaches are then added together to get the overall score for each category. The categories are then ranked from lowest score to highest, with draws in score resolved by the most recent



year level assessment. This ranking approach was only applied to the assessments including FOLU. The key categories identified in 2020, along with their ranking, are summarised in Table 1.6. The full key category analysis (level and trend, including and excluding FOLU) is provided in Appendix A.

Table 1.6: Key categories for South Africa for 2020 (including FOLU) and their ranking.

Rank	IPCC Category code	IPCC Category	GHG [#]
1	1A1a	Electricity and Heat Production (Solid fuel)	CO ₂
2	1A3b	Road Transport (Liquid fuel)	CO ₂
3	3B1a	Forest land remaining forest land	CO ₂
4	4A	Solid Waste Disposal	CH ₄
5	1A5a	Stationary (Solid fuel)	CO ₂
6	1B3	Other Emissions from Energy Production	CO ₂
7	1A4c	Agriculture/Forestry/Fishing/Fish Farms (Liquid fuel)	CO ₂
8	2C1	Iron and Steel Production	CO ₂
9	3A1a	Enteric fermentation - cattle	CH ₄
10	2F1	Refrigeration and Air Conditioning	HFCs
11	1A1c	Manufacture of Solid Fuels and Other Energy Industries (Liquid fuel)	CO ₂
12	1A2	Manufacturing Industries and Construction (Solid fuel)	CO ₂
13	3B1b	Land converted to forest land	CO ₂
14	2C2	Ferroalloys Production	CO ₂
15	1A2	Manufacturing Industries and Construction (Liquid fuel)	CO ₂
16	1A1a	Electricity and Heat Production (Liquid fuel)	CO ₂
17	3C4	Direct N ₂ O emissions from managed soils	N ₂ O
18	3A1c	Enteric fermentation - sheep	CH ₄
19	1A4a	Commercial/Institutional (Solid fuel)	CO ₂
20	1A3d	Water-Borne Navigation (Liquid fuel)	CO ₂
21	1A4b	Residential (Solid fuel)	CO ₂
22	4D1	Wastewater Treatment and Discharge	CH ₄
23	1A4b	Residential (Liquid fuel)	CO ₂
24	1A1b	Petroleum Refining (Gas fuel)	CO ₂
25	3D1	Harvested wood products	CO ₂
26	3B4	Wetland	CH ₄
27	3B5a	Settlements remaining settlements	CO ₂
28	4D2	Industrial Wastewater Treatment and Discharge	CH ₄
29	1A3a	Civil Aviation (Liquid fuel)	CO ₂
30	3C2	Liming	CO ₂
31	1A5a	Stationary (Liquid fuel)	CO ₂
32	2B	Chemical industry	C
33	2D1	Lubricant Use	CO ₂



34	3A1d	Enteric fermentation - goats	CH ₄
35	1A1b	Petroleum Refining (Liquid fuel)	CO ₂
36	3A2i	Manure management - poultry	N ₂ O
37	1A4a	Commercial/Institutional (Liquid fuel)	CO ₂
38	3B6b	Land converted to other lands	CO ₂
39	3B3a	Grassland remaining grassland	CO ₂
40	3B2b	Land converted to cropland	CO ₂
41	3A2a	Manure management - cattle	N ₂ O
42	1B3	Other Emissions from Energy Production	CH ₄
43	1A1a	Electricity and Heat Production (Solid fuel)	N ₂ O
44	2C2	Ferroalloys Production	CH ₄
45	2A2	Lime Production	CO ₂
46	3B2a	Cropland remaining cropland	CO ₂
47	4D1	Wastewater Treatment and Discharge	N ₂ O
48	3C3	Urea application	CO ₂
49	2D2	Paraffin Wax Use	CO ₂
50	2C3	Aluminium Production	PFCs
51	2C3	Aluminium Production	CO ₂
52	3B3b	Land converted to grassland	CO ₂
53	3B5b	Land converted to settlements	CO ₂
54	3C5	Indirect N ₂ O emissions from managed soils	N ₂ O
55	3B4a	Wetland remaining wetland	CO ₂

#C=Confidential

1.6.1 Changes in key categories since the 2017 submission

In the level assessment of emissions (excl. FOLU) there are a few new key categories in this submission which are *Electricity and heat production* (liquid fuels; CO₂), *Coal mining and handling* (CH₄), *Chemical industry*, *Water-borne-navigation* (liquid fuel; CO₂), *Manure management* emissions from cattle (N₂O), *Enteric fermentation* from goats (CH₄) and *Aluminium production* (CO₂). These categories are at the bottom of the key category list. There were three categories that moved off the list and these are *Commercial/Institutional* (solid fuels; CO₂) and *Indirect N₂O from managed soils*. *Commercial/institutional* (solid fuels) contribution was 5.4% in the previous submission, so this is a significant change. There is a large drop in emissions in this sector in 2020 and this is likely due to the COVID-19 lockdown restrictions.

Considering the main differences in contribution of each category to the current submission and the 2017 submission, *Road transport* decreased its contribution from 9.9% to 9.3% and *Electricity and heat production* increased its contribution from 41.8%



to 42.8% (Figure 1.5). *Direct N₂O emissions from managed soils* declined from 3.3% to 1.1% but this is likely due to the updated emission factor which was much lower than in the previous inventory. The *Ferroalloys production* and *Iron and Steel production* decreased their contribution, and this could be attributed to COVID-19 lockdown restrictions. The top five key categories have shifted in that *Commercial/Institutional* (solid fuels) moved off the key category list and out of the top five and *Other emissions from Energy Production* moved up into the top five, as well as *Enteric fermentation* from cattle.

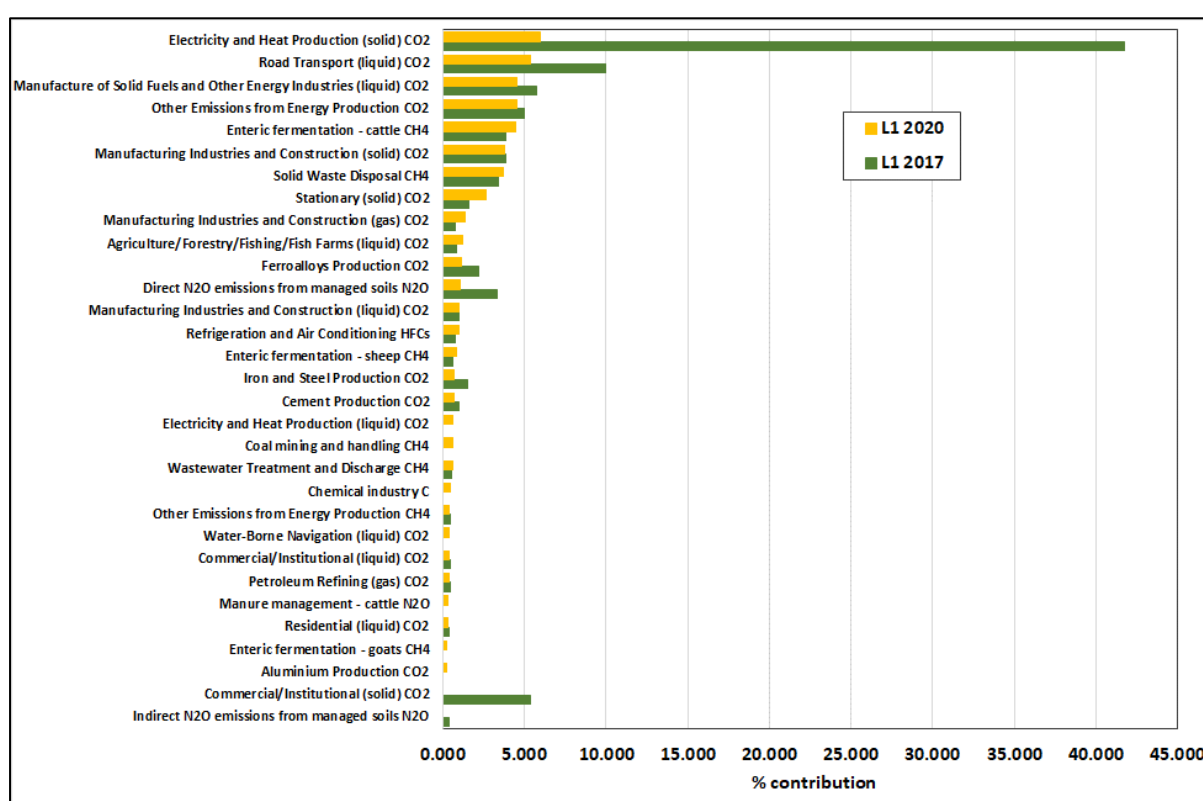


Figure 1.5: Difference in contribution to the level assessment (excl. FOLU) key category analysis between the current submission and the 2017 submission.

In the level assessment of emissions (incl. FOLU) there were several additional land key categories, namely *Wetland remaining wetland* (CO₂), *Cropland remaining cropland* (CO₂), *Other land remaining other land* (CO₂), *Settlements remaining settlements* (CO₂), *Manure management* (cattle, N₂O), *Enteric fermentation* (goats, CH₄), *Wetland* (CH₄) and *Land converted to wetland* (CO₂) (Figure 1.6). The wetland category CO₂ emissions were added in this inventory, and the land remaining land categories may have moved into the key categories due to the reporting of all SOC changes under the land remaining category



instead of under the land converted to another land category. *Forest land remaining forest land* contribution declined, while *Grassland remaining grassland* increased but these changes are due to updates as opposed to be actual changes.

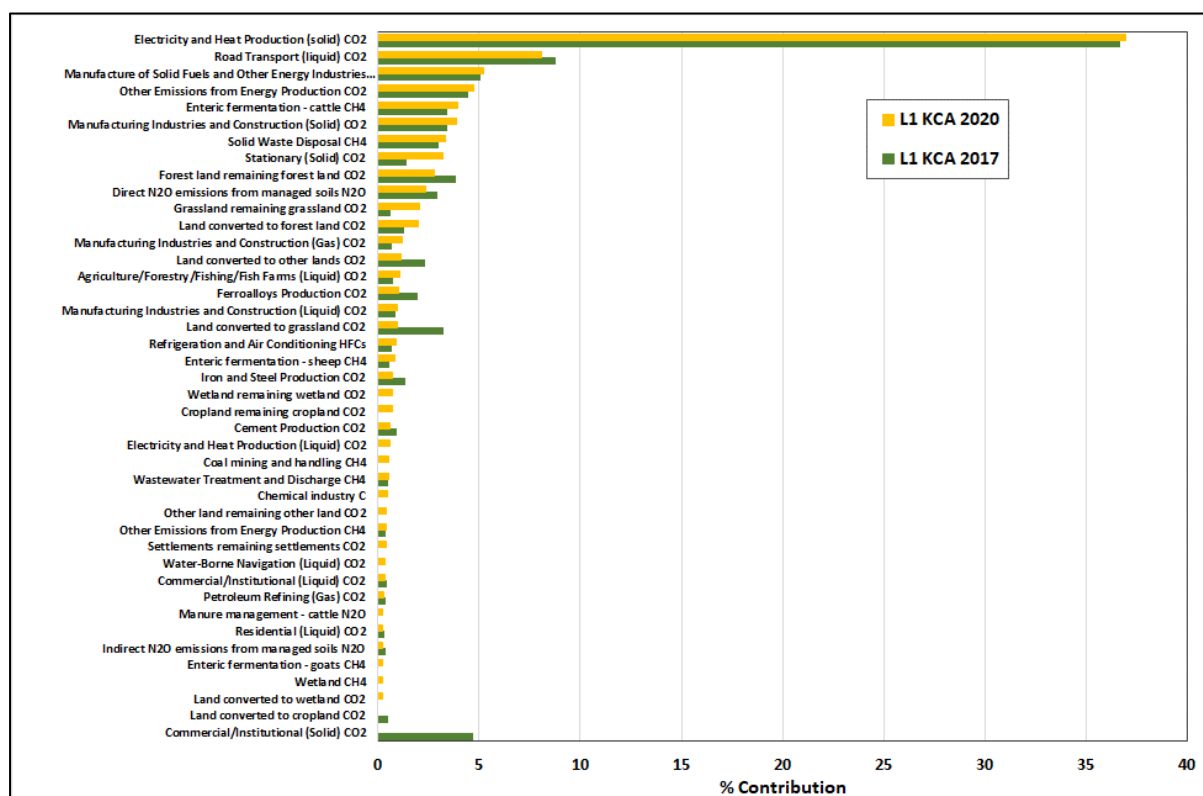


Figure 1.6: Comparison of level assessment key categories and their contribution to emissions (incl. FOLU) in the current and previous 2017 submission.

With the trend analysis on emissions (excl. FOLU) there were several additional key categories, namely, *Stationary* (liquid fuels; CO₂), *Water-borne navigation* (liquid fuels, CO₂), *Industrial wastewater treatment and discharge* (CH₄), *Lubricant use* (CO₂), *Coal mining and handling* (CH₄), *Petroleum refining* (gaseous fuels, CO₂), and *Ferroalloy production* (CH₄). There were also several categories moving off the list as can be seen in Figure 1.7. Even though Commercial/Institutional (solid fuel, CO₂) dropped off the level assessment key category list it increased its contribution from 2.5% to 3.8% in the trend assessment. This is likely because of the very large decrease shown in 2020 as the trend analysis shows declines as well as increases in emissions. The contribution from Electricity and heat production (solid fuels, CO₂) increased from 0.6% to 3.0%. The contributions from *Other emissions and energy production*, and *Manufacture of solid fuels and other energy industries* dropped significantly and this could be due to reduction in



consumption during the COVID-19 lockdown. Cattle *enteric fermentation* and *Direct N₂O emissions from managed soils* also showed significant declines, with the N₂O emissions being due to an updated emission factor and not necessarily because emissions declined.

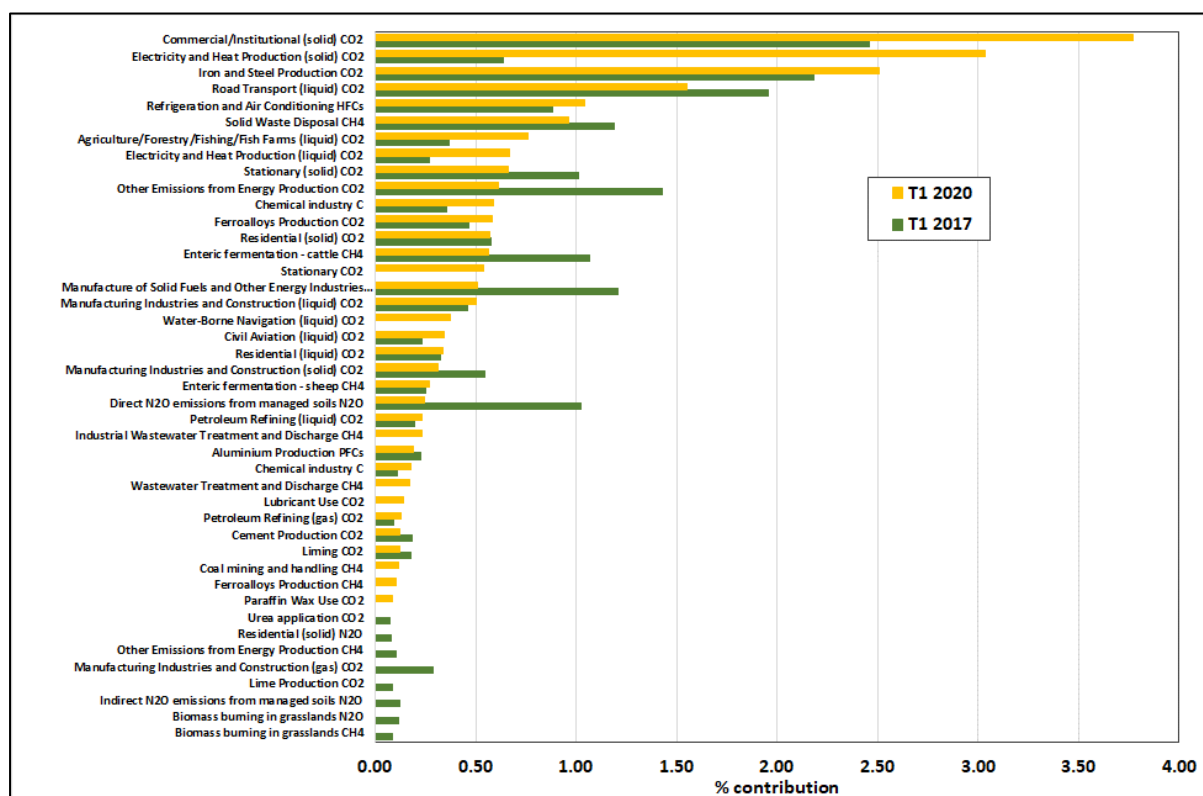


Figure 1.7: Difference in contribution to the trend assessment (excl. FOLU) key category analysis between the current submission and the 2017 submission.

Including FOLU in the trend analysis led to the inclusion of the land category *Wetlands* (CH₄) (Figure 1.8)¹. The categories *Settlements remaining settlements* (CO₂), *Land converted to other lands* (CO₂), *Land converted to grasslands* (CO₂) and *Grassland remaining grassland* (CO₂) were no longer on the trend key category list, but this may be due to the change of incorporating the SOC change under land remaining category instead of under the land converted to other land category.

¹ It should be noted that the categories that are no longer on the trend key category list are not shown in Figure 1.8 to reduce the number of categories shown on the chart so that the labels are legible.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

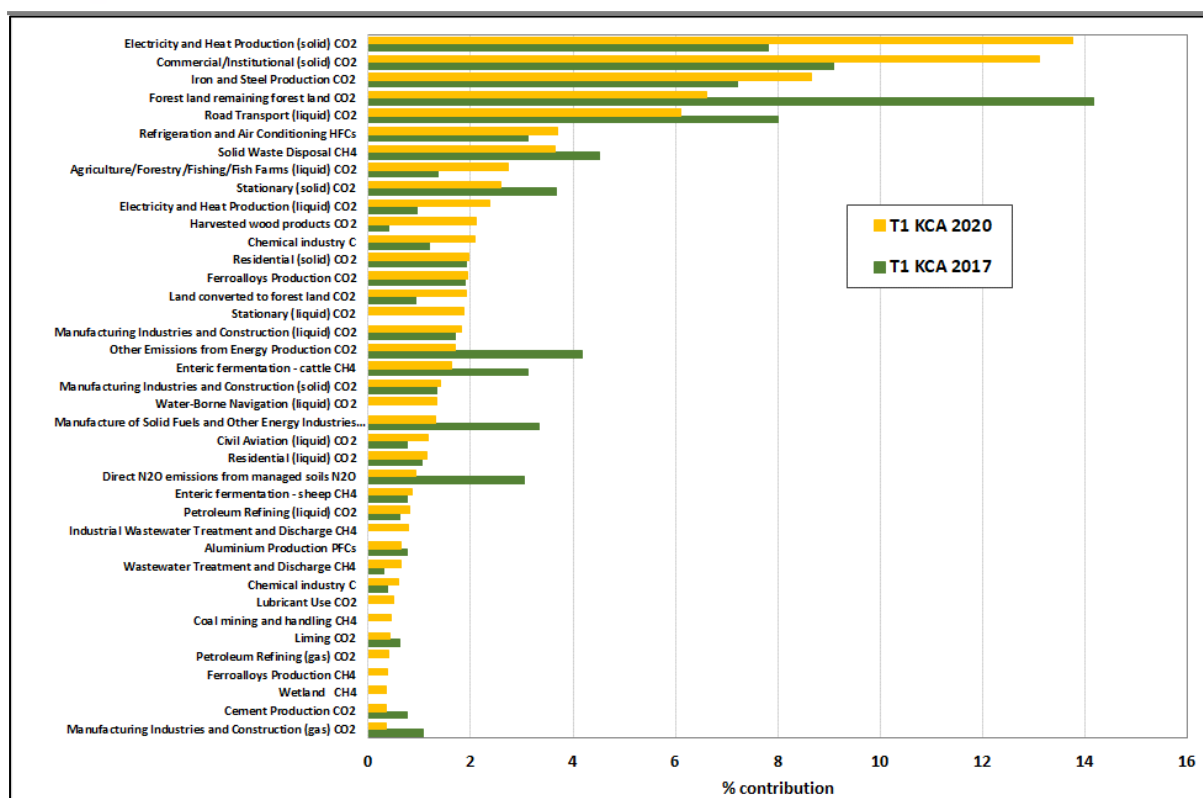


Figure 1.8: Comparison of trend assessment key categories and their contribution to emissions (incl. FOLU) in the current and previous 2017 submission.

1.7 Quality assurance, quality control and verification plans and procedures

1.7.1 Quality assurance and quality control procedures

1.7.1.1 QA/QC plan and procedures

As part of the NGHGIS, South Africa developed a formal quality assurance/quality control plan (see Appendix 1.A of 2015 NIR (DFFE, 2018)). 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, QAnylist, assisted with the process of tracking the comments by keeping a log in the front of each file.



1.7.1.2 General QC procedures

The quality control (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 2006 IPCC 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 2020 inventory are provided in Table 1.7.

Table 1.7: Quality control checks carried out on South Africa's 2020 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



ID	Type of check	Description	Level
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 of 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
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



ID	Type of check	Description	Level
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 NIR
QC032	Data aggregation	Has the data been correctly aggregated across the sectors?	Draft NIR
QC033	Documentation - CRF tables	Check CRF tables are included.	Draft NIR
QC034	Documentation - KCA	Check that key category analyses have been included.	Draft NIR
QC035	Documentation - Uncertainty	Check uncertainty analysis have been included.	Draft NIR
QC036	Documentation - Overall trends	Check overall trends are described both by sector and gas species.	Draft NIR
QC037	Documentation - NIR sections complete	Check all relevant sections are included in the NIR.	Draft NIR
QC038	Documentation - Improvement plan	Check that the improvement plan has been included.	Draft NIR
QC039	Documentation - Completeness	Check for completeness	Draft NIR
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 NIR
QC041	Documentation - References	Check consistency of references.	Draft NIR
QC042	Documentation - General format	Check general NIR format - acronyms, spelling, all notes removed; size, style and indenting of bullets are consistent.	Draft NIR
QC043	Documentation - Updated	Check that each section is updated with current year information.	Draft NIR
QC044	Double counting - Sectors	Check there is no double counting between the sectors.	Draft NIR
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



ID	Type of check	Description	Level
QC050	Documentation - QA/QC	Check the QA/QC procedure is adequately described.	Draft NIR
QC051	Complete uncertainty check	Check that the uncertainty analysis is complete.	Draft NIR
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 NIR been approved by the steering committee? Was there public consultation?	Draft NIR
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
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	Waste water 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

1.7.1.3 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 was something new in this round and proved to be very useful. Everyone had a chance to



understand other sectors and it also improved the cross linkages. This should continue in future inventories.

1.7.1.4 Review process

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 (Figure 1.9). 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. Appendix F provides the details of the last external review and the UNFCCC review and which comments have been addressed to date.

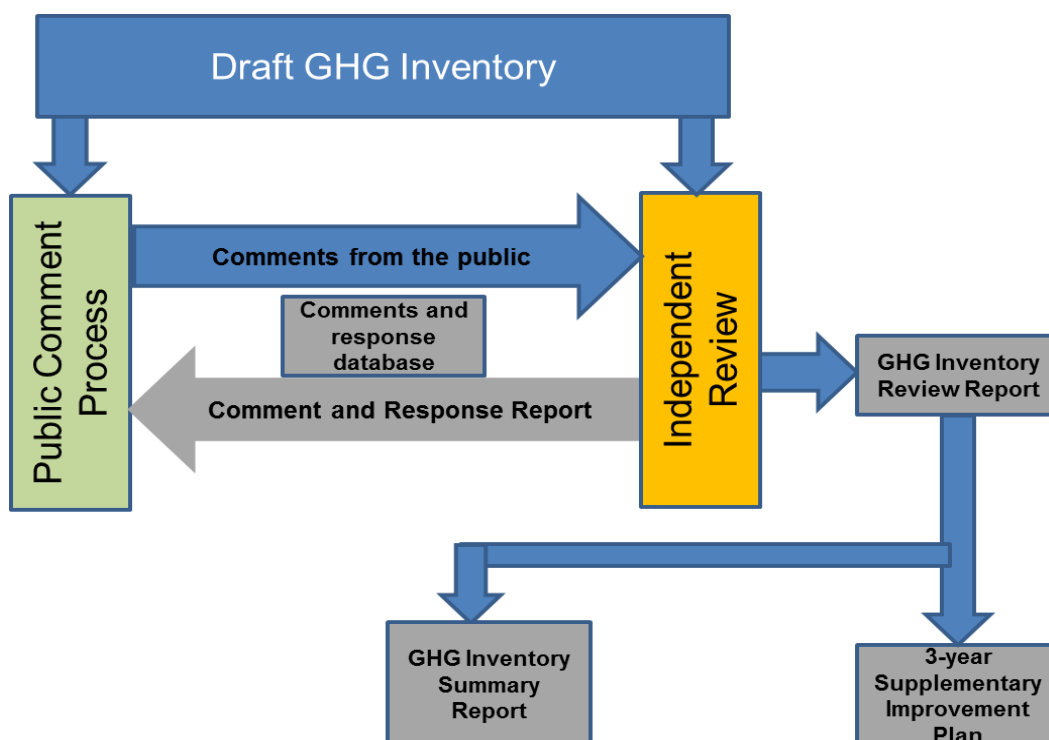


Figure 1.9: The independent review process for the 2000 – 2020 inventory.



1.7.2 Verification activities

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. The specific verification activities are described in detail in the relevant category sections in the following chapters.

1.8 General uncertainty evaluation

1.8.1 Procedures for determining uncertainty

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 as an important element of inventory preparation and development. Chapter 3 of the 2006 IPCC Guidelines 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.

The reporting of uncertainties requires a complete understanding of the processes of compiling the inventory, so that potential sources of inaccuracy can be qualified and possibly quantified. South Africa still lacks data in terms of country specific uncertainty for all sectors. As data becomes available it is incorporated but there is a general need to build capacity and develop projects to assess the uncertainty in each sector.

1.8.2 Results of uncertainty assessment

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 *AFOLU* and synthetic gases. Uncertainty ranges for the various



sectors (Appendix B) are largely consistent with typical uncertainty ranges expected for each sector (IPCC, 2014).

The IPCC good practice Tier 1 method was used to determine the overall aggregated uncertainty on South Africa's inventory estimate for 2020. A trend uncertainty between the base year and 2020, as well as a combined uncertainty of activity data and emission factor uncertainty was determined using an Approach 1. The total uncertainty for the inventory was determined to be 9.11%, with a trend uncertainty of 7.54%. Excluding FOLU reduced the overall uncertainty to 7.64%, with the trend uncertainty dropping to 6.78%. The full uncertainty assessment is provided in Appendix B.

1.9 General assessment of completeness

The South African GHG emission inventory for the period 2000 – 2020 is not complete, mainly due to the lack of sufficient data. Table 1.8 identifies the sources in the 2006 IPCC Guidelines which were not included or included elsewhere in this inventory and the reason for their omission is discussed further in the appropriate chapters. The table also indicates which activities do not occur in South Africa.

Table 1.8: Activities in the 2020 inventory which are not estimated (NE), included elsewhere (IE) or not occurring (NO).

NE, IE or NO	IPCC Category	Activity	Comments
NE	1B2	CO ₂ and CH ₄ fugitive emissions from oil and natural gas operations	CO ₂ emissions from Oil are included, but CH ₄ emissions need to be included along with natural gas emissions. To be included in the next inventory submission.
	1B1b	CO ₂ , CH ₄ and N ₂ O from spontaneous combustion of coal seams	New research work on sources of emissions from this category will be used to report emissions in the next inventory submission
	1B1ai2	CH ₄ emissions from abandoned mines	New research work on sources of emissions from this category will be used to report emissions in the next inventory submission
	1C1	CO ₂ transport	Insufficient data to include
	1C2	Injection and storage	Insufficient data to include
	2B7	CH ₄ and N ₂ O emissions from Soda Ash Production	CO ₂ included in this inventory so CH ₄ and N ₂ O will be included in the next inventory



	2C1	N ₂ O emissions from iron and steel production	Insufficient data to include
	2C2	N ₂ O emissions from ferroalloy production	Insufficient data to include
	2D2	CH ₄ and N ₂ O emissions from paraffin wax use	Insufficient data to include
	2E	Electronics industry	A study needs to be undertaken to understand emissions from this source category
	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
	3B	CO ₂ from organic soils	Due to priority this will only be included in the next inventory.
	3C4	N ₂ O from organic soils	Insufficient data to include
	4B	CH ₄ , N ₂ O emissions from biological treatment of waste	Insufficient data to include, but will be considered for inclusion in next inventory
	4C1	CO ₂ , CH ₄ and N ₂ O from waste incineration	Insufficient data to include
	2	SF ₆ emissions in the IPPU sector	Insufficient data. It is planned to include these by the 2021 inventory.
	All sectors	NO _x , CO, NMVOC emissions	These have only been included for biomass burning due to a lack of data in other sectors
	All sectors	SO ₂ emissions	Insufficient data. It is planned to include these by the 2021 inventory.
IE	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.
	3B	Precursor emissions from controlled burning	Emissions from controlled burning are not separated from biomass burning and so are included under Biomass burning (3C1)
	3B	SOC changes for converted land	This data is included under the land remaining land category as Formulation A of the SOC equation was applied.
	3C1	CO ₂ emissions from biomass burning	These are not included under biomass burning, but rather under disturbance losses in the Land sector (3B).
NO	2B3	CO ₂ , CH ₄ and N ₂ O emissions from Adipic acid production	
	2B4	CO ₂ , CH ₄ and N ₂ O Caprolactam, Glyoxal and Glyoxylic acid production	



1.10 Improvements introduced

1.1.1 Energy

Updated consumption data in the *Road transport, Manufacturing industries and construction, Other sectors and Non-specified emissions from energy production* categories was included, particularly for coal, diesel, natural gas and gas works gas. This was because the energy balance data from DMRE updated the fuel allocation in these sectors. In addition, new data became available from a fuel consumption study done by DFFE under the GHG improvement programme. This was completed for the transport sector which provided consumption data based on vehicle kilometres travelled (VKT). In this inventory the petrol, diesel and natural gas consumption data for *Road transport* was updated. Lastly the Department of Mineral Resources and Energy had updated coal statistics in its South Africa's Mineral Industry (SAMI) report series.

1.1.2 IPPU

Through the introduction of the SAGERS Portal, the GHG reporting tool, there have been various additions to the inventory as well as recalculations and these are:

- *Mineral Industry:*
 - The addition of Other Process Uses of Carbonates category from 2018.
 - Activity data for 2018 and 2019 were extrapolated for quicklime due to lack of activity data.
 - The addition of dolomitic lime from 2019.
- *Chemical Industry:*
 - Addition of silicon carbide production in 2019 has led to increased carbide production emissions through the estimation of CH₄ emissions.
 - Titanium dioxide production saw an error corrected from 2014 onwards resulting in higher but accurate emissions
 - Addition of Soda ash production category from 2019.
 - Addition of hydrogen production from 2018.
- *Metal Industry:*
 - The addition of Treatment of secondary raw material under Lead production, which has led to a change throughout the time series where the



emission factor was changed from 0.52 to 0.2 tonnes CO₂/tonne product) from 2000 – 2020.

1.1.3 AFOLU

1.10.1.1 Livestock

In the livestock category Tier 2 data for enteric fermentation and manure management emission factor calculations for cattle, goats and sheep were incorporated based on a recent study by ARC (2020). This also led to changes in the livestock categorisation and an update of manure management data.

1.10.1.2 Land

In the *Land* category several updates were made:

- Incorporation of the 1990-2018 land change matrix;
- Updated biomass, DOM and litter data from the NTCSA (DEFF, 2020) and scientific publications were incorporated;
- DOM included deadwood;
- Biomass accumulation rates were updated and forests were divided into primary and secondary forests to accommodate different growth rates;
- Mortality was included in forest biomass;
- Charcoal consumption was included in fuelwood collection data;
- New BCEF factors for plantations were included;
- Country specific SOC reference values and stock change factors were utilised; and
- CO₂ for mineral wetland soils was included, along with CH₄ and N₂O emissions.

1.10.1.3 Aggregated and non-CO₂ sources on land

This category was improved firstly by the changes in the livestock category as these have an input to this category. In addition, MODIS burnt area data was updated to Collection 6 data.

1.10.1.4 Other (HWP)

Country specific data was included in this category.



1.1.4 Waste

Various improvements were incorporated into the Waste sector:

- The population, waste per capita and the percentage of waste going to solid waste disposal sites was corrected in the FOD model for the years 1950 to 2000;
- Waste generation rate per person was adjusted from 511 kg/cap/yr in previous submissions to 398 kg/cap/yr in the current submission and this is consistent with the waste generation rates per capita provided in the 2019 refinement to the 2006 IPCC guidelines.
- Waste generation rate per GDP value, for purposes of estimating the amount of industrial waste generated was adjusted from 8Gg waste/GDP/yr in previous submissions to 0.4 waste/GDP/yr in the current submission.
- Amount sent to SWDS adjusted to 76% for MSW and 85% for Industrial waste to reflect changes in penetration of recycling and the evolution of other forms of waste management and/or treatment.
- The fraction of methane in developed gas was previously indicated to be 0.52 and this was corrected to the IPCC default value of 0.5.

1.11 Improvement plan

Table 1.9 shows planned improvements and the timelines for these improvements.



Table 1.9: List of planned improvements for South Africa's GHG inventory.

Sector	Improvement	Priority	Reason	Status	Completion timeframe	Barriers and constraints
Completed tasks						
Cross-cutting	Incorporate data from SAGERS into inventory (data reported due to NGER)	High	Accuracy	Completed	5 th BUR (2019 inventory)	Data will continue to be incorporated into the future.
	Set up MOUs with key data providers, e.g. DMRE, Eskom, SAPIA	High	Transparency	Resolved		This has proved to be difficult and is not working, therefore regulatory processes (NGER) and the GHGIP are being used for data gathering instead.
Energy	Incorporated all updated information from the recent fuel consumption study.	High	Key category; Accuracy	Completed	5 th BUR (2019 inventory)	The results of the study were incorporated to produce an enhanced inventory.
	Improve understanding of difference between reference and sectoral approach	Medium	Key category; Transparency	Resolved	5 th BUR (2019 inventory)	Updates were made to the Energy balance data and the actual methodology and calculation file for the reference approach was reassessed. Data was incorporated into the energy sector calculation file.
IPPU	Calculate CH ₄ emissions from Iron and steel production	High	Key category; Completeness	Completed	5 th BUR (2019 inventory)	Completed.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

	Estimate emissions from OPUC category using currently available data	Medium	Completeness	Completed	5 th BUR (2019 inventory)	Completed for ceramics.
AFOLU	Update HWP with country specific data	Low	Accuracy	Completed	5 th BUR (2019 inventory)	Completed.
Tasks in progress						
Cross-cutting	Improve transparency in reporting by including more detailed description of methodologies and activity data, particularly in energy and IPPU sectors.	High	Transparency	In progress	5 th BUR (2019 inventory)	Transparency in the Energy and IPPU sectors were enhanced, however this is an ongoing activity and further updates will be made in the 2021 inventory.
	Improve the improvement plan by incorporating all review activities not addressed in current inventory	High	Transparency	In progress	5 th BUR (2019 inventory)	Partly resolved. Challenges around inclusion of further improvements into the improvement plan are limited resources and process management. The DFFE inventory team has increased in size, but it is still taking time to completely address all the issues. The review outputs are included in this report as a reminder of what still needs to be completed.
Energy	CO ₂ and CH ₄ fugitive emissions from oil and natural gas operations	Medium	Completeness	In progress	5 th BUR (2019 inventory)	Partly resolved. CO ₂ emissions from Oil are included. Further gases from this source category will be added in the next inventory



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

						as information will be obtained through NGER.
	Improve explanation of large changes in trends	High	Transparency	In progress	5 th BUR (2019 inventory)	Partly resolved. Additional explanations have been provided, but there are still areas where this can be improved further. Ongoing process.
AFOLU	Incorporate all background data and equations for the Tier 2 calculations of enteric fermentation	High	Key category; Accuracy; Transparency	In progress	6 th BUR (2021 inventory)	Partly completed. All the background equations have been included, but average data is still being used for some of the factors (instead of annual data) due to a lack of a sustainable data source. This will be further investigated in the 2021 inventory.
	Incorporate updated National Terrestrial Carbon Sinks Assessment (NTCSA) data to improve estimates, particularly for soils	High	Key category; Accuracy	In progress	5 th BUR (2019 inventory)	Partly resolved. The NTCSA above-ground woody, above round herbaceous and DOM were included or used as validation data, but not as a Tier 3 approach due to there only being 1 year of data. The SOC data was incorporated. A study needs to be undertaken to fully incorporate the carbon sinks data and also to conduct an uncertainty assessment on the data. This could be a project for the GHGIP.
	Include deadwood in the DOM pool for all land categories	Low	Completeness	In progress	6 th BUR (2021 inventory)	Partly resolved. Deadwood was included for forest land categories.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

	Include CO ₂ estimates for wetlands	Low	Completeness	In progress	6 th BUR (2021 inventory)	Partly resolved. Wetlands were assumed to be mineral inland wetlands and CO ₂ estimates were incorporated on this basis. The data from the Blue Carbon study should however be used to update this and include other wetlands and mangroves.
	Include 2018 and 2020 SANLC maps	High	Key category; Completeness; Accuracy	In progress	6 th BUR (2021 inventory)	Partly resolved. The 2018 and 2020 SANLC maps were developed using Sentinel 2 data as opposed to the Landsat data that was used for 1990 and 2014. This posed some challenges as there was some reclassification of the land types which led to large area changes. The 2018 map was degraded to compare with the 1990 and 2014 maps and an assessment of the natural land change classes was completed. In this inventory the 1990-2018 matrix was applied with some assumptions based on the land change data assessment. At this stage the 2020 data has not been included, but a new land mapping platform is being planned which will enable various land maps, independent of their technology, to be incorporated. In addition, this will allow better analysis of land change over time which will assist in determining actual change as opposed to natural change (due to climate for example) in the natural land



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

						classes. The improved mapping is a high priority for the next inventory.
Waste	Data collection on quantities of waste disposed of into managed and unmanaged landfills		Key category; Accuracy	In progress	5 th BUR (2019 inventory)	Project is underway so data was incorporated in the 2020 inventory.
Tasks outstanding						
Cross cutting	Improve uncertainty data for all sectors but incorporating more country specific uncertainty values	Medium	Accuracy	Proposed	Incorporated as data becomes available	Lack of uncertainty data constrains this activity. As data becomes available it will be incorporated, but there are no specific planned projects for this activity at this stage.
	Extend time-series back to 1990 for energy, IPPU and waste sectors.	Medium	Completeness	Planned	6 th BUR (2021 inventory)	Lack of data for years prior to 2000, particularly for categories where data is highly variable (such as HFCs and PFCs), have constrained the completion of this task. A study is planned to extend/extrapolate the data back to 1990 for the three IPCC sectors.
	Investigate inconsistencies in lime activity data (for lime production in IPPU and lime application emission in AFOLU), explore alternative	Low	Consistency	Planned	5 th BUR (2019 inventory)	Not resolved. Various methods were compared but give varying results. Alternative data sources have not yet been found, but it may be possible to collect further data through the SAGERS system in future.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

	data sources or improve consistency.					
	Improve QA/QC process by addressing all issues in external review	High	Transparency	In progress	5 th BUR (2019 inventory)	Challenges in addressing external review comments have been limited by resources and process management. The DFFE inventory team has increased in size which should assist in addressing this issue. There are still a large number of issues not resolved but the inventory team is working through them. It is an ongoing process.
	Incorporate NO _x , CO, NMVOC, and SO _x emissions	High	Completeness	Proposed	5 th BUR (2019 inventory)	Not resolved. Limited data is available to complete the time series from 2000 – 2020.
Energy	CO ₂ , CH ₄ and N ₂ O from spontaneous combustion of coal seams	Low	Completeness	Planned	6 th BUR (2021 inventory)	New research will allow this category to be included in the 2021 inventory.
	CH ₄ emissions from abandoned mines	Low	Completeness	Planned	6 th BUR (2021 inventory)	New research outputs will enable this activity to be included in the 2021 inventory.
	Fugitive emissions from coke production to be reported separately from 2C process emissions	Low	Transparency	Planned	5 th BUR (2019 inventory)	Progress on this has been slow but reporting through the NGER will allow this activity to be incorporated in the next inventory.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

	Incorporate emissions from biogas	Low	Completeness	Proposed		This would require a study and so should be recommended as a project under the GHGIP.
	CO ₂ transport and storage	Low	Completeness	Proposed		Proposed but nothing planned.
	CO ₂ , CH ₄ and N ₂ O emissions from combined heat and power (CHP) combustion systems	Medium	Completeness	Proposed		Proposed but nothing planned.
	Develop EFs, carbon content of fuels and NCVs of liquid fuels	High	Key category; Accuracy	Planned	6 th BUR (2021 inventory)	Resources and funding are required to complete this study so it will be incorporated into the GHGIP. This study was planned to start in 2020.
	Development of T3 methods for CTL-GTC and GTL	Low	Accuracy	Proposed		Resources and funding are required to complete this study so it will be incorporated into the GHGIP.
IPPU	Development of country specific EF for ferroalloy industry	Medium	Key category; Accuracy	Proposed	6 th BUR (2021 inventory)	Resources and funding are required to complete this study so it will be incorporated into the GHGIP.
	Development of Tier 3 methodologies for aluminium production	Medium	Key category; Accuracy	Proposed		Resources and funding are required to complete this study so it will be incorporated into the GHGIP.
	Include emissions from electronics industry	Medium	Completeness	Planned	6 th BUR (2021 inventory)	A study needs to be undertaken to understand emissions from this source so it



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

AFOLU						should be highlighted as a project for the GHGIP.
	Incorporate emissions SF ₆ emissions	Medium	Completeness	In progress	5 th BUR (2019 inventory)	Lack of data is still a challenge.
	Improve manure management data, including biogas digesters as a management system	Medium	Accuracy	Proposed	6 th BUR (2021 inventory)	Proposed project as there is a high variability in this dataset.
	Incorporate organic soils study to include emissions from organic soils	Medium	Completeness	Planned	5 th BUR (2019 inventory)	Not resolved. Due to the other more pressing issues relating to land this was not a priority and will be incorporated once the land mapping system is running.
	Complete an assessment of crop types and areas and investigate discrepancies between crop statistics and NLC data	Medium	Consistency; Comparability	Planned	6 th BUR (2021 inventory)	Variability in crop classifications from the various data sources have made this challenging. Funding will be required to complete a proper assessment of croplands so this project can be included in the GHGIP.
	Improve HWP model by incorporating further country specific data and by comparing the production method to the atmospheric model.	Medium	Key category; Accuracy	Proposed	6 th BUR (2021 inventory)	Proposed project that could be considered under the GHGIP.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

	Complete a full uncertainty analysis for the Land sector, including area bias corrections	High	Key category; Accuracy	Proposed	6 th BUR (2021 inventory)	Proposed to conduct a study to complete an uncertainty analysis for the Land sector, include all spatial data. This could be a project for the NGHGP.
Waste	Improve MCF and rate constants		Key category; Accuracy	Proposed		This would require a study so will be recommended as a project under the GHGP.
	Include economic data for different population groups		Key category; Accuracy	In progress	5 th BUR (2019 inventory)	
	Include information on population distribution in rural and urban areas as a function of income	Medium	Key category; Accuracy	In progress	5 th BUR (2019 inventory)	Study was completed in March 2020 so data will be included in next inventory.
	Include HWP in solid waste	Medium	Key category; Completeness	Proposed		Insufficient data.
	Obtain data on waste streams and the bucket system		Accuracy	In progress	5 th BUR (2019 inventory)	Study was completed in March 2020 so data will be included in next inventory.
	CH ₄ , N ₂ O emissions from biological treatment of waste	Medium	Completeness	In progress	5 th BUR (2019 inventory)	Study was completed in March 2020 so data will be included in next inventory.
	CO ₂ , CH ₄ and N ₂ O from waste incineration	High	Completeness	In progress	5 th BUR	Study was completed in March 2020 so data will be included in next inventory.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

					(2019 inventory)	



1.12 References

- DFFE, 2004. National Environmental Management: Air Quality Act, 2004 (act No. 39 of 2004) (Notice 827). Government Printer, 36974, 1 Nov., Pretoria, Republic of South Africa.
- DFFE, 2011: The National Climate Change Response White Paper. Department of Environmental Affairs, Pretoria, Republic of South Africa.
- IPCC, 1996. *Climate Change 1995: The Science of Climate Change*, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Houghton, J.T.; Meira Filho, L.G.; Callander, B.A.; Harris, N.; Kattenberg, A.; Maskell, K., (eds.), Cambridge University Press.
- IPCC, 2001. IPCC Third Assessment Report (TAR): Climate Change 2001. Cambridge: Intergovernmental Panel on Climate Change. Cambridge University Press.
- IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The National Greenhouse Gas Inventories Programme, Eggleston H S, Buenida L, Miwa K, Ngara T, and Tanabe K, eds; Institute for Global Environmental Strategies (IGES). Hayama, Kanagawa, Japan.
- IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- IPCC, 2014. *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
- IPCC, 2014a. 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds), Published: IPCC, Switzerland.
- Moeletsi, M., Paterson, G., Van Der Walt, M., Malherbe, J., Nape, M., Nkambule, V. and Malaka, S., 2015. ARC Contribution to ALU GHG Project, ARC-ISCW, unpublished report no. GW/A/2013/19, Pretoria, Republic of South Africa.
- Tongwane M., Mdlambuzi T., Moeletsi M., Tsubo M., Mliswa V. and Grootboom, L. 2016. Greenhouse gas emissions from different crop production and management practices in South Africa. *Environmental Development*, 19: 23 – 35.
- UN, 1992. United Nations Framework Convention on Climate Change. FCCC/INFORMAL/84. GE. 05-62220 (E) 200705.



UNFCCC, 2013. *Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex 1 to the Convention*. Decision 24/CP.19. FCCC/CP/2013/10/Add.3.



Chapter 2: Trends in GHG emissions

2.1 Description and interpretation of trends for aggregated GHG emissions

This chapter provides a description and interpretation of emission trends by sector and describes trends for the aggregated national emission totals. A complete table of emission estimates for 2020 are provided in Appendix C.

2.1.1 National trends

2.1.1.1 Overall emissions (excluding FOLU)

Overall emissions (excluding FOLU) include those from *Energy, Industrial Processes and Product Uses, Livestock, Aggregated and non-CO₂ emissions from land, and Waste*. It does not include the sources and removals from the *Land and Harvested wood products* category (which is termed FOLU in this Report).

2000 - 2020

South Africa's GHG emissions excluding FOLU were 473 832 Gg CO₂e in 2000 and these increased by 1.0% by 2020 (Table 2.1). The *Energy* sector was the main contributor to the increasing emissions. Emissions (excl. FOLU) in 2020 were estimated at 478 634 Gg CO₂e. Emissions excl. FOLU increased slowly between 2000 and 2009 reaching a peak of 572 564 Gg CO₂e. There was a decline in emissions in 2010 with a slight increase to 2012. Emissions were then estimated to decrease to 2020 (Figure 2.1).

The annual change data shows that the number of years with a decrease has increased since 2009 (Table 2.2), and the number of years with consecutive decreases has also increased. The annual growth rate was 2.5% between 2000 and 2009, however between 2010 and 2020 there is an average annual decline of 1.6% excluding FOLU. This shows that the emissions are stabilising and even moving towards a declining trend.

Table 2.1: Changes in South Africa's emissions excluding and including FOLU between 2000, 2017 and 2020.



	Emissions (Gg CO ₂ e)			Change between 2000 and 2020		Change between 2017 and 2020	
	2000	2017	2020	Gg CO ₂ e	%	Gg CO ₂ e	%
Emissions (excl. FOLU)	473 832.0	519 378.9	478 634.1	4 802.1	1.0	-40 744.8	-7.8
Emissions (incl. FOLU)	446 275.1	494 461.0	445 565.6	-709.5	-0.2	-48 895.4	-9.9

2017 - 2020

Emissions (excl. FOLU) decreased by 7.8% between 2017 and 2020 (Table 2.1), while emissions (incl. FOLU) decreased by 9.9%. The decrease in the emissions excluding FOLU were mainly due to a decrease in emissions in the *Energy* and *IPPU* sectors, while the FOLU sector also contributed to the decline in the emissions when FOLU was included.

2020

The *Energy* sector was the largest contributor to South Africa's gross emissions (excl. FOLU) in 2020, comprising 79.4% of total emissions. This was followed by the *AFOLU* sector (excl. FOLU) (10.2%), *IPPU* sector (5.6%) and the *Waste* sector (4.8%).

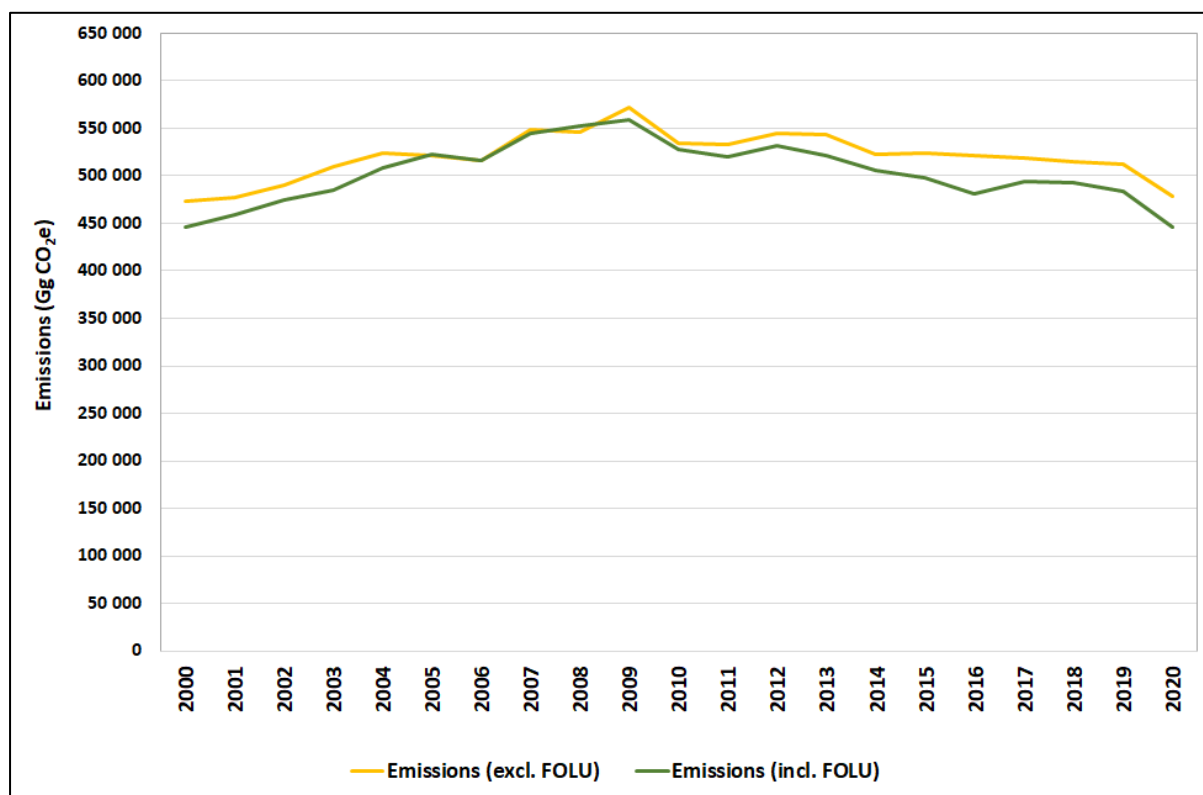


Figure 2.1: National GHG emissions (excluding and including FOLU) for South Africa, 2000 – 2020.

Table 2.2: Trends and annual change in emissions (excluding and including FOLU), 2000 – 2020.

	Emissions (excl. FOLU)		Emissions (incl. FOLU)	
	Gg CO ₂ e	Annual change (%)	Gg CO ₂ e	Annual change (%)
2000	473 832.0		446 275.1	
2001	477 829.9	0.84	459 267.7	2.91
2002	490 217.2	2.59	474 804.4	3.38
2003	509 430.2	3.92	484 580.7	2.06
2004	524 219.1	2.90	508 618.9	4.96
2005	521 031.4	-0.61	523 147.3	2.86
2006	516 757.5	-0.82	516 075.9	-1.35
2007	549 009.1	6.24	544 506.3	5.51
2008	546 098.9	-0.53	552 774.2	1.52
2009	572 564.3	4.85	559 066.0	1.14



2010	534 371.9	-6.67	528 151.2	-5.53
2011	532 753.5	-0.30	519 674.2	-1.61
2012	544 986.3	2.30	532 244.6	2.42
2013	543 858.5	-0.21	521 372.8	-2.04
2014	522 711.2	-3.89	505 406.7	-3.06
2015	524 105.8	0.27	497 766.3	-1.51
2016	521 212.5	-0.55	481 348.5	-3.30
2017	519 378.9	-0.35	494 461.0	2.72
2018	515 053.3	-0.83	492 198.6	-0.46
2019	511 780.4	-0.64	483 542.5	-1.76
2020	478 634.1	-6.48	445 565.6	-7.85

2.1.1.2 Net emissions (including FOLU)

Net emissions include all emissions (sources and sinks) from all sectors (i.e. *Energy, Industrial Processes and Product Uses, AFOLU and Waste*).

2000 – 2020

South Africa's GHG emissions (incl. FOLU) were 446 275 Gg CO₂e in 2000 and these decreased by 0.2% by 2020 (Table 2.1). Emissions (incl. FOLU) in 2020 were estimated at 445 566 Gg CO₂e. The emissions including FOLU followed a similar trend to the emissions excluding FOLU. Emissions, therefore, increased slowly between 2000 and 2009 after which there was a decline to 2011 with a slight increase in 2012, after which emissions declined to 2020 (Figure 2.1). Between 2000 and 2009 the average annual growth rate was 2.6%, however between 2010 and 2020 there was an average annual decline of 2.0%.

2017 – 2020

Emissions (incl. FOLU) decreased by 9.9% since the last inventory submission, and this was due to a decline in *Energy, IPPU and AFOLU* emissions during this time (Table 2.1).

2.1.2 Indicator trends

2.1.2.1 Total emission indicators



South Africa's carbon and energy intensity trends were determined from the GHG emissions, GDP data (Statistics SA, 2018), total primary energy supply data (DMRE Energy balance data) and population data (Statistics SA, 2018).

South Africa's per capita carbon² intensity was 10.1 t CO₂e in 2000 and this increased to a maximum of 11.1 t CO₂e in 2007, after which it declined steadily to 8.0 t CO₂e per capita by 2020 (Figure 2.2). The carbon intensity of the economy (i.e. emissions per million Rand of GDP) has declined by 35.3% since 2000. This is largely due to growth in the services and financial sectors, a decline in the manufacturing sector and stagnation in the mining sector. There was a sharp decline between 2009 and 2010 due to a significant increase in the GDP in 2010, along with a decline in emissions.

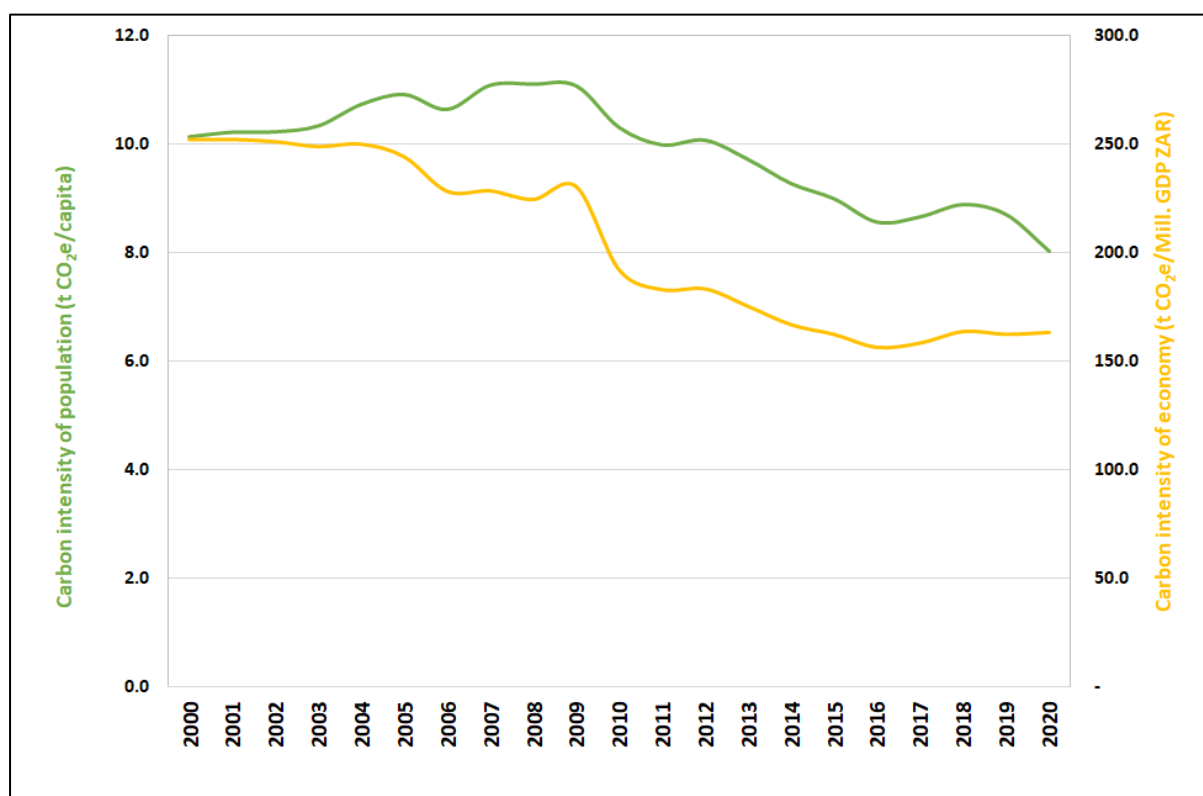


Figure 2.2: Trends in overall carbon intensity of the population and of the economy of South Africa between 2000 and 2020.

2.1.2.2 Energy emission indicators

² Carbon in this case refers to the total net emissions (i.e. emissions including FOLU).



The energy carbon intensity of the population (i.e. energy sector emissions per capita) increased significantly (8.3%) between 2000 and 2009, stabilised until 2009 and then showed a decline (30.2%) between 2009 and 2020 (Figure 2.3). Energy emissions per capita accounted for 80.1% of the total emissions (incl. FOLU) per capita in 2000 and this increased to 80.6% by 2020. The energy carbon intensity per capita trend is similar to that of the total carbon intensity of the population. This shows the large contribution to emissions from the energy sector.

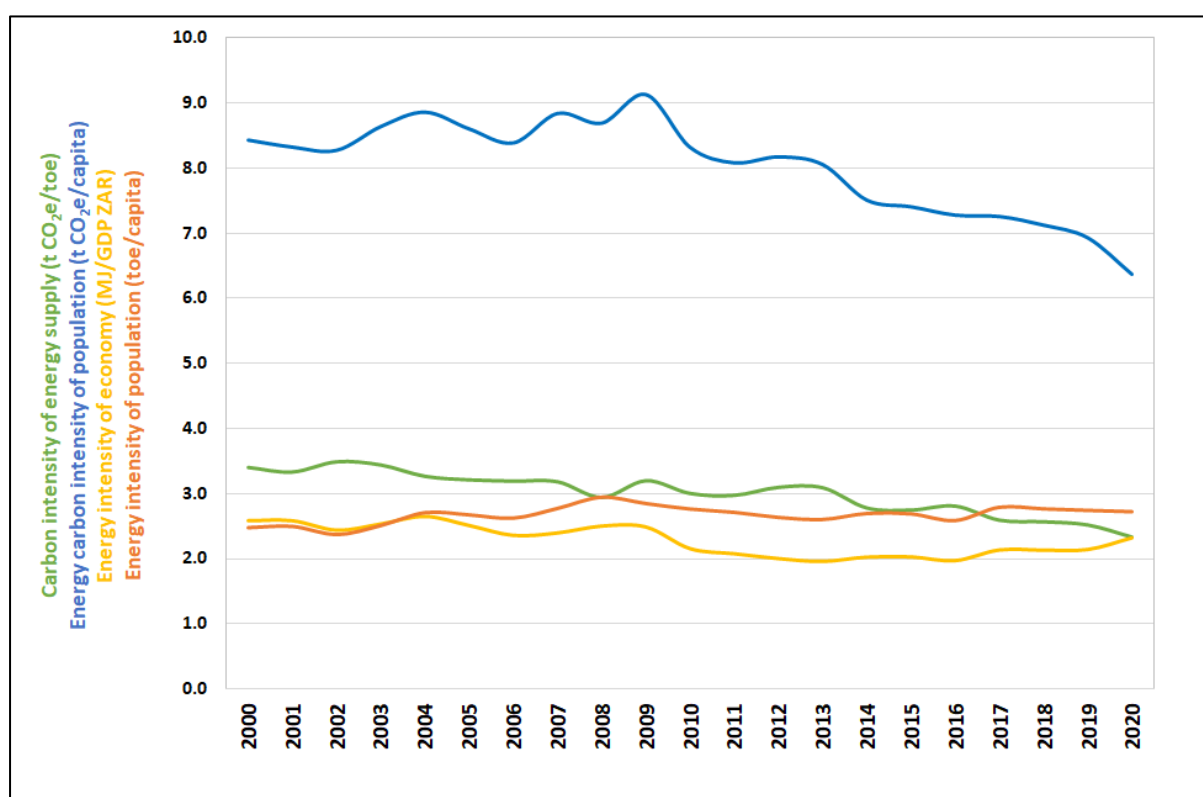


Figure 2.3: Trends in energy intensity indicators for South Africa between 2000 and 2020.

In terms of energy supply the Total Primary Energy Supply (TPES) data from South Africa's annual Energy Balances are applied. The carbon intensity of the energy supply, which is the amount of GHG emissions produced by the energy sector per unit of TPES, shows a declining trend between 2000 and 2020 and declines by 31.3% over the 20-year period (Figure 2.3). The energy intensity of the population (TPES per person) has increased by 9.9% between 2000 and 2020.



The energy intensity of the economy, which is TPES MJ per unit GDP, has declined between 2000 and 2020 (9.9%). As mentioned above the decline is likely due to the decline in the manufacturing and mining sectors and an increase in GDP in the service sectors in recent years.

2.2 Description and interpretation of emission trends by greenhouse gas

CO₂ gas is the largest contributor to South Africa's emissions (Figure 2.4). This is followed by CH₄ and then N₂O.

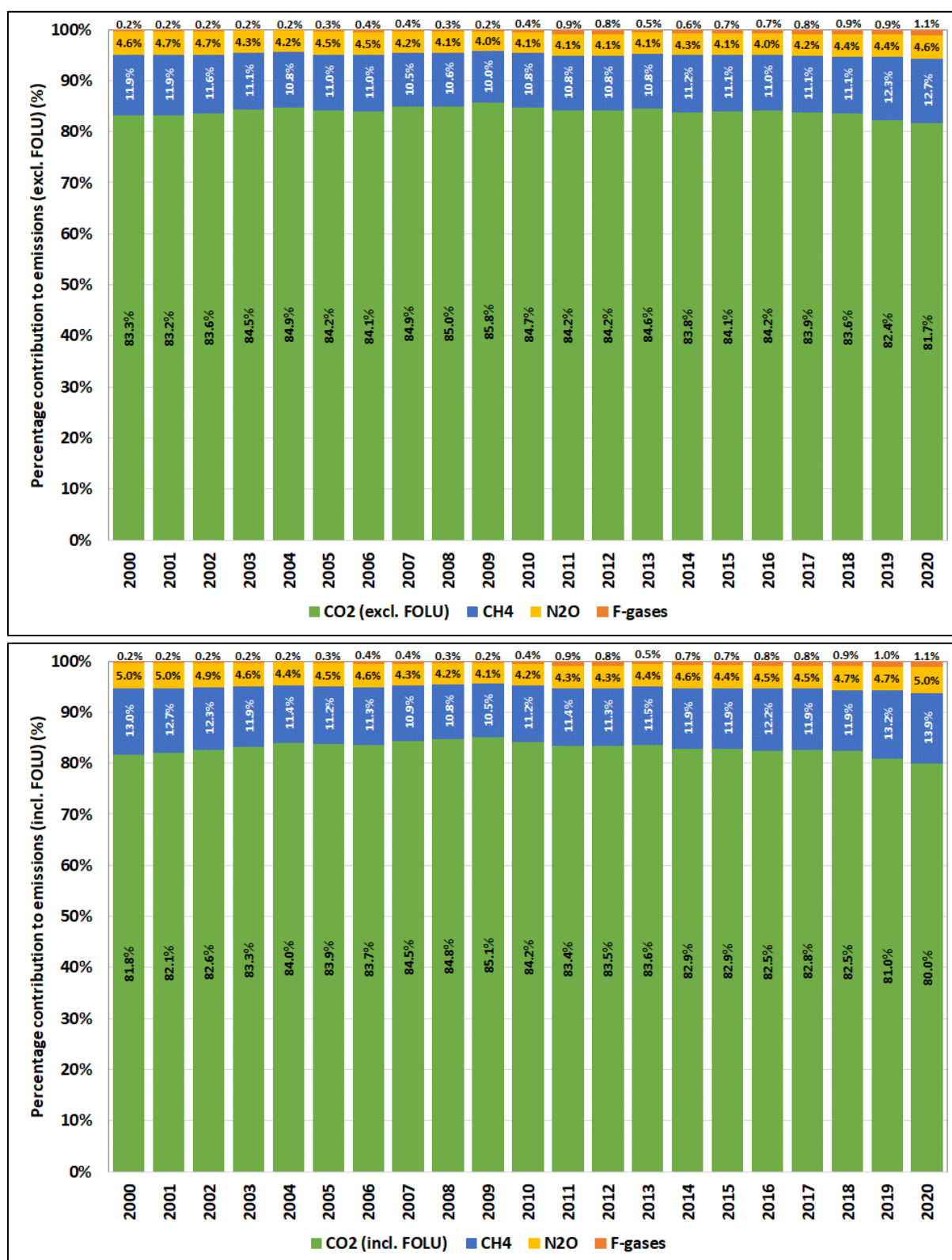


Figure 2.4: Percentage contributions from each of the gases to South Africa's emissions (excl. FOLU (top) and incl. FOLU (bottom)) between 2000 and 2020.



2.2.1 Carbon dioxide (CO₂)

The CO₂ emissions totalled 391 021 Gg CO₂ (excl. FOLU) and 356 324 Gg CO₂ (incl. FOLU) in 2020 (Table 2.3). Figure 2.5 presents the contribution of the main sectors to the trend in national CO₂ emissions (excl. FOLU). Since CO₂ is the largest contributor to national emissions the CO₂ emission trend follows that of the overall emission trend. The *Energy* sector is by far the largest contributor to CO₂ emissions in South Africa, contributing an average of 92.0% between 2000 and 2020, and 95.2% in 2020. The categories *1A1 energy industries* (60.2%), and *1A3 Transport* (12.1%) were the major contributors to the CO₂ emissions in 2020. The *IPPU* sector contribution an average of 7.7% between 2000 and 2020, while the AFOLU sector (excl. FOLU) contributed an average of 0.3%.



Table 2.3: Trend in CO₂, CH₄, N₂O and F-gases between 2000 and 2020.

	Emissions										
	CO ₂ (excl. FOLU)	CO ₂ (incl. FOLU)	CH ₄ (excl. FOLU)		CH ₄ (incl. FOLU)		N ₂ O (excl. FOLU)		N ₂ O (incl. FOLU)		F-gases
	Gg CO ₂		Gg CO ₂ e	Gg CH ₄	Gg CO ₂ e	Gg CH ₄	Gg CO ₂ e	Gg N ₂ O	Gg CO ₂ e	Gg N ₂ O	Gg CO ₂ e
2000	394 585.1	364 858.9	56 459.7	2 688.6	58 047.6	2 764.2	21 804.1	70.3	22 385.5	72.2	983.2
2001	397 652.7	376 948.2	56 711.1	2 700.5	58 279.2	2 775.2	22 458.4	72.4	23 032.6	74.3	1 007.7
2002	409 853.7	392 325.6	56 623.3	2 696.3	58 171.7	2 770.1	22 843.0	73.7	23 410.0	75.5	897.1
2003	430 467.0	403 529.2	56 377.7	2 684.7	57 906.3	2 757.4	21 689.3	70.0	22 249.0	71.8	896.2
2004	444 985.7	427 324.2	56 355.9	2 683.6	57 864.7	2 755.5	21 988.1	70.9	22 540.6	72.7	889.4
2005	438 805.0	438 886.6	57 316.0	2 729.3	58 805.0	2 800.2	23 197.0	74.8	23 742.3	76.6	1 713.4
2006	434 664.8	431 975.9	56 769.9	2 703.3	58 239.1	2 773.3	23 342.0	75.3	23 880.0	77.0	1 980.9
2007	466 352.3	459 869.3	57 801.2	2 752.4	59 250.7	2 821.5	22 821.5	73.6	23 352.3	75.3	2 034.1
2008	464 058.6	468 780.6	58 020.4	2 762.9	59 450.1	2 831.0	22 446.4	72.4	22 969.9	74.1	1 573.6
2009	491 406.6	475 982.1	57 413.2	2 734.0	58 823.2	2 801.1	22 644.2	73.0	23 160.5	74.7	1 100.3
2010	452 739.2	444 619.3	57 618.5	2 743.7	59 008.7	2 809.9	21 810.5	70.4	22 319.5	72.0	2 203.7
2011	448 609.4	433 657.9	57 648.7	2 745.2	59 019.1	2 810.4	21 810.1	70.4	22 311.9	72.0	4 685.2
2012	458 967.5	444 380.7	58 969.5	2 808.1	60 320.1	2 872.4	22 542.5	72.7	23 037.0	74.3	4 506.8
2013	460 170.5	435 866.7	58 491.5	2 785.3	59 822.3	2 848.7	22 344.0	72.1	22 831.3	73.6	2 852.5
2014	438 182.7	419 087.0	58 673.6	2 794.0	59 984.7	2 856.4	22 566.8	72.8	23 046.8	74.3	3 288.2
2015	440 708.4	412 604.8	58 136.9	2 768.4	59 428.3	2 829.9	21 557.7	69.5	22 030.5	71.1	3 702.7
2016	438 930.1	397 328.9	57 328.1	2 729.9	58 599.7	2 790.5	21 068.6	68.0	21 534.2	69.5	3 885.7
2017	436 001.2	409 373.2	57 519.8	2 739.0	58 771.6	2 798.6	21 709.9	70.0	22 168.3	71.5	4 148.0
2018	430 636.3	406 098.5	57 285.6	2 727.9	58 517.6	2 786.6	22 675.5	73.1	23 126.6	74.6	4 455.9
2019	421 786.4	391 892.3	62 810.1	2 991.0	64 022.3	3 048.7	22 413.2	72.3	22 857.1	73.7	4 770.8
2020	391 021.1	356 323.5	60 632.1	2 887.2	61 824.6	2 944.0	21 927.3	70.7	22 364.0	72.1	5 053.5

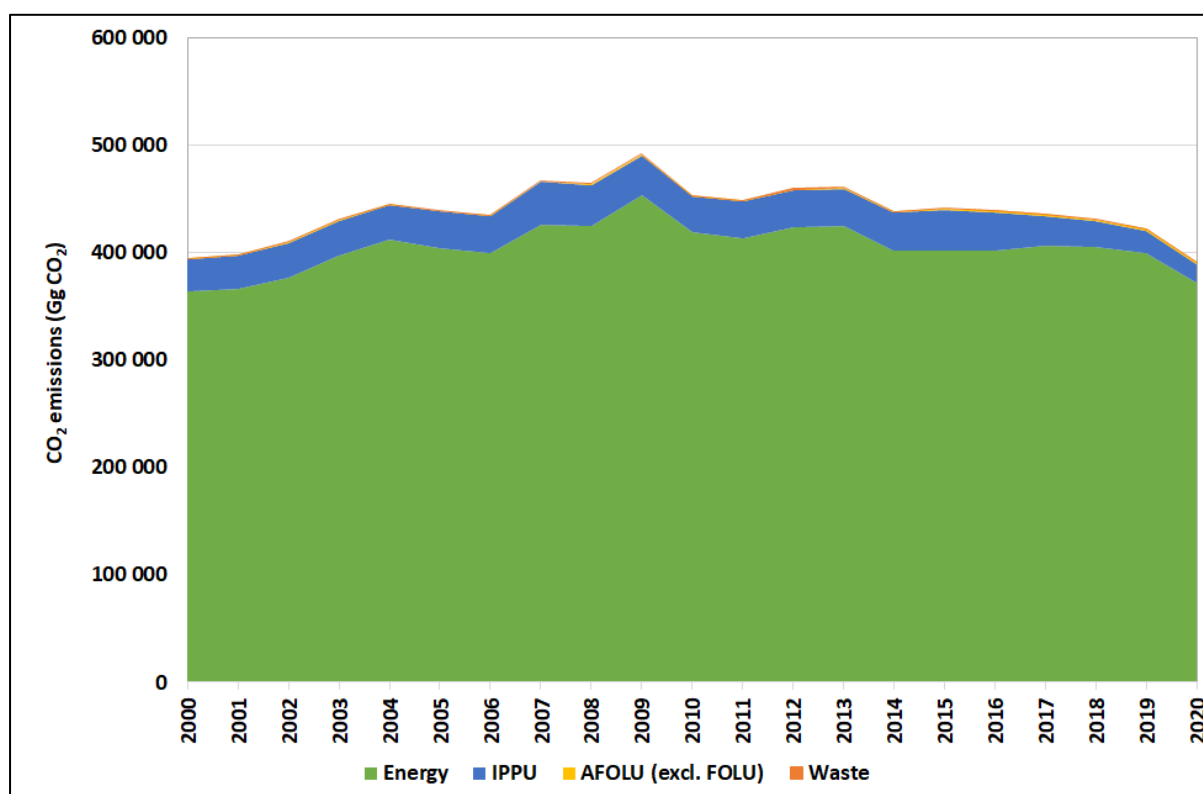


Figure 2.5: Trend and sectoral contribution to CO₂ emissions (excl. FOLU), 2000 – 2020.

2.2.2 Methane (CH₄)

The sector contributions to the total CH₄ emissions in South Africa are shown in Figure 2.6. National CH₄ emissions (excl. FOLU) increased from 56 460 Gg CO₂e (2 689 Gg CH₄) in 2000 to 60 632 Gg CO₂e (2 887 Gg CH₄) in 2020 (Figure 2.6). In the *Land* sector wetlands contributed an additional 1 193 Gg CO₂e (57 Gg CH₄) to the total CH₄, pushing the total CH₄ (incl. FOLU) to 61 825 Gg CO₂e. The *AFOLU livestock* category and *Waste* sectors were the major contributors, providing 47.4% and 36.5%, respectively, to the total CH₄ emissions in 2020.

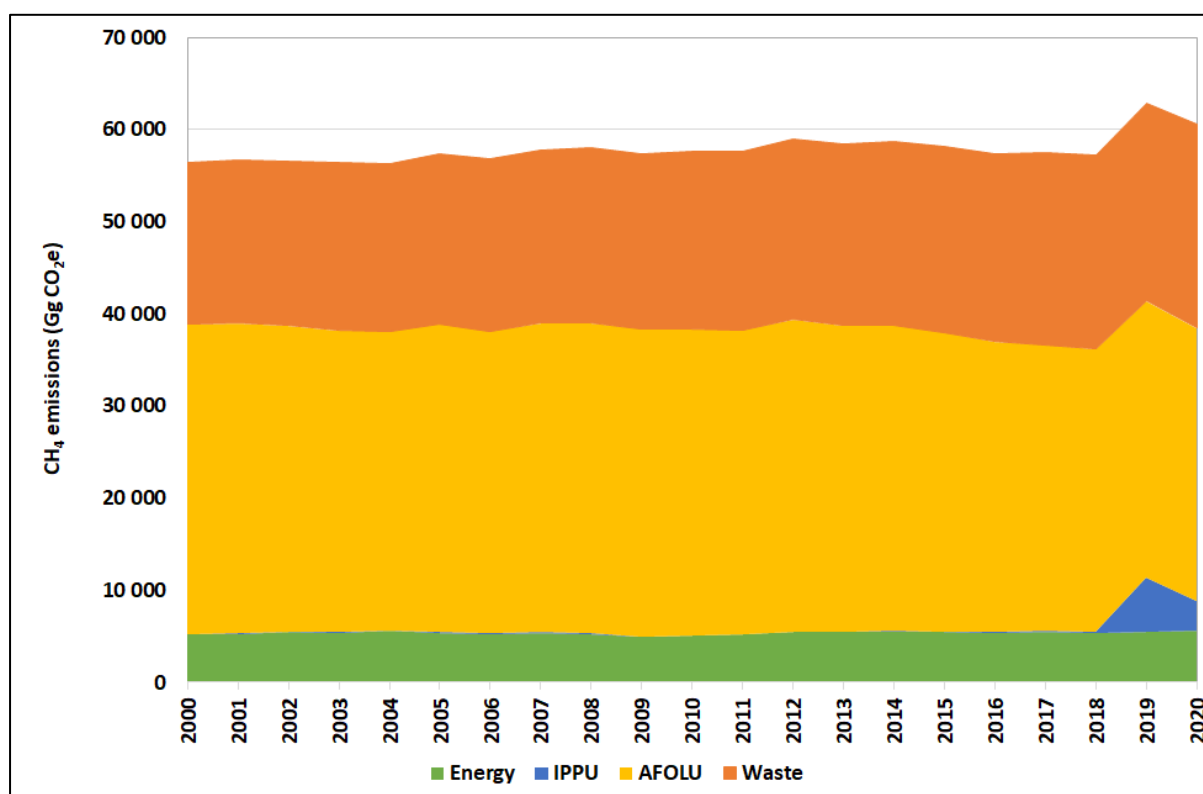


Figure 2.6: Trend and sectoral contribution to the CH₄ emissions, 2000 – 2020.

2.2.3 Nitrous oxide (N₂O)

Figure 2.7 shows the contribution from the major sectors to the national N₂O emissions in South Africa. The emissions (excl. FOLU) were 21 927 Gg CO₂e (70.7 Gg N₂O) in 2020 and 22 364 Gg CO₂e (72.1 Gg N₂O) including FOLU (Figure 2.7). The main contributors are the *AFOLU* (81.7%) and *Energy* (10.7%) sectors (Figure 2.4). The categories *3C Aggregated and non-CO₂ sources on land* (which includes emissions from managed soils and biomass burning) and *3A Livestock* are the main contributors to N₂O. Livestock manure, urine and dung inputs to managed soils provided the largest N₂O contribution in the *AFOLU* sector therefore the trend follows a similar pattern to the livestock population. N₂O emissions from IPPU declined by 82.2% between 2000 and 2017, but then increased again in 2018. The increase between 2018 and 2020 is due to improved data through the GHG Reporting Regulation.

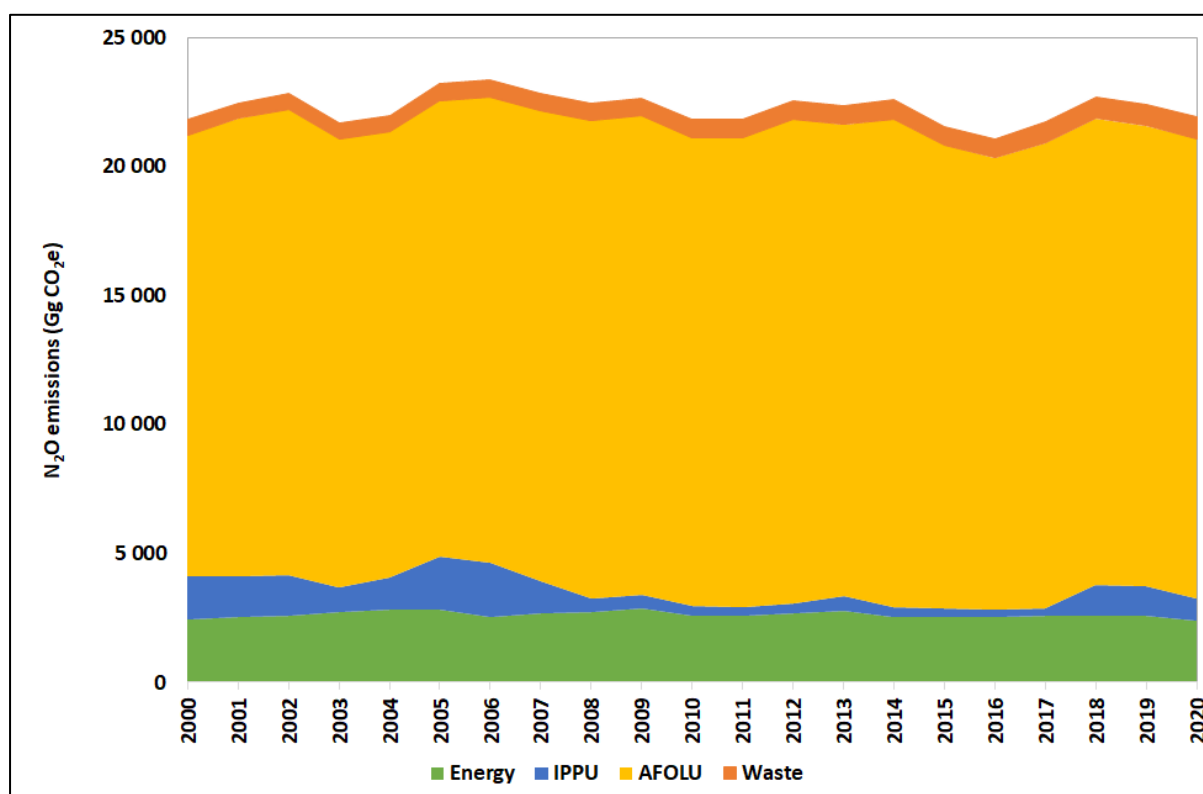


Figure 2.7: Trend and sectoral contribution to N₂O emissions in South Africa, 2000 – 2020.

2.2.4 F gases

Estimates of hydrofluorocarbon (HFC) and perfluorocarbon (PFC) emissions were only estimated for the IPPU sector in South Africa. F-gas emission estimates varied annually (Figure 2.8) and contributed 1.1% to overall emissions (excl. FOLU) in 2020. 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.

PFC emissions were estimated at 983 Gg CO₂e in 2000. This increased to 1 979 Gg CO₂e in 2012, then declined to 120 Gg CO₂e in 2020. 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 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 C_2F_4 and CF_4 . CF_4 emissions contribute the most to the PFC emissions (Table 2.4).

HFCs increased from 1 713 Gg CO_2e in 2005 to 4 933 Gg CO_2e in 2020, and the largest contributor is HFC-134a (Table 2.4).

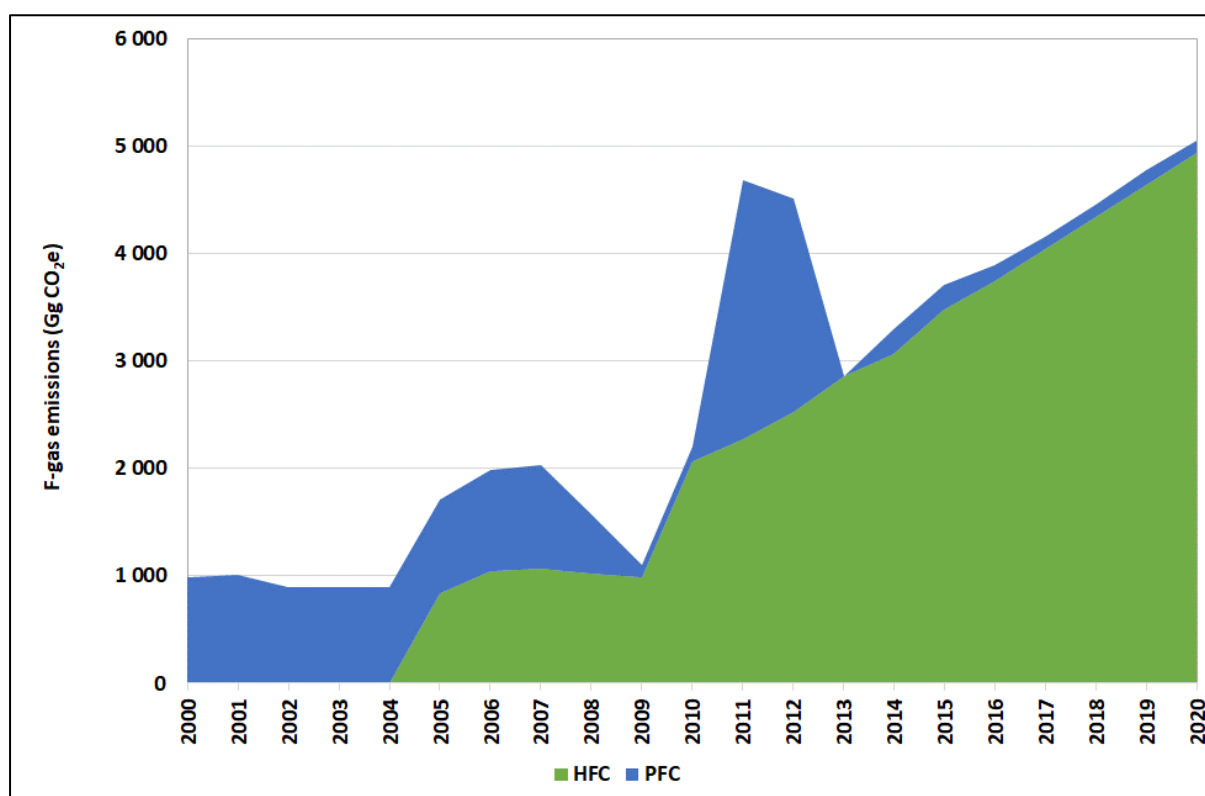


Figure 2.8: Trend in F-gas emissions in South Africa, 2000 – 2020.

Table 2.4: Trends in PFC and HFC emissions (Gg) by gas type.

	CF ₄	C ₂ F ₆	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-152a	HFC-143a	HFC-227ea	HFC-365mfc
	(Gg)									
SAR GWP	6 500	9200	11 700	650	2 800	1 300	140	3 800	2 900	890
2000	0.133	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.136	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.122	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000



2003	0.122	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.121	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.118	0.011	0.001	0.000	0.000	0.643	0.000	0.000	0.000	0.000
2006	0.127	0.012	0.004	0.000	0.039	0.442	0.100	0.079	0.000	0.000
2007	0.132	0.013	0.000	0.000	0.012	0.750	0.000	0.014	0.000	0.000
2008	0.074	0.007	0.002	0.000	0.004	0.696	0.000	0.022	0.000	0.000
2009	0.014	0.002	0.000	0.000	0.001	0.744	0.000	0.006	0.000	0.000
2010	0.018	0.002	0.001	0.000	0.013	1.423	0.000	0.045	0.000	0.000
2011	0.325	0.033	0.000	0.007	0.038	1.465	0.000	0.061	0.008	1.994
2012	0.267	0.027	0.000	0.010	0.050	1.588	0.000	0.076	0.009	1.913
2013	0.000	0.000	0.000	0.014	0.066	1.730	0.000	0.099	0.011	0.845
2014	0.029	0.004	0.000	0.020	0.088	1.786	0.000	0.117	0.012	0.251
2015	0.029	0.004	0.000	0.027	0.111	1.935	0.000	0.156	0.015	0.953
2016	0.020	0.002	0.000	0.031	0.126	2.046	0.000	0.171	0.016	0.953
2017	0.015	0.002	0.000	0.036	0.145	2.161	0.000	0.194	0.017	0.953
2018	0.016	0.002	0.001	0.041	0.164	2.276	0.000	0.218	0.019	0.953
2019	0.018	0.002	0.001	0.046	0.183	2.391	0.000	0.241	0.021	0.953
2020	0.016	0.002	0.001	0.051	0.201	2.506	0.000	0.264	0.022	0.953

2.3 Description and interpretation of emission trends by category

Figure 2.9 shows the percentage contributed by each sector over the period 2000 - 2020 and Table 2.5 shows the trend in the contribution from the four sectors to the total GHG emissions (excl. FOLU) in South Africa over the same period.

2.3.1 Energy

The *Energy* sector is the largest contributor to South Africa's emissions (excl. FOLU), contributing 79.4% in 2020 (Figure 2.9). *Energy* sector emissions increased between 2000 and 2009, then declined to 2014 after which total emissions were stable until 2019 (Table 2.5). Emissions declined by 6.8% between 2019 and 2020. The main contributor to the decline is a 19.7% reduction in emissions from *Other sectors* and a 13.7% reduction in *Transport* emissions. Commercial/institutional emissions declined by 19.7% in 2020, along with a 13.7% reduction in road transport and 54.28% reduction in civil aviation



emissions during this year. These reductions can be attributed to the reduced travel and trading during the COVID-19 lockdown restrictions.

2.3.2 IPPU

The *IPPU* sector contributed 5.6% to the total GHG emissions (excl. FOLU) in 2020 and this is a decline from 7.0% in 2000 (Figure 2.9). In 2020 the IPPU contribution was 26 595 Gg CO₂e (Table 2.5). IPPU sector emissions increased between 2000 and 2007, after which they declined to 2010, remaining stable to 2015. Emissions showed a sharp decline (35.7%) between 2015 and 2020. This decline can be seen in the *Mineral industries* (29.1%) and *Metal industries* (60.3%) during this period. It is noted that 24.9% and 12.1% of these reductions in the *Mineral* and *Metal* industries are seen between 2019 and 2020. There are some inconsistencies in the time series between 2015 and 2018 due to the introduction of new data coming from the GHG Regulation Reporting, which is contributing to the decline during this period, but the decline in 2020 can also be attributed to the COVID-19 lockdown which led to a reduction in production.

The largest source category is the *Metal industry* category, which contributes 41.77% to the total IPPU sector emissions. *Iron and steel production* and *Ferroalloys production* are the biggest CO₂ contributors to the metal industry subsector, producing 3 853 Gg CO₂ (3.7%) and 5457 Gg CO₂ (52%) respectively to the total metal industry CO₂ emissions. In addition, the HFC and PFC emissions should be monitored closely since HFC emissions have increased from 842 Gg CO₂e in 2005 to 4 035 Gg CO₂e in 2017 and 4 933 Gg CO₂e in 2020. PFC emissions did, however, increase from 2011 due to the addition of new categories (*Foam blowing agents*, *Fire protection* and *Aerosols*), but only 1.8% of the increase was accounted for by the new category emissions.

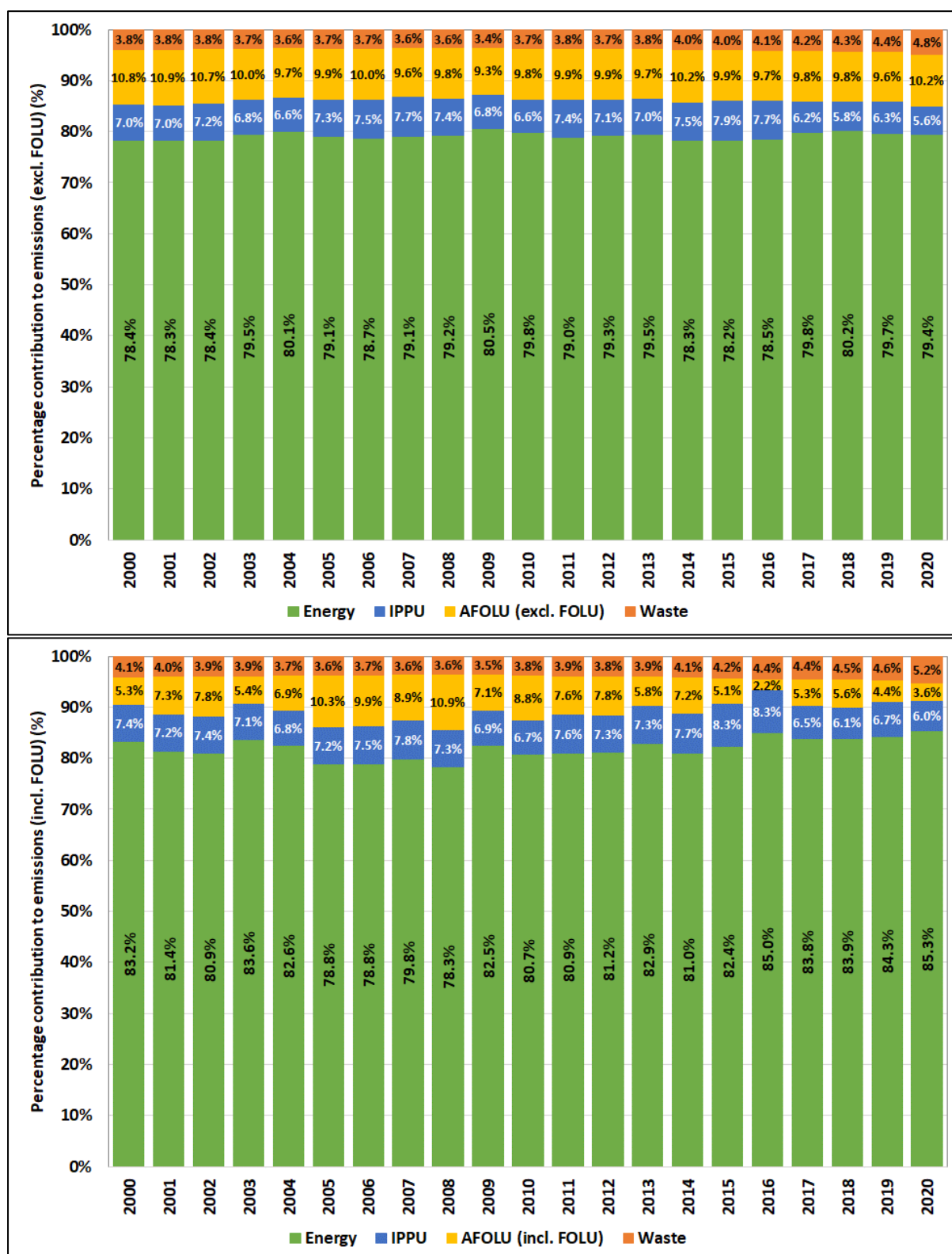


Figure 2.9: Percentage contributions from each of the sectors to South Africa's emissions (excluding (top) and including (bottom) FOLU) between 2000 and 2020.



Table 2.5: Trend in emissions and removals by sector for 2000 to 2020.

	Energy	IPPU	AFOLU (excl. FOLU)	AFOLU (incl. FOLU)	Waste
	Emissions (Gg CO ₂ e)				
2000	371 261.2	32 955.2	51 374.3	23 817.5	18 241.2
2001	374 055.3	33 220.9	52 210.1	33 648.0	18 343.6
2002	384 221.8	35 204.1	52 224.8	36 812.0	18 566.4
2003	405 081.0	34 506.9	51 039.1	26 189.6	18 803.2
2004	419 944.6	34 617.1	50 798.5	35 198.3	18 858.8
2005	412 391.2	37 825.5	51 729.2	53 845.0	19 085.5
2006	406 869.6	38 900.2	51 691.7	51 010.1	19 295.9
2007	434 275.9	42 498.8	52 732.7	48 229.9	19 501.8
2008	432 693.7	40 354.6	53 308.5	59 983.8	19 742.1
2009	460 985.8	38 815.7	53 030.5	39 532.2	19 732.3
2010	426 365.1	35 452.1	52 547.7	46 326.9	20 007.0
2011	420 629.7	39 510.4	52 499.4	39 420.2	20 113.9
2012	431 952.8	38 654.1	54 072.4	41 330.7	20 306.9
2013	432 419.5	38 213.3	52 734.6	30 248.9	20 491.1
2014	409 393.8	39 097.3	53 559.7	36 255.2	20 660.4
2015	410 108.9	41 402.0	51 698.6	25 359.1	20 896.3
2016	409 324.7	40 120.7	50 643.7	10 779.7	21 123.4
2017	414 409.6	32 266.3	51 003.7	26 085.8	21 699.3
2018	413 007.7	29 792.9	50 263.6	27 408.9	21 989.0
2019	407 769.1	32 392.4	49 319.5	21 081.6	22 299.3
2020	380 032.6	26 594.8	48 960.9	15 892.4	23 045.8

2.3.3 AFOLU

The *AFOLU* sector (excl. FOLU) contributed an average of 10.0% to the total emissions (excl. FOLU) between 2000 and 2020 (Figure 2.9). The contribution has declined by 0.6% since 2000. The main driver of change in the *AFOLU* emissions (excl. FOLU) is the livestock population. Livestock have input into the enteric fermentation, manure



management, as well as direct and indirect N₂O emissions. Enteric fermentation emissions show a declining trend due to a decline in livestock population. Dairy cattle, pigs and poultry are the largest contributors to manure management emissions, and with increasing poultry numbers these emissions increase over the 20-year period.

The *AFOLU* sector produced 48 961 Gg CO₂e (excl. FOLU) in 2020, while the emissions including FOLU were 15 892 Gg CO₂e (Table 2.5). The largest contributor to the sink is the *Forest land*, followed by *Grasslands*, while *Other land* is the main contributor to the source in the Land sector. Emissions in *Forests land* increase between 2003 and 2008 due to a combination of factors. During this time there was an increase in losses due to fire, both in plantations and natural vegetation classes, and an increase in wood harvest. The reduction in 2016 is also related to fires, but in this case the losses were reduced leading to a sink. Emissions and removals from *Grasslands* remained fairly constant, with *Grasslands remaining grasslands* and *Other land converted to grasslands* contributing to the sink.

Aggregated and non-CO₂ emissions on land contributed 35.9% to the AFOLU (excl. FOLU) emissions in 2020, and the largest contributor to this category is *Direct N₂O from managed soils* (72.9%). Nitrogen inputs from urine and dung contribute 49.4% to the direct N₂O emissions, followed by 23.7% from crop residues and 15.6% from inorganic fertiliser inputs.

2.3.4 Waste

The *Waste* sector emissions have increased from 18 241 Gg CO₂e in 2000 to 23 046 Gg CO₂e in 2020 (Table 2.5). The *Waste* sector contribution to overall emissions (excl. FOLU) has slowly increased from 3.8% in 2000 to 4.8% in 2020 (Figure 2.9). Solid waste disposal is the main contributor to this sector and these emissions are driven mainly by population growth.

2.4 Description and interpretation of emission trends for indirect GHG

The trend in emissions of carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic carbons (NMVOCs) is shown in Table 2.6. These emissions were estimated for biomass burning only. There is annual variability because the emissions include wildfires as well as controlled fires.



Table 2.6: Trends in indirect GHG emissions between 2000 and 2020.

	NO _x	CO	NM VOC
	(Gg)		
2000	59.9	1 313.4	56.8
2001	67.8	1 438.6	68.0
2002	71.4	1 503.3	76.0
2003	54.1	1 203.9	62.4
2004	50.5	1 120.9	53.0
2005	77.4	1 672.6	82.5
2006	75.0	1 592.1	75.5
2007	73.3	1 680.1	84.9
2008	69.0	1 476.7	76.1
2009	65.9	1 409.0	69.3
2010	67.3	1 441.3	68.0
2011	64.3	1 344.8	67.3
2012	58.3	1 246.1	63.6
2013	58.8	1 262.1	61.2
2014	60.5	1 344.0	69.5
2015	43.4	952.1	49.8
2016	24.6	545.0	30.0
2017	47.6	1 062.4	54.4
2018	49.2	1 091.8	58.4
2019	45.4	1 018.5	55.4
2020	48.7	1 093.9	53.4

2.5 References

Statistics SA, 2017. Gross domestic product, Statistical release P0441, Statistics South Africa, Pretoria, Republic of South Africa.

IEA, 2017. South Africa: Indicators, International Energy Agency, <https://www.iea.org/statistics/statisticssearch/report/>, accessed on 05/09/2017.



Chapter 3: Energy

3.1 Sector overview

South Africa's GDP is the 30th highest in the world, but in primary energy consumption South Africa is ranked 17th in the world. South Africa's energy intensity is high mainly because the economy is dominated by large-scale, energy-intensive primary minerals beneficiation industries and mining industries. Furthermore, there is a heavy reliance on fossil fuels for the generation of electricity and for a significant proportion of the liquid fuels consumed in the country. The energy sector is critical to the South African economy because it accounts for a total of 15% of the GDP.

In 2019, the Department of Mineral Resources and the Department of Energy were combined to form the Department of Mineral Resources and Energy (DMRE). The Energy division is responsible for the management, processing, exploration, utilisation and development of South Africa's energy resources.

The energy sector in South Africa is highly dependent on coal as the main primary energy source. The largest source of energy sector emissions in South Africa is the combustion of fossil fuels. Emission products of the combustion process include CO₂, N₂O, CH₄ and H₂O. A large quantity of liquid fuels is imported in the form of crude oil. Renewable energy comprises biomass, and natural processes that can be used as energy sources. Biomass is used commercially in industry to produce process heat and in households for cooking and heating.

The primary energy supply in South Africa (Figure 3.1) is dominated by coal (63 %), followed by crude oil (11 %), renewable and waste resources (20 %), natural gas (2 %) and nuclear (3 %) (DMRE, 2017).

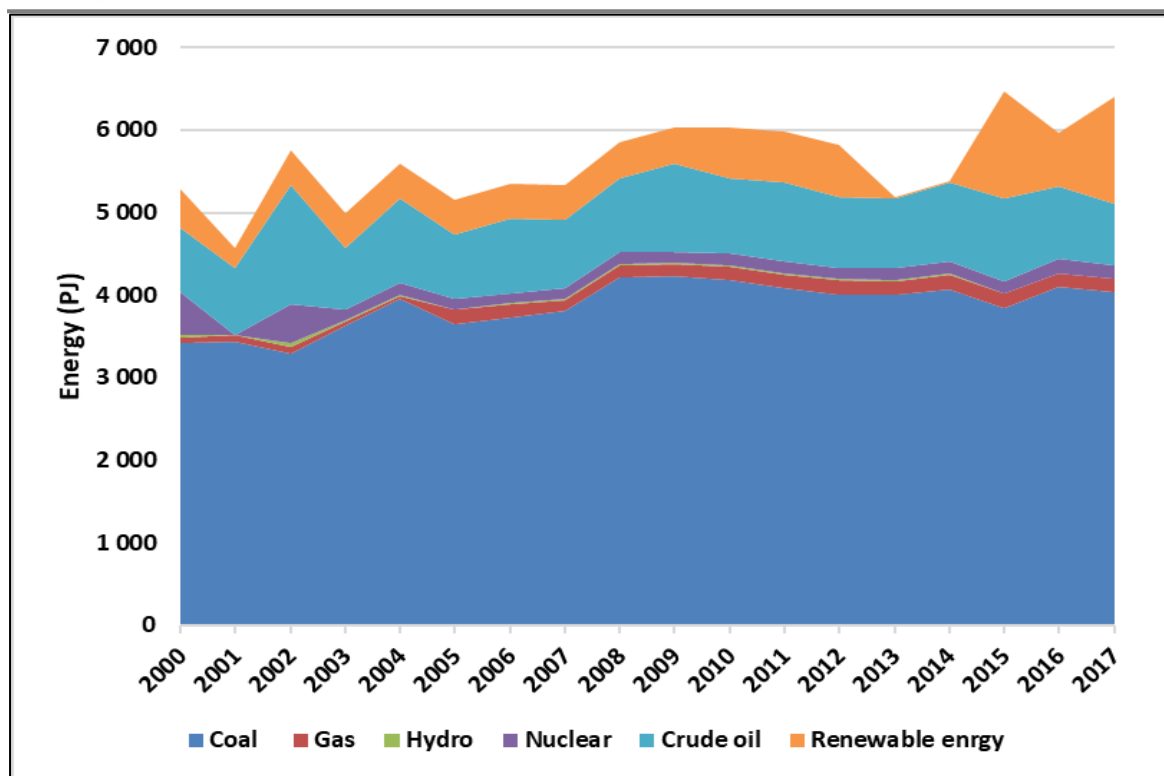


Figure 3.1: Trend in Total Primary Energy Consumption in South Africa, 2000 – 2017

In terms of energy demand, South Africa is divided into six sectors: industry, agriculture, commerce, residential, transport and other. The industrial sector (which includes mining, iron and steel, chemicals, non-ferrous metals, non-metallic minerals, pulp and paper, food and tobacco, and other) is the largest user of energy in South Africa.

The energy sector includes:

- Exploration and exploitation of primary energy sources;
- Conversion of primary energy sources 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 categories included in the energy sector for South Africa are *Fuel combustion activities* (1A), including international bunkers, and *Fugitive emissions from fuels* (1B).



3.1.1 Shares and trends in emissions

Total emissions from the *Energy* sector for 2020 are estimated to be 380 033 Gg CO₂e (Table 3.1). *Energy industries* were the main contributor, accounting for 62% of emissions from the *Energy* sector. This is followed by *transport* (13%), *manufacturing industries and construction* (9%) and *fugitive emissions* (8%). The other sectors contribute less than 3% to the total emissions while *Non-specific sector* (1A5) accounts for 5% of emissions. This is because of an improved energy balance, which resulted in massive reduction of coal usage in the commercial and residential sectors. The *residential* and *commercial* sectors are both heavily reliant on electricity for meeting most of the energy needs. A summary table of all emissions from the *Energy* sector by gas is provided in Appendix C.

Table 3.1: Summary of emissions from the Energy sector in 2020.

Greenhouse gas 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	372 073.3	265	5 566.4	8	2392.9	380 032.6
1A Fuel combustion activities	345 749.0	21.7	455.5	7.7	2 392.9	348 597.4
1B Fugitive emissions from fuels	26 324.3	243.4	5 110.9	NO	NO	31 435.2
1C Carbon dioxide transport and storage	NE	NE	NE	NE	NE	NE

Between 2000 and 2020, the *energy* sector emissions increased by 2.4% (Table 3.2). This growth in emissions is mainly from the 3.2% increase in *fuel combustion activities*. There was an increase of 7.2% in emissions in *energy industry* emissions, as well as 19.9% increase in transport sector emissions (Table 3.2). On the other hand, *fugitive emissions from fuels* declined by 6.4%. Economic growth and development led to increased demand for electricity and fossil fuels. Economic growth also increased the amount people travelling, leading to higher rates of consumption of petroleum fuels. In addition, growing populations led to increased consumption of fuels in households, producing increased residential emissions.

Energy emissions decreased by 8.3% (34 377 Gg CO₂e) since the previous 2017 submission. The main contributors to decrease were the *energy industries and transport* which decreased by 5.7% (12 679 Gg CO₂e) and 13.9% (5 590 Gg CO₂e) respectively. The other sectors and *Non-specified* sectors collectively decreased by 55% while the *Fugitive emissions* sector emissions decreased by 6.4%. The decrease in *Other sectors* is due to the change in allocation of fuel. Most of the coal that could not be accounted for within the residential sector was accounted for within the *Non-Specific sector* (1A5a). In the previous inventory the bulk of the coal that could not be accounted for was put in



commercial sector. Therefore, the improvement in this inventory was to change such allocation so that the unexplained spikes in data changes can be absorbed by the None-specific Sector.



Table 3.2: Summary of the change in emissions from the Energy sector between 2000 and 2020.

Greenhouse gas source and sink categories	Emissions (Gg CO ₂ e)			Difference (Gg CO ₂ e)		Change (%)	
	2000	2017	2020	2000-2020	2017-2020	2000-2020	2017-2020
1. ENERGY	371 261	414 410	380 033	8 771	-34 377	2.4%	-8.3%
1A Fuel combustion activities	337 675	382 956.64	348 597.39	10 922.03	-34 359.26	3.2%	-10.2%
1A1 Energy industries	220709	249342	236662	15954	-12679	7.2%	-5.7%
1A1a Electricity and heat production	186083	216489	205621	19538	-10868	10.5%	-5.8%
1A1b Petroleum refining	4050	3333	2414	-1636	-919	-40.4%	-22.7%
1A1c Manufacture of solid fuels	30576	29519	28627	-1949	-892	-6.4%	-2.9%
1A2 Manufacturing industries and construction	28744	30726	33196	4452	2470	15.5%	8.6%
1A3 Transport	40198	53783	48193	7995	-5590	19.9%	-13.9%
1A3a Domestic aviation	2257	1527	696	-1561	-832	-69.2%	-36.8%
1A3b Road transportation	37099	51407	44957	7858	-6450	21.2%	-17.4%
1A3c Railways	618	490	554	-64	63	-10.4%	10.3%
1A3d Water-borne navigation (domestic)	224	358	1986	1762	1628	786.8%	726.8%
1A3e Other transportation	NE	NE	NE				
1A4 Other sectors	30680	14333	12399	-18282	-1934	-59.6%	-59.6%
1A4a Commercial/Institutional	21095	4777	3758	-17337	-1019	-82.2%	-82.2%
1A4b Residential	7125	3408	2715	-4410	-693	-61.9%	-61.9%
1A4c Agriculture/Forestry/Fishing/Fish farms	2460	6148	5926	3466	-222	140.9%	140.9%
1A5 Non-specified	17344	34773	18147	803	-16626	4.6%	47.8%
1B Fugitive emissions from fuels	33 586	31 453	31 435	-2 151	-18	-6.4%	-6.4%
1B1 Solid fuels	2 369	2 881	2 931	562	50	23.7%	23.7%
1B2 Oil and natural gas	752	642	642	-	-	-14.7%	-14.7%
1B3 Other emissions from energy production	30 465	27 930	27 863	-	102	-8.5%	-0.2%
1C Carbon dioxide transport and storage	NE		NE				

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



Figure 3.2 shows the time-series for the *Energy* sector from 2000 to 2020. Emissions increased until 2009, followed by a decline in emissions in 2009/2010 due to the economic crisis in 2009, when South Africa's economy shrank by 1.4%. The economy rebounded from 2011 albeit at a very slow pace and not to the same growth level it was before the economic crisis. Consequently, the emissions also slightly increased from 2011 and reached a peak in 2013. In 2020, there was a 6.8% decline in emissions (Figure 3.3) which could partly be attributed to the COVID-19 lockdown during this time.

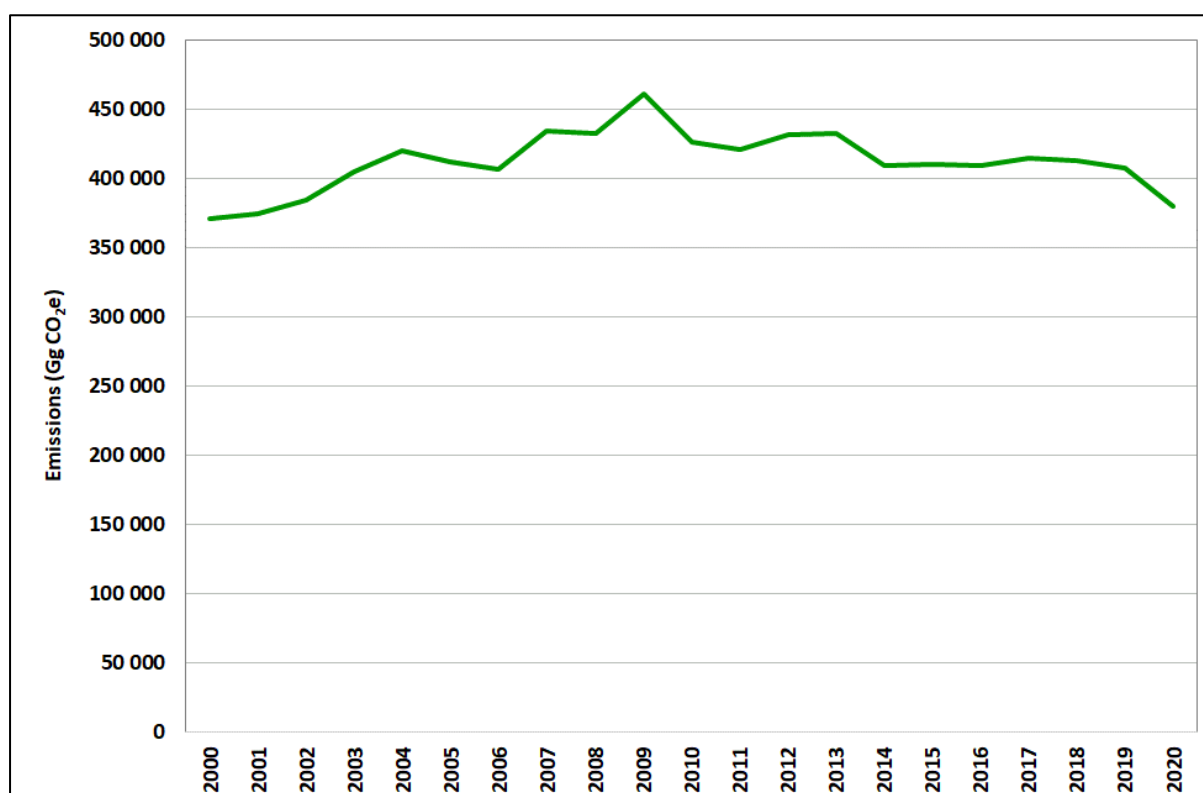


Figure 3.2: Trends in South Africa's energy sector emissions, 2000 – 2020.

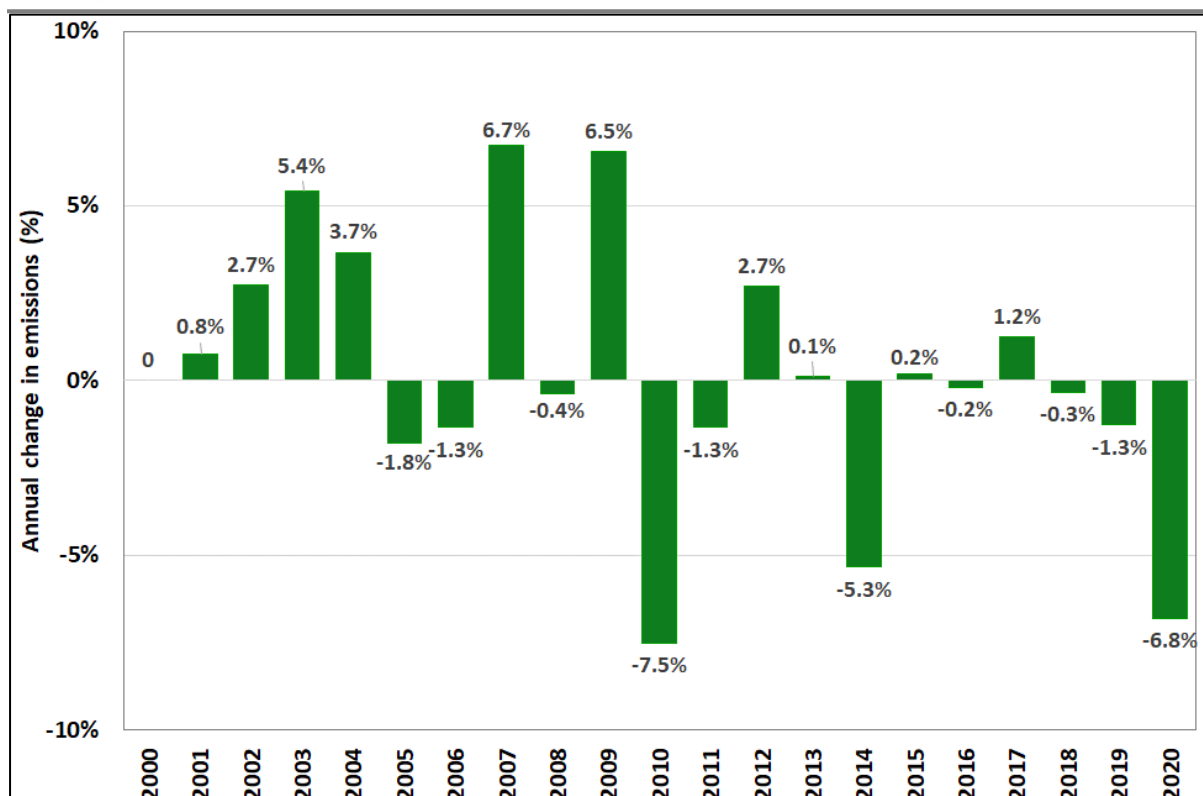


Figure 3.3: Trend in annual change in the total energy emissions in South Africa, 2000 – 2020.

3.1.1.1 Fuel combustion activities

Total estimated emissions from *fuel combustion* were 376 419 Gg CO₂e in 2019, equal to 92.3% of the *energy* sector emissions. In 2020, the emissions were at 348 597 Gg CO₂e. *Energy industries* contributed 67.9% to the total fuel combustion activity emissions in 2020.

From a series perspective, emissions increased by an average of 0.2% per annum from 2000 to 2020. While the economy was growing, there was a steady increase in emissions until 2008, followed by a decline in emissions due to the global economic crisis of 2008. There is a slight decline from 2014 to 2016 due to a decline in the energy industries emissions (Figure 3.4) as Eskom coal power stations were having lower energy availability factors, low economic growth and an increasing share of renewables into the electricity grid. There was a slight increase in 2017 and emissions stabilised in 2018 and 2019 due to very slow economic growth. Details of these declines, as well as further information about methodologies, emission factors, uncertainty, and quality control and assurance are provided in the various sub-category sections below.

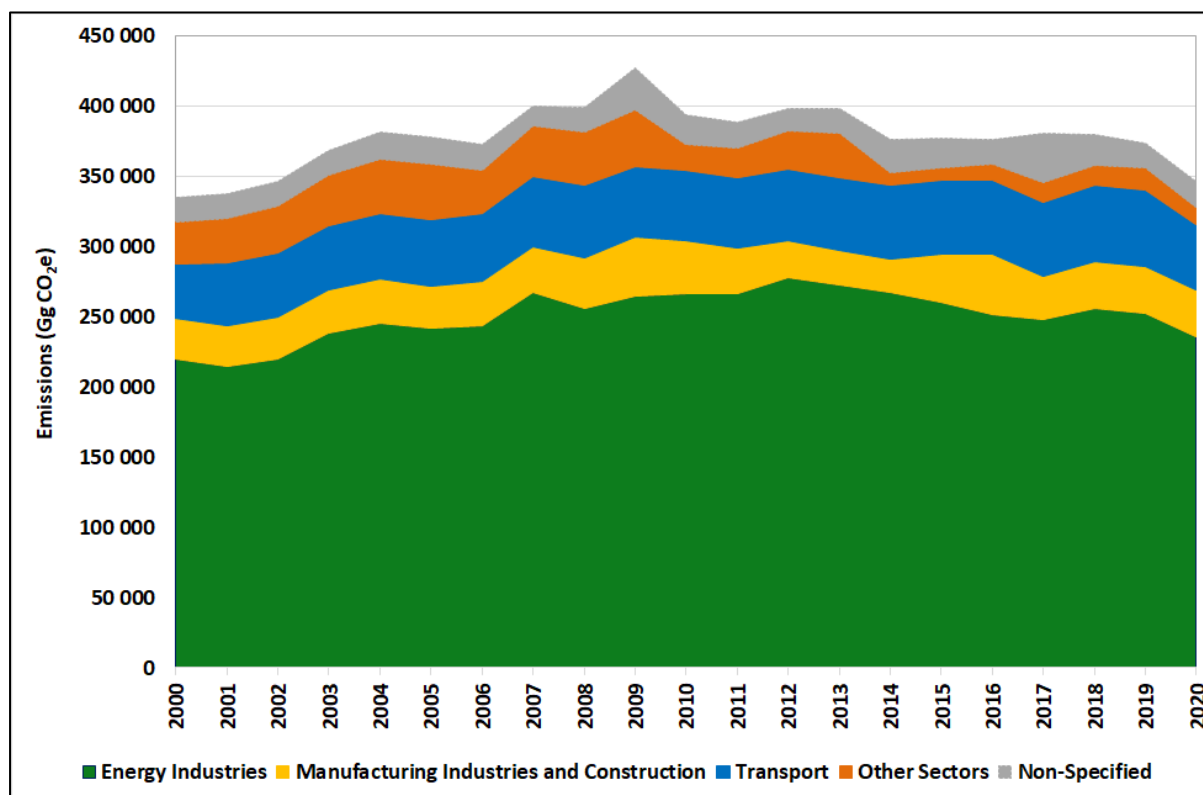


Figure 3.4: Trends and subcategory contributions to fuel combustion activity emissions in South Africa, 2000 – 2020.

Energy industries

The *energy industries* were estimated to produce 236 662 Gg CO_{2e} in 2020, which is 67.9% of the *Fuel combustion activities* emissions and 62.3 of *Energy sector* emissions. From the trend perspective, the emissions are 15 954 Gg CO_{2e} (7.2%) above the 2000 level and this was due to an increase in the electricity consumption over this period.

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

Emissions from the public electricity producer were 87% of the energy industry emissions. Overall, there has been an increasing trend in the emissions from the public electricity producer, however emissions have been showing a declining trend since 2013 (Table 3.3). Consumption increased by 13.3% over the 2000 - 2017 period, while emissions increased by 16.3%. The consumption of electricity and the associated emissions increased between 2000 and 2007 due to robust economic growth. In late 2007 and early 2008 the public electricity producer started to experience difficulties



supplying electricity and resorted to shedding customer loads. The load shedding had a negative impact on the key drivers of economic growth. GHG emissions from the public electricity producer decreased by 4.2% as a result of the electricity disruptions. The global economic crisis in late 2008 also affected key drivers of growth such as the manufacturing and mining sectors. The manufacturing sector consumes approximately 45% of South Africa's electricity. Emissions from the public electricity producer increased thereafter to a peak in 2012 (Table 3.3). Since 2013 there has been a 7.9% decline in electricity consumption, leading to 14.3% decline in emissions from the public electricity producer.

Table 3.3: Emission trends for the public electricity producer, 2000 - 2020

	CO ₂	CH ₄	N ₂ O	Total
	Gg CO ₂	Gg CH ₄	Gg N ₂ O	Gg CO ₂ e
2000	173 858.0	1.8	2.7	186 083.4
2001	175 475.2	1.8	2.7	180 990.9
2002	181 307.0	1.9	2.8	187 239.9
2003	194 985.2	2.0	3.0	203 991.6
2004	204 689.9	2.1	3.2	212 014.3
2005	206 208.9	2.1	3.2	209 990.8
2006	207 464.6	2.2	3.2	212 387.1
2007	228 111.4	2.4	3.6	233 979.7
2008	218 542.6	2.3	3.4	223 563.0
2009	224 578.8	2.4	3.5	232 398.0
2010	231 405.0	2.4	3.6	234 782.9
2011	233 189.1	2.5	3.6	235 260.1
2012	243 497.4	2.6	3.8	245 925.8
2013	237 464.0	2.6	3.7	239 851.9
2014	232 114.6	2.5	3.6	234 505.2
2015	223 999.4	2.5	3.4	226 328.8
2016	217 118.2	2.3	3.4	218 420.7
2017	214 668.3	2.3	3.3	216 489.5
2018	222 370.4	2.4	3.5	224 150.2
2019	217 994.9	2.4	3.4	221 197.3
2020	204 566.7	2.3	3.2	205 621.5

Despite the economy growing throughout the 2011 – 2019 period, (at an average rate of 1.6% per annum), the emissions decreased between 2013 and 2016. The decline in emissions is attributed to the decline of emissions from coal generated electricity as the



energy availability factor for coal power stations decreased between those years as shown in Figure 3.5 (Eskom, 2018). The energy availability factor was reduced due to load shedding events that increased in intensity and frequency in both 2014 and 2015. The main contributor to load shedding for six months from November 2014 to May 2015 was the collapse of the Majuba Power station. The station has an installed capacity of 3 600 MW and only came back in full capacity in May 2015. The Majuba incidence and other technical issues, resulted in the energy availability factor being 75.1% and 74% in 2014 and 2015 respectively. In the preceding years (2010 – 2013), the availability factor was between 77.7% and 85% (Figure 3.5).

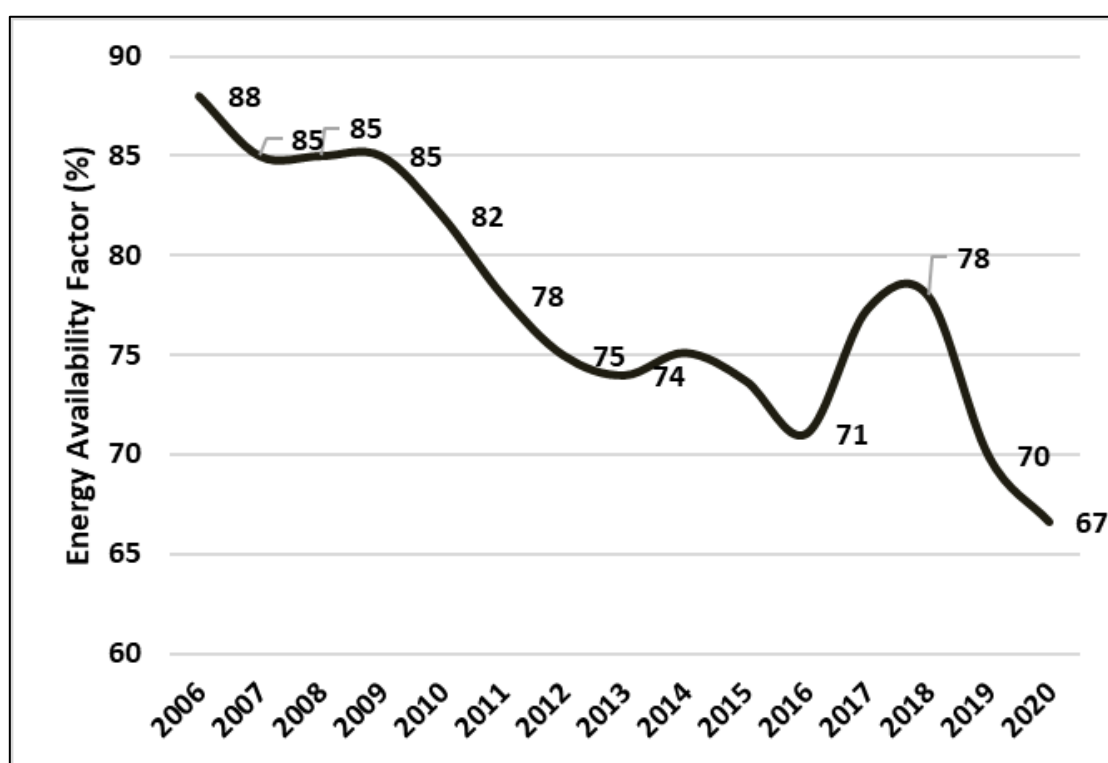


Figure 3.5: Eskom's system energy availability factor (%)

Given that electricity production contributes 54.1% of emissions in the Energy sector, a significant drop in coal use in the power stations resulted in reduced emissions. At the same time, the penetration of renewable energy resources (wind solar PV and concentrated solar power) within the electric grid (from the REIPPP) have steadily been increasing (Figure 3.6). The installed capacity increased from 457 MW in 2013 to 4 054 MW by the end of 2019 (CSIR, 2021). In 2013, about 0.1 TWh of electricity was produced from renewables and by 2019, 11.5 TWh of electricity was produced from wind, solar PV and CSP resulting in avoided emissions (CSIR, 2019). Using a high level assumption that electricity from these sources, with a penetration level of 5% replaced coal, 3 945 Gg of CO_{2e} was avoided resulting in 1.6% emissions reductions.

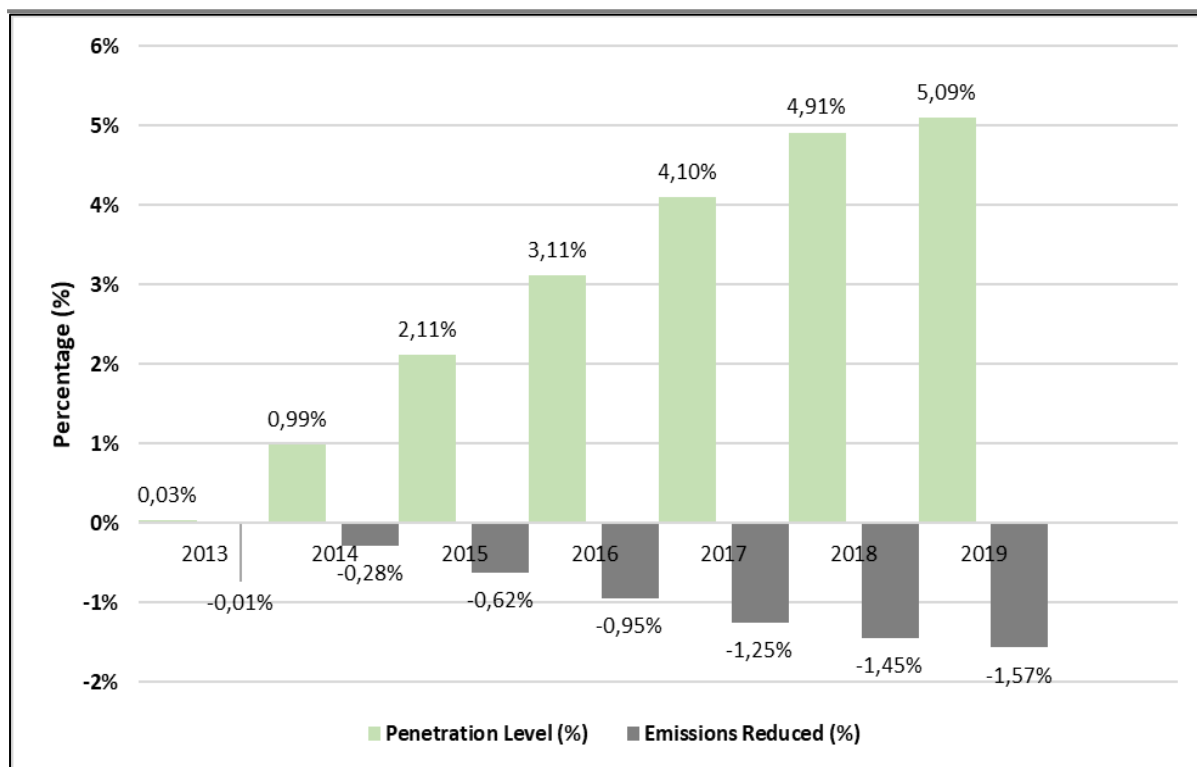


Figure 3.6: Renewable penetration and corresponding emissions reduction.

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

Total emissions from auto electricity producers in South Africa fluctuated significantly from year to year (Table 3.4). In 2003 the emissions increased by 59.9%. This may be attributed to the economic growth during that period which increased the demand for electricity. The global economic crisis could explain the 0.9% decline in GHG emissions during 2008. As the effect of the crisis continued, the emissions declined from 2009 until 2011 and increased in emissions started in 2012. Overall, there has been a declining trend in emissions with a decline of 86.1% (9 662 Gg CO₂e) since 2000, with 81.2% of this occurring since 2010. This was mainly brought about by the decommissioning of some coal power plants within municipalities. The only auto electricity producer using coal is Kelvin power plant which supplies the City of Johannesburg with power.

Table 3.4: Trend in emissions from the auto electricity producers, 2000 – 2020.

	CO ₂	CH ₄	N ₂ O	Total
	Gg CO ₂	Gg CH ₄	Gg N ₂ O	Gg CO ₂ e
2000	11 169.4	0.12	0.17	11 225.8



2001	4 557.0	0.05	0.07	4 580.0
2002	4 938.7	0.05	0.08	4 963.6
2003	7 896.0	0.08	0.12	7 935.8
2004	6 192.1	0.06	0.10	6 223.3
2005	2 697.7	0.03	0.04	2 711.4
2006	3 814.1	0.04	0.06	3 833.4
2007	4 642.5	0.05	0.07	4 665.9
2008	3 856.3	0.04	0.06	3 875.8
2009	6 581.6	0.07	0.10	6 614.9
2010	2 176.5	0.02	0.03	2 187.5
2011	882.0	0.01	0.01	886.5
2012	1 184.3	0.01	0.02	1 190.3
2013	1 176.1	0.01	0.02	1 182.1
2014	1 206.3	0.01	0.02	1 212.4
2015	1 188.9	0.01	0.02	1 194.8
2016	205.3	0.01	0.00	206.5
2017	727.8	0.01	0.01	731.5
2018	649.7	0.01	0.01	653.0
2019	1 615.7	0.02	0.03	1 624.0
2020	1 555.9	0.02	0.02	1 563.9

Petroleum refining (1.A.1.b)

The total GHG emissions from *petroleum refining* was estimated at 4 050 Gg CO₂e in 2000, decreasing to 2 414 Gg CO₂e in 2020. In 2000 refinery gas contributed 57.0% to the total GHG emissions in this subcategory and this increased to 67% in 2019. Emissions from residual fuel oil decreased from contributing 17% in 2000 to only 5.3% in 2019. A shift from residual fuel oil to refinery gas in most refineries is the main driver of emissions reduction in this source category.

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

Emissions from *manufacture of solid fuels and other energy industries* totalled 28 627 Gg CO₂e in 2020, and these emissions have remained fairly stable over the 20 year period since 2000. Emissions in this subsector decreased by 6.4% (1 949 Gg CO₂e) since 2000.



Manufacturing industries and construction

The *manufacturing industries and construction* were estimated to produce 33 196 Gg CO_{2e} in 2020, which is 8.7% of the *Energy* sector emissions. In the 20 year period, emissions from the sector increased by 4 452 Gg CO_{2e} (15.5%). The emissions increased at an annual average rate of 0.5%. This sector is growing in a very slow manner due to multitude of economic and structural issues, therefore, emissions are expected to not increase significantly. High share of emissions come from coal usage. Figure 3.7 shows that 64% of emissions within this sector comes from combustion of coal in stationary appliances (Figure 3.7). The significance of gas works gas has reduced from 14% in 2000 to 3% in 2020. This is due to increased use of natural gas. The country started importing additional gas from Mozambique as a result natural gas usage increased from 8% in 2000 to 17% in 2020. Overall, it can be seen that gaseous fuels have contributed 20% of emissions in the sector throughout the entire 20 year period. The share of emissions coming from diesel has increased from 7% to 13% in 2020).

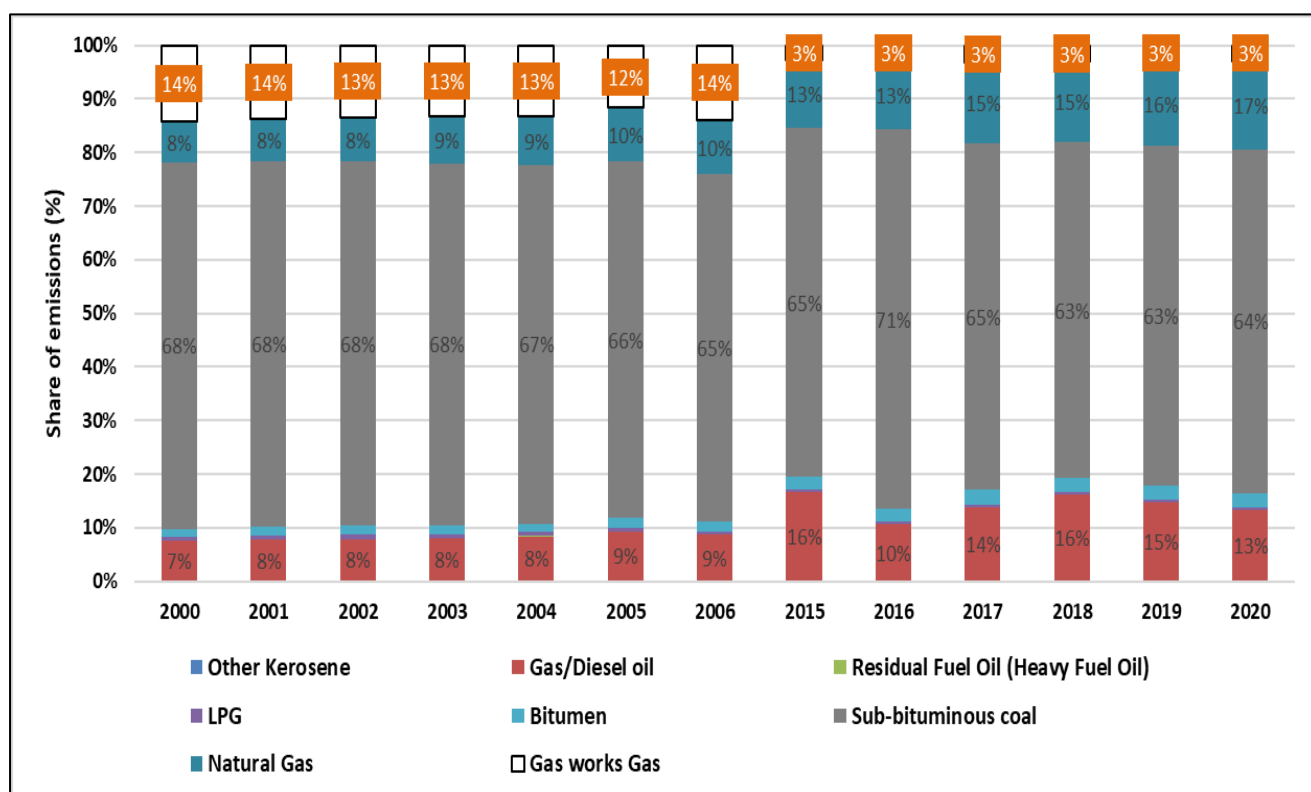


Figure 3.7: Emissions by fuel source



Transport

Emissions from transport sector have been in upward trend since 2000. In 2020 there is a 13.7% decline from 2019 emissions levels. The reduction is mainly coming from reduction from passenger travel in 2020 that was imposed as people shifted from working at the office to working from home due to the COVID-19 pandemic. In 2000 the transport sector contributed 11 % of the total Energy sector emissions, and in 2020 the transport sector contributed 13 % of the emissions. About 94% of emissions from the transport sector come from the road transport (1A3b). Diesel and Motor Gasoline are the main contributing fuels as shown in Figure 3. 8. Over the 20 years period, the contribution by diesel increased from 31% in 2000 to 51% in 2020 while that of gasoline decreased from 56% in 2000 to 41% in 2020.

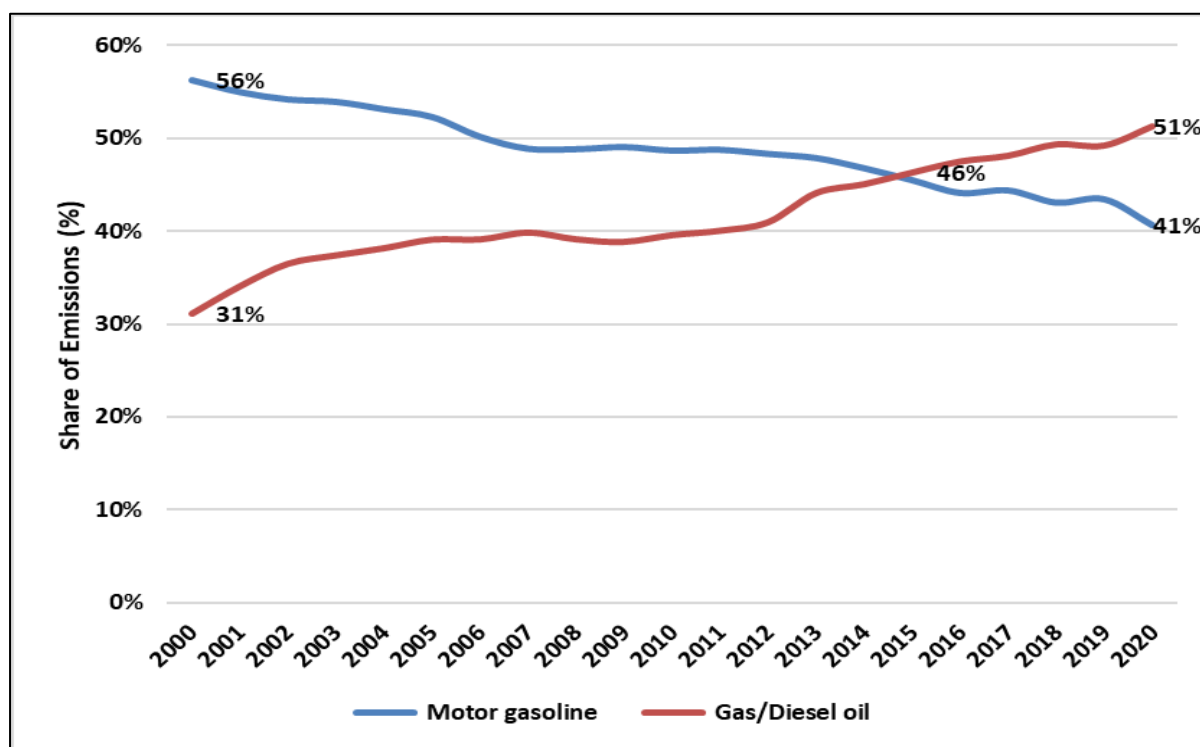


Figure 3. 8: Contribution of diesel and gasoline used in road transport to the total transport emissions



Other sectors

The *other sectors* were estimated to produce 15 446 Gg CO₂e and 12 399 Gg CO₂e in 2019 and 2020 respectively. In 2020, other sectors contributed 3% to the total energy sector emissions. The largest contributor to this category is the agricultural emissions (48%) followed by commercial sector at 30% and residential sector at 22%. In 2020, total *other sector* emissions were 18 282 Gg CO₂e below the 2000 level of 30 680 Gg CO₂e (Table 3.5).

Table 3.5: Trend in emissions from other sectors, 2000 – 2020.

	Commercial/ Institutional	Residential	Agriculture/ Forestry/ Fishing/ Fish farms	Total
	Gg CO ₂ e			
2000	21 095.1	7 125.4	2 459.9	30 680.5
2001	20 821.4	9 262.9	2 536.8	32 621.1
2002	20 638.9	11 152.3	2 624.4	34 415.6
2003	21 550.9	12 354.2	2 742.0	36 647.1
2004	23 067.9	14 043.6	2 816.9	39 928.4
2005	22 356.6	15 080.7	2 801.7	40 239.0
2006	9 757.5	17 337.5	3 518.4	30 613.4
2007	11 767.2	21 226.2	3 631.4	36 624.7
2008	13 045.8	22 603.1	3 495.6	39 144.6
2009	14 181.8	23 781.2	3 526.2	41 489.2
2010	5 141.3	10 062.9	3 422.6	18 626.8
2011	5 855.4	11 663.7	3 776.8	21 295.8
2012	8 193.5	16 203.9	3 486.2	27 883.6
2013	9 790.8	18 449.3	3 883.7	32 123.8
2014	2 645.9	2 698.2	3 937.0	9 281.1
2015	2 352.3	2 394.3	4 010.2	8 756.8
2016	3 150.2	2 797.9	6 133.9	12 082.0
2017	4 777.2	3 408.0	6 147.7	14 332.8
2018	5 227.9	2 749.9	6 292.3	14 270.1
2019	6 305.4	2 699.9	6 440.3	15 445.6
2020	3 757.8	2 715.0	5 926.0	12 398.8

Non-specified



The *non-specified* subsector was estimated to produce 18 147 Gg CO₂e in 2020, and these were 803 Gg CO₂e up from the 2000 level. Emissions in this subsector decreased by 47.8% since 2017. The increase was due to more coal being attributed to this sector, as well as having diesel being allocated to this sub-sector as per the Energy Balance allocations. During the same time coal usage tripled.

3.1.1.2 Fugitive emissions from fuels

Total estimated *fugitive emissions* for 2020 were 31 435 Gg CO₂e. Net *solid fuel* emissions contributed 9.3% (2 931 Gg CO₂e) of *fugitive emissions*. *Oil and natural gas* account for 2.0% (642 Gg CO₂e), while *other emissions from energy production* accounted for 88.6%. Overall *fugitive emissions* decreased by 6.4% (2 151 Gg CO₂e) between 2000 and 2020 (Table 3.6). There was a peak of emissions in 2004 (35 387 Gg CO₂e) due to an increase in *other emissions from energy production*, with an 11.2% decrease in 2005. Emissions declined slightly until 2011, after which they increased to 2020.

Table 3.6: Trend in fugitive emissions, 2000 – 2020.

	Solid Fuels	Oil and Natural Gas	Other Emissions from Energy Production	Total
	Gg CO ₂ e			
2000	2 368.7	752.0	30 465.2	33 585.9
2001	2 428.4	752.9	30 690.9	33 872.2
2002	2 572.2	955.1	30 690.9	34 218.3
2003	2 596.9	1 458.0	29 589.0	33 643.8
2004	2 620.4	1 378.9	31 387.2	35 386.5
2005	2 618.2	1 160.1	27 662.5	31 440.9
2006	2 649.3	1 133.2	27 524.7	31 307.2
2007	2 702.7	1 132.7	27 973.6	31 809.0
2008	2 661.8	1 138.2	26 609.5	30 409.5
2009	2 380.4	1 243.4	26 912.9	30 536.7
2010	2 521.6	964.2	26 704.5	30 190.4
2011	2 650.5	785.8	26 319.8	29 756.1
2012	2 860.0	641.8	27 298.7	30 800.5
2013	2 852.3	641.8	27 705.1	31 199.3
2014	2 889.8	641.8	27 266.8	30 798.4
2015	2 812.8	641.8	26 826.6	30 281.2
2016	2 783.0	641.8	27 032.6	30 457.5



2017	2 880.8	641.8	27 930.4	31 452.9
2018	2 786.0	641.8	27 036.9	30 464.7
2019	2 857.4	641.8	27 850.8	31 350.0
2020	2 930.7	641.8	27 862.7	31 435.2

Solid fuels

The *fugitive emissions from solid fuels* subsector was estimated to produce 2 931 Gg CO₂e in 2020, which is 0.8% of the energy sector emissions. Emissions were 562 Gg CO₂e (23.7%) above the 2000 level. Emissions increased by 6% between 2000 and 2010, then there was successive increase between 2011 until 2014. The decline and increase between 2014 and 2020 was minimal to such an extent that the missions stayed fairly constant throughout the years (Table 3.6).

Oil and natural gas

The *fugitive emissions from oil and natural gas* subsector was estimated to produce 642 Gg CO₂e in 2020, which is 0.2% of the *energy* sector emissions. Emissions were 110 Gg CO₂e (14.7%) below the 2000 level (752 Gg CO₂e) (Table 3.6). Fugitive emissions show no change since 2017 as there was a lack of updated data so emissions between 2013 and 2017 were assumed to be the same as they were in 2012.

Other emissions from energy production

Other emissions from energy production was estimated to produce 27 862 Gg CO₂e in 2020, which is 7.3% of the energy sector emissions. Emissions were 2 603 Gg CO₂e (8.5%) below the 2000 level (30 465 Gg CO₂e) (Table 3.6). Emissions in this subsector decreased by 0.2% (68 Gg CO₂e) since 2017.

3.1.2 Overview of methodology and completeness

Emissions for the *Energy* sector were estimated with a sectoral approach. In most cases a Tier 1 methodology was applied. Table 3.7 provides a summary of the methods and emission factors applied to each subsector of energy.



Table 3.7: Summary of methods and emission factors for the energy sector and an assessment of the completeness of the energy sector emissions.

GHG Source and sink category		CO ₂		CH ₄		N ₂ O		NO _x	CO	NM VOC	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	T1, T2	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
	b. Petroleum refining	T1	DF	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	DF	T1	DF	T1	DF	NE	NE	NE	NE
	b. Road transportation	T1	DF	T1	DF	T1	DF	NE	NE	NE	NE
	c. Railways	T1	DF	T1, T2	DF, CS	T1	DF	NE	NE	NE	NE
	d. Water-borne navigation	T1	DF	T1	DF	T1	DF	NE	NE	NE	NE
	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, T3	DF, CS	T1	DF	T1	DF	NE	NE	NE	NE
	c. Agriculture/ Forestry/ Fishing/ Fish farms	T1, T3	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



GHG Source and sink category		CO ₂		CH ₄		N ₂ O		NO _x	CO	NM VOC	SO ₂
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor				
1B	Fugitive emissions from fuels										
1B1	Solid fuels										
	a. Coal mining and handling	T2	CS	T2	CS	NO		NE	NE	NE	NE
	b. Uncontrolled combustion and burning coal dumps	NE		NE		NO		NE	NE	NE	NE
	c. Solid fuel transformation	IE		IE		NO		NE	NE	NE	NE
1B2	Oil and natural gas										
	a. Oil	T3	CS	T3	CS	NO		NE	NE	NE	NE
	b. Natural gas	NE		NE				NE	NE	NE	NE
1B3	Other emissions from energy production	T3	CS	T1, T3	DF, CS	NE		NE	NE	NE	NE
1C	Carbon dioxide transport and storage										
1C1	Transport of CO₂										
	a. Pipelines	NE		NE		NE		NE	NE	NE	NE
	b. Ships	NE		NE		NE		NE	NE	NE	NE
	c. Other	NE		NE		NE		NE	NE	NE	NE
1C2	Injection and storage										
	a. Injection	NE		NE		NE		NE	NE	NE	NE
	b. Storage	NE		NE		NE		NE	NE	NE	NE
1C3	Other	NE		NE		NE		NE	NE	NE	NE



3.1.3 Improvements and recalculations since the 2017 submission

Recalculated emission estimates for the *Energy* sector were between 6.3%-9.3% higher than previous estimates between 2000 and 2009, while in 2014 and 2015 estimates were 1.8% and 0.9% lower than previous estimates for the *Energy* sector (Figure 3.9). Estimates were 0.9% higher in the current inventory for the year 2017. These recalculations were necessary due to an update of consumption data in the *Road transport, Manufacturing industries and construction, Other sectors and Non-specified emissions from energy production* categories. The main fuels that necessitated recalculation are coal, diesel, natural gas and gas works gas in those sectors. There are three reasons why recalculations had to occur.

- 1) The energy balance from DMRE has updated fuel allocation in these sectors hence there was a need to recalculate the emissions.
- 2) The fuel consumption study done by DEFF under the GHG improvement programme was finalised
- 3) The Department of Mineral Resources and Energy had updated coal statistics in its South Africa's Mineral Industry (SAMI) report series.

A significant amount of diesel was allocated to 1A5a in the energy balance, which was not there before. Given that in the previous inventories, this category did not have any diesel allocated to it, this led to an increase in diesel consumption in the energy industries.

A recent parc model was finalised through the Fuel Consumption Study (DEFF, 2020) was completed for the transport sector which provided consumption data based on vehicle kilometres travelled (VKT). In this inventory the petrol, diesel and natural gas consumption data for *Road transport* was updated and this led to a 3.7% increase in the *Road transport* emission estimates between 2017 and 2019. In 2020, the emissions decreased by 13%. It is assumed that most of this reduction occurred due to the restricted travel from road transport, especially passenger travel where people converted to working from home. In the *Other emissions from energy production* category the charcoal consumption data was corrected, and this produced a 1% decline in emission estimates for 2008 to 2012 and a 12% reduction in the 2013 estimates. The new re-allocation of diesel significantly reduced diesel allocation in the manufacturing industries and construction sector.

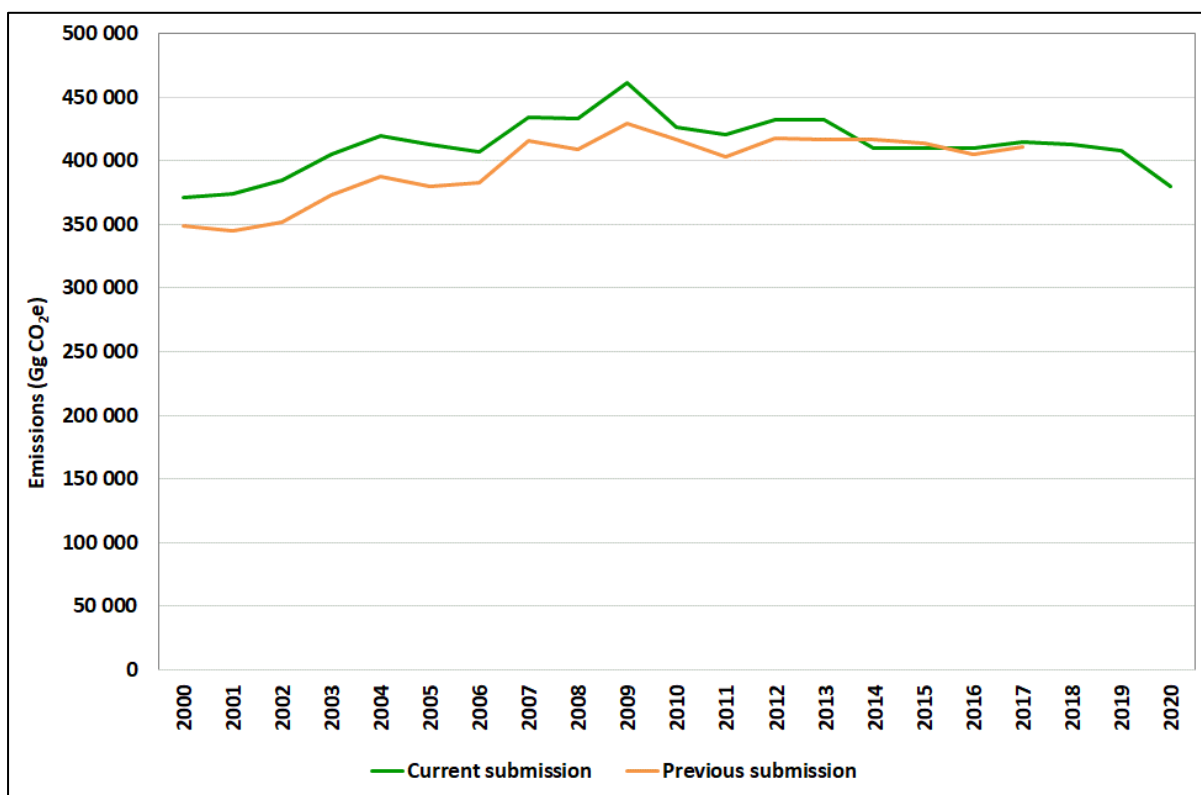


Figure 3.9: Recalculations for the Energy sector between 2000 and 2020.

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	Category	GHG	Identification Criteria
1A1a	Electricity and heat production (solid fuels)	CO ₂	L,T
1A1a	Electricity and heat production (liquid fuels)	CO ₂	L
1A1b	Petroleum refining (gaseous fuels)	CO ₂	L,T
1A1b	Petroleum refining (liquid fuels)	CO ₂	T
1A1c	Manufacture of solid fuels and other energy industries (solid fuels)	CO ₂	L,T
1A2	Manufacturing industries and construction (gaseous fuels)	CO ₂	L,T
1A2	Manufacturing industries and construction (solid fuels)	CO ₂	L,T
1A2	Manufacturing industries and construction (liquid fuels)	CO ₂	T



1A3a	Civil aviation (liquid fuels)	CO ₂	L,T
1A3b	Road transport (liquid fuels)	CO ₂	L,T
1A4a	Commercial/institutional (liquid fuels)	CO ₂	L,T
1A4a	Commercial/institutional (solid fuels)	CO ₂	L
1A4b	Residential (solid fuels)	CO ₂	L,T
1A4b	Residential (liquid fuels)	CO ₂	T
1A4c	Agriculture/forestry/fishing/fish farms (liquid fuels)	CO ₂	L,T
1B1a	Coal mining and handling	CH ₄	T
1B3	Other emissions from energy production	CH ₄	T

3.1.5 Planned improvements and recommendations

Improvements planned for the next inventory are:

- (i) There will be three instruments through which the data will be collected for the inventory in future. The first process will involve enhancement of the current direct communication between stakeholders and DFFE with memorandum of understandings being drafted to formalise the data collection process between significant industry players and government departments. For example, MoUs will be finalised for government departments such as Department of Minerals Resources and Energy (DMRE), public entities such as Eskom (electricity production) and associations such as South African Petroleum Industry Association (SAPIA);
- (ii) There are currently two studies that are being conducted to improve the emission factors for fuels used in industry. This is to move from Tier 1 to Tier 2 in those applicable industries. These studies are:
 - 1) Development of CO₂ emission factors for alternative fuels (mainly waste fuels such as tyres) used within the cement production industry.
 - 2) The second study is planned to look at country specific CO₂ emission factors for gaseous and liquid fuels used in stationary application.
- (iii) There is currently another study under the GHG improvement programme that is trying to improve the activity data for fuel wood consumption in different sub-sectors.
- (iv) Fugitive emissions from coke production are currently accounted for under category 2C as part of process emissions, however it is planned that by the 2021 inventory these will be separated from process emissions and reported separately; and
- (v) Time-series will be extended back to 1990 over the next few years, but this will likely only be available in the 6th BUR.



3.2 Fuel combustion (1.A)

3.2.1 Category description

The combustion of fuels includes both mobile and stationary sources with their respective combustion-related emissions. GHG emissions from the combustion of fossil fuels in this inventory will include the following categories and subcategories:

- 1A1 Energy industries
 - 1A1a Main activity electricity and heat production
 - 1A1b Petroleum activity
 - 1A1c Manufacture of solid fuels and other energy industries
- 1A2 Manufacturing industries and construction
- 1A3 Transport sector
 - 1A3a Civil aviation
 - 1A3b Road transportation
 - 1A3c Railways
 - 1A3d Water-borne navigation
- 1A4 Other sectors
 - 1A4a Commercial/ institutional
 - 1A4b Residential
 - 1A4c Agriculture / forestry/ fishing/ fish farms
- 1A5 Non-specified
 - 1A5a Stationary

3.2.2 Methodological issues

Unless otherwise noted in the relevant section, estimates of emissions from the combustion of individual fuel types are determined by multiplying an activity data item (physical quantity of fuel combusted) by a fuel-specific energy content factor and a fuel-specific emission factor for each relevant greenhouse gas as follows:

$$(\text{Emissions})_{ij} = Q_i \times EC_i \times EF_{ij} / 1\,000\,000$$

Where:

E_{ij} = the emissions of gas type (j) in Gigagrams (Gg), being carbon dioxide, methane or nitrous oxide, released from the combustion of fuel type (i)

Q_i = quantity of fuel type in tonnes (i)

EC_i = calorific value of the type of fuel (conversion factor) in Terajoule/tonne (Table 3.10)



$E_{f_{ij}}$ = emission factor for each gas type (j) released during the year measured in mass units (kg) per Terajoule (TJ) of fuel type (i) (Table 3.11)

A factor of 1 000 000 (to convert from kilograms to Gigagrams of greenhouse gas).

While small oxidation variations may be known for different types of fuel, a general oxidation factor of 1 was assumed.

3.2.2.1 Activity data

The required activity data and the main data providers for each subsector are provided in Table 3.9. The net calorific values for converting fuel quantities into energy units for solid, liquid and gaseous fuels are provided in Table 3. 10 and are taken from DFFE (2016).

Table 3.9: Data sources for the fuel combustion subcategory.

Sub-category	Activity data	Activity data sources
Electricity generation	Fuel consumption for public electricity generation	Eskom
	Fuel consumption for auto electricity producers	Energy balance (DoE)
	NCVs	Eskom
Petroleum refining	Fuel consumption	Refineries
Manufacture of solid fuels and other energy industries	No activity data, only emission data - based on Mass Balance Approach	PetroSA
		Sasol
Manufacturing industries and construction	Other kerosene, bitumen and natural gas consumption	Energy balance (DoE)
	Gas/Diesel consumption	SAPIA
	Residual fuel oil consumption	Energy digest
	LPG consumption	SAMI report (DMR)
Transport	Vehicle kilometres travelled for road transport	Fuel consumption study
	Domestic aviation gasoline consumption	SAPIA
	Domestic aviation jet kerosene consumption	Energy balance (DoE)
	Road transport fuel consumption	Energy balance (DoE)
	Road transportation other kerosene consumption	SAPIA
	Railway fuel oil consumption	Energy balance (DoE)
	Railway gas/diesel oil consumption	SAPIA
	Water-borne navigation fuel consumption	
	International aviation Jet Kerosene consumption	Energy balance (DoE); SAPIA



Sub-category	Activity data	Activity data sources
Commercial/institutional	Other kerosene, gas/diesel oil, gas works gas and natural gas consumption	Energy balance (DoE)
	Sub-bituminous coal consumption	Energy digest
	Residual fuel oil consumption	SAPIA
Residential	Coal consumption	SAMI report (DMR)
	LPG consumption	SAPIA
	Sub-bituminous coal consumption	Energy digest
	Other fuel consumption	Energy balance (DoE)
Agriculture/forestry/fishing/fish farms	Other kerosene consumption	SAPIA
	Gas/diesel oil consumption	Energy digest
	Other fuel consumption	Energy balance (DoE)
Stationary non-specified	Fuel consumption	SAPIA

Table 3. 10: Net calorific values for solid, liquid and gaseous fuels as provided by the South African Petroleum Industry Association.

	Fuel	Net calorific value	Unit	Density (kg/l)
Solid fuels	Coal: Eskom Average	19.8	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	
Liquid fuels	Paraffin	37.5	MJ/l	0.790
	Diesel	38.1	MJ/l	0.845
	Heavy Fuel Oil	43	MJ/kg	0.958
	Fuel Oil 180	42	MJ/kg	0.99
	Petrol	34.2	MJ/l	0.75
	Avgas (100LL)	33.9	MJ/l	0.71
	Jet Fuel (Jet-A1)	37.5	MJ/l	0.79
Gaseous fuels	LPG	46.1	MJ/ kg	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	
	Coke oven gas	17.3	MJ/Nm ³	

3.2.2.2 Emission factors

Table 3.11 provides the emission factors for stationary combustion. The default values are taken from 2006 IPCC Guidelines (Table 1.4 and 2.2 in volume 2). Country specific



values are from the Technical Guidelines for Monitoring Reporting and Verification of GHG Emissions by Industry (DFFE, 2016).

Table 3.11: Emission factors for stationary combustion (solid, liquid, gaseous and other fuels).

Fuel		CO ₂		CH ₄		N ₂ O	
		DF (Tier 1)	CS (Tier 2)	DF (Tier 1)	CS (Tier 2)	DF (Tier 1)	CS (Tier 2)
Liquid fuels	Crude oil	73 300		3		0.6	
	Orimulsion	77 000		3		0.6	
	Natural gas liquids	64 200		3		0.6	
	Gasoline	Motor gasoline		3		0.6	
		Aviation gasoline		3		0.6	
		Jet gasoline		3		0.6	
	Jet kerosene	71 500		3		0.6	
	Other kerosene	71 900		3		0.6	
	Shale oil	73 300		3		0.6	
	Gas/Diesel oil	74 100		3		0.6	
	Residual fuel oil	77 400		3		0.6	
	Liquified petroleum gases	63 100		1		0.1	
	Ethane	61 600		1		0.1	
	Naphtha	73 300		3		0.6	
	Bitumen	80 700		3		0.6	
	Lubricants	73 300		3		0.6	
	Petroleum coke	97 500		3		0.6	
	Refinery feedstocks	73 300		3		0.6	
	Other oil	Refinery gas		1		0.1	
		Paraffin waxes		3		0.6	
		White spirit and SBP		3		0.6	
		Other petroleum products		3		0.6	
Solid fuels	Anthracite	98 300		1		1.5	
	Coking coal	94 600		1		1.5	
	Other bituminous coal	94 600		1		1.5	
	Sub-bituminous coal	96 100	96 250	1		1.5	



Fuel		CO ₂		CH ₄		N ₂ O	
		DF (Tier 1)	CS (Tier 2)	DF (Tier 1)	CS (Tier 2)	DF (Tier 1)	CS (Tier 2)
	Lignite	101 000		1		1.5	
	Oil shale and Tar sands	107 000		1		1.5	
	Brown coal briquettes	97 500		1		1.5	
	Patent fuel	97 500		1		1.5	
	Coke	107 000		1		1.5	
	Gas coke	107 000		1		0.1	
	Coal tar	80 700		1		1.5	
	Derived gases	Gas works gas		1		0.1	
		Coke oven gas		1		0.1	
		Blast furnace gas		1		0.1	
		Oxygen steel furnace gas		1		0.1	
Gaseous fuels	Natural gas	56 100	48 000	1		0.1	
Other fuels							
Other fossil fuels	Municipal wastes (non-biomass fraction)	91 700		30		4	
	Industrial wastes	143 000		30		4	
	Waste oils	73 300		30		4	
	Peat	106 000		1		1.5	
Solid biofuels	Wood/wood waste	112 000		30		4	
	Sulphite lyes (Black liquor)	95 300		3		2	
	Other primary solid biomass	100 000		30		4	
	Charcoal	112 000		200		4	
Liquid biofuels	Biogasoline	70 800		3		0.6	
	Biodiesels	70 800		3		0.6	
	Other liquid biofuels	79 600		3		0.6	
Gas bio mass	Landfill gas	54 600		1		0.1	
	Sludge gas	54 600		1		0.1	



Fuel		CO ₂		CH ₄		N ₂ O	
		DF (Tier 1)	CS (Tier 2)	DF (Tier 1)	CS (Tier 2)	DF (Tier 1)	CS (Tier 2)
	Other biogas	54 600		1		0.1	
Other non-fossil fuels	Municipal wastes (biomass fraction)	100 000		30		4	

3.2.3 Comparison between sectoral and reference approach

The Reference Approach is a top-down approach, using a country's energy supply data to calculate the emissions of CO₂ from combustion of mainly fossil fuels. The Reference Approach was applied on the basis of relatively easily available energy supply statistics. It is good practice to apply both a sectoral approach and the reference approach to estimate a country's CO₂ emissions from fuel combustion and to compare the results of these two independent estimates. Significant differences may indicate possible problems with the activity data, net calorific values, carbon content, excluded carbon calculation etc.

The Reference Approach and the Sectoral Approach often have different results because the Reference Approach is a top-down approach using a country's energy supply data and has no detailed information on how the individual fuels are used in each sector.

The reference approach outputs were compared to the sectoral emissions for the period 2000 to 2017 (energy balance data for 2018 to 2019 was not available) and the CO₂ emissions were always higher using the reference approach (Figure 3.10). The difference in CO₂ emissions using the reference and sectoral approach was 17 % and 14 % for the years 2017 and 2018, respectively. The energy balance data for 2019 – 2020 has not been released yet and as a result, the comparison for latter years has not been done. The largest differences were seen in the solid fuels, where consumption is consistently higher with the reference approach (Appendix D). Allocation of solid fuels between energy use, non-energy use as well as use for synthetic fuels production remains one of the key drivers of the differences observed between the two datasets. The opposite is true for liquid fuels, with the sectoral approach showing higher values (Appendix D), whereas for gaseous fuels the consumption data is higher with the Reference Approach (Appendix D). Reasons for the differences between the emissions and fuel consumption data of the Reference and Sectoral Approach are:



-
- 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.
 - High distribution losses for gas will cause the Reference Approach to be higher than 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.
 - Net Calorific Values (NCV) used in the Sectoral Approach differ from those used in the Reference Approach. In power generation, NCV values in the sectoral approach vary over the 2000-2016 time series based on the information provided by industry;
 - 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.
 - Simplifications in the Reference Approach. There are small quantities of carbon which should be included in the Reference Approach because their emissions fall under fuel combustion. These quantities have been excluded where the flows are small or not represented by a major statistic available within energy data.

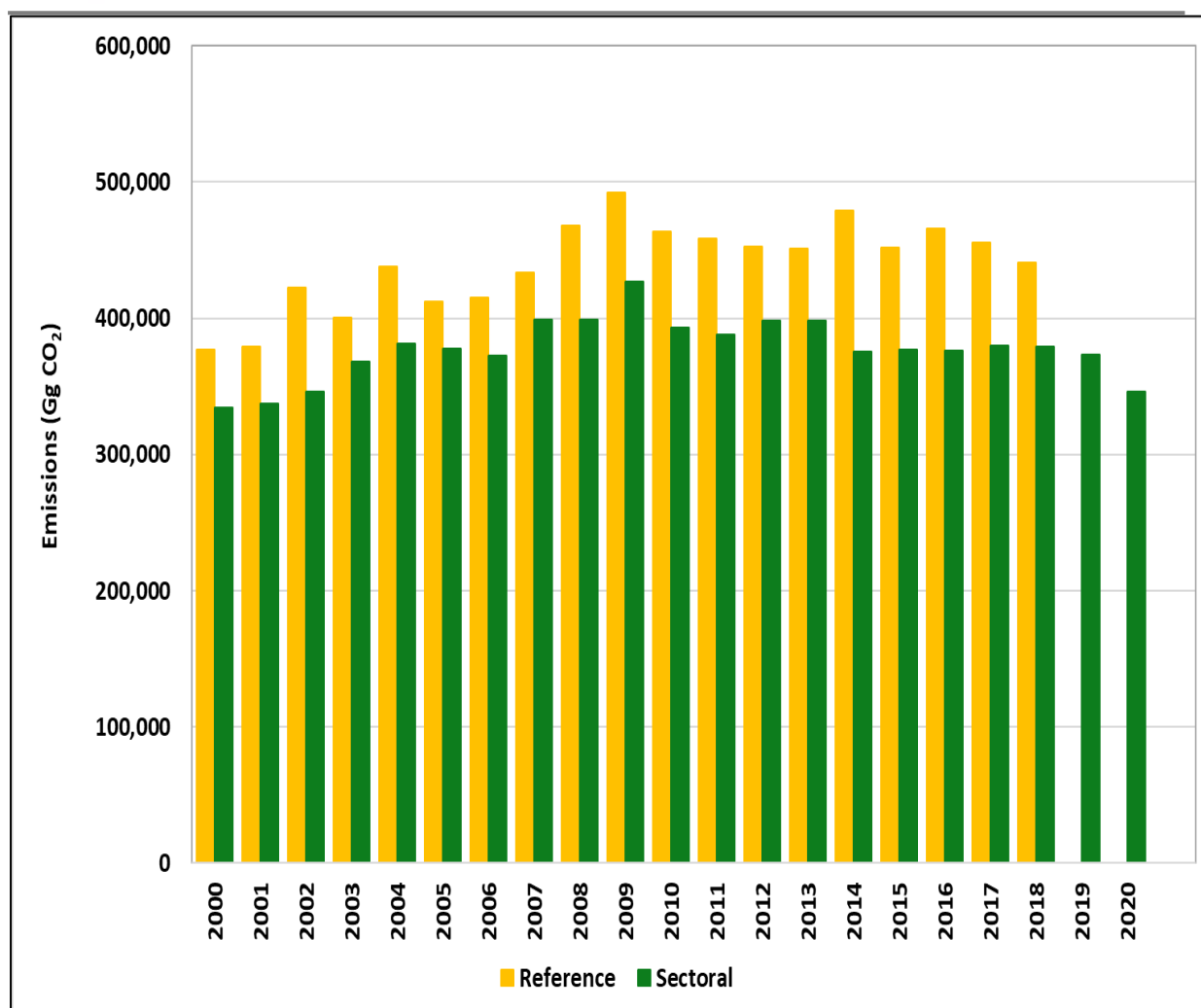


Figure 3.10: Comparisons between the reference and sectoral approach of determining the CO₂ emissions for the energy sector for South Africa.

3.2.4 International bunker fuels

GHG emissions from aircraft that returned from an international destination or were going to an international airport were included under this sub-category. That included civil commercial use of airplanes, scheduled and charter traffic for passengers and freight, air taxiing, agricultural airplanes, private jets and helicopters. The GHG emissions from military aviation were reported separately under the *other* category or under the memo item *multilateral operations*.



3.2.5 Feedstock and non-energy use of fuels

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 2006 IPCC 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.

3.2.6 Energy industries (1.A.1)

3.2.6.1 Category description

The fuel combustion sub-category includes combustion for *main activity electricity and heat production, petroleum refining, the manufacture of solid fuels and other energy industries and non-specified sources*.

Main activity electricity refers to public electricity plants that feed into the national grid and auto electricity producers, which are industrial companies that operate and produce their own electricity. Eskom generates, transmits and distributes 60% of electricity to various sectors, such as the industrial, commercial, agricultural and residential sectors. Forty percent of the electricity distribution is done by the municipalities.

Additional power stations are being built to meet the increasing demand for electricity in South Africa (Eskom, 2011). Eskom had planned to invest more than R300 billion in new generation, transmission and distribution capacity up to 2013. In 2008 Eskom's total sales of electricity were estimated at 239 109 GWh. Eskom introduced demand side management (DSM) in an effort to reduce electricity consumption by 3 000 MW by March 2011. The utility aims to increase this to 5 000 MW by March 2026. The process involves the installation of energy-efficient technologies to alter Eskom's load and demand profile. The DSM programme within the residential, commercial and industrial sectors has exponentially grown and exceeded its annual targets. The 2009 saving was 916 MW, against the target of 645 MW. That increased the cumulative saving to 1 999 MW since the inception of DSM in 2008.

Petroleum refining includes combustion emissions from crude oil refining and excludes emissions from the manufacture of synthetic fuels from coal and natural gas. Combustion-related emissions from the manufacture of synthetic fuels from coal and



natural gas are accounted for under 1A1c. South Africa has limited oil reserves and approximately 95% of its crude oil requirements are met by imports. Refined petroleum products such as petrol, diesel, fuel oil, paraffin, jet fuel and LPG are produced by crude oil refining, and the production of coal-to-liquid fuels and gas-to-liquid fuels.

In 2000 and 2015 the total crude oil distillation capacity of South Africa's petroleum refineries was 700 000 bbl/d and 703 000 bbl/d, respectively (SAPIA, 2006 & 2017). The production of oil was 689 000 tonnes in 2000 and 684 000 tonnes in 2006 (SAPIA, 2011). Activity data on the fuel consumed by refineries is sourced directly from refineries. National energy balance data from the DMRE is used to verify data reported by the petroleum industry.

The *manufacture of solid fuels and other energy industries* category refers to combustion emissions from solid fuels used during the manufacture of secondary and tertiary products, including the production of charcoal. The GHG emissions from the various industrial plants' own on-site fuel use, and emissions from the combustion of fuels for the generation of electricity and heat for their own use is also included in this category. The South African energy demand profile reveals that the industry/manufacturing sector utilizes the largest amount of electricity (36%), followed by the transport and residential sectors both at 27% (DoE, 2018).

3.2.6.2 Methodological issues

Electricity generation (1.A.1.a)

A Tier 2 approach, with country-specific emission factors, was used to determine CO₂ emissions from coal combustion. For emissions from other fuels (e.g. other kerosene and diesel oil), and for all CH₄ and N₂O emission estimates a Tier 1 approach was applied.

Petrol refining (1.A.1.b)

A Tier 1 approach was used to determine the emissions from petrol refining.

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

Emissions for this subcategory were determined by process balance analysis (Tier 3). Combustion-related emissions from charcoal production were not estimated in this category due to a lack of data on fuel use in charcoal production plants, therefore it was assumed that fuel consumption for charcoal production is included under the category non-specified- stationary (1A5a).



Activity data

Electricity generation (1.A.1.a)

Electricity generation is the largest key GHG emission source in South Africa, mainly because it mainly uses sub-bituminous coal which is abundantly available in the country. Data on fuel consumption for public electricity generation was obtained directly from the national power producer for the period 2000 to 2020. Eskom supplies more than 90% of South Africa's electricity needs (DoE, 2018). It generates, transmits and distributes electricity to various sectors, such as the industrial, commercial, agricultural and residential sectors. Total consumption in TJ is provided in Table 3.12. Auto electricity provider data was sourced from the DoE Energy balance spreadsheets (DoE, 2015).

To convert fuel quantities into energy units for public electricity generation, the net calorific values estimated by the national utility annually were applied (Table 3.12). The energy consumed to produce electricity dropped by 5.5% between 2019 and 2020.

Table 3.12: Trend in fuel consumption for the various categories in the energy industry sector, 2000 – 2020.

	Public electricity producer	Auto electricity producer	Petroleum refining
	Fuel consumption (TJ)		
2000	1 806 317	116 046	59 638
2001	1 823 119	47 346	57 599
2002	1 883 709	51 311	50 680
2003	2 025 822	82 036	57 487
2004	2 126 649	64 333	53 292
2005	2 142 682	28 029	51 610
2006	2 155 477	39 627	55 121
2007	2 369 988	48 233	56 073
2008	2 271 791	40 066	57 870
2009	2 335 101	68 381	56 523
2010	2 406 936	22 613	52 520
2011	2 426 965	9 164	50 235
2012	2 537 365	12 305	51 049
2013	2 477 632	12 220	51 890
2014	2 423 731	12 533	51 504
2015	2 343 934	12 352	51 118



	Public electricity producer	Auto electricity producer	Petroleum refining
	Fuel consumption (TJ)		
2016	2 259 087	2 133	50 731
2017	2 233 426	7 562	50 345
2018	2 314 985	6 750	50 147
2019	2 291 699	17 079	49 952
2020	2 166 339	16 448	37 154

Petroleum refining (1.A.1.b)

Activity data on the fuel consumed by refineries is sourced directly from refineries (Table 3.12). National energy balance data from the DoE is used to verify data reported by the petroleum industry. Some refineries did not record fuel consumption in the first four years of the time series (i.e. 2000-2003), therefore data splicing methodologies described in Chapter 5 of Volume 1 of the 2006 IPCC guidelines were applied for the filling of data gaps to ensure completeness and consistency in the data time series. The energy used in refining dropped by 26% between 2019 and 2020.

1A1c Manufacture of solid fuels and other energy industries

Emission estimates for this subcategory were supplied by the manufacturing plants PetroSA and Sasol.

Emission factors

Emission factors are provided in Table 3.11.

3.2.6.3 Uncertainties and time-series consistency

Activity data uncertainty

Regarding activity data, statistics of fuel combusted at large sources obtained from direct measurement or obligatory reporting are likely to be within 3% of the central estimate (IPCC, 2006). Those default IPCC uncertainty values have been used to report uncertainty for energy industries. Uncertainties are provided in (Table 3.13).

Emission factor uncertainty



According to the IPCC Guidelines, the uncertainties in CO₂ emission factors for the combustion of fossil fuels are negligible. The emission factors were determined from the carbon content of the fuel. A country-specific emission study to develop CO₂ emission factors for Energy Industries also produced uncertainty estimates that have been applied in this study. Uncertainties in CH₄ and N₂O emission factors were quite significant. The CH₄ emission factor has an uncertainty of between 50 and 150%, while the uncertainty on the N₂O emission factor can range from one-tenth of the mean value to ten times the mean value.

Time-series consistency

The time series is complete for this category. The national power utility changed its annual reporting planning cycle from a calendar year to an April-March financial year from 2006 onwards. That affected the time-series consistency, therefore, the national power utility was asked to prepare calendar-year fuel consumption estimates using its monthly fuel consumption statistics. From 2017 to 2020, the data was in calendar year as per the reporting requirements.

Table 3.13: Uncertainty for South Africa's fuel combustion emission estimates.

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1A1ai Electricity generation – liquid fuels	5	IPCC 2006	7	IPCC 2006
	1A1ai Electricity generation – solid fuels	5	IPCC 2006	7	IPCC 2006
	1A1b Petroleum refining – liquid fuels	5	IPCC 2006	7	IPCC 2006
	1A1ci Manufacture of solid fuels – liquid fuels	5	IPCC 2006	7	IPCC 2006
	1A1ci Manufacture of solid fuels – solid fuels	5	IPCC 2006	7	IPCC 2006
	1A1cii Other energy industries – liquid fuels	10	IPCC 2006	7	IPCC 2006
CH ₄	1A1 Energy industries – liquid fuels	5	IPCC 2006	75	IPCC 2006
	1A1 Energy industries – solid fuels	5	IPCC 2006	75	IPCC 2006
N ₂ O	1A1 Energy industries – liquid fuels	5	IPCC 2006	75	IPCC 2006
	1A1 Energy industries – solid fuels	5	IPCC 2006	75	IPCC 2006

3.2.6.4 Category specific QA/QC and verification

Consumption data from refineries was checked against the energy balance data and where there seems to be over-estimation of emissions, the data from refineries was queried and re-submissions were requested.



3.2.6.5 *Category specific recalculations*

No recalculations are conducted for this category.

3.2.6.6 *Category specific planned improvements*

Main activity electricity and heat production (1.A.1.a)

The electricity generation sector is a key category and its estimate has a significant influence on the country's total inventory of GHGs. Therefore, increasing the accuracy of GHG calculations by applying country-specific emission factors for this sector will improve the national GHG inventory estimate. Other improvements for this category would be to:

- Formalise the data collection process to ensure continuous collection of data and time-series consistency;
- Collect plant specific data for coal combusted;
- Obtain more detailed information from the national power producer to assist in the explanation of trends throughout the reporting period;
- Obtain a list of auto power producers and obtain data directly from the producers. This is important going forward since growth is expected within this sector.

Petroleum refining (1.A.1.b)

To improve the reporting of GHG emissions in this category it is important that the petroleum refineries provide plant-specific activity data, such as net calorific and carbon content values, and also develop country-specific emission factors that can be used for the calculation of GHG emissions.

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

To improve the estimation of GHG emissions from the *manufacture of solid fuels and energy industries*, a more regular collection of activity data would be useful. That would improve the time series and consistency of the data.

3.2.7 **Manufacturing industries and construction (1.A.2)**

3.2.7.1 *Category description*



Manufacturing industries and construction subsector comprise a variety of fuel combustion emission sources, mainly in the industrial sector. In manufacturing industries, raw materials are converted into products using fuels as the main source of energy. The industrial sector consumes 36% of the final energy supplied in South Africa (DoE, 2018). The *manufacturing industries and construction* subsector can be divided into mining, iron and steel, chemicals, non-ferrous metals, non-metallic minerals, pulp and paper, food and tobacco and other productions (includes manufacturing, construction, textiles, wood products etc.) categories. The largest category is *iron and steel* which consumes 19% of the total energy utilized by the industrial sector (DoE, 2018). Emissions from the combustion of fossil fuels in the construction sector are also included in this category. According to the energy balances compiled by the DoE, fossil fuels used in the construction sector include LPG, gas/diesel oil, residual fuel oil, other kerosene, bitumen, sub-bituminous coal and natural gas.

3.2.7.2 Methodological issues

Emission estimates for this subsector are mainly from fuel combusted for heating purposes. Fuels used as feed stocks and other non-energy uses are accounted for under the IPPU sector. For the manufacturing industries and construction subsector, a Tier 1 methodology was applied. The fuel consumption within the Energy balance by the individual sub-sectors does not have a complete time series data, therefore a decision was made to report this sector at an aggregated level, which reduces uncertainty when applying data amputation techniques to fill up the data for missing years.

Activity data

For the manufacturing industries and construction sector data for solid fuels for the period 2000 to 2007 were sourced from the DoE's energy digest, for the period 2007 to 2012 the SAMI report (DMR, 2015) was used to extrapolate the fuel consumption. The activity data on liquid fuels for this category was sourced from SAPIA (SAPIA, 2019) and from the fuel consumption study (DEFF, 2019). Data from industries were also acquired and used to compare the figures in the energy digest and the SAMI report. To avoid double counting of fuel activity data, the fuel consumption associated with petroleum refining (1A1b) was subtracted from the fuel consumption activity data sourced for 1A2. Table 3.14 shows the total fuel consumption in this category for the period 2000 to 2020. NCV are provided in Table 3. 10.



Table 3.14: Fuel consumption (TJ) in the manufacturing industries and construction category, 2000 – 2020.

Period	Other Kerosene	Gas/Diesel Oil	Residual Fuel Oil	LPG	Bitumen	Sub-Bituminous Coal	Natural Gas	Total
(TJ)								
2000	698	28 234	191	3 870	5 053	202 749	39 532	91 402
2001	640	29 499	194	3 814	5 584	204 130	41 241	88 807
2002	606	30 955	187	3 719	6 161	210 505	43 048	90 788
2003	626	32 915	185	3 566	6 276	217 464	48 749	92 373
2004	649	34 769	199	3 367	6 382	217 134	50 361	93 641
2005	619	36 784	171	3 133	7 038	205 238	53 166	78 425
2006	599	36 015	166	2 869	7 245	210 508	56 038	98 712
2007	547	38 199	164	2 640	7 707	221 647	58 908	98 712
2008	589	50 628	164	2 431	7 475	236 878	61 778	98 712
2009	504	44 769	207	2 257	7 602	341 078	69 749	17 564
2010	594	39 725	219	2 253	8 044	294 415	76 984	16 079
2011	594	48 835	167	2 339	7 536	233 387	76 576	15 816
2012	549	52 164	198	2 378	9 807	171 402	75 755	15 058
2013	501	53 346	186	2 455	9 095	152 795	75 443	16 631
2014	539	62 475	186	2 540	9 384	134 189	77 164	20,382
2015	419	73 652	186	2 623	9 673	236 467	74 589	21 048
2016	531	46 981	186	2 705	9 963	352 754	77 476	19 808
2017	642	55 637	187	2 785	10 252	206 062	81 675	21 876
2018	643	68 247	188	2 735	10 297	223 113	93 423	23 214
2019	645	61 689	189	2 685	10 342	221 862	96 747	23 224
2020	289	55 865	224	2 426	10 387	220 124	99 832	24 246

Emission factors

Emission factors are provided in Table 3.11. A country-specific emission factor for CO₂ for sub-bituminous coal was applied. For all other fuels the IPCC 2006 default emission factors were used to estimate emissions from the *manufacturing industries and construction* sector.

3.2.7.3 Uncertainties and time series consistency

The time-series is consistent and the uncertainties are provided in Table 3.15.



Table 3.15: Uncertainty for South Africa's Manufacturing industries and construction emission estimates.

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

Activity data uncertainty

Uncertainty associated with activity data based on less-developed statistical systems was in the range of 10 to 15%. Activity data sourced on fuel consumption was complete and hence there was no need to apply IPCC methodologies for filling data gaps.

Emission factor uncertainty

According to the 2006 IPCC Guidelines, uncertainty associated with default emission factors for industrial combustion is as high as 7% for CO₂, ranges from 50 to 150% for CH₄ and is an order of magnitude for N₂O.

Time-series consistency

There are no time-series inconsistencies for this category. To ensure time-series consistency in this source category the same emission factors were used for the complete time-series estimates.



3.2.7.4 *Category specific QA/QC and verification*

The national energy balances and the digest of energy statistics were used to verify fuel consumption data reported in the SAMI report. An independent reviewer was appointed to assess the quality of the inventory, determine the conformity of the procedures followed for the compilation of the inventory and identify areas of improvements.

3.2.7.5 *Category-specific recalculations*

No recalculations were performed for this category.

3.2.7.6 *Category-specific planned improvements*

In future, facility-level data needs to be sourced and country-specific emission factors have to be developed in order to move towards a Tier 2 methodology. The reliance on energy balances and other publications for the compilation of emissions needs to be reduced by sourcing facility-level activity data. The industry reporting required by the new GHG regulation should assist in providing some of this more detailed data. Improved detail would also help to reduce the uncertainty associated with the activity data.

3.2.8 **Transport (1.A.3)**

3.2.8.1 *Category description*

This category only includes direct emissions from transport activities, mainly from liquid fuels (gasoline, diesel, and aviation gas and jet fuel). Secondary fuels, such as electricity used by trains, are reported under the main activity electricity and heat production category and not under the transport category. The diversity of sources and combustion takes into consideration the age of the fleet, maintenance, the sulphur content of the fuel used and patterns of use of the various transport modes. The GHG inventory includes emissions from combustion and evaporation of fuels for all transport activity.

Civil aviation emissions are produced from the combustion of jet fuel (jet kerosene and jet gasoline) and aviation gasoline. Aircraft engine emissions (ground emissions and cruise emissions) are roughly composed of 70% CO₂, less than 30% water and 1.0% of other components (NO_x, CO, SO_x, NMVOCs, particulates, and trace components). Civil aviation data were sourced from both domestic and international aircrafts, including departures and arrivals. That also included civil commercial use of airplanes, scheduled and charter traffic for passengers and freight, agricultural airplanes, private jets and helicopters. Emissions from aircraft that returned from an international destination or were going to an international airport were included under *international bunkers*. The



emissions from military aviation are reported separately under the *other* category or the memo item *multilateral operations*.

Road transport emissions include fuel consumption by light-duty vehicles (cars and light delivery vehicles), heavy-duty vehicles (trucks, buses and tractors) and motorcycles (including mopeds, scooters and three-wheelers). Fuels used by agricultural vehicles on paved roads are also included in this category.

Railway locomotives are mostly one of three types: diesel, electric or steam. Diesel locomotives generally use engines in combination with a generator to produce the energy required to power the locomotive. Electric locomotives are powered by electricity generated at power stations and other sources. Steam locomotives are generally used for local operations, primarily as tourist attractions and their GHG emissions are very low (DME, 2002). Both freight and passenger railway traffic generate emissions. South Africa's railway sector uses electricity as its main source of energy, with diesel being the only other energy source.

Water-borne navigation includes emissions from use of heavy fuel oil/residual fuel oil as well as diesel. A fuel consumption study led by DFFE in collaboration with DoE allowed for estimation of fuel consumption for water born navigation for the 2000-2012 time period. Data splicing techniques described in the 2006 IPCC Guidelines were used to extrapolate fuel consumption activity data to the period 2013-2017. Previously, emissions related to water-borne navigation as well as international navigation were assumed to be included under the category *other sectors*.

3.2.8.2 *Methodological issues*

A Tier 1 approach was applied for this subsector.

Activity data

Civil aviation (1.A.3.a)

Activity data on gasoline fuel consumption was sourced from SAPIA's annual reports (SAPIA, 2016), the DFFE fuel consumption survey (DFFE, 2019), while jet kerosene data was obtained from energy balance data and the DFFE fuel consumption survey. It should however be noted that the SAPIA report indicates that data from 2009 are taken from the energy balance data anyway. The DFFE fuel consumption survey was therefore used to calibrate the 2009 data contained in the DoE energy balances. The 2006 IPCC Guidelines (p. 3.78) require only domestic aviation to be included in the national totals. Hence, in order to separate international from domestic aviation, the DoE energy balances were used to estimate the ratio of domestic to international consumption. The DFFE fuel



consumption study was then used to quantify the actual fuel consumption for both international and domestic aviation.

According to the 2006 IPCC Guidelines, it is good practice to separate military aviation from domestic aviation. It was, however, not possible to estimate the amount of fuel used for military aviation activities as military aviation consumption is not separated out in the source data. Military aviation emissions are thought to be accounted for under domestic aviation. In the DOE's energy balances civil aviation fuels include gasworks gas, aviation gasoline and jet kerosene.

Road transportation (1.A.3.b)

Petrol, diesel and natural gas consumption data was determined from vehicle kilometre travelled for each class of vehicle. To determine the fuel consumed per technology class, the following equation was used:

$$Q_i = VKT_{vc} \times FE_{vc} \times N_{vc} \quad (Eq. 3.2)$$

Where;

Q_i is the fuel (i) consumed in litres,

VKT_{vc} is the vehicle kilometre travelled per vehicle class,

FE_{vc} is the aggregate fuel economy of the vehicle class

N_{vc} is the number of vehicles per vehicle class

Activity data for these calculations were obtained from the fuel consumption study (Top Quartile, 2019).

The energy balance was the main source of data for residual fuel oil and LPG consumption, while SAPIA annual reports provided data on other kerosene consumption.

Road transport was responsible for the most fuel consumed in the transport sector (94% in 2017). Motor gas contributed 60.2% of the *road transport* fuel consumption in 2017, followed by gas/diesel oil. Over the time series there has been an increase in the percentage contribution of gas/diesel oil to road transport consumption, and a corresponding decline in the contribution from motor gasoline (Figure 3.11). This can be attributed to the efficiency and affordability of diesel compared with motor gasoline.

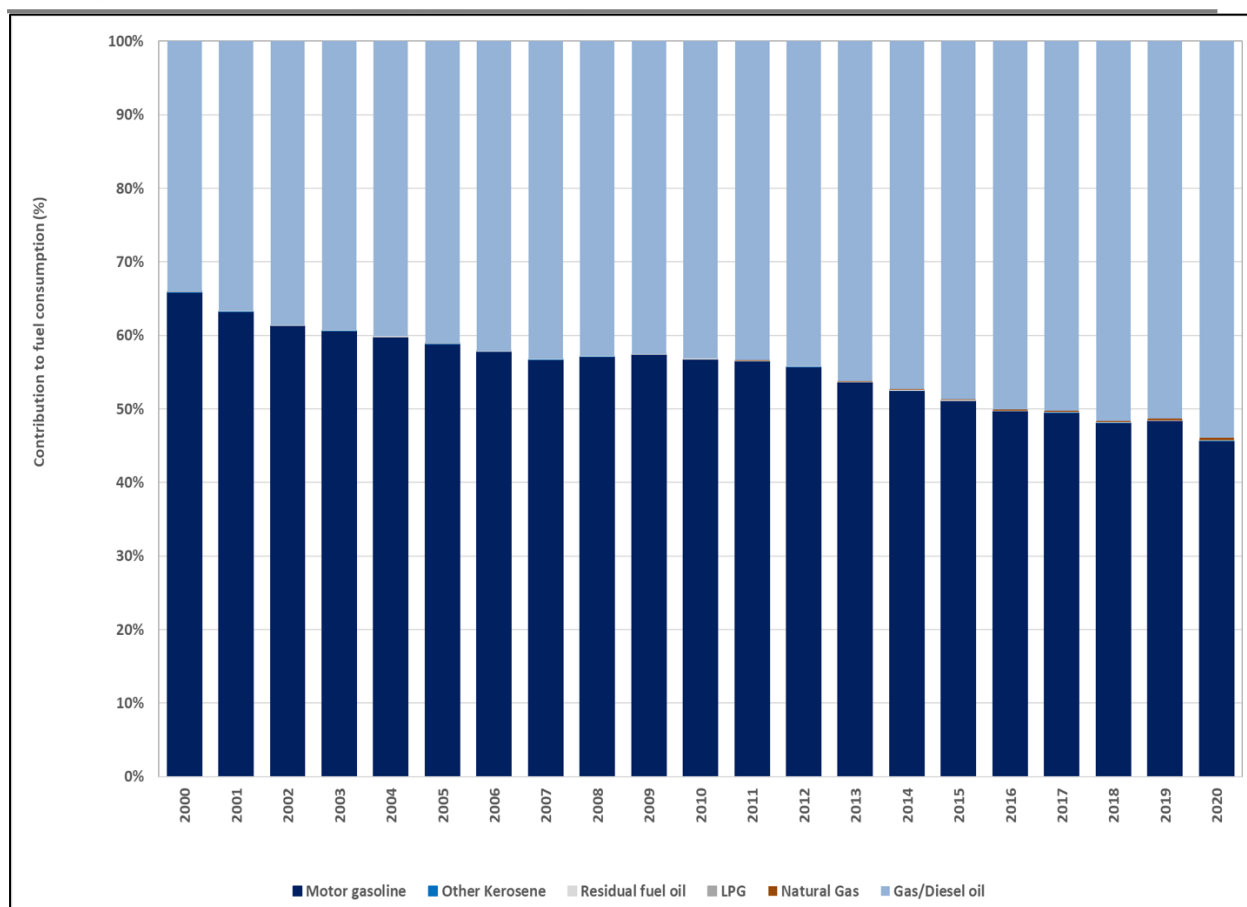


Figure 3.11: Percentage contribution of the various fuel types to fuel consumption in the road transport category (1A3b), 2000 – 2020.

Railways (1.A.3.c)

The national railway operator, Transnet, provided activity data for railways for the period 2000-2020.

Water-borne navigation (1.A.3.d)

A fuel consumption study led by DEFF in collaboration with DMRE allowed for estimation of fuel consumption for water born navigation for the 2000-2012 time period. Data splicing techniques described in the 2006 IPCC Guidelines were used to extrapolate fuel consumption activity data to the period 2013-2017. Default IPCC EFs for CO₂, CH₄ and N₂O were used to quantify emissions from this category using the IPCC default methodology.

Emission factors



IPCC default emission factors for road transport (Table 3.2.1 & Table 3.2.2, Chapter 3, IPCC 2006 Guidelines) were applied. Emission factors for railways were taken from the Technical Guidelines (DFFE, 2016).

3.2.8.3 *Uncertainties and time series consistency*

Civil aviation (1.A.3.a)

For non-CO₂ emission factors the uncertainty ranges between -57% to +100% and for CO₂ emission factors it is approximately $\pm 5\%$, as they are dependent on the carbon content of the fuel and the fraction oxidized (IPCC, 2006, p.3.65).

Road transport (1.A.3.b)

According to the 2006 IPCC Guidelines, the uncertainties in emission factors for CH₄ and N₂O are relatively high and are likely to be a factor of 2 to 3%. They also depend on the following: fleet age distribution; uncertainties in the maintenance pattern of vehicle stock; uncertainties related to combustion conditions and driving patterns; and application rates of post-emission control technologies (e.g. three-way catalytic converters), to mention a few.

Activity data was another primary source of uncertainty in the emission estimates. According to the IPCC Guidelines, possible sources of uncertainty, are typically $\pm 5\%$ due to the following: uncertainties in national energy sources of data; unrecorded cross-border transfers; misclassification of fuels; misclassification of vehicle stocks; lack of completeness; and uncertainty in conversion factors from one set of activity data to another.

Railways (1.A.3.c)

The GHG emissions from railways or locomotives are typically smaller than those from road transport because less fuel is consumed. Also, operations often occur on electrified lines, in which case the emissions associated with railway energy use will be reported under power generation and will depend on the characteristics of that sector. According to the IPCC Guidelines, possible sources of uncertainty are typically $\pm 5\%$ due to uncertainties in national energy sources of data; unrecorded cross-border transfers; misclassification of fuels; misclassification of vehicle stocks; lack of completeness and uncertainty in conversion factors from one set of activity data to another.

Water-borne navigation (1.A.3.d)



In terms of the emission factors, default CO₂ uncertainty values for Diesel fuel are about $\pm 1.5\%$ and for residual fuel oil $\pm 3\%$ and are primarily dependent of carbon content of the fuel. The uncertainty values for non-CO₂ gases are much higher (CH₄ $\pm 50\%$ whilst for N₂O the uncertainty values range from 40% below or 140% above the default value)

For activity data the major uncertainty driver is the ability to separate between domestic and international fuel consumption. For a comprehensive data collection programme, the uncertainty in fuel consumption activity data is estimate at $\pm 5\%$.

Table 3.16: Uncertainty for South Africa's transport emission estimates.

Gas	Sectors	Activity data uncertainty		Emission factor uncertainty	
		%	Source	%	Source
CO ₂	1A3a Civil aviation – liquid fuels	5	IPCC 2006	1.5	IPCC 2006
	1A3b Railways liquid fuels	5	IPCC 2006	5	IPCC 2006
	1A3d Waterborne navigation – liquid fuels	5	IPCC 2006	5	IPCC 2006
CH ₄	1A3a Civil aviation – liquid fuels	5	IPCC 2006	50	IPCC 2006
	1A3b Railways – liquid fuels	5	IPCC 2006	9	IPCC 2006
	1A3d Waterborne navigation – liquid fuels	5	IPCC 2006	50	IPCC 2006
N ₂ O	1A3a Civil aviation – liquid fuels	5	IPCC 2006	50	IPCC 2006
	1A3b Railways - liquid fuels	5	IPCC 2006	72	IPCC 2006
	1A3d Waterborne navigation – liquid fuels	5	IPCC 2006	50	IPCC 2006

Time-series consistency

The time-series is complete for this subsector. All uncertainties are provided in Table 3.16.

3.2.8.4 Category specific QA/QC and verification

All activity data was compared to the energy balance data.

3.2.8.5 Category-specific recalculations

No recalculations were performed for this category.

3.2.8.6 Category-specific planned improvements



In this inventory *Road transport* consumption data for petrol, diesel and LPG was updated from the recently completed fuel consumption study (Top Quartile, 2019). Other disaggregated fuel consumption data from this study will be incorporated into the next inventory.

Civil aviation (1.A.3.a)

Improvement of emission estimation for this category requires an understanding of aviation parameters, including the number of landings/take-offs (LTOs), fuel use and the approaches used to distinguish between domestic/international flights. This would ensure the use of higher-tier approaches for the estimation of emissions. To improve transparency of reporting, military aviation should be removed from domestic aviation and reported separately (IPCC, 2006, p.3.78).

It is also recommended that a more detailed description of the methodology for splitting domestic and international fuel consumption be included in the next inventory report.

Road transport (1.A.3.b)

The VKT data from the fuel consumption study will be considered for Tier 2 calculations of CH₄ and N₂O emissions. Furthermore, the development of local emission factors by fuel and vehicle-type will enhance the accuracy of the emission estimation.

Railways (1.A.3.c)

National-level fuel consumption data are needed for estimating CO₂ emissions for Tier 1 and Tier 2 approaches. In order to estimate CH₄ and N₂O emissions using a Tier 2 approach, locomotives category-level data are needed. These approaches require that railway, locomotive companies or the relevant transport authorities provide fuel consumption data. The use of representative locally estimated data is likely to improve accuracy although uncertainties will remain large.

Water-borne navigation (1.A.3.d)

No further improvements are planned for this subcategory.

3.2.9 Other sectors (1.A.4)

3.2.9.1 Category description



This source category includes emissions from fuel combustion in commercial/institutional buildings (as well as government, information technology, retail, tourism and services), residential households and agriculture (including large modern farms and small traditional subsistence farms), forestry, fishing and fish farms. Fuels included are residual fuel oil, other kerosene, gas/diesel oil, sub-bituminous coal, gas work gas, LPG and natural gas. In the residential sector there is also charcoal and other solid biomass.

3.2.9.2 Methodological issues

A Tier 1 approach was utilized for the estimation of emissions in this subsector.

Activity data

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

Data on fuel consumption in the commercial/institutional buildings category was sourced from the DMRE's energy balance reports, the DMRE's SAMI report (solid fuels and natural gas) and SAPIA (liquid fuels) for 2000 to 2018 as well as the Fuel Consumption Study (DEFF, 2019). NCV are provided in Table 3. 10. Fuels included are residual fuel oil, other kerosene, gas/diesel oil, sub-bituminous coal, gas work gas and natural gas (Figure 3.12).

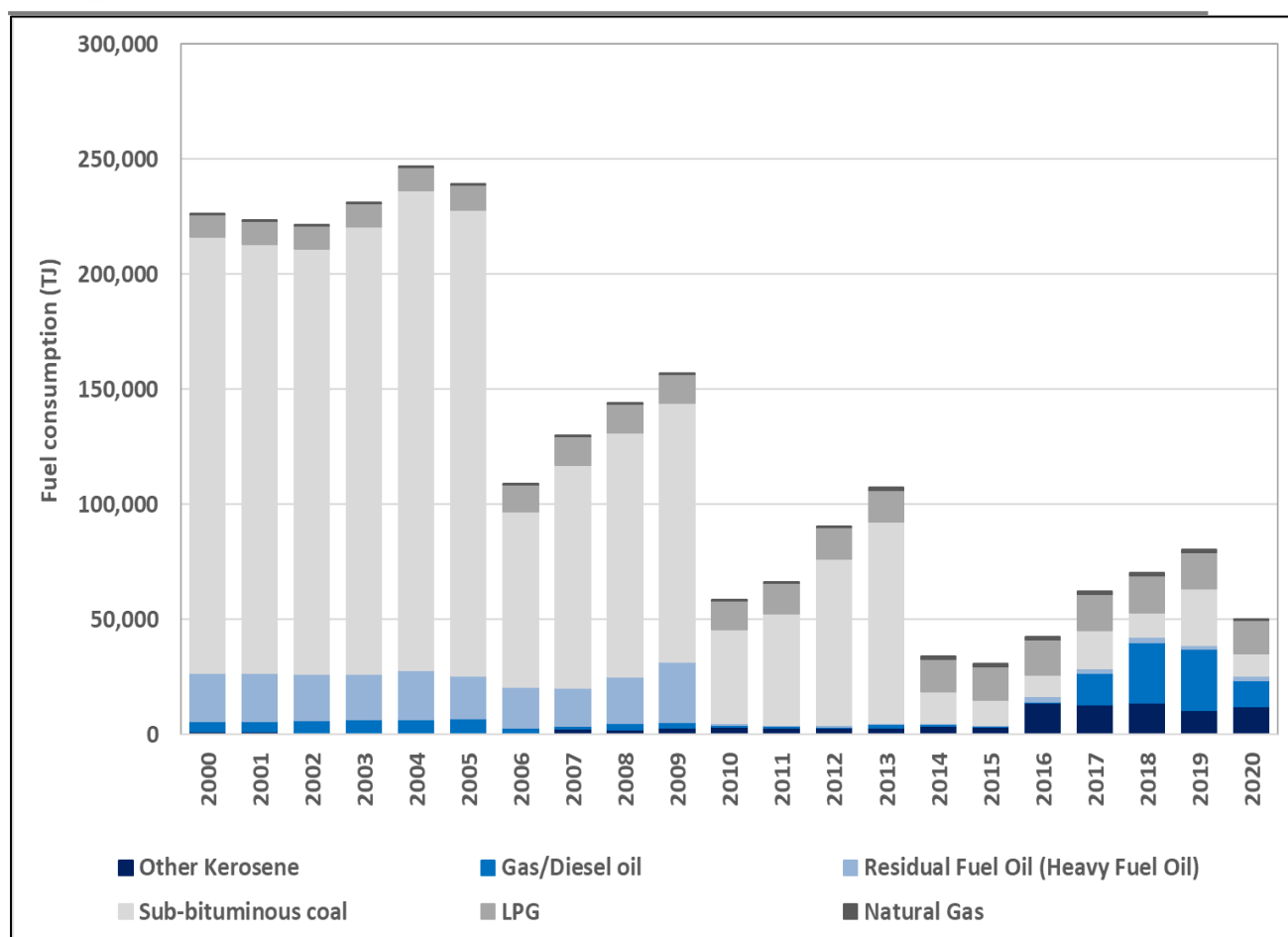


Figure 3.12: Fuel consumption in the commercial/institutional category, 2000 – 2020.

Residential (1.A.4.b)

Data on fuel consumption in the residential sector was obtained from the DMRE's energy digest reports (sub-bituminous coal), the DMRE's SAMI report (coal consumption), Fuel Consumption Study (DEFF,2020), SAPIA (LPG) and DoE energy balance for all other fuels. The DMRE energy reports were used to source solid fuels for the period 2000 to 2006, for the period 2007 to 2017 the SAMI report was used to extrapolate the consumption of solid fuels for this category. NCV are given in Table 3. 10.

The wood/wood product consumption, which is a Memo item, was assumed to be the same as the fuel wood consumption calculated as described in the *AFOLU* sector. Charcoal consumption data from 2010 was updated as in the previous inventory this data was not available and assumed values were applied.

Fuels consumed in this category are other kerosene, residual fuel oil, LPG, sub-bituminous coal, wood/wood waste, other primary solid biomass and charcoal. In 2000



biomass fuel sources dominated, however, from 2006 onwards there was no data reported for other primary solid biomass (Figure 3.13) therefore the biomass fuel source declined. Domestic coal consumption increases between 2000 and 2009, decreasing in 2010 and increasing again to 2013. After this the coal consumption was minimal.

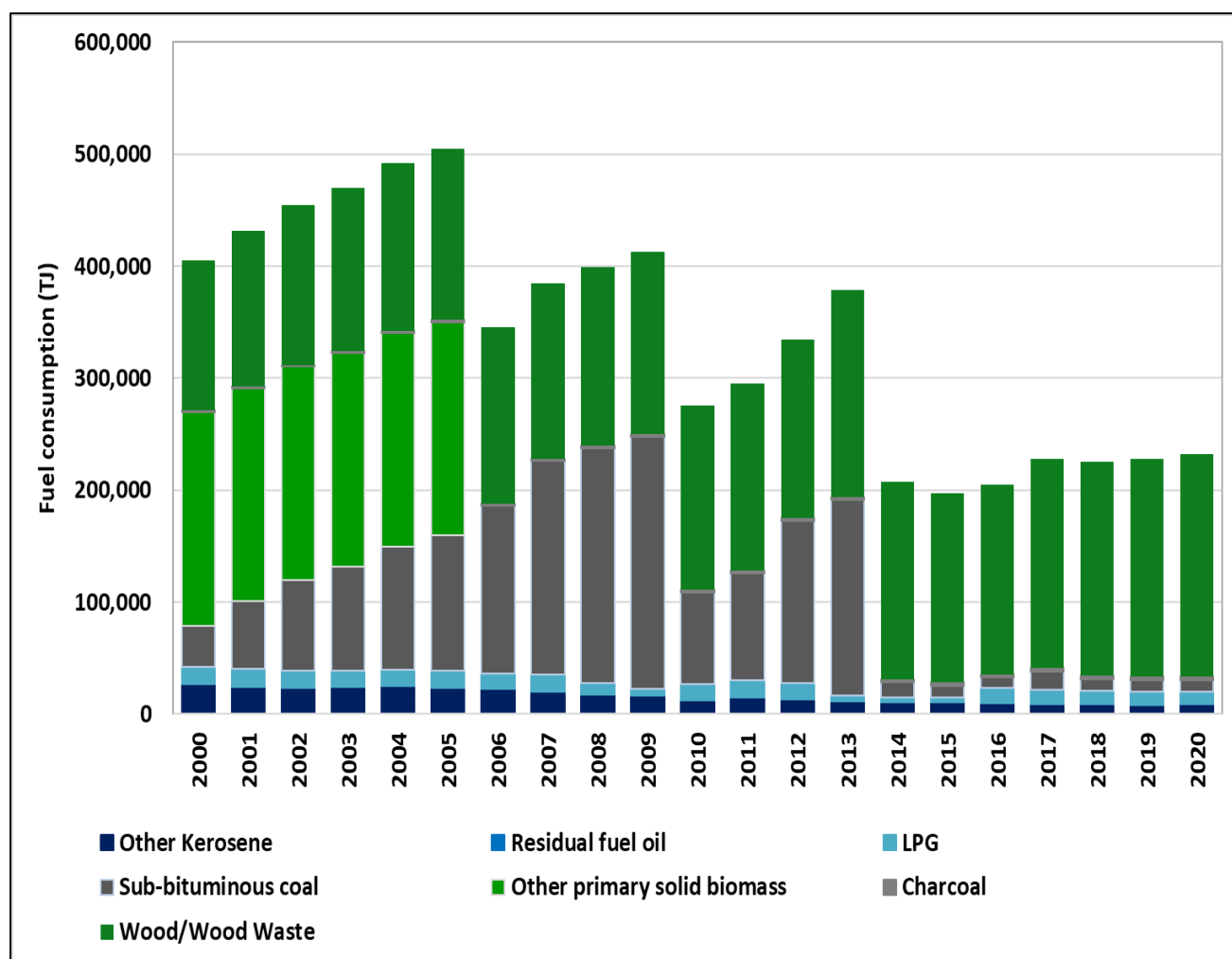


Figure 3.13: Trend in fuel consumption in the residential category, 2000 – 2020.

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

Data on fuel consumption in the agriculture, forestry, fishing and fish farms category was obtained from SAPIA (other kerosene), Energy digest (gas/diesel oil) and the energy balance for all other fuels. The consumption of fuels in this category has been increasing and decreasing throughout the period 2000 to 2020. NCV are provided in Table 3. 10.



Fuels included in this category are motor gasoline, other kerosene, gas/diesel oil, residual fuel oil, LPG and sub-bituminous coal. Liquid fuels dominate in this category (Figure 3.14).

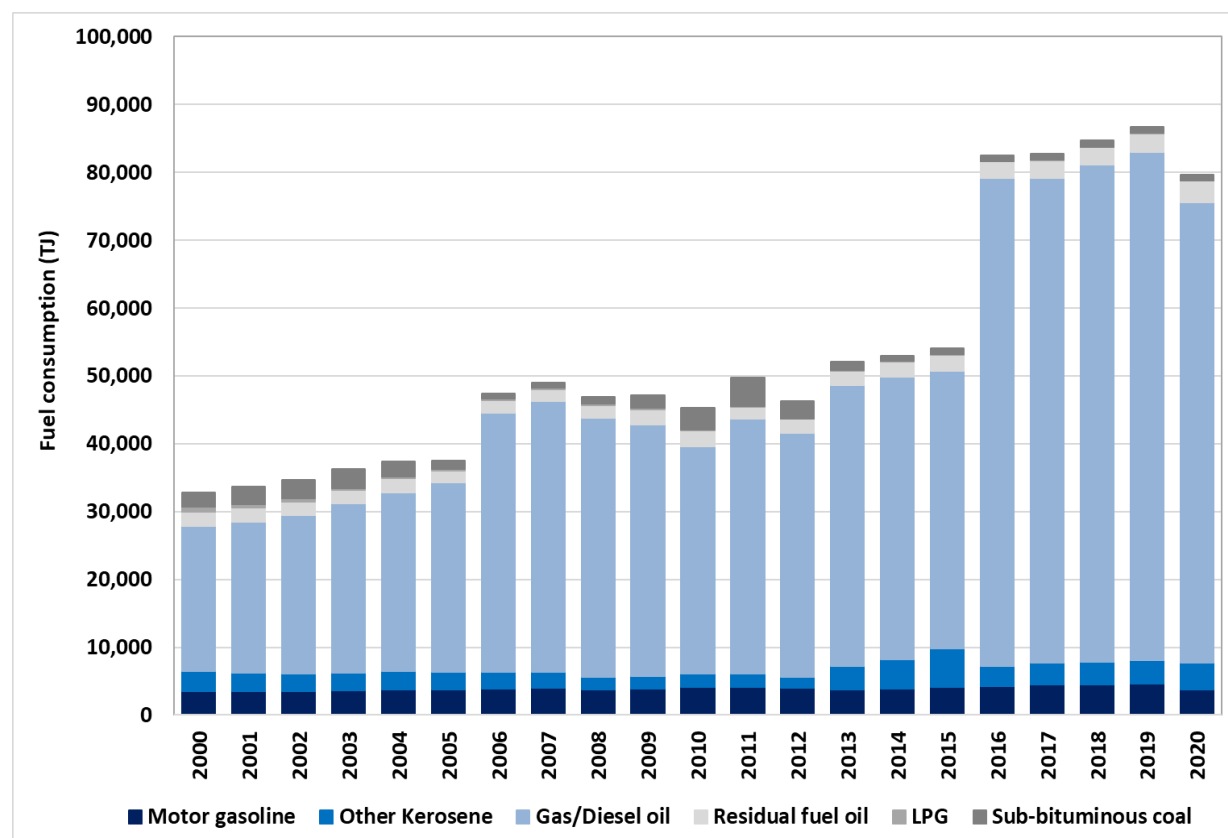


Figure 3.14: Trend in fuel consumption in the agriculture/forestry/fishing category, 2000 – 2020.

Emission factors

A country specific emission factor for CO₂ for sub-bituminous coal was applied (Table 3.11). For all other fuels the IPCC 2006 Guideline default emission factors were used.

3.2.9.3 Uncertainties and time series consistency

Activity data uncertainty



The data for this category for non-gaseous fuels comes from the Energy Balance of the Department of Mineral Resources and Energy (DMRE). For the gaseous fuels the data was sourced from the Fuel Consumption Study (DFFE, 2019). The data is not published with uncertainty information and as a result the default uncertainty from the IPCC 2006 Guidelines were used.

Emission factor uncertainty

The uncertainties in CO₂ emissions are relatively low in fossil fuel combustion. These emission factors are determined by the carbon content of the fuel. Emission factors for CH₄ and more specifically N₂O are highly uncertain. The uncertainty on the CH₄ emission factor is 50 to 150%, while for N₂O it is an order of magnitude higher. This high uncertainty is due to the lack of relevant and accurate measurements and/or insufficient understanding of the emission generating process. The default uncertainty for emission factors from the IPCC 2006 Guidelines were used.

Table 3.17: 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 fuels	10	IPCC 2006	7	IPCC 2006
	1A4 Other sectors – solid fuels	10	IPCC 2006	7	IPCC 2006
	1A4 Other sectors – gaseous fuels	10	IPCC 2006	7	IPCC 2006
	1A4 Other sectors – biomass	40	IPCC 2006	7	IPCC 2006
CH ₄	1A4 Other sectors – liquid fuels	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – solid fuels	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – gaseous fuels	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – biomass	40	IPCC 2006	75	IPCC 2006
N ₂ O	1A4 Other sectors – liquid fuels	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – solid fuels	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – gaseous fuels	10	IPCC 2006	75	IPCC 2006
	1A4 Other sectors – biomass	40	IPCC 2006	75	IPCC 2006

Time-series consistency

There is no time-series inconsistency in the data.

3.2.9.4 Category specific QA/QC and verification



Consumption data determined from SAMI and SAPIA reports were compared to the energy balance data. The data from specific industries was perceived to be more accurate than the data from the energy balance.

3.2.9.5 Category-specific recalculations

Recalculations were performed for all years due to updated charcoal consumption data, however this change was very small and so did not have an overall impact on the sub-category emissions.

3.2.9.6 Category-specific planned improvements

There are several opportunities for improvement in this category including the collection of additional activity data, identification and disaggregation of contributing sources in each section, and the development of source specific methodologies.

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

The Tier 1 approach is used for the simplest calculation methods or methods that require the least data; therefore, this approach provides the least accurate estimates of emissions. The Tier 2 and Tier 3 approaches require more detailed data and resources to produce accurate estimates of emissions. The recently implemented GHG regulation should assist in obtaining improved data from industries, and future inventories should draw on information gathered from industries.

Residential (1.A.4.b)

Investigations and studies of the residential sector in South Africa are necessary for the accurate estimation of emissions. Due to the great number of households, uniform reporting would be possible if data were collected by local government.

Agriculture/ forestry/ fishing/ fish farms (1.A.4.c)

As with the commercial/institutional sector, the GHG regulation should lead to more detailed data for this sector which should be explored in future inventories.

3.2.10 Non-specified sectors (1.A.5)



3.2.10.1 *Category description*

This section includes emissions from fuel combustion in stationary sources that are not specified elsewhere. Three fuels were reported under this category – namely motor gasoline, diesel and coal. In comparison to previous inventory reports, where most of the coal was allocated in the commercial sector, in this inventory, the coal that is not accounted for in other sectors was allocated here as per the Energy Balance from the Department of Mineral Resources and Energy (DMRE).

3.2.10.2 *Methodological issues*

The Tier 1 approach was utilized for the estimation of emissions in the *non-specified* subsector.

Activity data

Data on motor gasoline fuel consumption in the non-specified category were sourced from the SAPIA reports for the years 2007 to 2017, and from the DMRE's energy balance data for the rest of the years. Table 3. 10 provides the NCVs. The coal consumption was taken from SAMI Reports (Department of Mineral Resources, 2017) while the diesel consumption was taken from the Department of Mineral Resources and Energy's energy balances.

Emission factors

IPCC 2006 default emission factor are shown in Table 3.11.

3.2.10.3 *Uncertainties and time series consistency*

Activity data uncertainty

The data for 1A5 comes solely from the Energy Balance of the Department of Mineral Resources and Energy (DMRE). The data is not published with uncertainty information and as a result the default uncertainty from the IPCC 2006 Guidelines were used.

Emission factor uncertainty

The uncertainties in CO₂ emissions are relatively low in fossil fuel combustion. These emission factors are determined by the carbon content of the fuel. Emission factors for CH₄ and, more specifically, N₂O are highly uncertain.



Time-series consistency

There is limited time-series uncertainty as data was sourced from 1 source.

3.2.10.4 Category specific QA/QC and verification

Data from SAPIA was compared to the energy balance data. In cases where the energy balance differed with the industry specific data (SAPIA), SAPIA data was used over the data reported in the energy balance.

3.2.10.5 Category-specific recalculations

Due to new allocation of coal use from *Commercial* to *Non-specified* category, a recalculation occurred for this category. Emission estimates are on average 350% (or 14 365 Gg CO₂e) higher than estimated in the previous inventory.

3.2.10.6 Category-specific planned improvements

Sourcing of activity data for pipeline transport, and fuel consumption associated with ground activities at airports and harbours is planned for the next inventory compilation cycle.

3.3 Fugitive emissions from fuels (1.B)

Fugitive emissions refer to the intentional and unintentional release of GHGs that occur during the extraction, processing and delivery of fossil fuels to the point of final use. CH₄ is the main gas released during this process.

In coal mining activities, the fugitive emissions considered were from the following sources:

- Coal mining, including both surface and underground mining;
- Coal processing;
- The storage of coal and wastes; and
- The processing of solid fuels (mostly coal)

3.3.1 Solid fuels (1.B.1)



3.3.1.1 Category description

This subsector includes emissions for *coal mining and handling* only. The geological processes of coal formation produce CH₄ and CO₂. CH₄ is the major GHG emitted from coal mining and handling. In underground mines, ventilation causes significant amounts of methane to be pumped into the atmosphere. Such ventilation is the main source of CH₄ emissions in hard coal mining activities. However, methane releases from surface coal mining operations are low. In addition, methane can continue to be emitted from abandoned coal mines after mining has ceased.

According to the 2006 IPCC Guidelines, the major sources for the emission of GHGs for both surface and underground coal mines are:

- *Mining emissions:* The release of gas during the breakage of coal and the surrounding strata during mining operations
- *Post-mining emissions:* Emissions released during the handling, processing and transportation of coal. Coal continues to emit gas even after it has been mined, but at a much slower rate than during the coal breakage stage.
- *Low-temperature oxidation:* Emissions are released when coal is exposed to oxygen in air; the coal oxidizes to slowly produce CO₂.
- *Uncontrolled combustion:* Uncontrolled combustion occurs when heat produced by low-temperature oxidation is trapped. This type of combustion is characterized by rapid reactions, sometimes visible flames and rapid CO₂ formation. It may be anthropogenic or occur naturally.

3.3.1.2 Methodological issues

The Tier 2 approach was used for the calculation of fugitive emissions from *coal mining and handling*. Fugitive emission estimates were based on coal production data. Coal waste dumps were also considered as another emission source. The methodology required coal production statistics by mining-type (above-ground and below-ground) and this split (average of 62.20% surface mining and 37.8% underground mining) was based on the SAMI reports from 2009 to 2017 (Department of Mineral Resources, 2017) for 2013. The split changed slightly from year to year from 2009 to 2017. The average split was used for the years 2000 – 2008 as there was no actual split data in those years.

Activity data

Data on coal production was obtained from the South Africa's Mineral Industry (SAMI), a report compiled by the Department of Mineral Resources and Energy (DMR, 2017) and Coaltech (Table 3.18).



Table 3.18: Amount of coal produced from opencast and underground mining, 2000 – 2020.

	Opencast	Underground
	Coal produced (tonne)	
2000	106 308 704	174 918 853
2001	108 990 110	179 330 802
2002	115 444 975	189 951 547
2003	116 549 508	191 768 929
2004	117 605 558	193 506 539
2005	117 509 553	193 348 574
2006	118 901 619	195 639 060
2007	121 301 252	199 587 383
2008	119 464 910	196 565 890
2009	141 515 800	175 784 200
2010	131 286 250	186 213 750
2011	120 472 200	195 727 800
2012	118 800 000	211 200 000
2013	120 864 900	210 635 100
2014	124 900 360	213 399 640
2015	116 283 600	207 716 400
2016	113 583 645	205 516 355
2017	116 066 400	212 733 600
2018	125 037 631	205 735 169
2019	124 172 907	211 010 145
2020	123 314 162	216 420 371

Emission factors

Country specific emission factors were sourced from the study undertaken by the local coal research institute (DME, 2002). This study showed that emission factors for the South African coal mining industry are significantly lower than the IPCC default emission factors (Table 3. 19).

The 2006 IPCC Guidelines do not provide CO₂ emission factors related to the low-temperature oxidation of coal, however, South Africa has developed country-specific CO₂ emission factors for this and, therefore, has estimated emissions related to this activity.



Table 3. 19: 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

3.3.1.3 Uncertainties and time series consistency

Activity data uncertainty

The major source of uncertainty in this category is activity data on coal production statistics. According to the 2006 IPCC Guidelines, country-specific tonnages are likely to have an uncertainty in the ± 1 to $\pm 2\%$ range, but if raw coal data are not available, then the uncertainty will increase to about $\pm 5\%$, when converting from saleable coal production data. The data are also influenced by moisture content, which is usually present at levels between 5 and 10%, and may not be determined with great accuracy. Uncertainties for fugitive emissions are provided in Table 3.20.

Emission factor uncertainty

The default IPCC uncertainty for coal mining is used and the values are presented in Table 3.20.

Table 3.20: Uncertainty for South Africa's fugitive emissions estimates.

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
CH ₄	1B1ai1 Mining	10	IPCC 2006	63	IPCC 2006
	1B1ai2 Post-mining seam gas emissions	10	IPCC 2006	50	IPCC 2006

Time-series consistency



The data comes from South African Mineral's Industry reports and since it is from 1 source, the data has time series consistency.

3.3.1.4 Category specific QA/QC and verification

An inventory compilation manual documenting sources of data, data preparation and sources of emission factors was used to compile emission estimates for this source category. Emission estimates were also verified with emission estimates produced by the coal mining industry. An independent reviewer was appointed to assess the quality of the inventory, determine the conformity of the procedures followed for the compilation of this inventory and identify areas of improvements.

3.3.1.5 Category-specific recalculations

No recalculations have been undertaken for this category.

3.3.1.6 Category-specific planned improvements

More attention needs to be placed on the collection of fugitive emissions from abandoned mines and the spontaneous combustion of underground coal seams. Fugitive emissions from coke production are currently accounted for under category 2C as part of process emissions, however it is planned that by the 2021 inventory these will be separated from process emissions and reported separately.

3.3.2 Oil and natural gas (1.B.2)

3.3.2.1 Category description

The sources of *fugitive emissions from oil and natural gas* included, but were not limited to, equipment leaks, evaporation and flashing losses, venting, flaring, incineration and accidental losses (e.g. tank, seal, well blow-outs and spills) as well as transformation of natural gas into petroleum products.

3.3.2.2 Methodological issues

Fugitive emissions are a direct source of GHGs due to the release of CH₄ and formation of CO₂ (CO₂ produced in oil and gas when it leaves the reservoir). Use of facility-level production data and facility-level gas composition and vent flow rates has facilitated the



use of Tier 3 methodology. Hence, CO₂ emissions from venting and flaring have been estimated using real continuous monitoring results and therefore no emission factors were used.

Activity data

Emissions data is supplied by refineries only, and not the activity data. Data on oil and natural gas emissions for 2000 to 2012 were obtained directly from refineries and, to a lesser extent, from the energy digest reports (DoE, 2009a). Data was not available for the years 2013 to 2017 therefore the 2012 estimates were carried through to 2017. This data will be updated in the next submission.

Emission factors

Emission data is supplied by the refineries so no emission factor data is supplied.

3.3.2.3 Uncertainties and time series consistency

According to the 2006 IPCC Guidelines, gas compositions are usually accurate to within $\pm 5\%$ on individual components. Flow rates typically have errors of $\pm 3\%$ or less for sales volumes and $\pm 15\%$ or more for other volumes. Given that the activity data used is sourced at facility level, the uncertainty is expected to be less than 3%. Uncertainties are provided in Table 3.20. The default IPCC uncertainty ranges are used for this category.

Time-series consistency

The data has time-series consistency.

3.3.2.4 Category specific QA/QC and verification

No category specific checks were undertaken.

3.3.2.5 Category-specific recalculations

No recalculations were conducted for this category.

3.3.2.6 Category-specific planned improvements

To improve the completeness of the accounting of emissions from this subsector, future activity data collection activities need to focus on upstream natural gas production and downstream transportation and distribution of gaseous products.



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

3.3.3.1 Category description

According to the 2006 IPCC Guidelines (p.4.35), *other emissions from energy production* refers to emissions from geothermal energy production and other energy production not included in the 1.B.1 and/or 1.B.2 categories. In the South African context, this refers to the coal-to-liquid (CTL) and gas-to-liquid (GTL) processes. These GHG emissions are most specifically fugitive emissions related to the two mentioned processes (CTL and GTL) with the emphasis on CO₂ removal.

3.3.3.2 Methodological issues

The use of facility-level production data and facility-level gas composition and vent flow rates enabled the use of Tier 3 methodology. Hence, CO₂ emissions from other emissions from energy production have been estimated using real continuous monitoring results and material balances.

Activity data

Data on *other emissions from energy production* were obtained from both Sasol and PetroSA. Emissions estimates were supplied but not the activity data.

Emission factors

Only emission estimates were supplied by industry so no emission factors are available.

3.3.3.3 Uncertainties and time series consistency

Activity data

No source-specific uncertainty analysis has been performed for this source category. Currently, uncertainty data does not form part of the data collection and measurement programme. This is an area that will require improvement in future inventories. Facilities are to be encouraged to collect uncertainty data as part of data collection and measurement programmes.

Emission factors



Tier 3 emission factors are used in this category as the data solely comes from the SAGERS reporting programme.

Time-series consistency

Time-series activity data was validated using information on mitigation projects that have been implemented in the past 15 years and other factors such as economic growth and fuel supply and demand. The data is internally consistent because for the entire time series (2000 – 2020), the same data source is used specifically for all sectors that are not reporting to the SAGERS data collection system.

3.3.3.4 Category specific QA/QC and verification

The department reviews the material balance and measurement data supplied by facilities. An independent reviewer was appointed to assess the quality of the inventory, determine the conformity of the procedures which were followed for the compilation of this inventory and identify areas of improvement.

3.3.3.5 Category-specific recalculations

No recalculations were done for this sub-sector.

3.3.3.6 Category-specific planned improvements

No improvements are planned for this section.

3.4 References

- CSIR, 2021. Calitz, J.R. & Wright, J.G. 2021. Statistics of utility-scale power generation in South Africa in 2020
- DEFF, 2020. Phase II Survey on economy-wide fuel consumption with emphasis on demand-side sectors for the period 2013 – 2018 and Estimation of Vehicle Kilometres Travelled (VKT) for the period 2000 – 2018 and projections to 2035
- DFFE, 2004. National Climate Change Response, White Paper. Department of Environmental Affairs, Pretoria.
- DFFE, 2015. National Fuel Consumption Survey for all Demand Side Sectors. Available by request. Chief Directorate: Climate Change Monitoring & Evaluation.



-
- DoE, 2005. Digest of South African Energy Statistics, Department of Energy, Pretoria.
- DoE, 2009a. Digest of South African Energy Statistics, Department of Energy, Pretoria.
- DoE, 2018. South African State of Energy Report 2018. Department of Energy, <http://www.energy.gov.za> [Accessed December 2018]
- DME, 2000. Hydrocarbons and Energy Planning Branch – Liquid Fuel, Department of Minerals and Energy, Pretoria.
- DME, 2001. National Electrification Programme NEP. Summary evaluation Report, Department of Minerals and Energy, Pretoria.
- DME, 2002. South African National Energy Database: Energy Prices, Department of Minerals and Energy, Pretoria.
- DME, 2008. National Efficiency Strategy of the Republic of South Africa, Report 32342, Department of Minerals and Energy, Pretoria.
- DME, 2010a. Department of Minerals and Energy annual reports 2009/2010, Department of Minerals and Energy, Pretoria.
- DME, 2010b. Department of Minerals and Energy annual reports 2009/2010, Department of Minerals and Energy, Pretoria.
- DME, 2002. Eskom, Energy Research Institute and University of Cape Town 2002: Energy Outlook for South Africa 2002. <http://www.info.gov.za/view/DownloadFileAction> [Accessed August 2012].
- DMR, 2001a. Department of Minerals and Resources Annual Report 2001/2002. Pretoria
- DMR, 2015. South Africa's mineral industry (SAMI) 2015. Pretoria
- DoT, 2009. Transport Statistics 2008. Annual Transport Statistics Bulletin, Pretoria. <http://www.dot.gov.za>, [Accessed 11 July 2012].
- Eskom, 2005. Eskom Annual Report, 2005. <http://www.eskom.co.za/c/article/289/publications/> [Accessed February 2012]
- Eskom, 2011. Eskom Annual Report, 2011. <http://www.eskom.co.za/c/article/289/publications/> [Accessed February 2012]
- Eskom, 2021. Eskom Integrated Report, 2021. <http://www.eskom.co.za/c/article/289/publications/> [Accessed September 2021]
- IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, Eggleston H S, Buenida L, Miwa K, Ngara T, and Tanabe K, eds; Institute for Global Environmental Strategies (IGES). Hayama, Kanagawa, Japan.



-
- SAPIA, 2011. South African Petroleum Industry Association (SAPIA) Annual Report 2011. <http://www.sapia.co.za>. [Accessed September 2012].
- SAPIA, 2016. South African Petroleum Industry Association (SAPIA) Annual Report 2016. <http://www.sapia.co.za>. [Accessed October 2016].
- SAPIA, 2017. South African Petroleum Industry Association (SAPIA) Annual Report 2017. <http://www.sapia.co.za>. [Accessed September 2017].
- SAPIA, 2019. South African Petroleum Industry Association (SAPIA) Annual Report 2019. <http://www.sapia.co.za>. [Accessed November 2021].
- TOP QUARTILE, 2019. Phase II Survey on economy-wide fuel consumption with emphasis on demand-side sectors for the period 2013 – 2018 and Estimation of Vehicle Kilometres Travelled (VKT) for the period 2000 - 2018 and projections to 2035. Johannesburg: TOP QUARTILE.



Chapter 4: Industrial Processes and Product Use (IPPU)

4.1 Sector overview

The IPPU sector includes non-energy related emissions from industrial processing plants. The main emission sources are releases from industrial processes that chemically or physically transform raw materials (e.g. ammonia products manufactured from fossil fuels). GHG emissions released during these processes are CO₂, CH₄, N₂O, HFCs and PFCs. Also included in the IPPU sector are emissions used in products such as refrigerators, foams and aerosol cans. CO₂, CH₄ and N₂O emissions from the following industrial processes are included in South Africa's IPPU sector:

- Production of cement
- Production of lime
- Glass production
- Other Process Uses of Carbonates
- Production of ammonia
- Nitric acid production
- Carbide production
- Production of titanium dioxide
- Soda Ash Production
- Petrochemical and carbon black production
- Hydrogen Production
- Production of steel from iron and scrap steel
- Ferroalloys production
- Aluminium production
- Production of lead
- Production of zinc
- Lubricant use
- Paraffin wax use

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are used in many products and in refrigeration and air conditioning equipment. PFCs are also emitted as a result of anode effects in aluminium smelting. Therefore, the IPPU sector includes estimates of PFCs from aluminium production, and HFCs from refrigeration and air conditioning.



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 largest source of emissions in the IPPU sector in South Africa is the production of iron and steel.

The performance of the economy is the key driver for trends in the IPPU sector. The South African economy is directly 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. In the third and fourth quarters of 2008, the economy experienced enormous recession, and this continued into the first and second quarters of 2009. As a result of the recession, GHG emissions during that period decreased enormously across almost all categories in the IPPU sector. Since the recession GDP annual growth has slowed compared to growth before the recession.

4.1.1 Shares and trends in emissions

The IPPU sector produces CO₂ emissions (65.4%), fluorinated gases (19.0%) and smaller amounts of CH₄ and N₂O (Table 4.1). Carbon dioxide and any other emissions from combustion of fuels in these industries are reported under the *energy* sector.

In 2020 the IPPU sector produced 26 595 Gg CO₂e, which is 5.6% of South Africa's emission (excluding FOLU). The largest source category is the *metal industry* category, which contributes 41.8% to the total IPPU sector emissions. *Iron and steel production* and *Ferroalloys production* are the biggest CO₂ contributors to the metal industry subsector, producing 3 856 Gg CO₂e (34.7%) and 5 954 Gg CO₂e (53.6%) respectively to the total metal industry CO₂ emissions. The *mineral industry* and the *chemical industry* subsectors contribute 16.2% and 18.7%, respectively, to the IPPU sector emissions (Table 4.1)., *carbon black production, iron and steel production, ferroalloy production and ammonia production* produce 3 320 Gg CO₂e of CH₄, while chemical industries are estimated to produce 836 Gg CO₂e of N₂O.

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



Table 4.1: Summary of the estimated emissions from the IPPU sector in 2020 for South Africa.

GHG source categories	CO ₂	CH ₄	N ₂ O	HFCs	PFCs	Total
	Gg CO ₂ e					
2. IPPU	17 385.6	3 320.2	835.5	4 933.1	120.4	26 594.8
2.A Mineral industry	4 321.1	NE	NE	NE	NE	4 321.1
2.B Chemical industry	1 328.0	2 820.2	835.5	NE	NE	4 984.3
2.C Metal industry	10 488.3	499.4			120.4	11 108.2
2.D Non-energy products from fuels and solvents	1 248.1					1 248.1
2.E Electronic industry	NE			NE	NE	
2.F Product uses as substitute ODS				4 993.1	NE	4 993.1
2.G Other product manufacture and use	NE	NE	NE	NE	NE	
2.H Other	NE	NE	NE	NE	NE	

Numbers may not sum exactly due to rounding off.

Estimated emissions from the *IPPU* sector are 6 360 Gg CO₂e (-19.3%) lower than the emissions in 2000 (Table 4.2). This was mainly due to the decline in production in the iron and steel as well as carbide production categories in 2020.

The overall decrease in the IPPU sector emissions is due mostly to the 56.6% (14 507 Gg CO₂e) decrease in the *metal industry* emissions (Table 4.2). In the chemical industry there was a 79.7% increase in emissions mostly due to an increase of 2 771 Gg CO₂e in the *Carbide production* emissions. Emissions also increased in the *Non-energy products from fuels and solvents* due to an increase in emissions from paraffin wax production.

Figure 4.1 shows that IPPU emissions increased by 17.9% between 2000 and 2006, after which there was a 0.2% decline to 2009. This decrease was mainly due to the global economic recession and the electricity crisis that occurred in South Africa during that period. In 2010 emissions decreased by .7% due to a decrease in the non-energy products from fuels and solvent use category. Emissions decreased by -9.0% between 2010 and 2017. Emissions within the sector decreased further from 2017 to 2020 by -17.6 % due to lower production demands in the mineral, chemical and metal industry.

IPPU emissions showed a decrease of 17.6% (5 671.5 Gg CO₂e) between 2017 and 2020. The main contributor to this decrease was the *iron and steel and ferroalloy* production categories which decreased by 50.1% (3 871.2 Gg CO₂e) and -47.5% (5 376 Gg CO₂e), respectively, over this period. The *mineral industry* emissions decreased by 30.9%



(1 936.2 Gg CO₂e) between 2017 and 2020, and the *metal industry* showed an overall decrease of 45.5% (9 267.7Gg CO₂e).

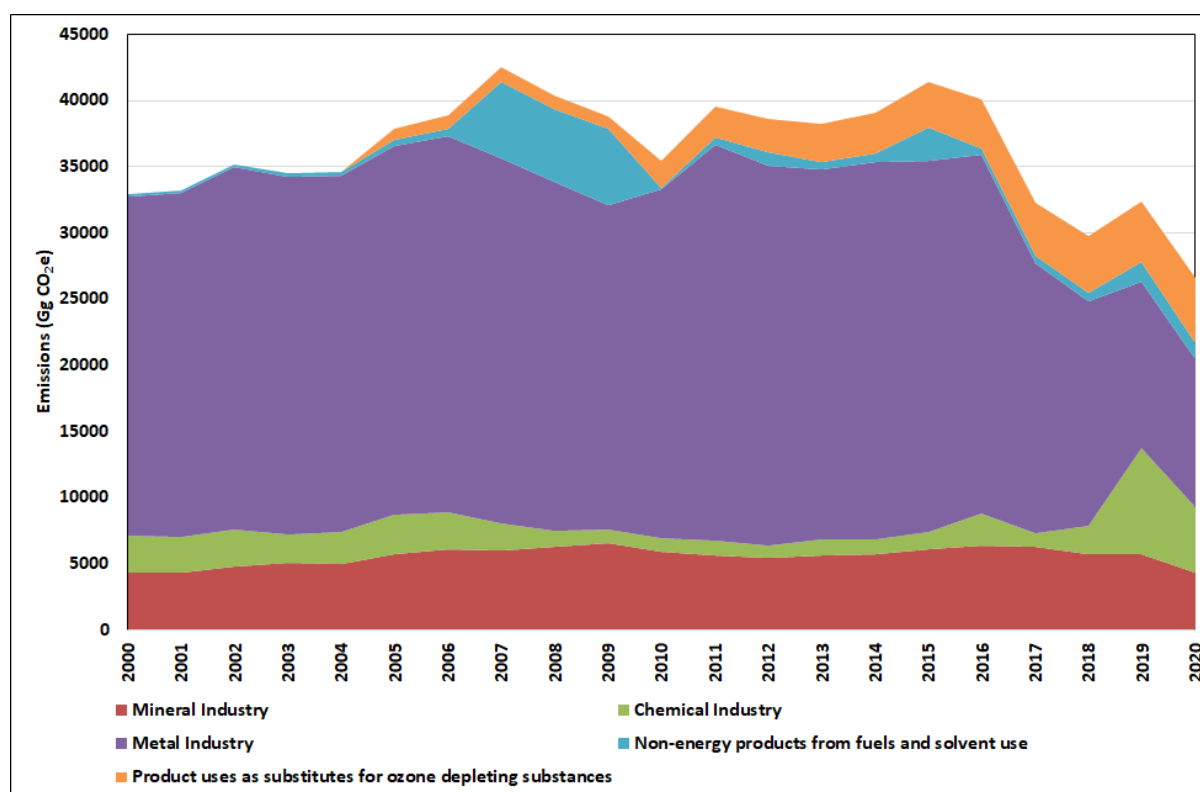


Figure 4.1: Trend in South Africa's IPPU sector emissions, 2000 – 2020.



Table 4.2: Summary of the change in emissions from the IPPU sector between 2000 and 2020.

GHG source categories	Emissions (Gg CO ₂ e)			Difference (Gg CO ₂ e)		Change (%)	
	2000	2017	2020	2000-2020	2017-2020	2000-2020	2017-2020
2. IPPU	32 955	32 266.3	26 594.8	6 360	5 671.5	-19.3	-17.6
2A Mineral industry	4 371.0	6 257.3	4 321.1	-50.0	-1 936.2	-1.1	-30.9
2A1 Cement Production	3 870.6	5 246.4	3 357.2	-513.4	-1 889.2	-13.3	-36.0
2A2 Lime Production	426.1	890.0	714.9	288.8	-175.2	67.8	-19.7
2A3 Glass Production	74.4	120.9	154.5	80.1	33.6	107.8	27.8
2A4 Other Process Uses of Carbonates	NE	NE	94.5	-	-	-	-
2B Chemical industry	2 773.6	1 067.7	4 984.3	2 210.7	3 916.6	79.7	366.8
2B1 Ammonia Production	C	C	C	C	C	C	C
2B2 Nitric Acid Production	C	C	C	C	C	C	C
2B5 Carbide Production	C	C	C	C	C	C	C
2B6 Titanium Production	C	C	C	C	C	C	C
2B7 Soda Ash Production	NE	NE	C	C	C	-	-
2B8f Petrochemical and Black Carbon Production	C	C	C	C	C	C	C
2B8g Hydrogen Production	NE	NE	C	C	C	-	-
2C Metal industry	25 614.7	20 375.8	11 108.2	-14 506.5	-9 267.7	-56.6	-45.5
2C1 Iron and Steel Production	15 334.4	7 727.5	3 856.3	-11 478.1	-3 871.2	-74.9	-50.1
2C2 Ferroalloy Production	8 082.4	11 329.5	5 953.5	-2 128.9	-5 376.0	-26.3	-47.5
2C3 Aluminium Production	2 074.4	1 256.2	1 255.2	-819.3	-1.0	-39.5	-0.1
2C5 Lead Production	15.1	9.6	6.6	-8.5	-3.1	-56.4	-31.8
2C6 Zinc Production	108.4	52.9	36.6	-71.8	-16.4	-66.2	-30.9
2D Non-energy products from fuels and solvents	195.9	530.6	1 248.1	1 052.2	717.5	537.1	135.2
2D1 Lubricant Use	188.5	424.5	855.0	666.5	430.5	353.6	101.4
2D2 Paraffin Wax Use	7.4	106.2	393.2	385.7	287.0	5 213.5	270.3
2E Electronic industry	NE	NE	NE	NE	NE	-	-



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

GHG source categories	Emissions (Gg CO ₂ e)			Difference (Gg CO ₂ e)		Change (%)	
	2000	2017	2020	2000-2020	2017-2020	2000-2020	2017-2020
2F Product uses as substitute ODS	NE	4 034.9	4 933.1	4 933.1	898.2	-	22.3
2F1 Refrigeration and Air Conditioning	NE	3 963.5	4 846.9	-4 846.9	-883.4	-	22.3
2F2 Foam Blowing Agents	NE	2.1	2.1	-2.1	0.0	-	0.0
2F3 Fire Protection	NE	51.1	65.9	-65.9	-14.8	-	29.0
2F4 Aerosols	NE	18.2	18.2	-18.2	0.0	-	0.0
2G Other product manufacture and use	NE	NE	NE	NE	NE	-	-
2H Other	NE	NE	NE	NE	NE	-	-



4.1.1.1 Mineral industry

In 2020 the *mineral industries* produced 4 321.1 Gg CO₂, which is 16.2% of the IPPU sector emissions. *Cement production* accounted for 77.7% of these emissions. All the emissions in this category were CO₂ emissions.

The overall emissions were -1.1% (50 Gg CO₂) lower than the 4 371 Gg CO₂ in 2000. There was a 39.4% increase in the *mineral industry* emissions between 2000 and 2009, after which emissions declined by 11.2% to 5 420 Gg CO₂ in 2012 (Figure 4.2). The increase between 2000 and 2009 was due to increased emissions from *cement production* as a result 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. 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). Between 2012 and 2019 emissions increased again by 336.9 Gg CO₂ (6.2%) due mainly to the inclusion of the *other process uses of carbonates* category in the 2019 inventory. Emissions declined between 2019 and 2020 due to a decrease in the cement production category.

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

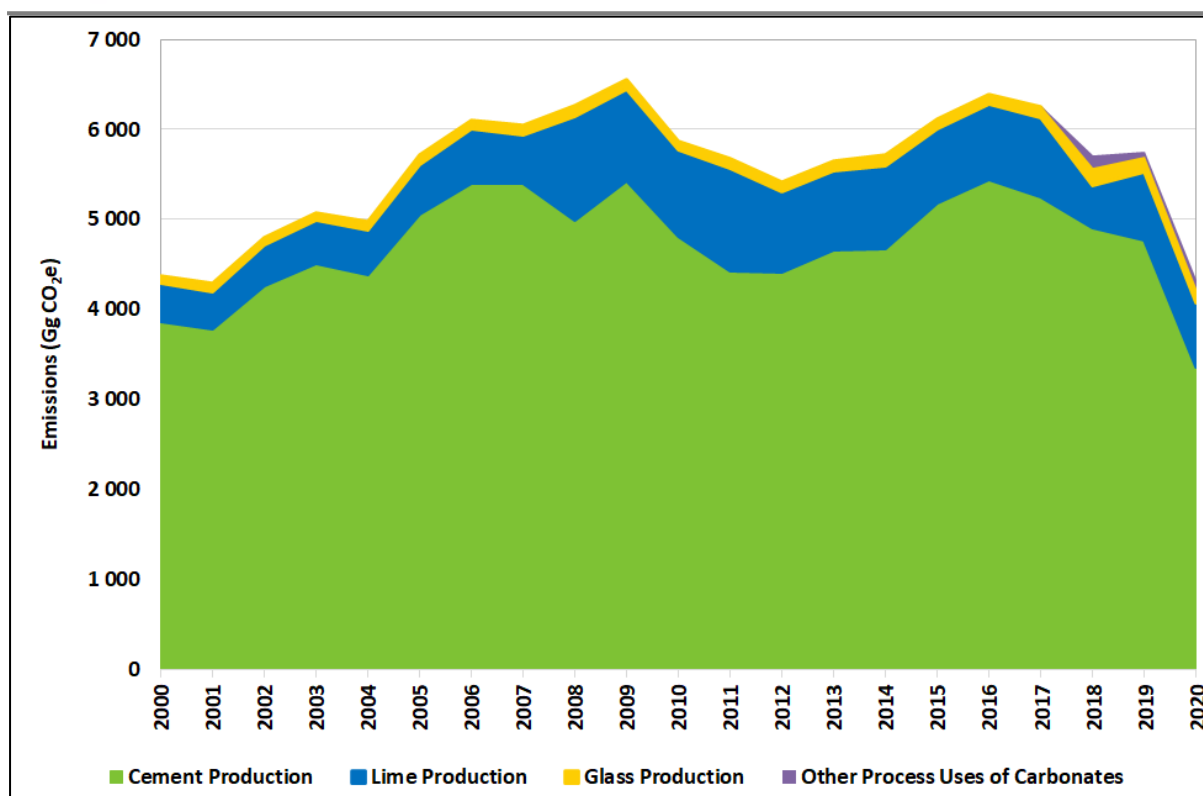


Figure 4.2: Category contribution and trend for the mineral subsector, 2000 – 2020.

Cement production

Cement production was estimated to produce 3 357 Gg CO₂e in 2020, which is 12.6% of the *IPPU* sector emissions. Emissions were 513.4 Gg CO₂e (-13.3%) below the 2000 level (3 871 Gg CO₂e). Emissions in this subsector showed a 36.0% decrease (1 889 Gg CO₂e) since 2017.

Lime production

Lime production was estimated to produce 715 Gg CO₂ in 2020, which is 2.7% of the *IPPU* sector emissions. Emissions were 289Gg CO₂ (67.8%) above the 2000 level (426Gg CO₂). 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 including pyrometallurgical quicklime and hydrated lime only including lime for water purification. 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. Furthermore, lime production



reported for the 2019 inventory did not segregate quicklime from hydrated lime. The 2019 inventory also included the addition of dolomitic lime to the calculation, as previously this type of lime was not reported. Emissions in this subsector decreased by 19.7% (175.2 Gg CO₂e) since 2017. Emissions for 2018 and 2019 were extrapolated for quicklime due to a lack of activity data received.

Glass production

Glass production was estimated to produce 154.5 Gg CO₂ in 2020, which is 0.6% of the IPPU sector emissions. Emissions were 80.1 Gg CO₂e (107.8%) above the 2000 level (74 Gg CO₂). Emissions increased by 33.6 Gg CO₂e (27.8%) since 2017.

Other process uses of carbonates

Emissions from the *OPUC* were not reported in previous inventories due to a lack in activity data and emissions. *OPUC* emissions were estimated to produce 94.5 Gg CO₂ in 2020, which is 0.36% of the IPPU sector emissions. Emissions were only estimated from 2018 for this category.

4.1.1.2 Chemical industry

The *chemical industries* were estimated to produce 4 984 Gg CO₂e in 2020, which is 18.7% of the IPPU sector emissions. The largest contributions are from *carbide production* and *nitric acid production*.

Emissions from the *chemical industries* increased by 2 211 Gg CO₂e (80.0%) since 2000 (2 774 Gg CO₂e). Emissions from this subsector fluctuated considerably over the 20-year period (Figure 4.1). 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*. Thereafter the emissions remained at the lower level. The addition of silicon carbide production resulted in an increase in emissions in 2019.

4.1.1.3 Metal industry

The *metal industry* was estimated to produce 11 108 Gg CO₂e in 2020, which is 41.8% of the IPPU sector emissions. The largest contribution comes from *ferroalloy production* (5 954 Gg CO₂e or 53.6%), followed by *iron and steel production* (3 856 Gg CO₂e or 34.7%).

Emissions from the *metal industry* decreased by 14 507 g CO₂e (-56.6%) below the 2000 emissions of 25 615 Gg CO₂e. Figure 4. 3 shows that emissions from the *metal industries* increased slowly (11.2%) between 2000 and 2006, after which there was a -14.1%



decline to 24 471 Gg CO₂e in 2009. This decrease was evident in the *iron and steel production* emissions (26.1%), *aluminium production* emissions (40.7%) and *zinc production* emissions (17.6%).

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 electricity grid. In 2017 the contribution from PFCs to emissions from aluminium production emissions was 9.0%. In 2020 PFCs contribution rose to 9,6%.

Iron and steel production emissions decreased by 11 478 GgCO₂e (-74.9 %) between 2000 and 2020 due to a decrease in production in the industry.

Ferroalloy industry emissions increased steadily by 64.2% (5 189 GgCO₂e) between 2000 and 2015, with a slight decline of 14.6% (1 942 Gg CO₂e) between 2015 and 2017. A decrease of 5 376Gg CO₂e (-47.5%) occurred between 2017 and 2020.

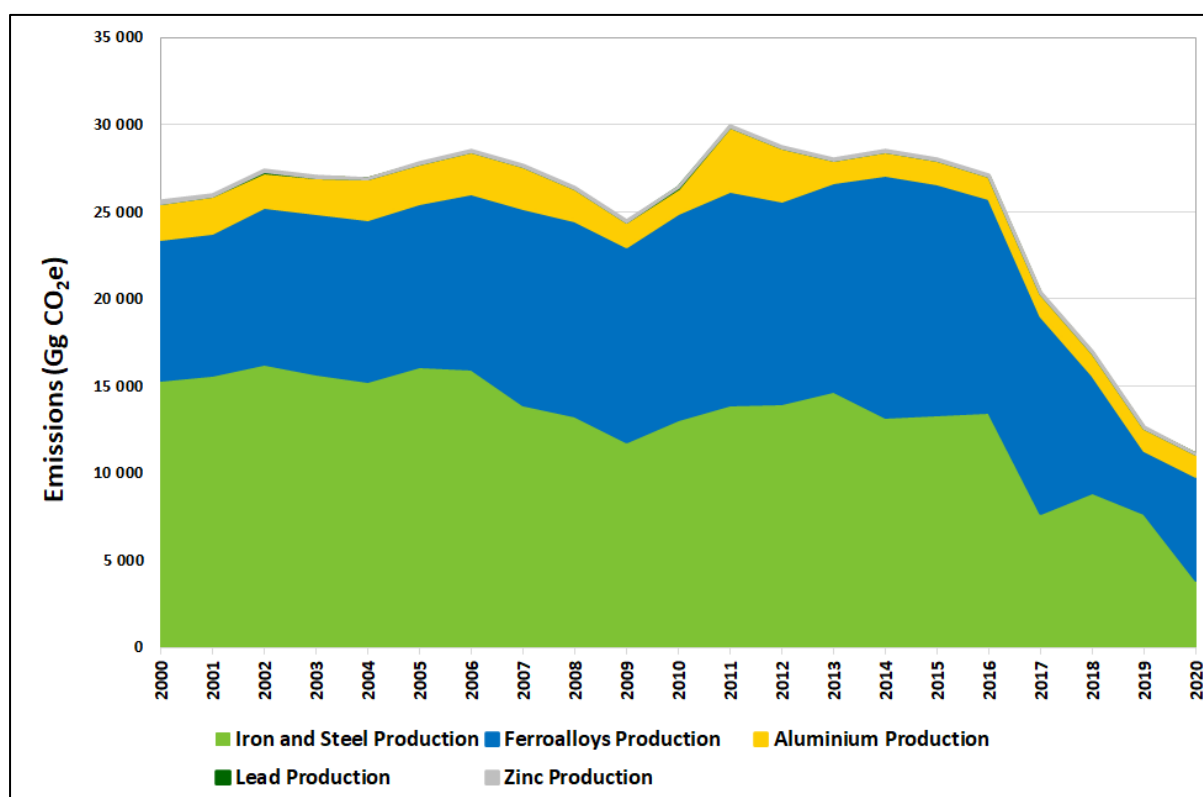


Figure 4. 3: Trend and category contribution to emissions from the metal industries, 2000 – 2020.



Iron and steel production

Iron and steel production was estimated to produce 3 856.3 Gg CO₂e in 2020, which is 14.5% of the IPPU sector emissions. Emissions were 11 478.06 Gg CO₂e (74.9%) below the 2000 level (15 334 Gg CO₂e) (Figure 4. 3). Emissions in this subsector decreased by -50.1% (3 871.2 Gg CO₂e) since 2017.

Ferroalloy production

Ferroalloys production was estimated to produce 5 953.5 Gg CO₂e in 2020, which is 22.4% of the IPPU sector emissions. Emissions were 2 128.9 Gg CO₂e (-26.3%) below the 2000 level (8 082 Gg CO₂e). Emissions in this subcategory declined by -47.5% (5 376 Gg CO₂e) since 2017.

Aluminium production

Aluminium production was estimated to produce 1 255.2 Gg CO₂e in 2020, which is 4.7% of the IPPU sector emissions. Emissions were 819.3 Gg CO₂e (-39.5%) below the 2000 level (2 074 Gg CO₂e). In 2020 CO₂ emissions accounted for 90.4% of the total aluminium production emissions, with the rest being PFCs (CF₄ and C₂F₆). Emissions in this subsector decreased by -0.08% (1.0 Gg CO₂e) since 2017.

Lead production

Lead production was estimated to produce 6.6 Gg CO₂e in 2020, which is 0.02% of the IPPU sector emissions. Emissions were 8.5 Gg CO₂e (-56.4%) below the 2000 level (15.1 Gg CO₂e). During 2003/04 South Africa's lead mine production declined by 6.2%, as did the emissions, due mainly to the depletion of a part of the Broken Hill ore body at Black Mountain mine, which contained a higher-grade ore (DMR, 2005). Emissions from *lead production* decreased by 3.1 Gg CO₂e (-31.8%) since 2017.

Zinc production

Zinc production was estimated to produce 36.6 Gg CO₂e in 2020, which is 0.1% of the IPPU sector emissions. Emissions were 71.8 Gg CO₂e (66.2%) below the 2000 level (108 Gg CO₂e). During 2004/05 zinc production decreased by 6.3% due to the closure of Metorex's Maranda operation in July 2004 (DMR, 2004) and emissions declined by 1.0% over this period. In 2009/2010, emissions from zinc production increased by 4.9%, and this was attributed to new mine developments, such as the Pering Mine and the Anglo American Black Mountain mine and Gamsberg project (DMR, 2009). Emissions from zinc



production have remained very low since 2004. *Zinc production* emissions decreased by 16.4 Gg CO₂e (30.9%) since 2017.

4.1.1.4 Non-energy products from fuels and solvents

The *non-energy products from fuels and solvent use* was estimated to produce 1 248.1Gg CO₂e in 2020, which is 4.7% of the IPPU sector emissions. The largest contribution comes from lubricant use (855 Gg CO₂e or 68.5%).

Emissions from the *non-energy products from fuels and solvent use* category were 1 052.2Gg CO₂e (537%) higher than the 2000 level of 196 Gg CO₂e. Emissions fluctuated between 196 Gg CO₂e and 250 Gg CO₂e between 2000 and 2004, with a peak in emissions (5 773 Gg CO₂e) occurring between 2007 and 2009 (Figure 4. 4). In 2010 there was a decline in emissions to 59.1 Gg CO₂e. Between 2011 and 2017 emissions remained steady with a spike in 2015 due to increased usage of paraffin wax. Emissions increased from 2017 to 2020 by 717.5 Gg CO₂e (135%).

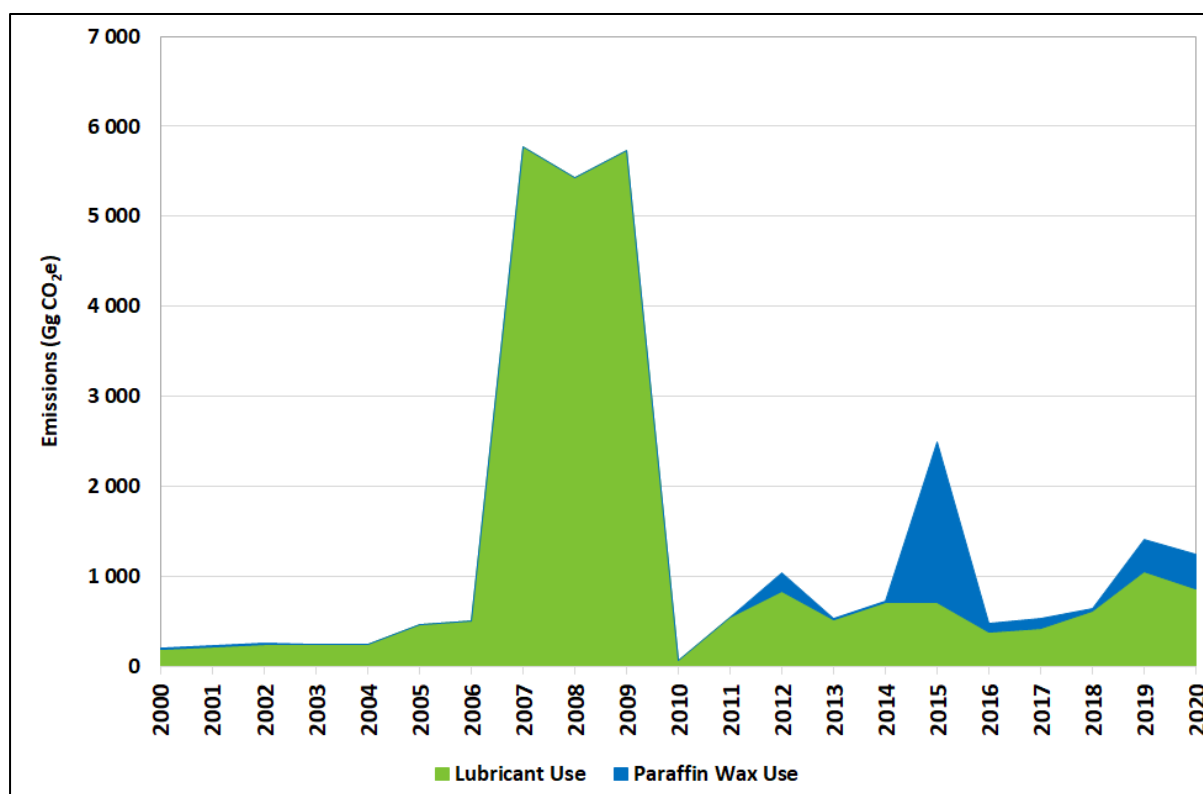


Figure 4. 4: Trend and category contribution in the emissions from non-energy products from fuels and solvents, 2000 – 2020.



Lubricant use

Lubricant use was estimated to produce 855 Gg CO₂e in 2020, which is 3.2% of the IPPU sector emissions. Emissions increased since 2000, with an increase of 666.5 Gg CO₂e (353.6%) above the 2000 level (188 Gg CO₂e). Emissions in this subsector increased by 101% (430.5 Gg CO₂e) since 2017.

Paraffin wax use

Paraffin wax use was estimated to produce 393.2 Gg CO₂e in 2020. Emissions were 385.7 Gg CO₂e (5 213%) above the 2000 level (7 Gg CO₂e). Emissions in this subsector increased by 270% since 2017.

4.1.1.5 Product uses as substitute ODS

Production uses as substitutes for ODSs category was estimated to produce 4 933 Gg CO₂e in 2020, which is 18.5% of the IPPU sector emissions. The largest contribution comes from *refrigeration and air conditioning* (4 847 Gg CO₂e or 98.3%).

Emissions were only estimated from 2005 when emissions were estimated at 842 Gg CO₂e in 2005. In 2010 there was a doubling of emissions (Figure 4.5) due to an increase in the mobile air conditioning emissions. In 2013 emissions from *air conditioning, foam blowing agents, fire protection* and *aerosols* were added, therefore the emissions for this subcategory increased to 2 929 Gg CO₂e in 2013. There was then a 40.7% increase in emissions between 2013 and 2019. The increase was seen throughout the subcategories.

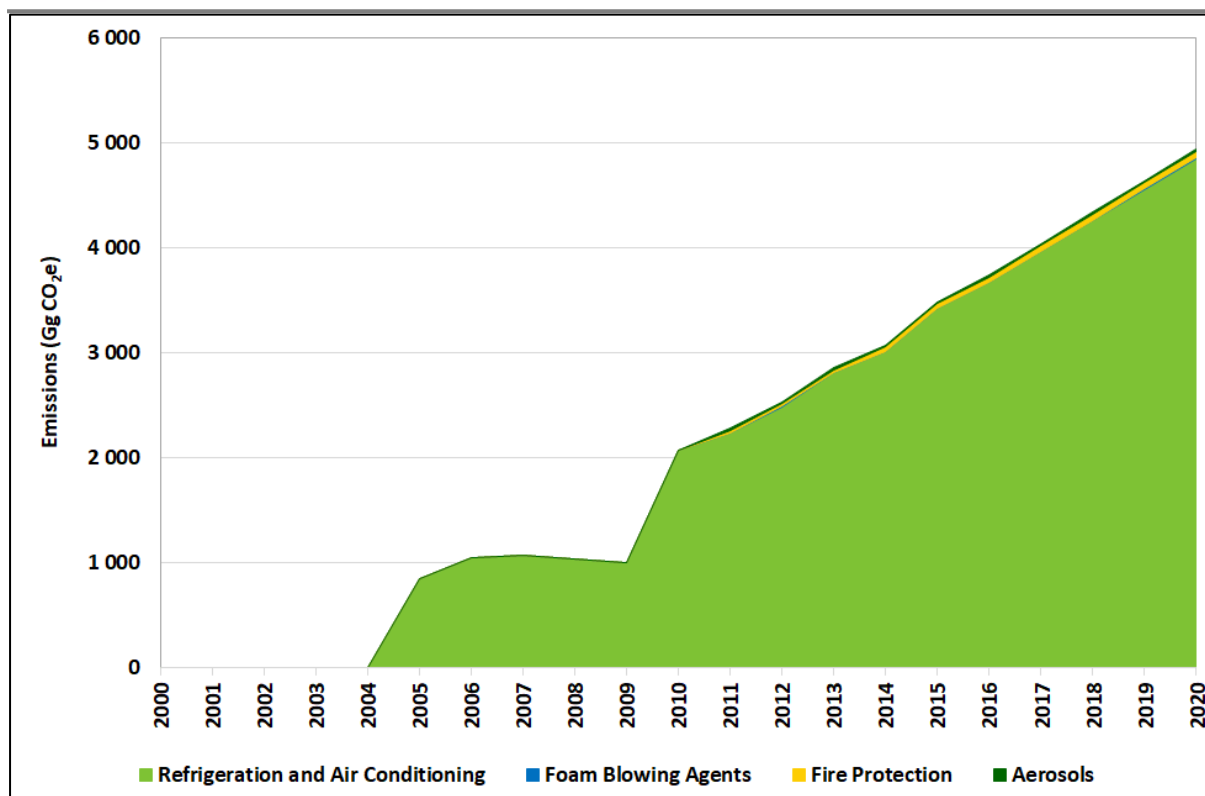


Figure 4.5: Trend and category contribution to the product uses as substitutes for ODS emissions, 2000 – 2020.

Refrigeration and air conditioning

Refrigeration and air conditioning was estimated to produce 4 847 Gg CO₂e of HFCs in 2020, which is 98.3% of the *product uses as substitute ODS emissions*. Since the addition of the *mobile air conditioning* estimates in 2011 the emissions for this subcategory have more than doubled (Figure 4.5). Emissions from *refrigeration and air conditioning* have increased by 883.4 Gg CO₂e (22.3%) since 2017.

Foam blowing agents

Emissions from *foam blowing agents* was estimated to produce 2.1 Gg CO₂e in 2020. Emissions in this subcategory were added since the 2012 inventory, but recalculations were not done for years prior to 2011 due to a lack of data. This sub-category added 4 Gg CO₂e each year to the 2011 and 2012 emission estimates for *refrigeration and air conditioning*.



Fire protection

Emissions from *fire protection* was estimated to produce 65.9 Gg CO_{2e} in 2020. Emissions in this subcategory increased by 14.8 Gg CO_{2e} (29 %) since 2017.

Aerosols

Emissions from *aerosols* was estimated to produce 18.2Gg CO_{2e} in 2020. Emissions in this subcategory were added since the 2012 inventory, but recalculations were not done for years prior to 2011 due to a lack of data. This sub-category contributed an additional 15 Gg CO_{2e} and 16 Gg CO_{2e} to the emissions in 2011 and 2012 respectively.

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 (EF) 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		NO _x	CO	NMVOC	SO ₂
		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	T1	DF	NO		NO		NO		NO		NO	NO	NO	NO
2	Lime production	T1,T2	DF	NO		NO		NO		NO		NO	NO	NO	NO
3	Glass production	T3	CS	NO		NO		NO		NO		NO	NO	NO	NO
4	Other process uses of carbonates	T1,T3	DF,CS	NO		NO		NO		NO		NO	NO	NO	NO
B	Chemical industry														
1	Ammonia production	T3	CS	T3	CS	NO		NO		NO		NO	NO	NO	NO
2	Nitric acid production	NO		NO		T3	CS	NO		NO		NO	NO	NO	NO
3	Adipic acid production	NO		NE		NE		NO		NO		NO	NO	NO	NO
4	Caprolactam, glyoxal and glyoxylic acid production	NO		NE		NE		NO		NO		NO	NO	NO	NO
5	Carbide production	T1	DF	T1	DF	NE		NO		NO		NO	NO	NO	NO
6	Titanium dioxide production	T3	CS	NE		NE		NO		NO		NO	NO	NO	NO
7	Soda Ash production	T3	CS	NE		NE		NO		NO		NO	NO	NO	NO
8a	Methanol	NO		NE		NE		NO		NO		NO	NO	NO	NO
8b	Ethylene	NO		NE		NE		NO		NO		NO	NO	NO	NO
8c	Ethylene Dichloride and Vinyl Chloride Monomer	NO		NE		NE		NO		NO		NO	NO	NO	NO
8d	Ethylene Oxide	NO		NE		NE		NO		NO		NO	NO	NO	NO



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

8e	Acrylonitrile	NO		NE		NE		NO		NO		NO	NO	NO	NO
8f	Petrochemical and carbon black production	T1	DF	T1	DF	NE		NO		NO		NO	NO	NO	NO
9	Hydrogen Production	T3	CS	NE		NE		NO		NO		NO	NO	NO	NO
10	Fluorochemical production			NE		NE		NO		NO		NO	NO	NO	NO
C	Metal industry														
1	Iron and steel production	T1, T3	DF, CS	NE		NE		NO		NO		NO	NO	NO	NO
2	Ferroalloy production	T1, T2, T3	DF, CS	T1, T2	DF, CS	NE		NO		NO		NO	NO	NO	NO
3	Aluminium production	T3	CS	NE		NE		NO		T3	CS	NO	NO	NO	NO
4	Magnesium production	NO		NE		NE		NO		NO		NO	NO	NO	NO
5	Lead production	T1	DF	NE		NE		NO		NO		NO	NO	NO	NO
6	Zinc production	T1	DF	NE		NE		NO		NO		NO	NO	NO	NO
D	Non-energy products from fuels and solvents														
1	Lubricant use	T1	DF	NE		NE		NO		NO		NO	NO	NO	NO
2	Paraffin wax use	T1	DF	NE		NE		NO		NO		NO	NO	NO	NO
3	Solvent use	NE		NE		NE		NO		NO		NO	NO	NO	NO
E	Electronics industry														
1	Integrated circuit or semiconductor	NE		NE		NE		NO		NO		NO	NO	NO	NO
2	TFT flat panel display	NE		NE		NE		NO		NO		NO	NO	NO	NO
3	Photovoltaics	NE		NE		NE		NO		NO		NO	NO	NO	NO
4	Heat transfer fluid	NE		NE		NE		NO		NO		NO	NO	NO	NO
F	Product uses as substitute ODS														
1	Refrigeration and air conditioning	NO		NO		NO		T2a, T2b	DF	NE		NO	NO	NO	NO
2	Foam blowing agents	NO		NO		NO		T1	DF	NE		NO	NO	NO	NO
3	Fire protection	NO		NO		NO		T1	DF	NE		NO	NO	NO	NO
4	Aerosols	NO		NO		NO		T1a, T2a	DF	NE		NO	NO	NO	NO
5	Solvents	NO		NO		NO		NE		NE		NO	NO	NO	NO



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

G Other product manufacture and use															
1	Electrical equipment	NE		NE		NE		NO		NO		NO	NO	NO	NO
2	SF6 and PFCs from other product uses	NE		NA		NA		NE		NE		NO	NO	NO	NO
3	N ₂ O from product uses	NO		NE		NE		NO		NO		NO	NO	NO	NO
H Other															
1	Pulp and paper industry	NE		NE		NE		NE		NE		NO	NO	NO	NO
2	Food and beverage industry	NE		NE		NE		NE		NE		NO	NO	NO	NO



4.1.3 Improvements and recalculations since 2017 submission

- Through the introduction of the SAGERS Portal, the GHG reporting tool, there have been various additions to the inventory as well as recalculations. *Mineral Industry:*
 - The addition of Other Process Uses of Carbonates category from 2018.
 - Activity data for 2018 and 2019 were extrapolated for quicklime due to lack of activity data.
 - The addition of dolomitic lime from 2019.
- Chemical Industry:*
 - Addition of silicon carbide production in 2019 has led to increased carbide production emissions through the estimation of CH₄ emissions.
 - Titanium dioxide production saw an error corrected from 2014 onwards resulting in higher but accurate emissions
 - Addition of Soda ash production category from 2019.
 - Addition of hydrogen production from 2018.
- Metal Industry:*
 - The addition of Treatment of secondary raw material under Lead production, which has led to a change throughout the time series where the emission factor was changed from 0.52 to 0.2 from 2000 – 2019.

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	Identification Criteria
2A1	Cement production	CO ₂	L
2B	Chemical industry	C	T
2C1	Iron and steel production	CO ₂	L,T
2C2	Ferroalloys production	CO ₂	L,T
2C3	Aluminium production	PFCs	L,T
2F1	Refrigeration and air conditioning	HFCs	L

4.1.5 Planned improvements and recommendations



There are no overarching planned improvements other than to include any updated data from SAGERS.

4.2 Mineral industry (2.A)

Mineral production emissions are mainly 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).

4.2.1 Cement production (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.

4.2.1.2 Methodological issues

A Tier 1 approach was used to determine emissions from clinker produced in the cement production category. From 2008 to 2015 imports of clinker were included in the calculations.

Activity data

Data on cement production in South Africa was obtained from the SAMI Reports (DMR, 2019) produced by DMR for 2000 to 2017 (Table 4.5). Clinker production for the years 2018 and 2020 were provided by the cement industries (Table 4.5). Clinker fraction for the years 2000 to 2012 were obtained from cement industries but was not available for this submission so the 2012 ratio was assumed to remain unchanged between 2012 and 2017. This will be updated once new data becomes available. The clinker fraction for the years 2018 and 2019 were not provided by all cement industries, however the clinker produced was provided (Table 4.5).

Table 4.5: Production data for the mineral industries, 2000 – 2020.

	Cement production	Clinker production	Quick lime production	Hydrated lime production	Dolomitic lime production	Glass production	Ceramics	Other uses of soda ash	Other
	Production (tonne)								
2000	9 794 000		532 100	46 270		561 754			
2001	9 700 000		522 910	45 470		624 156			
2002	11 218 000		572 369	49 771		667 110			
2003	11 893 000		586 969	51 041		702 008			
2004	11 565 000		608 056	52 874		726 644			
2005	13 519 000		685 860	59 640		775 839			
2006	14 225 000		755 302	65 678		808 328			
2007	14 647 000		660 772	57 458		858 382			
2008	14 252 000		1 436 000	142 000		978 488			
2009	14 860 000		1 264 000	104 000		993 784			
2010	13 458 000		1 179 000	113 000		1 009 043			
2011	12 373 000		1 422 000	118 000		1 019 755			



	Cement production	Clinker production	Quick lime production	Hydrated lime production	Dolomitic lime production	Glass production	Ceramics	Other uses of soda ash	Other
	Production (tonne)								
2012	12 358 000		1 113 000	97 000		1 095 264			
2013	13 053 000		1 091 000	100 000		1 095 264			
2014	13 099 000		1 111 579	148 760		1 095 264			
2015	14 456 000		1 026 591	92 623		1 095 264			
2016	15 182 000		1 035 000	93 000		1 146 296			
2017	14 622 000		1 112 000	96 000		1 162 436			
2018		9 429 753.9	1 055 730				689 841.2	12 135	278 551
2019		9 174 823.8	1 055 730		61 810		752 256.2		115 048
2020		6 456 183.4	818 211.2	146 157.6	24 729.3	1 085 565.4	146 935.5	58 756.5	114 870.7

Emission factors

For the calculation of GHG emissions in cement production, CO₂ emission factors were sourced from the 2006 IPCC Guidelines. It was assumed that the CaO composition (one tonne of clinker) contains 0.65 tonnes of CaO from 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 2020 ranged between 69% - 78%.

4.2.1.3 Uncertainties and time-series consistency

Activity data uncertainty

The largest uncertainty in this sub-category is the production and import/export data. According to IPCC 2006 the uncertainties are: $\pm 1\%$ for chemical analysis of clinker to determine CaO; $\pm 10\%$ for country production data; $\pm 30\%$ for the CKD correction factor default assumption; and $\pm 10\%$ on the trade data.

Emission factor uncertainty

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



Time-series consistency

A Tier 1 method has been used from 2000 to 2020 to estimate emissions from this category. 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

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

For verification of cement production data, the facility-level clinker production submitted by cement industries for the inventory was compared with estimated clinker production from previous inventories. The clinker production follows the same trend as the facility level clinker production for the 2019 inventory. Comparison against the SAMI Report (2019) 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 DMRE data do not include clinker exports due to a lack of data. It is not clear if the industry level clinker data takes imports and exports into account. These differences lead to increased uncertainty and the reasons for the discrepancies need to be further investigated.

4.2.1.5 Category specific recalculations

Recalculations were not performed for this category.

4.2.1.6 Category specific planned improvements

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

The activity data should include the CaO content of the clinker and the fraction of this CaO from carbonate. According to the 2006 IPCC Guidelines, it is *good practice* to separate CaO from non-carbonate sources (e.g. slag and fly ash) and CaO content of the clinker when calculating emissions. It is evident that there are discrepancies between the



cement production data from industry and the cement production data published by the DMR, 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 (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 calcium carbonate (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, 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 time period (DMR, 2019).

4.2.2.2 Methodological issues

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 1 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.

Activity data

The DMRE publishes data on lime product that is divided into quicklime which includes pyrometallurgical and chemical components; and hydrated lime that includes water



purification, chemical and other (DMR, 2019). In the previous submissions only pyrometallurgical quicklime and water purification hydrated lime was incorporated from the SAMI Reports (DMR, 2019) (Table 4.5). It was assumed that all quicklime is high calcium lime. The 2020 inventory included activity data provided by the lime industries reported via South African 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.

Emission factors

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

4.2.2.3 Uncertainties and time-series consistency

Activity data uncertainty

According to the 2006 IPCC Guidelines, uncertainty of the 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 $\pm 30\%$.

Emission factor uncertainty

According to the IPCC 2006 Guidelines, the uncertainty on lime production emissions are: $\pm 6\%$ for assuming an average CaO in lime; $\pm 2\%$ for high-calcium EF; $\pm 5\%$ for correction for hydrated lime (Table 2.5).

Time-series consistency

A Tier 1 method was used to estimate emissions from 2000 to 2020. The time series was updated to include the 2006 IPCC default emission factor of 0.59 for hydrated lime in 2017. Dolomitic lime was added to the time series in 2019.

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 for 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 actually 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 Portal 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

No category specific improvements are planned.

4.2.3 Glass production (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 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



The Tier 3 approach was used to determine estimates of the GHG emissions from glass production by the glass production industries for the 2020 inventory.

Activity data

Production data was provided by the glass production industries (PG Group, Consol Glass, Nampak and Isanti), and a Tier 3 approach was used to estimate emissions, which looks at the raw material used during the process.

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.

4.2.3.3 Uncertainties and time-series consistency

Activity data uncertainty

As per the 2006 IPCC Guidelines, uncertainty related to activity data using a Tier 3 approach is between ± 1 and $\pm 3\%$. Carbonates lost as dust is negligible under the Tier 3 method.

Emission factor uncertainty

As per the 2006 IPCC Guidelines, uncertainty related to emission factors developed using a Tier 3 approach is between ± 1 and $\pm 3\%$. There is some uncertainty when assuming that all carbonates are calcined, but this is minimal.

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 GHG Reporting Regulations, glass production industries began using the Tier 3 method to estimate emissions.

4.2.3.4 Category specific QA/QC and verification

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



4.2.3.5 Category specific recalculations

No recalculations were performed for this category.

4.2.3.6 Category specific planned improvements

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

4.2.4 Other process uses of carbonates (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 also are 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).

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, deadburned 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 a number of 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 ceramics industries and soda ash usage. A Tier 1 approach was used to estimate emissions from other uses of carbonates (Table 4.3).

Activity data

Activity data for 2020 were obtained from industries operating under the relevant sector. Activity data was reported via the SAGERS Portal. This is a new category added to the inventory from 2018 and all activity data has been reported via the GHG Reporting Regulations from specific industries.

Emission factors

The 2006 IPCC 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) were applied where a Tier 1 approach was used for Ceramics. The 2006 IPCC default emission factor for other usage of carbonates (0.47732 tonnes CO₂ per tonne lime) was applied to dolomite usage.

4.2.4.3 Uncertainties and time-series consistency

Activity data uncertainty

According to the 2006 IPCC Guidelines, uncertainty arising from a Tier 3 approach is between ± 1 and $\pm 3\%$, and where a Tier 1 approach has been used uncertainty rises to between ± 15 and $\pm 85\%$. As both approaches were used to estimate emissions in 2020 activity data uncertainty will fall between the range of ± 1 to $\pm 85\%$.

Emission factor uncertainty

As per the 2006 IPCC 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 and $\pm 5\%$ should apply.

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 at



this time. The time series consistency will be updated as industry continues to report in future via the SAGERS Portal.

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 (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, titanium dioxide production and carbon black. 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 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 (2.B.1)



4.3.1.1 Category description

Ammonia is the most important nitrogenous material produced and is a major industrial chemical. According to the 2006 IPCC 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.

Activity data

Consumption data is not provided within this report due to confidentiality.

Emission factors

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

4.3.1.3 Uncertainties and time-series consistency

Activity data uncertainty

According to the 2006 IPCC 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 2006 IPCC Guidelines should activity data be obtained from producers.

Emission factor uncertainty

The 2006 IPCC Guidelines default uncertainty for Tier 1 is $\pm 6\%$ therefore it is expected that for a Tier 3 approach the uncertainty would be less, therefore an assumption of $\pm 2\%$ is made.

Time-series consistency



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

4.3.1.4 Category specific QA/QC and verification

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

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 (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 2006 IPCC 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). Sasol emissions were also included.

Activity data

Consumption data was not provided by industry as the information is confidential, only emission data was provided.

Emission factors

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



4.3.2.3 Uncertainties and time-series consistency

Activity data uncertainty

According to the 2006 IPCC Guidelines (p. 3.24) the plant-level activity data required for the Tier 3 approach include production data disaggregated by technology and abatement system type. The IPCC 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, vol 3, chpt 3, pg 3.25).

Emission factor uncertainty

According the 2006 IPCC 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. For emission factors the default uncertainty range between $\pm 10\%$ and $\pm 40\%$ for a Tier 2 approach (IPCC 2006, vol 3, chpt 3, pg 3.23, Table 3.3). Since a Tier 3 approach was applied in this inventory the lower uncertainty value of $\pm 10\%$ was assumed.

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

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

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 (2.B.3)

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

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

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

4.3.5 Carbide production (2.B.5)

4.3.5.1 Category description

Carbide production can result in GHG emissions such as CO₂ and CH₄. According to the 2006 IPCC 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.

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 is a new activity added in 2019.

Emission factors

An IPCC 2006 default emission factor was applied and is shown in Table 4.6.

Table 4.6: Emission factors applied in the chemical industry emission estimates.

Sub-category	CO ₂ EF	CH ₄ EF	Source



	(tonnes CO ₂ /tonne product)	(kg CH ₄ /tonne product)	
Calcium Carbide production	1.09		IPCC 2006
Silicon Carbide Production	2.62	11.6	IPCC 2006

4.3.5.3 Uncertainties and time-series consistency

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 $\pm 10\%$.

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, p. 3.45). Emission factor uncertainty for Tier 1 is $\pm 10\%$ for both CO₂ and CH₄ as per the 2006 IPCC Guidelines.

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.

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 (2.B.6)

4.3.6.1 Category description

Titanium dioxide (TiO_2) is a white pigment used mainly in paint manufacture, paper, plastics, rubber, ceramics, fabrics, floor coverings, printing ink, among others. According to 2006 IPCC Guidelines (p. 3.47), there are three processes in titanium dioxide production that result in GHG emissions, namely, a) titanium slag production in electric furnaces; b) synthetic rutile production using the Becher Process and c) rutile TiO_2 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.

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.

Emission factors

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

4.3.6.3 Uncertainties and time-series consistency

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.

Emission factor uncertainty

The 2006 IPCC Guidelines state that uncertainty for titanium slag is unavailable due to confidentiality and lack of production plants.



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 SAGERS will be included.

4.3.7 Soda ash production (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 a large number of 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 (2006, IPCC).

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.



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.

Emission factors

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

4.3.7.3 Uncertainties and time-series consistency

Activity data uncertainty

According to the IPCC 2006 Guidelines (p. 3.50), the uncertainty of the activity data when uncertainty is unavailable is $\pm 5\%$ for activity data collected at plant level.

Emission factor uncertainty

The 2006 IPCC 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.

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 will be included.



4.3.8 Carbon black production (2.B.8.f)

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, 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, 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.

Activity data

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

Emission factors

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

Table 4.7: Emission factors applied in the chemical industry 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

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.

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.

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 not 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 will be included.

4.3.9 Flourochemical production (2.B.9)

There is no *flourochemical production* occurring in South Africa.



4.4 Metal industry (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, CH₄ from ferroalloy production, and perfluorocarbons (CF₄ and C₂F₆) from aluminium production.

4.4.1 Iron and steel production (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 2006 IPCC 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; tinsplate; 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.

4.4.1.2 Methodological issues

A Tier 1 and 3 approach was applied to calculate the emissions from *iron and steel production* for the different process types in 2020. Default IPCC emission factors were used for the calculation of GHG emissions from basic oxygen furnace, electric arc furnace and pig iron production, direct reduced iron production and sinter. Industry also used a Tier 3 approach to estimate emissions from electric arc furnaces using raw material input and output. The separation of energy and process emissions emanating from the use of coke was not done due to a lack of disaggregated information on coke consumption. Hence, energy-related emissions from iron and steel production have been accounted for through the application of default IPCC emission factors.

Activity data



Activity data was provided by the iron and steel production plants (Table 4.8) via the SAGERS Portal.

Table 4.8: Production data for the iron and steel industry, 2000 – 2020.

	Basic oxygen furnace	Electric arc	Pig iron	Direct reduced iron	Sinter	Other
	Production (tonne)					
2000	4 674 511	4 549 828	4 674 511	1 552 553		705 872
2001	4 849 655	4 716 954	4 849 655	1 220 890		706 225
2002	5 051 936	4 888 870	5 051 936	1 340 976		706 578
2003	5 083 168	5 353 456	4 474 699	1 542 008		706 931
2004	4 949 693	5 508 488	4 224 487	1 632 767		733 761
2005	5 255 831	5 089 818	4 441 904	1 781 108		735 378
2006	5 173 676	5 413 204	4 435 551	1 753 585		739 818
2007	4 521 461	5 473 908	3 642 520	1 735 914		705 428
2008	4 504 275	4 581 523	3 746 786	1 177 925		460 746
2009	3 953 709	4 359 556	3 184 566	1 339 720		429 916
2010	4 366 727	4 235 993	3 695 327	1 120 452		584 452
2011	3 991 686	3 554 803	4 603 558	1 414 164		570 129
2012	3 904 276	3 904 276	4 599 015	1 493 420		677 891
2013	4 271 948	3 292 870	4 927 550	1 295 000		590 356
2014	3 622 909	2 789 291	4 401 734	1 611 530		585 728
2015	3 907 513	2 490 587	4 463 759	1 124 971		581 399
2016	3 498 862	3 039 702	4 650 922	1 806 067		577 332
2017	4 242 430	1 153 047	101 115	660 605	3 631 445	107 153
2018	4 967 074	1 443 030		837 515	4 060 025	107 153
2019	4 242 431	1 555 741	10 115	684 134	3 631 445	
2020	2 085 522	1 785 641	48 670	236 497	2 173 111	

Emission factors

IPCC default emission factors were applied for the calculation of emissions from *iron and steel production* (Table 4.9). The country-specific emission factor for electric arc furnace (EAF) production is slightly higher than the IPCC default value; this emission factor was, however, not used for the estimation of GHG emissions from EAF because it was based on a small sample and needs further investigation before it can be applied.



Table 4.9: Emission factors applied in the metal industry emission estimates.

Sub-category	CO ₂ EF	CH ₄ EF	Source
	(tonnes CO ₂ /tonne product)	(kg CH ₄ /tonne product)	
Iron and steel production			
<i>Basic oxygen furnace</i>	1.46		IPCC 2006
<i>Electric arc furnace</i>	0.08		IPCC 2006
<i>Pig iron production</i>	1.35		IPCC 2006
<i>Direct reduced iron</i>	0.7		IPCC 2006
<i>Sinter</i>	0.2		IPCC 2006
<i>Other*</i>	1.06		IPCC 2006

*The Corex process is the only process included under this sub-category

4.4.1.3 Uncertainties and time-series consistency

Activity data uncertainty

There is a default $\pm 10\%$ uncertainty on the activity data (IPCC 2006, Table 4.4).

Emission factor uncertainty

The Tier 1 approach for metal production emission estimates generates a number of uncertainties. 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, Vol 3, Chpt 4, page 4.40, Table 4.9). For this inventory the maximum default uncertainty for T1 of 25% was assumed for the EF.

Time-series consistency

Data was not consistent throughout the time series as the data was provided by different sources for the 2019 inventory. The 2020 inventory included activity data directly from industry via the SAGERS Portal. Prior to 2017 sinter production was reported, however since the promulgation of the GHG Reporting Regulations there has been disaggregation between direct reduced iron and sinter processes.

4.4.1.4 Category specific QA/QC and verification

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



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 SAGERS will be included. An improvement to consider in the future is the estimation of CH₄ emissions.

4.4.2 Ferroalloys production (2.C.2)

4.4.2.1 Category description

Ferroalloy refers to concentrated alloys of iron and one or more metals such as silicon, manganese, chromium, molybdenum, vanadium and tungsten. Ferroalloy plants manufacture concentrated compounds that are delivered to steel production plants to be incorporated in alloy steels. Ferroalloy production involves a metallurgical reduction process that results in significant CO₂ emissions (IPCC, 2006, 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).

4.4.2.2 Methodological issues

A Tier 1,2 and 3 approach was applied across the different ferroalloy production plants for different types of ferroalloys.

Activity data

Ferroalloy production data for 2000 to 2012 (Table 4.10) were obtained from ferroalloy production plants. Activity data from 2013 to 2017 were obtained from the SAMI annual reports (DMR, 2019). Activity data is provided in Table 4.10, however for 2018 to 2020 activity data was again supplied by the ferroalloy 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 ferromanganese 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. This will be investigated further in the next inventory. 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). Production data for 2018 to 2020 were not supplied as various Tier approaches were used to estimate emissions and production data was not always available.

Most plants provided a split between ferromanganese 1% and 7%, however where the split was not reported, the split from 2013 was applied. The inconsistency will be overcome in future inventories as the SAGERS Portal requires the split to be reported. Activity data was sourced directly from industry but is not shown due to confidentiality issues.

Table 4.10: Production data for the ferroalloy industry, 2000 – 2017.

	Ferro- chromium	Ferro- manganese (7% C)	Ferro- manganese (1% C)	Ferro- silicon (65% Si)	Silicon metal
	Production (tonne)				
2000	2 574 000	596 873	310 400	108 500	40 600
2001	2 141 000	523 844	259 176	107 600	39 400
2002	2 351 000	618 954	315 802	141 700	42 500
2003	2 813 000	607 362	313 152	135 300	48 500
2004	3 032 000	611 914	373 928	140 600	50 500
2005	2 802 000	570 574	275 324	127 000	53 500
2006	3 030 000	656 235	277 703	148 900	53 300
2007	3 561 000	698 654	327 794	139 600	50 300
2008	3 269 000	502 631	259 014	134 500	51 800
2009	2 346 000	274 923	117 683	110 400	38 600
2010	3 607 000	473 000	317 000	127 700	46 400
2011	3 422 000	714 000	350 000	126 200	58 800
2012	3 063 000	706 000	177 000	83 100	53 000
2013	3 219 000	681 000	163 000	78 400	34 000
2014	3 719 000	814 263	194 737	87 700	47 200
2015	3 685 000	492 000	123 000	91 800	46 300
2016	3 524 000	296 000	74 000	73 200	26 600
2017	3 268 000	354 400	88 600	48 200	4 700

Emission factors

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



4.4.2.3 Uncertainties and time-series consistency

Activity data uncertainty

There is a default $\pm 5\%$ uncertainty on the activity data (IPCC 2006, Table 4.9) due to national production data being provided by industry.

Emission factor uncertainty

IPCC 2006 Guidelines indicate that for Tier 1 the default emission factors may have an uncertainty of $\pm 25\%$ (IPCC 2006, Vol 3, Chpt 4, page 4.40, Table 4.9). For this inventory the maximum default uncertainty for Tier 1 of $\pm 25\%$ was assumed for the EF for both CO_2 and CH_4 , as no segregation was provided between the two.

Time-series consistency

The time series is not consistent due to a change in data sources in 2018 and 2019. During 2020 industry reported via the SAGERS Portal.

4.4.2.4 Category specific QA/QC and verification

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

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 SAGERS will be included.

4.4.3 Aluminium production (2.C.3)

4.4.3.1 Category description

According to the 2006 IPCC Guidelines, aluminium production is realised 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):

- Carbon dioxide (CO₂) emissions from the consumption of carbon anodes in the reaction to convert aluminium oxide to aluminium metal;
- Perfluorocarbon (PFC) emissions of CF₄ and C₂F₆ during anode effects. Also emitted are smaller amounts of process emissions, CO, SO₂, and NMVOCs. SF₆ is not emitted during the electrolytic process and is only rarely used in the aluminium manufacturing process, where small quantities are emitted when fluxing specialized high-magnesium aluminium alloys.

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 in the 2018-2020 period.

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.

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

Activity data uncertainty

As per the 2006 IPCC Guidelines, uncertainty is minimal regarding aluminium production data. A default uncertainty of $\pm 1\%$ is used (2006 IPCC, Page 4.57).

Emission factor uncertainty



The uncertainty on the Tier 3 CO₂ emission factors for aluminium production is $\pm 15\%$ (IPCC 2006, Page 4.56). Even though a Tier 3 approach was used for *aluminium production* PFC emission, no data was collected on uncertainty. The Tier 3 default uncertainty for CF₄ and C₂F₆ are indicated to be $\pm 15\%$ (IPCC 2006, Vol 3, Chpt 4, page 4.56).

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 CWPB, SWPB, VSS and 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 and Prebake from 2014 onwards.

4.4.3.4 Category specific QA/QC and verification

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

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 (2.C.4)

There is no *magnesium production* occurring in South Africa.

4.4.5 Lead production (2.C.5)

4.4.5.1 Category description



According to the 2006 IPCC Guidelines, there are two primary processes for the production of lead bullion from lead concentrates:

- Sintering/smelting, 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 2006 IPCC Guidelines, involves the recycling of lead acid batteries. Recycling occurs through the following processes:

- crushed using a hammer mill and entered into 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.

Activity data

Lead production data for 2000 to 2017 were obtained from the SAMI annual reports (DMR, 2019) and are provided in Table 4.11, however for 2018 to 2020 activity data was supplied by the lead production plants via the SAGERS Portal for 2020.

Table 4.11: Production data for the lead and zinc industries, 2000 – 2020.

	Lead	Zinc
	Production (tonne)	
2000	75 300	63 000
2001	51 800	61 000
2002	49 400	64 000
2003	39 900	41 000
2004	37 500	32 000
2005	42 200	32 000
2006	48 300	34 000
2007	41 900	31 000
2008	46 400	29 000
2009	49 100	28 000
2010	50 600	36 000



2011	54 460	37 000
2012	52 489	37 000
2013	41 848	30 145
2014	29 348	26 141
2015	34 573	29 040
2016	39 344	26 695
2017	48 150	30 778
2018	32 383	21 090
2019	37 519	20 918
2020	32 860	21 268

Emission factors

IPCC 2006 default emission factor of 0.2 t CO₂ per t lead produced was applied.

4.4.5.3 Uncertainties and time-series consistency

and a $\pm 50\%$ uncertainty on the IPCC default emission factor

Activity data uncertainty

For lead production emissions using the Tier 1 method there is a $\pm 10\%$ uncertainty on the activity data (IPCC, 2006, vol 3, Table 4.23).

Emission factor uncertainty

Uncertainty for default lead production emission factors has an uncertainty of $\pm 50\%$ (2006, IPCC, Page 4.75).

Time-series consistency

The time series is not consistent as the source of activity data changed in 2018 from the SAMI Report (DMRE, 2019) to industry reporting via the SAGERS Portal.

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 2000 – 2020.



4.4.5.6 Category specific planned improvements

There are no subcategory specific planned improvements, however it is recommended that data be collected to determine the relative amounts of lead produced from primary and from secondary materials. This would allow for the selection of more appropriate emission factors. Updated information from SAGERS will also be included.

4.4.6 Zinc production (2.C.6)

4.4.6.1 Category description

According to the 2006 IPCC Guidelines, there are three primary processes for the production of 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.
- Concentrate: The process results in the simultaneous production of lead and zinc and the release of non-energy CO₂ emissions.
- The 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.

Activity data

In the previous submission the *zinc production* data was supplied by industry, however this was not available for this submission. Data was therefore sourced by applying an extrapolation from 2017.

Emission factors



IPCC 2006 default emission factor of 1.72 t CO₂ per t zinc produced was applied. It was assumed that for *zinc production* it was 60% imperial smelting and 40% Waelz Kiln (IPCC 2006 default values).

4.4.6.3 Uncertainties and time-series consistency

Activity data uncertainty

For *zinc production* emissions there is a $\pm 10\%$ uncertainty on the activity data (IPCC, 2006, vol 3, Table 4.25).

Emission factor uncertainty

Uncertainty for default zinc production emission factors has an uncertainty of $\pm 50\%$ (2006, IPCC, Page 4.82).

Time-series consistency

The time series is inconsistent as activity data has not been available since 2017 and an extrapolation was undertaken to obtain data values.

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 are no subcategory specific planned improvements, however it is recommended that data be collected to determine the relative amounts of zinc produced from primary and from secondary materials. This would allow for the selection of more appropriate emission factors. Updated information from SAGERS will also be included.

4.4.7 Other (2.C.7)

No activities were included under this sub-category.



4.5 Non-Energy Products from Fuels and Solvent Use (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, 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 2006 IPCC 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 (2.D.1)

4.5.1.1 Category description

According to the 2006 IPCC 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.

Activity data

The source of activity data for lubricants was the energy balance tables published annually by the DMRE (Table 4.12). An extrapolation was applied to the 2018 activity data, as the updated energy balance tables are currently unavailable.

Table 4.12: Lubricant and paraffin wax consumption, 2000 – 2020.



	Lubricant	Paraffin wax
	Consumption (tonne)	
2000	12 851	507
2001	15 093	314
2002	16 561	506
2003	16 430	521
2004	16 295	490
2005	31 549	350
2006	34 391	324
2007	393 505	141
2008	370 423	182
2009	390 718	231
2010	4 000	27
2011	37 000	52
2012	57 160	13 939
2013	35 574	207
2014	48 652	366
2015	48 531	121 607
2016	25 489	6 755
2017	28 940	7 240
2018	92 043	26 921
2019	71 940	24 388
2020	58 293	26 807

Emission factors

IPCC 2006 default emission factor (0.2 tonnes CO₂ per TJ product) was applied to this subsector.

4.5.1.3 Uncertainties and time-series consistency

Activity data uncertainty

According to the IPCC 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 $\pm 5\%$ may be used in countries with well-developed energy statistics and ± 10 to $\pm 20\%$ in other countries, based on expert judgement of the accuracy of energy statistics (2006, IPCC, Page 5.10).



Emission factor uncertainty

The default oxidised during use (ODU) factors available in the IPCC guidelines are very uncertain, as they are based on limited knowledge of typical lubricant oxidation rates. Expert judgment suggests using a default uncertainty of $\pm 50\%$. 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 $\pm 3\%$ was estimated (2006, IPCC, Page 5.10).

Time-series consistency

The time series is inconsistent as activity data has not been available since 2018 and an extrapolation was undertaken to obtain data values. Category specific QA/QC and verification

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

4.5.1.4 Category specific recalculations

No recalculations were performed for this category.

4.5.1.5 Category specific planned improvements

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

4.5.2 Paraffin wax use (2.D.2)

4.5.2.1 Category description

According to the 2006 IPCC 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.



Activity data

The source of activity data for paraffin wax was the energy balance tables published annually by the DoE (Table 4.12). An extrapolation was applied to the 2018 activity data, as the updated energy balance tables are currently unavailable.

Emission factors

IPCC 2006 default emission factor (0.2 tonnes CO₂ per TJ product) was applied to this subsector.

4.5.2.3 Uncertainties and time-series consistency

Activity data uncertainty

According to the IPCC 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 $\pm 5\%$ may be used in countries with well-developed energy statistics and ± 10 to $\pm 20\%$ in other countries, based on expert judgement of the accuracy of energy statistics (2006, IPCC, Page 5.13).

Emission factor uncertainty

The default oxidised during use (ODU) factors available in the IPCC guidelines are very uncertain, as they are based on limited knowledge of typical lubricant oxidation rates. Expert judgment suggests using a default uncertainty of $\pm 50\%$. 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 $\pm 3\%$ was estimated (2006, IPCC, Page 5.13).

Time-series consistency

The time series is inconsistent as activity data has not been available since 2018 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 SAGERS will be included.

4.5.3 Solvent use (2.D.3)

No activities were included under this sub-category.

4.6 Electronics industry (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 greenhouse gas emissions for this category and report progress in its future GHG inventory submissions.

4.7 Product Uses as Substitutes for Ozone Depleting Substances (ODS) (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. Hydrofluorocarbons (HFCs) and, to a limited extent, perfluorocarbons (PFCs) are ozone-depleting substances (ODS) being phased out under this protocol. According to the 2006 IPCC 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.



4.7.1 Refrigeration and air conditioning (2.F.1)

4.7.1.1 Category description

According to the 2006 IPCC 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,
- Mobile air-conditioning systems used in passenger cars, truck cabins, buses, and trains.

4.7.1.2 Methodological issues

The IPCC 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 4.13 summarises the approach used for each sub-application in the RAC sector.

Table 4.13: 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.

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 the South African Refrigeration Distribution Association (SARDA). Other sources included the members of the DFFE's Chemical Management 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.

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

Activity data uncertainty

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

Emission factor uncertainty

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

Time-series consistency

Time series is not consistent over the full 20-year time period as emission data is only available from 2005, with an enhanced data set (including mobile air conditioning) from 2011. Discussions with the ODS management unit to retrieve data for the 1990-2004 period are on-going and a progress report will be added in the next inventory.

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 in order to improve emissions estimates from this category. In addition, if data becomes available through discussions with ODS unit a full time-series will be considered in the next inventory.

4.7.2 Foam blowing agents (2.F.2)



4.7.2.1 Category description

HFCs are being used as replacements for CFCs and HCFCs in foams and particularly in insulation applications according to the 2006 IPCC 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 (de-commissioning 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 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Chapter 7: Emissions of Fluorinated Substitutes for Ozone Depleting Substances), as given in Equation 3 (IPCC, 2006, Ashford et al., 2005). 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.

Activity data

Where data is difficult to obtain in the country the IPCC guidelines suggest obtaining historic regional usage to account for HFC banks and emissions factors from the UNEP Foams Technical Options Committee (FTOC). The latest 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).

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 4.14.



Table 4. 14: Emission factors and defaults applied in the foam blowing agents emission estimates.

Sub-category	Value	Units	Source
Foam blowing agents			
<i>Product life</i>	34	Years	(UNEP, 2005, IPCC, 2006)
<i>First year loss</i>	14	%	
<i>Annual loss</i>	0.66	%	
<i>Landfilling loss</i>	16	%	
<i>Landfill annual loss</i>	0.75	%	

4.7.2.3 Uncertainties and time-series consistency

Activity data uncertainty

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

Emission factor uncertainty

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

Time-series consistency

Time series is not consistent over the full 20-year time period as emission data for this sub-category is only available from 2011. Extrapolation of a full time-series will be considered in the next inventory.

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



Extrapolation of HFCs across the full time-series will be considered in the next inventory. The equation was pulled through correctly from 2016 on the calculation sheet as a zero-emission value was appearing before.

4.7.3 Fire protection (2.F.3)

4.7.3.1 Category description

According to the 2006 IPCC 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 guidelines, Equation 12 and Equation 13.

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.

Emission factors

Emissions from Fire Protection were calculated in accordance with the IPCC 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 (*EF*) or the emissions of agent during recovery, recycling or disposal at the time of removal from service (*RRL*). However, experience gained with the emissions patterns of



halon 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

Activity data uncertainty

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

Emission factor uncertainty

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

Time-series consistency

Time series is not consistent over the full 20-year time period as emission data for this sub-category is only available from 2011. Extrapolation of a full time-series will be considered in the next inventory.

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 (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.

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:

- Metered Dose Inhalers (MDIs)
- Personal Care Products
- Household Products
- Industrial Products
- 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.

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 emission factor (EF) of 50% of the initial charge per year (Commonwealth of Australia, 2015).

4.7.4.3 Uncertainties and time-series consistency

Activity data uncertainty

An uncertainty of $\pm 25\%$ was assumed for activity data (IPCC, 2006).

Emission factor uncertainty

An uncertainty of $\pm 25\%$ was assumed for emission factors (IPCC, 2006).

Time-series consistency

Time series is not consistent over the full 20-year time period as emission data for this sub-category is only available from 2011. Extrapolation of a full time-series will be considered in the next inventory.

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

Extrapolation of HFCs across the full time-series will be considered in the next inventory. The equation was pulled through correctly from 2016 on the calculation sheet as a zero-emission value was appearing before.

4.8 Other product manufacture and use (2.G)



Emissions from *other product manufacture and use* were not estimated for South Africa due to a lack of data.

4.9 Other (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.

4.10 References

DMR, 2001a. Department of Minerals and Resources Annual Report 2001/2002. Pretoria

DMR, 2004. South Africa's mineral industry (SAMI) 2004/2005. Pretoria

DMR, 2005. South Africa's mineral industry (SAMI) 2005/2006. Pretoria

DMR, 2009. South Africa's mineral industry (SAMI) 2009/2010. Pretoria

DMR, 2019. South Africa's mineral industry (SAMI) 2017/2018. Pretoria

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, Eggleston H S, Buenida L, Miwa K, Ngara T, and Tanabe K, eds; Institute for Global Environmental Strategies (IGES). Hayama, Kanagawa, Japan.

World Steel Association, 2010. Key Facts about World Steel Industry. <http://www.worldsteel.org/media-centre/key-facts.html>. [Accessed May 2012].



Chapter 5: Agriculture, Forestry and Other Land Use (AFOLU)

5.1 Sector overview

This chapter includes GHG emissions and removals from agriculture as well as land use and forestry. Based on the IPCC 2006 Guidelines, the main categories included in the emission estimates for the AFOLU sector are shown in Table 5.1.

Table 5.1: Main IPCC categories included in the AFOLU sector emission estimates.

IPCC Category	Category name	Included
3A1	Enteric fermentation	✓
3A2	Manure management	✓
3B1	Forest lands	✓
3B2	Croplands	✓
3B3	Grasslands	✓
3B4	Wetlands	✓
3B5	Settlements	✓
3B6	Other lands	✓
3C1	Biomass burning	✓
3C2	Liming	✓
3C3	Urea application	✓
3C4	Direct N ₂ O emissions from managed soils	✓
3C5	Indirect N ₂ O from managed soils	✓
3C6	Indirect N ₂ O from manure management	✓
3C7	Rice cultivation	NO
3C8	Other	NO
3D1	Harvested wood products	✓
3D2	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. The land use component includes Forest lands, Croplands, Grasslands, Wetlands, Settlements and Other lands. In addition, for each of these classes both land remaining in the same land use as well as land converted to another land use are considered. The land component includes



biomass, dead organic matter (DOM) and soil organic carbon (SOC). A Tier 1 (Formulation A) approach to the mineral soil carbon pool. Organic carbon is considered insignificant in this inventory (discussed further in section 5.4.1).

Rice cultivation is not included. FAO statistics indicates that there is a small area of rice cultivation in South Africa and therefore in the UNFCCC review it was indicated that this should be investigated and included if necessary. Discussions with various experts at the Agricultural Research Council (ARC) suggests that there have been some small experimental plots for rice cultivation but the precise area was not known but it is thought to be less than 50 ha. For this reason, rice cultivation is considered insignificant.

Emissions from fuel combustion in this sector are not included here as these fall under the *agriculture/forestry/fisheries* subsector (see Section 3.2.9) in the energy sector.

5.1.1 Shares and trends in emissions

5.1.1.1 Overall AFOLU

The overall AFOLU emissions totalled 15 892 Gg CO₂e (incl. FOLU) in 2020, and 48 961 Gg CO₂e excluding FOLU (Figure 5.1). There was a 4.7% decline in emissions (excl. FOLU) and 39.0% decline in emissions including FOLU between 2000 and 2020. The various trends and drivers are discussed in the sections below.

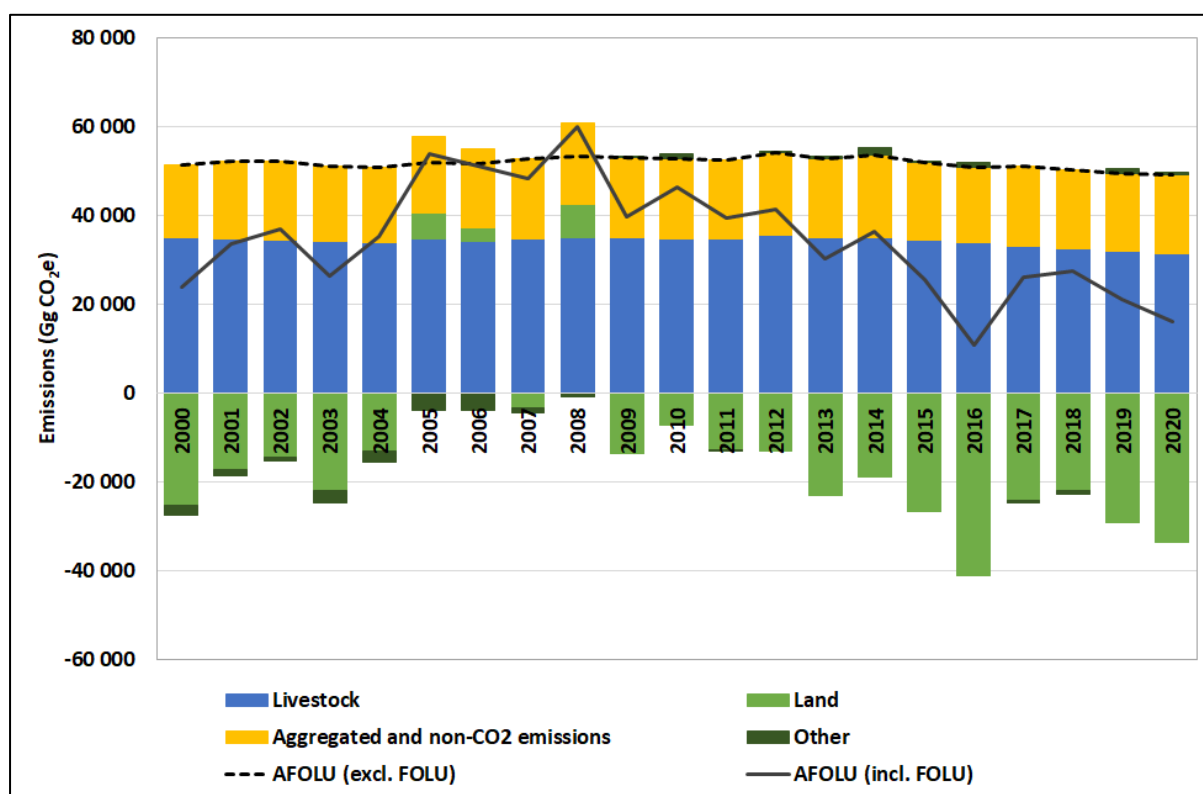


Figure 5.1: The overall AFOLU emissions for South Africa between 2000 – 2020.

5.1.1.2 Agriculture

Livestock (3A)

Enteric fermentation (3A1)

Enteric fermentation emissions have been fairly constant between 2000 and 2015, with a slight decline in 2006 and a slight increase in 2012. After 2015 emissions declined to 2020 (Figure 5.2; Table 5.2). This trend follows the same pattern as cattle population, the largest contributors to emissions from the livestock population data (Figure 5.3). The main reasons for the declining livestock numbers in recent years are the consecutive droughts that occurred in 2015 and 2016 (BFAP, 2018) and livestock owners struggling to rebuild their herds to pre-2014 levels.



The other cattle³ population has declined by 12.5% since 2014, leading to a decline in other cattle emissions. In comparison to other cattle, the total number of dairy cattle⁴ (less than 10% of the cattle population) declined slightly between 2000 and 2007 but returned to similar levels by 2017. There was a slight drop in 2019, with numbers recovering in 2020 and this is reflected in the enteric fermentation emissions. Poultry numbers have also increased, mainly due to chicken being a cheaper meat and in higher demand. Poultry do not use enteric fermentation to break down food, therefore do not contribute to the *Enteric fermentation* emissions.

In 2020 the *Enteric fermentation* category contributed 27 589 Gg CO₂e (Table 5.3). Other cattle and sheep were the largest contributors to the *Enteric fermentation* category (Table 5.3). Emissions from horses showed a slight increase between 2000 and 2020, while emissions from all other livestock declined during this time.

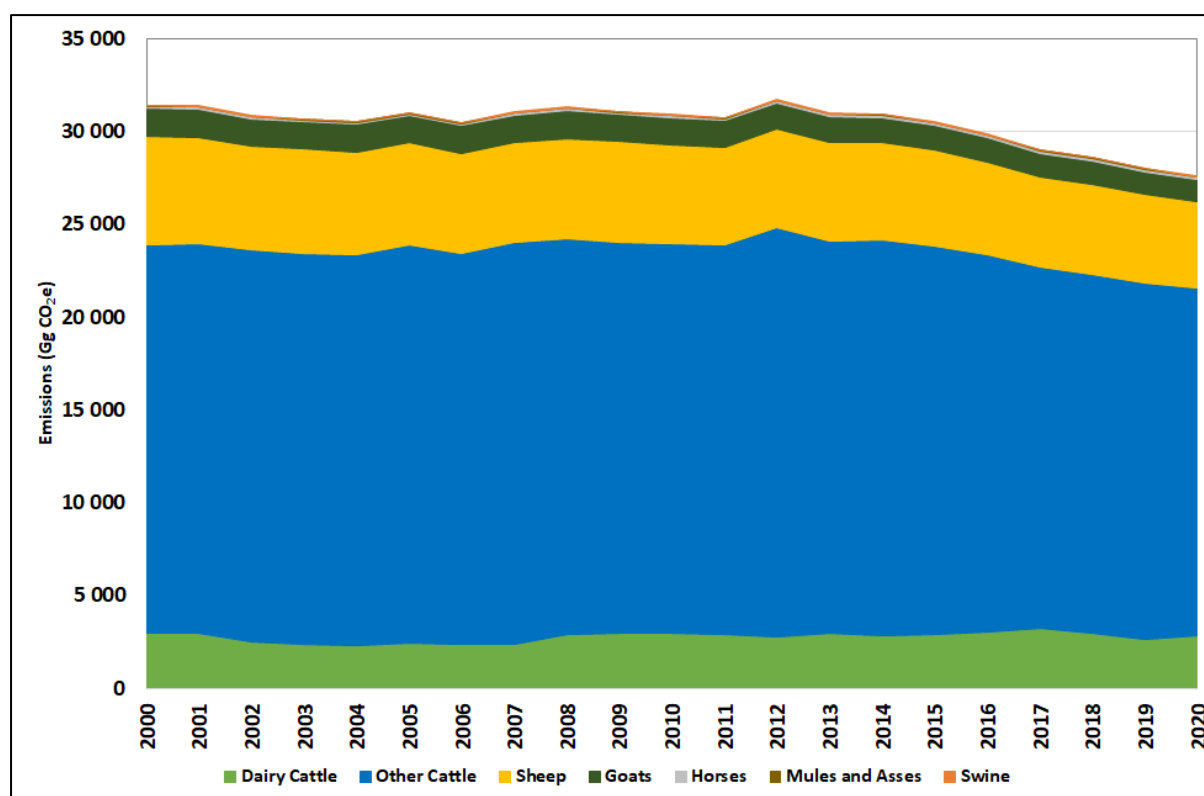


Figure 5.2: *Enteric fermentation* emission trends, 2000 – 2020.

³ All cattle except dairy cows and lactating heifers.

⁴ Only dairy cows and lactating heifers.



Table 5.2: Enteric fermentation emission trends between 2000 and 2020.

	2000	2005	2010	2015	2016	2017	2018	2019	2020
	Gg CO ₂ e								
Dairy cattle	2 932.8	2 429.2	2 962.4	2 873.5	2 992.0	3 199.4	2 932.8	2 606.9	2 814.3
Other cattle	20 968.3	21 438.0	21 012.7	20 951.8	20 353.9	19 469.3	19 361.3	19 211.7	18 740.3
Buffalo	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sheep	5 837.3	5 505.1	5 291.7	5 151.2	5 014.7	4 892.9	4 870.7	4 798.3	4 653.5
Goats	1 493.1	1 462.9	1 441.0	1 350.7	1 298.5	1 260.2	1 243.9	1 209.4	1 190.0
Camels	NO	NO	NO	NO	NO	NO	NO	NO	NO
Horses	102.1	102.1	113.4	119.4	121.5	122.3	123.5	124.7	124.7
Mules & asses	34.4	34.4	34.9	35.5	34.0	34.2	34.1	33.9	33.9
Swine	39.8	39.8	38.5	36.8	36.5	35.7	35.1	33.5	32.8
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	31 407.7	31 011.4	30 894.6	30 518.9	29 851.1	29 014.1	28 601.4	28 018.5	27 589.5

Note: Numbers may not add exactly due to rounding off.

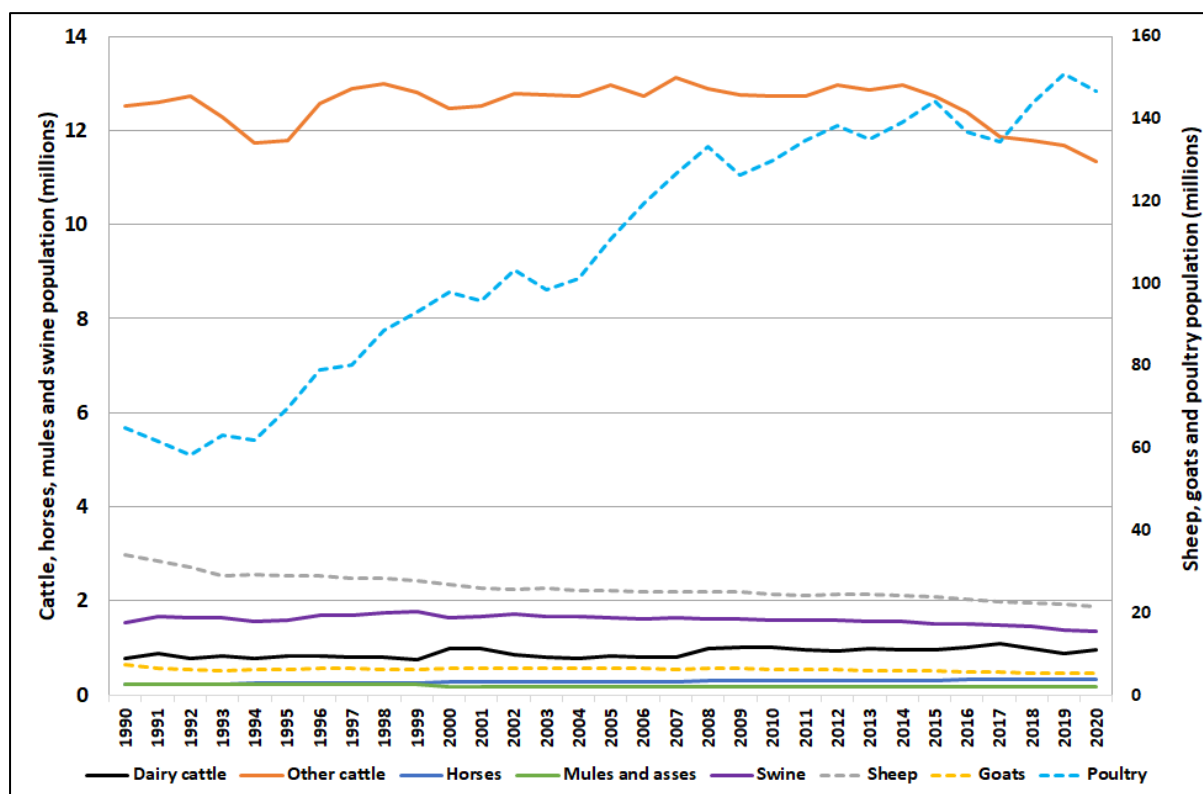


Figure 5.3: Livestock population trends, 2000 – 2020 (Data source: DALRRD, 2020).



Table 5.3: Change in *Enteric fermentation* emissions (2000 – 2020) and relative contribution of the various livestock categories to the total emissions.

	Emissions (Gg CO ₂ e)		Change (2000-2020)		Share of enteric fermentation (%)	
	2000	2020	Diff	%	2000	2020
Dairy cattle	2 932.8	2 814.3	-118.5	-4.0	9.3	10.2
Other cattle	20 968.3	18 740.3	-2 227.9	-10.6	66.8	67.9
Buffalo	NO	NO	NO	NO	NO	NO
Sheep	5 837.3	4 653.5	-1 183.8	-20.3	18.6	16.9
Goats	1 493.1	1 190.0	-303.1	-20.3	4.8	4.3
Camels	NO	NO	NO	NO	NO	NO
Horses	102.1	124.7	22.7	22.2	0.3	0.5
Mules & asses	34.4	33.9	-0.5	-1.5	0.1	0.1
Swine	39.8	32.8	-7.0	-17.6	0.1	0.1
Other	NO	NO	NO	NO	NO	NO
Total	31 407.7	27 589.5	-3 818.2	-12.2	100	100

Note: Numbers may not add exactly due to rounding off.

Manure management (3A2)

Emissions from manure management increased by 11.8% between 2000 and 2020 (Table 5.4). CH₄ emissions declined (Table 5.5), while N₂O emissions increased (Table 5.6).

Table 5.4: Trends and changes in manure management emissions (2000 to 2020).

	Emissions (Gg CO ₂ e)		Change (2000 – 2020)		Share of manure management	
	2000	2020	Diff	%	2000	2020
					%	%
Methane	1 191.2	1 175.9	-15.3	-1.3	35.2	31.1
Nitrous oxide	2 190.5	2 606.3	415.8	19.0	64.8	68.9
Total manure management	3 381.7	3 782.2	400.5	11.8	100	100

Most of South Africa's livestock (cattle, sheep, goats, horses, mules and asses) are kept on pasture, range and paddock (Table 5.18), therefore the *Manure management* category emissions were relatively small in 2020. Methane from *Manure management* declined in 2019 and started to increase again in 2020 (Figure 5.4), while the N₂O emissions have been increasing from 2000 to 2015, after which the emissions started to level off. The N₂O emissions have remained constant since the last inventory in 2017. This is because,



even though, poultry numbers are increasing, the decline in cattle numbers has been counteracting this increase (Figure 5.5). Managed manure from non-dairy and dairy cattle contributed the most to the CH₄ emissions (37.9% and 35.2% respectively); while the largest contributors to the N₂O emissions were non-dairy cattle (51.5%) and poultry (37.4%).

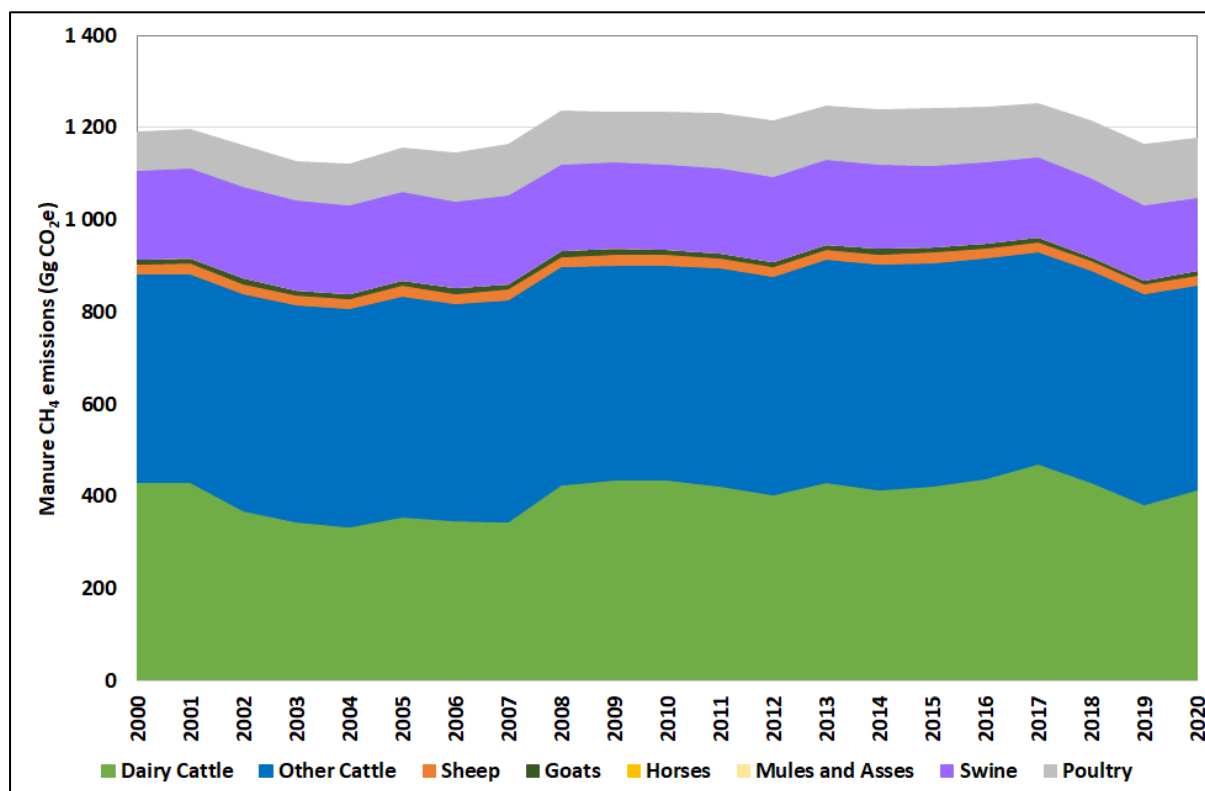


Figure 5.4: Trend in manure management CH₄ emissions from livestock, 2000 – 2020.

Table 5.5: *Manure management* CH₄ emission trends between 2000 and 2020.

	2000	2005	2010	2015	2016	2017	2018	2019	2020
	Gg CO ₂ e								
Dairy cattle	430.0	356.1	434.3	421.3	438.7	469.1	430.0	382.2	412.6
Other cattle	451.6	478.8	466.8	485.1	477.8	461.9	460.3	458.3	446.4
Buffalo	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sheep	22.1	22.4	23.2	23.6	22.8	21.9	20.8	19.5	21.1
Goats	11.3	11.6	11.6	10.7	10.3	10.0	9.8	9.5	9.4
Camels	NO	NO	NO	NO	NO	NO	NO	NO	NO
Horses	NO	NO	NO	NO	NO	NO	NO	NO	NO



	2000	2005	2010	2015	2016	2017	2018	2019	2020
	Gg CO ₂ e								
Mules & asses	NO	NO	NO	NO	NO	NO	NO	NO	NO
Swine	192.0	192.5	185.8	177.6	176.3	172.7	169.5	162.0	158.2
Poultry	84.2	94.5	112.0	123.5	118.3	115.1	123.8	131.6	128.2
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	1 191.2	1 155.8	1 233.8	1 241.8	1 244.1	1 250.6	1 214.2	1 163.3	1 175.9

Note: Numbers may not add exactly due to rounding off.

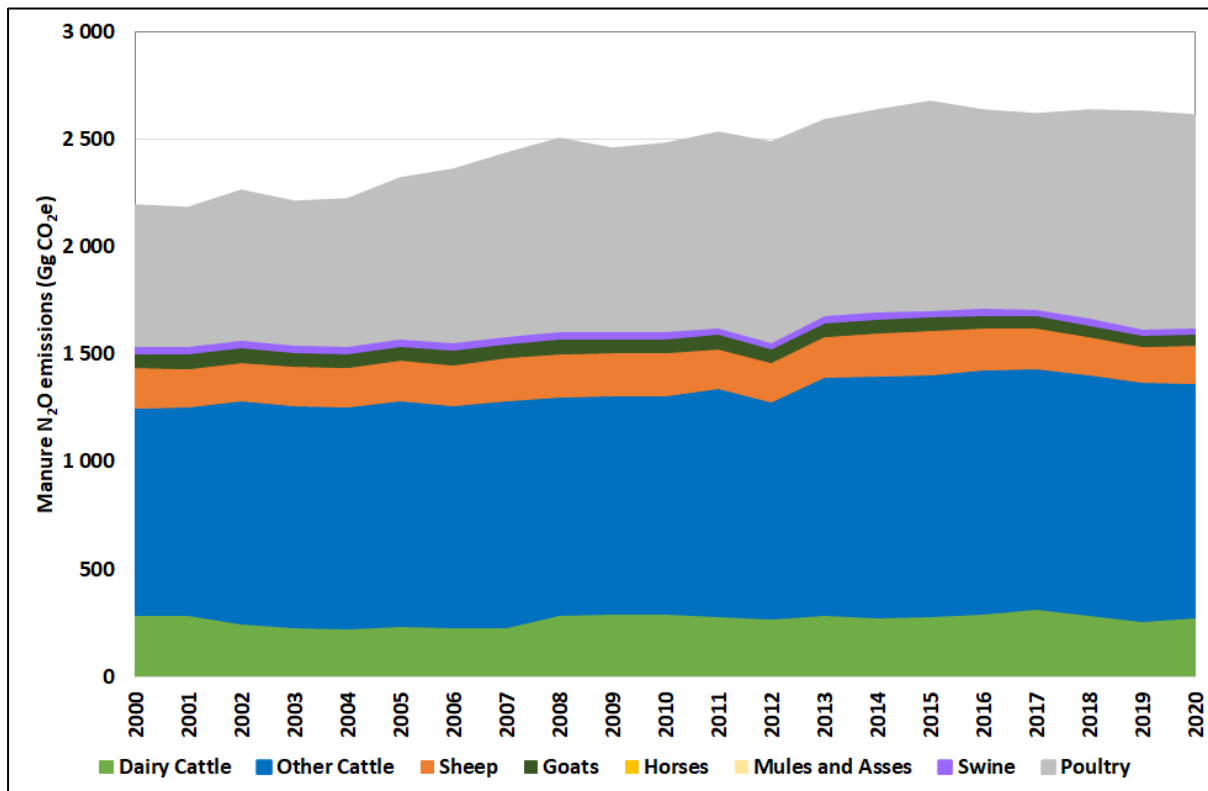


Figure 5.5: Trend in manure management N₂O emissions from livestock, 2000 – 2020.

Table 5.6: Manure management N₂O emission trends between 2000 and 2020.

	2000	2005	2010	2015	2016	2017	2018	2019	2020
	Gg CO ₂ e								
Dairy cattle	291.2	241.2	294.2	285.3	297.1	317.7	291.2	258.9	279.4
Other cattle	958.2	1 038.9	1 010.0	1 120.3	1 127.2	1 114.9	1 111.0	1 108.2	1 080.8



	2000	2005	2010	2015	2016	2017	2018	2019	2020
	Gg CO ₂ e								
Buffalo	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sheep	185.3	189.6	199.9	205.5	197.8	189.4	178.0	165.7	182.5
Goats	69.2	71.2	71.1	65.9	63.1	61.2	60.5	58.5	57.9
Camels	NO	NO	NO	NO	NO	NO	NO	NO	NO
Horses	NO	NO	NO	NO	NO	NO	NO	NO	NO
Mules & asses	NO	NO	NO	NO	NO	NO	NO	NO	NO
Swine	34.7	34.8	33.6	32.1	31.8	31.2	30.6	29.3	28.6
Poultry	651.9	740.4	866.9	962.3	910.9	897.8	958.3	1 004.1	977.1
Other	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	2 190.5	2 316.0	2 475.6	2 671.4	2 628.0	2 612.2	2 629.7	2 624.6	2 606.3

Note: Numbers may not add exactly due to rounding off.

Aggregated and non-CO₂ emissions on land (3C)

Emissions from *Aggregated and non-CO₂ emissions on land* are summarised in Table 5.7. *Direct N₂O from managed soils* contribute the most toward this category, while *Biomass burning* is the second largest contributor. The contribution from biomass burning and indirect N₂O from managed soils has declined since 2000, while all others increased. Emissions in this category have remained constant over the period of 2000 to 2020, except for a decline in 2003-2004 and 2015-2016 (Figure 5.6). Reduced emissions due to biomass burning appears to be the main contributor to these dips.

Table 5.7: Changes in aggregated and non-CO₂ emission sources on land between 2000 and 2020.

Category	Emissions (Gg CO ₂ e)		Change (2000 – 2020)	
	2000	2020	Diff	%
Biomass burning	1 936.6	1 649.2	-287.4	-14.8
Liming	384.1	942.3	558.2	145.3
Urea application	297.3	584.7	287.4	96.6
Direct N ₂ O from managed soils	12 363.6	12 825.3	461.7	3.7
Indirect N ₂ O from managed soils	1 256.4	1 200.4	-56.0	-4.5



Indirect N ₂ O from manure management	347.1	387.47	40.3	11.6
Total	16 585.0	17 589.3	1 004.3	6.0

Note: Numbers may not sum exactly due to rounding off.

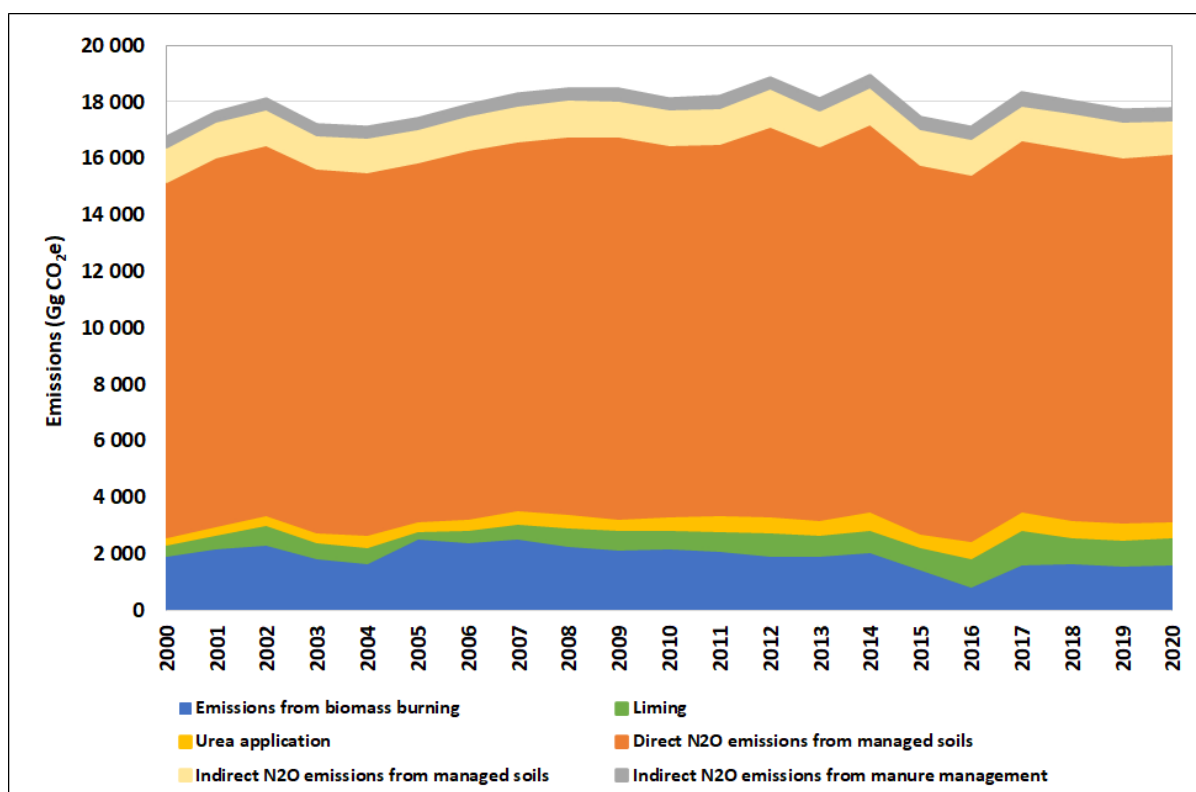


Figure 5.6: Trends in aggregated and non-CO₂ emissions on land, 2000 – 2020.

5.1.1.3 FOLU

Forest land (3B1)

Forest land was a sink between 2000 and 2004 after which it became a source. In 2011 Forest land became a sink again and this sink increased to 2020 (Figure 5.7). In 2020 the sink was estimated at 26 226 Gg CO₂. *Forest land remaining forest land* was the main contributor to the source between 2004 and 2008 due to biomass losses through fire and wood collection. Fuelwood removals⁵ decline over the time-series, due to increased electrification and reduced demand, but start to stabilise after 2017 (Figure 5.8) as the

⁵ Note that this is only fuelwood collected from live biomass, and thus excludes that collected as deadwood (see section 5.4.6 for more details).



number of households using wood does not change significantly over this period. This initial decline contributes to the increasing sink. Fuel wood removal could not be split between land remaining and land converted to forest land categories, therefore, all fuelwood losses were allocated to forest land remaining forest land. This would also contribute to the higher carbon losses and emissions from forest land remaining forest land.

Another driver is loss due to biomass burning. The burnt area declined between 2009 and 2016 and then increased again in 2017 and 2018 contributing to the increasing sink at this time. There are also emissions due to conversion between the various forest types and a conversion from indigenous forest to woodland, for example, leading to a loss of carbon. The last contributing factor to the increasing sink is the increasing Forest land area. Indigenous forest and woodland area increased, while thicket area decreased. The total forest land area increased from 20 795 653 ha to 21 007 068 ha between 1990 and 2020. Increasing area means an increase in the gains and this is enhanced by reduced losses. As more frequent and higher resolution land change data becomes available this pattern may change.

Plantations are shown to be a slight source of emissions; however this varies from year to year depending on the amount of wood removals and so in some years it is a sink, but numbers vary around zero.

Grasslands converted to forest lands are the largest sink component in the converted lands category, along with *Other lands converted to Forest lands*. Biomass is the dominant pool contributing to change in the Forest land (Table 5.8).

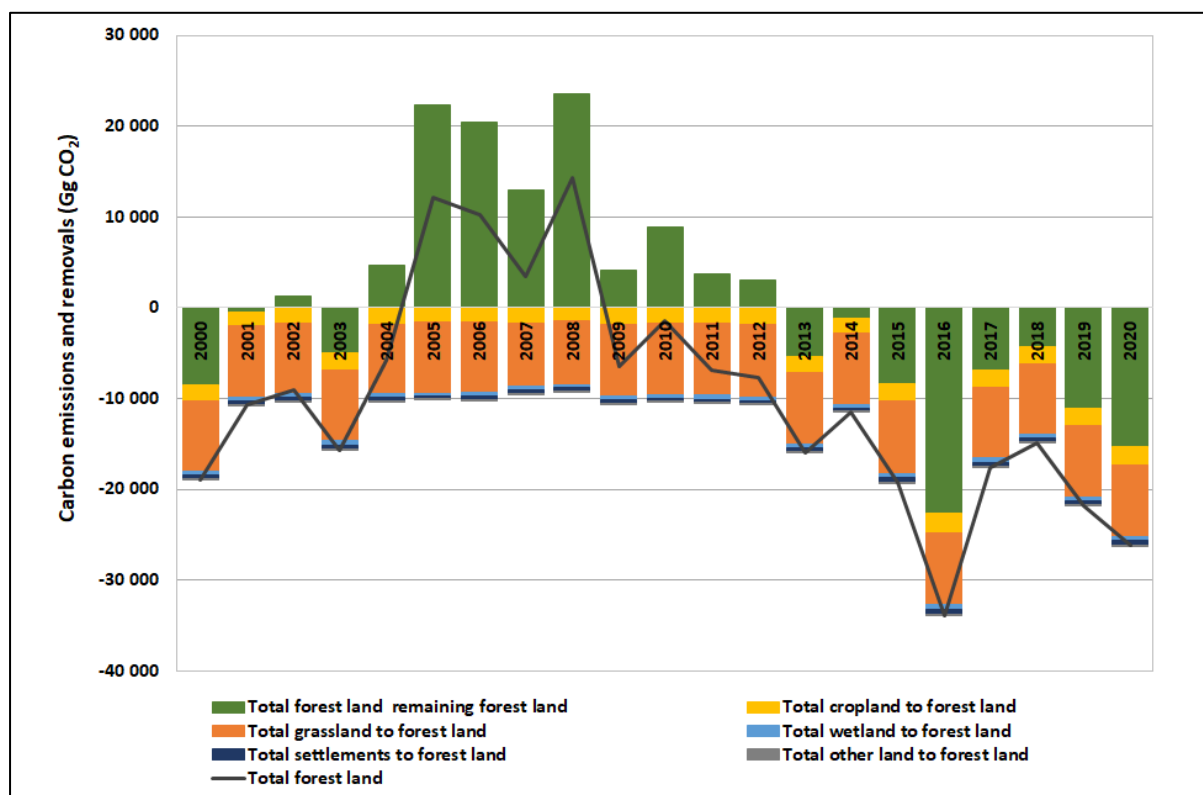


Figure 5.7: South Africa's carbon stock change (Gg CO₂) for Forest land, 2000 – 2020.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

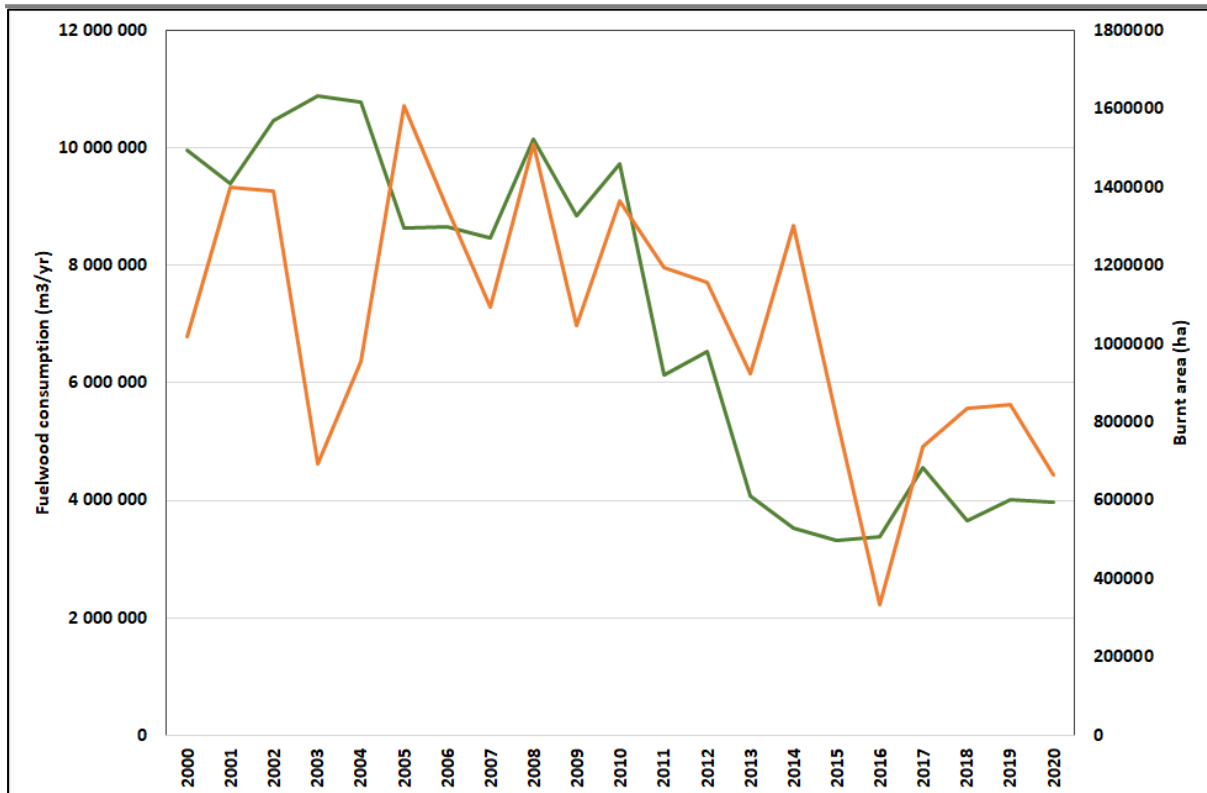


Figure 5.8: Estimated fuelwood consumption (green) and forest burnt area (orange) between 2000 and 2020.

Table 5.8: South Africa's net carbon stock change (Gg CO₂) by carbon pool for the Forest land, 2000 – 2020.

	Forest land remaining forest land			Land converted to forest land		
	Biomass	DOM	Mineral soil	Biomass	DOM	Mineral soil
2000	-4 260.8	106.1	-4 284.6	-10 191.2	-317.2	IE
2001	3 753.5	106.1	-4 284.6	-9 963.9	-317.2	IE
2002	5 443.6	106.1	-4 284.6	-10 027.8	-317.2	IE
2003	-778.8	106.1	-4 284.6	-10 425.7	-317.2	IE
2004	8 851.6	106.1	-4 284.6	-10 126.1	-317.2	IE
2005	26 512.7	106.1	-4 284.6	-9 823.4	-317.2	IE
2006	24 663.7	106.1	-4 284.6	-9 864.6	-317.2	IE
2007	17 133.6	106.1	-4 284.6	-9 202.9	-317.2	IE
2008	27 758.5	106.1	-4 284.6	-8 890.7	-317.2	IE
2009	8 356.9	106.1	-4 284.6	-10 329.9	-317.2	IE



2010	13 128.8	106.1	-4 284.6	-10 068.9	-317.2	IE
2011	7 905.0	106.1	-4 284.6	-10 245.8	-317.2	IE
2012	7 159.7	106.1	-4 284.6	-10 378.9	-317.2	IE
2013	-1 135.1	106.1	-4 284.6	-10 342.1	-317.2	IE
2014	3 050.9	106.1	-4 284.6	-10 061.3	-317.2	IE
2015	-4 216.4	106.1	-4 284.6	-10 576.1	-317.2	IE
2016	-18 439.5	106.1	-4 284.6	-10 944.5	-317.2	IE
2017	-2 669.2	106.1	-4 284.6	-10 449.7	-317.2	IE
2018	-88.8	106.1	-4 284.6	-10 326.4	-317.2	IE
2019	-6 887.9	106.1	-4 284.6	-10 409.4	-317.2	IE
2020	-11 151.5	106.1	-4 284.6	-10 578.7	-317.2	IE

Cropland (3B2)

Croplands are estimated to be an overall source of CO₂. *Cropland remaining cropland* is a sink (3 817 Gg CO₂ in 2020) and this is mainly due to biomass in orchards and vineyards and mineral SOC. *Land converted to croplands* emitted 1 002 Gg CO₂ in 2020 (Figure 5.9) and this is because all land types, except for *Other lands*, converted to croplands results in an emission of CO₂. The dominant contributor to the emissions is the conversion of *Forest lands* to *Croplands*. There is some annual variation in the emissions and these are due to losses due to fire and also changes in management practices or areas of the various crop types. For *Croplands remaining croplands* the sink is declining very slightly between 2000 and 2020 and this is because only the growth in orchards and vineyards is considered and these show a slight decline in area. In *Land converted to croplands* there is little annual variation as there are not large changes in crop areas and management. The SOC pool is the dominant carbon pool followed by biomass (Table 5.9).

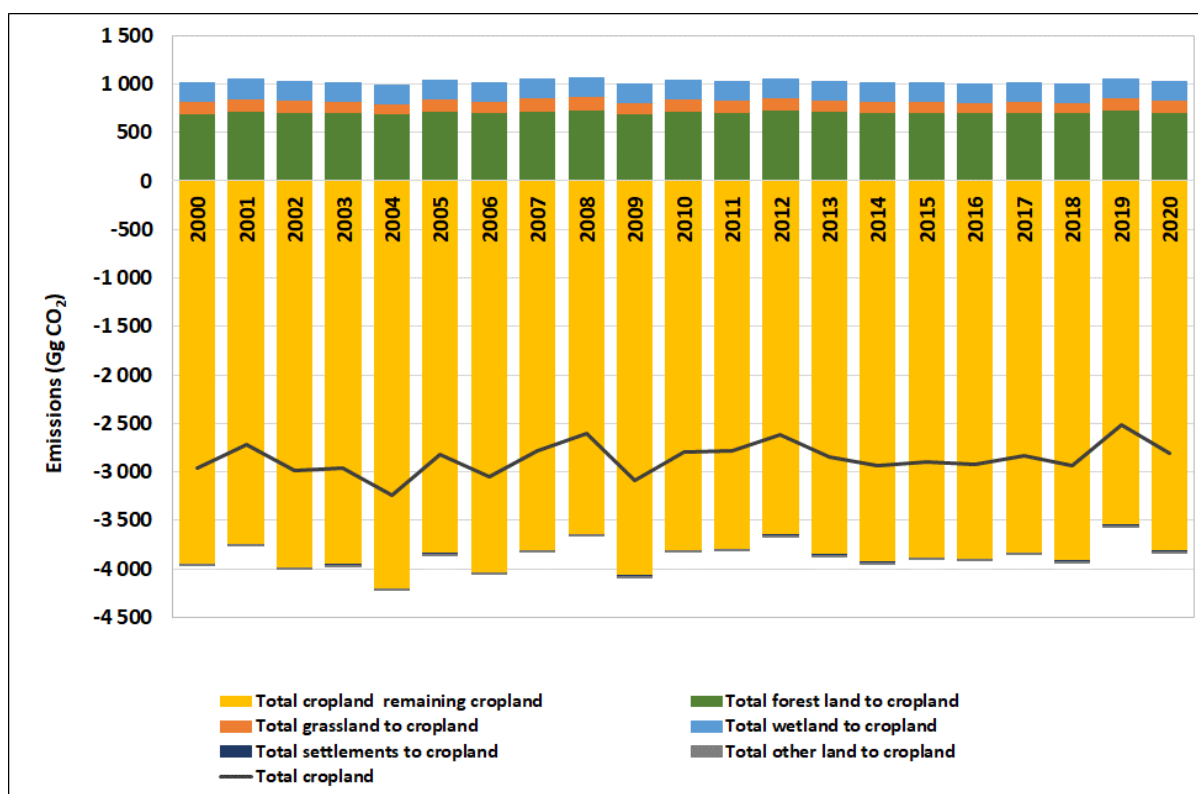


Figure 5.9: CO₂ emissions and removals (Gg CO₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Cropland.

Table 5.9: South Africa's net carbon stock change (Gg CO₂) by carbon pool for Croplands, 2000 – 2020.

	Cropland remaining cropland			Land converted to cropland		
	Biomass	DOM	Mineral soil	Biomass	DOM	Mineral soil
2000	-1 548.4	29.1	-2 436.6	1 082.3	-53.1	IE
2001	-1 342.0	29.1	-2 436.6	1 111.7	-53.1	IE
2002	-1 582.9	29.1	-2 436.6	1 082.2	-53.1	IE
2003	-1 550.2	29.1	-2 436.6	1 081.1	-53.1	IE
2004	-1 798.4	29.1	-2 436.6	1 045.9	-53.1	IE
2005	-1 434.6	29.1	-2 436.6	1 105.1	-53.1	IE
2006	-1 635.1	29.1	-2 436.6	1 074.5	-53.1	IE
2007	-1 406.2	29.1	-2 436.6	1 110.9	-53.1	IE
2008	-1 236.9	29.1	-2 436.6	1 125.1	-53.1	IE
2009	-1 664.8	29.1	-2 436.6	1 063.6	-53.1	IE
2010	-1 407.9	29.1	-2 436.6	1 099.1	-53.1	IE



2011	-1 388.6	29.1	-2 436.6	1 092.9	-53.1	IE
2012	-1 246.2	29.1	-2 436.6	1 114.7	-53.1	IE
2013	-1 447.0	29.1	-2 436.6	1 087.2	-53.1	IE
2014	-1 523.5	29.1	-2 436.6	1 076.2	-53.1	IE
2015	-1 483.6	29.1	-2 436.6	1 071.1	-53.1	IE
2016	-1 492.4	29.1	-2 436.6	1 062.3	-53.1	IE
2017	-1 426.9	29.1	-2 436.6	1 079.5	-53.1	IE
2018	-1 514.8	29.1	-2 436.6	1 064.9	-53.1	IE
2019	-1 144.2	29.1	-2 436.6	1 119.5	-53.1	IE
2020	-1 409.6	29.1	-2 436.6	1 084.6	-53.1	IE

Grassland (3B3)

Grasslands remaining grasslands are a sink of CO₂ (Figure 5.10) due mainly to the SOC pool, but also because of the conversions of low shrubland and degraded land (which are also included under *Grasslands*) to grasslands. The sink amounted to 11 309 Gg CO₂ in 2020. *Land converted to grassland* is a sink of 5 167 Gg CO₂ in 2020. There is annual variation and the driver of the annual variation is burnt area which varies across the time-series. The dominant contributor to the land conversion sink is the conversion of *Other land* to *Grassland* as this represents both a gain in biomass and soil carbon. Soil carbon contributed 66.0% to the *Grassland* sink (Table 5.10).

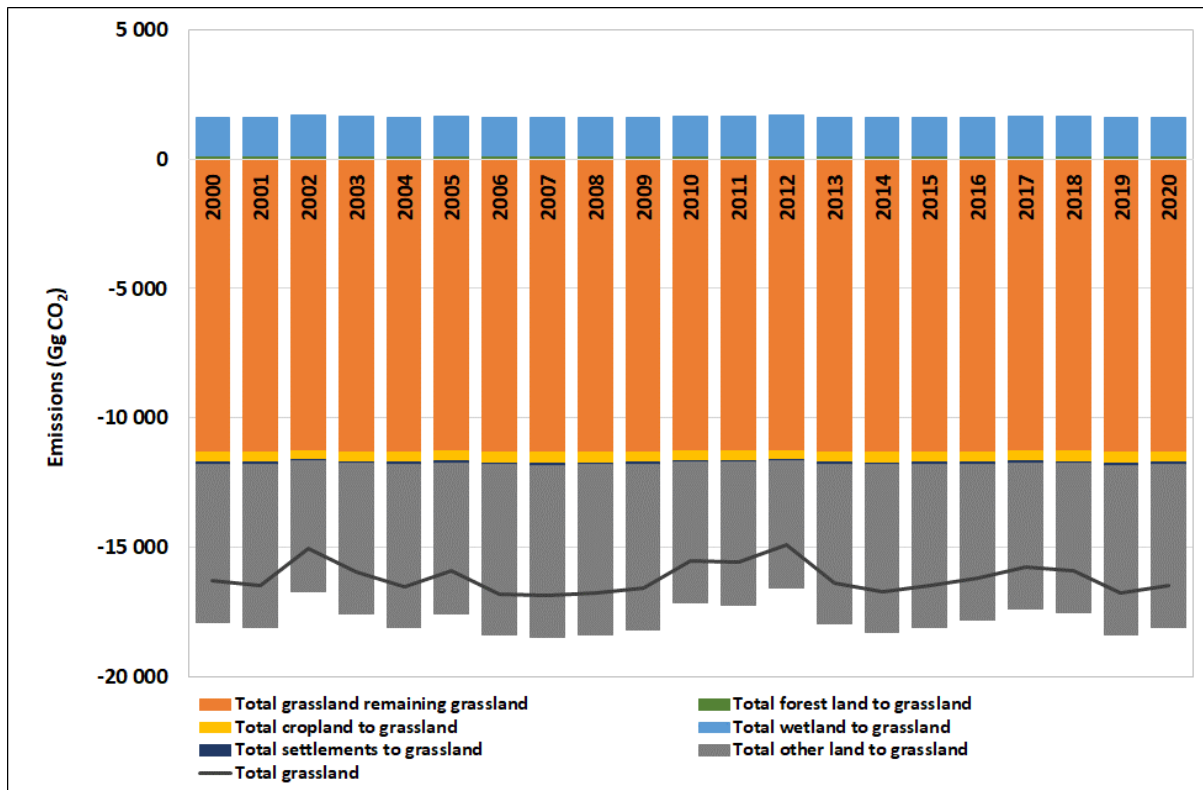


Figure 5.10: CO₂ emissions and removals (Gg CO₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Grassland.

Table 5.10: South Africa's net carbon stock change (Gg CO₂) by carbon pool for Grasslands, 2000 – 2020.

	Grassland remaining grassland			Land converted to grassland		
	Biomass	DOM	Mineral soil	Biomass	DOM	Mineral soil
2000	-422.9	-2.4	-10 877.1	-4 573.2	-398.5	IE
2001	-428.0	-2.4	-10 877.1	-4 753.7	-398.5	IE
2002	-390.1	-2.4	-10 877.1	-3 367.9	-398.5	IE
2003	-416.4	-2.4	-10 877.1	-4 237.5	-398.5	IE
2004	-429.4	-2.4	-10 877.1	-4 797.9	-398.5	IE
2005	-412.8	-2.4	-10 877.1	-4 222.0	-398.5	IE
2006	-434.5	-2.4	-10 877.1	-5 063.8	-398.5	IE
2007	-440.8	-2.4	-10 877.1	-5 139.5	-398.5	IE
2008	-435.7	-2.4	-10 877.1	-5 048.3	-398.5	IE
2009	-431.7	-2.4	-10 877.1	-4 857.5	-398.5	IE
2010	-403.2	-2.4	-10 877.1	-3 825.5	-398.5	IE



2011	-402.5	-2.4	-10 877.1	-3 879.0	-398.5	IE
2012	-388.4	-2.4	-10 877.1	-3 240.6	-398.5	IE
2013	-426.2	-2.4	-10 877.1	-4 647.5	-398.5	IE
2014	-435.4	-2.4	-10 877.1	-4 972.5	-398.5	IE
2015	-430.4	-2.4	-10 877.1	-4 758.9	-398.5	IE
2016	-424.0	-2.4	-10 877.1	-4 472.2	-398.5	IE
2017	-411.1	-2.4	-10 877.1	-4 057.0	-398.5	IE
2018	-414.7	-2.4	-10 877.1	-4 213.8	-398.5	IE
2019	-438.1	-2.4	-10 877.1	-5 050.8	-398.5	IE
2020	-429.8	-2.4	-10 877.1	-4 768.8	-398.5	IE

Wetlands (3B4)

Wetlands, assumed to be wetlands on mineral soils, are an overall source of emissions over the period 2000 to 2020 (Figure 5.11) with an emission of 2 673 Gg CO₂e (excluding CH₄ and N₂O emissions) in 2020. *Wetlands remaining wetlands* contribute the most to the source and this is due to conversions between wetlands and waterbodies. A conversion of a wetland to a waterbody results in a loss of carbon. Land conversions to wetlands led to a sink of 1 155 Gg CO₂e in 2020 with the main contributor being the conversion of grasslands to wetlands.

Non-CO₂ emissions add an additional 1 629 Gg CO₂e to the total in 2020, which declined from 2 169 Gg CO₂e in 2000. The decline in non-CO₂ emissions was as a result of the decline in the wetland area between 2000 and 2020.

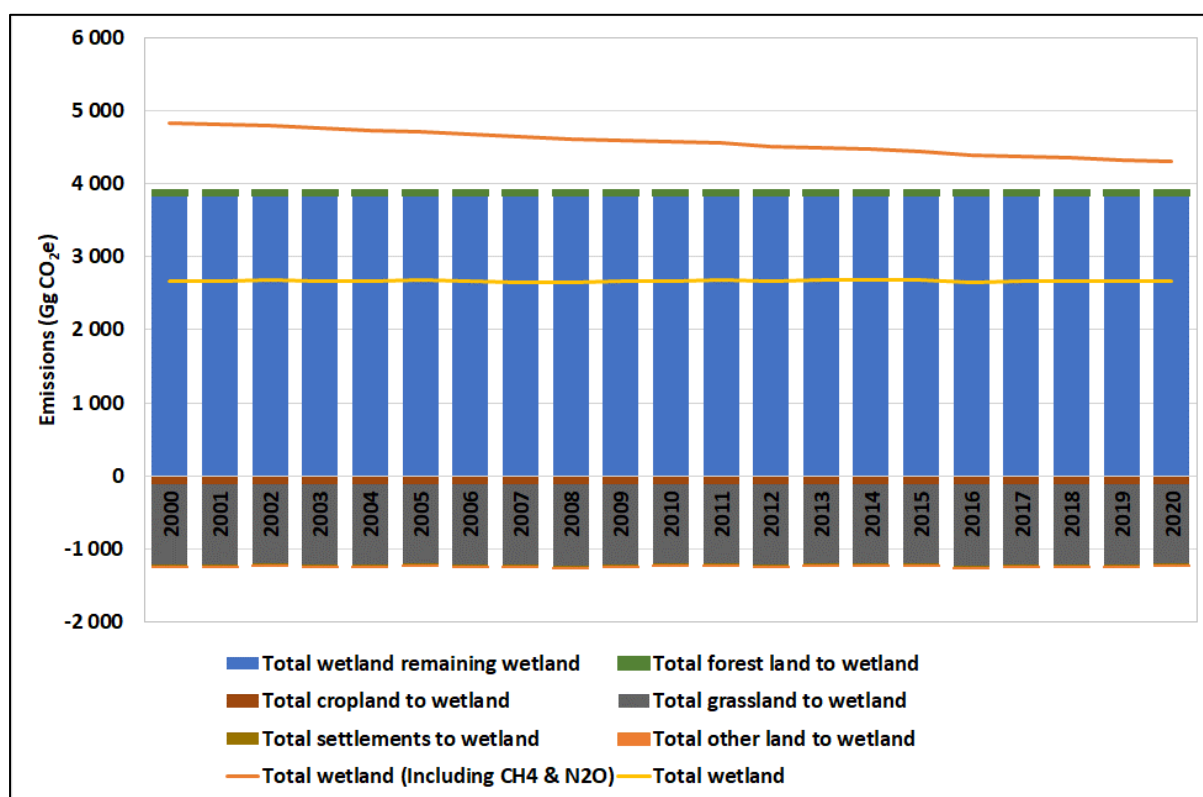


Figure 5.11: CO₂ emissions and removals (Gg CO₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Wetlands.

Settlements (3B5)

Settlements were estimated to be a sink of CO₂ (Figure 5.12) and this is due to the presence of biomass in settlement areas. Conversion of land to settlements results in an emission of CO₂, except when *Other land* is converted to settlements. Forest land converted to *Other land* is the main contributor to the land conversion emissions. The emission is due to the loss of biomass and a reduction in SOC. The biomass pool is dominant in the *Settlements* category (Table 5.11).

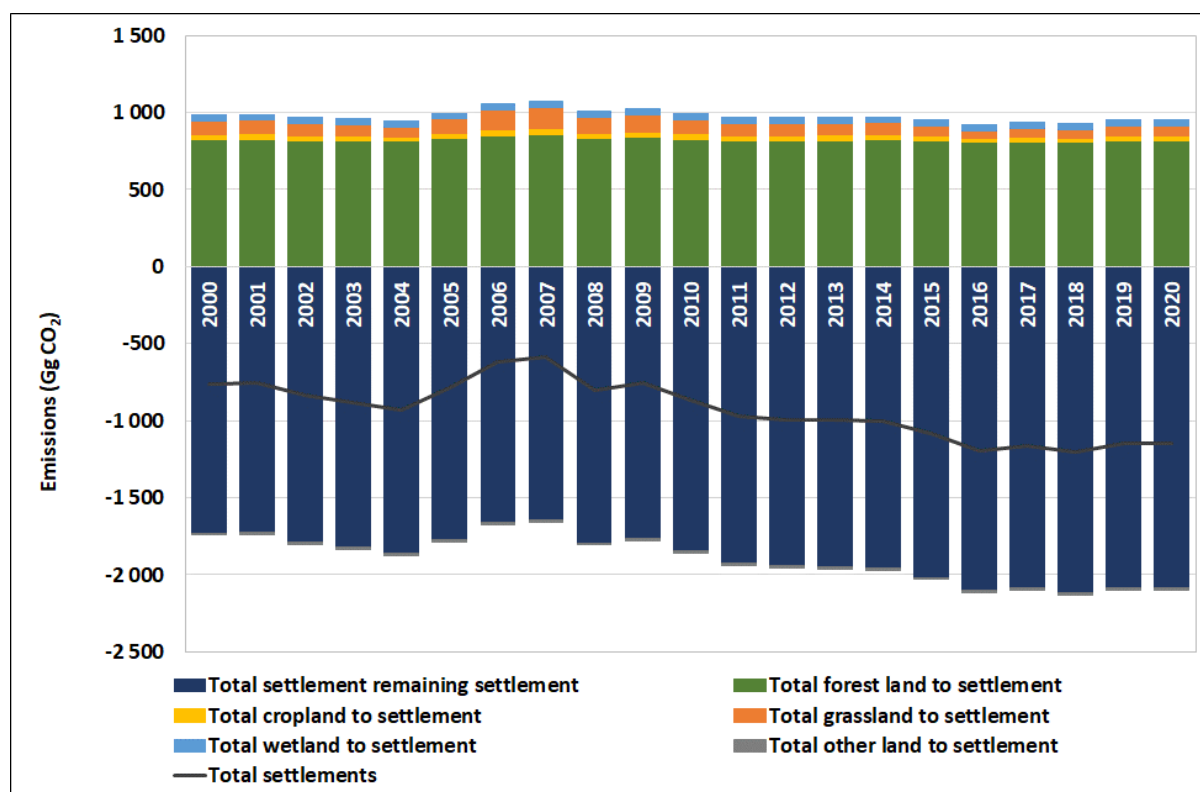


Figure 5.12: CO₂ emissions and removals (Gg CO₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Settlements.

Table 5.11: South Africa's net carbon stock change (Gg CO₂) by carbon pool for Settlements, 2000 – 2020.

	Settlements remaining settlements			Land converted to settlements		
	Biomass	DOM	Mineral soil	Biomass	DOM	Mineral soil
2000	-1 555.4	5.5	-178.3	984.8	-17.4	IE
2001	-1 554.8	5.5	-178.3	992.5	-17.4	IE
2002	-1 616.5	5.5	-178.3	969.4	-17.4	IE
2003	-1 649.7	5.5	-178.3	960.4	-17.4	IE
2004	-1 689.5	5.5	-178.3	948.3	-17.4	IE
2005	-1 598.8	5.5	-178.3	1 000.1	-17.4	IE
2006	-1 489.7	5.5	-178.3	1 060.5	-17.4	IE
2007	-1 471.8	5.5	-178.3	1 075.6	-17.4	IE
2008	-1 621.8	5.5	-178.3	1 010.3	-17.4	IE
2009	-1 593.5	5.5	-178.3	1 030.5	-17.4	IE
2010	-1 675.3	5.5	-178.3	998.6	-17.4	IE



2011	-1 751.1	5.5	-178.3	971.4	-17.4	IE
2012	-1 770.6	5.5	-178.3	969.2	-17.4	IE
2013	-1 776.6	5.5	-178.3	973.5	-17.4	IE
2014	-1 786.1	5.5	-178.3	976.1	-17.4	IE
2015	-1 846.5	5.5	-178.3	953.9	-17.4	IE
2016	-1 929.7	5.5	-178.3	923.9	-17.4	IE
2017	-1 914.3	5.5	-178.3	937.3	-17.4	IE
2018	-1 947.4	5.5	-178.3	930.6	-17.4	IE
2019	-1 911.6	5.5	-178.3	952.6	-17.4	IE
2020	-1 915.7	5.5	-178.3	957.9	-17.4	IE

Other lands (3B6)

Other lands are estimated to be a source of CO₂ due to the loss of carbon in the *Other land remaining other land* and the *land converted to other lands* (Figure 5.13) categories. Both biomass and soil carbon is lost when vegetated lands are converted to non-vegetated lands. Grasslands converted to other lands is the dominant contributor to the emissions. The soil and biomass carbon pools are important in the category (Table 5.12).

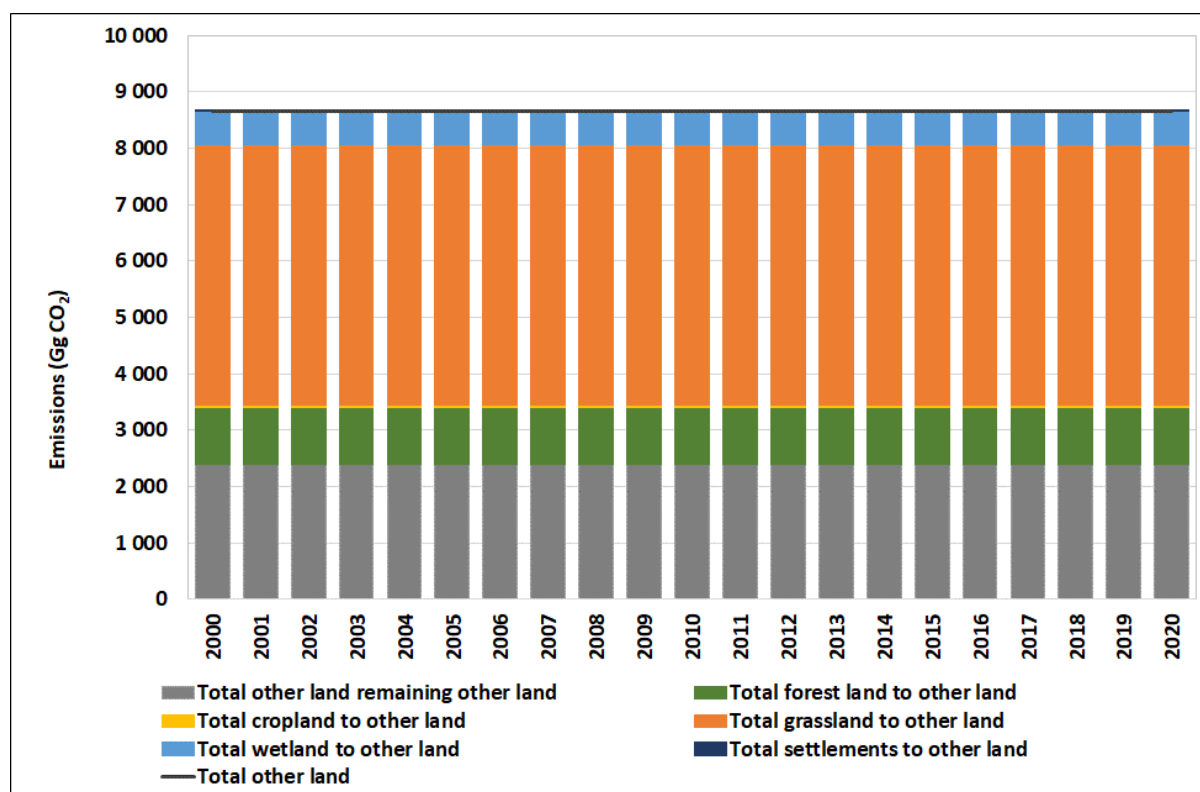


Figure 5.13: CO₂ emissions and removals (Gg CO₂) due to changes in carbon stocks between 2000 and 2020 for South Africa's Other lands.

Table 5.12: South Africa's net carbon stock change (Gg CO₂) by carbon pool for Other lands, 2000 – 2020.

	Other land remaining other land			Land converted to other land		
	Biomass	DOM	Mineral soil	Biomass	DOM	Mineral soil
2000	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2001	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2002	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2003	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2004	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2005	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2006	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2007	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2008	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2009	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2010	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2011	0.0	0.0	2 385.6	5 181.2	1 092.2	IE



2012	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2013	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2014	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2015	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2016	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2017	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2018	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2019	0.0	0.0	2 385.6	5 181.2	1 092.2	IE
2020	0.0	0.0	2 385.6	5 181.2	1 092.2	IE

Harvested wood products (3D1)

In 2020 harvested wood products were a source of 635 Gg CO₂ (Table 5.13). Most years prior to 2009 showed a sink, while most years thereafter are a source of CO₂. There is annual variability which is related to production and the exports.

Table 5.13: Trends in HWP net emissions and removals between 2000 and 2020.

	HWP Gg CO ₂ e
2000	-2 106.2
2001	-1 394.3
2002	-919.1
2003	-2 792.4
2004	-2 531.0
2005	-3 931.0
2006	-3 865.1
2007	-1 002.1
2008	-796.0
2009	139.4
2010	1 155.8
2011	-138.2
2012	322.3
2013	529.0
2014	1 700.6
2015	303.7
2016	1 262.5



2017	-588.8
2018	-900.7
2019	1 003.6
2020	635.2

Note: Negative values are a sink, while positive values show emissions.

5.1.2 Overview of methodology and completeness

The IPCC 2006 methodology is applied in this sector, with a few updated methodologies being taken from the IPCC 2019 Refinement. 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 5.14 shows the methods and types of EF used in the AFOLU inventory.



Table 5.14: Summary of methods and emission factors for the AFOLU sector and an assessment of the completeness of the AFOLU 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				
3A LIVESTOCK	1 Enteric fermentation										
	a.i. Dairy cattle	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
	a.ii. Other cattle	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
	b. Buffalo	NA	NA	NO	NO	NA	NA	NA	NA	NA	NA
	c. Sheep	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
	d. Goats	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
	e. Camels	NA	NA	NO	NO	NA	NA	NA	NA	NA	NA
	f. Horses	NA	NA	T1	DF	NA	NA	NA	NA	NA	NA
	g. Mules and asses	NA	NA	T1	DF	NA	NA	NA	NA	NA	NA
	h. Swine	NA	NA	T2	CS	NA	NA	NA	NA	NA	NA
	j. Other	NA	NA	NO	NO	NA	NA	NA	NA	NA	NA
	2 Manure management										
	a.i. Dairy cattle	NA	NA	T2	CS	T2	DF	NE	NA	NA	NE
	a.ii. Other cattle	NA	NA	T2	CS	T2	DF	NE	NA	NA	NE
	b. Buffalo	NA	NA	NO	NO	NO	NO	NE	NA	NA	NE
	c. Sheep	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE
	d. Goats	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE
	e. Camels	NA	NA	NO	NO	NO	NO	NE	NA	NA	NE
	f. Horses	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE
	g. Mules and asses	NA	NA	T2	CS	NO	NO	NE	NA	NA	NE
	h. Swine	NA	NA	T2	CS	T2	DF	NE	NA	NA	NE
	i. Poultry	NA	NA	T2	CS	T2	DF	NE	NA	NA	NE
	j. Other	NA	NA	NO	NO	NO	NO	NE	NA	NA	NE



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3B LAND

1 Forest land										
a. Forest land remaining forest land	Biomass: T2	Biomass: CS	NE		NE					
	Litter: T2	Litter: CS								
	Soil: T2	Soil: CS								
b. Land converted to forest land	Biomass: T2	Biomass: CS	NE		NE					
	Litter: T2	Litter: CS								
	Soil: IE	Soil: IE								
2 Cropland										
a. Cropland remaining cropland	Biomass: T1	Biomass: CS	NE		NE					
	Litter: T1	Litter: CS								
	Soil: T2	Soil: CS								
b. Land converted to cropland	Biomass: T2	Biomass: CS	NE		NE					
	Litter: T2	Litter: CS								
	Soil: IE	Soil: IE								
3 Grassland										
a. Grassland remaining grassland	Biomass: T1	Biomass: DF	NE		NE					
	Litter: T2	Litter: CS								
	Soil: T2	Soil: CS								
b. Land converted to grassland	Biomass: T2	Biomass: CS	NE		NE					
	Litter: T2	Litter: CS								
	Soil: IE	Soil: IE								
4 Wetland										
a. Wetland remaining wetland	Biomass: T1 Litter: T2 Soils: T2	Biomass: CS Litter: CS Soil: CS	T1	CS	T1	CS				
b. Land converted to wetland	Biomass: T2 Litter: T2 Soil: IE	Biomass: CS Litter: CS Soil: IE	NE		NE					
5 Settlements										
a. Settlements remaining settlements	Biomass: T2	Biomass: CS	NE		NE					
	Litter: T2	Litter: CS								



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

b. Land converted to settlements	Soil: T2	Soil: CS									
	Biomass: T2	Biomass: CS	NE		NE						
	DOM: T2	Litter: CS									
	Soil: IE	Soil: IE									
6 Other land											
a. Other land remaining other land	Biomass: NE		NE		NE						
	Soil: T2	Soil: CS									
b. Land converted to other land	Biomass: T2	Biomass: CS	NE		NE						
	Soil: IE	Soil: IE									
1 Biomass burning											
Biomass burning in all lands	T2	DF, CS	T2	DF, CS	T2	DF, CS					
2 Liming											
Liming	T1	DF	NA		NA		NA	NA	NA	NA	
3 Urea application											
Urea application	T1	DF	NA		NA		NA	NA	NA	NA	
4 Direct emissions from managed soils											
Synthetic fertilizers	NA		NA		T1	DF		NA	NA		
Animal waste added to soils	NA		NA		T1	DF		NA	NA		
Other organic fertilizers	NA		NA		T1	DF		NA	NA		
Urine and dung deposited by grazing livestock	NA		NA		T1	DF		NA	NA		
Crop residues	NA		NA		T1	DF		NA	NA		
5 Indirect emissions from managed soils											
Atmospheric deposition	NA		NA		T1	DF					
Nitrogen leaching and runoff	NA		NA		T1	DF					
6 Indirect emissions from manure management											
Volatilization	NA		NA		T1	DF					
Nitrogen leaching and runoff	NA		NA		T1	DF					
7 Rice cultivation											
Rice cultivation	NO		NO		NO						



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3D OTHER	1 Harvested wood products									
	Harvested wood products	T2	DF	NA		NA				
	2 Other									
	Other	NO		NA		NA				

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 since the 2017 submission

The AFOLU sector is under continual improvement which leads to recalculations. The recalculations for the AFOLU sector led to an average 1.8% increase in the estimates excluding FOLU and an average 23.0% increase (although this varied annually) in emissions including FOLU (Figure 5.14).

The recalculations led to a 25.1% increase in the 2017 estimates for *Livestock* with the main improvements being:

- a) Incorporation of Tier 2 data for enteric fermentation and manure management emission factor calculations for cattle, goats and sheep;
- b) Changes in livestock categorisation; and
- c) Updated manure management data.

These updates also had an impact on the *Aggregated and non-CO₂ emissions on land* which showed a 19.0% decrease in the 2017 emission estimates. Other updates in this category include:

- a) Updated MODIS collection 6 burnt area data.

The *Land* category showed a 18.5% decline in the 2017 sink estimate which was high compared to the other years. This was because there was a correction in the burnt area data for 2017. Between 2011 and 2019 the recalculated emission values were, on average, 18.9% higher than was estimated in the previous inventory. These recalculations For the other years an average decline of 23.0% in emission estimates was seen due to:

- a) Incorporation of 1990-2018 land change data;
- b) Incorporation of updated biomass and DOM data;
- c) Updated biomass accumulation rates;
- d) Division of forests into primary and secondary forest to include different growth rates;
- e) Inclusion of mortality in forest land and harvest losses in croplands;
- f) Incorporation of country specific SOC reference data and stock change data;
- g) Inclusion of CO₂, CH₄ and N₂O emissions from wetlands in mineral soils; and
- h) Updated plantation BCEF factors.

Recalculations for *HWP* due to the inclusion of country specific data produced a 24.2% decline in the 2017 estimates, but this varied annually (showing both increases and decreases) over the full time series.



Specific details of the improvements and their impacts are provided in the relevant category sections below.

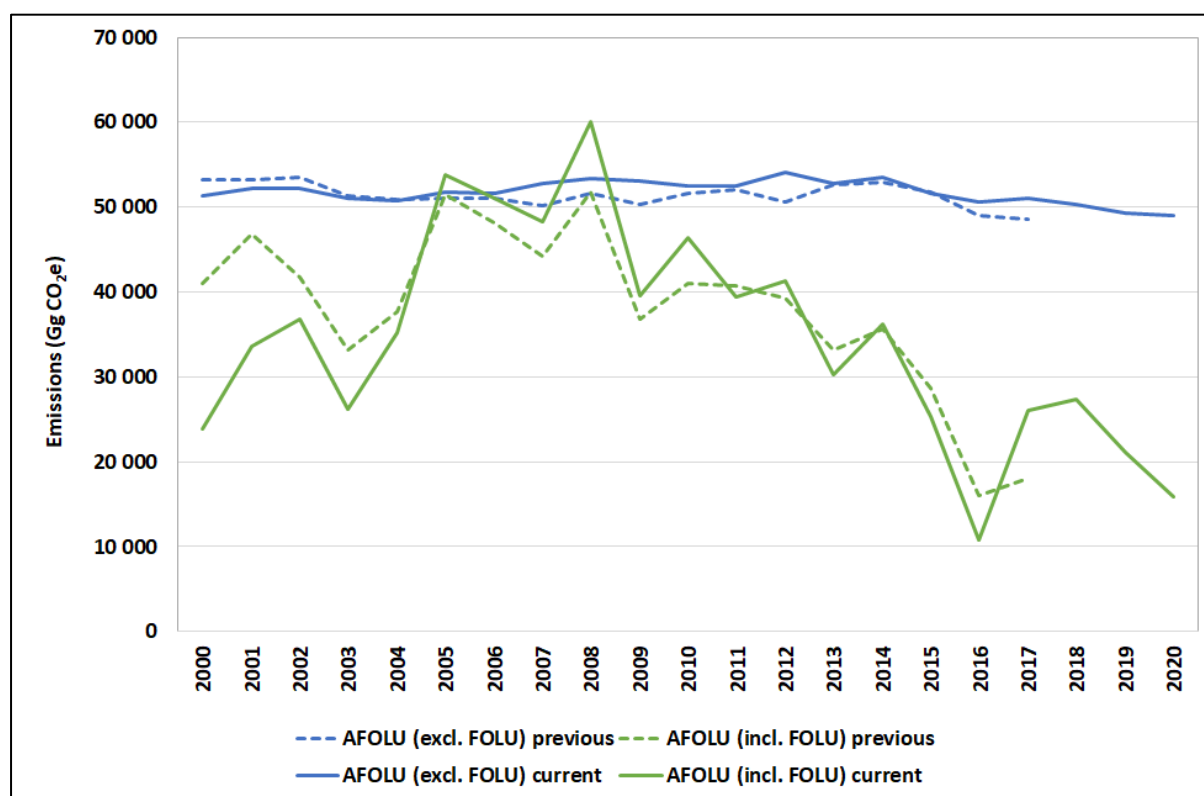


Figure 5.14: Change in AFOLU emission estimates due to recalculations since 2017 submission.

In addition to the actual estimates, time was spent on improving the calculation files to improve their transparency. A lot of detail and verification was incorporated into the agriculture calculation file along with data sources. It was noted in the previous inventory review that the Land sector excel file was very large and complex making it difficult to complete error and logic checking. Therefore, an attempt was made to improve the transparency of the file and to include all calculations and equations so data could be followed through. In addition, factors were named in the equations and details of the equations included. In future, however, it would be useful to move towards a more dynamic model, such as FLINT, which can use spatial data and incorporate models as well. In a previous inventory an attempt was made to use the ALU software (<https://www.nrel.colostate.edu/projects/alusoftware/download-software.php>) as it can take spatial data as an input, however the numbers of categories in South Africa's land cover maps (72 classes), together with 6 soil types and the various biomes created a huge number of data points and so the software was running at its limit. Also, data



needed to be entered for all data points and so time was a limitation. Moving towards the use of FLINT is a more appropriate option and this way the Land inventory can move towards a Tier 3 approach.

5.1.4 Key categories in the AFOLU sector

The key categories for the AFOLU sector are shown in Table 5.15 with the detailed key category results presented in Appendix B.

Table 5.15: Key categories in the AFOLU sector in 2020.

IPCC Code	Category	GHG	Identification Criteria [#]
3A1a	Enteric fermentation - cattle	CH ₄	L,T
3A1c	Enteric fermentation - sheep	CH ₄	L,T
3A1d	Enteric fermentation - goats	CH ₄	L
3B1a	Forest land remaining forest land	CO ₂	L,T
3B1b	Land converted to forest land	CO ₂	L,T
3B2a	Cropland remaining cropland	CO ₂	L
3B3a	Grassland remaining grassland	CO ₂	L
3B3b	Land converted to grassland	CO ₂	L
3B4	Wetlands	CH ₄	L,T
3B4a	Wetland remaining wetland	CO ₂	L
3B4b	Land converted to wetlands	CO ₂	L
3B5a	Settlements remaining settlements	CO ₂	L
3B6a	Other land remaining other land	CO ₂	L
3B6b	Land converted to other land	CO ₂	L
3C2	Liming	CO ₂	T
3C4	Direct N ₂ O from managed soil	N ₂ O	L,T
3C5	Indirect N ₂ O emissions from managed soils	N ₂ O	L
3D1	Harvested wood products	CO ₂	T

[#]L = Level Assessment; T = Trend Assessment

5.1.5 Planned improvements and recommendations

In terms of livestock there are three recommendations for improving estimates in the future:



-
- a) Improve livestock population data: There have been several studies on the emission factors and now the population data is the most uncertain component. Setting up a Livestock Estimates Committee could assist with this, although this has been mentioned before and not much progress has been made in terms of the committee. Further engagement is required between DFFE and the Department of Agriculture. It could also be an activity to discuss the Agricultural Research Council which has a livestock division.
 - 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.

In terms of the LULUCF sector there are also three very critical issues which need attention, and which are a much higher priority than the agriculture improvement requirements, and these are:

- a) Set up a land mapping platform that can integrate the various land change maps, along with other additional data. This is already being planned and put in place. Collect Earth can also be considered for map validation purposes;
- b) Continue to update the National Terrestrial Carbon Sinks Assessment (NTCSA) carbon density maps and integrate this with the land mapping system. A dynamic model, such as FLINT, should be considered in future; and
- c) Conduct a detailed uncertainty analysis on all LULUCF data, particularly the spatial data. This was due to happen in this inventory but there was insufficient capacity and data to complete the uncertainty analysis.

5.2 Livestock (3.A)

5.2.1 Livestock population and characterisation

5.2.1.1 Population data sources and estimations



The data sources for the livestock population estimates are shown in Table 5.16. The main data source is the Abstracts of Agricultural Statistics (DALRRD, 2021a) which is a sustainable data source released every year. In addition, the total livestock number for cattle, sheep, goats and pigs is obtained from data provided by the DALRRD (2021b). The same data for number of animals of the various animal groups is used in all the different calculations of emissions.

Table 5.16: Livestock population data sources.

Livestock category		Data source
Cattle	Total cattle	DALRRD (2021b)
	Commercial dairy cows (>2yrs)	DALRRD (2021a)
	Commercial dairy heifers (1-2 yrs)	DALRRD (2021a)
	Feedlot cattle	Feedlot SA (2021)
	Commercial other cattle total	DALRRD (2021a)
	Subsistence cattle	Calculated (see text)
Sheep	Total sheep	DALRRD (2021b)
	Commercial sheep total	DALRRD (2021a)
	Feedlot sheep	Calculated from DALRRD (2021a) slaughter data (see text)
	Subsistence sheep	Calculated (see text)
Goats	Total goats	DALRRD (2021b)
	Commercial goats total	DALRRD (2021a)
	Subsistence goats	Calculated (see text)
Horses, mules and asses		FAOSTAT (2021)
Swine	Total swine	DALRRD (2021b)
	Commercial swine	Calculated (see text)
	Subsistence swine	Calculated (see text)
Poultry	Commercial broilers	Leadingedge Poultry Software CC (2021)
	Commercial broiler parents	Leadingedge Poultry Software CC (2021)
	Commercial layers	Leadingedge Poultry Software CC (2021)
	Commercial pullets	Leadingedge Poultry Software CC (2021)
	Subsistence broilers	Calculated (see text)
	Subsistence layers	Calculated (see text)

Other cattle calves and subsistence cattle

The total number of calves is obtained from the Abstracts of Agricultural Statistics (DALRRD, 2021a), 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 (2021b). 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 (2021a) provides the total commercial other cattle, therefore this is subtracted from the total other cattle to obtain an estimate of the subsistence cattle population.

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, 2021a). 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, 2021a).

The subsistence sheep population is estimated by subtracting the total commercial sheep (DALRRD, 2021a) from the total sheep (DALRRD, 2021b).

Subsistence goats

The subsistence goat population is estimated by subtracting the total commercial goats (DALRRD, 2021a) from the total goats (DALRRD, 2021b).

Commercial and subsistence swine

The total swine population provided by DALRRD (2021b) is almost the same as that provided in the Abstracts of Agricultural Statistics (DALRRD, 2021a), suggesting that there are no subsistence swine. Du Toit et al (2013c) noted that there was a large discrepancy between DALRRD (2021a) 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 (2021b) data, but that this data is split into commercial and subsistence using the 0.26 ratio provided by Du Toit et al. (2013c).

Poultry



The number of broilers and layers is obtained from Leadingedge Poultry Software CC (2021), who provides data to the South African Poultry Association (SAPA). The data is modelled data. In this inventory the total broiler parents and pullets are also included. These numbers are small and were not in the previous inventory. 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.

Leadingedge Poultry Software CC (2021) indicated that in 2015 the subsistence population was 4-5% of the commercial poultry population. The percentage (4%) is assumed constant between 2000 and 2015. In 2020 the number provided for subsistence poultry is 4-5% of commercial poultry, therefore 5% was applied in 2020 and a linear extrapolation is used to estimate the percentage of subsistence poultry in the other years.

5.2.1.2 Population characterisation and herd composition

In the previous inventory there was a more detailed livestock characterisation. This was based on a study in 2010 (Du Toit et al., 2013a, b, c) which provided country-specific emission factors for all livestock categories. 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 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 5.17) 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 5.17) 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 5.17: 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) - Commercial dual-purpose (Mutton Merino, Dohne merino)	- Mature ewe - Replacement ewe - Mature ram - Young ram - Female lamb - Male lamb	Commercial 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; species distribution taken from ARC Report (2021a)
	Subsistence	- Mature ewe - Replacement ewe - Mature ram - Young ram	Subsistence sheep herd composition based on ARC Report (2021) data; even distribution of



		- Female lamb - Male lamb	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	Commercial swine herd composition based on Du Toit et al. (2013c) data



Poultry	• Commercial • Subsistence	• Replacement sows • Dry gestating sows • Lactating sows • Pre-wean-piglets • Broilers • Broiler parents • Layers • Pullets	Composition determined from population data

5.2.1.3 Population data verification

The livestock population data is compared to FAO data and other studies. For all livestock except poultry, the national statistics data (DALRRD, 2021a) utilised in this inventory match those from the FAO database. There are small discrepancies in the earlier years (1990 – 2002) but thereafter the data is aligned. In terms of poultry data, the data applied in this inventory is on average 33% lower than the FAO data. It is noted though that much of the FAO poultry data is estimated and does 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 (2021a) data. The commercial and subsistence other cattle numbers provided by Du Toit et al. (2013a) are 22% and 4% higher than the DALRRD (2021a) 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 (2021a). 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.

Swine population data from industry (Du Toit et al., 2013c) are 60% lower than that provided in DALRRD (2021a). 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 suggests that there is still a discrepancy 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.

5.2.1.4 Population data uncertainty

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.

5.2.2 Manure management

5.2.2.1 Data sources

The manure management data for cattle, sheep and goats was sourced from the recent ARC Report (2021) and there were various sources for this data as indicated in Table 5.18. Data for horses, swine and poultry is sourced from Moeletsi and Tongwane (2015) and Du Toit et al. (2013c).

5.2.2.2 Data verification

Manure management data is compared to data from various studies and Table 5.19 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 which is something to investigate further in the future. 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.

5.2.2.3 *Manure management data uncertainty*

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 TMR manure management systems, respectively. Considering the variation in the reported data (Table 5.18) 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 5.19, 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 5.19 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.



Table 5.18: 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, asses²									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 DFFE (2014); ² Moeletsi and Tongwane (2015); ³ Malaka (2017); ⁴ Expert opinion; ⁵ Du Toit et al. (2013c);



Table 5.19: Verification of livestock manure management systems.

Livestock	DALRRD (2010)	Du Toit et al. (2013a, b, c)	Moeletsi et al. (2015)	Moeletsi and Tongwane (2015)	ARC Report (2021)	IPCC 2019 Refinement (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 Subsistence: 10% dry lot, 90% PRP	Commercial: 100% PRP; Feedlot: 80% dry lot, 20% solid storage; Subsistence: 100% PRP	Commercial: 2% solid storage, 1% daily spread, 95% PRP, 2% manure with bedding; Feedlot: 20% solid storage, 80% manure with bedding; Subsistence: 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; Subsistence: 10% dry lot, 80% PRP, 10% manure with bedding	Commercial: 3% dry lot, 97% PRP; Feedlot: 5% lagoon, 85% dry lot, 10% solid storage; Subsistence: 35% dry lot, 65% PRP	15% solid storage, 30% dry lot, 50% PRP, 5% burned for fuel
Sheep	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



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

Livestock	DALRRD (2010)	Du Toit et al. (2013a, b, c)	Moeletsi et al. (2015)	Moeletsi and Tongwane (2015)	ARC Report (2021)	IPCC 2019 Refinement (SSA default)
					Feedlot: 2% lagoon, 98% dry lot	
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%	Layers: 5% liquid slurry, 70% dry lot, 5% daily spread, 10% compost, 10% poultry manure without litter;		Layers: 90% pit>1 month, 10% poultry manure with litter; Broilers: 100% poultry manure with litter



Livestock	DALRRD (2010)	Du Toit et al. (2013a, b, c)	Moeletsi et al. (2015)	Moeletsi and Tongwane (2015)	ARC Report (2021)	IPCC 2019 Refinement (SSA default)
			poultry manure with litter	Broilers: 80% dry lot, 5% compost, 15% poultry manure with litter		



5.2.3 Enteric Fermentation (3.A.1)

5.2.3.1 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 the method for estimating CH₄ emissions from enteric fermentation requires three basic steps:

- a) Divide livestock population into animal subgroups based on sex, age and production level.
- b) Estimate the emission factors for each subgroup in terms of kilograms of CH₄ per animal per year.
- c) Multiply the subgroup emission factors by the subgroup populations to estimate subgroup emissions, and sum across the subgroups to estimate total emission.

Enteric fermentation contributed 26 355 Gg CO₂e in 2020, which is 58.4% of the AFOLU (excl. FOLU) sector emissions. Emissions decreased by 13.1% in the period 2000-2020 and decreased by 4.9% between 2017-2020.

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.

5.2.3.2 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 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:

$$\text{CH}_4 \text{ emissions} = \text{EF} * \text{Population}$$

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 5.20)

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 5.20: 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).

Activity data

The activity data for enteric fermentation is livestock population and this is described in detail in section 5.2.1.

Emission factors

Tier 1 IPCC 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 5.21) for the livestock categories with population data. The weighting is based on the herd and breed composition assumptions provided in Table 5.17.

Table 5.21: Enteric fermentation emission factors (kg CH₄ head⁻¹ yr⁻¹) 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)
Sheep	Commercial wool	9.95	Calculated (see text)
	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)
Goats	Commercial mohair	6.64	Calculated (see text)
	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

Cattle

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 5.22).

Sheep and goats

Emission factors for sheep and goats are calculated using a Tier 2 methodology (Table 5.23). 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.



Table 5.22: Equations for the calculation of emissions factors for cattle using the Tier 2 approach.

IPCC Equation	IPCC 2006 equations	Variables/constants/assumptions
10.3	$NE_m = C_{fi} \times (weight)^{0.75}$	NE_m = net energy for maintenance (MJ day ⁻¹) C_{fi} = 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 pastures ¹ , other cattle assume to graze on large grazing areas ¹ ; 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) $Hours$ = 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	$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM} \right) + \left(\frac{NE_g}{REG} \right)}{\frac{DE\%}{100}} \right]$	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 CH₄ 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 CH₄) is the energy content of CH₄ constant

¹ARC (2021)



Table 5.23: 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	$NE_m = Cf_i \times (weight)^{0.75}$	NE_m = net energy for maintenance ($MJ\ day^{-1}$) Cf_i = 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 pastures¹; IPCC 2019 Refinement, Table 10.5: all sheep = 0.0107] Weight = live weight of animal (kg)
10.7	$NE_g = \frac{WG_{lamb/kid} \times (a + 0.5b(BW_i + BW_f))}{365}$	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 intact¹] 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 intact¹]
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)



		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]
10.12	$NE_{\text{wool}} = \frac{EV_{\text{wool}} \times \text{Production}_{\text{wool}}}{365}$	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)
10.13	$NE_p = C_{\text{preg}} \times NE_m$	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 1 ¹ , therefore single birth coefficient is applied ² ; IPCC 2019 Refinement, Table 10.7: single births for sheep and goats = 0.077]
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): Sheep in grazing land = 60%, Sheep in feedlots = 75%, Subsistence sheep = 50%, Goats in grazing land = 60%, Dairy goats = 70%, Subsistence goats = 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	$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{\text{work}} + NE_p}{REM} \right) + \left(\frac{NE_g}{REG} \right)}{\frac{DE\%}{100}} \right]$	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



Swine

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.

5.2.3.3 Uncertainties and time series consistency

Activity data uncertainty

Activity data time-series is complete from 1990 to 2020, however only data from 2000 is presented due to incomplete time-series in other sectors. Activity data uncertainty is discussed in section 5.2.1.4.

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 5.24). 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 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.

Table 5.24: Enteric fermentation emission factor uncertainties.

Animal categories	Animal subcategories	Emission Factor uncertainty	Reference
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)
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)
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	
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)
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)
Horses		± 40	IPCC 2006
Mules & asses		± 40	IPCC 2006
Swine		± 20	IPCC 2006

Time-series consistency

The time-series for enteric fermentation is consistent.

5.2.3.4 Category specific QA/QC and verification

Activity data verification is provided in section 5.2.1.3. 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. Dairy cattle 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.



5.2.3.5 *Category-specific recalculations*

This inventory incorporates new data for the calculation of the Tier 2 emission factors and includes changes and updates to the herd composition and characterisation. In addition, the weighting is applied to the emission factors and not to the population data as was done in the previous inventory. Emissions were therefore recalculated for the entire time series and led to a 16% increase in emissions compared to the previous inventory.

5.2.3.6 *Category-specific planned improvements*

In this inventory all the background activity data 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. No specific improvements plans are in place; 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.

5.2.4 Manure Management (3.A.2)

5.2.4.1 *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. 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. This category therefore includes emissions of both CH₄ and N₂O.

Ammonia (NH₃) and nitrous oxides (NO_x) volatilise from manure storage; however these emissions are not estimated due to a lack of data.

According to IPCC the method for estimating CH₄ and direct N₂O emissions from manure management requires the following steps:

- a) Divide livestock population into animal subgroups based on sex, age, and production level.
- b) 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.
- c) For N₂O emissions:
- i. Determine average annual nitrogen excretion rate per head for each livestock subcategory.
 - 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.

Manure management contributes 3 782 CO₂e in 2020, which is 7.7% of the AFOLU (excl. FOLU) sector emissions. Methane emissions contribute 31.1% to these emissions and the rest is N₂O. Emissions increased by 11.8% in the period 2000-2020 and decreased by 2.0% between 2017-2020.

5.2.4.2 Methodological issues

CH₄

Manure CH₄ emissions are calculated with a Tier 2 IPCC methodology for all livestock categories using the following equation:

$$CH_{4manure} = EF \cdot Population$$

and:

$$EF_{(T)} = (VS_T \cdot 365) \cdot \left[B_{o(T)} \cdot 0.67 \text{ kg m}^{-3} \cdot \sum_{S,k} \frac{MCF_{S,k}}{100} \cdot MS_{(T,S,k)} \right]$$

Where:

EF_(T) = annual emission factor for defined livestock population T (kg)

VS_(T) = daily VS excreted for an animal within defined population T (kg)

B_{o(T)} = maximum CH₄ producing capacity for manure produced by an animal within defined population T (m³ kg of VS⁻¹)



$MCF_{S,k}$ = CH_4 conversion factors for each manure management system j by climate region k

$MS_{(T,S,k)}$ = percentage of animal species/category T 's manure handled using manure system S in climate region k (%)

N_2O

Direct manure N_2O emissions are calculated following the IPCC equation 10.25 (IPCC, 2006, volume 4, chapter 10).

Activity data

CH_4

Activity for manure CH_4 emissions is livestock population data which is described in section 5.2.1.

N_2O

Direct N_2O emissions require information on livestock population (section 5.2.1), manure management (section 5.2.2) 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 $0.46 \text{ kg N (1000 kg animal mass)}^{-1} \text{ day}^{-1}$, 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 Equation 10.31 and 10.32) is utilised to calculate annual N excretion rates for cattle, sheep, and goats. 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 swine and poultry is taken from Du Toit et al. (2013c). In all cases the N retention values are sourced from IPCC 2006 Table 10.2.

Emission factors

CH_4



Annual volatile solid (VS) excretion from horses and mules/asses is determined with a Tier 1 methodology (IPCC 2006, 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 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, Equation 10.24). The fraction of ash content of feed (ASH) is set at 0.08 for all livestock (IPCC 2006, Equation 10.24), except for swine where a value of 0.17 is applied (Du Toit et al., 2013c).

N₂O

Emission factors for all livestock are obtained from IPCC 2019 Refinement (Table 10.21).

5.2.4.3 *Uncertainties and time series consistency*

Activity data uncertainty

The population data uncertainties are discussed in section 5.2.1.4. Uncertainty on manure management systems is provided in section 5.2.2.3. The IPCC 2006 default uncertainty for N excretion is ± 50%, but this is for a Tier 1 method. It is therefore assumed that the Tier 2 method reduces uncertainty to ± 30%.

Emission factor uncertainty

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 (Table 5.25). 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 indicates that a Tier 2 approach is likely to have an uncertainty of around ± 20%. The same applies to poultry. Tier 1 default factors for horses, and mules/asses have an uncertainty of between ± 30% - 50%, that an average of ± 40% is applied.

Uncertainty on the IPCC default N₂O manure emission factors is -50% to +100%.

Table 5.25: Uncertainty data for livestock manure CH₄ emission factors.

Animal categories	Animal subcategories	Emission Factor uncertainty	Reference



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)
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	
	Feedlot cattle	± 6	ARC (2021)
Subsistence cattle	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	
	Calves	± 17	
Sheep	Mature ewes	±15	ARC (2021)
	Replacement ewes	±8	ARC (2021)
	Female lambs	±15	ARC (2021)
	Male lambs	±16	ARC (2021)
	Young rams	±11	ARC (2021)
	Rams	±9	ARC (2021)
	Feedlot sheep	±15	ARC (2021)
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)
Horses		± 30	IPCC 2006
Mules & asses		± 30	IPCC 2006
Swine		± 20	IPCC 2006
Poultry		± 20	IPCC 2006

Time-series consistency

The time-series is consistent throughout the period 2000 – 2020.



5.2.4.4 *Category specific QA/QC and verification*

Activity data verification is provided in section 5.2.1.3. 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.

5.2.4.5 *Category-specific recalculations*

This inventory incorporates new data for the calculation of the Tier 2 emission factors and includes changes and updates to the herd composition and characterisation. In addition, the weighting is applied to the emission factors and not to the population data as was done in the previous inventory. Emissions were therefore recalculated for the entire time series and led to a 59.1% increase (79.8% for manure CH₄ emissions and 49.7% for manure N₂O emissions) in emissions compared to the previous inventory.

5.2.4.6 *Category-specific planned improvements*

There are no planned improvements for this category in the next year.

5.3 Aggregated and non-CO₂ emissions on land (3.C)

5.3.1 Category description

The aggregated and non-CO₂ emissions on land category is composed of the following sub-categories:

- Biomass burning (3C1)
- Liming (3C2)
- Urea application (3C3)
- Direct N₂O from managed soils (3C4)
- Indirect N₂O from managed soils (3C5)
- Indirect N₂O from manure management (3C6)

Details for calculating emissions for each of these sub-categories is detailed in the sections below.

5.3.2 Emissions from biomass burning (3.C.1)



5.3.2.1 Category description

Biomass burning is an important ecosystem process in Southern Africa, with significant implications for regional and global atmospheric chemistry and biogeochemical cycles (Korontzi *et al.*, 2003). Fire plays an important role in South African biomes, where grassland, savanna and fynbos fires maintain ecological health. 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).

South Africa reports emissions of non-CO₂ gases (CH₄, CO, N₂O and NO_x) from all land categories. There is insufficient data to separate controlled fires from wildfires, so all emissions are for total fires. The burning of biomass is classified into the six land-use categories defined in the 2006 Guidelines, namely, forest land, cropland, grassland, wetlands, settlements, and other land. The IPCC Guidelines suggest that emissions from savanna burning should be included under the grassland category; however, since, in this inventory woodlands and open bush have been classified as forest land, their emissions were dealt with under forest land.

Although the burning of croplands might be limited, burning has been shown to occur on cultivated land (Archibald *et al.*, 2010), mainly due to the spread of fires from surrounding grassland areas.

The CO₂ emissions from burning are not included in this category as they are accounted under the disturbance losses in the Land (3B) category. IPCC indicates that net CO₂ emissions should be reported when CO₂ emissions and removals from the biomass pool are not equivalent in the inventory year. For grasslands and annual croplands, the annual CO₂ removals (through growth) and emissions (whether by decay or fire) are in balance. CO₂ emissions are therefore assumed to be zero for these categories. All non-CO₂ emissions, on the other hand, are included in this category.

5.3.2.2 Methodological issues

The Tier 2 methodology was applied, with the emissions from biomass burning being calculated using the following equation (Equation 2.27 from IPCC 2006 Guidelines):

$$L_{\text{fire}} = A * M_B * C_f * G_{ef} * 10^{-3}$$

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)



Cf = combustion factor (dimensionless)

G_{ef} = emission factor (g kg⁻¹ dm burnt)

Activity data

Burnt area data

The MODIS Collection 6 Burnt Area data was utilised in this inventory, which is an upgrade from the Collection 5 used in the last inventory. Annual burnt-area maps were produced from the MODIS monthly burnt-area product for the years 2001, 2005, 2010, and 2014-2018. Data was incomplete for 2000 so this data set was excluded, and there was insufficient time to process all the years in between. An IPCC splicing technique using the previous inventory data as proxy data was applied to update the data for the years in between. All years can be updated in the next inventory.

The MODIS Collection 6 Burned Area Product Geotiff version (<http://modis-fire.umd.edu/pages/BurnedArea.php?target=GeoTIFF>) is used in this inventory. This is a level 3 gridded 500 m product and the quality of the information is described in Giglio et al. (2018). Data processing involved the following steps:

a) Burnt area:

- i) Each year's dataset contained 12 files (1 per month). Each month was reclassified to remove NoData (classes -2, -1, and 0) and each day value was changed to 1 to obtain total area burnt per month.
- ii) Every month of data was reprojected into the UTM 35S projection to remain consistent with the 2014 and 2018 land-cover dataset project.
- iii) Each month's dataset was clipped (extract by mask) to the South African boundary (South African Boundary shapefile (2018) obtained from the Municipal Demarcation Board (<https://dataportal-mdb-sa.opendata.arcgis.com/search?tags=2018>) with a 1km buffer. This allowed for improved data retention.
- iv) Each month's dataset was combined using the "mosaic to new raster" to create a dataset per year.
- v) Each year's dataset was resampled to change the cell size to the same as the land cover dataset:
 - For all years the 2014 land cover dataset was used with a cell size of 30 x 30m.
- vi) Each year's dataset was clipped (extract by mask) to the actual South African boundary.

b) Land cover/land use:



-
- i) The 2014 (GTI, 2015) and 2018 land cover datasets (GTI, 2019a) (72 and 73 classes, respectively) were reclassified into 20 categories (see section 5.4.2 for more details). The 20 categories are the same as the latest land change categories for 1990-2018 and 2014-2018 using the same process as conducted by the land change study (GTI, 2019a; GTI, 2019b).
 - c) Combining burnt area and land cover datasets:
 - i) The land cover type where each year's burnt area was associated with was conducted using the raster calculator feature. This was done for each year.

The output dataset for each year was collated in Microsoft Excel and the total area burnt was calculated in hectares. Due to time limitations not all the post years could be reanalysed using the Collection 6 data. The years 2001, 2005, 2010 and 2014 onwards 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. There was not much difference in the two data sets, however, it would be ideal to maintain consistency throughout the time-series.

Mass of fuel available for combustion (MB) and the combustion factor (C_f)

The values for fuel density were sourced from various sources (Table 5.26). A weighted average for fuel density and the combustion factor (C_f) was determined for low shrublands. According to the 2013/2014 land cover map report (GTI, 2015) low shrublands are mainly karoo type vegetation. Also included in this category is a portion of fynbos (13% according to the 2013/2014 land cover map). The karoo vegetation classes have similar fuel densities and C_f values, but these are very different for fynbos (Table 5.26). A weighted average fuel density and C_f value was calculated from these numbers for the low shrubland category in this inventory. Wetlands were assumed to have the same values as grasslands as done in the previous inventory (DEFF, 2021).

Comparing the data to IPCC values the low shrubland weighted average fuel density is lower than the general shrubland values provided in IPCC. The reason for this is that for South Africa this category includes arid shrublands which have much lower fuel density than the shrublands used to determine the IPCC default table (IPCC, 2006, Table 2.4, vol 4, chapter 2, page 2.46).



Table 5.26: Fuel density and combustion fractions for the various vegetation classes.

Vegetation class	Fuel density (t/ha)			Combustion factor			Fuel consumption (t/ha) ^a		
	Value	Source	IPCC default	Value	Source	IPCC value	Value	Source	IPCC value
Plantations							33.6	Weighted average based on IPCC (2006) ^b	19.8 – 53.0
Indigenous forests							19.8	IPCC (2006)	19.8
Thickets/ dense bush	1.4	1994 NIR		0.95	1994 NIR				
Natural woodlands	4.4	Van Leeuwen et al. (2014)		0.8	Van Leeuwen et al. (2014)				2.5 – 26.7
Croplands	7	DALRRD (2010)		1	DALRRD (2010)				4 – 10
Grasslands							4.1	IPCC (2006)	2.1 – 10
Low shrublands	2.42 ^c	Weighted average	5.7 – 26.7	0.91 ^c	Weighted average	0.61 – 0.95			
<i>Fynbos</i>	12.9	IPCC (2006)		1	IPCC (2006)				
<i>Nama karoo</i>	1	1994 NIR		0.95	1994 NIR				
<i>Succulent karoo</i>	0.6	1994 NIR		0.95	1994 NIR				
Wetlands^d							4.1	IPCC (2006)	

^a Fuel consumption is a product of fuel density and the combustion factor.

^b Applied IPCC wildfire values for Eucalyptus forests for hardwood plantations and other temperate forests for softwoods.

^c See text for explanation.

^d Assumed the same as grasslands.



Emission factors

IPCC 2006 default emission factors (IPCC, 2006, vol 4, chapter 2, Table 2.5, page 2.47) are applied.

5.3.2.3 Uncertainties and time series consistency

Activity data uncertainty

Boschetti et al. (2019) indicates that MODIS collection 6 burnt area products have an uncertainty of less than 6%. The 2013/14 land cover map showed an average user and producer accuracy of 83.74% and 88.34% respectively. Based on the accuracy assessment in the 2014 SANLC report the following uncertainties were assigned to the various land cover categories:

- a) Forest land: $\pm 45\%$
- b) Cropland: $\pm 8\%$
- c) Grassland: $\pm 15\%$
- d) Wetland: $\pm 12\%$
- e) Settlements: $\pm 8\%$
- f) Other land: $\pm 22\%$

Uncertainty is higher for land use change areas so these were assumed to have a 5% higher uncertainty. Fuel density varies as a function of type, age and condition of the vegetation. It is also affected by the type of fire. Since the calculations do not distinguish between the type of fire or the season when the fire occurs the uncertainty can be high. The biggest uncertainty is for savannas and woodlands. The IPCC 2006 guideline default values show that for savanna woodlands the fuel consumption can vary between 2.6 t ha^{-1} and 4.6 t ha^{-1} depending on the season, while savanna grassland fuel consumption can vary between 2.1 t ha^{-1} and 10 t ha^{-1} . The standard deviation on fuel loads and fuel consumption in savannas can be as high as 85% and 45% respectively (Van Leeuwen et al., 2014). Van Leeuwen et al. (2014) also estimated the uncertainty of fuel consumption in a South African savanna to be 40%. Based on uncertainties in IPCC (IPCC, 2006; Table 2.4) and van Leeuwen et al. (2014) fuel consumption uncertainty was determined to be 40%, 20%, 75%, 75%, 40% and 10% for forest lands, croplands, grasslands, wetlands, settlements and other lands respectively.

Emission factor uncertainty



IPCC default uncertainties for emission factors are provided in the guidelines (IPCC, 2006; Table 2.5).

Time-series consistency

Time series is consistent as same data sources are used throughout.

5.3.2.4 Category specific QA/QC and verification

Burnt area data was compared to those from the Meraka Institute (Meraka Institute, 2019) who are also using the MODIS collection 6 data. The datasets compare very well (within 10% of each other) and show the same annual trend.

5.3.2.5 Category-specific recalculations

Recalculations are completed for the entire time series due to the changes in the land cover classes and the updated burnt area maps, particularly for the years 2000 – 2009 as the MODIS collection 6 data replaced the collection 5 data. The updates led to a 10% to 15% decline in emissions between 2000 and 2005, after which the annual variation is between a 2.6% decline to a 6.6% increase in emissions, except for 2017 where emissions doubled. There appeared to be an error in the previous 2017 data, and this has been corrected.

5.3.2.6 Category-specific planned improvements

There are no specific planned improvements for this category.

5.3.3 Liming (3.C.2)

5.3.3.1 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.

Liming produced 942 Gg CO₂ in 2020 which is 5.3% of the *Aggregated and non-CO₂ emissions on land* and 1.9% of the AFOLU (excl. FOLU) emissions. These emissions have more than doubled since 2000, however, there was a 22% reduction in emissions since 2017.



5.3.3.2 *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).

Activity data

Limestone and dolomite data between 1990 and 2008 are obtained from the Fertilizer Association of South Africa (FertSA) (<http://www.fssa.org.za/Statistics.html>). This data stops in 2008, and so for later years the amount of agricultural lime sold was obtained from the SAMI report (DMR, 2018). FertSA data was considered more accurate in terms of the amount being applied to soils and it reports the consumption for both dolomite and limestone. These two data sets are therefore spliced together using the IPCC surrogate data technique. The trend in the SAMI consumption data is similar to the limestone consumption data from FertSA, therefore the SAMI data is used as surrogate data to determine the limestone application. The relationship between limestone and dolomite is plotted and a linear extrapolation of the relationship is utilised to calculate the dolomite consumption for 2008-2020. There have not been any updated SAMI Reports and so the data for 2018 to 2020 were extrapolated.

Emission factors

The IPCC 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*.

5.3.3.3 *Uncertainties and time series consistency*

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%.

Emission factor uncertainty

The dolomite and limestone default emission factors have an uncertainty of -50% (IPCC 2006 Guidelines, p. 11.27).

Time-series consistency



A splicing technique was used to combine data sets so as to ensure a consistent time-series.

5.3.3.4 Category specific QA/QC and verification

Past inventory reviews have mentioned upgrading this information and investigating the alternate method of calculating potential lime use. This was done by using the crop area estimates combined with application rates from Tongwane et al. (2016) but this yielded a value of over 3 million tons of lime in 2008 compared to the 1.5 million tons provided by the Fertiliser Association of SA. This data was therefore not incorporated and rather an alternate data source should be sought in future. It may be possible to obtain future data from the SAGERS system.

5.3.3.5 Category-specific recalculations

There have been no recalculations performed for this source category this year.

5.3.3.6 Category-specific planned improvements

No improvements are planned for this category.

5.3.4 Urea application (3.C.3)

5.3.4.1 Category description

Adding urea to soils during fertilization leads to a loss of CO₂ that was fixed in the industrial production process.

Urea application is estimated to produce 584 Gg CO₂ in 2020 (1.2% of the AFOLU (excl. FOLU) emissions) and this is almost double what was produced in 2000. Emissions declined by 14.0% since 2017.

5.3.4.2 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).

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 20/06/2021).

Emission factors

The IPCC default emission factor of $0.2 \text{ t C (t urea)}^{-1}$ is applied in the equation to calculate the CO₂ emissions.

5.3.4.3 Uncertainties and time series consistency

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.

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).

Time-series consistency

The time-series is consistent.

5.3.4.4 Category specific QA/QC and verification

Urea data is checked against the FAOStat dataset and found to be very similar.

5.3.4.5 Category-specific recalculations

No recalculations are performed for this category.

5.3.4.6 Category-specific planned improvements

No improvements are planned for this category in the next year.



5.3.5 Direct nitrous oxide emissions from managed soils (3.C.4)

5.3.5.1 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 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) 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 emissions from sewage sludge are included under waste (IE) and organic soils are not included (NE) due to their insignificance.

Direct N₂O emissions from managed soils amounted to 12 825 Gg CO₂e in 2020, which is 26.2% of the AFOLU (excl. FOLU) emissions. The emission contribution of the various types of N inputs is shown in Table 5.27. The total Direct N₂O emissions increased by 3.7% between 2000 and 2020, showing a 1.0% decline since 2017.

Direct N₂O emissions from managed soils is a key category based on the level and trend assessments.



Table 5.27: Emission trends for the various sub-categories of direct N₂O emissions from managed soils.

		Inorganic N fertilisers	Organic N fertilisers	Urine and dung from grazing animals	Crop residues
2000	Emissions (Gg CO ₂ e)	2 026.2	764.4	7 223.0	1 803.9
	% AFOLU (excl. FOLU)	3.9	1.5	14.1	3.5
2017	Emissions (Gg CO ₂ e)	2 157.6	915.1	6 583.6	2 754.1
	% AFOLU (excl. FOLU)	4.2	1.8	12.9	5.4
2020	Emissions (Gg CO ₂ e)	2 004.6	911.2	6 329.5	3 033.9
	% AFOLU (excl. FOLU)	4.1	1.9	12.9	6.2
Change	2000 – 2020 (%)	-1.1	19.2	-12.4	68.2
	2017 – 2020 (%)	-7.1	-0.4	-3.9	10.2

5.3.5.2 Methodological issues

A Tier 1 approach is used to calculate Direct N₂O emission from managed soils following the IPCC 2006 Equation 11.1 (IPCC, 2006, Volume 4, Chapter 11).

Inorganic fertiliser N inputs

IPCC Tier 1 methodologies and default emission factors (IPCC 2006) are used for estimating direct N₂O emissions from managed soils. The amount of inorganic N applied to soils is multiplied with the IPCC default emission factor (IPCC 2006).

Organic fertiliser N inputs

The amount of N (kg N yr⁻¹) from organic N additions applied to soil is calculated using IPCC 2006 Equation 11.3 (IPCC, 2006; Volume 4, chapter 11).

Animal manure applied to soils



A Tier 1 approach was used to calculate N from animal manure applied to soils (IPCC 2006, 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 Equation 10.34 (IPCC, 2006, volume 4, chapter 10).

Sewage sludge applied to soils

N₂O emissions from sludge are included in the *Waste* sector and are therefore excluded here so as to avoid double counting.

Compost applied to soils

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 (DALRRD, 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 DALRRD (2010) and Otter (2011)).

Urine and dung N deposited by grazing animals

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).

Crop residues N inputs

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 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.



Mineralised N due to land use change

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.

Activity data

Inorganic fertiliser N inputs

For nitrogen emissions the Fertilizer Association of SA reports total N consumption (<http://www.fertasa.co.za/fertilizer-information/historic-sales-data/> and <http://www.fertasa.co.za/wp-content/uploads/2021/03/Fertilizer-Usage-2020-and-2021-RSA.pdf>). 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 Equation 10.34 (IPCC, 2006; volume 4, chapter 10) requires the following data:

- Livestock population data (section 5.2.1);
- N excretion data (section 5.2.4.2);
- Manure management system usage data (Table 5.18);
- Amount of managed manure nitrogen that is lost in each manure management system ($Frac_{LossMS}$). IPCC 2006 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 5.2.1) and manure management (section 5.2.4) data.

Crop residue N inputs

Planted area and production data is obtained from Abstracts of Agricultural Statistics (DALRRD, 2021) 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 (section 5.4).

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).

5.3.5.3 Uncertainties and time series consistency

Activity data uncertainty

Inorganic N fertiliser

Expert opinion (Corne Louw, corne@grainsa.co.za) suggests that the N consumption would likely be within 15% of the number.

Organic N fertiliser



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.

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 $FracLossMS$ factor (IPCC 2006, Table 10.23).

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 ± 50 uncertainty on above and below ground ratios (IPCC 2019 Refinement, Table 11.1A) and a $\pm 10\%$ uncertainty on residue management data.

F_{SOM}

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.

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).

Time-series consistency

The time-series for direct N_2O emissions is complete and consistent.



5.3.5.4 *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.

5.3.5.5 *Category-specific recalculations*

Recalculations were performed for the entire time-series and the updated data is on average 71.8% lower than provided in the previous inventory. The difference seen is because of changes in both the activity (livestock herd composition and manure management) and emission factor data. Much of the decline in emissions is due to 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.

5.3.5.6 *Category-specific planned improvements*

There are no category specific improvements planned.

5.3.6 **Indirect nitrous oxide emissions from managed soils (3.C.5)**

5.3.6.1 *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 2006 IPCC guidelines).

Indirect N₂O from managed soils contributed 1 200 Gg CO₂e to the total emissions in 2020.



5.3.6.2 *Methodological issues*

Due to limited data a Tier 1 approach was used to calculate the indirect N_2O emissions in this category.

Indirect N_2O from atmospheric deposition of volatilized N

The annual amount of N_2O -N produced from atmospheric deposition of N volatilized from managed soils ($N_2O_{(ATD)}-N$) was calculated with IPCC 2006 Equation 11.9.

Indirect N_2O from leaching/runoff

The annual amount of N_2O -N produced from leaching and runoff of N additions to managed soils ($N_2O_{(L)}-N$) is determined by IPCC 2006 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 $0.02 \text{ kg N (kg N additions)}^{-1}$ was applied to cultivated lands.

Activity data

The calculation of F_{SN} , F_{ON} , and F_{PRP} are described above.

Emission factors

Indirect N_2O from atmospheric deposition of volatilized N

The emission factor (EF_4), 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 N_2O from leaching/runoff

The emission factor (EF_5) was taken from the IPCC 2019 Refinement (Table 11.3, Chapter 11, Volume 4).

5.3.6.3 *Uncertainties and time series consistency*



Activity data uncertainty

Uncertainty on activity data for F_{SN} , F_{ON} , and F_{PRP} are provided in section 5.3.5.3. $Frac_{GASF}$ has an uncertainty of -82% and +200%, while $Frac_{GASM}$ has an uncertainty of -100% + 48% (IPCC 2019 Refinement, Table 11.3).

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).

Time-series consistency

The time-series is consistent throughout the inventory time period.

5.3.6.4 Category specific QA/QC and verification

No were no category specific quality control checks.

5.3.6.5 Category-specific recalculations

Recalculations across the entire time-series produced lower emissions, with an average reduction of 68% for volatilisation and 15% for leaching losses. The reduction in emissions is due mostly to the updated emission factors from the IPCC 2019 Refinement, but also due to changes in livestock herd composition and manure management.

5.3.6.6 Category-specific planned improvements

There are no planned improvements for this category.

5.3.7 Indirect nitrous oxide emissions from manure management (3.C.6)

5.3.7.1 Category description

Indirect emissions of N_2O -N can take place in two ways: i) volatilization of N as NH_3 and oxides of N, and ii) through runoff and leaching from land where N was applied (IPCC, 2006).



5.3.7.2 *Methodological issues*

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.

Activity data

Both of the indirect N₂O emission equations require data on livestock population, N excretion, and manure management which are described in section 5.2.1.1, section 5.3.5.2 and section 5.2.2, 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).

Emission factors

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.

5.3.7.3 *Uncertainties and time series consistency*

Activity data uncertainty

Uncertainty on activity data for livestock population and N excretion are discussed in sections 5.2.4.3. Fra_{CGASMS} and Fra_{LeachMS} uncertainties are provided in IPCC 2019 Refinement (volume 4, chapter 10, Table 10.22).

Emission factor uncertainty

The uncertainty on EF₄ is -100% and +120%, and for EF₅ it is -100% and +82% (IPCC 2019 Refinement, Table 11.3).

Time-series consistency



The time-series for this category is consistent.

5.3.7.4 Category specific QA/QC and verification

No specific quality control checks or verification procedures were undertaken for this category.

5.3.7.5 Category-specific recalculations

Recalculations across the entire time-series produced lower emissions, with an average reduction of 48% for volatilisation and 49% for leaching and runoff. The reduction in emissions is due mostly to the updated emission factors from the IPCC 2019 Refinement, but also due to changes in livestock herd composition and manure management.

5.3.7.6 Category-specific planned improvements

No category specific improvements are planned; however it is recommended that data be collected on manure inputs to biogas plants so the data can be incorporated into the equation in future.

5.4 Land (3.B)

5.4.1 Category description

The land component of the AFOLU sector includes CO₂ emissions and sinks of the carbon pools above-ground and below-ground biomass, litter and soils from the categories *Forest land* (3.B.1), *Croplands* (3.B.2), *Grasslands* (3.B.3), *Wetlands* (3.B.4), *Settlements* (3.B.5), *Other lands* (3.B.6), and the relevant land-use change categories. The N₂O and CH₄ emissions from biomass burning were estimated but are included in the *aggregated and non-CO₂ emission sources on land* section, while CH₄ and N₂O emissions from wetlands were included here.

Organic soils were assumed to be negligible (Moeletsi et al., 2015). A more recent study by Schulze and Schutte (2018) was conducted to identify organic soils and it indicated that high-C soils are very small in area and only 885 out of 27 491 terrain units contain either humic or organic soils in terms of the binomial classification system. In addition, a blue carbon study (Raw et al., 2021) indicates that wetlands cover approximately 19 000ha of which most are assumed to contain high organic soils. It is therefore



acknowledged that there is a small percentage of area under organic soils. Initially the incorporation of these soils was considered but due to differences in data between the International Soil Reference and Information Centre (ISRIC) soils data (<https://www.isric.org/explore/isric-soil-data-hub>) utilised in this inventory and difficulties in integrating the various maps the inclusion of organic soils will be deferred to the next inventory due to its priority.

5.4.1.1 National circumstances

South Africa has an area of 123 562 851 ha and has a warm, temperate and dry climate. Low shrublands dominate the land covering approximately a third of the land area, followed by grasslands which cover around 21% (Table 5.28). Indigenous forests and plantations cover around 2% of the area, while woodlands and thickets cover 10% and 6.6%, respectively. The largest change between 1990 and 2014 was seen in the cultivated area, with a 223% increase in the irrigated annual crop area. Plantations and grasslands show a decline in area (Table 5.28), whereas forest lands showed an increase.

Table 5.28: Land cover change between 1990 and 2014 (Source: GTI, 2015; DEFF, 2020).

Land class	1990		2014		% change
	1000 ha	% of total area	1000 ha	% of total area	
Indigenous Forest	465	0.38	530	0.43	14.13
Thicket / Dense Bush	6 487	5.25	8 119	6.57	25.16
Natural woodland	10 950	8.86	12 387	10.03	13.13
Planted Forest	1 915	1.55	1 868	1.51	-2.46
Shrubland	41 220	33.36	41 956	33.96	1.79
Grassland	27 678	22.40	25 808	20.89	-6.76
Waterbodies	2 196	1.78	2 041	1.65	-7.08
Wetlands	1 521	1.23	1 017	0.82	-33.11
Barren Land	13 510	10.93	12 445	10.07	-7.88
Eroded Land	446	0.36	219	0.18	-50.76
Cultivated Commercial					
Permanent Orchards	312	0.25	345	0.28	10.83
Cultivated Commercial					
Permanent Vines	161	0.13	187	0.15	16.23
Commercial Annuals Pivot					
Irrigated	241	0.20	780	0.63	223.42
Commercial Annuals Non-Pivot	11 464	9.28	10 594	8.57	-7.58
Cultivated Subsistence	1 982	1.60	2 040	1.65	2.93
Built-Up Residential All	2 391	1.94	2 559	2.07	7.00



Built-Up Smallholdings	246	0.20	240	0.19	-2.52
Built-Up Commercial	45	0.04	52	0.04	16.73
Built-Up Industrial	58	0.05	56	0.05	-4.72
Mines	277	0.22	319	0.26	15.08
Total	123 563		123 563		

5.4.1.2 Emissions and removals

The *Land* sector was estimated to be a source of CO₂ between 2005 and 2008, but a sink in all other years (Figure 5.15). *Forest land* was the main contributor to the sink, followed by *Grasslands*. *Croplands*, *Wetlands* and *Other lands* were sources (Table 5.29). The main drivers of change are fires and fuelwood removals.

A detailed summary table of emissions and removals for the *Land* sector in 2020 are provided in Appendix C.

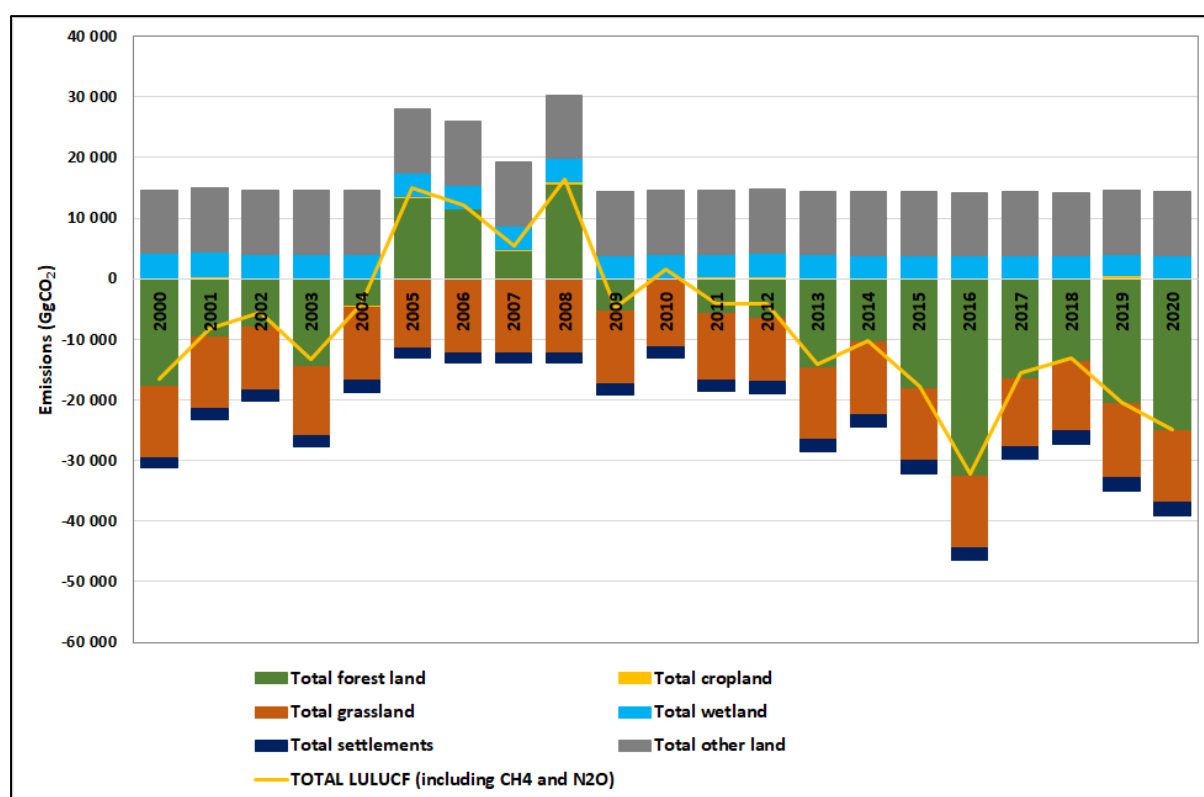


Figure 5.15: Time series for GHG emissions and removals (Gg CO₂) in the Land sector in South Africa, 2000 - 2020.



Table 5.29: Trends in emissions and removals between 2000 and 2020 from the Land sector in South Africa.

	Emissions and removals (Gg CO ₂ e)					
	3B1 Forest land	3B2 Cropland	3B3 Grassland	3B4 Wetlands	3B5 Settlements	3B6 Other lands
2000	-17 789.5	78.9	-11 720.7	4 084.9	-1 751.9	10 514.0
2001	-9 548.0	314.6	-11 906.3	4 067.6	-1 743.6	10 514.0
2002	-7 921.8	44.1	-10 482.6	4 047.3	-1 828.4	10 514.0
2003	-14 542.1	75.8	-11 378.4	4 010.4	-1 870.5	10 514.0
2004	-4 612.1	-207.6	-11 952.0	3 977.1	-1 922.4	10 514.0
2005	13 351.8	215.4	-11 359.4	3 971.2	-1 779.9	10 514.0
2006	11 461.5	-15.7	-12 223.0	3 923.3	-1 610.5	10 514.0
2007	4 593.1	249.5	-12 304.8	3 891.2	-1 577.5	10 514.0
2008	15 530.2	433.1	-12 208.5	3 861.5	-1 792.8	10 514.0
2009	-5 310.6	-56.3	-12 013.7	3 839.4	-1 744.3	10 514.0
2010	-277.7	236.1	-10 953.3	3 828.5	-1 857.8	10 514.0
2011	-5 678.4	249.1	-11 006.2	3 807.6	-1 960.9	10 514.0
2012	-6 556.8	413.4	-10 353.6	3 767.8	-1 982.6	10 514.0
2013	-14 814.8	185.2	-11 798.4	3 749.9	-1 984.3	10 514.0
2014	-10 348.0	97.6	-12 132.5	3 721.3	-1 991.2	10 514.0
2015	-18 130.1	132.4	-11 914.0	3 694.5	-2 073.8	10 514.0
2016	-32 721.6	114.8	-11 620.8	3 640.4	-2 187.0	10 514.0
2017	-16 456.5	197.6	-11 192.7	3 633.0	-2 158.3	10 514.0
2018	-13 752.7	95.0	-11 353.1	3 607.1	-2 198.0	10 514.0
2019	-20 634.8	520.2	-12 213.6	3 579.2	-2 140.2	10 514.0
2020	-25 067.8	219.9	-11 923.2	3 558.6	-2 139.0	10 514.0

5.4.2 Land representation

5.4.2.1 Land cover datasets and methodology

South Africa developed land-cover⁶ datasets for 1990 (GTI, 2015), 2013-14 (GTI, 2014), 2018 (DFFE, 2019a) and more recently, 2020. The details of the processing and development of each of the maps is provided in the relevant reports (GTI, 2014; 2015; DFFE, 2019a; DFFE, 2019b) and are summarised here. The original 1990 and 2013-14

⁶ The term 'land cover' is used loosely here as the classes are a combination of land cover and land use.



National Land-Cover Datasets were derived from multi-seasonal Landsat 5 and Landsat 8 imagery with 30 x 30 m raster cells, respectively. The 1990 National Land-Cover Dataset made use of imagery from 1989 to 1991, while the 2013-14 National Land-Cover Dataset used 2013 to 2014 imagery. On the other hand, the 2018 dataset was derived from Sentinel 2 data which has a higher spatial resolution compared to Landsat. This has led to improved reclassification of some of the land classes which meant that the land areas for some of the land categories were very different in the 2014 and 2018 datasets. To make the 2018 map more comparable with the 1990 and 2014 map the 2018 map was degraded. The key data processing steps used to generate the 1990/2018 and 2013/14/2018 SANLC change assessment outcomes (DFFE, 2019b) are:

- Convert all geographic coordinate format SANLC datasets to the new, simplified land-cover change legend format and content;
- Re-project the legend modified geographic coordinate 1990, 2013/14 and 2018 SANLC datasets to Albers Equal Area map projection, including a single-step spatial resampling for the SANLC 2018 dataset (using nearest-neighbour class code allocation) to a 30 x 30m cell resolution output;
- Ensure pixel-to-pixel registration between all 30m resolution Albers Equal Area map projection outcomes, using the 2018 SANLC as the reference dataset against which the 1990 and 2013/14 datasets are registered. This approach has been taken as the ortho-precision of the source Sentinel 2 imagery from which the SANLC 2018 has been 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 extent of land-cover geographic coverage between all SANLC datasets, so that the change assessment results do not include a null class in the year-on-year assessments due to differences in mapped land-cover extents resulting from buffer zone mapping; and
- Generate a national 30m resolution, land-cover class-pair based change-reporting matrix for both 1990 vs 2018 and 2013/14 vs 2018 change comparisons.

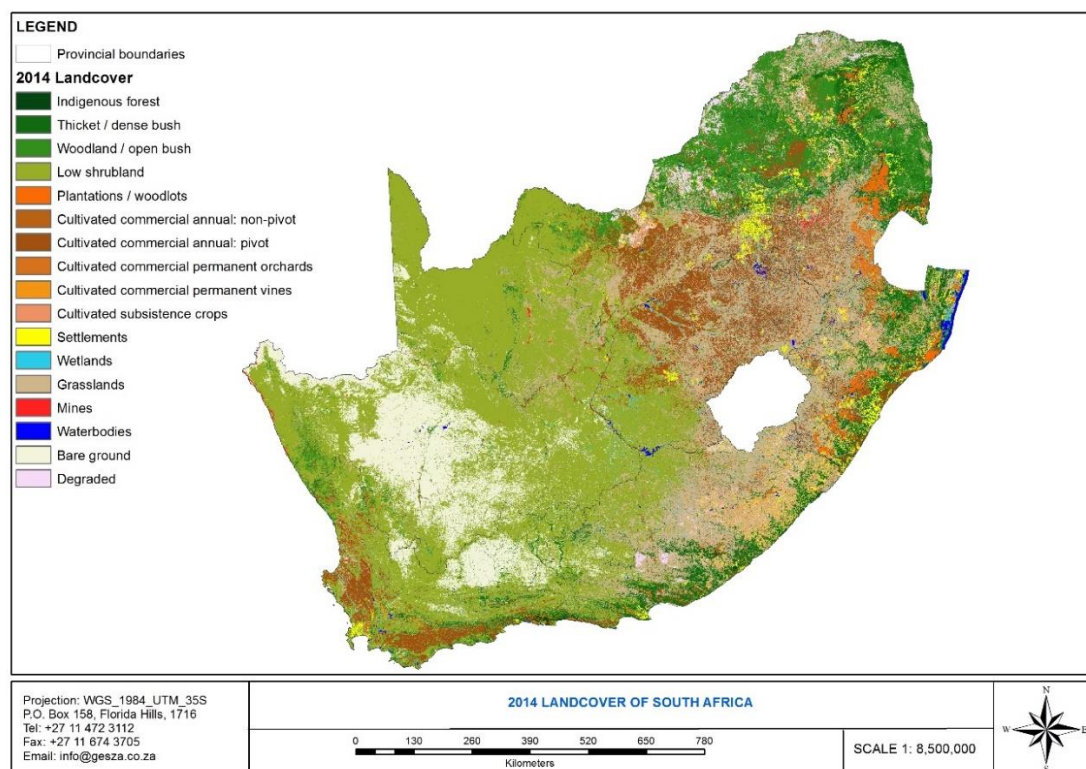


Figure 5.16: Land cover maps for South Africa for 2014 (Source: GTI, 2015).

5.4.2.2 Land category definitions

The 1990-2018 National Land Cover Datasets had 72 land classes. For the purpose of this 2020 inventory these were simplified into 20 classes due to the size of the dataset and the available time frame. Annual land change data had to be derived from the 1990 – 2018 land cover change data, and the more categories that were included the more complex and time consuming the process became. It is, however, recommended that in future an attempt is made to incorporate the more detailed land use classes, particularly in the forest land category, as this would improve the accuracy of the land data. Information from the detailed classes for settlements and croplands were utilized in the calculations and the methodology is described in further detail in the relevant category methodology sections.

The classes used in the 2020 inventory are provided in Table 5.30. Detailed descriptions of the land cover classes provided in the LC maps are described in detail in DFFE (2019a) and the following additional information is provided regarding the IPCC classification:



- *Forest land:*
 - Includes indigenous forests, plantation/woodlots, thicket/dense bush and woodland/open bush, i.e. all areas that have a woodland canopy cover of over 5%.
 - This is in line with the National Forest Act (Act 84 of 1998) (NFA) which 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 well with the UNFCCC decision in this regard that was adopted in Marakesh Accord. It also 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.
- *Croplands:*
 - Includes annual commercial croplands (pivot and non-pivot), permanent perennial orchards, permanent perennial vines, and semi-commercial or subsistence croplands.
- *Grasslands:*
 - Includes grasslands, low shrublands and degraded land;
 - Grasslands include range and pasture lands that were not considered cropland. The category also included all grassland from wild lands to recreational areas as well as agricultural and silvi-pastoral systems, consistent with national definitions.
- *Settlements:*
 - Includes 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;

- Mines are also included in this category. The mining activity footprint includes extraction pits, tailings, waste dumps, flooded pits and associated surface infrastructure such as roads and buildings (unless otherwise indicated), for both active and abandoned mining activities. This class may also include open cast pits, sand mines, quarries and borrow pits etc.
- *Wetlands:*
 - Includes all wetlands and waterbodies as defined in GTI (2019a).
- *Other lands:*
 - Includes bare ground and rocks.

Table 5.30: Relationship between SANLC, land change and IPCC categories in the 2020 inventory.

No	SANLC 1990 and 2013/14 Class	No	Change class	IPCC category	No	SANLC 2018 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	Water seasonal/permanent	7	Waterbodies	Wetland	14	Rivers
					15	Estuaries and lagoons
					16	



38	Mine water seasonal/permanent				17 18 19 20 21	Ocean and coastal Lakes Pans Artificial dams Artificial sewage ponds Artificial flooded mine pits
3	Wetlands	8	Wetlands	Wetlands	22 23 73	Herbaceous wetlands Fallow land (wetlands)
41	Bare non vegetated	9	Barren land	Other land	25 26 28 29 30 31 45	Rock surfaces Dry pans Sand dunes Coastal sand dunes Bare riverbed Other bare Fallow land bare
40	Erosion (donga)	10	Eroded land	Grassland	27	Eroded land
16 17 18 22	Cultivated orchards Cultivated pineapples	11	Permanent orchards	Cropland	32 35	Permanent orchards Permanent 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	Various urban small holdings	17	Built-up smallholdings	Settlements	57 58 59 60	Various smallholdings



42						
42	Urban commercial	18	Built-up commercial	Settlements	65	Commercial
43	Urban industrial	19	Built-up industrial	Settlements	66	Industrial
35	Mine bare	20	Mines	Settlements	68	Mines
36	Mine semi-bare				69	
39	Mine buildings				70	
					71	
					72	Land-fills

5.4.2.3 Land use change

Land-use changes were mapped using an Approach 2 method as described in 2006 IPCC Guidelines. The 1990-2018 change map was utilized in this inventory and data was extrapolated to 2020 assuming the same rate of change between 1990 and 2018. A 2018 South African National Land Cover Change Assessments report (GTI, 2020b) was completed as part of the 2018 land cover mapping project to verify the natural land class changes between 1990/2014/2018. This assessment showed that most of the land changes between the natural land classes were not real changes. It indicated that there may be some loss of indigenous forest to grassland, loss of thicket to woodland (although hard to detect due to extent of area), and thicket to shrubland. This information was incorporated into the land change data by making some assumptions. The conversion areas where no conversion is considered to occur were reverted back to the 2018 land remaining land class. Based on the assessment the conversion from shrubland to grassland could be real, therefore this change was left as given in the change map. In the conversions there were pockets of real change were considered to occur (indigenous forest to grassland, thicket to woodland, thicket to shrubland) it was assumed that a quarter of the actual reported change occurs.

For plantations only conversions between plantations, grasslands and woodlands were assumed to occur and all other conversions are reverted back to original land use. Plantation areas from the land cover maps were compared to Forestry SA data (FSA, 2018) and it was found that the LC maps had much larger plantation areas. Corrections were not included in the land change matrix, but rather in the calculation file. The *Plantation remaining plantation* area was adjusted to reflect the area provided by Forestry SA (FSA, 2018) and the excess area was allocated to thickets and dense bush, based on the information from the Department of Forestry.

In the previous inventory corrections were made to the wetland and degraded areas to try to account for the wet and dry years, however, in order to reduce the number of corrections and assumptions these corrections were not implemented in this inventory.



These areas are relatively small, so these changes do not have a large impact on the emission outputs. The resulting land change matrix is provided in Table 5.31.

There is an urgent need to conduct further validation of the change data as this is the largest limitation to the LULUCF inventory. The previous review highlighted that validation data, perhaps using Collect Earth, was required however a new land mapping platform is being developed and so efforts have been put into this system which will be implemented in the next inventory. The land mapping platform will be able to integrate various datasets and create a consistent time series across the entire time period and provide more accurate data on actual change. More frequent datasets would also provide further accuracy and DFFE GIS Department has setup a system (Computer Automated Land Cover (CALC)) for generating the 20 class land cover maps every 2 years from Sentinel 2 data. A full detailed land cover map is expected to be produced every 4 years. As more maps are produced the natural variability will be distinguished from the permanent change. This system can be used in future to provide more quantitative data for excluding non-permanent changes.

5.4.2.4 *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:

$$LC_{i\ 1990} = ALC_{i\ 1990} * 20\ yrs$$

$$LRL_{i\ 1990} = A_{i\ 1990} - LC_{i\ 1990}$$

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:

$$LC_{it} = LC_{it-1} + ALC_{it} - ALC_{i\ (t-20)}$$

$$LRL_{it} = LRL_{it-1} + ALC_{it} - ACF_{it}$$



Where:

LC_{it} = area (ha) of land converted to land category i in year t ;

LC_{it-1} = area (ha) of land converted to land category i in year $t-1$;

ALC_{it} = 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_{it} = area (ha) of land remaining in the land category i in year t ;

LRL_{it-1} = area (ha) of land remaining in the land category i in year $t-1$;

ACF_{it} = annual total area (ha) converted from land category i to another land category in year t .

It was assumed that the annual change between 1990 and 2018 continued to 2020. This assumption will be corrected in the next inventory when the updated land mapping system is setup and the various maps (1990/2014/2018/2020) are integrated.



Table 5.31: Annual land conversion areas (ha) for South Africa between 1990 and 2014.

Land categories		1990																			
		Indigenous Forest	Thicket / Dense Bush	Natural woodland	Planted Forest	Shrubland	Grassland	Waterbodies	Wetlands	Barren Land	Eroded Land	Cultivated Commercial Permanent Orchards	Cultivated Commercial Permanent Vines	Commercial Annuals Pivot Irrigated	Commercial Annuals Non-Pivot	Cultivated Subsistence	Built-Up Residential All	Built-Up Smallholdings	Built-Up Commercial	Built-Up Industrial	Mines
2018	Indigenous Forest		0	0	0	0	0	22	336	35	0	4	0	0	43	10	159	8	2	1	1
	Thicket / Dense Bush	0		0	0	0	0	165	1 204	237	2	160	17	12	591	305	683	34	17	20	5
	Natural woodland	0	28 899		0	0	0	782	6 350	1 429	811	897	147	395	13 015	6 055	2 367	230	126	107	545
	Planted Forest	0	0	1 756		0	14 054	57	846	23	4	80	11	7	1 436	57	194	50	2	4	95
	Shrubland	0	3 131	0	0		0	1 576	3 298	157 744	4 758	378	430	111	8 324	69	113	15	8	18	997
	Grassland	153	0	0	0	0		1 326	17 120	7 043	3 460	352	72	397	34 331	4 756	2 089	154	207	284	2 884
	Waterbodies	9	763	642	80	716	1 780		1 115	1 315	25	8	5	3	188	46	37	13	1	3	156
	Wetlands	28	2 309	1 165	619	1 109	9 728	674		157	60	26	12	13	1 107	72	161	35	5	10	78
	Barren Land	21	3 798	10 592	174	99 565	19 622	3 477	1 039		357	40	31	17	867	226	113	9	8	17	163
	Eroded Land	2	210	589	6	4 188	3 954	11	159	181		2	0	2	39	105	28	0	0	0	27
	Cultivated Commercial Permanent Orchards	8	609	271	206	399	249	9	71	11	0		368	147	1 104	53	19	29	0	1	0
	Cultivated Commercial Permanent Vines	0	91	36	11	375	45	4	58	124	0	40		26	175	0	4	17	0	1	0
	Commercial Annuals Pivot Irrigated	1	352	1 295	26	2 696	2 860	6	242	68	11	167	28		16 161	63	3	19	0	0	5



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

Commercial Annals Non- Pivot	38	2 372	2 181	654	8 279	17 902	110	1 359	100	17	1 890	547	756		898	127	486	1	5	37
Cultivated Subsistence	89	1 410	2 380	139	2 290	4 233	31	548	6	146	168	0	23	727		831	80	0	0	11
Built-Up Residential All	50	3 151	4 031	1 171	3 738	12 532	33	347	273	111	70	38	20	1 141	787		622	140	35	48
Built-Up Smallholdings	0	65	341	339	113	466	3	12	1	5	2	3	0	352	6	113		2	5	2
Built-Up Commercial	1	99	62	29	134	242	3	12	11	0	2	3	1	35	3	1 221	49		50	5
Built-Up Industrial	1	143	120	30	372	421	34	20	119	2	78	8	27	223	3	358	40	20		52
Mines	18	373	569	150	892	1 731	154	68	362	24	1	1	20	1 245	76	131	10	9	80	



5.4.2.5 Climate

Long term climate maps were developed for South Africa (Moeletsi et al., 2015) which categorize the climate into the classes provided by 2006 IPCC Guidelines (Figure 5.17). The dominant climate is the warm, temperate dry climate and for the purposes of this inventory this climate was adopted throughout.

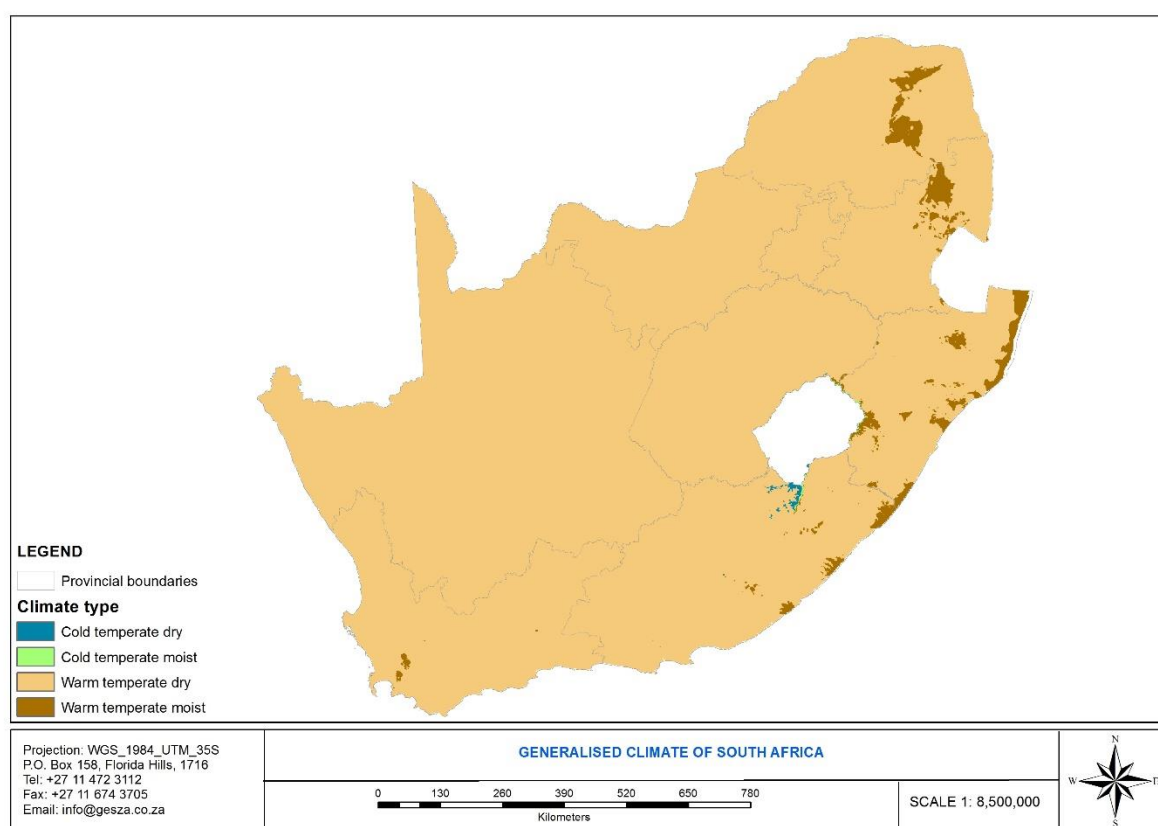


Figure 5.17: South Africa's long term climate map classified into the IPCC climate classes (Source: Moeletsi et al., 2015).

5.4.2.6 Soil

South Africa's detailed soils map was reclassified into the 7 soil classes provided by IPCC 2006 Guidelines (Moeletsi et al., 2015) (Figure 5.18). 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 5.32 indicates the soil categories and what criteria was used for their classification. Volcanic mineral soils are not found in South Africa so this category was excluded. Organic soils were found to be insignificant, so these were also excluded.

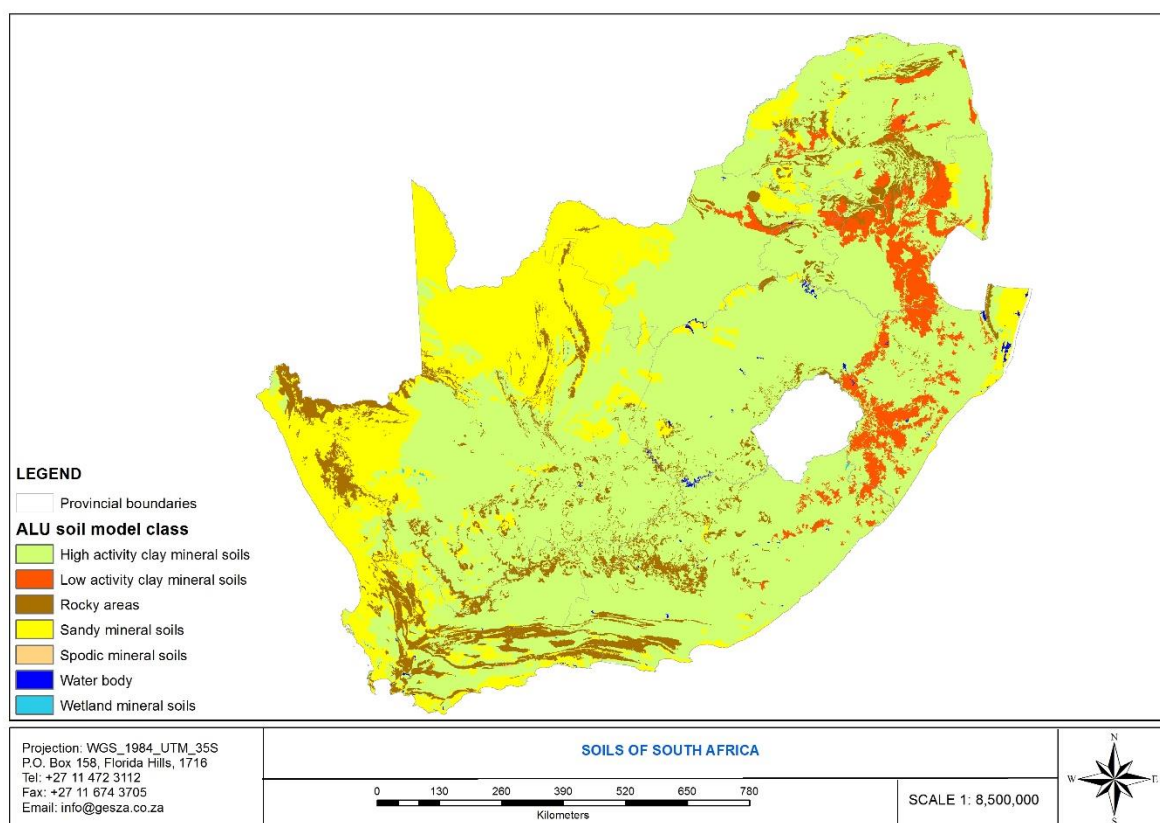


Figure 5.18: South African soils classified into the IPCC classes (Moeletsi et al., 2015).

Table 5.32: Soil types and their description (Source: Moeletsi et al., 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.



5.4.2.7 Annual change by soil and land type

To determine the area of each land class in a particular soil type, the soil datasets were extracted using the national boundary to represent South Africa only. Each dataset was re-projected into the same projection as the land cover datasets (UTM 35s). Each dataset was resampled to a 30 m x 30 m pixel size to match the land cover datasets. Once the 1990 and 2014 land cover datasets and the soil datasets were processed into the same projection and pixel size, they were merged to generate a land cover change dataset within each soil category. An output table was then generated, and annual areas calculated in a similar manner to that mentioned above.

5.4.3 Methodological issues

A summary of the methods used are provided in Table 5.14.

5.4.3.1 Biomass and DOM

General emission calculations

South Africa uses a combination of Tier 1, and Tier 2 methods for estimating emissions for the *Land* category. The NTCSA (DEFF, 2020) provided soil carbon density maps for above and below ground woody, herbaceous and litter layers for 1990, 2014 and 2018, which is a Tier 3 approach, however it was found that for most of the maps there was only a 2014 dataset, in particular the woody biomass layer, was only available for 2014. Without the other years the carbon stock approach could not be applied, and emissions were therefore estimated using the process-based gain-loss method.

For the *land remaining in the same land-use category* 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 the Tier 1 approach (IPCC, 2006; equation 2.10) with country specific data. For plantations the Tier 2 approach of this equation was applied. The annual decrease in carbon stocks due to biomass losses were estimated from IPCC equations 2.11 to 2.14 (IPCC, 2006). A Tier 2 approach was implemented for the estimation of carbon biomass stock change in *Forest land* for both *land remaining land* and *land converted to forest land*, while for all the other land classes a Tier 1 approach for *land remaining land* and a Tier 2 approach for *land converted to other land* (IPCC, 2006; equations 2.15 and 2.16) were applied. The dead organic matter pool includes litter and deadwood, and it is assumed that all litter pool carbon losses occur entirely in the year of transition (Tier 1).



The general equation for calculating emissions from biomass changes on land remaining land is the IPCC (2006) equation 2.4:

$$\Delta C_B = \Delta C_G - \Delta C_L$$

Where:

ΔC_B = annual change in carbon stocks in biomass for each land sub-category (tonnes C yr⁻¹);

ΔC_G = annual increase in carbon stocks due to biomass growth for each land sub-category (tonnes C yr⁻¹);

ΔC_L = annual decrease in carbon stocks due to biomass loss (due to harvesting, fuel wood removals and disturbance) for each land sub-category (tonnes C yr⁻¹).

The general equation for calculating emissions from biomass changes on land conversions (IPCC, 2006; equation 2.15) is:

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

Where:

ΔC_B = annual change in carbon stocks in biomass for each land sub-category (tonnes C yr⁻¹);

ΔC_G = annual increase in carbon stocks due to biomass growth for each land sub-category (tonnes C yr⁻¹);

ΔC_L = annual decrease in carbon stocks due to biomass loss (due to harvesting, fuel wood removals and disturbance) for each land sub-category (tonnes C yr⁻¹).

Also (IPCC, 2006; equation 2.16),

$$\Delta C_{CONVERSION} = \sum \{ (B_{AFTERi} - B_{BEFOREi}) * \Delta A_{TO\_OTHERSi} \} * CF$$

Where:

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

B_{AFTER} = biomass stocks on land type i immediately after conversion (tonnes C yr⁻¹);

B_{BEFORE} = biomass stocks on land type i before the conversion (tonnes C yr⁻¹);

ΔA_{TO_OTHERS} = area of land use i converted to another land-use category in a certain year (ha yr⁻¹);

CF = carbon fraction of dry matter (tonne C (tonnes d.m.)⁻¹).

Changes in DOM were calculated with the IPCC (2006) equation 2.23:

$$\Delta C_{DOM} = \{ (C_n - C_o) * A_{on} \} / T_{on}$$



Where:

ΔC_{DOM} = annual change in carbon stocks in DOM (tonnes C yr⁻¹);

C_n = DOM stock under the new land-use category (tonnes C yr⁻¹);

C_o = DOM stock under the old land-use category (tonnes C yr⁻¹);

A_{on} = area undergoing conversion from old to new land-use category (ha);

T_{on} = time period of transition from old to new land-use category (yr). Tier 1 default is 20 years.

Activity data

The activity data for this sector is the land use change data which is described in detail under the land representation section (section 5.4.2). The burnt area data was obtained from MODIS (see section 5.3.2.2.). Forestry SA (FSA, 2018) supplies all the plantation data, while crop statistics are extracted from various sources (DALRRD, 2020; Stats SA, 2007; FAOStats, 2020). Fuelwood consumption is determined from the number of households using fuel for cooking and heating (Statistics SA, 2019). Further specific details are provided in the sections below.

Emission factors

Biomass data is sourced from two main data sources, namely scientific literature and the carbon density maps from the NTCSA (DEFF, 2020). The carbon stocks for each land class type were determined from the NTCSA data by merging the carbon layers with the land cover to determine an average for each land class (methodology details provided in the Carbon density map data section below). If scientific literature was available then these values were applied and the NTCSA data was used as validation, but if there was no other data the NTCSA stock data was used. In general, the biomass data from the NTCSA overlay are much lower than the data from the literature and IPCC defaults, therefore it is recommended that further validation of the merged output data be conducted.

Carbon density data methodology

The NTCSA was initially conducted in 2015 (DFFE, 2015) and updated in 2020 (DEFF, 2020). The technical reports provide the detailed methodology which is summarized below.

The size of each major carbon pool was estimated for every 1000 x 1000 m pixel across the range of different land-use and vegetation types in South Africa. The above-ground woody plant biomass was estimated using remotely sensed tree height (from ICESAT-GLAS) and canopy cover (MODIS). The woody biomass product was developed through



the integration of ALOS PALSAR-1 synthetic aperture radar images, SRTM30m DEM parameters (elevation, slope and aspect), LiDAR tracks, and field data of woody biomass. The LiDAR tracks were processed to derive a canopy height model for woody vegetation above 0.5m at 1m pixel size. A detailed LiDAR (AGB woody), product was generated at 30m pixel size using LiDAR woody cover and height products and field data. The dual-polarized (HV, HH) SAR bands and DEM parameters were modelled using the LiDAR woody aboveground biomass as reference data for calibration and validation of the final woody aboveground biomass (AGB woody) map. Above-ground herbaceous and litter biomass in the NTCSA was calculated using published relationships between rainfall and annual grass and litter production.

A layer for below ground biomass was created through the NTCSA, but there seemed to be some inconsistencies in the map output and the data reported in the technical report, so this will need further assessment before being incorporated. The corresponding below ground biomass was, therefore estimated using the root:shoot ratios provided in the report to set up the models and data from the literature

An above ground litter and deadwood carbon density layer was also provided so DOM stocks could be determined for each land class. Again DOM data was supplemented with data from the literature where available.

Above ground woody biomass, above ground herbaceous and litter was determined for each land class by combining the biomass layers with the land cover maps. The biomass layers from DEFF (2020) were obtained from CSIR and the land cover data for 2014 obtained from DFFE EGIS website, both were reclassified to 20 classes. The land cover was converted to the same projection and datum as the biomass layers. The biomass layers' cell size was resampled from 1000m cell size to the same size as the relevant land cover layers (30m for the 2014). During the resampling the layers were also converted from the original .tiff format to .img (Imagine Image) format. Thereafter the biomass layers were converted from a floating-point pixel type to an unsigned integer in order to process it alongside the land cover data. Finally, the Combine (ESRI ArcGIS) function was used to get a combined attribute table to assess the biomass data per land cover class. The combine function combines multiple rasters so that a unique output value is assigned to each unique combination of the input values. The combine tool works on integer values and their associated attribute tables. A weighted average for each land class, along with the standard deviation, was determined.

Forest land

DEFF (2020) indicated that the estimates for indigenous forests are likely underestimates due to the sensors saturating at densities higher than 130t/ha therefore data from the literature was applied for this category. Mucina and Rutherford (2011) indicates there



are different forest types (Afrotemperate forests, Mistbelt forests, Scarp forest, Coastal forests, Sand forests and other forests). Literature provides values for the various forest types and then using the relative areas of these forest types in Mucina and Rutherford (2011) a weighted average for indigenous forests was calculated (Table 5.33 **Error! Reference source not found.**). A similar approach was applied to thickets, where thickets include mangroves as well as thickets. The thicket was determined from data from various literature applying the ratio of degraded to restored provided in DFFE (2015). For woodlands and average value of various literature biomass data for woodlands, savannas and fynbos was applied. Plantation data was determined from the Timber Statistics data (DALRRD, 2018) and from Alembong (2014).

In most cases the carbon density data from the NTCSA is lower than the literature data, but for indigenous forests and plantations this is expected due to the saturation of the sensor. The carbon density data for woodlands and thickets is at the low end of the IPCC defaults, while the literature data is within range. The carbon density data is averaged over the large woodland area, and it is recommended that in the next inventory the carbon density data be determined for the various biomes to provide more specific data for comparison, particularly for the woodland category. Furthermore, a more detailed biome break down would also allow for easier comparison and validation with the outputs provided in the DFFE (2020) report.

Root to shoot ratios for the calculation of below ground biomass are provided in Table 5.34, while DOM and biomass accumulation rates are found in Table 5.35 and Table 5.36, respectively.

Croplands

The carbon density data value was applied to the annual crops as there is a wide variation in crop types and the NTCSA included more detail on annual crop types. For the perennial crops the input data provided for the original NTCSA (DFFE, 2015) was applied. The data for all crops is low relative to the IPCC 2006 default values, however they are country specific data so are assumed to be more accurate.

Root to shoot ratios for the calculation of below ground biomass are provided in Table 5.34, while DOM and biomass accumulation rates are found in Table 5.35 and Table 5.36, respectively.

Grasslands

Data from the literature was averaged and applied for grassland biomass. This value was in the range of the IPCC default data. The carbon density data for grasslands is very high, but this may be due to wooded grasslands being incorporated into the grassland area.



Further investigation is required in order to understand the reason for the difference. For degraded land the carbon density data from the NTCSA was applied.

Root to shoot ratios for the calculation of below ground biomass are provided in Table 5.34, while DOM data is found in Table 5.35.

Wetlands

Waterbodies were assumed to have no biomass, while wetland biomass data was sourced from the literature. Wetlands were assumed to be non-woody as mangroves are included under thickets.

Root to shoot ratios for the calculation of below ground biomass are provided in Table 5.34, while DOM data is found in Table 5.35.

Settlements

The carbon density data was applied for settlements, however the value was taken from the initial NTCSA (DFFE, 2015) as the updated data indicated that the LiDAR sensor overestimated for settlements and was not suitable for estimating biomass in these landscapes. The value of 4.21 t C/ha is given in the DFFE(2015) report but this includes litter so 1.67 t C/ha of litter (obtained from the NTCSA overlay data) is removed from the number to obtain a value of 2.54 t C/ha (or 5.4 t dm/ha) as a total carbon value. For mines the updated carbon density data was applied.

Root to shoot ratios for the calculation of below ground biomass are provided in Table 5.34, while DOM and biomass accumulation rates are found in Table 5.35 and Table 5.36, respectively.

Bareground

Bare ground was assumed to have no biomass.



Table 5.33: Above ground biomass factors for the various vegetation classes.

	Data applied in the inventory			Comparison to other data sets		
	Above ground biomass (t dm/ha)	SD	Reference	IPCC default	Above ground biomass from updated NTCSA (t dm/ha)	Spatial mapping deviation (%)
Indigenous forests	175.1 (Afrotemperate) 358.0 (Mistbelt) 103.4 (Scarp) 175.6 (Coastal) 80.0 (Sand) 71.86 (Other) 190.7 (Weighted average)	57.9	Adie et al. 2013 Mensah et al. 2016 Glenday, 2007 Glenday, 2007 Glenday, 2007 DFFE, 2015	35.1 – 65.2 (subtropical Africa, IPCC 2019 Refinement) 20 – 200 (Subtropical Africa, IPCC 2006)	39.6	53.5
Thickets	35.9 (Thickets) 121.2 (Mangroves) 36.1 (Weighted average)	12.2	Glenday, 2007 Van der Vyver et al., 2013 Powel, 2009 Van der Vyver & Cowling, 2019 Johnson et al. 2020 Steinke et al. 1995		18.34	69.1
Woodlands	22.9 (Average)		Glenday, 2007 Mograbi et al. 2015 Wessels et al. 2013		11.07	63.2



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

		3.3	Mills et al. 2012 Colgan et al. 2012 Scholes & Walker, 1993 Van Wilgen 1982 Shackleton and Scholes, 2011 Gander, 1994			
Plantations	77.6		Calculated from Timber Statistics Reports (DALRRD, 2018), supported by data from Alembong 2014	15 – 70 (subtropical Africa, IPCC 2019 Refinement) 10 – 150 (Subtropical Africa, IPCC 2006)	29.74	63
Annual non-pivot crops	No additional literature data so NTCSA data was applied		NA	10.63 (annual crops, IPCC 2006)	5.83	134
Annual pivot crops					9.94	112
Subsistence crops					7.20	97
Orchards	80.9		DFFE, 2015	134.0 (temperate conditions, IPCC 2006)	17.45	65
Vineyards	29.8		DFFE, 2015		12.89	68
Grasslands	2.0 (Average)	0.9	Snyman, 2006 Snyman & Fouche, 1991 Snyman, 2005 Mills et al., 2005a O'Connor et al. 2001 Gander, 1994	1.6 (warm temperate dry, IPCC 2006)	8.31	85
Low shrublands	7.6 (Average)	0.4	Milton, 1990 Rutherford and Westfall, 1986 Rutherford, 1978	NA	3.83	150



			Mills et al, 2005a Anderson et al., 2010			
Degraded land	No additional literature data therefore the NTCSA data was applied		NA	NA	6.4	86
Wetlands	31.3	3.9	Glenday, 2007 Els, 2019		8.96	99
Waterbodies	0	NA	NA		0	0
Settlements – residential	5.4		DFFE, 2015		11.63	71
Settlements – smallholdings					10.17	67
Settlements – commercial					12.33	71
Settlements – industrial					13.31	75
Mines	No additional literature data therefore the NTCSA data was applied		NA		5.44	100
Bare ground	0	NA	NA		0.79	420

Table 5.34: Root:shoot ratios for each of the land classes.

Land class	Root:shoot ratio	Reference	IPCC default
Indigenous forest	0.27	Glenday, 2007 Mangwale et al. 2017	0.24 – 0.56



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

				(subtropical dry forests, IPCC 2006)
Plantations				
Softwoods	0.28			
Euc. Grandis	0.24			
Other Euc.	0.24			
Wattle	0.28			
Other hardwoods	0.26			
Thicket/dense bush	0.34		Glenday, 2007 Powell, 2009	0.24 – 0.56 (subtropical dry forests, IPCC 2006)
Woodlands	0.25		DFFE, 2015	
Annual crop (pivot)	0.2		DFFE, 2015	
Annual crop (non-pivot)	0.2		DFFE, 2015	
Subsistence crop	0.2		DFFE, 2015	
Perennial orchard	0.42		DFFE, 2015	
Perennial vine	0.42		DFFE, 2015	
Wetland	0.96		IPCC 2014 Wetland supplement (Mineral soils)	
Grassland	1		DFFE, 2015	1.6 – 2.8 (subtropical to semi-arid grassland, IPCC 2006)
Low shrubland	2		DFFE, 2015	
Settlements	0.5		DFFE, 2015	
Mine	0.25		DFFE, 2015	
Other land	0		Assumed	



Table 5.35: DOM data applied in the inventory for each of the land classes.

	Data applied in the inventory		Comparison with other data	
	DOM (t dm/ha)	Reference	DOM from updated NTCSA (t dm/ha)	Spatial deviation (%)
Indigenous forests	8.4	Glenday, 2007 (average of coastal scarp, coastal lowland and dune forest)	9.93	59
Thickets	3.4	Glenday, 2007	4.99	114
Woodlands	2.4	Glenday, 2007 (average of woodland, bushclump grassland)	2.16	116
Plantations	2.38	Dames et al., 1998	4.81	107
Annual non-pivot crops	No additional data from literature therefore data from NTCSA was applied	NA	3.40	164
Annual pivot crops			2.72	158
Subsistence crops			1.36	190
Orchards			6.86	97
Vineyards			9.80	76
Grasslands			1.55	147
Low shrublands			2.72	198
Wetlands			2.48	167
Settlements – residential			2.96	160
Settlements smallholdings			2.4	152



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

Settlements commercial	-			2.35	182
Settlements - industrial				4.3	134
Mines				1.34	181
Eroded land				1.53	130
Bare ground				0	NA



Table 5.36: Biomass growth or accumulation rates for the various woody land categories.

Land class	Forest type	Biomass growth rate (t C/ha/yr)	Reference	IPCC default (t C/ha/yr)
Indigenous forest	Primary (undisturbed)	0	Glenday, 2007	0.3 – 0.85 (subtropical dry forest in Africa >20yrs)
	Secondary (disturbed)	1.8	Glenday, 2007	1.1 – 1.2 (subtropical dry forest in Africa <20yrs)
Thicket/dense bush	Primary (undisturbed)	0	Glenday, 2007	0.3 – 0.85 (subtropical dry forest in Africa >20yrs)
	Secondary (disturbed)	1.3	Mills & Cowling, 2006 Van der Vyver et al. 2013 Smart, 2018 Glenday, 2007	1.1 – 1.2 (subtropical dry forest in Africa <20yrs)
Woodlands	Primary (undisturbed)	0	Glenday, 2007	0.3 – 0.85 (subtropical dry forest in Africa >20yrs)
	Secondary (disturbed)	0.9	Scholes & Walker, 1993 Hoffman & Franco, 2009	1.1 – 1.2 (subtropical dry forest in Africa <20yrs)
Perennial orchard	NA	2.16	Carbon stock divided by 25 yr harvest cycle	2.1 (temperate climate)
Perennial vine		0.80	Carbon stock divided by 25 yr harvest cycle	
Low shrubland		0.54	Carbon stock divided by default 20yrs	NA
Settlements		0.19	Carbon stock divided by default 20 yrs	NA

5.4.3.2 Mineral soils

Emission calculation

Soil carbon change was determined using the IPCC 2006 equation 2.25:



$$\Delta C_{Mineral} = [\sum \{ (SOC_{REF} * F_{LU} * F_{MG} * F_I)_0 - (SOC_{REF} * F_{LU} * F_{MG} * F_I)_{(0-T)} \} * A] / D$$

Where:

SOC_{REF} = the reference carbon stock ($t\ C\ ha^{-1}$) for each soil type;

F_{LU} = stock change factor for land-use system for a particular land-use (dimensionless);

F_{MG} = stock change factor for management regime (dimensionless);

F_I = stock change factor for input of organic matter (dimensionless);

Time $_0$ = last year of inventory time period;

Time $_{(0-T)}$ = beginning of the inventory time period;

A = land area (ha);

D = time dependence of stock change factor.

Activity data

Activity data is land cover area data per land class.

Emission factors

The NTCSA (DEFF, 2020) produced updated SOC maps for 1990, 2014 and 2018. The NTCSA used the original 1990, 2014 and 2018 SANLC maps and there is the large difference in classification between 2014 and 2018 which is indicated in the NTCSA Technical report (DEFF, 2020) to make change detection and comparisons between pre-2018 land cover products and post 2018 land cover products problematic. The NTCSA also makes use of the 1990-2014 dataset to make projections due to this discrepancy in the 2018 data set. For this reason, for the soils data the 1990 to 2014 period was used to determine an annual average change in soil carbon per land class and this change rate was assumed to be the same for the years 2014 to 2020.

To include the data in the inventory the SOC data from the NTCSA (DEFF, 2020) needed to be divided into the IPCC classes for reporting purposes, therefore the SOC maps (top 30cm) were merged with the 1990 and 2014 SANLC maps to obtain SOC values per land type. The SOC from DEFF (2020) were obtained from CSIR and the land cover data for 2014 obtained from DFFE EGIS website, both were reclassified to 20 classes. The land cover was converted to the same projection and datum as the SOC layer. The SOC layers' cell size was resampled from 1000m cell size to the same size as the relevant land cover layers (30m for the 2014). During the resampling the layers were also converted from the original .tiff format to .img (Imagine Image) format. Thereafter the SOC layer was converted from a floating-point pixel type to an unsigned integer in order to process it alongside the land cover data. Finally, the Combine (ESRI ArcGIS) function was used to



get a combined attribute table to assess the SOC data per land cover class. The combine function combines multiple rasters so that a unique output value is assigned to each unique combination of the input values. The combine tool works on integer values and their associated attribute tables. A weighted average for each land class was determined. Utilizing the land areas, the stock could be determined for each land type for both years. The annual change per land class was then estimated. Since the data is per land class and is merged with the original SANLC datasets rather than the change datasets, SOC changes could only be determined per land class and cannot be divided into *land remaining land* or *land converted to another land category*. In this case the value is assigned to the *land remaining land* category and the SOC data for *land converted to another land class* is indicated to be included elsewhere (IE)

SOC data comparison using Formulation A approach

As a type of validation, the SOC data determined for the inventory was compared to a Formulation A approach using country specific SOC reference data and stock change data (detailed methodology shown in Appendix E). Even though Approach 2 was used for land representation in the inventory the actual land parcels are not tracked so only a Formulation A of the SOC method can be applied.

The data comparison between the NTCSA data and the Formulation A default approach are shown in Table 5.37. Values show similar trends between the various land classes, but there are differences in the strength of the source or sink particularly for grasslands and croplands. The differences are due to the greater detail included in the NTCSA data as opposed to the Tier 1 approach and also the slightly different stock change data included in the calculations.

Table 5.37: Comparison between annual SOC change per land class using the NTCSA data and a Tier 1 approach.

	Change in SOC from NTCSA data (t C/yr)	Change in SOC with Tier 1 IPCC approach (t C/yr)
Indigenous forest	-34 108.3	-837.9
Thicket	-106 608.4	-354 949.1
Woodland	857 998.3	869 799.5
Plantation	451 249.2	338 639.2
Low shrubland	-3 993 702.4	-4 169 024.8
Grassland	7 180 400.1	6 172 229.3
Waterbodies	-271 556.8	-233 174.3
Wetlands	-759 398.8	-594 886.8



Other land	-650 609.6	-1 156 504.7
Degraded land	-220 217.8	-278 575.1
Perennial orchard	47 279.9	49 703.0
Perennial vineyard	38 334.0	24 573.2
Annual pivot crop	809 657.6	535 538.4
Annual non-pivot crop	-547 148.0	-838 130.5
Subsistence crop	316 396.5	65 213.0
Built-Up Residential All	-4 562.3	243 239.3
Built-Up Smallholdings	-23 920.8	-10 254.4
Built-Up Commercial	11 262.7	10 121.8
Built-Up Industrial	-5 897.5	-3 386.5
Mines	71 738.9	79 189.0

5.4.4 Recalculations since the 2017 inventory

Recalculations were performed for the entire time series for the *Land* sector due to several updates and improvements:

- Land areas:
 - Incorporation of 1990-2018 land change data;
 - Exclusion of corrections for wetlands and degraded lands;
- Biomass gains data:
 - Updated biomass data;
 - Updated DOM data;
 - Updated SOC data;
 - Inclusion of no growth for primary (or undisturbed) forest areas;
 - Updated BCEF factors for plantations;
 - Corrected plantation area to reflect the areas provided by Forestry SA;
- Biomass losses:
 - Burnt area data was updated to MODIS collection 6 data;
 - Fuelwood removals from woodlands were adjusted for charcoal and fuelwood from plantations;
 - Inclusion of mortality rate.

The recalculations produced a sink estimate that was 18.5% lower than the previous submission for the year 2017. The estimated sink was greater in the years 2000 to 2004 and between 2011 and 2016, but was less during the other years (Figure 5.19).

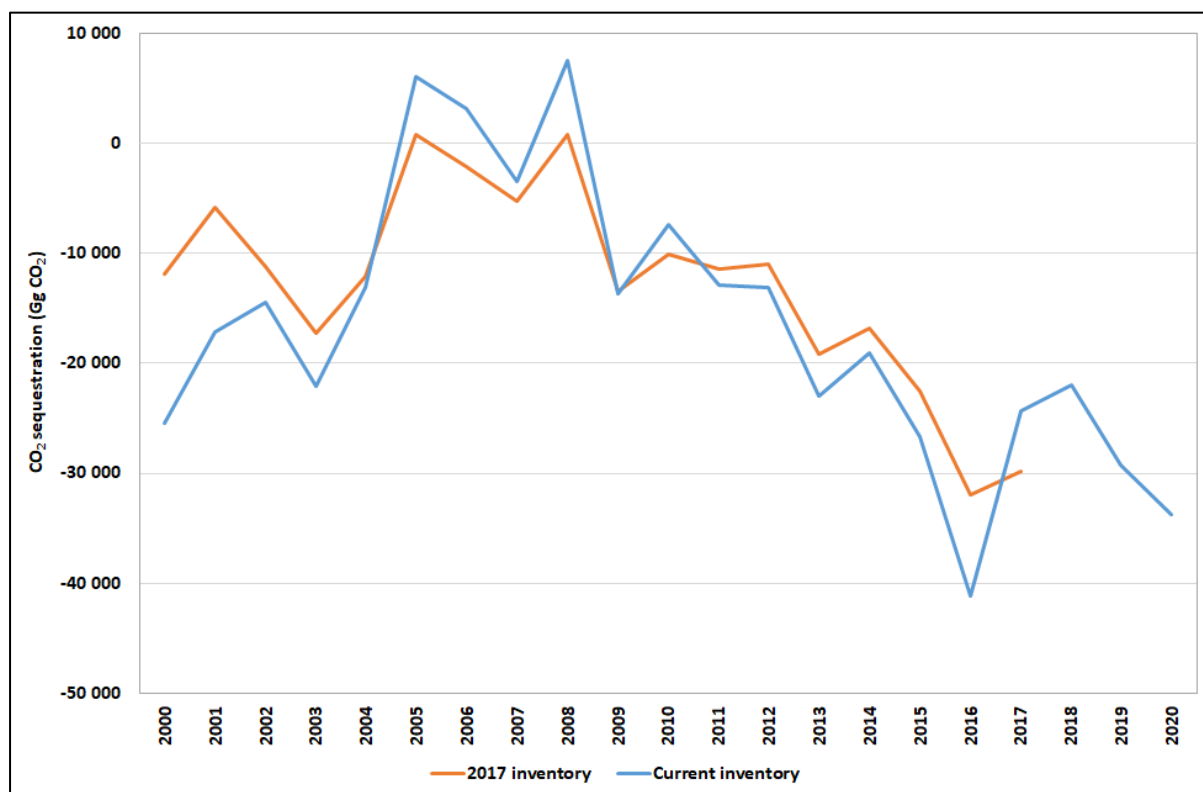


Figure 5.19: Recalculated Land category emissions in 2020 compared to 2017 submission data.

5.4.5 Uncertainties and time-series consistency

5.4.5.1 Uncertainties

Land cover maps

The 2018 South African National Land-Cover dataset was verified in terms of mapping accuracy to provide a measure of end user confidence in data use. The satellite image generated land-cover / land-use information was verified visually, as part of a desk-top only procedure, against equivalent date, high resolution imagery and photography in Google Earth ©. Accuracies are reported using industry standard error (confusion) matrices, and included Producer, User accuracies and Kappa values. The map accuracy



results for the 2018 South African National Land-Cover dataset, modelled from multi-seasonal Sentinel 2 imagery, based on the modified legend format, are provided in Figure 5.20.

OVERALL SUMMARY			
Overall Map Accuracy	91.32	%	
Mean Class Accuracy	91.38	%	
90 % confidence limits	90.87	91.78	
	low	high	
Kappa Index	91.12		
Number of classes present		47	
Number of sample sites		6570	

Figure 5.20: Mapping accuracies for the 2018 SA National Land Cover dataset (Source: GTI, 2020).

The overall map accuracy for the 2018 South African National Land-Cover map is 91.32%, with a mean land-cover / land-use class accuracy of 91.38%. This has been determined from 6 570 sample points representing 47 land cover classes. A breakdown of individual class accuracies is provided in Figure 5.21.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

CLASS SUMMARY STATISTICS			User	Prod	90% C.L	90% C.L	Omm	Comm
			Acc %	Acc %	low	high	Error	Error
LAND	Contiguous Forest (indigenous)	1	98.90	84.11	79.50	88.73	0.16	0.01
COVER	Contiguous Low Forest	2	80.74	93.16	90.06	96.27	0.07	0.19
CLASS	Dense Forest & Woodland	3	77.25	93.59	90.97	96.21	0.06	0.23
	Open Woodland	4	79.49	92.26	89.53	95.00	0.08	0.21
	Plantation Forest	5	99.35	96.20	94.12	98.28	0.04	0.01
	Low Shrubland (non-fynbos)	6	78.86	86.25	82.69	89.81	0.14	0.21
	Low Shrubland (fynbos)	7	93.92	85.80	82.22	89.39	0.14	0.06
	Low Shrubland (succulent karoo)	8	94.00	74.60	69.57	79.64	0.25	0.06
	Low Shrubland (nama karoo)	9	86.45	87.58	84.09	91.08	0.12	0.14
	Sparsely Wooded Grassland	10	91.18	88.57	84.49	92.65	0.11	0.09
	Natural Grassland	11	48.36	88.08	84.62	91.54	0.12	0.52
	Natural Rivers	12	99.36	99.36	98.26	100.00	0.01	0.01
	Natural Estuaries & Lagoons	13	97.09	100.00	99.30	100.00	0.00	0.03
	Natural Ocean	14	97.04	100.00	99.21	100.00	0.00	0.03
	Natural Lakes	15	100.00	100.00	98.26	100.00	0.00	0.00
	Natural Pans (flooded @ observation time)	16	93.33	97.67	95.80	99.55	0.02	0.07
	Artificial Dams (including canals)	17	94.41	95.60	93.39	97.80	0.04	0.06
	Artificial Sewage Ponds	18	100.00	96.15	93.58	98.73	0.04	0.00
	Artificial Flooded Mine Pits	19	95.49	95.49	93.05	97.93	0.05	0.05
	Herbaceous Wetlands	20	97.56	78.82	75.09	82.55	0.21	0.02
	Mangrove Wetlands	21	100.00	88.79	84.78	92.79	0.11	0.00
	Natural Rock Surfaces	22	97.22	82.84	79.06	86.62	0.17	0.03
	Dry Pans	23	95.51	76.58	71.35	81.80	0.23	0.04
	Eroded Lands	24	100.00	86.75	83.30	90.19	0.13	0.00
	Sand Dunes	25	100.00	91.14	86.92	95.36	0.09	0.00
	Coastal Dunes & Beach Sand	26	96.39	98.16	96.63	99.68	0.02	0.04
	Bare Riverbed Material	27	98.15	95.50	92.83	98.16	0.05	0.02
	Other Bare	28	84.52	82.91	79.01	86.82	0.17	0.15
	Cultivated Commercial Permanent Orchards	29	96.20	95.00	92.68	97.32	0.05	0.04
	Cultivated Commercial Permanent Vines	30	99.37	97.52	95.79	99.24	0.02	0.01
	Cultivated Commercial Sugarcane Pivot Irrigated	31	96.81	86.67	82.32	91.01	0.13	0.03
	Commercial Permanent (Pineapples)	32	100.00	92.80	89.73	95.87	0.07	0.00
	Cultivated Commercial Sugarcane Non-Pivot (all other)	33	90.48	93.66	90.93	96.39	0.06	0.10
	Cultivated Emerging Farmer Sugarcane Non-Pivot (all other)	34	100.00	82.91	78.37	87.45	0.17	0.00
	Commercial Annuals Pivot Irrigated	35	92.44	96.95	95.09	98.81	0.03	0.08
	Commercial Annuals Non-Pivot Irrigated	36	94.48	93.90	91.40	96.40	0.06	0.06
	Commercial Annuals (Non-Pivot)	37	88.50	90.77	88.03	93.50	0.09	0.12
	Subsistence Annual Crops	38	85.11	87.43	84.22	90.64	0.13	0.15
	Residential Formal	39	84.21	100.00	99.28	100.00	0.00	0.16
	Residential Informal	40	100.00	97.16	95.41	98.90	0.03	0.00
	Village	41	95.24	68.97	63.39	74.54	0.31	0.05
	Smallholdings	42	95.58	97.30	95.14	99.45	0.03	0.04
	Urban Recreational Fields	43	98.95	94.95	91.98	97.91	0.05	0.01
	Commercial	44	100.00	95.98	94.08	97.88	0.04	0.00
	Industrial	45	95.65	98.72	97.35	100.00	0.01	0.04
	Mines	46	91.56	90.38	87.27	93.50	0.10	0.08
	Land-fills	47	100.00	97.78	94.65	100.00	0.02	0.00
Total				91.32	90.87	91.78		

Figure 5.21: Class accuracies for the 2013/2014 SA National Land Cover Map (Source: GTI, 2020).

Carbon density data

The top-level products of the NTCSA are accompanied by error estimates, defined as the likely range for a given level of confidence (such as 80%). They take into account the error



of estimation associated with uncertainty in the measurements and models. In order to estimate the top-level error, the underlying errors in each of the variables which went into the calculation must be known or estimated. Where possible, and especially for values which make a large contribution to the overall error, these are statistically-rigorous, data-based derivatives of the variance. For factors where the data are sparse ($n < 5$) or where the factor makes a small contributions to the overall error ($< 5\%$), an expert-based assessment of the variance (σ^2) has been made.

The propagation of error in the equations used in this study are mostly covered by the two rules outlined below, used alone or in combination.

For the sum (or subtraction) of statistically-independent, normally distributed variables with a variance denoted σ^2 , the overall error is given by:

$$\text{Error} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \dots + \sigma_n^2}$$

For the product of statistically-independent, normally-distributed variables each with a variance denoted σ^2 and an expected value of q , where the overall expected value is Q , the overall error is given by

$$\text{Error}/|Q| = \sqrt{(\sigma_1/q_1)^2 + (\sigma_2/q_2)^2 + (\sigma_3/q_3)^2 + \dots + (\sigma_4/q_4)^2}$$

While these calculations could be completed for top-level products, individual sampling error was however not provided as the whole country is measured and therefore there is no statistical sampling error. The inherent spatial and temporal variability of carbon stocks and fluxes is rather reflected separately in the report tables as the spatial standard deviation (SD). The spatial deviation can be large as is seen in section 5.4.3.4. Without having an uncertainty on the spatial data it is difficult to complete a full uncertainty analysis. Global carbon stock maps (Baccini et al., 2012) show an uncertainty of $\pm 13\%$ for Africa, and global AGB models (Saatchi et al. 2011), show an uncertainty of $\pm 32\%$ for Africa and therefore uncertainties could be expected to be less than this due to country specific data being used. A detailed uncertainty analysis needs to be conducted on all spatial data so that uncertainty data can be improved in the future.

5.4.5.2 *Time-series consistency*

The time series is consistent throughout the time-period.

5.4.6 Forest land (3.B.1)



5.4.6.1 Category description

Reporting in this category covers emissions and removals from above-ground and below-ground biomass, DOM and mineral soils. The category included indigenous forests, plantations/woodlots, thickets/dense bush, and woodlands/open bush. As in the previous inventory the 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 plantations differed. The majority of the *Eucalyptus* plantations are used for pulp so the *Eucalyptus* species were not split by use. *Eucalyptus grandis* and *Other Eucalyptus* species were separated.

Changes in biomass include wood removal, fuelwood collection, and losses due to disturbance. Harvested wood was included for plantations, while fuelwood collection was estimated for all forest land subcategories. In 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. It should be noted that only CO₂ emissions from fires were included in this section as all other non-CO₂ emissions were included under category 3C1 (see Section 5.3.2.). Also, all emissions from the burning of fuelwood for energy or heating purposes were reported as part of the energy sector. Emissions from *harvested wood products* are included under 3D1.

This category reports emissions and removals from the categories *forest land remaining forest land* and *land converted to forest land* (new forest established, via afforestation or natural succession, on areas previously used for other land-use classes). Calculations are carried out on the basis of a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years.

5.4.6.2 Methodological issues

Forest land remaining forest land (3.B.1.a)

Living biomass

A Gain-loss approach is used to determine carbon stock changes in forest land remaining forest land. For plantations a Tier 2 approach was applied. The total carbon flux (ΔC) was calculated from the IPCC 2006 Guidelines (Equations 2.7 and 2.11) where carbon losses are subtracted from the carbon gains:

$$\Delta C = \Delta C_G - L_{\text{wood-removals}} - L_{\text{fuelwood}} - L_{\text{disturbances}}$$



Carbon gains

Removals and emissions of CO₂ from changes in above- and below-ground biomass are estimated using the Tier 2 gain-loss Method in the 2006 IPCC Guidelines. The gains in biomass stock growth were calculated using the following equations (Equation 2.9 and 2.10 from IPCC 2006 Guidelines):

$$\Delta CG = \sum (A_i * G_{TOTALi} * CF_i)$$

where for G_{TOTAL} a Tier 1 approach was used for natural vegetation classes and a Tier 2 approach was applied for plantations.

The IPCC 2006 default value of 0.47 t C per t dm⁻¹ (IPCC 2006, Table 4.3) was used for the carbon fraction of dry matter of all Forest lands.

Natural forest lands remaining forest lands are classed as either undisturbed (or primary) or disturbed (secondary forest) to make use of different growth rates (Table 5.36). In the absence of data on specific areas of primary and secondary forests, it was assumed that primary forests are those that fall into protected areas. According to Statistics SA (StatsSA, 2021) 40%, 13% and 15% of indigenous forests, thickets and woodlands are protected. Annual above-ground biomass growth in primary indigenous forests, thickets and woodlands are considered to be zero (IPCC 2019), which is in line with the findings of Glenday (2007). For secondary forests the growth rates in Table 5.36 **Error! Reference source not found.** were applied, and were assumed to grow until they reach their maximum biomass. A mortality factor was included due to a review comment, however there is no data on mortality rate fractions therefore and expert judgement of 10% was applied to natural forest land categories. DEFF (2020) indicates that 10% of above ground biomass is deadwood, which supports this assumption. Data needs to be collected on this and improved in future. Root to shoot ratios (Table 5.34 **Error! Reference source not found.**) were utilized to include the below ground biomass.

For plantations a Tier 2 method is applied to calculate biomass gains. The plantation area provided in the land cover datasets is overestimated according to the FSA data, therefore in the calculation files a correction was made so that the FSA plantation area (FSA, 2019) is used for calculating gains. It should be noted that data for 2019 and 2020 was not available at the time of completing this inventory and these years were just assumed to be the same as for 2018. The data will be corrected in the next inventory.

The mean annual increments and biomass conversion and expansion factors required for this are provided in Table 5.38. A weighted value for each factor was determined based



on the plantation species composition and these values were used with the area data to calculate gains and losses. Currently there is an improvement underway to utilize the Timber Statistics data with the detailed data provided, as opposed to weighted averages) to determine the plantation stock each year and then use the stock change method for plantations. This data will be incorporated into the next inventory.

Table 5.38: Factors applied for plantation data.

	Softwoods (e.g. Pines)	Eucalyptus grandis	Other Eucalyptus sp.	Acacia sp. (Wattles)	Other hardwood sp.
Mean annual increment (m ³ /ha/yr)	Sawlogs: 11 Pulpwood: 15 Mining timber: 10.1 Poles: 10	Sawlogs: 27 Pulpwood: 23 Mining timber: 19 Poles: 18	Sawlogs: 16 Pulpwood: 17 Mining timber: 15 Poles: 16	Sawlogs: 8.8 Pulpwood: 9 Mining timber: 9 Poles: 8	Sawlogs: 16 Pulpwood: 16 Mining timber: 13 Poles: 13
BCEFs for growing stock: <20 21-40 41-100 101-200 >200)	2.4 1.3 0.8 0.7 0.6	1.5 1.0 0.8 0.7 0.6	1.5 1.0 0.8 0.7 0.6	2.2 1.3 1.0 0.8 0.8	1.5 1.0 0.8 0.7 0.6
Ratio of below- ground biomass to above ground biomass	0.28	0.24	0.24	0.28	0.26

There are some conversions between forest types and for these areas the gains and loss are calculated as described above, but a Tier 2 approach is applied where the initial change in biomass carbon stocks on the converted land is added to the equation. The carbon stocks on the forest land before conversion are the values associated with the initial vegetation type (Table 5.33 **Error! Reference source not found.**). For values immediately after conversion are those associated with the final vegetation type. Carbon losses are assumed to occur within the year of conversion. It is assumed the change for natural forest systems is gradual (i.e. from natural vegetation carbon stock to new vegetation stock), while for plantations it is assumed the land is cleared, i.e. carbon stocks immediately after conversion are zero.

Carbon losses



The total carbon flux (ΔC) was calculated from the IPCC 2006 Guidelines (Equations 2.7 and 2.11) where carbon losses are subtracted from the carbon gains:

$$\Delta C = \Delta C_G - L_{\text{wood-removals}} - L_{\text{fuelwood}} - L_{\text{disturbances}}$$

The losses were calculated for three components:

- Loss of carbon from harvested wood;
- Loss of carbon from fuelwood removals; and
- Loss of carbon from disturbance.

Losses due to wood harvesting

Loss of carbon from harvested wood was calculated for plantations only and followed the equation (Equation 2.12 IPCC 2006 Guidelines):

$$L_{\text{wood-removals}} = [H * BCEF_R * (1+R) * CF]$$

Where:

H = annual wood removals ($\text{m}^3 \text{ yr}^{-1}$)

$BCEF_R$ = biomass conversion and expansion factor for conversion of wood removal volume to above-ground biomass removal ($\text{t biomass removed} (\text{m}^3 \text{ of removals})^{-1}$)

R = ratio of below-ground biomass to above-ground biomass ($\text{t dm below-ground} (\text{t dm above-ground})^{-1}$).

CF = Carbon fraction of dry matter ($\text{t C} (\text{t dm})^{-1}$)

Loss of carbon due to wood harvesting was only determined for plantations using FSA data (FSA, 2019) as wood harvesting does not occur in woodlands/open bush, thickets or indigenous forests. The industry conversion factors provided were used to convert between tonnes and m^3 . The $BCEF_R$ were determined from the $BCEF_S$ factors provided in Dovey et al. (2020) and the relationship between $BCEF_R$ and $BCEF_I$ provided in IPCC 2006 Guidelines. The harvested wood includes the 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 have harvesting due to the long harvest cycle.



Losses due to fuelwood removals

Loss of carbon from fuelwood removals was calculated using the following equation (Equation 2.13 of IPCC 2006 Guidelines):

$$L_{\text{fuelwood}} = [FG_{\text{trees}} * BCEF_R * (1+R) + FG_{\text{part}} * D] * CF$$

Where:

FG_{trees} = annual volume of fuelwood removal of whole trees ($\text{m}^3 \text{yr}^{-1}$)

FG_{part} = annual volume of fuelwood removal as tree parts ($\text{m}^3 \text{yr}^{-1}$)

$BCEF_R$ = biomass conversion and expansion factor for conversion of removals in merchantable volume to biomass removals (including bark), ($\text{t biomass removal} (\text{m}^3 \text{ of removals})^{-1}$)

R = ratio of below-ground biomass to above-ground biomass ($\text{t dm below-ground} (\text{t dm above-ground})^{-1}$)

D = basic wood density (t dm m^{-3})

CF = carbon fraction of dry matter ($\text{t C} (\text{t dm})^{-1}$)

The amount of fuelwood collected is determined from the number of households using fuelwood for cooking and heating (Statistics SA, 2019). It is assumed that there is overlap between the houses that use wood for heating and cooking and so the higher value (households for heating) is 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 and Holdo, 2016) is applied. This may be overestimated as it is indicated that the households that use wood but also have electricity use an average of 2.9 t per household per year. Some of the fuelwood comes from plantations and this removal is already accounted for under harvested wood, therefore the fuelwood and charcoal removals from plantations was subtracted from the determined fuelwood consumption. In a review it was suggested that losses due to charcoal production also be included. There is no national data on charcoal production, therefore the charcoal production data from FAOStat was utilised. The wood consumption in m^3 was determined based on the assumption that 6kg wood are required to make 1kg charcoal. This consumption was then added to the fuelwood consumption. Some fuelwood would also be coming from the harvesting of alien invasive species, however this is another complex issue which needs to be considered for incorporation in future inventories. A wood density of 0.65 t dm/m^3 (Glenday, 2007) is applied to convert the volume to mass.

The fuelwood consumption numbers are within the range of the value provided by the FAOStat and a UNEP report (UNEP, 2019). The fuelwood consumption estimates show a



decline since 2000 due to the increased electrification and reduction in households using fuelwood. There is very little information on how this amount is split between the various vegetation types, therefore, the whole amount was allocated to woodlands/open bush with no removal from forests and thickets.

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.

Losses due to disturbance

Finally, the loss of carbon from disturbance was calculated following IPCC Equation 2.14:

$$L_{\text{disturbances}} = A_{\text{disturbance}} * B_W * (1+R) * CF * fd$$

Where:

$A_{\text{disturbance}}$ = area affected by disturbances (ha yr^{-1})

B_W = average above-ground biomass of areas affected by disturbance (t dm ha^{-1})

R = ratio of below-ground biomass to above-ground biomass ($\text{t dm below-ground} / (\text{t dm above-ground})^{-1}$).

CF = carbon fraction of dry matter ($\text{t C} / (\text{t dm})^{-1}$)

fd = fraction of biomass lost in disturbance; a stand-replacing disturbance will kill all ($fd = 1$) biomass while an insect disturbance may only remove a portion (e.g. $fd = 0.3$) of the average biomass C density

For fire disturbance losses the burnt area data is determined as described in section 5.4.2. Burnt area is provided for the total area of each land class and in order to split this into land remaining land and land converted to forests the fraction of burnt area was calculated and then applied to the land remaining and the converted land areas. Carbon biomass is taken to be the carbon density for each land type (section 5.4.5.). There is no country specific data on the fraction of fuelwood lost during the fire disturbance, so the combustion fractions provided by IPCC 2006 are used as a proxy. The Tier 1 assumption that all the disturbance losses are emitted in the year of the disturbance is applied.

For plantations the loss due to other disturbances was also included. Forestry statistics (FSA, 2019; DALRRD, 2018a) provides data on the area damaged during fire and other disturbances. FSA data reports on the severity of the fire disturbance, so it was assumed that for severe damage $fd=1$, moderate damage $fd=0.6$ and slight damage $fd=0.1$. Based on the fraction of each the fd for plantation hardwoods and softwoods were determined to be 0.63 and 0.68, respectively for fire disturbance, and 0.29 and 0.36, respectively for other disturbances. The AGB (B_W) data are provided in section 5.4.3.4.



Losses due to fire disturbance were calculated for both the *Forest land remaining forest land* and *land converted to forest land* by applying the percentage burnt area to each of the land sub-categories.

Dead organic matter

A Tier 1 approach is applied to DOM for forest land where it is assumed there is no change in DOM in forest land remaining forest land. For areas that are converted from one forest type to another, the DOM from the initial and final land types is utilized and 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. A Tier 1 assumption that all carbon contained in biomass killed during a land-use conversion event is emitted directly to the atmosphere and none is added to the deadwood and litter pools.

Mineral soils

Calculations and outputs for mineral SOC in *Forest land remaining forest land* is described in section 5.4.3.2.

Land converted to forest land (3.B.1.b)

Living biomass

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 and converted from other land types to forest lands are calculated as for forest lands remaining forest lands. For the initial change in biomass due to the conversion the carbon stock of the initial land use (calculated from the biomass data; see section 5.4.3.2), is subtracted from the biomass immediately after the conversion. For natural land types the conversion is assumed to be gradual, thus biomass transitions from the initial to the final biomass, but for conversion to plantations the land is assumed to be cleared first. All carbon gains are assumed to occur gradually over the default 20-year period, while losses are assumed to be emitted in the year of conversion.

Dead organic matter

For areas that are converted from another land type to a forest land, the DOM from the initial and final land types is utilized and 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. A Tier 1 assumption that all carbon contained in biomass killed during a land-use conversion event is emitted directly to the atmosphere and none is added to the deadwood and litter pools.

Mineral soils

Carbon changes in mineral SOC in land converted to forest land are included in the Forest land remaining forest land category.

5.4.6.3 *Uncertainties and time series consistency*

Uncertainty estimates on emission factors and activity data is limited, but where data is available the uncertainty has been calculated. The overall accuracy for the 2018 land cover map was determined to be 91.3% (GTI, 2020). No uncertainty was provided for the soil maps. There is a large amount of statistics for plantations and the FSA statistics have a high confidence rating (80% (Vorster, 2008) with an uncertainty range from -11% to 3%. For data from the carbon density maps, although error was calculated the error on specific point data could not be provided and only an overall spatial standard deviation was provided. A full uncertainty assessment on the carbon density maps needs to be conducted.

IPCC 2006 provides default uncertainties which are applied for now. Growing stock or gains are indicated to have a $\pm 30\%$ uncertainty for non-industrialised countries. Fuelwood losses are shown to have a $\pm 20\%$ uncertainty in industrialized countries, so in South Africa this is expected to be higher, particularly due to the way the fuelwood consumption is estimated. An uncertainty of $\pm 30\%$ is applied. Disturbance losses in industrialised countries have a default uncertainty of $\pm 15\%$, so a $\pm 20\%$ uncertainty is assumed. Land conversions are assumed to have a $\pm 5\%$ greater uncertainty on the area. Since the DOM and SOC data have greater uncertainty than the biomass data an uncertainty of $\pm 35\%$ is assigned to these categories.

5.4.6.4 *Category specific QA/QC and verification*

All general QC listed in Table 1.7 were completed for this category. Land areas were checked. Carbon emission factors were compared to literature, and to IPCC values. Where possible outputs were compared to the NTCSA (DFFE, 2015; DEFF, 2020). Data could not be compared at the land class level as the land class information in the DEFF (2020) report was based on biomes as opposed to the land categories in the SANLC, but the total data for the various biomass pools was compared and shown to be similar in range.

Plantation area and fuelwood consumption data was compared to FAO data



Soil changes were determined from the NTCSA SOC data and for validation an Approach 1 formulation A was applied for comparison (section 5.4.3.2). In terms of the calculation files, during the NDC update process a LULUCF model for estimating projections for the sector was compiled. This model recreated the LULUCF sector emission profile using a slightly more simplistic approach. The data outputs from this model were compared to the inventory outputs and the comparison enabled the detection and correction of calculation errors in both the model and the inventory calculations.

5.4.6.5 Category-specific recalculations

Recalculations were completed for the forest land category for the full time series due to a number of improvements:

- a) Inclusion of 1990 to 2018 change data and updated area conversion assumptions;
- b) Updated biomass, biomass accumulation rates and DOM data;
- c) Updated SOC data;
- d) Updated BCEF factors for plantations;
- e) Addition of mortality rate;
- f) Addition of separate growth rates for primary and secondary forests; and
- g) Inclusion of charcoal losses.

Overall, the forest land recalculation led to a decrease in the sink compared to the previous inventory (Figure 5.22) and this varied across the years. There are differences between *Forest land remaining forest land* and *Land converted to forest land* compared to the previous inventory as the SOC data was not divided by land conversions and all changes are reported under *Forest land remaining forest land*.

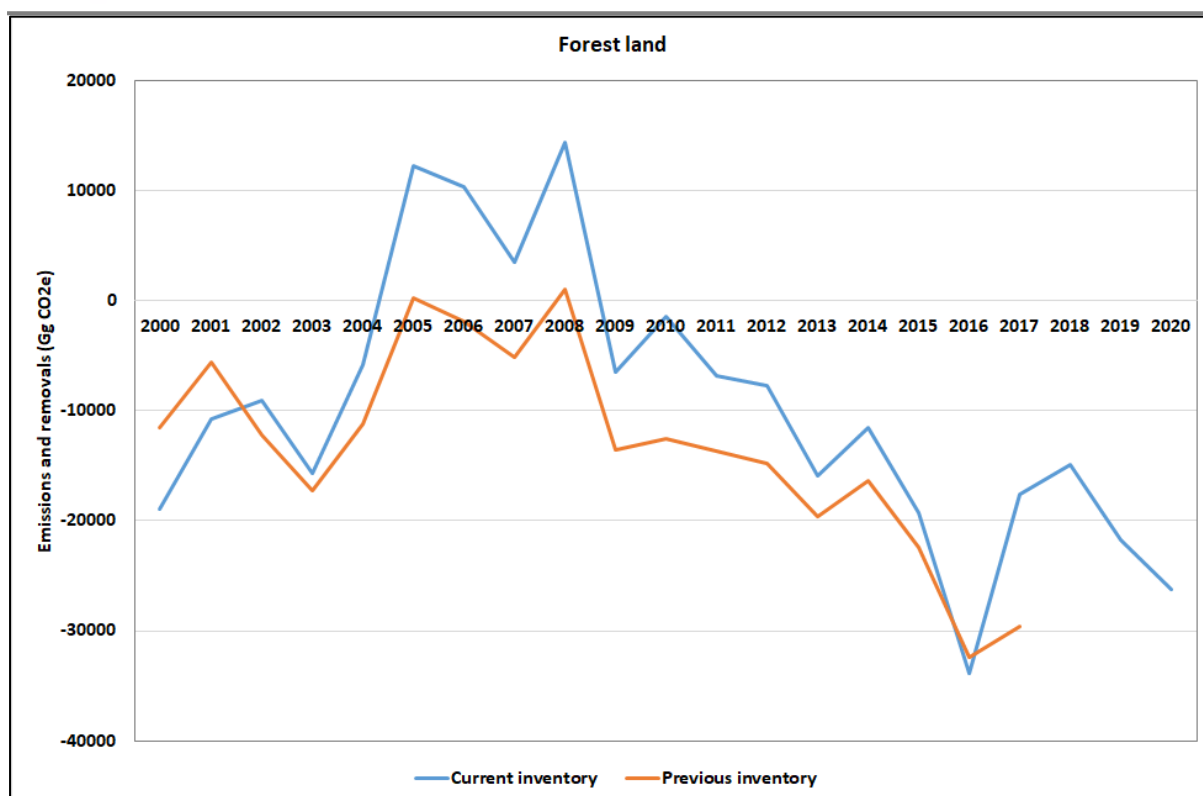


Figure 5.22: Recalculations for Forest lands.

5.4.6.6 Category-specific planned improvements

The incorporation of more detailed plantation data using the stock difference approach is planned. In addition, more detailed stratification of forest land is recommended.

5.4.7 Croplands (3.B.2)

5.4.7.1 Category description

The *Cropland* category covers perennial crops (orchards and vineyards) and annual crops (pivot irrigation, non-pivot and subsistence crops). Reporting in the *cropland* category covers emissions and removals of CO₂ from mineral soils, and from above- and below-ground biomass and litter. *Croplands* include annual commercial crops, annual semi-commercial or subsistence crops, orchards, and viticulture. This category reports emissions and removals from the category *cropland remaining cropland* (cropland that remains cropland during the period covered by the report) and the *land converted to*



cropland category. Calculations are carried out on the basis of a 20-year transition period in that once a land area is converted it remains in the converted land category for 20 years.

5.4.7.2 Methodological issues

Cropland remaining cropland (3.B.2.a)

Living biomass

A Tier 1 approach is applied where annual crops are assumed to be in equilibrium, so biomass gains and losses are only accounted for in perennial crops. The area of perennial crops is multiplied by a biomass accumulation rate (Table 5.36).

Losses accounted are those from biomass burning and harvest losses. Harvest losses were not included previously but have been incorporated as per UNFCCC reviewer suggestion. For harvest losses the maturity cycle is 25 years and so the area is divided by 25 to divide the crops into age classes. Every year it is assumed then that the oldest age class is harvested. These calculations are as provided in the review. Burnt area is determined as for forest lands, with the fraction of biomass lost to disturbance being assumed to equal the combustion factor for croplands (IPCC 2006).

There is some conversion between cropland types and for these areas the gains and losses are calculated as described above, but a Tier 2 approach is applied where the initial change in biomass carbon stocks on the converted land is added to the equation. The carbon stocks on the croplands before conversion are the values associated with the initial vegetation type (see section 5.4.3.1). The biomass stocks immediately after conversion are assumed to be zero, as it is assumed all land is cleared before being converted to cropland. A default time period of 20 years is applied to carbon stock increases for perennial crops (i.e. it is assumed the carbon stock will increase from the initial carbon stock to the final carbon stock over a period of 20 years). For annual crop only 1 year's worth of growth is accounted for, after which the biomass is assumed to be at equilibrium. This is also the case for losses in annual crops. Carbon losses are assumed to occur within the year of conversion. For perennial crop the loss occurs across the total converted land area instead of the annual converted area.

Dead organic matter

The Tier 1 assumption for the litter pool is that the stocks in *Cropland remaining cropland* are not changing over time, therefore DOM 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 crop types so changes in DOM were calculated for these areas using Eq.5.4. For land converted to croplands the changes in litter are determined from the data provided in and Eq.5.4. It is assumed that the change occurs slowly over the 20-year default transition period.

Mineral soils

Annual change in carbon stocks in mineral soils for *Croplands* was calculated as described in section 5.4.3.2.

Land converted to cropland (3.B.2.b)

Living biomass

For this a Tier 2 approach was applied. The annual increase in carbon stocks in biomass due to land conversions was estimated using equation 5.2 and 5.3 above. Carbon gains and losses are calculated as for *Cropland remaining cropland*, with only the woody perennial crops being included. Losses are also only for fire disturbance. The carbon stock change due to the removal of biomass from the initial land use (i.e. $\Delta C_{CONVERSION}$) is only calculated for the area of lands undergoing a conversion in a given year, and in subsequent years it is zero.

Dead organic matter

For areas that are converted from another land to cropland, the DOM from the initial and final land types is utilized and 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. A Tier 1 assumption that all carbon contained in biomass killed during a land-use conversion event is emitted directly to the atmosphere and none is added to the deadwood and litter pools.

Mineral soils

SOC changes in mineral soils in land converted to croplands is included under *Cropland remaining cropland*.

5.4.7.3 Uncertainties and time series consistency

The time series is consistent.



Uncertainties on land areas is discussed in section 5.4.5.1. Since there is no specific uncertainty data on the carbon biomass data a value of $\pm 20\%$ was assigned to biomass changes as the uncertainty on global maps is between 13% and 32% (Baccini et al., 2012; Saatchi et al. 2011) and since country specific data is applied the uncertainty is expected to be less. As indicated for Forest lands, the uncertainty on DOM and SOC data is assumed to be $\pm 30\%$ and $\pm 35\%$ respectively.

5.4.7.4 *Category specific QA/QC and verification*

All general QC listed in Table 1.7 were completed for this category. Land areas were checked. There is very little data available on carbon stock changes in croplands, making verification difficult. Carbon emission factors were compared to literature, and to IPCC values. SOC carbon stock values were compared to the data from DEFF (2020) and were found to be comparable. Where possible other outputs were compared to the NTCSA (DFFE, 2015; DEFF, 2020). SOC changes were compared to a Tier 1 Approach.

In terms of the calculation files, during the NDC update process a LULUCF model for estimating projections for the sector was compiled. This model recreated the LULUCF sector emission profile using a slightly more simplistic approach. The data outputs from this model were compared to the inventory outputs and the comparison enabled the detection and correction of calculation errors in both the model and the inventory calculations.

5.4.7.5 *Category-specific recalculations*

Recalculations were completed for the *Cropland* land category for the full time series due to a number of improvements:

- a) Inclusion of 1990 to 2018 land change data and updated land change assumptions;
- b) Updated biomass and DOM data;
- c) Updated SOC and stock change factor data;
- d) Inclusion of harvest losses of perennial crops.

Recalculations for the Cropland category were significant. The previous inventory indicated that Croplands were a source of CO₂, while this inventory estimates that is a sink which is twice that of the original source. In the 2017 inventory Croplands were estimated to produce 1 580 Gg CO₂e in 2017 while in this inventory it is estimated to sequester 2 837 Gg CO₂e. Much of this change is due to updated change areas and SOC data. The increase in the sink is fairly consistent over the period between 2000 and 2020.

5.4.7.6 *Category-specific planned improvements*



There are no category specific improvement plans for this category, but it is recommended to include more crop specific biomass data.

5.4.8 Grasslands (3.B.3)

5.4.8.1 Category description

The *Grassland* category includes all grasslands, managed pastures and rangelands. The IPCC does recommend separating out improved grasslands so an attempt was made in this inventory to include improved and degraded grasslands.

This section deals with emissions and removals of CO₂ in the biomass, DOM and mineral soil carbon pools. Estimates are provided for *Grasslands remaining grasslands* and *land converted to grasslands*. CO₂ emissions from biomass burning of grasslands were not reported since emissions are largely balanced by the CO₂ that is reincorporated back into the biomass via photosynthetic activity. Emissions were only reported for the change area in the first year.

5.4.8.2 Methodological issues

Grassland remaining grassland (3.B.3.a)

Living biomass

According to the IPCC Tier 1, the change in biomass is only estimated for woody vegetation because for annual grasses the increase in biomass stocks in a single year is assumed to equal the biomass losses in that same year. In the IPCC review it was recommended that, since the growth and low shrublands is very low, it should be considered in equilibrium, as are the grasslands, therefore, in this inventory gains and losses in low shrubland were not included in land remaining land. The carbon losses from fire disturbance in annual grasses and low shrublands is not reported, as the carbon released during combustion is assumed to be reabsorbed by the vegetation during the next growing season. Where there has been land-use change between the grasslands and low shrublands, carbon stock changes are reported under *Grasslands remaining grasslands*.

Dead organic matter



The Tier 1 assumption for the litter pool is that the stocks in *grasslands remaining grasslands* are not changing over time, therefore DOM 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 crop types so changes in DOM were calculated for these areas as discussed in section 5.4.3.1. For land converted to grasslands the changes in litter are determined from the data provided in Table 5.35 **Error! Reference source not found..** It is assumed that the change occurs slowly over the 20-year default transition period.

Mineral soils

Annual change in carbon stocks in mineral soils for *grasslands remaining grasslands* are calculated as discussed in section 5.4.3.2.

Land converted to grasslands (3.B.3.b)

Living biomass

For *land converted to grasslands* only the biomass increase for shrubs were included for the annual area undergoing change, while in annual grasslands carbon stocks were assumed to be in balance and not included in the annual gain calculation. Converted lands remain in the converted category for a period of 20 years.

For land conversions a Tier 2 approach was applied. The annual increase in carbon stocks in biomass due to land conversions was estimated following methods provided in section 5.4.3.1.

Carbon gains and losses are calculated as for *Grasslands remaining grasslands*, with only the woody shrubs being included. Losses are also only for fire disturbance. The carbon stock change due to the removal of biomass from the initial land use (i.e. $\Delta C_{CONVERSION}$) is only calculated for the area of lands undergoing a conversion in a given year, and in subsequent years it is zero. It is assumed that only croplands and plantations are cleared before being converted to a grassland, while all other conversions are slow transitions and not abrupt changes.

Dead organic matter

Calculated as discussed in section 5.4.3.1.

Mineral soils



For land converted to Grassland the mineral SOC change is included under *Grassland remaining grassland*.

5.4.8.3 *Uncertainties and time series consistency*

The time series is consistent. Uncertainties on land areas is discussed in section 5.4.5.1. Since there is no specific uncertainty data on the biomass a value of $\pm 20\%$ was assigned to biomass changes as the uncertainty on global maps is between 13% and 32% (Baccini et al., 2012; Saatchi et al. 2011) and since country specific data is applied the uncertainty is expected to be less. As indicated for Forest lands, the uncertainty on DOM and SOC data is assumed to be $\pm 30\%$ and $\pm 35\%$ respectively.

5.4.8.4 *Category specific QA/QC and verification*

All general QC listed in Table 1.7 were completed for this category. Land areas were checked. Carbon emission factors were compared to literature, and to IPCC values. Where possible outputs were compared to the NTCSA (DFFE, 2015; DEFF, 2020). SOC estimates were compared against a Tier 1 approach (see section 5.4.3.2).

In addition, during the NDC update process a LULUCF model for estimating projections for the sector was compiled. This model recreated the LULUCF sector emission profile using a slightly more simplistic approach. The data outputs from this model were compared to the inventory outputs and the comparison enabled the detection and correction of calculation errors in both the model and the inventory calculations.

5.4.8.5 *Category-specific recalculations*

Recalculations were completed for the *Grassland* category for the full time series due to a number of improvements:

- a) Inclusion of 1990 to 2018 land change data and updated land change assumptions;
- b) Updated biomass and DOM data;
- c) Updated SOC and stock change factor data;
- d) Exclusion of low shrubland gains and losses from Grasslands remaining grasslands.

The recalculated sink was on average 4.9% greater than estimated in the previous inventory. This varied over the time series, with there being no difference between 2000 and 2003 and a 24.7% difference in 2012.



5.4.8.6 *Category-specific planned improvements*

No specific plans have been put in place for this category.

5.4.9 Wetlands (3.B.4)

5.4.9.1 *Category description*

Waterbodies and wetlands are the two sub-divisions in the wetland category and are defined in GTI (2015). Mangroves are not included under wetlands as these are within the thicket category. The wetland category is therefore only herbaceous (annual) vegetation. The wetlands are not separated into coastal or inland wetlands and since organic soils were assumed to be insignificant the wetlands were assumed to be on mineral soils. It is noted that this is a broad assumption and that a recent Blue Carbon Study (Raw et al., 2020) indicated there is a small amount of organic soils, this assumption and data will be updated in the next inventory.

In this inventory the CO₂ emissions as well as the N₂O emissions from wetlands was determined. This is in addition to the CH₄ emissions that were previously estimated.

5.4.9.2 *Methodological issues*

Wetlands on mineral soils are calculated as per Chapter 2, Volume 4 of the IPCC 2006 Guidelines (IPCC, 2013; Chapter 5). This methodology is the same as for the other land types which are also on mineral soils

Wetlands remaining wetlands (3.B.4.a)

Living biomass

According to IPCC Tier 1 gains and losses are in equilibrium in annual vegetation, so there are no changes in Wetlands remaining wetlands unless there is a change from a waterbody with no vegetation to a wetland which has vegetation.

Dead organic matter

Calculated as discussed in section 5.4.3.1.

Mineral soils



Calculated as discussed in section 5.4.3.2.

CH₄ and N₂O emissions

CH₄ emissions from wetlands were calculated following equation 5.1. of the IPCC Wetland Supplement (IPCC, 2014; Chapter 5) which is the wetland area multiplied by the emission factor. N₂O was calculated in the same way. Emission factors of 55.9 kg CH₄/ha/yr and 1.4 kg N₂O/ha/yr (Kruger et al., 2012) were applied. The CH₄ emission factor is lower than the 235 kg CH₄/ha/yr that provided by the IPCC Guidelines (IPCC, 2014) but is a country specific factor.

Land converted to wetlands (3.B.4.b)

Living biomass

For land conversions a Tier 2 approach was applied. The annual increase in carbon stocks in biomass due to land conversions was estimated following methods describe in section 5.4.3.1. For *land converted to wetlands* the annual wetland growth and losses are only accounted for on the annual change area, even though the area remains in the land converted category for 20 years.

The carbon stock change due to the removal of biomass from the initial land use (i.e. $\Delta C_{CONVERSION}$) is only calculated for the area of lands undergoing a conversion in a given year, and in subsequent years it is zero. It is assumed that only croplands are cleared before being converted to a wetland, while all other conversions are slow transitions and not abrupt changes.

Dead organic matter

Calculated as discussed in section 5.4.3.1.

Mineral soils

SOC changes in *Land converted to wetlands* is included under *Wetlands remaining wetlands*. The rewetting default stock change factor of 0.8 was applied.

5.4.9.3 *Uncertainties and time series consistency*

Uncertainties on land areas is discussed in section 5.4.5.1. Since there is no specific uncertainty data on the biomass data a value of $\pm 20\%$ was assigned to biomass changes



as the uncertainty on global maps is between 13% and 32% (Baccini et al., 2012; Saatchi et al. 2011) and since country specific data is applied the uncertainty is expected to be less. As indicated for Forest lands, the uncertainty on DOM and SOC data is assumed to be $\pm 30\%$ and $\pm 35\%$ respectively.

5.4.9.4 Category specific QA/QC and verification

All general QC listed in Table 1.7 were completed for this category. Land areas were checked. Carbon emission factors were compared to literature, and to IPCC values. Where possible outputs were compared to the NTCSA (DFFE, 2015; DEFF, 2020). SOC change values were compared to a Tier 1 approach (see section 5.4.3.2).

5.4.9.5 Category-specific recalculations

CH₄ emissions were recalculated due to the inclusion of a country specific factor. Emissions were 57% higher than in the previous submission. There were no recalculations for the CO₂ or N₂O as these were not included in the previous inventory.

5.4.9.6 Category-specific planned improvements

It is planned that in the next inventory the data from the Blue Carbon Study (Raw et al., 2020) be included, along with organic soils.

5.4.10 Settlements (3.B.5)

5.4.10.1 Category description

Settlements include all formal built-up areas, in which people reside on a permanent or near-permanent basis. It includes transportation infrastructure as well as mines. Changes in the extent of urban areas between 1990 and 2020 (increase of 6.7%) may not be as locally significant as expected as the settlements category includes peripheral smallholding areas around the main built-up areas; and these tend to be the first land-use that is converted to formal urban areas, before further expansion into natural and cultivated lands. Settlements were divided into wooded and non-wooded areas.

This section deals with emissions and removals of CO₂ in the biomass, litter and mineral soil carbon pools, but there was insufficient data to include the dead wood component. Gains and losses are only determined for the wooded areas. Estimates are provided for



both *Settlements remaining settlements* and *land converted to settlements*. Converted lands remain in the converted category for a period of 20 years.

5.4.10.2 Methodological issues

Settlements remaining settlements (3.B.5.a)

Living biomass

In the previous inventory the percentage wooded area was determined for the settlement category by using the percentage woodland and shrubland area of settlements from Fairbanks et al. (2000). This was not done in this inventory since carbon density data was being applied it is assumed that the carbon biomass value determined for settlements would be an average over the settlement area since it is spatial data. Biomass gains and losses were determined as for *Forest land remaining forest land*.

Dead organic matter

The Tier 1 assumption for the litter pool is that the stocks in *Settlements remaining settlements* are not changing over time, therefore DOM changes are reported to be zero.

Mineral soils

Annual change in carbon stocks in mineral soils for *settlements remaining settlements* were calculated as discussed in section 5.4.3.2.

Land converted to settlements (3.B.5.b)

Living biomass

For this a Tier 2 approach was applied. The annual increase in carbon stocks in biomass due to land conversions was estimated following Eq. 5.2 and Eq. 5.3 above. Only gains and losses in wooded areas were included as it is assumed that the gains and losses in the grass areas are in balance, and where there is infrastructure there is no vegetation and therefore no gains or losses. The carbon stock change due to the removal of biomass from the initial land use (i.e. $\Delta C_{CONVERSION}$) is only calculated for the area of lands undergoing a conversion in a given year, and in subsequent years it is zero. It is assumed that all land is cleared before it is converted to a settlement.

Dead organic matter



The changes in litter are determined from the data provided in Table 5.35. It is assumed that change occurs slowly over the 20-year default transition period.

Mineral soils

Mineral soil SOC changes for *Land converted to settlements* are included under *Settlements remaining settlements*.

5.4.10.3 Uncertainties and time series consistency

The time series is consistent. Uncertainties on land areas is discussed in section 5.4.5.1. Since there is no specific uncertainty data on the carbon density data a value of $\pm 20\%$ was assigned to biomass changes as the uncertainty on global maps is between 13% and 32% (Baccini et al., 2012; Saatchi et al. 2011) and since country specific data is applied the uncertainty is expected to be less. As indicated for Forest lands, the uncertainty on DOM and SOC data is assumed to be $\pm 30\%$ and 35% respectively.

5.4.10.4 Category specific QA/QC and verification

All general QC listed in Table 1.7 were completed for this category. Land areas were checked. There is very little data available on carbon stock changes in settlements, making verification difficult. Carbon emission factors were compared to any available literature, and to IPCC values.

In addition, during the NDC update process a LULUCF model for estimating projections for the sector was compiled. This model recreated the LULUCF sector emission profile using a slightly more simplistic approach. The data outputs from this model were compared to the inventory outputs and the comparison enabled the detection and correction of calculation errors in both the model and the inventory calculations.

5.4.10.5 Category-specific recalculations

Recalculations were completed for the *Settlements* land category for the full time series due to a number of improvements:

- a) Inclusion of 1990 to 2018 land change data and updated land change assumptions;
- b) Updated biomass and DOM data;
- c) Updated SOC and stock change factor data.

In the previous inventory Settlements were estimated to be a small source of emissions between 2000 and 2010, after which it became a sink. This sink increased from 2010 to 2017. The recalculated estimates now show Settlements to be a larger sink. In 2017 the



previous inventory estimated a sink of 397 Gg CO₂e, while the recalculated estimate is 1 167 Gg CO₂e. The trend is still the same with the sink increasing from 2010 to 2017.

5.4.10.6 Category-specific planned improvements

No category specific improvements are planned for this category.

5.4.11 Other lands (3.B.6)

5.4.11.1 Category description

Other land includes bare soil, rock, and all other land areas that do not fall into the other land classes. This category includes emissions and sinks for *land converted to other lands*. There are assumed to be no changes in the *Other land remaining Other land* category. For the *land converted to other land* category the biomass, litter and soil carbon changes are included.

5.4.11.2 Methodological issues

Other lands remaining other lands (3.B.6.a)

Living biomass

Tier 1 of IPCC 2006 assumes that there are no carbon gains or losses on *other lands remaining other lands*.

Dead organic matter

The Tier 1 assumption for the litter pool is that the stocks in *Other lands remaining other lands* are zero.

Mineral soils

Annual change in carbon stocks in mineral soils for *other lands remaining other lands* and *land converted to other lands* were calculated as discussed in section 5.4.3.2. The Tier 1 assumption that the final carbon stock is zero was adjusted based on review comments.

Land converted to other lands (3.B.6.b)



Living biomass

For this a Tier 2 approach was applied. The change in carbon stocks in biomass due to land conversions was estimated following the methodology provided in section 5.4.3.1. Only losses due to conversion were estimated as other lands are assumed to be void of vegetation. The carbon stock change due to the removal of biomass from the initial land use (i.e. $\Delta C_{CONVERSION}$) is only calculated for the area of lands undergoing a conversion in a given year, and in subsequent years it is zero. It is assumed that all land is cleared before it is converted to other lands.

Dead organic matter

The changes in litter are determined from the data provided in **Error! Reference source not found.** and it assumes that the change occurs slowly over the 20-year default transition period.

Mineral soils

Changes in SOC for *Land converted to other land* is included under *Other land remaining other land*.

5.4.11.3 Uncertainties and time series consistency

The time series is consistent. Uncertainties on land areas is discussed in section 5.4.5.1. Other land is assumed not to have any biomass or DOM. As indicated for Forest lands, the uncertainty on SOC data is assumed to be $\pm 35\%$ respectively.

5.4.11.4 Category specific QA/QC and verification

All general QC listed in Table 1.7 were completed for this category, but no additional source specific QA/QC was conducted. There is very little data available on carbon stock changes in other lands, making verification very difficult.

In addition, during the NDC update process a LULUCF model for estimating projections for the sector was compiled. This model recreated the LULUCF sector emission profile using a slightly more simplistic approach. The data outputs from this model were compared to the inventory outputs and the comparison enabled the detection and correction of calculation errors in both the model and the inventory calculations.

5.4.11.5 Category-specific recalculations



Recalculations were completed for the *Other land* category for the full time series due to a number of improvements:

- a) Inclusion of 1990 to 2018 land change data and updated land change assumptions;
- b) Updated biomass and DOM for other land categories being converted to *Other lands*;
- c) Soil stock change factor adjust to 0.7 so final soil carbon not assumed to be zero.

Other land recalculations led to a 35.9% lower emission estimate for this category across the time series.

5.4.11.6 Category-specific planned improvements

No category specific improvements are planned for this category.

5.5 Other (3.D)

5.5.1 Category description

Much of the wood that is harvested from forest land, cropland and other land types 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.

5.5.2 Harvested wood products (3.D.1)

5.5.2.1 Methodological issues

All the data on production was obtained from Forestry SA (FSA, 2018) from 1990, while export data was obtained from the SARS website at https://tools.sars.gov.za/tradestatsportal/data_download.aspx. The production data was split into sawlogs and veneer logs, and pulpwood. Sawlogs and veneer data then had to be split into sawnwood and wood-based panels and this was done using the fraction sales of timber to sawn timber and panel products (FSA, 2019).

The HWP contribution was determined by following the updated guidance provided in the 2013 IPCC KP Supplement (IPCC, 2014). One of the implications of Decision 2/CMP.7



is that accounting of HWP is confined to products in use where the wood was derived from domestic harvest. Carbon in imported HWP is excluded. The guidelines also suggest that it is good practice to allocate the carbon in HWP to the activities afforestation (A), reforestation (R) and deforestation (D) under Article 3 paragraph 3 and forest management (FM) under Article 3 paragraph 4. For South Africa, there is insufficient data to differentiate between the harvest from AR and FM, it is conservative and in line with good practice to assume that all HWPs entering the accounting framework originate from FM (KP Supplement, Chapter 2, p 2.118).

Equation 5.2 and 5.3 (Eq 2.8.1 and 2.8.2 in KP Supplement) were applied to estimate the annual fraction of feedstock for HWP production originating from domestic harvest and domestically produced wood pulp as feedstock for paper and paperboard production.

$$f_{IRW}(i) = (IRW_P(i) - IRW_{EX}(i)) / (IRW_P(i) + IRW_{IM}(i) - IRW_{EX}(i)) \quad (Eq. 5.1)$$

Where:

$f_{IRW}(i)$ = share of industrial roundwood for the domestic production of HWP originating from domestic forests in year i ;

$IRW_P(i)$ = production of industrial roundwood in year i (Gg C yr⁻¹);

$IRW_{IM}(i)$ = import of industrial roundwood in year i (Gg C yr⁻¹);

$IRW_{EX}(i)$ = export of industrial roundwood in year i (Gg C yr⁻¹).

$$f_{PULP}(i) = (PULP_P(i) - PULP_{EX}(i)) / (PULP_P(i) + PULP_{IM}(i) - PULP_{EX}(i)) \quad (Eq. 5.2)$$

Where:

$f_{PULP}(i)$ = share of domestically produced pulp for the domestic production of paper and paperboard in year i ;

$PULP_P(i)$ = production of wood pulp in year i (Gg C yr⁻¹);

$PULP_{IM}(i)$ = import of wood pulp in year i (Gg C yr⁻¹);

$PULP_{EX}(i)$ = export of wood pulp in year i (Gg C yr⁻¹).

The resulting feedstock factors were applied to Equation 5.4 (Eq 2.8.4 KP Supplement) to estimate the HWP contribution of the aggregate commodities sawnwood, wood-based panels and paper and paperboard.

$$HWP_j(i) = HWP_P(i) * f_{DP}(i) * f_j(i) \quad (Eq. 5.3)$$

Where:



$HWP_j(i)$ = HWP amounts produced from domestic harvest associated with activity j in year i ($m^3 yr^{-1}$ or $Mt yr^{-1}$);

$HWP_P(i)$ = production of the particular HWP commodities (i.e. sawnwood, wood-based panels and paper and paperboard) in year i ($m^3 yr^{-1}$ or $Mt yr^{-1}$);

$f_{DP}(i)$ = share of domestic feedstock for the production of the particular HWP category originating from domestic forests in year i , with:

$f_{DP}(i) = f_{IRW}(i)$ for HWP categories 'sawnwood' and 'wood-based panels'; and

$f_{DP}(i) = f_{IRW}(i) * f_{PULP}(i)$ for HWP category 'paper and paperboard'; and

$f_{IRW}(i) = 0$ if $f_{IRW}(i) < 0$ and $f_{PULP}(i) = 0$ if $f_{PULP}(i) < 0$.

$f_j(i)$ = share of harvest originating from the particular activity j (FM or AR or D) in year i .

For SA this was assumed to be 1 as all the harvest was allocated to FM.

First order decay

Transparent and verifiable data were available for sawnwood, wood-based panels and paper and paperboard, but no country-specific information for Tier 3 was available so a Tier 2 first order decay approach (Eq 5.5 (Eq 12.1 in 2006 IPCC Guidelines)) was applied to estimate the HWP contribution:

$$C(i+1) = e^{-k} * C(i) + ((1 - e^{-k})/k) * Inflow(i) \quad (Eq. 5.4)$$

Where:

$C(i)$ = the carbon stock in the particular HWP category at the beginning of year i (Gg C);
 k = decay constant of FOD for each HWP category (units yr^{-1}) ($k = \ln(2)/HL$ where HL is the half life of the HWP pool in years);

$Inflow(i)$ = the inflow to the particular HWP category during year i (Gg C yr^{-1});

$\Delta C(i) = C(i+1) - C(i)$ = carbon stock change of the HWP category during year i (Gg C yr^{-1}).

As a proxy in the Tier 2 method it is assumed that the HWP pools are in steady state at the initial time (t_0) from which the activity data start. This means that as a proxy $\Delta C(t_0)$ is assumed to be equal to 0 and this steady state for each HWP commodity category is approximated using the following equation 5.6 (Eq 2.8.6 KP Supplement):

$$C(t_0) = Inflow_{average}/k \quad (Eq. 5.5)$$

Where:

$$Inflow_{average} = (\sum_{i=t_0}^{t_4} Inflow(i))/5 \quad (Eq. 5.6)$$



$C(t_0)$ was taken to be 1990 (S. Ruter, pers. comm.) and was substituted into Eq 5.5 so that $C(i)$ and $\Delta C(i)$ in the sequential time instants can be calculated.

5.5.2.2 *Uncertainties and time series consistency*

The activity data was obtained from Forestry SA from 1990 and is consistent over the time-series. Uncertainties for activity data and parameters associated with HWP variables are provided in the IPCC Guidelines (IPCC 2006, 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.

5.5.2.3 *Category specific QA/QC and verification*

In the previous inventory the data was run through the WoodCarbonMonitor model and the outputs correlated well which meant the calculation file is set up correctly. In this inventory the country specific data was populated into the same file.

5.5.2.4 *Category-specific recalculations*

Recalculations were performed for the entire time series due to the inclusion of country specific data. There was a 24% decrease in the sink for 2017, however this data varied from year to year with an increase in some years and a decrease in others.

5.5.2.5 *Category-specific planned improvements*

There are no planned improvements for this category, but it is recommended that a more detailed assessment of HWP be conducted that includes a wider range of products. In addition, as indicated in the review, the production data outputs should be compared to other approaches, such as the atmospheric approach, as a quality checking process.



5.6 References

- Alembong, O.A., 2015. Carbon flow analysis in the South African Forest and the Forestry Sector, MSC thesis, University of Kwazulu-Natal.
- Banda, S.P., Adams, J.B., Rajkaran, A., Johnson, J.L. and Raw, J.L., 2021. Blue carbon storage comparing mangroves with salt marsh and seagrass habitats at a warm-temperate continental limit. In: Dynamic Sedimentary Environments of Mangrove Coasts. Sidik, F., Friess, D.A. (eds) Elsevier, pp 447-471.
- Berliner, D. D., van der Merwe, I., Benn, G., & Rouget, M., 2006. Systematic conservation planning for the forest biome of South Africa: approach, methods and results used for the selection of priority forests. Pretoria: Department: Water Affairs and Forestry. Accessed 8 February 2020 at: https://www.daff.gov.za/daffweb3/Portals/0/Scientific%20And%20Technical%20Information/FCP_final_edited%5b1%5d.pdf
- Brennan, J., Gómez-Dans, J. L., Disney, M., and Lewis, P., 2019. Theoretical uncertainties for global satellite-derived burned area estimates, Biogeosciences, 16, 3147–3164, <https://doi.org/10.5194/bg-16-3147-2019>, 2019.
- DALRRD, 2010. The South African Agricultural GHG Inventory for 2004. Department of Agriculture, Forestry and Fisheries, ISBN: 978-1-86871-321-9, DALRRD, Pretoria, RSA.
- DALRRD, 2018. Abstracts of Agricultural Statistics 2018. Department of Agriculture Forestry and Fisheries, Pretoria, RSA. <https://www.dalrrd.gov.za/Portals/0/Statistics%20and%20Economic%20Analysis/Statistical%20Information/Abstract%202018.pdf> [Accessed, October 2018].
- DALRRD, 2018a. Report on Commercial Timber Resources and Primary Roundwood Processing in South Africa 2017/2018. Department of Agriculture, Forestry and Fisheries. https://www.forestry.co.za/uploads/File/industry_info/statistical_data/statistical%20data%20april%202020/Timber%20Statistics%20Report%20-%202017%20-%202018.pdf
- De Waal, H.O., 1990. Animal production from native pasture (veld) in the Free State region – A perspective of the grazing ruminant. S. Afr. J. Anim. Sci. 20, 1-9.
- DFFE, 2015. The South African National Terrestrial Carbon Sink Assessment. Synopsis report, Department of Environmental Affairs, Pretoria, Republic of South Africa.
- DFFE, 2019a. South African National Land-Cover 2018 Report and Accuracy Assessment. Department of Forestry, Fisheries and Environment, Pretoria, South Africa.



- DFFE, 2019b. 2018 South African National Land-Cover Change Assessment. Department of Forestry, Fisheries and Environment, Pretoria, South Africa.
- DFFE, 2014. GHG Inventory for South Africa 2000-2010. Department of Environmental Affairs, Pretoria.
- Schulze, R. and Schutte, R., 2018. Identification and mapping of soils rich in organic carbon in South Africa as a climate change mitigation option 2019. Department of Environmental Affairs, Pretoria, South Africa.
- DFFE, 2009. Greenhouse Gas Inventory South Africa, 1990 to 2000. National Inventory Report, May 2009. Pretoria: Department of Environmental Affairs and Tourism.
- DFFE, 2020. National Terrestrial Carbon Sinks Assessment: Technical Report (2020), Department of Environment, Forestry and Fisheries, Pretoria, South Africa.
- DMRE, 2018. South Africa's Mineral Industry 2017/2018. Department of Mineral Resources, Pretoria, RSA.
<https://www.dmr.gov.za/LinkClick.aspx?fileticket=PClz-cRGkyg%3D&portalid=0> [Accessed October, 2018].
- Dovey, S. B. 2009. Estimating biomass and macronutrient content of some commercially important plantation species in South Africa. *Southern Forests: a Journal of Forest Science*, 71(3), 245–251. doi:10.2989/SF.2009.71.3.9.921
- Dovey, S., du Toit, B. and Crous, J., 2021. Tier 2 above-ground biomass expansion functions for South African plantation forests. *Southern Forests*, 83: 69-78.
- Du Toit, B., Dovey, S., Seifert, T., Muyambo, P. and Malherbe, D. 2016. Carbon sequestration in South African plantation forests. Progress Report 1. PAMSA, RSA.
- Du Toit, C.J.L., Meissner, H.H. and van Niekerk, W.A., 2013a. Direct methane and nitrous oxide emissions of South African dairy and beef cattle. *South African Journal of Animal Science*, 43 (3): 320 – 339.
- Du Toit, C.J.L., Meissner, H.H. and van Niekerk, W.A., 2013d. Direct greenhouse gas emissions of the game industry in South Africa. *South African Journal of Animal Science*, 43 (3): 376 – 393.
- Du Toit, C.J.L., van Niekerk, W.A. and Meissner, H.H., 2013b. Direct greenhouse gas emissions of the South African small stock sectors. *South African Journal of Animal Science*, 43 (3): 340 – 361.
- Du Toit, C.J.L., van Niekerk, W.A. and Meissner, H.H., 2013c. Direct methane and nitrous oxide emissions of monogastric livestock in South Africa. *South African Journal of Animal Science*, 43 (3): 362 - 375.



- Dugmore, T.J. & Du Toit, J.H., 1988. The chemical and nutritive value of kikuyu pasture. *S. Afr. J. Anim. Sci.* 18, 72-75.
- Els, J., 2019. Carbon and nutrient storage of the Swartkops Estuary salt marsh and seagrass habitats. MSc, Nelson Mandela University, Port Elizabeth, South Africa.
- Fairbanks, D.H.K., Thompson, M.W., Vink, D.E., Newby, T.S., van der Berg, H.M. and Everards, D.A. 2000. The South African Land-cover Characteristics Database: A synopsis of the landscape. *South African Journal of Science*.
- FAOSTAT, 2018. Food and Agriculture Organization of the United Nations: Statistics. 2012. <http://www.fao.org/faostat/en/#home>[Accessed in November 2018].
- FASA, 2019. Fertiliser Association of South Africa. <http://www.fertasastats.co.za/pages/>
- FSA, 2019. South African Forestry and Forest Product Industry Facts 1980 – 2019, Forestry South Africa, KwaZulu-Natal.
- FSSA, 2009. Fertilizer Society of South Africa, <http://www.fssa.org.za>.
- GTI, 2014. 2013-2014 South African National Land-cover dataset. Department of Environmental Affairs, Pretoria.
- GTI, 2015. 1990 – 2013-14 South African National Land-cover change. Department of Environmental Affairs, Pretoria.
- Glenday, J., 2007. Carbon Storage and Sequestration Analysis for the eThekweni Environmental Services Management Plan Open Space System. Durban: eThekweni Municipality Environmental Management Department. Accessed 10 February 2020 at: <http://assaf.org.za/files/2010/04/EESMPCarbonstock-report2006.pdf>
- Grain SA, 2011. Grain SA Fertiliser Report. Grain SA, RSA.
- Hély, C., Dowty, P.R., Alleane, S., Caylor, K.K., Korontzi, S., Swap, R.J., Shugart, H.H. and Justice, C.O., 2003. Regional fuel load for two climatically contrasting years in southern Africa. *Journal of Geophysical Research*, 108.
- Howden, S.M. & Reyenga, P.J., 1987. Methane emissions from Australian livestock: Implication of the Kyoto protocol. *Aust. J. Agric. Res.* 50, 1285-1291.
- IPCC, 2019. Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. (E. Calvo Buendia, K. Tanabe, A. Kranjc, J. Baasansuren, M. Fukuda, N. S., ... S. Federici, Eds.) (Vol. 4). Switzerland: Intergovernmental Panel on Climate Change. Retrieved from <https://www.ipccnggip.iges.or.jp/public/2019rf/index.html>
- IPCC, 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry.



- IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, Eggleston H S, Buenida L, Miwa K, Ngara T, and Tanabe K, eds; Institute for Global Environmental Strategies (IGES). Hayama, Kanagawa, Japan.
- Jewitt, D., Goodman, B. F. N., O'Connor, T. G. O. and Witkowski, E.T.F., 2015. Systematic land-cover change in KwaZulu-Natal, South Africa: Implications for biodiversity, South African Journal of Science, 111, pp. 9.
- Johnson, J.L., Raw, J.L. and Adams, J.B., 2020. First report on carbon storage in a warm-temperate mangrove forest in South Africa. Estuarine, Coastal and Shelf Science, 235: 106566.
- Korontzi, S., Justice, C.O. and Scholes, R.J., 2003. Influence of timing and spatial extent of Savanna fires in Southern Africa on atmospheric emissions. Journal of Arid Environments, 54: 395 - 404.
- Lechmere-Oertel, R.G., Kerley, G.I.H., Mills, A.J. and Cowling, R.M., 2008. Litter dynamics across browsing-induced fenceline contrasts in succulent thicket, South Africa. S.A.J.Bot (74): 651-659.
- Malan, P.J. and Snyman, H.A., 2008. Dry matter production and partitioning of two palatable karoo shrubs. International Grassland Congress Proceedings.
- Meissner, H.H., Hofmeyr, H.S., Van Rensburg, W.J.J. & Pienaar, J.P., 1983. Classification of livestock for realistic prediction of substitution values in terms of biologically defined Large Stock Unit. Technical communication, Department of Agriculture, Pretoria, Republic of South Africa.
- Midgley, J.J. and Seydack, A.H.W., 2006. No adverse signs of the effect of environmental change on tree biomass in the Knysna forest during the 1990s. S A J Science 102: 96-97.
- Mills, A.J. and Cowling, R.M., 2006. Rate of carbon sequestration at two thicket restoration sites in the Eastern Cape, South Africa. Restoration Ecology, 14: 38-49.
- Mills, A.J., Birch, S.C., Stephenson, J.D. and Bailey, R.V., 2012. Carbon stocks in fynbos, pastures and vineyards on the Agulhas Plain, South Africa: A preliminary assessment. S.A.J.Plant and Soil: 1-3.
- Mills, A.J., Cowling, R.M., Fey, M.V., Kerley, G.I.H., Donaldson, J.S., Lechmere-Oertel, R.G., Sigwela, A.M., Skowno, A.L. and Rundel, P., 2005. Effects of goat pastoralism on ecosystem carbon storage in semiarid thicket, Eastern Cape, South Africa. Austral Ecology 30: 797 – 804.
- Mills, A.J., O'Connor, T.G., Donaldson, J.S., Fey, M.V., Skowno, A.L., Sigwela, A.M., Lechmere-Oertel, R.G. and Bodsberg, J.D. Ecosystem carbon storage under different land



-
- uses in three semi-arid shrublands and a mesic grassland in South Africa. *S.Afr.J. Plant Soil*, 22:183.
- Minson, D.J. and McDonald, C.K., 1987. Estimating forage intake from growth of cattle. *Tropical grasslands*, 21(3): 116 – 121.
- Moe, P.W. and Tyrell, H.F., 1979. Methane production in dairy cows. *J. Dairy Sci.* 62: 1583 – 1586.
- Moeletsi, M.E., and Tongwane, M.I., 2015. Methane and Nitrous Oxide Emissions from Manure Management in South Africa. *Animals*, 5, 193–205.
- Moeletsi, M.E.; Tongwane, M.I.; Mdlambuzi, T.; Grootboom, L.; Mliswa, V.K.; Nape, K.M.; Mazibuko, S., 2015. Improvement of the Greenhouse Gas Emissions Inventory for the Agricultural Sector; DFID: Pretoria, Southern Africa.
- Mograbi, P.J., Erasmus, B.F.N., Witkowski, E.T.F., Asner, G.P., Wessels, K.J., Mathieu, R., Knapp, D.E., Martin, R.E. and Main, R., 2015. Biomass increases go under cover: Woody vegetation dynamics in South African rangelands. *PLoS ONE* 10 (5).
- Moss, A.R., 1993. Methane: global warming and production by animals. Chalcombe Publ., Kent, U.K.
- NFA, 1998. National Forest Act, 1998 (Act 84 of 1998). Office of the President, South Africa.
- O'Reagain, P.J. & Owen-Smith, R.N., 1996. Effects of species composition and sward structure on dietary quality in cattle and sheep grazing South African sourveld. *J. Agric. Sci.* 127, 261-270.
- O'Connor, T.G., Haines, L.M. and Snyman, H.A., 2001. Influence of precipitation and species composition on phytomass of a semi-arid African grassland. *J. Ecology*, 89: 850-860.
- OECD, 1991. Estimation of GHG emissions and sinks. Final report from the OECD experts meeting 18 - 21 Feb 1991. The Organisation for Economic Co-operation and Development, Paris, France, Revised 1991.
- Powell, M.J., 2009. Restoration of degraded subtropical thickets in the Baviaanskloof Megareserve, South Africa. The role of carbon stocks and *Portulacaria afra* survivorship. MSc. Thesis. Rhodes University, Grahamstown, South Africa.
- Roy, D.P. and Boschetti, L., 2009. Southern Africa validation of the MODIS, L3JRC and GlobCarbon Burned-Area Products, *IEEE Transactions on Geoscience and Remote Sensing*, 47(4):1–13.
- Shackleton, C.M. and Scholes, R.J., 2011. Above ground woody community attributes, biomass and carbon stocks along a rainfall gradient in the savannas of the central lowveld, South Africa. *S.A.J. Bot.* 77: 184-192.
-



- Snyman, 2005. Rangeland degradation in a semi-arid South Africa - 1: Influence on seasonal root distribution, root/shoot ratios and water-use efficiency. *J.Arid Environ.* 60 (3): 457-481
- Snyman, H.A. 2006. Estimating grasland production loss due to fire from a semi-arid climate. *S.A.J. Animal Science*, 5: 38-41.
- Snyman., H.A. and Fouche, H.J. 1991. Production and water-use efficiency of semi-arid grasslands of South Africa as affected by field condition and rainfall. *Water SA*, 17:263 - 268.
- Statistics SA, 2019. General household survey, Statistical release P0318, Pretoria, South Africa.
- StatisticsSA, 2007. Census of commercial agriculture. Statistics South Africa, 11-02-01 2007. Pretoria, RSA.
- StatisticsSA, 2021. Natural capital 2: Accounts for protected areas, 1900 to 2020. Report D0401.2. Pretoria, South Africa.
- Tainton, N.M., 1999. Veld Management in South Africa. Chapter 2: The ecology of the main grazing lands of South Africa. Pietermaritzburg: University of Natal Press, South Africa.
- Van der Vyver, M.L., Cowling, R.M., Mills, A.J. and Difford, M. 2013. Spontaneous return of biodiversity in restored subtropical thicket: *Portulacaria afra* as an ecosystem engineer. *Restoration Ecology*: 1-9.
- Van Leeuwen, TT. et al. 2014. Biomass burning fuel consumption rates: a field measurement database. *Biogeosciences Discussions*, 11, pp 8115-8180.
- Van Rooyen, M.W., van Rooyen, N. and Staffberg, G.H. 2013. Carbon sequestration potential of post-mining reforestation activities on the Kwa-Zulu-Natal coast, South Africa. *Forestry* (86): 211-223.
- Wessels, K.J., Colgan, M.S., Erasmus, B.F.N., Asner, G.P., Twine, W.C., Mathieu, R., van Aardt, J.N.A., Fisher, J.T. and Smith, I.P.J. 2013. Unsustainable fuelwood extraction from South African savannas. *Environ. Res. Lett.* 8.



Chapter 6: Waste

6.1 Sector overview

Methane is generated during anaerobic fermentation of degradable organic waste deposited in landfill sites (IPCC, 2006). If waste were not disposed of in landfill sites, the degradation would take place in aerobic conditions without the formation of methane. Methane emissions from waste disposal in Landfill sites are thus of anthropogenic origin and, consequently, a constituent part of national GHG inventories in accordance with the 2006 IPCC guidelines.

This chapter highlights the GHG emissions into the atmosphere from managed landfill sites, open burning of waste, biological treatment of solid waste and wastewater treatment systems in South Africa, estimated using the IPCC 2006 Guidelines for National Greenhouse Gas Inventories. In South Africa, CH₄ emissions from solid waste disposal sites (landfill sites) are the largest source of greenhouse gas emissions in the Waste Sector, followed by CH₄ emissions from wastewater treatment and discharge.

Various improvements have been made in the current waste sector inventory covering the period 2000 - 2020 in order to enhance the accuracy of emissions estimates and take into account national circumstances. These are discussed in detail under category-specific improvements.

In the past GHG inventories, the waste sector only covered three sources. In the current 2000 – 2020 GHG inventory, the waste sector considers the following sources:

- 4A Solid waste disposal;
 - CH₄ emissions from Managed Solid Waste Disposal Sites
- 4B Biological Treatment of Solid Waste, CH₄ and N₂O emissions from:
 - from Composting (*New Source*)
 - Anaerobic Digestion at Biogas Facilities (*New Source*)
- 4C Open burning of waste; and
- 4D Wastewater treatment and discharge, CH₄ and indirect N₂O emissions from treatment of wastewater.
 - Domestic Wastewater treatment and discharge.
 - Industrial Wastewater treatment and discharge (*New Source*)

For completeness in this sector, emissions from incineration still need to be addressed. Emissions from use of solid waste as fuel for combustion in Energy Industries and Manufacturing Industries are reported in the *Energy Sector*.



6.1.1 Overview of shares and trends in emissions

In South Africa the total *Waste* sector emissions for 2020 were 23 046 Gg CO₂e (Table 6.1) of total net national emissions. The majority of these emissions are from *Solid waste disposal* contributing 18 253 Gg CO₂e (79.2%) of the total *Waste* sector emissions. *Wastewater treatment and discharge* contributed a further 4 458 Gg CO₂e (19.3%) of waste emissions while *open burning* of waste contributed 335 Gg CO₂e (1.5%). Emissions from the *biological treatment of solid waste* were estimated to be insignificant (0.0019 Gg CO₂e). *Solid waste disposal* increased its contribution to the total *Waste* sector emissions by 4.5% (from 74.6% to 79.2%) since 2000. *Incineration and open burning of waste* increased its contribution since 2000 by 0.5% (1.0% to 1.5%), while the contribution from *Wastewater treatment and discharge* declined from 24.4% to 19.3% by 2020. This is largely driven by a 54.2% decline in Industrial wastewater treatment and discharge.

A detailed summary table of the 2020 *Waste* sector emissions is provided in Appendix C.

6.1.1.1 2020

In 2020 the *Waste* sector produced 23 046 Gg CO₂e. The largest source category is the *Solid waste disposal* which contributed 79.2% (18 253 Gg CO₂e) towards the total sector emissions.

Table 6.1: Summary of the estimated emissions from the Waste sector in 2020.

Categories	Emissions [Gg]							Total emissions
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NM VOCs	SO ₂	(Gg CO ₂ e)
4. WASTE	35.4	1 055.1	2.8	NE	NE	NE	NE	23 045.8
4A Solid Waste Disposal		869.2		0.0	0.0	0.0	0.0	18 252.8
4A1 Managed Waste Disposal Sites				NE	NE	NE	NE	NE
4A2 Unmanaged Waste Disposal Sites				NE	NE	NE	NE	NE
4A3 Uncategorised Waste Disposal Sites				NE	NE	NE	NE	NE
4B Biological Treatment of Solid Waste		0.0	0.0	NE	NE	NE	NE	0.0
4C Incineration and Open Burning of Waste	35.4	10.6	0.3	0.0	0.0	0.0	0.0	334.9
4C1 Waste Incineration	NE	NE	NE	NE	NE	NE	NE	NE



Categories	Emissions [Gg]							Total emissions
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NM VOCs	SO ₂	(Gg CO ₂ e)
4C2 Open Burning of Waste	35.4	10.6	0.3	NE	NE	NE	NE	334.9
4D Wastewater Treatment and Discharge	0.00	175.3	2.5	0.0	0.0	0.0	0.0	4 458.1
4D1 Domestic Wastewater Treatment and Discharge		132.5	2.5	NE	NE	NE	NE	3 560.8
4D2 Industrial Wastewater Treatment and Discharge		42.7		NE	NE	NE	NE	897.3
4E Other (please specify)				0.0	0.0	0.0	0.0	0.0

Numbers may not sum exactly due to rounding off.

6.1.1.2 2000 – 2020

In the 2000 – 2020 GHG inventory, waste sector emissions have been recalculated to reflect changes in the 2019 IPCC Refinement, and from addition of new sources in particular biological treatment of solid waste and emissions from industrial wastewater treatment and discharge.

Waste sector emissions have increased by 26.3% from the 18 241 Gg CO₂e in 2000 (Table 6.2). Emissions increased steadily between 2000 and 2020 (Figure 6.1; Table 6.3). There are two likely reasons for the increase observed in the waste sector:

- The first being that the first order decay (FOD) methodology has an in-built lag-effect and, as a result, the reported emissions from solid waste in managed landfills in a given year are likely to be due to solid waste disposed of over the previous 10 to 15 years.
- Secondly, in South Africa the expected growth in the provision of sanitation services, particularly with respect to collecting and managing solid waste streams in managed landfills, is likely to result in an increase in emissions of more than 5% annually. In addition, at present very little methane is captured at the country's landfills and the percentages of recycled organic waste are low. Intervention mechanisms designed to reduce GHG emissions from solid waste are likely to yield significant reductions in the waste sector.

The key driver for the increase of emissions is the increase in the amount of biodegradable part of the municipal waste deposited on the SWDS. This has been adjusted in the FOD methodology by adjusting the waste composition quantities deposited in SWDS. These are discussed in detail in category specific sections.

Emissions from *Solid waste disposal* increased by 34.1% (13 610 Gg CO₂e) since 2000 to 18 253 Gg CO₂e in 2020. Emissions from *Incineration and open burning of waste* increased



by 90.2% while the trend in emissions from *Wastewater treatment and discharge* remained stable over this period.

Table 6.2: GHG emissions from South Africa's Waste sector between 2000 and 2020.

IPCC Code	Source Category	Gas	2000	2020	Change (%)
4	TOTAL WASTE	All	18 241.2	23 045.8	26.3
4A	Solid Waste Disposal	CH ₄	13 610.5	18 252.8	34.1
4B	Biological treatment of solid waste	All	0.00132	0.0	-100.0
4B	Biological Treatment of Solid Waste	CH ₄	0.0008	0.0	-100.0
4B	Biological Treatment of Solid Waste	N ₂ O	0.0005	0.0	-100.0
4C	Incineration and open burning of waste	All	176.1	334.9	90.2
4C2	Open Burning of Waste	CO ₂	18.6	35.4	90.2
4C2	Open Burning of Waste	CH ₄	117.5	223.4	90.2
4C2	Open Burning of Waste	N ₂ O	40.0	76.1	90.2
4D	Wastewater Treatment and Discharge	All	4 454.6	4 458.1	8.0
4D1	Wastewater Treatment and Discharge	CH ₄	1 951.2	2 782.9	42.6
4D1	Wastewater Treatment and Discharge	N ₂ O	545.4	777.9	42.6
4D2	Wastewater Treatment and Discharge	CH ₄	1 958.1	897.3	-54.2

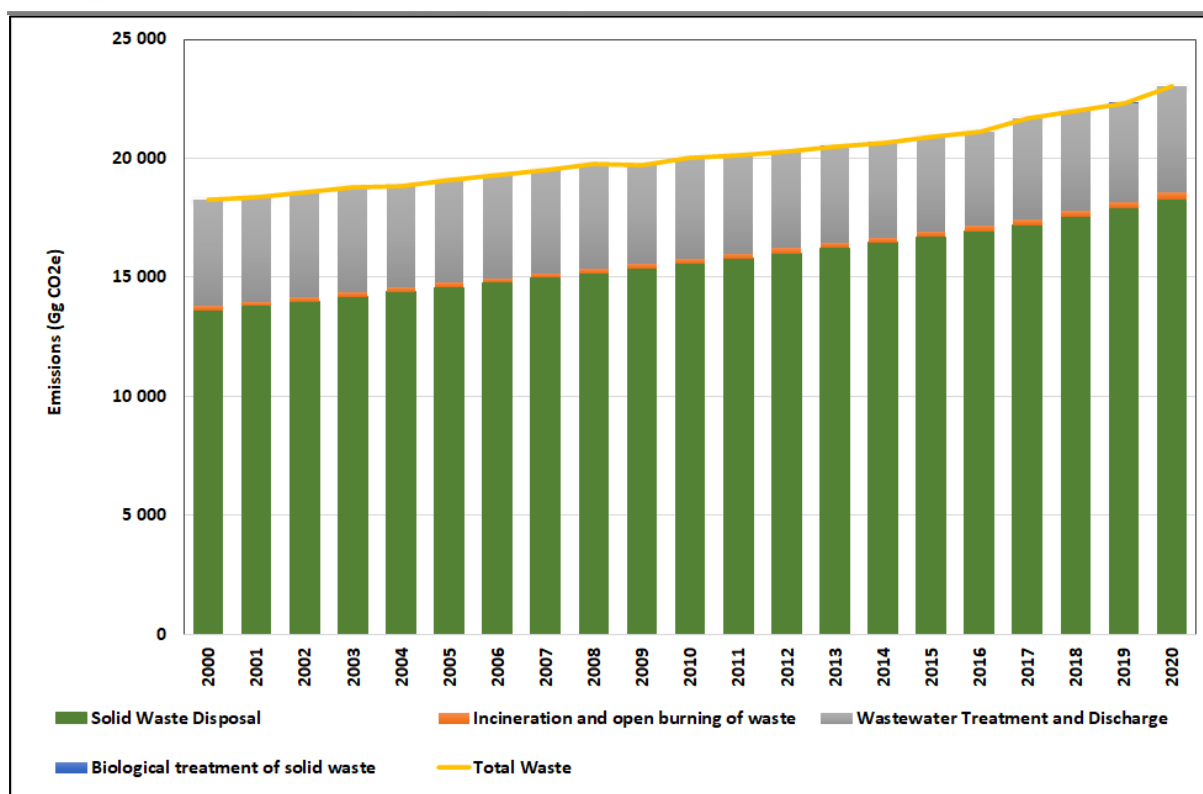


Figure 6.1: Trend in emissions from Waste sector, 2000 - 2020.



Table 6.3: Trend in Waste sector category emissions between 2000 and 2020.

	Solid Waste Disposal	Biological treatment of solid waste	Incineration and open burning of waste	Wastewater Treatment and Discharge	Total Waste
	Emissions (Gg CO ₂ e)				
2000	13 610.5	0.0	176.1	4 454.6	18 241.2
2001	13 782.7	0.0	179.7	4 381.2	18 343.6
2002	13 965.2	0.0	185.7	4 415.5	18 566.4
2003	14 175.1	0.0	187.5	4 440.5	18 803.2
2004	14 379.1	0.0	189.5	4 290.2	18 858.8
2005	14 579.6	0.0	191.7	4 314.2	19 085.5
2006	14 778.3	0.0	194.0	4 323.6	19 295.9
2007	14 976.3	0.0	196.4	4 329.0	19 501.8
2008	15 175.3	0.0	199.1	4 367.7	19 742.1
2009	15 376.6	0.0	201.9	4 153.7	19 732.3
2010	15 581.4	0.0	205.0	4 220.7	20 007.0
2011	15 791.9	0.0	208.1	4 114.0	20 113.9
2012	16 008.4	0.0	211.4	4 087.2	20 306.9
2013	16 230.9	0.0	214.7	4 045.6	20 491.1
2014	16 462.4	0.0	218.0	3 980.0	20 660.4
2015	16 698.7	0.0	221.4	3 976.2	20 896.3
2016	16 939.0	0.0	224.9	3 959.5	21 123.4
2017	17 183.9	0.0	250.7	4 264.7	21 699.3
2018	17 551.8	0.0	254.1	4 183.2	21 989.0
2019	17 908.7	0.0	257.5	4 133.1	22 299.3
2020	18 252.8	0.0	334.9	4 458.1	23 045.8

6.1.2 Overview of methodology and completeness

The emissions for the *Waste* sector were derived by either using available data or estimates based on accessible surrogate data sourced from the scientific literature. Table 6.4 shows the methods and emission factors applied in this sector. For the waste sector, among the chief limitations of quantifying the GHG emissions from different waste streams was the lack of a periodically updated national inventory on: the quantities of organic waste deposited in well-managed landfills; the annual recovery of methane from landfills; quantities generated from anaerobically decomposed organic matter from wastewater treated; and per capita annual protein consumption in South Africa.



Table 6.4: 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			T1	DF			Tier 1 FOD model was used.
B	Biological treatment of solid waste	NA		T1		T1		2006 IPCC GL
C	Incineration and open burning of waste	T1	DF	T1	DF	T1	DF	2006 IPCC GL
D	Waste water treatment and discharge	NA		T1	DF, CS	T1	DF	2006 IPCC GL

6.1.2.1 Data sources

The main data sources for the Waste sector are provided in Table 6.5.

Table 6.5: Main data sources for the Waste sector emission calculations.

Sub-category	Activity data	Data source
Solid waste disposal	Population data	Statistics SA (2015); UN (2012)
	Waste composition	IPCC 2006, and 2019 IPCC Refinement
	Waste generation rate for each component	State of Waste Report (2018)
	GDP	World bank
Open burning of waste	Population data	Statistics SA (2015); 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 (2015); UN (2012)
	Split of population by income group	Statistics SA (2015)



Sub-category	Activity data	Data source
	BOD generation rates per treatment type	IPCC 2006
	Per capita nitrogen generation rate	IPCC 2006

6.1.3 Key categories in the Waste sector

The key categories in the Waste sector were determined to be:

- Level assessment for 2020:
 - Solid waste disposal (CH₄)
 - Wastewater treatment and discharge (CH₄)
- Trend assessment between 2000 and 2020:
 - Solid waste disposal (CH₄)

6.1.4 Recalculations and improvements since the 2017 submission

Recalculations were performed for the category *Solid waste disposal* for all years between 2000 to the latest inventory year (2020) due to the following changes:

- The population, waste per capita and the percentage of waste going to solid waste disposal sites was corrected in the FOD model for the years 1950 to 2000. In the previous submission these numbers were only input for the years from 2000 onwards, while default values were left for the years prior to this.
- Waste generation rate per person was adjusted from 511 kg/cap/yr in previous submissions to 398 kg/cap/yr in the current submission and this is consistent with the waste generation rates per capita provided in the 2019 refinement to the 2006 IPCC guidelines. This is used from the base year of 2000 until 2020.
- Waste generation rate per GDP value, for purposes of estimating the amount of industrial waste generated was adjusted from 8Gg waste/GDP/yr in previous submissions to 0.4 waste/GDP/yr in the current submission (calculated based on data contained in the 2018 state of waste report). This is used from the base year of 2000 until 2020.



- Amount sent to SWDS adjusted to 76% for MSW and 85% for Industrial waste to reflect changes in penetration of recycling and the evolution of other forms of waste management and/or treatment.
- The fraction of methane in developed gas was previously indicated to be 0.52 and this was corrected to the IPCC default value of 0.5.

6.1.5 Planned improvements and recommendations

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, as a consequence, 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 for the future:

- (i) Obtain data on the quantities of waste disposed of into managed and unmanaged landfills including its composition;
- (ii) Improve the classification of landfill sites
- (iii) 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;
- (iv) Obtain information on population distribution trends between rural and urban settlements as a function of income; and
- (v) Conduct a study to trace waste streams and obtain more information on the bucket system which is still widely used in South Africa.
- (vi) Collect data on CH₄ recovery at SWDS based on metering data.

6.2 Solid Waste Disposal (4.A)

6.2.1 Category information

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. Furthermore,



only GHG's generated from managed disposal landfills in South Africa were included, as data on unmanaged sites are not documented and the sites are generally shallow. A periodic survey is still needed to assess the percentage share of unmanaged sites and semi-managed sites. Generating this information is central to understanding methane generation rates for different solid waste disposal pathways.

Methane flaring is an activity that occurs at a few Solid Waste Disposal Sites. Currently the projects⁷ highlighted below are known to be in place to generate electricity from SWDS:

- EThekweni Municipality has two major sites, Mariannhill and Bisasar Road (generating approx. 45 000 MWh/year).
- Ekurhuleni Metropolitan Municipality with installed capacity of 1 MW Landfill Gas to electricity plant at its Simmer and Jack landfill site in Germiston.

According to the 2006 IPCC 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. 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.

6.2.1.1 Overview of shares and trends in emissions

2020

Solid waste disposal was estimated to produce 18 253 Gg CO₂e in 2020, which was all from CH₄ emissions. It contributes 79.2% to the total *Waste* sector emissions.

2000 – 2020

Emissions in this category increased by 34.1% (from 13 610 Gg CO₂e in 2000 to 18 253 in 2020). The main driver of this increase is the population numbers and therefore the amount of waste being generated. In addition to this the various updates on parameters

⁷ [http://www.sustainable.org.za/userfiles/waste%20to%20energy%20\(2\).pdf](http://www.sustainable.org.za/userfiles/waste%20to%20energy%20(2).pdf)



such as Waste generation rates per person and the updated waste composition used in the FOD model.

6.2.2 Methodology

The methodology for calculating GHG emissions from solid waste is consistent with the IPCC Tier 1 First Order Decay (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. Input data includes population data (StatsSA, 2015), waste generation rates, GDP (World bank), annual waste generation, population growth rates, emission rates, half-lives of bulk waste stream (default value for the half-life is 14 years), 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 Guidelines were applied (Table 6.6).

The FOD method requires data to be collected or estimated for historical disposals of waste over a time 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 2020, 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 2017 (StatsSA, 2015). Waste generation rates for industrial waste were estimated using GDP values sourced from the World Bank for period 2013 to 2019.

Table 6.6: 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

In addition, the inventory compilers noted that the information on national waste composition presented in the National Waste Baseline Information Report (DFFE, 2012) was not compatible with the approach set out in the 2006 IPCC Guidelines, therefore, even though domestic information on waste composition was available, it could not be used for the purposes of this inventory. Instead, default IPCC waste composition values were used. The National Waste Information Baseline Report (DFFE, 2012) indicated that 11% of waste was recycled in 2011 and then a further 9% went to open burning. Due to a lack of data for other years, these values were assumed to be constant over the time period and so the percentage of generated waste which goes to solid waste disposal sites was set at 80%.

No detailed analysis of the methane recovery from landfills was accounted for between 2000 and 2017. As noted in the previous inventory, the recovery of methane from landfills commenced on a large-scale after 2000, with some sites having a lifespan of about 21 years (DME, 2008). To address these data limitations, the DFFE has implemented the National Climate Change Response Database, which captures valuable data from mitigation and adaptation projects for future GHG estimates from landfills. This tool will be used in the future to identify and implement methane recovery projects. However, at present there are limited publicly accessible data on the quantities of methane recovered annually from managed landfills in South Africa.

The key assumptions applied in this method were:



- waste generation rate per capita was assumed to be constant (511 kg/cap/yr) (calculated based on the 2018 State of Waste Report) throughout the time series 2000 – 2020.
- percentage of MSW going into landfills was assumed to be constant (76%) throughout the time series 2000 – 2020
- percentage of Industrial Solid Waste going into landfills was assumed to be constant (85%) throughout the time series 2000 – 2020
- Composition of waste going into SWDS was assumed to be 24 % food, 0% garden, 14.5% paper, 0% wood, 5,5% textile, 0% nappies and 56% plastic or other inert substance (default IPCC Regional values – 2019 Refinement)
- waste generation rate per GDP (Gg/\$m GDP/yr) was assumed to be constant (0,4 tonnes/per unit of GDP in US dollar) throughout the time series (calculated based on the 2018 State of Waste Report).

6.2.3 Uncertainty and time series consistency

6.2.3.1 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 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). Another source of uncertainty is that methane production is calculated using bulk waste because of a lack of data on waste composition, therefore, uncertainty is more than a factor of two (DFFE, 2009). For the purpose of the bulk waste estimates, the whole of South Africa is classified as a “warm temperate dry” climate zone, even though some landfills are located in dry tropical climatic conditions. Other uncertainties are provided in Table 6.7.

6.2.3.2 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 UN secretariat provided consistent time-series activity data for solid waste disposal.

Table 6.7: 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	

6.2.4 Planned improvements

Planned improvements include:

- Collection of actual quantities of waste disposed into landfill sites for period 2000 – 2020.
- Collection of wastewater related activity data for period 2000 – 2020 taking into account different wastewater treatment pathways in South Africa.
- 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.

6.3 Biological Treatment of Solid Waste (4.B)

6.3.1 Category information



In this source category only the emissions from biological treatment of Industrial Solid Waste have been taken into account. This category excludes biological treatment of Municipal Solid Waste. The GHG emissions from biological treatment of solid waste were calculated using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. These guidelines provide default methane and nitrous oxide emission factors that were used in conjunction with the mass of waste estimated to be treated by composting or anaerobic digestion, on a dry-weight basis.

6.3.1.1 Overview of shares and trends in emissions

2020

Emissions from Biological Treatment of Solid Waste were estimated to produce 0 Gg CO_{2e} in 2020. Emissions were considered to be insignificant as they are below 500 Gg CO_{2e} of the national total.

However, in the current inventory, the only waste covered that undergoes biological treatment is industrial waste and no MSW is taken into account. It is envisaged that as more data is collected on the amount of MSW that undergoes biological treatment, emissions for this category are likely to increase.

6.3.2 Methodology

A Tier 1 approach, with default IPCC 2006 emission factors, was applied in the calculation of CH₄ and N₂O emissions from biological treatment of solid waste. The amount of Industrial waste undergoing biological treatment on a dry weight basis is shown below. Emissions were estimated using Equation 4.1 of the IPCC 2006 Guidelines (IPCC, 2006; vol 5, chapt. 4; pg. 4.5).

6.3.2.1 Activity data

Activity data used to estimate emissions from this category are shown in Table 6.8.

Table 6.8: Activity data for biological treatment systems.



Period	Biological Treatment System	Types of Waste	Total Annual amount treated by biological treatment facilities (Gg)	CH ₄ Recovered
2000	Composting	Industrial	2677	
2001		Industrial	2781	
2002		Industrial	2955	
2003		Industrial	2866	
2004		Industrial	3096	
2005		Industrial	3215	
2006		Industrial	3333	
2007		Industrial	3622	
2008		Industrial	3957	
2009		Industrial	3803	
2010		Industrial	4052	
2011		Industrial	4156	
2012		Industrial	4315	
2013		Industrial	4386	
2014		Industrial	4409	
2015		Industrial	4335	
2016		Industrial	4357	
2017		Industrial	4099	
2018		Industrial	4741	
2019		Industrial	4842	
2000	Anaerobic digestion at biogas facilities	Industrial	5662	10.75759
2001		Industrial	5732	10.88992
2002		Industrial	5838	11.09145
2003		Industrial	5808	11.03606
2004		Industrial	5923	11.25376
2005		Industrial	5888	11.18803
2006		Industrial	5729	10.88481
2007		Industrial	5980	11.36284
2008		Industrial	5415	10.28811
2009		Industrial	7118	13.52474
2010		Industrial	8324	15.81632
2011		Industrial	5631	10.69833
2012		Industrial	5726	10.87883
2013		Industrial	5691	10.81221
2014		Industrial	6260	11.89394
2015		Industrial	5698	10.82596
2016		Industrial	5753	10.93055
2017		Industrial	5683	10.79762
2018		Industrial	6078	11.54978
2019		Industrial	6054	11.50436



6.3.2.2 Emission factors

Emission factors are shown in Table 6.9 on a dry weight basis.

Table 6.9: 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

6.4 Incineration and open burning of waste (4.C)

6.4.1 Category information

According to the IPCC 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 as a means 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.



Overview of shares and trends in emissions

2020

Open burning was estimated to produce 335 Gg CO₂e in 2020. Emissions were 10.4% CO₂ (35 Gg CO₂e), 66.8% CH₄ (223 Gg CO₂e) and 22.8% N₂O (76 Gg CO₂e).

2000 – 2020

Emissions in this category increased by 90.2% (159 Gg CO₂e) between 2000 and 2020 (Table 6.3).

6.4.2 Methodology

A Tier 1 approach, with default IPCC 2006 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, chapt. 5; pg. 5.16).

6.4.2.1 Activity data

The activity data for the calculation of MSW are described in section 6.2.2. The fraction of population carrying out open-burning was estimated at 9% (Expert Judgement). CO₂ emissions were calculated for the different waste types using the IPCC default breakdown.

6.4.2.2 Emission factors

Emission factors are shown in Table 6.10.

Table 6.10: Emission factors for estimating emissions from open burning of waste.

Sub-category	Value	Unit	Source
Dry matter content			
Food	0.4	fraction	IPCC 2006
Garden	0.4		
Paper	0.9		
Wood	0.85		



Sub-category	Value	Unit	Source
<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		
<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		
<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
CH ₄ emission factor	6500	g/t MSW	IPCC 2006
N ₂ O emission factor	150	G N ₂ O/t waste	IPCC 2006

6.4.3 Uncertainty and time series consistency

6.4.3.1 Uncertainty

Activity data uncertainty are provided in Table 6.7. Uncertainties associated with CO₂ emission factors for open burning 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 ±40% is suggested by IPCC 2006. Uncertainties on default N₂O and CH₄ emission factors have been estimated to be ±100%.

6.4.3.2 Time series consistency



The time series is consistent as the activity data source is the same throughout the time series.

6.4.4 Planned improvements

As a planned improvement for this sector, collection of activity data on amounts of waste incinerated, by category of waste and the technologies used to incinerate waste in South Africa.

6.5 Wastewater Treatment and Discharge (4.D)

6.5.1 Domestic wastewater treatments and discharge (4.D.1)

6.5.1.1 *Category information*

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.

Wastewater can be treated on site (mostly industrial sources) or treated in septic systems and centralised systems (mostly for urban domestic sources) or disposed of untreated (mostly in rural and peri-urban settlements). Most domestic wastewater CH₄ emissions are generated from centralised aerobic systems that are not well managed, or from anaerobic systems (anaerobic lagoons and facultative lagoons), or from anaerobic digesters where the captured biogas is not flared or completely combusted.

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.



6.5.1.2 Overview of shares and trends in emissions

2020

Wastewater treatment and discharge were estimated to produce 4 458 Gg CO₂e in 2020, of which 80% (3 561 Gg CO₂e) is from *Domestic Wastewater treatment* and 20% (897 Gg CO₂e) is from *Industrial wastewater treatment*.

2000 - 2020

Emissions from *Domestic wastewater treatment* increased by 42.6% and emissions from *Industrial wastewater treatment* and discharge decreased by 54.1% between 2000 and 2020 (Table 6.2), resulting in an overall increase of 0.08% for the entire category.

6.5.1.3 Methodology

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 BOD generated from domestic and commercial sources in South Africa annually, the yearly estimates were determined using the IPCC 2006 default Tier 1 method.

The projected methane emissions from the wastewater follow the same methodology described in the 2012 National GHG Inventory Report (DFFE, 2016). The estimated methane emissions reported are from domestic and commercial sources of wastewater because the IPCC 2006 Guidelines do not stipulate a different set of equations or differentiated computational approaches for the two sources, as was previously stipulated in 1996 IPCC Guidelines. It should be noted that the data on quantities of wastewater from specific industrial sources with high organic content are largely lacking in South Africa and, therefore, the estimated values in this report are assumed to be due to domestic and industrial sources treated in municipal wastewater treatment systems. However, wastewater from commercial and industrial sources discharged into sewers is accounted for, so the term “domestic wastewater” in this inventory refers to the total wastewater discharged into sewers from all sources. This is achieved by employing the default IPCC methane correction factor (MCF) of 1.25 used to account for commercial and industrial wastewater. It is highly likely that the MCF value for South Africa ranges between 1.2 and 1.4.



Activity data

To be consistent, the specific-category data described in Section 6.4.1 of the National GHG Inventory Report for 2000 (DFFE, 2009) and its underlying assumptions were adopted. In determining the total quantity of kg BOD yr⁻¹, population data was sourced from Statistics South Africa. This is the same population data as used in the FOD model.

Emission factors

Default population distribution trends between rural and urban settlements as a function of income, as well as a default average South African BOD production value of 37 g person⁻¹ day⁻¹ were sourced from the 2006 IPCC 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, therefore, it could not be included in the waste sector model. In this case, a default IPCC correction factor of 1.25 was applied in order to take into account the industrial wastewater treated in sewage treatment systems. The emissions factors for different wastewater treatment and discharge systems were taken from the 2006 IPCC Guidelines (Table 6.11) as was the data on distribution and utilization of different treatment and discharge systems (Table 6.12).

Table 6.11: 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 6.12: Distribution and utilization of different treatment and discharge systems

Income group		Type of treatment or discharge pathway	Degree of utilization



	Fraction of population income group	(kg CH ₄ /kg BOD)	(T _{ij})
Rural	0.39	Septic tank	0.10
		Latrine – rural	0.28
		Sewer stagnant	0.10
		Other	0.04
		None	0.48
Urban high-income	0.12	Sewer closed	0.70
		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 and Wastewater Treatment

The default values provided by the IPCC 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 instance, a default value for per capita protein consumption of 27.96 kg yr⁻¹ was applied in the model (FAO, 2017).

N₂O emissions from discharge of effluent

The per capita protein consumption value of 27.96 was used consistently throughout the time series (sourced from the 2006 IPCC GLs). Indirect N₂O emissions were then estimated by multiplying the N effluent by the N₂O emission factor to estimate indirect N₂O emissions.

6.5.1.4 Uncertainty and time series consistency

Uncertainties

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 the United Nations (StatsSA, 2016), the presumed constant country BOD production of about 37 g person⁻¹ day⁻¹ from 2001 to



2020, 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.

Time series consistency

Time-series consistency was achieved by using population datasets obtained from the UN secretariat. Assumptions about wastewater streams were assumed to be constant over the 20-year time series and default IPCC emission factors used.

6.5.1.5 Planned improvements

There are no planned improvements for this category.

6.5.2 Industrial wastewater treatment and discharge (4.D.2)

To be updated...

6.6 References

- DFFE, 2012. National Waste Information Baseline Report. Department of Environmental Affairs, Pretoria.
- DFFE, 2016. National GHG Inventory Report for South Africa: 2000 – 2012. Department of Environmental Affairs, Pretoria.
- DFFE, 2009. Greenhouse Gas Inventory South Africa, 1990 to 2000. National Inventory Report, May 2009. Pretoria: Department of Environmental Affairs and Tourism.
- IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, Eggleston H S, Buendia L, Miwa K, Ngara T, and Tanabe K, eds; Institute for Global Environmental Strategies (IGES). Hayama, Kanagawa, Japan.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

UN, 2012. Population Division of the Department of Economic and Social Affairs of the
Secretariat, World Population Prospects:
<http://esa.un.org/unpd/wpp/index.htm> [Accessed April 2013]



Appendix A: Key category analysis

Table A.1: Level assessment on emissions excluding FOLU for South Africa (2000) with the key categories highlighted in green.

IPCC Category code	IPCC Category	Fuel type	GHG	2000 Ex,t (Gg CO ₂ Eq)	Lx,t	Cumulative Total
1A1a	Electricity and Heat Production	Solid	CO ₂	185027.4	0.390	0.390
1A3b	Road Transport	Liquid	CO ₂	36302.9	0.077	0.467
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CO ₂	30454.7	0.064	0.531
1B3	Other Emissions from Energy Production		CO ₂	28146.6	0.059	0.591
3A1a	Enteric fermentation - cattle		CH ₄	23901.0	0.050	0.641
1A2	Manufacturing Industries and Construction	Solid	CO ₂	19545.0	0.041	0.682
1A4a	Commercial/Institutional	Solid	CO ₂	18248.1	0.039	0.721
2C1	Iron and Steel Production		CO ₂	15334.4	0.032	0.753
1A5a	Stationary	Solid	CO ₂	14372.8	0.030	0.784
4A	Solid Waste Disposal		CH ₄	13610.5	0.029	0.812
3C4	Direct N ₂ O emissions from managed soils		N ₂ O	12363.6	0.026	0.838
2C2	Ferroalloys Production		CO ₂	8079.1	0.017	0.856
1A2	Manufacturing Industries and Construction	Gas	CO ₂	6276.0	0.013	0.869
3A1c	Enteric fermentation - sheep		CH ₄	5837.3	0.012	0.881
2A1	Cement Production		CO ₂	3870.6	0.008	0.889
1A4b	Residential	Solid	CO ₂	3604.2	0.008	0.897
1A5a	Stationary	Liquid	CO ₂	2888.6	0.006	0.903
1A4b	Residential	Liquid	CO ₂	2868.4	0.006	0.909
1A2	Manufacturing Industries and Construction	Liquid	CO ₂	2809.0	0.006	0.915
1B1a	Coal mining and handling		CH ₄	2338.1	0.005	0.920
1B3	Other Emissions from Energy Production		CH ₄	2318.6	0.005	0.925
1A1b	Petroleum Refining	Gas	CO ₂	2307.1	0.005	0.930
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CO ₂	2251.0	0.005	0.934



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3a	Civil Aviation	Liquid	CO ₂	2249.1	0.005	0.939
1A4a	Commercial/Institutional	Liquid	CO ₂	2028.6	0.004	0.943
4D2	Industrial Wastewater Treatment and Discharge		CH ₄	1958.1	0.004	0.948
4D1	Wastewater Treatment and Discharge		CH ₄	1951.2	0.004	0.952
1A1b	Petroleum Refining	Liquid	CO ₂	1735.5	0.004	0.955
2B	Chemical industry		C	C	0.003	0.959
3A1d	Enteric fermentation - goats		CH ₄	1493.1	0.003	0.962
3C5	Indirect N ₂ O emissions from managed soils		N ₂ O	1256.4	0.003	0.965
3A2a	Manure management - cattle		N ₂ O	1249.4	0.003	0.967
2C3	Aluminium Production		CO ₂	1091.3	0.002	0.970
2C3	Aluminium Production		PFCs	983.2	0.002	0.972
1A1a	Electricity and Heat Production	Solid	N ₂ O	893.9	0.002	0.974
3A2a	Manure management - cattle		CH ₄	881.6	0.002	0.975
1B2a	Oil		CO ₂	752.0	0.002	0.977
3A2i	Manure management - poultry		N ₂ O	651.9	0.001	0.978
1A4a	Commercial/Institutional	Gas	CO ₂	631.0	0.001	0.980
3C1c	Biomass burning in grasslands		N ₂ O	557.4	0.001	0.981
1A3c	Railways	Liquid	CO ₂	551.5	0.001	0.982
4D1	Wastewater Treatment and Discharge		N ₂ O	545.4	0.001	0.983
1A3b	Road Transport	Liquid	N ₂ O	545.1	0.001	0.984
2B	Chemical industry		C	C	0.001	0.985
1A4b	Residential	Solid	N ₂ O	439.1	0.001	0.986
2B	Chemical industry		C	C	0.001	0.987
2A2	Lime Production		CO ₂	426.1	0.001	0.988
3C1c	Biomass burning in grasslands		CH ₄	413.5	0.001	0.989
3C2	Liming		CO ₂	384.1	0.001	0.990
3C6	Indirect N ₂ O emissions from manure management		N ₂ O	347.1	0.001	0.991
3C1a	Biomass burning in forest land		N ₂ O	298.7	0.001	0.991
3C3	Urea application		CO ₂	297.3	0.001	0.992
3C1a	Biomass burning in forest land		CH ₄	293.6	0.001	0.992



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3b	Road Transport	Liquid	CH ₄	247.9	0.001	0.993
3C1b	Biomass burning in croplands		CH ₄	235.6	0.000	0.993
1A3d	Water-Borne Navigation	Liquid	CO ₂	222.2	0.000	0.994
1A4b	Residential	Solid	CH ₄	206.2	0.000	0.994
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CO ₂	199.5	0.000	0.995
3A2h	Manure management - swine		CH ₄	192.0	0.000	0.995
2D1	Lubricant Use		CO ₂	188.5	0.000	0.996
3A2c	Manure management - sheep		N ₂ O	185.3	0.000	0.996
1A4a	Commercial/Institutional	Solid	N ₂ O	176.3	0.000	0.996
2B	Chemical industry		C	C	0.000	0.997
1A1a	Electricity and Heat Production	Liquid	CO ₂	121.3	0.000	0.997
4C2	Open Burning of Waste		CH ₄	117.5	0.000	0.997
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	N ₂ O	110.3	0.000	0.997
2C6	Zinc Production		CO ₂	108.4	0.000	0.998
3A1f	Enteric fermentation - horses		CH ₄	102.1	0.000	0.998
1A2	Manufacturing Industries and Construction	Solid	N ₂ O	94.3	0.000	0.998
3C1b	Biomass burning in croplands		N ₂ O	90.2	0.000	0.998
3A2i	Manure management - poultry		CH ₄	84.2	0.000	0.998
2A3	Glass Production		CO ₂	74.4	0.000	0.999
1A5a	Stationary	Solid	N ₂ O	69.4	0.000	0.999
3A2d	Manure management - goats		N ₂ O	69.2	0.000	0.999
1A3c	Railways	Liquid	N ₂ O	66.0	0.000	0.999
2B	Chemical industry		C	C	0.000	0.999
1A1a	Electricity and Heat Production	Solid	CH ₄	40.4	0.000	0.999
4C2	Open Burning of Waste		N ₂ O	40.0	0.000	0.999
3A1h	Enteric fermentation - swine		CH ₄	39.8	0.000	0.999
3A2h	Manure management - swine		N ₂ O	34.7	0.000	0.999
3A1g	Enteric fermentation - mules and asses		CH ₄	34.4	0.000	0.999
1B1a	Coal mining and handling		CO ₂	30.6	0.000	1.000
3A2c	Manure management - sheep		CH ₄	22.1	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

4C2	Open Burning of Waste		CO ₂	18.6	0.000	1.000
3C1d	Biomass burning in wetlands		N ₂ O	16.7	0.000	1.000
2C5	Lead Production		CO ₂	15.1	0.000	1.000
3C1d	Biomass burning in wetlands		CH ₄	12.4	0.000	1.000
3A2d	Manure management - goats		CH ₄	11.3	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CH ₄	10.6	0.000	1.000
3C1e	Biomass burning in settlements		N ₂ O	10.5	0.000	1.000
3C1e	Biomass burning in settlements		CH ₄	7.8	0.000	1.000
2D2	Paraffin Wax Use		CO ₂	7.4	0.000	1.000
1A5a	Stationary	Liquid	N ₂ O	7.4	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	N ₂ O	6.4	0.000	1.000
1A3a	Civil Aviation	Liquid	N ₂ O	5.9	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	N ₂ O	5.6	0.000	1.000
1A4b	Residential	Liquid	N ₂ O	5.4	0.000	1.000
1A4a	Commercial/Institutional	Liquid	N ₂ O	4.9	0.000	1.000
1A2	Manufacturing Industries and Construction	Solid	CH ₄	4.3	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	N ₂ O	4.2	0.000	1.000
1A4a	Commercial/Institutional	Solid	CH ₄	4.0	0.000	1.000
1A1b	Petroleum Refining	Liquid	N ₂ O	3.6	0.000	1.000
1A3b	Road Transport	Gas	CO ₂	3.4	0.000	1.000
2C2	Ferroalloys Production		CH ₄	3.3	0.000	1.000
1A5a	Stationary	Solid	CH ₄	3.1	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	CH ₄	2.8	0.000	1.000
1A5a	Stationary	Liquid	CH ₄	2.5	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	CH ₄	2.2	0.000	1.000
1A4b	Residential	Liquid	CH ₄	2.0	0.000	1.000
1A3a	Civil Aviation	Liquid	CH ₄	2.0	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	N ₂ O	1.9	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CH ₄	1.9	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A4a	Commercial/Institutional	Liquid	CH ₄	1.7	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	N ₂ O	1.3	0.000	1.000
1A1b	Petroleum Refining	Gas	N ₂ O	1.2	0.000	1.000
1A1b	Petroleum Refining	Liquid	CH ₄	1.2	0.000	1.000
1A1b	Petroleum Refining	Gas	CH ₄	0.8	0.000	1.000
1A3c	Railways	Liquid	CH ₄	0.6	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	CH ₄	0.4	0.000	1.000
1A4a	Commercial/Institutional	Gas	N ₂ O	0.3	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	N ₂ O	0.3	0.000	1.000
1A4a	Commercial/Institutional	Gas	CH ₄	0.2	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	CH ₄	0.1	0.000	1.000
1A3b	Road Transport	Gas	CH ₄	0.1	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CH ₄	0.0	0.000	1.000
1A3b	Road Transport	Gas	N ₂ O	0.0	0.000	1.000
4B	Biological treatment of waste		CH ₄	0.0	0.000	1.000
4B	Biological treatment of waste		N ₂ O	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CO ₂	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CO ₂	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CH ₄	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CH ₄	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	N ₂ O	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	N ₂ O	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CO ₂	0.0	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3c	Railways	Gas	CO ₂	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CO ₂	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CH ₄	0.0	0.000	1.000
1A3c	Railways	Gas	CH ₄	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CH ₄	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	N ₂ O	0.0	0.000	1.000
1A3c	Railways	Gas	N ₂ O	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	N ₂ O	0.0	0.000	1.000
2A4	OPUC		CO ₂	0.0	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
2C1	Iron and Steel Production		CH ₄	0.0	0.000	1.000
2F1	Refrigeration and Air Conditioning		HFCs	0.0	0.000	1.000
2F2	Foam Blowing Agents		HFCs	0.0	0.000	1.000
2F3	Fire Protection		HFCs	0.0	0.000	1.000
2F4	Aerosols		HFCs	0.0	0.000	1.000
3A1j	Enteric fermentation - other game		CH ₄	0.0	0.000	1.000
3A2f	Manure management - horses		CH ₄	0.0	0.000	1.000
3A2g	Manure management - mules and asses		CH ₄	0.0	0.000	1.000
3A2j	Manure management - other game		CH ₄	0.0	0.000	1.000
3C1f	Biomass burning in other lands		CH ₄	0.0	0.000	1.000
3C1f	Biomass burning in other lands		N ₂ O	0.0	0.000	1.000

C=Confidential data



Table A.2: Level assessment on emissions including FOLU for South Africa (2000) with the key categories highlighted in green.

IPCC Category code	IPCC Category	Fuel type	GHG	2017 Ex,t (Gg CO ₂ Eq)	Lx,t	Cumulative Total
1A1a	Electricity and Heat Production	Solid	CO ₂	185 027.4	0.346	0.346
1A3b	Road Transport	Liquid	CO ₂	36 302.9	0.068	0.414
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CO ₂	30 454.7	0.057	0.471
1B3	Other Emissions from Energy Production		CO ₂	28 146.6	0.053	0.524
3A1a	Enteric fermentation - cattle		CH ₄	23 901.0	0.045	0.568
1A2	Manufacturing Industries and Construction	Solid	CO ₂	19 545.0	0.037	0.605
1A4a	Commercial/Institutional	Solid	CO ₂	18 248.1	0.034	0.639
2C1	Iron and Steel Production		CO ₂	15 334.4	0.029	0.668
1A5a	Stationary	Solid	CO ₂	14 372.8	0.027	0.695
4A	Solid Waste Disposal		CH ₄	13 610.5	0.025	0.720
3C4	Direct N ₂ O emissions from managed soils		N ₂ O	12 363.6	0.023	0.743
3B3a	Grassland remaining grassland - Net CO ₂		CO ₂	-11 302.5	0.021	0.764
3B1b	Land converted to forest land - Net CO ₂		CO ₂	-10 508.4	0.020	0.784
3B1a	Forest land remaining forest land - Net CO ₂		CO ₂	-8 439.3	0.016	0.800
2C2	Ferroalloys Production		CO ₂	8 079.1	0.015	0.815
1A2	Manufacturing Industries and Construction	Gas	CO ₂	6 276.0	0.012	0.827
3B6b	Land converted to other lands - Net CO ₂		CO ₂	6 273.4	0.012	0.838
3A1c	Enteric fermentation - sheep		CH ₄	5 837.3	0.011	0.849
3B3b	Land converted to grassland - Net CO ₂		CO ₂	-4 971.7	0.009	0.859
3B2a	Cropland remaining cropland - Net CO ₂		CO ₂	-3 955.8	0.007	0.866
2A1	Cement Production		CO ₂	3 870.6	0.007	0.873
3B4a	Wetland remaining wetland		CO ₂	3 828.7	0.007	0.880
1A4b	Residential	Solid	CO ₂	3 604.2	0.007	0.887
1A5a	Stationary	Liquid	CO ₂	2 888.6	0.005	0.892
1A4b	Residential	Liquid	CO ₂	2 868.4	0.005	0.898



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A2	Manufacturing Industries and Construction	Liquid	CO ₂	2 809.0	0.005	0.903
3B6a	Other land remaining other land		CO ₂	2 385.6	0.004	0.908
1B1a	Coal mining and handling		CH ₄	2 338.1	0.004	0.912
1B3	Other Emissions from Energy Production		CH ₄	2 318.6	0.004	0.916
1A1b	Petroleum Refining	Gas	CO ₂	2 307.1	0.004	0.921
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CO ₂	2 251.0	0.004	0.925
1A3a	Civil Aviation	Liquid	CO ₂	2 249.1	0.004	0.929
3D1	Harvested wood products		CO ₂	-2 106.2	0.004	0.933
1A4a	Commercial/Institutional	Liquid	CO ₂	2 028.6	0.004	0.937
4D2	Industrial Wastewater Treatment and Discharge		CH ₄	1 958.1	0.004	0.940
4D1	Wastewater Treatment and Discharge		CH ₄	1 951.2	0.004	0.944
1A1b	Petroleum Refining	Liquid	CO ₂	1 735.5	0.003	0.947
3B5a	Settlements remaining settlements - Net CO ₂		CO ₂	-1 728.2	0.003	0.951
2B	Chemical industry		C	C	0.003	0.954
3B4	Wetland		CH ₄	1 587.9	0.003	0.957
3A1d	Enteric fermentation - goats		CH ₄	1 493.1	0.003	0.959
3C5	Indirect N ₂ O emissions from managed soils		N ₂ O	1 256.4	0.002	0.962
3A2a	Manure management - cattle		N ₂ O	1 249.4	0.002	0.964
3B4b	Land converted to wetland		CO ₂	-1 169.2	0.002	0.966
2C3	Aluminium Production		CO ₂	1 091.3	0.002	0.968
3B2b	Land converted to cropland - Net CO ₂		CO ₂	1 000.1	0.002	0.970
2C3	Aluminium Production		PFCs	983.2	0.002	0.972
3B5b	Land converted to settlements - Net CO ₂		CO ₂	967.3	0.002	0.974
1A1a	Electricity and Heat Production	Solid	N ₂ O	893.9	0.002	0.975
3A2a	Manure management - cattle		CH ₄	881.6	0.002	0.977
1B2a	Oil		CO ₂	752.0	0.001	0.979
3A2i	Manure management - poultry		N ₂ O	651.9	0.001	0.980
1A4a	Commercial/Institutional	Gas	CO ₂	631.0	0.001	0.981
3B4	Wetlands		N ₂ O	581.4	0.001	0.982
3C1c	Biomass burning in grasslands		N ₂ O	557.4	0.001	0.983



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3c	Railways	Liquid	CO ₂	551.5	0.001	0.984
4D1	Wastewater Treatment and Discharge		N ₂ O	545.4	0.001	0.985
1A3b	Road Transport	Liquid	N ₂ O	545.1	0.001	0.986
2B	Chemical industry		C	C	0.001	0.987
1A4b	Residential	Solid	N ₂ O	439.1	0.001	0.988
2B	Chemical industry		C	C	0.001	0.989
2A2	Lime Production		CO ₂	426.1	0.001	0.989
3C1c	Biomass burning in grasslands		CH ₄	413.5	0.001	0.990
3C2	Liming		CO ₂	384.1	0.001	0.991
3C6	Indirect N ₂ O emissions from manure management		N ₂ O	347.1	0.001	0.992
3C1a	Biomass burning in forest land		N ₂ O	298.7	0.001	0.992
3C3	Urea application		CO ₂	297.3	0.001	0.993
3C1a	Biomass burning in forest land		CH ₄	293.6	0.001	0.993
1A3b	Road Transport	Liquid	CH ₄	247.9	0.000	0.994
3C1b	Biomass burning in croplands		CH ₄	235.6	0.000	0.994
1A3d	Water-Borne Navigation	Liquid	CO ₂	222.2	0.000	0.995
1A4b	Residential	Solid	CH ₄	206.2	0.000	0.995
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CO ₂	199.5	0.000	0.995
3A2h	Manure management - swine		CH ₄	192.0	0.000	0.996
2D1	Lubricant Use		CO ₂	188.5	0.000	0.996
3A2c	Manure management - sheep		N ₂ O	185.3	0.000	0.996
1A4a	Commercial/Institutional	Solid	N ₂ O	176.3	0.000	0.997
2B	Chemical industry		C	C	0.000	0.997
1A1a	Electricity and Heat Production	Liquid	CO ₂	121.3	0.000	0.997
4C2	Open Burning of Waste		CH ₄	117.5	0.000	0.997
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	N ₂ O	110.3	0.000	0.998
2C6	Zinc Production		CO ₂	108.4	0.000	0.998
3A1f	Enteric fermentation - horses		CH ₄	102.1	0.000	0.998
1A2	Manufacturing Industries and Construction	Solid	N ₂ O	94.3	0.000	0.998
3C1b	Biomass burning in croplands		N ₂ O	90.2	0.000	0.998



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3A2i	Manure management - poultry		CH ₄	84.2	0.000	0.999
2A3	Glass Production		CO ₂	74.4	0.000	0.999
1A5a	Stationary	Solid	N ₂ O	69.4	0.000	0.999
3A2d	Manure management - goats		N ₂ O	69.2	0.000	0.999
1A3c	Railways	Liquid	N ₂ O	66.0	0.000	0.999
2B	Chemical industry		C	C	0.000	0.999
1A1a	Electricity and Heat Production	Solid	CH ₄	40.4	0.000	0.999
4C2	Open Burning of Waste		N ₂ O	40.0	0.000	0.999
3A1h	Enteric fermentation - swine		CH ₄	39.8	0.000	0.999
3A2h	Manure management - swine		N ₂ O	34.7	0.000	0.999
3A1g	Enteric fermentation - mules and asses		CH ₄	34.4	0.000	1.000
1B1a	Coal mining and handling		CO ₂	30.6	0.000	1.000
3A2c	Manure management - sheep		CH ₄	22.1	0.000	1.000
4C2	Open Burning of Waste		CO ₂	18.6	0.000	1.000
3C1d	Biomass burning in wetlands		N ₂ O	16.7	0.000	1.000
2C5	Lead Production		CO ₂	15.1	0.000	1.000
3C1d	Biomass burning in wetlands		CH ₄	12.4	0.000	1.000
3A2d	Manure management - goats		CH ₄	11.3	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CH ₄	10.6	0.000	1.000
3C1e	Biomass burning in settlements		N ₂ O	10.5	0.000	1.000
3C1e	Biomass burning in settlements		CH ₄	7.8	0.000	1.000
2D2	Paraffin Wax Use		CO ₂	7.4	0.000	1.000
1A5a	Stationary	Liquid	N ₂ O	7.4	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	N ₂ O	6.4	0.000	1.000
1A3a	Civil Aviation	Liquid	N ₂ O	5.9	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	N ₂ O	5.6	0.000	1.000
1A4b	Residential	Liquid	N ₂ O	5.4	0.000	1.000
1A4a	Commercial/Institutional	Liquid	N ₂ O	4.9	0.000	1.000
1A2	Manufacturing Industries and Construction	Solid	CH ₄	4.3	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	N ₂ O	4.2	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A4a	Commercial/Institutional	Solid	CH ₄	4.0	0.000	1.000
1A1b	Petroleum Refining	Liquid	N ₂ O	3.6	0.000	1.000
1A3b	Road Transport	Gas	CO ₂	3.4	0.000	1.000
2C2	Ferroalloys Production		CH ₄	3.3	0.000	1.000
1A5a	Stationary	Solid	CH ₄	3.1	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	CH ₄	2.8	0.000	1.000
1A5a	Stationary	Liquid	CH ₄	2.5	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	CH ₄	2.2	0.000	1.000
1A4b	Residential	Liquid	CH ₄	2.0	0.000	1.000
1A3a	Civil Aviation	Liquid	CH ₄	2.0	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	N ₂ O	1.9	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CH ₄	1.9	0.000	1.000
1A4a	Commercial/Institutional	Liquid	CH ₄	1.7	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	N ₂ O	1.3	0.000	1.000
1A1b	Petroleum Refining	Gas	N ₂ O	1.2	0.000	1.000
1A1b	Petroleum Refining	Liquid	CH ₄	1.2	0.000	1.000
1A1b	Petroleum Refining	Gas	CH ₄	0.8	0.000	1.000
1A3c	Railways	Liquid	CH ₄	0.6	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	CH ₄	0.4	0.000	1.000
1A4a	Commercial/Institutional	Gas	N ₂ O	0.3	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	N ₂ O	0.3	0.000	1.000
1A4a	Commercial/Institutional	Gas	CH ₄	0.2	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	CH ₄	0.1	0.000	1.000
1A3b	Road Transport	Gas	CH ₄	0.1	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CH ₄	0.0	0.000	1.000
1A3b	Road Transport	Gas	N ₂ O	0.0	0.000	1.000
4B	Biological treatment of waste		CH ₄	0.0	0.000	1.000
4B	Biological treatment of waste		N ₂ O	0.0	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A1a	Electricity and Heat Production	Gas	CO ₂	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CO ₂	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CH ₄	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CH ₄	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	N ₂ O	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	N ₂ O	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CO ₂	0.0	0.000	1.000
1A3c	Railways	Gas	CO ₂	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CO ₂	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CH ₄	0.0	0.000	1.000
1A3c	Railways	Gas	CH ₄	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CH ₄	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	N ₂ O	0.0	0.000	1.000
1A3c	Railways	Gas	N ₂ O	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	N ₂ O	0.0	0.000	1.000
2A4	OPUC		CO ₂	0.0	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
2C1	Iron and Steel Production		CH ₄	0.0	0.000	1.000
2F1	Refrigeration and Air Conditioning		HFCs	0.0	0.000	1.000
2F2	Foam Blowing Agents		HFCs	0.0	0.000	1.000
2F3	Fire Protection		HFCs	0.0	0.000	1.000
2F4	Aerosols		HFCs	0.0	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3A1j	Enteric fermentation - other game		CH ₄	0.0	0.000	1.000
3A2f	Manure management - horses		CH ₄	0.0	0.000	1.000
3A2g	Manure management - mules and asses		CH ₄	0.0	0.000	1.000
3A2j	Manure management - other game		CH ₄	0.0	0.000	1.000
3C1f	Biomass burning in other lands		CH ₄	0.0	0.000	1.000
3C1f	Biomass burning in other lands		N ₂ O	0.0	0.000	1.000

C=Confidential data

Table A.3: Level assessment on emissions excluding FOLU for South Africa (2020) with the key categories highlighted in green.

IPCC Category code	IPCC Category	Fuel type	GHG	2020 Ex,t (Gg CO ₂ Eq)	Lx,t	Cumulative Total
1A1a	Electricity and Heat Production	Solid	CO ₂	201332.7	0.421	0.421
1A3b	Road Transport	Liquid	CO ₂	43 949.2	0.092	0.512
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CO ₂	28 454.1	0.059	0.572
1B3	Other Emissions from Energy Production		CO ₂	25 644.5	0.054	0.625
3A1a	Enteric fermentation - cattle		CH ₄	21 554.6	0.045	0.671
1A2	Manufacturing Industries and Construction	Solid	CO ₂	21 220.0	0.044	0.715
4A	Solid Waste Disposal		CH ₄	18 252.8	0.038	0.753
1A5a	Stationary	Solid	CO ₂	17 633.3	0.037	0.790
3C4	Direct N ₂ O emissions from managed soils		N ₂ O	12 825.3	0.027	0.817
1A2	Manufacturing Industries and Construction	Gas	CO ₂	6 677.1	0.014	0.831
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CO ₂	5 822.5	0.012	0.843
2C2	Ferroalloys Production		CO ₂	5 457.3	0.011	0.854
1A2	Manufacturing Industries and Construction	Liquid	CO ₂	5 169.1	0.011	0.865
2F1	Refrigeration and Air Conditioning		HFCs	4 846.9	0.010	0.875
3A1c	Enteric fermentation - sheep		CH ₄	4 653.5	0.010	0.885
2C1	Iron and Steel Production		CO ₂	3 853.1	0.008	0.893



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2A1	Cement Production		CO ₂	3 357.2	0.007	0.900
1A1a	Electricity and Heat Production	Liquid	CO ₂	3 234.0	0.007	0.907
1B1a	Coal mining and handling		CH ₄	2 892.8	0.006	0.913
4D1	Wastewater Treatment and Discharge		CH ₄	2 783.0	0.006	0.918
2B	Chemical industry		C	C	0.006	0.924
1B3	Other Emissions from Energy Production		CH ₄	2 218.2	0.005	0.929
1A3d	Water-Borne Navigation	Liquid	CO ₂	1 970.6	0.004	0.933
1A4a	Commercial/Institutional	Liquid	CO ₂	1 865.6	0.004	0.937
1A1b	Petroleum Refining	Gas	CO ₂	1 745.0	0.004	0.941
3A2a	Manure management - cattle		N ₂ O	1 360.3	0.003	0.943
1A4b	Residential	Liquid	CO ₂	1 334.1	0.003	0.946
3C5	Indirect N ₂ O emissions from managed soils		N ₂ O	1 200.3	0.003	0.949
3A1d	Enteric fermentation - goats		CH ₄	1 190.0	0.002	0.951
2C3	Aluminium Production		CO ₂	1 134.8	0.002	0.953
1A1a	Electricity and Heat Production	Solid	N ₂ O	998.8	0.002	0.956
1A4b	Residential	Solid	CO ₂	990.0	0.002	0.958
3A2i	Manure management - poultry		N ₂ O	977.1	0.002	0.960
1A4a	Commercial/Institutional	Gas	CO ₂	947.4	0.002	0.962
3C2	Liming		CO ₂	942.3	0.002	0.964
1A4a	Commercial/Institutional	Solid	CO ₂	928.5	0.002	0.966
4D2	Industrial Wastewater Treatment and Discharge		CH ₄	897.3	0.002	0.967
3A2a	Manure management - cattle		CH ₄	859.0	0.002	0.969
2D1	Lubricant Use		CO ₂	855.0	0.002	0.971
2B	Chemical industry		C	C	0.002	0.973
4D1	Wastewater Treatment and Discharge		N ₂ O	777.9	0.002	0.974
2B	Chemical industry		C	C	0.002	0.976
2A2	Lime Production		CO ₂	714.9	0.001	0.977
1A3a	Civil Aviation	Liquid	CO ₂	693.4	0.001	0.979
1A3b	Road Transport	Liquid	N ₂ O	677.9	0.001	0.980
1A1b	Petroleum Refining	Liquid	CO ₂	665.6	0.001	0.982



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1B2a	Oil		CO ₂	641.8	0.001	0.983
3C3	Urea application		CO ₂	584.7	0.001	0.984
1A3c	Railways	Liquid	CO ₂	501.8	0.001	0.985
2C2	Ferroalloys Production		CH ₄	496.2	0.001	0.986
3C1c	Biomass burning in grasslands		N ₂ O	471.6	0.001	0.987
1A5a	Stationary	Liquid	CO ₂	423.3	0.001	0.988
2B	Chemical industry		C	C	0.001	0.989
2D2	Paraffin Wax Use		CO ₂	393.2	0.001	0.990
3C6	Indirect N ₂ O emissions from manure management		N ₂ O	387.5	0.001	0.991
3C1c	Biomass burning in grasslands		CH ₄	349.9	0.001	0.991
3C1a	Biomass burning in forest land		CH ₄	288.6	0.001	0.992
3C1a	Biomass burning in forest land		N ₂ O	265.6	0.001	0.993
1A4b	Residential	Solid	N ₂ O	260.3	0.001	0.993
4C2	Open Burning of Waste		CH ₄	223.4	0.000	0.994
1A3b	Road Transport	Liquid	CH ₄	221.3	0.000	0.994
3A2c	Manure management - sheep		N ₂ O	182.5	0.000	0.994
3C1b	Biomass burning in croplands		CH ₄	167.0	0.000	0.995
3A2h	Manure management - swine		CH ₄	158.2	0.000	0.995
2A3	Glass Production		CO ₂	154.5	0.000	0.995
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	N ₂ O	143.8	0.000	0.996
3A2i	Manure management - poultry		CH ₄	128.2	0.000	0.996
1A4b	Residential	Solid	CH ₄	127.6	0.000	0.996
3A1f	Enteric fermentation - horses		CH ₄	124.7	0.000	0.997
2C3	Aluminium Production		PFCs	120.4	0.000	0.997
1A3b	Road Transport	Gas	CO ₂	108.6	0.000	0.997
1A2	Manufacturing Industries and Construction	Solid	N ₂ O	102.4	0.000	0.997
2A4	OPUC		CO ₂	94.5	0.000	0.997
2B	Chemical industry		C	C	0.000	0.998
1A5a	Stationary	Solid	N ₂ O	85.2	0.000	0.998
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CO ₂	83.0	0.000	0.998



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2B	Chemical industry		C	C	0.000	0.998
4C2	Open Burning of Waste		N ₂ O	76.1	0.000	0.998
2F3	Fire Protection		HFCs	65.9	0.000	0.998
3C1b	Biomass burning in croplands		N ₂ O	63.9	0.000	0.999
2B	Chemical industry		C	C	0.000	0.999
3A2d	Manure management - goats		N ₂ O	57.9	0.000	0.999
1A3c	Railways	Liquid	N ₂ O	51.3	0.000	0.999
1A1a	Electricity and Heat Production	Solid	CH ₄	45.1	0.000	0.999
1B1a	Coal mining and handling		CO ₂	37.9	0.000	0.999
2C6	Zinc Production		CO ₂	36.6	0.000	0.999
4C2	Open Burning of Waste		CO ₂	35.4	0.000	0.999
3A1g	Enteric fermentation - mules and asses		CH ₄	33.9	0.000	0.999
3A1h	Enteric fermentation - swine		CH ₄	32.8	0.000	0.999
2B	Chemical industry		C	C	0.000	0.999
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CH ₄	29.1	0.000	0.999
3A2h	Manure management - swine		N ₂ O	28.6	0.000	1.000
3A2c	Manure management - sheep		CH ₄	21.1	0.000	1.000
2F4	Aerosols		HFCs	18.2	0.000	1.000
3C1d	Biomass burning in wetlands		N ₂ O	16.6	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	N ₂ O	14.7	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	N ₂ O	12.4	0.000	1.000
3C1d	Biomass burning in wetlands		CH ₄	12.3	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	N ₂ O	11.8	0.000	1.000
3A2d	Manure management - goats		CH ₄	9.4	0.000	1.000
1A4a	Commercial/Institutional	Solid	N ₂ O	9.0	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	N ₂ O	8.1	0.000	1.000
3C1e	Biomass burning in settlements		N ₂ O	7.8	0.000	1.000
2C5	Lead Production		CO ₂	6.6	0.000	1.000
3C1e	Biomass burning in settlements		CH ₄	5.8	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CH ₄	5.0	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2B	Chemical industry		C	C	0.000	1.000
1A4a	Commercial/Institutional	Liquid	N ₂ O	4.7	0.000	1.000
1A2	Manufacturing Industries and Construction	Solid	CH ₄	4.6	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	CH ₄	4.2	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	N ₂ O	3.9	0.000	1.000
1A5a	Stationary	Solid	CH ₄	3.8	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	CH ₄	3.7	0.000	1.000
2C1	Iron and Steel Production		CH ₄	3.2	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	CH ₄	2.7	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	CH ₄	2.7	0.000	1.000
2F2	Foam Blowing Agents		HFCs	2.1	0.000	1.000
1A4b	Residential	Liquid	N ₂ O	2.1	0.000	1.000
1A3a	Civil Aviation	Liquid	N ₂ O	1.8	0.000	1.000
1A4a	Commercial/Institutional	Liquid	CH ₄	1.6	0.000	1.000
1A1b	Petroleum Refining	Liquid	N ₂ O	1.3	0.000	1.000
1A5a	Stationary	Liquid	N ₂ O	1.1	0.000	1.000
1A1b	Petroleum Refining	Gas	N ₂ O	0.9	0.000	1.000
1A4b	Residential	Liquid	CH ₄	0.8	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	N ₂ O	0.8	0.000	1.000
1A1b	Petroleum Refining	Gas	CH ₄	0.6	0.000	1.000
1A3a	Civil Aviation	Liquid	CH ₄	0.6	0.000	1.000
1A3c	Railways	Liquid	CH ₄	0.5	0.000	1.000
1A4a	Commercial/Institutional	Gas	N ₂ O	0.5	0.000	1.000
1A1b	Petroleum Refining	Liquid	CH ₄	0.4	0.000	1.000
1A5a	Stationary	Liquid	CH ₄	0.4	0.000	1.000
1A4a	Commercial/Institutional	Gas	CH ₄	0.3	0.000	1.000
1A4a	Commercial/Institutional	Solid	CH ₄	0.2	0.000	1.000
1A3b	Road Transport	Gas	N ₂ O	0.1	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
1A3b	Road Transport	Gas	CH ₄	0.0	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CH ₄	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CO ₂	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CO ₂	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CH ₄	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CH ₄	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	N ₂ O	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	N ₂ O	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CO ₂	0.0	0.000	1.000
1A3c	Railways	Gas	CO ₂	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CO ₂	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CH ₄	0.0	0.000	1.000
1A3c	Railways	Gas	CH ₄	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CH ₄	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	N ₂ O	0.0	0.000	1.000
1A3c	Railways	Gas	N ₂ O	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	N ₂ O	0.0	0.000	1.000

C=Confidential data

Table A.4: Level assessment on emissions including FOLU for South Africa (2020) with the key categories highlighted in green.



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

IPCC Category code	IPCC Category	Fuel type	GHG	2020 Ex,t (Gg CO ₂ Eq)	Lx,t	Cumulative Total
1A1a	Electricity and Heat Production	Solid	CO ₂	201 332.7	0.369	0.369
1A3b	Road Transport	Liquid	CO ₂	43 949.2	0.081	0.450
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CO ₂	28 454.1	0.052	0.502
1B3	Other Emissions from Energy Production		CO ₂	25 644.5	0.047	0.549
3A1a	Enteric fermentation - cattle		CH ₄	21 554.6	0.040	0.589
1A2	Manufacturing Industries and Construction	Solid	CO ₂	21 220.0	0.039	0.628
4A	Solid Waste Disposal		CH ₄	18 252.8	0.033	0.661
1A5a	Stationary	Solid	CO ₂	17 633.3	0.032	0.694
3B1a	Forest land remaining forest land - Net CO ₂		CO ₂	-15 330.1	0.028	0.722
3C4	Direct N ₂ O emissions from managed soils		N ₂ O	12 825.3	0.024	0.745
3B3a	Grassland remaining grassland - Net CO ₂		CO ₂	-11 309.4	0.021	0.766
3B1b	Land converted to forest land - Net CO ₂		CO ₂	-10 896.0	0.020	0.786
1A2	Manufacturing Industries and Construction	Gas	CO ₂	6 677.1	0.012	0.798
3B6b	Land converted to other lands - Net CO ₂		CO ₂	6 273.4	0.012	0.810
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CO ₂	5 822.5	0.011	0.820
2C2	Ferroalloys Production		CO ₂	5 457.3	0.010	0.830
1A2	Manufacturing Industries and Construction	Liquid	CO ₂	5 169.1	0.009	0.840
3B3b	Land converted to grassland - Net CO ₂		CO ₂	-5 167.3	0.009	0.849
2F1	Refrigeration and Air Conditioning		HFCs	4 846.9	0.009	0.858
3A1c	Enteric fermentation - sheep		CH ₄	4 653.5	0.009	0.867
2C1	Iron and Steel Production		CO ₂	3 853.1	0.007	0.874
3B4a	Wetland remaining wetland		CO ₂	3 828.7	0.007	0.881
3B2a	Cropland remaining cropland - Net CO ₂		CO ₂	-3 817.1	0.007	0.888
2A1	Cement Production		CO ₂	3 357.2	0.006	0.894
1A1a	Electricity and Heat Production	Liquid	CO ₂	3 234.0	0.006	0.900
1B1a	Coal mining and handling		CH ₄	2 892.8	0.005	0.905
4D1	Wastewater Treatment and Discharge		CH ₄	2 783.0	0.005	0.910



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2B	Chemical industry		C	C	0.005	0.915
3B6a	Other land remaining other land		CO ₂	2 385.6	0.004	0.920
1B3	Other Emissions from Energy Production		CH ₄	2 218.2	0.004	0.924
3B5a	Settlements remaining settlements - Net CO ₂		CO ₂	-2 088.4	0.004	0.928
1A3d	Water-Borne Navigation	Liquid	CO ₂	1 970.6	0.004	0.931
1A4a	Commercial/Institutional	Liquid	CO ₂	1 865.6	0.003	0.935
1A1b	Petroleum Refining	Gas	CO ₂	1 745.0	0.003	0.938
3A2a	Manure management - cattle		N ₂ O	1 360.3	0.002	0.940
1A4b	Residential	Liquid	CO ₂	1 334.1	0.002	0.943
3C5	Indirect N ₂ O emissions from managed soils		N ₂ O	1 200.3	0.002	0.945
3B4	Wetlands		CH ₄	1 192.5	0.002	0.947
3A1d	Enteric fermentation - goats		CH ₄	1 190.0	0.002	0.949
3B4b	Land converted to wetland		CO ₂	-1 155.2	0.002	0.952
2C3	Aluminium Production		CO ₂	1 134.8	0.002	0.954
3B2b	Land converted to cropland - Net CO ₂		CO ₂	1 002.4	0.002	0.955
1A1a	Electricity and Heat Production	Solid	N ₂ O	998.8	0.002	0.957
1A4b	Residential	Solid	CO ₂	990.0	0.002	0.959
3A2i	Manure management - poultry		N ₂ O	977.1	0.002	0.961
1A4a	Commercial/Institutional	Gas	CO ₂	947.4	0.002	0.963
3C2	Liming		CO ₂	942.3	0.002	0.964
3B5b	Land converted to settlements - Net CO ₂		CO ₂	940.5	0.002	0.966
1A4a	Commercial/Institutional	Solid	CO ₂	928.5	0.002	0.968
4D2	Industrial Wastewater Treatment and Discharge		CH ₄	897.3	0.002	0.969
3A2a	Manure management - cattle		CH ₄	859.0	0.002	0.971
2D1	Lubricant Use		CO ₂	855.0	0.002	0.973
2B	Chemical industry		C	C	0.002	0.974
4D1	Wastewater Treatment and Discharge		N ₂ O	777.9	0.001	0.976
2B	Chemical industry		C	C	0.001	0.977
2A2	Lime Production		CO ₂	714.9	0.001	0.978
1A3a	Civil Aviation	Liquid	CO ₂	693.4	0.001	0.980



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3b	Road Transport	Liquid	N ₂ O	677.9	0.001	0.981
1A1b	Petroleum Refining	Liquid	CO ₂	665.6	0.001	0.982
1B2a	Oil		CO ₂	641.8	0.001	0.983
3D1	Harvested wood products		CO ₂	635.2	0.001	0.984
3C3	Urea application		CO ₂	584.7	0.001	0.985
1A3c	Railways	Liquid	CO ₂	501.8	0.001	0.986
2C2	Ferroalloys Production		CH ₄	496.2	0.001	0.987
3C1c	Biomass burning in grasslands		N ₂ O	471.6	0.001	0.988
3B4	Wetland		N ₂ O	436.6	0.001	0.989
1A5a	Stationary	Liquid	CO ₂	423.3	0.001	0.990
2B	Chemical industry		C	C	0.001	0.990
2D2	Paraffin Wax Use		CO ₂	393.2	0.001	0.991
3C6	Indirect N ₂ O emissions from manure management		N ₂ O	387.5	0.001	0.992
3C1c	Biomass burning in grasslands		CH ₄	349.9	0.001	0.992
3C1a	Biomass burning in forest land		CH ₄	288.6	0.001	0.993
3C1a	Biomass burning in forest land		N ₂ O	265.6	0.000	0.993
1A4b	Residential	Solid	N ₂ O	260.3	0.000	0.994
4C2	Open Burning of Waste		CH ₄	223.4	0.000	0.994
1A3b	Road Transport	Liquid	CH ₄	221.3	0.000	0.995
3A2c	Manure management - sheep		N ₂ O	182.5	0.000	0.995
3C1b	Biomass burning in croplands		CH ₄	167.0	0.000	0.995
3A2h	Manure management - swine		CH ₄	158.2	0.000	0.996
2A3	Glass Production		CO ₂	154.5	0.000	0.996
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	N ₂ O	143.8	0.000	0.996
3A2i	Manure management - poultry		CH ₄	128.2	0.000	0.996
1A4b	Residential	Solid	CH ₄	127.6	0.000	0.997
3A1f	Enteric fermentation - horses		CH ₄	124.7	0.000	0.997
2C3	Aluminium Production		PFCs	120.4	0.000	0.997
1A3b	Road Transport	Gas	CO ₂	108.6	0.000	0.997
1A2	Manufacturing Industries and Construction	Solid	N ₂ O	102.4	0.000	0.998



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2A4	OPUC		CO ₂	94.5	0.000	0.998
2B	Chemical industry		C	C	0.000	0.998
1A5a	Stationary	Solid	N ₂ O	85.2	0.000	0.998
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CO ₂	83.0	0.000	0.998
2B	Chemical industry		C	C	0.000	0.998
4C2	Open Burning of Waste		N ₂ O	76.1	0.000	0.998
2F3	Fire Protection		HFCs	65.9	0.000	0.999
3C1b	Biomass burning in croplands		N ₂ O	63.9	0.000	0.999
2B	Chemical industry		C	C	0.000	0.999
3A2d	Manure management - goats		N ₂ O	57.9	0.000	0.999
1A3c	Railways	Liquid	N ₂ O	51.3	0.000	0.999
1A1a	Electricity and Heat Production	Solid	CH ₄	45.1	0.000	0.999
1B1a	Coal mining and handling		CO ₂	37.9	0.000	0.999
2C6	Zinc Production		CO ₂	36.6	0.000	0.999
4C2	Open Burning of Waste		CO ₂	35.4	0.000	0.999
3A1g	Enteric fermentation - mules and asses		CH ₄	33.9	0.000	0.999
3A1h	Enteric fermentation - swine		CH ₄	32.8	0.000	0.999
2B	Chemical industry		C	C	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CH ₄	29.1	0.000	1.000
3A2h	Manure management - swine		N ₂ O	28.6	0.000	1.000
3A2c	Manure management - sheep		CH ₄	21.1	0.000	1.000
2F4	Aerosols		HFCs	18.2	0.000	1.000
3C1d	Biomass burning in wetlands		N ₂ O	16.6	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	N ₂ O	14.7	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	N ₂ O	12.4	0.000	1.000
3C1d	Biomass burning in wetlands		CH ₄	12.3	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	N ₂ O	11.8	0.000	1.000
3A2d	Manure management - goats		CH ₄	9.4	0.000	1.000
1A4a	Commercial/Institutional	Solid	N ₂ O	9.0	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	N ₂ O	8.1	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3C1e	Biomass burning in settlements		N ₂ O	7.8	0.000	1.000
2C5	Lead Production		CO ₂	6.6	0.000	1.000
3C1e	Biomass burning in settlements		CH ₄	5.8	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CH ₄	5.0	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
1A4a	Commercial/Institutional	Liquid	N ₂ O	4.7	0.000	1.000
1A2	Manufacturing Industries and Construction	Solid	CH ₄	4.6	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	CH ₄	4.2	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	N ₂ O	3.9	0.000	1.000
1A5a	Stationary	Solid	CH ₄	3.8	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	CH ₄	3.7	0.000	1.000
2C1	Iron and Steel Production		CH ₄	3.2	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	CH ₄	2.7	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	CH ₄	2.7	0.000	1.000
2F2	Foam Blowing Agents		HFCs	2.1	0.000	1.000
1A4b	Residential	Liquid	N ₂ O	2.1	0.000	1.000
1A3a	Civil Aviation	Liquid	N ₂ O	1.8	0.000	1.000
1A4a	Commercial/Institutional	Liquid	CH ₄	1.6	0.000	1.000
1A1b	Petroleum Refining	Liquid	N ₂ O	1.3	0.000	1.000
1A5a	Stationary	Liquid	N ₂ O	1.1	0.000	1.000
1A1b	Petroleum Refining	Gas	N ₂ O	0.9	0.000	1.000
1A4b	Residential	Liquid	CH ₄	0.8	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	N ₂ O	0.8	0.000	1.000
1A1b	Petroleum Refining	Gas	CH ₄	0.6	0.000	1.000
1A3a	Civil Aviation	Liquid	CH ₄	0.6	0.000	1.000
1A3c	Railways	Liquid	CH ₄	0.5	0.000	1.000
1A4a	Commercial/Institutional	Gas	N ₂ O	0.5	0.000	1.000
1A1b	Petroleum Refining	Liquid	CH ₄	0.4	0.000	1.000
1A5a	Stationary	Liquid	CH ₄	0.4	0.000	1.000
1A4a	Commercial/Institutional	Gas	CH ₄	0.3	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A4a	Commercial/Institutional	Solid	CH ₄	0.2	0.000	1.000
1A3b	Road Transport	Gas	N ₂ O	0.1	0.000	1.000
2B	Chemical industry		C	C	0.000	1.000
1A3b	Road Transport	Gas	CH ₄	0.0	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CH ₄	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CO ₂	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CO ₂	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CO ₂	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CH ₄	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CH ₄	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CH ₄	0.0	0.000	1.000
1A1a	Electricity and Heat Production	Gas	N ₂ O	0.0	0.000	1.000
1A1b	Petroleum Refining	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	N ₂ O	0.0	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	N ₂ O	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CO ₂	0.0	0.000	1.000
1A3c	Railways	Gas	CO ₂	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CO ₂	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	CH ₄	0.0	0.000	1.000
1A3c	Railways	Gas	CH ₄	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CH ₄	0.0	0.000	1.000
1A3a	Civil Aviation	Gas	N ₂ O	0.0	0.000	1.000
1A3c	Railways	Gas	N ₂ O	0.0	0.000	1.000
1A3d	Water-Borne Navigation	Gas	N ₂ O	0.0	0.000	1.000
3A1j	Enteric fermentation - other game		CH ₄	0.0	0.000	1.000
3A2f	Manure management - horses		CH ₄	0.0	0.000	1.000
3A2g	Manure management - mules and asses		CH ₄	0.0	0.000	1.000
3A2j	Manure management - other game		CH ₄	0.0	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3C1f	Biomass burning in other lands		CH ₄	0.0	0.000	1.000
3C1f	Biomass burning in other lands		N ₂ O	0.0	0.000	1.000
4B	Biological treatment of waste		CH ₄	0.0	0.000	1.000
4B	Biological treatment of waste		N ₂ O	0.0	0.000	1.000

C=Confidential data



Table A.5: Trend assessment on emissions excluding FOLU for South Africa (2000 - 2020) with the key categories highlighted in green.

IPCC Category code	IPCC Category	Fuel type	GHG	2000 Ex,t	2020 Ex,t	Tx,t	% contribution to trend	Cumulative Total
				(Gg CO ₂ Eq)				
1A4a	Commercial/Institutional	Solid	CO ₂	18 248.1	928.5	0.038	0.155	0.155
1A1a	Electricity and Heat Production	Solid	CO ₂	185 027.4	201 332.7	0.030	0.125	0.280
2C1	Iron and Steel Production		CO ₂	15 334.4	3 853.1	0.025	0.103	0.384
1A3b	Road Transport	Liquid	CO ₂	36 302.9	43 949.2	0.016	0.064	0.447
2F1	Refrigeration and Air Conditioning		HFCs	0.0	4 846.9	0.010	0.043	0.490
4A	Solid Waste Disposal		CH ₄	13 610.5	18 252.8	0.010	0.040	0.530
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CO ₂	2 251.0	5 822.5	0.008	0.031	0.561
1A1a	Electricity and Heat Production	Liquid	CO ₂	121.3	3 234.0	0.007	0.028	0.589
1A5a	Stationary	Solid	CO ₂	14 372.8	17 633.3	0.007	0.027	0.616
1B3	Other Emissions from Energy Production		CO ₂	28 146.6	25 644.5	0.006	0.025	0.642
2B	Chemical industry		C	C	C	0.006	0.024	0.666
2C2	Ferroalloys Production		CO ₂	8 079.1	5 457.3	0.006	0.024	0.690
1A4b	Residential	Solid	CO ₂	3 604.2	990.0	0.006	0.024	0.713
3A1a	Enteric fermentation - cattle		CH ₄	23 901.0	21 554.6	0.006	0.023	0.737
1A5a	Stationary	Liquid	CO ₂	2 888.6	423.3	0.005	0.022	0.759
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CO ₂	30 454.7	28 454.1	0.005	0.021	0.780
1A2	Manufacturing Industries and Construction	Liquid	CO ₂	2 809.0	5 169.1	0.005	0.021	0.800
1A3d	Water-Borne Navigation	Liquid	CO ₂	222.2	1 970.6	0.004	0.015	0.816
1A3a	Civil Aviation	Liquid	CO ₂	2 249.1	693.4	0.003	0.014	0.830
1A4b	Residential	Liquid	CO ₂	2 868.4	1 334.1	0.003	0.014	0.844
1A2	Manufacturing Industries and Construction	Solid	CO ₂	19 545.0	21 220.0	0.003	0.013	0.857
3A1c	Enteric fermentation - sheep		CH ₄	5 837.3	4 653.5	0.003	0.011	0.868



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3C4	Direct N2O emissions from managed soils		N ₂ O	4 093.0	5 276.0	0.002	0.010	0.878
1A1b	Petroleum Refining	Liquid	CO ₂	1 735.5	665.6	0.002	0.010	0.887
4D2	Industrial Wastewater Treatment and Discharge		CH ₄	1 958.1	897.3	0.002	0.010	0.897
2C3	Aluminium Production		PFCs	983.2	120.4	0.002	0.008	0.905
2B	Chemical industry		C	C	C	0.002	0.007	0.912
4D1	Wastewater Treatment and Discharge		CH ₄	1 951.2	2 783.0	0.002	0.007	0.919
2D1	Lubricant Use		CO ₂	188.5	855.0	0.001	0.006	0.925
1A1b	Petroleum Refining	Gas	CO ₂	2 307.1	1 745.0	0.001	0.005	0.930
2A1	Cement Production		CO ₂	3 870.6	3 357.2	0.001	0.005	0.935
3C2	Liming		CO ₂	384.1	942.3	0.001	0.005	0.940
1B1a	Coal mining and handling		CH ₄	2 338.1	2 892.8	0.001	0.005	0.945
2C2	Ferroalloys Production		CH ₄	3.3	496.2	0.001	0.004	0.949
2D2	Paraffin Wax Use		CO ₂	7.4	393.2	0.001	0.003	0.953
1A2	Manufacturing Industries and Construction	Gas	CO ₂	6 276.0	6 677.1	0.001	0.003	0.956
3A1d	Enteric fermentation - goats		CH ₄	1 493.1	1 190.0	0.001	0.003	0.958
3A2i	Manure management - poultry		N ₂ O	651.9	977.1	0.001	0.003	0.961
1A4a	Commercial/Institutional	Gas	CO ₂	631.0	947.4	0.001	0.003	0.964
2B	Chemical industry		C	C	C	0.001	0.003	0.967
3C3	Urea application		CO ₂	297.3	584.7	0.001	0.003	0.969
2A2	Lime Production		CO ₂	426.1	714.9	0.001	0.003	0.972
4D1	Wastewater Treatment and Discharge		N ₂ O	545.4	777.9	0.000	0.002	0.974
1A4a	Commercial/Institutional	Liquid	CO ₂	2 028.6	1 865.6	0.000	0.002	0.975
1A4b	Residential	Solid	N ₂ O	439.1	260.3	0.000	0.002	0.977
1A4a	Commercial/Institutional	Solid	N ₂ O	176.3	9.0	0.000	0.002	0.978
1B3	Other Emissions from Energy Production		CH ₄	2 318.6	2 218.2	0.000	0.001	0.980
1A3b	Road Transport	Liquid	N ₂ O	545.1	677.9	0.000	0.001	0.981
1B2a	Oil		CO ₂	752.0	641.8	0.000	0.001	0.982
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CO ₂	199.5	83.0	0.000	0.001	0.983
1A3b	Road Transport	Gas	CO ₂	3.4	108.6	0.000	0.001	0.984
4C2	Open Burning of Waste		CH ₄	117.5	223.4	0.000	0.001	0.985



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3A2a	Manure management - cattle		N ₂ O	1 249.4	1 360.3	0.000	0.001	0.986
2A4	OPUC		CO ₂	0.0	94.5	0.000	0.001	0.986
1A1a	Electricity and Heat Production	Solid	N ₂ O	893.9	998.8	0.000	0.001	0.987
2B	Chemical industry		C	C	C	0.000	0.001	0.988
3C1c	Biomass burning in grasslands		N ₂ O	557.4	471.6	0.000	0.001	0.989
1A4b	Residential	Solid	CH ₄	206.2	127.6	0.000	0.001	0.990
2A3	Glass Production		CO ₂	74.4	154.5	0.000	0.001	0.990
2C6	Zinc Production		CO ₂	108.4	36.6	0.000	0.001	0.991
3C1b	Biomass burning in croplands		CH ₄	235.6	167.0	0.000	0.001	0.992
3C1c	Biomass burning in grasslands		CH ₄	413.5	349.9	0.000	0.001	0.992
2F3	Fire Protection		HFCs	0.0	65.9	0.000	0.001	0.993
2B	Chemical industry		C	C	C	0.000	0.001	0.993
1A3c	Railways	Liquid	CO ₂	551.5	501.8	0.000	0.000	0.994
2B	Chemical industry		C	C	C	0.000	0.000	0.994
3A2i	Manure management - poultry		CH ₄	84.2	128.2	0.000	0.000	0.995
3C1a	Biomass burning in forest land		N ₂ O	298.7	265.6	0.000	0.000	0.995
3A2h	Manure management - swine		CH ₄	192.0	158.2	0.000	0.000	0.995
4C2	Open Burning of Waste		N ₂ O	40.0	76.1	0.000	0.000	0.996
3A2a	Manure management - cattle		CH ₄	881.6	859.0	0.000	0.000	0.996
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	N ₂ O	110.3	143.8	0.000	0.000	0.996
2C3	Aluminium Production		CO ₂	1 091.3	1 134.8	0.000	0.000	0.996
1A3b	Road Transport	Liquid	CH ₄	247.9	221.3	0.000	0.000	0.997
2B	Chemical industry		C	C	C	0.000	0.000	0.997
3C1b	Biomass burning in croplands		N ₂ O	90.2	63.9	0.000	0.000	0.997
3C6	Indirect N ₂ O emissions from manure management		N ₂ O	201.4	227.5	0.000	0.000	0.997
3C5	Indirect N ₂ O emissions from managed soils		N ₂ O	737.5	723.3	0.000	0.000	0.998
3A1f	Enteric fermentation - horses		CH ₄	102.1	124.7	0.000	0.000	0.998
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CH ₄	10.6	29.1	0.000	0.000	0.998



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2F4	Aerosols		HFCs	0.0	18.2	0.000	0.000	0.998
4C2	Open Burning of Waste		CO ₂	18.6	35.4	0.000	0.000	0.998
1A3c	Railways	Liquid	N ₂ O	66.0	51.3	0.000	0.000	0.998
1A5a	Stationary	Solid	N ₂ O	69.4	85.2	0.000	0.000	0.998
3A2d	Manure management - goats		N ₂ O	69.2	57.9	0.000	0.000	0.999
2B	Chemical industry		C	C	C	0.000	0.000	0.999
1A3d	Water-Borne Navigation	Liquid	N ₂ O	1.3	11.8	0.000	0.000	0.999
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	N ₂ O	5.6	14.7	0.000	0.000	0.999
2C5	Lead Production		CO ₂	15.1	6.6	0.000	0.000	0.999
3C1a	Biomass burning in forest land		CH ₄	293.6	288.6	0.000	0.000	0.999
1A1a	Electricity and Heat Production	Liquid	N ₂ O	0.3	8.1	0.000	0.000	0.999
3A1h	Enteric fermentation - swine		CH ₄	39.8	32.8	0.000	0.000	0.999
1A2	Manufacturing Industries and Construction	Solid	N ₂ O	94.3	102.4	0.000	0.000	0.999
1B1a	Coal mining and handling		CO ₂	30.6	37.9	0.000	0.000	0.999
3A2h	Manure management - swine		N ₂ O	34.7	28.6	0.000	0.000	0.999
1A5a	Stationary	Liquid	N ₂ O	7.4	1.1	0.000	0.000	0.999
1A2	Manufacturing Industries and Construction	Liquid	N ₂ O	6.4	12.4	0.000	0.000	0.999
3A2c	Manure management - sheep		N ₂ O	185.3	182.5	0.000	0.000	0.999
2B	Chemical industry		C	C	C	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Solid	CH ₄	40.4	45.1	0.000	0.000	1.000
1A3a	Civil Aviation	Liquid	N ₂ O	5.9	1.8	0.000	0.000	1.000
1A4a	Commercial/Institutional	Solid	CH ₄	4.0	0.2	0.000	0.000	1.000
1A4b	Residential	Liquid	N ₂ O	5.4	2.1	0.000	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	CH ₄	0.4	3.7	0.000	0.000	1.000
2C1	Iron and Steel Production		CH ₄	0.0	3.2	0.000	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CH ₄	1.9	5.0	0.000	0.000	1.000
3C1e	Biomass burning in settlements		N ₂ O	10.5	7.8	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	CH ₄	0.1	2.7	0.000	0.000	1.000
1A1b	Petroleum Refining	Liquid	N ₂ O	3.6	1.3	0.000	0.000	1.000
1A5a	Stationary	Liquid	CH ₄	2.5	0.4	0.000	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3C1e	Biomass burning in settlements		CH ₄	7.8	5.8	0.000	0.000	1.000
2F2	Foam Blowing Agents		HFCs	0.0	2.1	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	CH ₄	2.2	4.2	0.000	0.000	1.000
3A2d	Manure management - goats		CH ₄	11.3	9.4	0.000	0.000	1.000
1A3a	Civil Aviation	Liquid	CH ₄	2.0	0.6	0.000	0.000	1.000
3A2c	Manure management - sheep		CH ₄	22.1	21.1	0.000	0.000	1.000
1A4b	Residential	Liquid	CH ₄	2.0	0.8	0.000	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	N ₂ O	1.9	0.8	0.000	0.000	1.000
3A1g	Enteric fermentation - mules and asses		CH ₄	34.4	33.9	0.000	0.000	1.000
1A1b	Petroleum Refining	Liquid	CH ₄	1.2	0.4	0.000	0.000	1.000
1A5a	Stationary	Solid	CH ₄	3.1	3.8	0.000	0.000	1.000
1A1b	Petroleum Refining	Gas	N ₂ O	1.2	0.9	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction	Solid	CH ₄	4.3	4.6	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	N ₂ O	4.2	3.9	0.000	0.000	1.000
3C1d	Biomass burning in wetlands		N ₂ O	16.7	16.6	0.000	0.000	1.000
1A4a	Commercial/Institutional	Liquid	N ₂ O	4.9	4.7	0.000	0.000	1.000
3C1d	Biomass burning in wetlands		CH ₄	12.4	12.3	0.000	0.000	1.000
1A1b	Petroleum Refining	Gas	CH ₄	0.8	0.6	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	CH ₄	2.8	2.7	0.000	0.000	1.000
1A4a	Commercial/Institutional	Gas	N ₂ O	0.3	0.5	0.000	0.000	1.000
1A3c	Railways	Liquid	CH ₄	0.6	0.5	0.000	0.000	1.000
1A4a	Commercial/Institutional	Gas	CH ₄	0.2	0.3	0.000	0.000	1.000
1A4a	Commercial/Institutional	Liquid	CH ₄	1.7	1.6	0.000	0.000	1.000
1A3b	Road Transport	Gas	N ₂ O	0.0	0.1	0.000	0.000	1.000
1A3b	Road Transport	Gas	CH ₄	0.1	0.0	0.000	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CH ₄	0.0	0.0	0.000	0.000	1.000
2B	Chemical industry		C	C	C	0.000	0.000	1.000
4B	Biological treatment of waste		CH ₄	0.0	0.0	0.000	0.000	1.000
4B	Biological treatment of waste		N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A1b	Petroleum Refining	Solid	CO ₂	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CO ₂	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1b	Petroleum Refining	Solid	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1b	Petroleum Refining	Solid	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A3a	Civil Aviation	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A3c	Railways	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A3a	Civil Aviation	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A3c	Railways	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A3a	Civil Aviation	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000

C=Confidential data



Table A.6: Trend assessment on emissions including FOLU for South Africa (2000 - 2020) with the key categories highlighted in green.

IPCC Category code	IPCC Category	Fuel type	GHG	2000 Ex,t	2020 Ex,t	Tx,t	% contribution to trend	Cumulative Total
				(Gg CO ₂ Eq)				
1A1a	Electricity and Heat Production	Solid	CO ₂	185 027.4	201 332.7	0.033	0.138	0.138
1A4a	Commercial/Institutional	Solid	CO ₂	18 248.1	928.5	0.032	0.131	0.268
2C1	Iron and Steel Production		CO ₂	15 334.4	3 853.1	0.021	0.087	0.355
3B1a	Forest land remaining forest land - Net CO2		CO ₂	21 530.5	12 672.4	0.016	0.066	0.421
1A3b	Road Transport	Liquid	CO ₂	36 302.9	43 949.2	0.015	0.061	0.482
2F1	Refrigeration and Air Conditioning		HFCs	0.0	4 846.9	0.009	0.037	0.519
4A	Solid Waste Disposal		CH ₄	13 610.5	18 252.8	0.009	0.036	0.556
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CO ₂	2 251.0	5 822.5	0.007	0.027	0.583
1A5a	Stationary	Solid	CO ₂	14 372.8	17 633.3	0.006	0.026	0.609
1A1a	Electricity and Heat Production	Liquid	CO ₂	121.3	3 234.0	0.006	0.024	0.633
3D1	Harvested wood products		CO ₂	-2 106.2	635.2	0.005	0.021	0.654
2B	Chemical industry		C	C	C	0.005	0.021	0.675
1A4b	Residential	Solid	CO ₂	3 604.2	990.0	0.005	0.020	0.694
2C2	Ferroalloys Production		CO ₂	8 079.1	5 457.3	0.005	0.019	0.714
3B1b	Land converted to forest land - Net CO2		CO ₂	-8 901.1	-11 507.6	0.005	0.019	0.733
1A5a	Stationary	Liquid	CO ₂	2 888.6	423.3	0.005	0.019	0.752
1A2	Manufacturing Industries and Construction	Liquid	CO ₂	2 809.0	5 169.1	0.004	0.018	0.770
1B3	Other Emissions from Energy Production		CO ₂	28 146.6	25 644.5	0.004	0.017	0.787
3A1a	Enteric fermentation - cattle		CH ₄	23 901.0	21 554.6	0.004	0.016	0.803
1A2	Manufacturing Industries and Construction	Solid	CO ₂	19 545.0	21 220.0	0.003	0.014	0.817
1A3d	Water-Borne Navigation	Liquid	CO ₂	222.2	1 970.6	0.003	0.013	0.831
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CO ₂	30 454.7	28 454.1	0.003	0.013	0.844
1A3a	Civil Aviation	Liquid	CO ₂	2 249.1	693.4	0.003	0.012	0.856



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A4b	Residential	Liquid	CO ₂	2 868.4	1 334.1	0.003	0.012	0.867
3C4	Direct N ₂ O emissions from managed soils		N ₂ O	4 093.0	5 276.0	0.002	0.009	0.876
3A1c	Enteric fermentation - sheep		CH ₄	5 837.3	4 653.5	0.002	0.009	0.885
1A1b	Petroleum Refining	Liquid	CO ₂	1 735.5	665.6	0.002	0.008	0.893
4D2	Industrial Wastewater Treatment and Discharge		CH ₄	1 958.1	897.3	0.002	0.008	0.901
2C3	Aluminium Production		PFCs	983.2	120.4	0.002	0.007	0.908
4D1	Wastewater Treatment and Discharge		CH ₄	1 951.2	2 783.0	0.002	0.006	0.914
2B	Chemical industry		C	C	C	0.001	0.006	0.920
2D1	Lubricant Use		CO ₂	188.5	855.0	0.001	0.005	0.925
1B1a	Coal mining and handling		CH ₄	2 338.1	2 892.8	0.001	0.004	0.930
3C2	Liming		CO ₂	384.1	942.3	0.001	0.004	0.934
1A1b	Petroleum Refining	Gas	CO ₂	2 307.1	1 745.0	0.001	0.004	0.938
2C2	Ferroalloys Production		CH ₄	3.3	496.2	0.001	0.004	0.942
3B4	Wetland		CH ₄	1 542.9	1 048.8	0.001	0.004	0.946
2A1	Cement Production		CO ₂	3 870.6	3 357.2	0.001	0.004	0.949
1A2	Manufacturing Industries and Construction	Gas	CO ₂	6 276.0	6 677.1	0.001	0.004	0.953
2D2	Paraffin Wax Use		CO ₂	7.4	393.2	0.001	0.003	0.956
3A2i	Manure management - poultry		N ₂ O	651.9	977.1	0.001	0.003	0.958
1A4a	Commercial/Institutional	Gas	CO ₂	631.0	947.4	0.001	0.002	0.961
2B	Chemical industry		C	C	C	0.001	0.002	0.963
2A2	Lime Production		CO ₂	426.1	714.9	0.001	0.002	0.965
3C3	Urea application		CO ₂	297.3	584.7	0.001	0.002	0.967
3A1d	Enteric fermentation - goats		CH ₄	1 493.1	1 190.0	0.001	0.002	0.970
3B5a	Settlements remaining settlements - Net CO ₂		CO ₂	-3 297.4	-3 613.9	0.001	0.002	0.972
3B2b	Land converted to cropland - Net CO ₂		CO ₂	4 443.1	4 683.6	0.001	0.002	0.974
4D1	Wastewater Treatment and Discharge		N ₂ O	545.4	777.9	0.000	0.002	0.976
1A4b	Residential	Solid	N ₂ O	439.1	260.3	0.000	0.001	0.977
3B4	Wetland		N ₂ O	1 345.0	1 164.1	0.000	0.001	0.978
1A4a	Commercial/Institutional	Solid	N ₂ O	176.3	9.0	0.000	0.001	0.980
1A4a	Commercial/Institutional	Liquid	CO ₂	2 028.6	1 865.6	0.000	0.001	0.981



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3b	Road Transport	Liquid	N ₂ O	545.1	677.9	0.000	0.001	0.982
3A2a	Manure management - cattle		N ₂ O	1 249.4	1 360.3	0.000	0.001	0.983
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CO ₂	199.5	83.0	0.000	0.001	0.984
1A1a	Electricity and Heat Production	Solid	N ₂ O	893.9	998.8	0.000	0.001	0.984
4C2	Open Burning of Waste		CH ₄	117.5	223.4	0.000	0.001	0.985
1A3b	Road Transport	Gas	CO ₂	3.4	108.6	0.000	0.001	0.986
1B2a	Oil		CO ₂	752.0	641.8	0.000	0.001	0.987
2A4	OPUC		CO ₂	0.0	94.5	0.000	0.001	0.988
2B	Chemical industry		C	C	C	0.000	0.001	0.988
2A3	Glass Production		CO ₂	74.4	154.5	0.000	0.001	0.989
3C1c	Biomass burning in grasslands		N ₂ O	557.4	471.6	0.000	0.001	0.989
1B3	Other Emissions from Energy Production		CH ₄	2 318.6	2 218.2	0.000	0.001	0.990
1A4b	Residential	Solid	CH ₄	206.2	127.6	0.000	0.001	0.991
2C6	Zinc Production		CO ₂	108.4	36.6	0.000	0.001	0.991
3C1b	Biomass burning in croplands		CH ₄	235.6	167.0	0.000	0.001	0.992
2F3	Fire Protection		HFCs	0.0	65.9	0.000	0.001	0.992
3C1c	Biomass burning in grasslands		CH ₄	413.5	349.9	0.000	0.000	0.993
2B	Chemical industry		C	C	C	0.000	0.000	0.993
3B6b	Land converted to other lands - Net CO ₂		CO ₂	6 048.7	6 048.5	0.000	0.000	0.994
2C3	Aluminium Production		CO ₂	1 091.3	1 134.8	0.000	0.000	0.994
3A2i	Manure management - poultry		CH ₄	84.2	128.2	0.000	0.000	0.994
1A3c	Railways	Liquid	CO ₂	551.5	501.8	0.000	0.000	0.995
2B	Chemical industry		C	C	C	0.000	0.000	0.995
3B2a	Cropland remaining cropland - Net CO ₂		CO ₂	-503.2	-549.5	0.000	0.000	0.995
3B3a	Grassland remaining grassland - Net CO ₂		CO ₂	-6 927.6	-7 030.8	0.000	0.000	0.996
4C2	Open Burning of Waste		N ₂ O	40.0	76.1	0.000	0.000	0.996
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	N ₂ O	110.3	143.8	0.000	0.000	0.996
3A2h	Manure management - swine		CH ₄	192.0	158.2	0.000	0.000	0.996
3B5b	Land converted to settlements - Net CO ₂		CO ₂	146.2	113.4	0.000	0.000	0.997



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3C1a	Biomass burning in forest land		N ₂ O	298.7	265.6	0.000	0.000	0.997
3C6	Indirect N ₂ O emissions from manure management		N ₂ O	201.4	227.5	0.000	0.000	0.997
2B	Chemical industry		C	C	C	0.000	0.000	0.997
3C1b	Biomass burning in croplands		N ₂ O	90.2	63.9	0.000	0.000	0.997
1A3b	Road Transport	Liquid	CH ₄	247.9	221.3	0.000	0.000	0.998
3A1f	Enteric fermentation - horses		CH ₄	102.1	124.7	0.000	0.000	0.998
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Liquid	CH ₄	10.6	29.1	0.000	0.000	0.998
2F4	Aerosols		HFCs	0.0	18.2	0.000	0.000	0.998
4C2	Open Burning of Waste		CO ₂	18.6	35.4	0.000	0.000	0.998
1A5a	Stationary	Solid	N ₂ O	69.4	85.2	0.000	0.000	0.998
3A2a	Manure management - cattle		CH ₄	881.6	859.0	0.000	0.000	0.998
1A3c	Railways	Liquid	N ₂ O	66.0	51.3	0.000	0.000	0.999
2B	Chemical industry		C	C	C	0.000	0.000	0.999
3A2d	Manure management - goats		N ₂ O	69.2	57.9	0.000	0.000	0.999
1A3d	Water-Borne Navigation	Liquid	N ₂ O	1.3	11.8	0.000	0.000	0.999
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	N ₂ O	5.6	14.7	0.000	0.000	0.999
1A2	Manufacturing Industries and Construction	Solid	N ₂ O	94.3	102.4	0.000	0.000	0.999
3B3b	Land converted to grassland - Net CO ₂		CO ₂	-16 107.6	-16 264.6	0.000	0.000	0.999
2C5	Lead Production		CO ₂	15.1	6.6	0.000	0.000	0.999
1A1a	Electricity and Heat Production	Liquid	N ₂ O	0.3	8.1	0.000	0.000	0.999
1B1a	Coal mining and handling		CO ₂	30.6	37.9	0.000	0.000	0.999
3C5	Indirect N ₂ O emissions from managed soils		N ₂ O	737.5	723.3	0.000	0.000	0.999
3A1h	Enteric fermentation - swine		CH ₄	39.8	32.8	0.000	0.000	0.999
1A5a	Stationary	Liquid	N ₂ O	7.4	1.1	0.000	0.000	0.999
1A2	Manufacturing Industries and Construction	Liquid	N ₂ O	6.4	12.4	0.000	0.000	0.999
3B4b	Land converted to wetland		CO ₂	198.7	202.8	0.000	0.000	0.999
3A2h	Manure management - swine		N ₂ O	34.7	28.6	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Solid	CH ₄	40.4	45.1	0.000	0.000	1.000
2B	Chemical industry		C	C	C	0.000	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3a	Civil Aviation	Liquid	N ₂ O	5.9	1.8	0.000	0.000	1.000
1A4a	Commercial/Institutional	Solid	CH ₄	4.0	0.2	0.000	0.000	1.000
1A3d	Water-Borne Navigation	Liquid	CH ₄	0.4	3.7	0.000	0.000	1.000
1A4b	Residential	Liquid	N ₂ O	5.4	2.1	0.000	0.000	1.000
2C1	Iron and Steel Production		CH ₄	0.0	3.2	0.000	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Liquid	CH ₄	1.9	5.0	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Liquid	CH ₄	0.1	2.7	0.000	0.000	1.000
3C1e	Biomass burning in settlements		N ₂ O	10.5	7.8	0.000	0.000	1.000
1A1b	Petroleum Refining	Liquid	N ₂ O	3.6	1.3	0.000	0.000	1.000
3C1a	Biomass burning in forest land		CH ₄	293.6	288.6	0.000	0.000	1.000
1A5a	Stationary	Liquid	CH ₄	2.5	0.4	0.000	0.000	1.000
2F2	Foam Blowing Agents		HFCs	0.0	2.1	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction	Liquid	CH ₄	2.2	4.2	0.000	0.000	1.000
3C1e	Biomass burning in settlements		CH ₄	7.8	5.8	0.000	0.000	1.000
3A2d	Manure management - goats		CH ₄	11.3	9.4	0.000	0.000	1.000
1A3a	Civil Aviation	Liquid	CH ₄	2.0	0.6	0.000	0.000	1.000
1A4b	Residential	Liquid	CH ₄	2.0	0.8	0.000	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	N ₂ O	1.9	0.8	0.000	0.000	1.000
3A2c	Manure management - sheep		N ₂ O	185.3	182.5	0.000	0.000	1.000
3A2c	Manure management - sheep		CH ₄	22.1	21.1	0.000	0.000	1.000
1A1b	Petroleum Refining	Liquid	CH ₄	1.2	0.4	0.000	0.000	1.000
1A5a	Stationary	Solid	CH ₄	3.1	3.8	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction	Solid	CH ₄	4.3	4.6	0.000	0.000	1.000
3B4a	Wetland remaining wetland		CO ₂	-34.2	-34.2	0.000	0.000	1.000
1A1b	Petroleum Refining	Gas	N ₂ O	1.2	0.9	0.000	0.000	1.000
1A2	Manufacturing Industries and Construction	Gas	N ₂ O	4.2	3.9	0.000	0.000	1.000
3A1g	Enteric fermentation - mules and asses		CH ₄	34.4	33.9	0.000	0.000	1.000
1A1b	Petroleum Refining	Gas	CH ₄	0.8	0.6	0.000	0.000	1.000
1A4a	Commercial/Institutional	Gas	N ₂ O	0.3	0.5	0.000	0.000	1.000
1A4a	Commercial/Institutional	Liquid	N ₂ O	4.9	4.7	0.000	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A2	Manufacturing Industries and Construction	Gas	CH ₄	2.8	2.7	0.000	0.000	1.000
1A3c	Railways	Liquid	CH ₄	0.6	0.5	0.000	0.000	1.000
1A4a	Commercial/Institutional	Gas	CH ₄	0.2	0.3	0.000	0.000	1.000
1A3b	Road Transport	Gas	N ₂ O	0.0	0.1	0.000	0.000	1.000
1A4a	Commercial/Institutional	Liquid	CH ₄	1.7	1.6	0.000	0.000	1.000
3C1d	Biomass burning in wetlands		N ₂ O	16.7	16.6	0.000	0.000	1.000
3C1d	Biomass burning in wetlands		CH ₄	12.4	12.3	0.000	0.000	1.000
1A3b	Road Transport	Gas	CH ₄	0.1	0.0	0.000	0.000	1.000
1A4c	Agriculture/Forestry/Fishing/Fish Farms	Solid	CH ₄	0.0	0.0	0.000	0.000	1.000
2B	Chemical industry		C	C	C	0.000	0.000	1.000
4B	Biological treatment of waste		CH ₄	0.0	0.0	0.000	0.000	1.000
4B	Biological treatment of waste		N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A1b	Petroleum Refining	Solid	CO ₂	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CO ₂	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1b	Petroleum Refining	Solid	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A1a	Electricity and Heat Production	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1b	Petroleum Refining	Solid	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Solid	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A1c	Manufacture of Solid Fuels and Other Energy Industries	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A3a	Civil Aviation	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3c	Railways	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CO ₂	0.0	0.0	0.000	0.000	1.000
1A3a	Civil Aviation	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A3c	Railways	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A3d	Water-Borne Navigation	Gas	CH ₄	0.0	0.0	0.000	0.000	1.000
1A3a	Civil Aviation	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A3c	Railways	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000
1A3d	Water-Borne Navigation	Gas	N ₂ O	0.0	0.0	0.000	0.000	1.000
3A1j	Enteric fermentation - other game		CH ₄	0.0	0.0	0.000	0.000	1.000
3A2f	Manure management - horses		CH ₄	0.0	0.0	0.000	0.000	1.000
3A2g	Manure management - mules and asses		CH ₄	0.0	0.0	0.000	0.000	1.000
3A2j	Manure management - other game		CH ₄	0.0	0.0	0.000	0.000	1.000
3B6a	Other land remaining other land		CO ₂	0.0	0.0	0.000	0.000	1.000
3C1f	Biomass burning in other lands		CH ₄	0.0	0.0	0.000	0.000	1.000
3C1f	Biomass burning in other lands		N ₂ O	0.0	0.0	0.000	0.000	1.000

C=Confidential data



Appendix B: Uncertainty analysis

Table B.1: Overall uncertainty analysis for 2000 to 2020.

IPCC Category		Gas	Base year emissions / removals (2000)	Year t emissions / removals (2017)	Activity data uncertainty		Emission factor/estimation parameter uncertainty		Combined uncertainty		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
			Gg CO ₂ e	Gg CO ₂ e	(-)%	(+)%	(-)%	(+)%	(-)%	(+)%	(%)	%	%	%
1A1a	Electricity and Heat Production	CO ₂	185 148.7	204 566.7	3.00%	5.00%	7.00%	7.00%	7.62%	8.60%	0.1560%	0.31%	3.24%	0.11%
1A1b	Petroleum Refining	CO ₂	4 042.6	2 410.6	3.00%	5.00%	7.00%	7.00%	7.62%	8.60%	0.0000%	0.03%	0.04%	0.00%
1A1c	Manufacture of Solid Fuels and Other Energy Industries	CO ₂	30 454.7	28 454.1	3.00%	5.00%	7.00%	7.00%	7.62%	8.60%	0.0030%	0.03%	0.45%	0.00%
1A1a	Electricity and Heat Production	CH ₄	40.5	47.8	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0000%	0.00%	0.00%	0.00%
1A1b	Petroleum Refining	CH ₄	2.1	1.1	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0000%	0.00%	0.00%	0.00%
1A1c	Manufacture of Solid Fuels and Other Energy Industries	CH ₄	10.6	29.1	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0000%	0.00%	0.00%	0.00%
1A1a	Electricity and Heat Production	N ₂ O	894.2	1 006.9	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0003%	0.02%	0.02%	0.00%
1A1b	Petroleum Refining	N ₂ O	4.9	2.2	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0000%	0.00%	0.00%	0.00%
1A1c	Manufacture of Solid Fuels and Other Energy Industries	N ₂ O	110.3	143.8	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0000%	0.01%	0.00%	0.00%
1A2	Manufacturing Industries and Construction	CO ₂	28 630.0	33 066.2	5.00%	10.00%	7.00%	7.00%	8.60%	12.21%	0.0082%	0.07%	1.05%	0.01%
1A2	Manufacturing Industries and Construction	CH ₄	9.2	11.5	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.00%	0.00%	0.00%
1A2	Manufacturing Industries and Construction	N ₂ O	104.8	118.7	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.00%	0.00%	0.00%



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3a	Civil Aviation	CO2	2 249.1	693.4	5.00%	5.00%	1.50%	1.50%	5.22%	5.22%	0.0000%	0.01%	0.01%	0.00%
1A3b	Road Transport	CO2	36 306.3	44 057.9	5.00%	5.00%	2.00%	2.00%	5.39%	5.39%	0.0028%	0.03%	0.70%	0.00%
1A3c	Railways	CO2	551.5	501.8	5.00%	5.00%	5.00%	5.00%	7.07%	7.07%	0.0000%	0.00%	0.01%	0.00%
1A3d	Water-Borne Navigation	CO2	222.2	1 970.6	5.00%	5.00%	5.00%	5.00%	7.07%	7.07%	0.0000%	0.02%	0.03%	0.00%
1A3a	Civil Aviation	CH4	2.0	0.6	5.00%	5.00%	50.00%	50.00%	50.25%	50.25%	0.0000%	0.00%	0.00%	0.00%
1A3b	Road Transport	CH4	248.0	221.4	5.00%	5.00%	9.00%	9.00%	10.30%	10.30%	0.0000%	0.00%	0.00%	0.00%
1A3c	Railways	CH4	0.6	0.5	5.00%	5.00%	9.00%	9.00%	10.30%	10.30%	0.0000%	0.00%	0.00%	0.00%
1A3d	Water-Borne Navigation	CH4	0.4	3.7	5.00%	5.00%	50.00%	50.00%	50.25%	50.25%	0.0000%	0.00%	0.00%	0.00%
1A3a	Civil Aviation	N2O	5.9	1.8	5.00%	5.00%	50.00%	50.00%	50.25%	50.25%	0.0000%	0.00%	0.00%	0.00%
1A3b	Road Transport	N2O	545.1	678.0	5.00%	5.00%	70.00%	72.00%	70.18%	72.17%	0.0001%	0.02%	0.01%	0.00%
1A3c	Railways	N2O	66.0	51.3	5.00%	5.00%	70.00%	72.00%	70.18%	72.17%	0.0000%	0.00%	0.00%	0.00%
1A3d	Water-Borne Navigation	N2O	1.3	11.8	5.00%	5.00%	40.00%	140.00%	40.31%	140.09%	0.0000%	0.00%	0.00%	0.00%
1A4a	Commercial/Institutional	CO2	20 907.7	3 741.5	5.00%	10.00%	7.00%	7.00%	8.60%	12.21%	0.0001%	0.27%	0.12%	0.00%
1A4b	Residential	CO2	6 472.7	2 324.1	5.00%	10.00%	7.00%	7.00%	8.60%	12.21%	0.0000%	0.06%	0.07%	0.00%
1A4c	Agriculture/Forestry/Fishing/Fish Farms	CO2	2 450.5	5 905.5	5.00%	10.00%	7.00%	7.00%	8.60%	12.21%	0.0003%	0.05%	0.19%	0.00%
1A4a	Commercial/Institutional	CH4	5.9	2.1	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.00%	0.00%	0.00%
1A4b	Residential	CH4	208.2	128.4	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.01%	0.00%	0.00%
1A4c	Agriculture/Forestry/Fishing/Fish Farms	CH4	1.9	5.0	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.00%	0.00%	0.00%
1A4a	Commercial/Institutional	N2O	181.6	14.2	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.03%	0.00%	0.00%
1A4b	Residential	N2O	444.6	262.4	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.03%	0.01%	0.00%
1A4c	Agriculture/Forestry/Fishing/Fish Farms	N2O	7.5	15.5	5.00%	10.00%	75.00%	75.00%	75.17%	75.66%	0.0000%	0.00%	0.00%	0.00%
1A5a	Stationary	CO2	17 261.4	18 056.5	3.00%	5.00%	7.00%	7.00%	7.62%	8.60%	0.0012%	0.01%	0.29%	0.00%
1A5a	Stationary	CH4	5.6	4.2	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0000%	0.00%	0.00%	0.00%
1A5a	Stationary	N2O	76.9	86.3	3.00%	5.00%	75.00%	75.00%	75.06%	75.17%	0.0000%	0.00%	0.00%	0.00%
1B1a	Coal mining and handling	CO2	30.6	37.9	10.00%	10.00%	63.00%	63.00%	63.79%	63.79%	0.0000%	0.00%	0.00%	0.00%
1B1a	Coal mining and handling	CH4	2 338.1	2 892.8	10.00%	10.00%	63.00%	63.00%	63.79%	63.79%	0.0017%	0.08%	0.09%	0.00%
1B2a	Oil	CO2	752.0	641.8	25.00%	25.00%	75.00%	75.00%	79.06%	79.06%	0.0001%	0.02%	0.05%	0.00%
1B3	Other Emissions from Energy Production	CO2	28 146.6	25 644.5	25.00%	25.00%	75.00%	75.00%	79.06%	79.06%	0.2070%	0.41%	2.03%	0.04%
1B3	Other Emissions from Energy Production	CH4	2 318.6	2 218.2	25.00%	25.00%	75.00%	75.00%	79.06%	79.06%	0.0015%	0.02%	0.18%	0.00%



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2A1	Cement Production	CO2	3 870.6	3 357.2	30.00%	30.00%	35.00%	35.00%	46.10%	46.10%	0.0012%	0.04%	0.32%	0.00%
2A2	Lime Production	CO2	426.1	714.9	30.00%	30.00%	6.00%	6.00%	30.59%	30.59%	0.0000%	0.00%	0.07%	0.00%
2A3	Glass Production	CO2	74.4	154.5	1.00%	3.00%	1.00%	3.00%	1.41%	4.24%	0.0000%	0.00%	0.00%	0.00%
2A4	OPUC	CO2	0.0	94.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2B1	Ammonia Production	CO2	485.3	398.2	15.00%	85.00%	1.00%	5.00%	15.03%	85.15%	0.0001%	0.00%	0.11%	0.00%
2B1	Ammonia Production	CH4	65.6	77.7	15.00%	85.00%	1.00%	5.00%	15.03%	85.15%	0.0000%	0.00%	0.02%	0.00%
2B3	Nitric Acid Production	N2O	1 644.5	835.5	2.00%	2.00%	2.00%	2.00%	2.83%	2.83%	0.0000%	0.00%	0.01%	0.00%
2B5	Carbide Production	CO2	2.0	29.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2B5	Carbide Production	CH4	0.0	2 743.1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2B6	Titanium Dioxide Production	CO2	437.6	742.1	5.00%	5.00%	10.00%	10.00%	11.18%	11.18%	0.0000%	0.01%	0.01%	0.00%
2B7	Soda Ash Production	CO2	0.0	4.8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2B8f	Petrochemical and Carbon Black Production	CO2	138.6	93.7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2B8f	Petrochemical and Carbon Black Production	CH4	0.1	0.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2B8g	Hydrogen production	CO2	0.0	59.7	10.00%	10.00%	15.00%	15.00%	18.03%	18.03%	0.0000%	0.00%	0.00%	0.00%
2C1	Iron and Steel Production	CO2	15 334.4	3 853.1	10.00%	10.00%	85.00%	85.00%	85.59%	85.59%	0.0055%	2.18%	0.12%	0.05%
2C1	Iron and Steel Production	CH4	0.0	3.2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2C2	Ferroalloys Production	CO2	8 079.1	5 457.3	10.00%	110.00%	25.00%	25.00%	26.93%	112.81%	0.0191%	0.15%	1.90%	0.04%
2C2	Ferroalloys Production	CH4	3.3	496.2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2C3	Aluminium Production	CO2	1 091.3	1 134.8	5.00%	5.00%	25.00%	25.00%	25.50%	25.50%	0.0000%	0.00%	0.02%	0.00%
2C3	Aluminium Production	PFCs	983.2	120.4	5.00%	5.00%	25.00%	25.00%	25.50%	25.50%	0.0000%	0.05%	0.00%	0.00%
2C5	Lead Production	CO2	15.1	6.6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2C6	Zinc Production	CO2	108.4	36.6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
2D1	Lubricant Use	CO2	188.5	855.0	10.00%	10.00%	50.00%	50.00%	50.99%	50.99%	0.0001%	0.07%	0.03%	0.00%
2D2	Paraffin Wax Use	CO2	7.4	393.2	10.00%	10.00%	50.00%	50.00%	50.99%	50.99%	0.0000%	0.04%	0.01%	0.00%
2F1	Refrigeration and Air Conditioning	HFCs	0.0	4 846.9	10.00%	10.00%	50.00%	50.00%	50.99%	50.99%	0.0031%	0.54%	0.15%	0.00%
2F2	Foam Blowing Agents	HFCs	0.0	2.1	10.00%	10.00%	50.00%	50.00%	50.99%	50.99%	0.0000%	0.00%	0.00%	0.00%
2F3	Fire Protection	HFCs	0.0	65.9	25.00%	25.00%	25.00%	25.00%	35.36%	35.36%	0.0000%	0.00%	0.01%	0.00%
2F4	Aerosols	HFCs	0.0	18.2	50.00%	50.00%	25.00%	25.00%	55.90%	55.90%	0.0000%	0.00%	0.00%	0.00%
3A1a	Enteric fermentation - cattle	CH4	23 901.0	21 554.6	5.10%	22.36%	15.00%	27.80%	15.84%	35.68%	0.0298%	0.14%	1.53%	0.02%
3A1c	Enteric fermentation - sheep	CH4	5 837.3	4 653.5	11.18%	20.62%	32.00%	32.00%	33.90%	38.07%	0.0016%	0.08%	0.30%	0.00%



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3A1d	Enteric fermentation - goats	CH4	1 493.1	1 190.0	20.63%	20.62%	39.80%	39.80%	44.83%	44.82%	0.0001%	0.03%	0.08%	0.00%
3A1f	Enteric fermentation - horses	CH4	102.1	124.7	7.07%	7.07%	40.00%	40.00%	40.62%	40.62%	0.0000%	0.00%	0.00%	0.00%
3A1g	Enteric fermentation - mules and asses	CH4	34.4	33.9	11.18%	11.18%	40.00%	40.00%	41.53%	41.53%	0.0000%	0.00%	0.00%	0.00%
3A1h	Enteric fermentation - swine	CH4	39.8	32.8	50.20%	50.20%	20.00%	20.00%	54.04%	54.04%	0.0000%	0.00%	0.01%	0.00%
3A1j	Enteric fermentation - other game	CH4	0.0	0.0					0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
3A2a	Manure management - cattle	CH4	881.6	859.0	5.10%	22.36%	10.00%	19.00%	11.23%	29.34%	0.0000%	0.00%	0.06%	0.00%
3A2c	Manure management - sheep	CH4	22.1	21.1	11.18%	20.62%	18.70%	18.70%	21.79%	27.84%	0.0000%	0.00%	0.00%	0.00%
3A2d	Manure management - goats	CH4	11.3	9.4	20.63%	20.62%	50.40%	50.40%	54.46%	54.45%	0.0000%	0.00%	0.00%	0.00%
3A2f	Manure management - horses	CH4	0.0	0.0	7.07%	7.07%	30.80%	30.80%	31.60%	31.60%	0.0000%	0.00%	0.00%	0.00%
3A2g	Manure management - mules and asses	CH4	0.0	0.0	11.18%	11.18%	30.00%	30.00%	32.02%	32.02%	0.0000%	0.00%	0.00%	0.00%
3A2h	Manure management - swine	CH4	192.0	158.2	50.20%	50.20%	20.00%	20.00%	54.04%	54.04%	0.0000%	0.00%	0.03%	0.00%
3A2i	Manure management - poultry	CH4	84.2	128.2	20.60%	20.60%	20.00%	20.00%	28.71%	28.71%	0.0000%	0.00%	0.01%	0.00%
3A2j	Manure management - other game	CH4	0.0	0.0					0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
3A2a	Manure management - cattle	N2O	1 249.4	1 360.3	30.84%	60.37%	58.70%	116.30%	66.31%	131.04%	0.0016%	0.03%	0.26%	0.00%
3A2c	Manure management - sheep	N2O	185.3	182.5	32.10%	32.10%	59.40%	105.00%	67.52%	109.80%	0.0000%	0.00%	0.02%	0.00%
3A2d	Manure management - goats	N2O	69.2	57.9	36.50%	36.50%	61.90%	106.40%	71.86%	112.49%	0.0000%	0.00%	0.01%	0.00%
3A2h	Manure management - swine	N2O	34.7	28.6	59.40%	59.40%	77.60%	116.30%	97.72%	130.59%	0.0000%	0.00%	0.01%	0.00%
3A2i	Manure management - poultry	N2O	651.9	977.1	44.20%	44.20%	66.70%	109.30%	80.02%	117.90%	0.0007%	0.08%	0.14%	0.00%
3B1a	Forest land remaining forest land - Net CO2	CO2	-8 439.3	-15 330.1	30.70%	30.70%	44.70%	44.70%	54.23%	54.23%	0.0348%	0.69%	1.49%	0.03%
3B1b	Land converted to forest land - Net CO2	CO2	-10 508.4	-10 896.0	35.70%	35.70%	44.70%	44.70%	57.21%	57.21%	0.0196%	0.04%	1.23%	0.02%
3B2a	Cropland remaining cropland - Net CO2	CO2	-3 955.8	-3 817.1	8.40%	8.40%	90.00%	90.00%	90.39%	90.39%	0.0060%	0.03%	0.10%	0.00%
3B2b	Land converted to cropland - Net CO2	CO2	1 000.1	1 002.4	13.40%	13.40%	90.00%	90.00%	90.99%	90.99%	0.0004%	0.00%	0.04%	0.00%
3B3a	Grassland remaining grassland - Net CO2	CO2	-11 302.5	-11 309.4	21.70%	21.70%	90.00%	90.00%	92.58%	92.58%	0.0552%	0.01%	0.78%	0.01%
3B3b	Land converted to grassland - Net CO2	CO2	-4 971.7	-5 167.3	26.70%	26.70%	90.00%	90.00%	93.88%	93.88%	0.0119%	0.04%	0.44%	0.00%
3B4a	Wetland remaining wetland	CO2	3 828.7	3 828.7	7.00%	7.00%	90.00%	90.00%	90.27%	90.27%	0.0060%	0.00%	0.08%	0.00%
3B4b	Land converted to wetland	CO2	-1 169.2	-1 155.2	12.00%	12.00%	90.00%	90.00%	90.80%	90.80%	0.0006%	0.00%	0.04%	0.00%



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3B4	Wetland	CH4	1 587.9	1 192.5	7.00%	7.00%	90.00%	90.00%	90.27%	90.27%	0.0006%	0.08%	0.03%	0.00%
3B4	Wetland	N2O	581.4	436.6	7.00%	7.00%	90.00%	90.00%	90.27%	90.27%	0.0001%	0.03%	0.01%	0.00%
3B5a	Settlements remaining settlements - Net CO2	CO2	-1 728.2	-2 088.4	6.60%	6.60%	90.00%	90.00%	90.24%	90.24%	0.0018%	0.07%	0.04%	0.00%
3B5b	Land converted to settlements - Net CO2	CO2	967.3	940.5	11.60%	11.60%	90.00%	90.00%	90.74%	90.74%	0.0004%	0.01%	0.03%	0.00%
3B6a	Other land remaining other land	CO2	2 385.6	2 385.6	0.00%	0.00%	90.00%	90.00%	90.00%	90.00%	0.0023%	0.00%	0.00%	0.00%
3B6b	Land converted to other lands - Net CO2	CO2	6 273.4	6 273.4	22.00%	22.00%	90.00%	90.00%	92.65%	92.65%	0.0170%	0.00%	0.44%	0.00%
3C1a	Biomass burning in forest land	CH4	293.6	288.6	60.51%	60.51%	72.53%	72.53%	94.46%	94.46%	0.0000%	0.00%	0.06%	0.00%
3C1b	Biomass burning in croplands	CH4	235.6	167.0	22.36%	22.36%	45.83%	45.83%	50.99%	50.99%	0.0000%	0.01%	0.01%	0.00%
3C1c	Biomass burning in grasslands	CH4	413.5	349.9	76.72%	76.72%	86.52%	86.52%	115.64%	115.64%	0.0001%	0.01%	0.09%	0.00%
3C1d	Biomass burning in wetlands	CH4	12.4	12.3	76.19%	76.19%	86.05%	86.05%	114.93%	114.93%	0.0000%	0.00%	0.00%	0.00%
3C1e	Biomass burning in settlements	CH4	7.8	5.8	41.23%	41.23%	57.45%	57.45%	70.71%	70.71%	0.0000%	0.00%	0.00%	0.00%
3C1f	Biomass burning in other lands	CH4	0.0	0.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
3C1a	Biomass burning in forest land	N2O	298.7	265.6	60.51%	60.51%	72.53%	72.53%	94.46%	94.46%	0.0000%	0.01%	0.05%	0.00%
3C1b	Biomass burning in croplands	N2O	90.2	63.9	22.36%	22.36%	45.83%	45.83%	50.99%	50.99%	0.0000%	0.00%	0.00%	0.00%
3C1c	Biomass burning in grasslands	N2O	557.4	471.6	76.72%	76.72%	86.52%	86.52%	115.64%	115.64%	0.0001%	0.02%	0.11%	0.00%
3C1d	Biomass burning in wetlands	N2O	16.7	16.6	76.19%	76.19%	86.05%	86.05%	114.93%	114.93%	0.0000%	0.00%	0.00%	0.00%
3C1e	Biomass burning in settlements	N2O	10.5	7.8	41.23%	41.23%	57.45%	57.45%	70.71%	70.71%	0.0000%	0.00%	0.00%	0.00%
3C1f	Biomass burning in other lands	N2O	0.0	0.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.0000%	0.00%	0.00%	0.00%
3C2	Liming	CO2	384.1	942.3	75.00%	75.00%	90.10%	90.10%	117.23%	117.23%	0.0006%	0.11%	0.22%	0.00%
3C3	Urea application	CO2	297.3	584.7	10.00%	10.00%	51.00%	51.00%	51.97%	51.97%	0.0000%	0.03%	0.02%	0.00%
3C4	Direct N2O emissions from managed soils	N2O	12 363.6	12 825.3	5.00%	91.20%	100.10%	100.10%	100.22%	135.42%	0.1519%	0.11%	3.71%	0.14%
3C5	Indirect N2O emissions from managed soils	N2O	1 256.4	1 200.3	5.00%	207.00%	97.90%	97.90%	98.03%	228.98%	0.0038%	0.01%	0.79%	0.01%
3C6	Indirect N2O emissions from manure management	N2O	347.1	387.5	58.70%	116.30%	116.10%	116.10%	130.10%	164.33%	0.0002%	0.01%	0.14%	0.00%
3D1	Harvested wood products	CO2	-2 106.2	635.2	10.00%	10.00%	10.00%	10.00%	14.14%	14.14%	0.0000%	0.06%	0.02%	0.00%
4A	Solid Waste Disposal	CH4	13 610.5	18 252.8	50.00%	50.00%	40.00%	40.00%	64.03%	64.03%	0.0688%	0.42%	2.89%	0.09%
4B	Biological treatment of waste	CH4	0.0	0.0	50.00%	50.00%	50.00%	50.00%	70.71%	70.71%	0.0000%	0.00%	0.00%	0.00%
4B	Biological treatment of waste	N2O	0.0	0.0	50.00%	50.00%	50.00%	50.00%	70.71%	70.71%	0.0000%	0.00%	0.00%	0.00%



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

4C2	Open Burning of Waste	CO2	18.6	35.4	50.00%	50.00%	40.00%	40.00%	64.03%	64.03%	0.0000%	0.00%	0.01%	0.00%
4C2	Open Burning of Waste	CH4	117.5	223.4	50.00%	50.00%	100.00%	100.00%	111.80%	111.80%	0.0000%	0.02%	0.04%	0.00%
4C2	Open Burning of Waste	N2O	40.0	76.1	50.00%	50.00%	100.00%	100.00%	111.80%	111.80%	0.0000%	0.01%	0.01%	0.00%
4D1	Wastewater Treatment and Discharge	CH4	1 951.2	2 783.0	50.00%	50.00%	40.00%	40.00%	64.03%	64.03%	0.0016%	0.07%	0.44%	0.00%
4D1	Wastewater Treatment and Discharge	N2O	545.4	777.9	50.00%	50.00%	90.00%	90.00%	102.96%	102.96%	0.0003%	0.05%	0.12%	0.00%
4D2	Industrial Wastewater Treatment and Discharge	CH4	1 958.1	897.3	50.00%	50.00%	40.00%	40.00%	64.03%	64.03%	0.0002%	0.09%	0.14%	0.00%
			446 275.1	445 565.6							0.83%			0.57%
										Uncertainty in total inventory	9.11%		Trend uncertainty	7.54%

C = Confidential



Appendix C: Summary emission tables for 2020

Table C.1: Summary emission table for South Africa for 2020.

IPCC 2006 category	Emissions and removals								
	Net CO ₂	CH ₄	N ₂ O	HFCs	PFCs	NO _x	CO	NMVOC	Total GHGs
	(Gg) ^a	(Gg) ^a	(Gg) ^a	(Gg CO ₂ e) ^b	(Gg CO ₂ e) ^b	(Gg) ^a	(Gg) ^a	(Gg) ^a	(Gg CO ₂ e)
Emissions (incl. FOLU)	356 323.5	2 944.0	72.1	4 933.1	120.4	48.7	1 093.9	53.4	445 565.6
Emissions (excl. FOLU)	391 021.1	2 887.2	70.7	4 933.1	120.4	48.7	1 093.9	53.4	478 634.1
1 - Energy	372 073.3	265.1	7.7						380 032.6
1.A - Fuel Combustion Activities	345 749.0	21.7	7.7			NE	NE	NE	348 597.4
1.A.1 - Energy Industries	235 431.4	3.7	3.7			NE	NE	NE	236 662.3
1.A.2 - Manufacturing Industries and Construction	33 066.2	0.5	0.4			NE	NE	NE	33 196.3
1.A.3 - Transport	47 223.7	10.8	2.4			NE	NE	NE	48 192.9
1.A.4 - Other Sectors	11 971.2	6.5	0.9			NE	NE	NE	12 398.8
1.A.5 - Non-Specified	18 056.5	0.2	0.3			NE	NE	NE	18 147.0
1.B - Fugitive emissions from fuels	26 324.3	243.4	NE			NE	NE	NE	31 435.2
1.B.1 - Solid Fuels	37.9	137.8	NE			NE	NE	NE	2 930.7
1.B.2 - Oil and Natural Gas	641.8	NE	NE			NE	NE	NE	641.8
1.B.3 - Other emissions from Energy Production	25 644.5	105.6	NE			NE	NE	NE	27 862.7
1.C - Carbon dioxide Transport and Storage	NE					NE	NE	NE	0.0
1.C.1 - Transport of CO ₂	NE					NE	NE	NE	0.0
1.C.2 - Injection and Storage	NE					NE	NE	NE	0.0
1.C.3 - Other	NA					NE	NE	NE	0.0
2 - Industrial Processes and Product Use	17 385.6	158.1	2.7	4 933.1	120.4				26 594.8
2.A - Mineral Industry	4 321.1	NE				NE	NE	NE	4 321.1
2.B - Chemical Industry	1 328.0	134.3	2.7			NE	NE	NE	4 984.3
2.C - Metal Industry	10 488.3	23.8	NE	NE	120.4	NE	NE	NE	11 108.2
2.D - Non-Energy Products from Fuels and Solvent Use	1 248.1	NE	NE			NE	NE	NE	1 248.1



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2.E - Electronics Industry	NE		NE	NE	NE	NE	NE	NE	0.0
2.F - Product Uses as Substitutes for Ozone Depleting Substances	NE			4 933.1	NE	NE	NE	NE	4 933.1
2.G - Other Product Manufacture and Use			NE	NE	NE	NE	NE	NE	0.0
2.H - Other	NA	NA	NA			NE	NE	NE	0.0
3 - Agriculture, Forestry, and Other Land Use	-33 170.7	1 465.8	59.0			48.7	1 093.9	53.4	15 892.4
3.A - Livestock		1 369.8	8.4						31 371.7
3.A.1 - Enteric Fermentation		1 313.8							27 589.5
3.A.2 - Manure Management		56.0	8.4						3 782.2
3.B - Land	-35 332.8	56.8	1.4						-33 703.7
3.B.1 - Forest land	-26 226.0	NE	NE						-26 226.0
3.B.2 - Cropland	-2 814.7	NE	NE						-2 814.7
3.B.3 - Grassland	-16 476.6	NE	NE						-16 476.6
3.B.4 - Wetlands	2 673.4	56.8	1.4						4 302.5
3.B.5 - Settlements	-1 147.9	NE	NE						-1 147.9
3.B.6 - Other Land	8 659.0	NE	NE						8 659.0
3.C - Aggregate sources and non-CO2 emissions sources on land	1 526.9	39.2	49.2			48.7	1 093.9	53.4	17 589.2
3.C.1 - Emissions from biomass burning	IE	39.2	2.7			48.7	1 093.9	53.4	1 649.2
3.C.2 - Liming	942.3								942.3
3.C.3 - Urea application	584.7								584.7
3.C.4 - Direct N ₂ O Emissions from managed soils			41.4						12 825.3
3.C.5 - Indirect N ₂ O Emissions from managed soils			3.9						1 200.3
3.C.6 - Indirect N ₂ O Emissions from manure management			1.2						387.5
3.C.7 - Rice cultivations		NO	NO						0.0
3.C.8 - Other (please specify)	NO	NO	NO						0.0
3.D - Other	635.2	NA	NA						635.2
3.D.1 - Harvested Wood Products	635.2								635.2
3.D.2 - Other (please specify)	NO	NO	NO						0.0
4 - Waste	35.4	1 055.1	2.8						23 045.8



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

4.A - Solid Waste Disposal		869.2	NE			NA	NA	NA	18 252.8
4.B - Biological Treatment of Solid Waste		0.0	0.0			NA	NA	NA	0.0
4.C - Incineration and Open Burning of Waste	35.4	10.6	0.2			NA	NA	NA	334.9
4.D - Wastewater Treatment and Discharge		175.3	2.5			NA	NA	NA	4 458.1
4.E - Other	NO	NO	NO	NO	NO	NO	NO	NO	
5 - Other									
5.A - Indirect N ₂ O emissions from the atmospheric deposition of nitrogen in NO _x and NH ₃			NE			NE	NE	NE	
5.B - Other			NO			NO	NO	NO	
Memo items									
International bunkers	5 283.1	0.3	0.1	NA	NA	NA	NA	NA	5 329.5
International aviation	2 268.8	0.1	0.0	NA	NA	NA	NA	NA	2 274.8
International water-borne transport	3 014.4	0.2	0.1	NA	NA	NA	NA	NA	3 054.7
Multilateral operations	NA	NA	NA	NA	NA	NA	NA	NA	

^a The emissions in Gg CO₂e for CH₄ and N₂O per category are provided in the next table.

^b The emissions of PFC and HFCs are reported in Gg in Table 2.4.

Table C.2: Summary Energy sector emission table for South Africa for 2020.

Categories	Emissions (Gg)							Emissions
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOCs	SO ₂	(Gg CO ₂ e)
1 ENERGY	372 073.3	265.1	7.7	0.0	0.0	0.0	0.0	380 032.6
1A Fuel Combustion Activities	345 749.0	21.7	7.7	0.0	0.0	0.0	0.0	348 597.4
1A1 Energy Industries	235 431.4	3.7	3.7	0.0	0.0	0.0	0.0	236 662.3
1A1a Main Activity Electricity and Heat Production	204 566.7	2.3	3.2	NE	NE	NE	NE	205 621.5



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A1ai Electricity Generation	204 566.7	2.3	3.2	NE	NE	NE	NE	205 621.5
1A1aii Combined Heat and Power Generation (CHP)				NE	NE	NE	NE	0.0
1A1aiii Heat Plants				NE	NE	NE	NE	0.0
1A1b Petroleum Refining	2 410.6	0.1	0.0	NE	NE	NE	NE	2 413.9
1A1c Manufacture of Solid Fuels and Other Energy Industries	28 454.1	1.4	0.5	NE	NE	NE	NE	28 627.0
1A1ci Manufacture of Solid Fuels	28 454.1	1.4	0.5	NE	NE	NE	NE	28 627.0
1A1cii Other Energy Industries	NE	NE	NE	NE	NE	NE	NE	NE
1A2 Manufacturing Industries and Construction	33 066.2	0.5	0.4	0.0	0.0	0.0	0.0	33 196.3
1A2a Iron and Steel				NE	NE	NE	NE	0.0
1A2b Non-Ferrous Metals				NE	NE	NE	NE	0.0
1A2c Chemicals				NE	NE	NE	NE	0.0
1A2d Pulp, Paper and Print				NE	NE	NE	NE	0.0
1A2e Food Processing, Beverages and Tobacco				NE	NE	NE	NE	0.0
1A2f Non-Metallic Minerals				NE	NE	NE	NE	0.0
1A2g Transport Equipment				NE	NE	NE	NE	0.0
1A2h Machinery				NE	NE	NE	NE	0.0
1A2i Mining (excluding fuels) and Quarrying				NE	NE	NE	NE	0.0
1A2j Wood and wood products				NE	NE	NE	NE	0.0
1A2k Construction				NE	NE	NE	NE	0.0
1A2l Textile and Leather				NE	NE	NE	NE	0.0
1A2m Non-specified Industry				NE	NE	NE	NE	0.0
1A3 Transport	47 223.7	10.8	2.4	0.0	0.0	0.0	0.0	48 192.9
1A3a Civil Aviation	693.4	0.0	0.0	NE	NE	NE	NE	695.8
1A3ai International Aviation (International Bunkers) (1)								0.0
1A3aii Domestic Aviation	693.4	0.0	0.0	NE	NE	NE	NE	695.8
1A3b Road Transportation	44 057.9	10.5	2.2	NE	NE	NE	NE	44 957.2



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A3bi Cars				NE	NE	NE	NE	0.0
1A3bi1 Passenger cars with 3-way catalysts				NE	NE	NE	NE	0.0
1A3bi2 Passenger cars without 3-way catalysts				NE	NE	NE	NE	0.0
1A3bii Light-duty trucks				NE	NE	NE	NE	0.0
1A3bii1 Light-duty trucks with 3-way catalysts				NE	NE	NE	NE	0.0
1A3bii2 Light-duty trucks without 3-way catalysts				NE	NE	NE	NE	0.0
1A3biii Heavy-duty trucks and buses				NE	NE	NE	NE	0.0
1A3biv Motorcycles				NE	NE	NE	NE	0.0
1A3bv Evaporative emissions from vehicles				NE	NE	NE	NE	0.0
1A3bvi Urea-based catalysts				NE	NE	NE	NE	0.0
1A3c Railways	501.8	0.0	0.2	NE	NE	NE	NE	553.7
1A3d Water-borne Navigation	1 970.6	0.2	0.0	NE	NE	NE	NE	1 986.2
1A3di International water-borne navigation (International bunkers) (1)								0.0
1A3dii Domestic Water-borne Navigation	1 970.6	0.2	0.0	NE	NE	NE	NE	1 986.2
1A3e Other Transportation				NE	NE	NE	NE	0.0
1A3ei Pipeline Transport	NE	NE	NE	NE	NE	NE	NE	NE
1A3eii Off-road	IE	IE	IE	NE	NE	NE	NE	NE
1A4 Other Sectors	11 971.2	6.5	0.9	0.0	0.0	0.0	0.0	12 398.8
1A4a Commercial/Institutional	3 741.5	0.1	0.0	NE	NE	NE	NE	3 757.8
1A4b Residential	2 324.1	6.1	0.8	NE	NE	NE	NE	2 715.0
1A4c Agriculture/Forestry/Fishing/Fish Farms	5 905.5	0.2	0.0	NE	NE	NE	NE	5 926.0
1A4ci Stationary	5 905.5	0.2	0.0	NE	NE	NE	NE	5 926.0
1A4cii Off-road Vehicles and Other Machinery	IE	IE	IE	NE	NE	NE	NE	NE
1A4ciii Fishing (mobile combustion)	IE	IE	IE	NE	NE	NE	NE	NE
1A5 Non-Specified	18 056.5	0.2	0.3	0.0	0.0	0.0	0.0	18 147.0



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1A5a Stationary	18 056.5	0.2	0.3	NE	NE	NE	NE	18 147.0
1A5b Mobile				NE	NE	NE	NE	0.0
1A5bi Mobile (aviation component)	NE	NE	NE	NE	NE	NE	NE	NE
1A5bii Mobile (water-borne component)	NE	NE	NE	NE	NE	NE	NE	NE
1A5biii Mobile (Other)	NE	NE	NE	NE	NE	NE	NE	NE
1A5c Multilateral Operations (1)(2)								0.0
1B Fugitive emissions from fuels	26 324.3	243.4	0.0	0.0	0.0	0.0	0.0	31 435.2
1B1 Solid Fuels	37.9	137.8		0.0	0.0	0.0	0.0	2 930.7
1B1a Coal mining and handling	37.9	137.8		NE	NE	NE	NE	2 930.7
1B1ai Underground mines	37.9	137.8		NE	NE	NE	NE	2 930.7
1B1ai1 Mining	30.7	111.7		NE	NE	NE	NE	2 375.4
1B1ai2 Post-mining seam gas emissions	7.2	26.1		NE	NE	NE	NE	555.3
1B1ai3 Abandoned underground mines	NE	NE		NE	NE	NE	NE	NE
1B1ai4 Flaring of drained methane or conversion of methane to CO2	NE	NE		NE	NE	NE	NE	NE
1B1aii Surface mines	0.0	0.0		NE	NE	NE	NE	0.0
1B1aii1 Mining	0.0	0.0		NE	NE	NE	NE	0.0
1B1aii2 Post-mining seam gas emissions	0.0	0.0		NE	NE	NE	NE	0.0
1B1b Uncontrolled combustion and burning coal dumps	NE	NE	NE	NE	NE	NE	NE	NE
1B1c Solid fuel transformation	NE	NE	NE	NE	NE	NE	NE	NE
1B2 Oil and Natural Gas	641.8	0.0	0.0	0.0	0.0	0.0	0.0	641.8
1B2a Oil	641.8	0.0	0.0	NE	NE	NE	NE	641.8
1B2ai Venting	NE	NE		NE	NE	NE	NE	NE
1B2aii Flaring	641.8	NE		NE	NE	NE	NE	NE
1B2aiii All Other				NE	NE	NE	NE	0.0
1B2aiii1 Exploration				NE	NE	NE	NE	0.0



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

1B2aiii2 Production and Upgrading				NE	NE	NE	NE	0.0
1B2aiii3 Transport				NE	NE	NE	NE	0.0
1B2aiii4 Refining				NE	NE	NE	NE	0.0
1B2aiii5 Distribution of oil products				NE	NE	NE	NE	0.0
1B2aiii6 Other				NE	NE	NE	NE	0.0
1B2b Natural Gas				NE	NE	NE	NE	0.0
1B2bi Venting				NE	NE	NE	NE	0.0
1B2bii Flaring				NE	NE	NE	NE	0.0
1B2biii All Other				NE	NE	NE	NE	0.0
1B2biii1 Exploration				NE	NE	NE	NE	0.0
1B2biii2 Production				NE	NE	NE	NE	0.0
1B2biii3 Processing				NE	NE	NE	NE	0.0
1B2biii4 Transmission and Storage				NE	NE	NE	NE	0.0
1B2biii5 Distribution				NE	NE	NE	NE	0.0
1B2biii6 Other				NE	NE	NE	NE	0.0
1B3 Other emissions from Energy Production	25 644.5	105.6	0.0	0.0	0.0	0.0	0.0	27 862.7
1C Carbon dioxide Transport and Storage	0.0			0.0	0.0	0.0	0.0	0.0
1C1 Transport of CO2	0.0			0.0	0.0	0.0	0.0	0.0
1C1a Pipelines	NE			NE	NE	NE	NE	NE
1C1b Ships	NE			NE	NE	NE	NE	NE
1C1c Other (please specify)	NE			NE	NE	NE	NE	NE
1C2 Injection and Storage	0.0			0.0	0.0	0.0	0.0	0.0
1C2a Injection	NE			NE	NE	NE	NE	NE
1C2b Storage	NE			NE	NE	NE	NE	NE
1C3 Other	0.0			0.0	0.0	0.0	0.0	0.0



Table C.3: Summary IPPU sector emission table for South Africa for 2017.

Categories	(Gg)										
	CO ₂	CH ₄	N ₂ O	HFCs	PFCs	SF ₆	NO _x	CO	NMVOCs	SO ₂	(Gg CO ₂ e)
2. INDUSTRIAL PROCESSES AND PRODUCT USE	17 385.6	158.1	2.7	4 933.1	120.4	0.0	0.0	0.0	0.0	0.0	26 594.8
2A Mineral Industry	4 321.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4 321.1
2A1 Cement production	3 357.2						NE	NE	NE	NE	3 357.2
2A2 Lime production	714.9						NE	NE	NE	NE	714.9
2A3 Glass Production	154.5						NE	NE	NE	NE	154.5
2A4 Other Process Uses of Carbonates	94.5						NE	NE	NE	NE	94.5
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
2B Chemical Industry	1 328.0	134.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4 984.3
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



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2B7 Soda Ash Production	4.8						NE	NE	NE	NE	C
2B8 Petrochemical and Carbon Black Production	C	C	NE	NE	NE	NE	NE	NE	NE	NE	C
2B8a Methanol	NO	NO					NO	NO	NO	NO	NO
2B8b Ethylene	NO	NO					NO	NO	NO	NO	NO
2B8c Ethylene Dichloride and Vinyl Chloride Monomer	NO	NO					NO	NO	NO	NO	NO
2B8d Ethylene Oxide	NO	NO					NO	NO	NO	NO	NO
2B8e Acrylonitrile	NO	NO					NO	NO	NO	NO	NO
2B8f Carbon Black	C	C					NE	NE	NE	NE	C
2B8g Hydrogen Production	C	NO					NE	NE	NE	NE	C
2B9 Fluorochemical Production	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2B9a By-product emissions (4)				NE			NE	NE	NE	NE	NE
2B9b Fugitive Emissions (4)							NE	NE	NE	NE	0.0
2B10 Other (Please specify) (3)							NE	NE	NE	NE	0.0
2C Metal Industry	10 488.3	23.8	0.0	0.0	120.4	0.0	0.0	0.0	0.0	0.0	11 108.2
2C1 Iron and Steel Production	3 853.1	0.2					NE	NE	NE	NE	3 856.3
2C2 Ferroalloys Production	5 457.3	23.6					NE	NE	NE	NE	5 953.5
2C3 Aluminium production	1 134.8				120.4		NE	NE	NE	NE	1 255.2
2C4 Magnesium production (5)	0.0					NO	NO	NO	NO	NO	NO
2C5 Lead Production	6.6						NE	NE	NE	NE	6.6
2C6 Zinc Production	36.6						NE	NE	NE	NE	36.6
2C7 Other (please specify) (3)	0.0						NE	NE	NE	NE	0.0
2D Non-Energy Products from Fuels and Solvent Use (6)	1 248.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 248.1
2D1 Lubricant Use	855.0						NE	NE	NE	NE	855.0
2D2 Paraffin Wax Use	393.2						NE	NE	NE	NE	393.2
2D3 Solvent Use (7)							NE	NE	NE	NE	0.0



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2D4 Other (please specify) (3). (8)							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
2E1 Integrated Circuit or Semiconductor (9)				NE	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
2F Product Uses as Substitutes for Ozone Depleting Substances	0.0	0.0	0.0	4 933.1	0.0	0.0	0.0	0.0	0.0	0.0	4 933.1
2F1 Refrigeration and Air Conditioning	0.0	0.0	0.0	4 846.9	NE	NE	NE	NE	NE	NE	4 846.9
2F1a Refrigeration and Stationary Air Conditioning				2 524.1			NE	NE	NE	NE	2 524.1
2F1b Mobile Air Conditioning				2 322.7			NE	NE	NE	NE	2 322.7
2F2 Foam Blowing Agents				2.1			NE	NE	NE	NE	2.1
2F3 Fire Protection				65.9	NE		NE	NE	NE	NE	65.9
2F4 Aerosols				18.2			NE	NE	NE	NE	18.2
2F5 Solvents				NE	NE		NE	NE	NE	NE	NE
2F6 Other Applications (please specify) (3)				NO	NO		NO	NO	NO	NO	NO
2G Other Product Manufacture and Use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2G1 Electrical Equipment	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2G1a Manufacture of Electrical Equipment					NE	NE	NE	NE	NE	NE	NE
2G1b Use of Electrical Equipment					NE	NE	NE	NE	NE	NE	NE
2G1c Disposal of Electrical Equipment					NE	NE	NE	NE	NE	NE	NE



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2G2 SF6 and PFCs from Other Product Uses	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2G2a Military Applications					NE	NE	NE	NE	NE	NE	NE
2G2b Accelerators					NE	NE	NE	NE	NE	NE	NE
2G2c Other (please specify) (3)					NE	NE	NE	NE	NE	NE	NE
2G3 N2O from Product Uses	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2G3a Medical Applications			NE				NE	NE	NE	NE	NE
2G3b Propellant for pressure and aerosol products			NE				NE	NE	NE	NE	NE
2G3c Other (Please specify) (3)			NE				NE	NE	NE	NE	NE
2G4 Other (Please specify) (3)							NE	NE	NE	NE	NE
2H Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2H1 Pulp and Paper Industry							NE	NE	NE	NE	0.0
2H2 Food and Beverages Industry							NE	NE	NE	NE	0.0
2H3 Other (please specify) (3)							NE	NE	NE	NE	0.0

Table C.4: Summary AFOLU sector emission table for South Africa for 2020.

	Net CO ₂ emissions / removals	Emissions					Total emissions
	(Gg)						(Gg CO ₂ e)
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOCs	
3 - Agriculture, Forestry, and Other Land Use	-33 170.7	1 465.8	59.0	1 093.9	47.7	53.4	15 892.4
3 - AFOLU (excluding FOLU)	1 526.9	1 409.0	57.6	1 093.9	47.7	53.4	48 960.9



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3.A - Livestock	0.0	1 369.8	8.4	0.0	0.0	0.0	31 371.7
3.A.1 - Enteric Fermentation	0.0	1 313.8	0.0	0.0	0.0	0.0	27 589.5
3.A.1.a - Cattle		1 026.4					21 554.6
3.A.1.a.i - Dairy Cows		134.0					2 814.3
3.A.1.a.ii - Other Cattle		892.4					18 740.3
3.A.1.b - Buffalo		NO					NO
3.A.1.c - Sheep		221.6					4 653.5
3.A.1.d - Goats		56.7					1 190.0
3.A.1.e - Camels		NO					NO
3.A.1.f - Horses		5.9					124.7
3.A.1.g - Mules and Asses		1.6					33.9
3.A.1.h - Swine		1.6					32.8
3.A.1.j - Other		NO					NO
3.A.2 - Manure Management	0.0	56.0	8.4	0.0	0.0	0.0	3 782.2
3.A.2.a - Cattle		40.9	4.4				2 219.3
3.A.2.a.i - Dairy cows		19.6	0.9				692.1
3.A.2.a.ii - Other cattle		21.3	3.5				1 527.2
3.A.2.b - Buffalo		NO	NO				NO
3.A.2.c - Sheep		1.0	0.6				21.1
3.A.2.d - Goats		0.4	0.2				9.4
3.A.2.e - Camels		NO	NO				NO
3.A.2.f - Horses		NO	NO				NO
3.A.2.g - Mules and Asses		NO	NO				NO
3.A.2.h - Swine		7.5	0.1				158.2
3.A.2.i - Poultry		6.1	3.2				128.2
3.A.2.j - Other		NO	NO				NO
3.B - Land	-35 332.8	56.8	1.4	0.0	0.0	0.0	-33 703.7
3.B.1 - Forest land	-26 226.0	0.0	0.0	0.0	0.0	0.0	-26 226.0
3.B.1.a - Forest land Remaining Forest land	-15 330.1						-15 330.1
3.B.1.b - Land Converted to Forest land	-10 896.0						-10 896.0
3.B.1.b.i - Cropland converted to Forest Land	-1 972.2						-1 972.2
3.B.1.b.ii - Grassland converted to Forest Land	-7 862.9						-7 862.9



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3.B.1.b.iii - Wetlands converted to Forest Land	-526.7						-526.7
3.B.1.b.iv - Settlements converted to Forest Land	-419.6						-419.6
3.B.1.b.v - Other Land converted to Forest Land	-114.6						-114.6
3.B.2 - Cropland	-2 814.7	0.0	0.0	0.0	0.0	0.0	-2 814.7
3.B.2.a - Cropland Remaining Cropland	-3 817.1						-3 817.1
3.B.2.b - Land Converted to Cropland	1 002.4						1 002.4
3.B.2.b.i - Forest Land converted to Cropland	711.2						711.2
3.B.2.b.ii - Grassland converted to Cropland	117.8						117.8
3.B.2.b.iii - Wetlands converted to Cropland	191.3						191.3
3.B.2.b.iv - Settlements converted to Cropland	-4.5						-4.5
3.B.2.b.v - Other Land converted to Cropland	-13.5						-13.5
3.B.3 - Grassland	-16 476.6	0.0	0.0	0.0	0.0	0.0	-16 476.6
3.B.3.a - Grassland Remaining Grassland	-11 309.4						-11 309.4
3.B.3.b - Land Converted to Grassland	-5 167.3						-5 167.3
3.B.3.b.i - Forest Land converted to Grassland	110.0						110.0
3.B.3.b.ii - Cropland converted to Grassland	-411.1						-411.1
3.B.3.b.iii - Wetlands converted to Grassland	1 494.7						1 494.7
3.B.3.b.iv - Settlements converted to Grassland	-81.6						-81.6
3.B.3.b.v - Other Land converted to Grassland	-6 279.3						-6 279.3
3.B.4 - Wetlands	2 673.4	56.8	1.4	0.0	0.0	0.0	4 302.5
3.B.4.a - Wetlands Remaining Wetlands	3 828.7	56.8	1.4				5 457.8
3.B.4.b - Wetlands Converted to wetlands	-1 155.2						-1 155.2
3.B.4.b.i - Forest Land converted to wetlands	86.6						86.6
3.B.4.b.ii - Cropland converted to wetlands	-113.6						-113.6
3.B.4.b.iii - Grasslands converted to wetlands	-1 086.1						-1 086.1
3.B.4.b.iv - Settlements converted to wetlands	-25.6						-25.6
3.B.4.b.v - Other Land converted to wetlands	-16.5						-16.5
3.B.5 - Settlements	-1 147.9	0.0	0.0	0.0	0.0	0.0	-1 147.9
3.B.5.a - Settlements Remaining Settlements	-2 088.4						-2 088.4
3.B.5.b - Land Converted to Settlements	940.5						940.5
3.B.5.b.i - Forest Land converted to Settlements	814.8						814.8
3.B.5.b.ii - Cropland converted to Settlements	31.5						31.5



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3.B.5.b.iii - Grassland converted to Settlements	68.8						68.8
3.B.5.b.iv - Wetlands converted to Settlements	38.6						38.6
3.B.5.b.v - Other Land converted to Settlements	-13.2						-13.2
3.B.6 - Other Land	8 659.0	0.0	0.0	0.0	0.0	0.0	8 659.0
3.B.6.a - Other land Remaining Other land	2 385.6						2 385.6
3.B.6.b - Land Converted to Other land	6 273.4						6 273.4
3.B.6.b.i - Forest Land converted to Other Land	1 018.6						1 018.6
3.B.6.b.ii - Cropland converted to Other Land	30.9						30.9
3.B.6.b.iii - Grassland converted to Other Land	4 637.8						4 637.8
3.B.6.b.iv - Wetlands converted to Other Land	580.6						580.6
3.B.6.b.v - Settlements converted to Other Land	5.5						5.5
3.C - Aggregate sources and non-CO2 emissions sources on land	1 526.9	39.2	49.2	1 093.9	47.7	53.4	17 589.2
3.C.1 - Emissions from biomass burning	0.0	39.2	2.7	1 093.9	47.7	53.4	1 649.2
3.C.1.a - Biomass burning in forest lands	IE	13.7	0.9	327.6	11.6	27.5	554.2
3.C.1.b - Biomass burning in croplands	IE	8.0	0.2	271.0	7.4	NO	231.0
3.C.1.c - Biomass burning in grasslands	IE	16.7	1.5	470.9	28.3	24.6	821.5
3.C.1.d - Biomass burning in wetlands	IE	0.6	0.1	16.6	0.0	0.9	29.0
3.C.1.e - Biomass burning in settlements	IE	0.3	0.0	7.8	0.5	0.4	13.6
3.C.1.f - Biomass burning in other lands	IE	NO	NO	NO	NO	NO	NO
3.C.2 - Liming	942.3						942.3
3.C.3 - Urea application	584.7						584.7
3.C.4 - Direct N2O Emissions from managed soils			41.4				12 825.3
3.C.5 - Indirect N2O Emissions from managed soils			3.9				1 200.3
3.C.6 - Indirect N2O Emissions from manure management			1.2				387.5
3.C.7 - Rice cultivations	NO	NO	NO				NO
3.C.8 - Other (please specify)							0.0
3.D - Other	635.2	0.0	0.0	0.0	0.0	0.0	635.2
3.D.1 - Harvested Wood Products	635.2						635.2
3.D.2 - Other (please specify)							0.0



Table C.5: Summary Land sector emission table for South Africa for 2020.

Categories	Activity Data		Net carbon stock change and CO2 emissions									Net CO ₂ emissions (Gg CO2)
	Total Area (ha)	Thereof: Area of organic soils (ha)	Biomass				Dead organic matter			Soils		
			Increase (Gg C)	Decrease (Gg C)	Carbon emitted as CH ₄ and CO from fires (1) (Gg C)	Net carbon stock change (Gg C)	Carbon stock change (Gg C)	Carbon emitted as CH ₄ and CO from fires (1) (Gg C)	Net carbon stock change (Gg C)	Net carbon stock change in mineral soils (2) (Gg C)	Carbon loss from drained organic soils (Gg C)	
3.B - Land	123 896 185.4	NE	26 187.2	17 707.4	IE	4 763.4	0.0	IE	326.3	520.4	NE	-35 332.8
3.B.1 - Forest land	21 007 068.2	NE	27 678.4	21 752.0	IE	5 926.4	57.6	IE	57.6	1 168.5	NE	-26 226.0
3.B.1.a - Forest land Remaining Forest land	19 922 055.9	NE	24 325.5	21 284.2		3 041.3	-28.9		-28.9	1 168.5	NE	-15 330.1
3.B.1.b - Land Converted to Forest land	1 085 012.3	NE	3 352.9	467.8	IE	2 885.1	86.5	IE	86.5	IE	NE	-10 896.0
3.B.1.b.i - Cropland converted to Forest Land	464 837.8	NE	647.8	133.9		513.9	24.0		24.0	IE	NE	-1 972.2
3.B.1.b.ii - Grassland converted to Forest Land	297 414.3	NE	2 210.0	99.8		2 110.2	34.2		34.2	IE	NE	-7 862.9
3.B.1.b.iii - Wetlands converted to Forest Land	195 236.4	NE	317.8	190.9		126.9	16.8		16.8	IE	NE	-526.7



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3.B.1.b.iv - Settlements converted to Forest Land	93 030.2	NE	140.6	33.1		107.4	7.0		7.0	IE	NE	-419.6
3.B.1.b.v - Other Land converted to Forest Land	34 493.5	NE	36.7	10.1		26.7	4.6		4.6	IE	NE	-114.6
3.B.2 - Cropland	13 459 383.9	NE	1 038.5	949.9	IE	88.6	14.5	IE	14.5	664.5	NE	-2 814.7
3.B.2.a - Cropland Remaining Cropland	12 337 548.0	NE	742.3	357.9		384.4	-7.9		-7.9	664.5	NE	-3 817.1
3.B.2.b - Land Converted to Cropland	1 121 835.9	NE	296.2	592.0	IE	-295.8	22.4	IE	22.4	IE	NE	1 002.4
3.B.2.b.i - Forest Land converted to Cropland	243 335.1	NE	92.3	268.7		-176.4	-17.6		-17.6	IE	NE	711.2
3.B.2.b.ii - Grassland converted to Cropland	790 022.8	NE	179.1	249.0		-69.9	37.7		37.7	IE	NE	117.8
3.B.2.b.iii - Wetlands converted to Cropland	48 748.4	NE	13.0	66.8		-53.8	1.7		1.7	IE	NE	191.3
3.B.2.b.iv - Settlements converted to Cropland	33 558.0	NE	8.6	7.1		1.4	-0.2		-0.2	IE	NE	-4.5
3.B.2.b.v - Other Land converted to Cropland	6 171.5	NE	3.2	0.4		2.8	0.9		0.9	IE	NE	-13.5
3.B.3 - Grassland	69 915 762.5	NE	2 292.5	874.7	IE	1 417.8	109.4	IE	109.4	2 966.5	NE	-16 476.6
3.B.3.a - Grassland Remaining Grassland	64 607 622.8	NE	150.1	32.8		117.2	0.7		0.7	2 966.5	NE	-11 309.4
3.B.3.b - Land Converted to Grassland	5 308 139.7	NE	2 142.5	841.9	IE	1 300.6	108.7	IE	108.7	IE	NE	-5 167.3
3.B.3.b.i - Forest Land converted to Grassland	81 805.5	NE	42.7	63.0		-20.3	-9.7		-9.7	IE	NE	110.0
3.B.3.b.ii - Cropland converted to Grassland	987 359.3	NE	235.6	61.1		174.4	-62.3		-62.3	IE	NE	-411.1



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3.B.3.b.iii - Wetlands converted to Grassland	469 804.1	NE	116.1	507.2		-391.1	-16.6		-16.6	IE	NE	1 494.7
3.B.3.b.iv - Settlements converted to Grassland	469 804.1	NE	31.8	4.8		27.0	-4.8		-4.8	IE	NE	-81.6
3.B.3.b.v - Other Land converted to Grassland	3 299 366.6	NE	1 716.3	205.8		1 510.5	202.1		202.1	IE	NE	-6 279.3
3.B.4 - Wetlands (1)	3 164 895.4	NE	500.5	194.9	IE	305.6	-3.7	IE	-3.7	-1 031.0	NE	2 673.4
3.B.4.a - Wetlands Remaining Wetlands	2 715 182.1	NE	19.4	32.1		-12.7	-0.5		-0.5	-1 031.0	NE	3 828.7
3.B.4.b - Land Converted to Wetlands	449 713.3	NE	481.0	162.7	IE	318.3	-3.2	IE	-3.2	IE	NE	-1 155.2
3.B.4.b.i - Forest Land converted to wetlands	112 339.3	NE	118.8	130.5		-11.7	-12.0		-12.0	IE	NE	86.6
3.B.4.b.ii - Cropland converted to wetlands	29 598.6	NE	35.4	3.5		31.9	-0.9		-0.9	IE	NE	-113.6
3.B.4.b.iii - Grasslands converted to wetlands	268 364.6	NE	314.0	27.4		286.6	9.6		9.6	IE	NE	-1 086.1
3.B.3.b.iv - Settlements converted to wetlands	9 969.2	NE	8.3	1.2		7.2	-0.2		-0.2	IE	NE	-25.6
3.B.3.b.v - Other Land converted to wetlands	29 441.6	NE	4.5	0.2		4.3	0.2		0.2	IE	NE	-16.5
3.B.5 Settlements	3 712 351.5	NE	707.2	446.0	IE	261.2	3.2	IE	3.2	48.6	NE	-1 147.9
3.B.5.a - Settlements Remaining Settlements	2 969 850.3	NE	565.8	43.3		522.5	-1.5		-1.5	48.6	NE	-2 088.4
3.B.5.b - Land Converted to Settlements	742 501.2	NE	141.4	402.7	IE	-261.3	4.7	IE	4.7	IE	NE	940.5



forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

3.B.5.b.i - Forest Land converted to Settlements	214 883.5	NE	40.9	247.2		-206.3	-16.0		-16.0	IE	NE	814.8
3.B.5.b.ii - Cropland converted to Settlements	82 918.8	NE	15.8	24.5		-8.7	0.1		0.1	IE	NE	31.5
3.B.5.b.iii - Grassland converted to Settlements	415 663.4	NE	79.2	117.4		-38.2	19.5		19.5	IE	NE	68.8
3.B.5.b.iv - Wetlands converted to Settlements	13 710.5	NE	2.6	13.4		-10.8	0.3		0.3	IE	NE	38.6
3.B.5.b.v - Other Land converted to Settlements	15 325.0	NE	2.9	0.2		2.7	0.9		0.9	IE	NE	-13.2
3.B.6 - Other Land	12 636 723.9	NE	0.0	1 413.1	IE	-1 413.1	-297.9	IE	-297.9	-650.6	NE	8 659.0
3.B.6.a - Other land Remaining Other land	9 833 999.5	NE				0.0			0.0	-650.6	NE	2 385.6
3.B.6.b - Land Converted to Other land	2 802 724.4	NE	0.0	1 413.1	IE	-1 413.1	-297.9	IE	-297.9	IE	NE	6 273.4
3.B.6.b.i - Forest Land converted to Other Land	291 705.6	NE	0.0	238.9		-238.9	-38.9		-38.9	IE	NE	1 018.6
3.B.6.b.ii - Cropland converted to Other Land	23 612.8	NE	0.0	6.6		-6.6	-1.8		-1.8	IE	NE	30.9
3.B.6.b.iii - Grassland converted to Other Land	2 390 879.2	NE	0.0	1 136.4		-1 136.4	-128.4		-128.4	IE	NE	4 637.8
3.B.6.b.iv - Wetlands converted to Other Land	90 330.6	NE	0.0	29.9		-29.9	-128.4		-128.4	IE	NE	580.6
3.B.6.b.v - Settlements converted to Other Land	6 196.2	NE	0.0	1.2		-1.2	-0.3		-0.3	IE	NE	5.5



Table C.6: Summary Waste sector emission table for South Africa for 2020.

Categories	Emissions [Gg]							Total emissions
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOCs	SO ₂	(Gg CO ₂ e)
4. WASTE	35.4	1 055.1	2.8	NE	NE	NE	NE	23 045.8
4A Solid Waste Disposal		869.2		0.0	0.0	0.0	0.0	18 252.8
<i>4A1 Managed Waste Disposal Sites</i>				<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>
<i>4A2 Unmanaged Waste Disposal Sites</i>				<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>
<i>4A3 Uncategorised Waste Disposal Sites</i>				<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>
4B Biological Treatment of Solid Waste		0.0	0.0	NE	NE	NE	NE	0.0
4C Incineration and Open Burning of Waste	35.4	10.6	0.2	0.0	0.0	0.0	0.0	334.9
<i>4C1 Waste Incineration</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>
<i>4C2 Open Burning of Waste</i>	<i>35.4</i>	<i>10.6</i>	<i>0.2</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>334.9</i>
4D Wastewater Treatment and Discharge	0.0	175.3	2.5	0.0	0.0	0.0	0.0	4 458.1
<i>4D1 Domestic Wastewater Treatment and Discharge</i>		<i>132.5</i>	<i>2.5</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>3 560.8</i>
<i>4D2 Industrial Wastewater Treatment and Discharge</i>		<i>42.7</i>		<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>NE</i>	<i>897.3</i>
4E Other (please specify)				0.0	0.0	0.0	0.0	0.0



Appendix D: Reference and sectoral fuel consumption

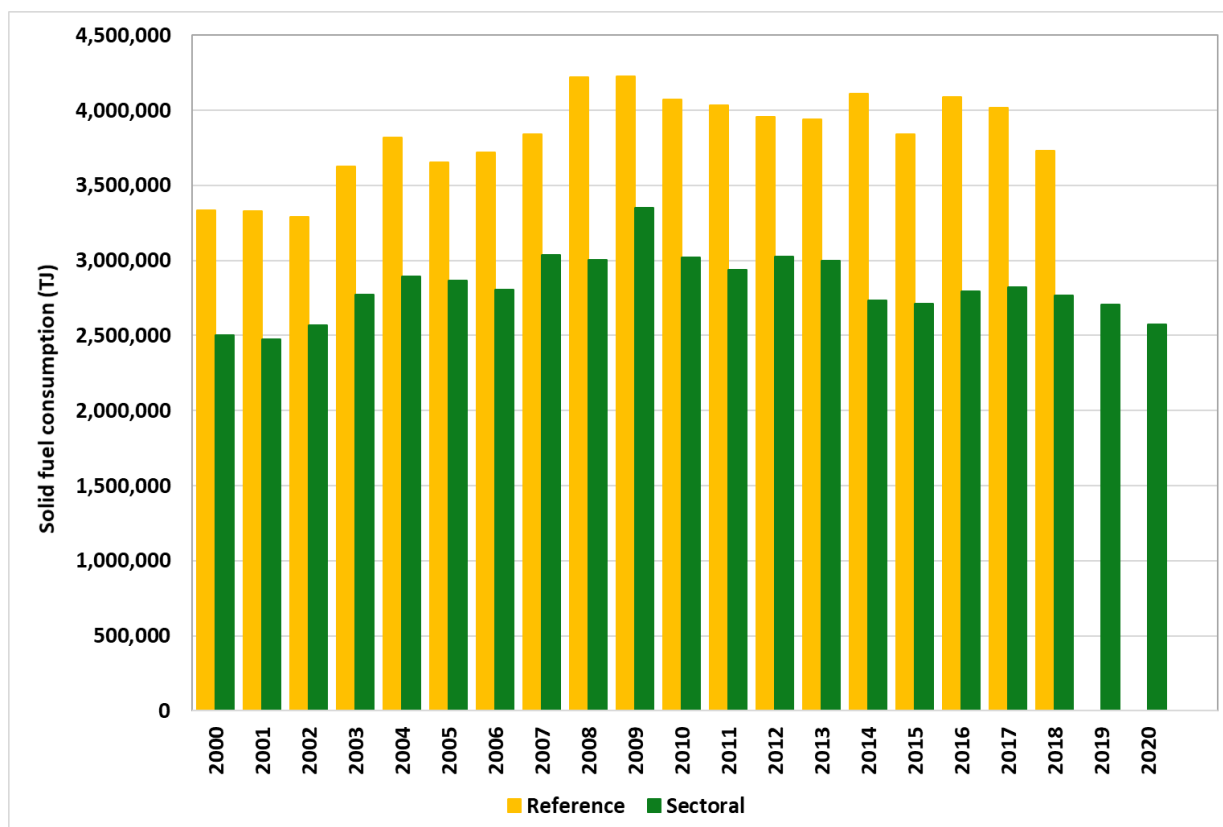


Figure D.1: Comparisons between the solid fuel consumption determined by the reference and sectoral approaches, 2000 – 2017.

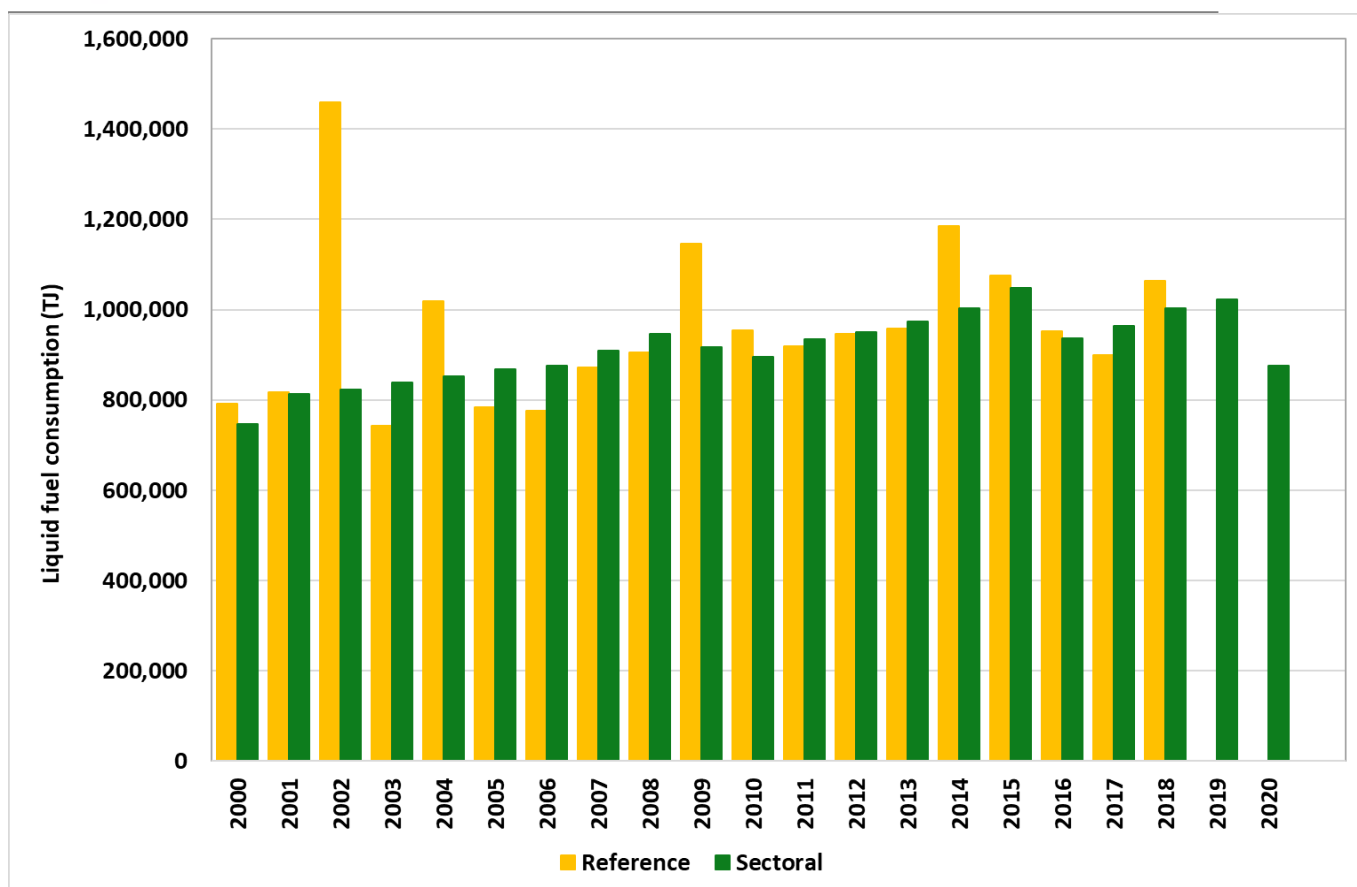


Figure D.2: Comparisons between the liquid fuel consumption determined by the reference and sectoral approaches, 2000 – 2017⁸.

⁸ 2017 is the latest year in which there is an Energy Balance

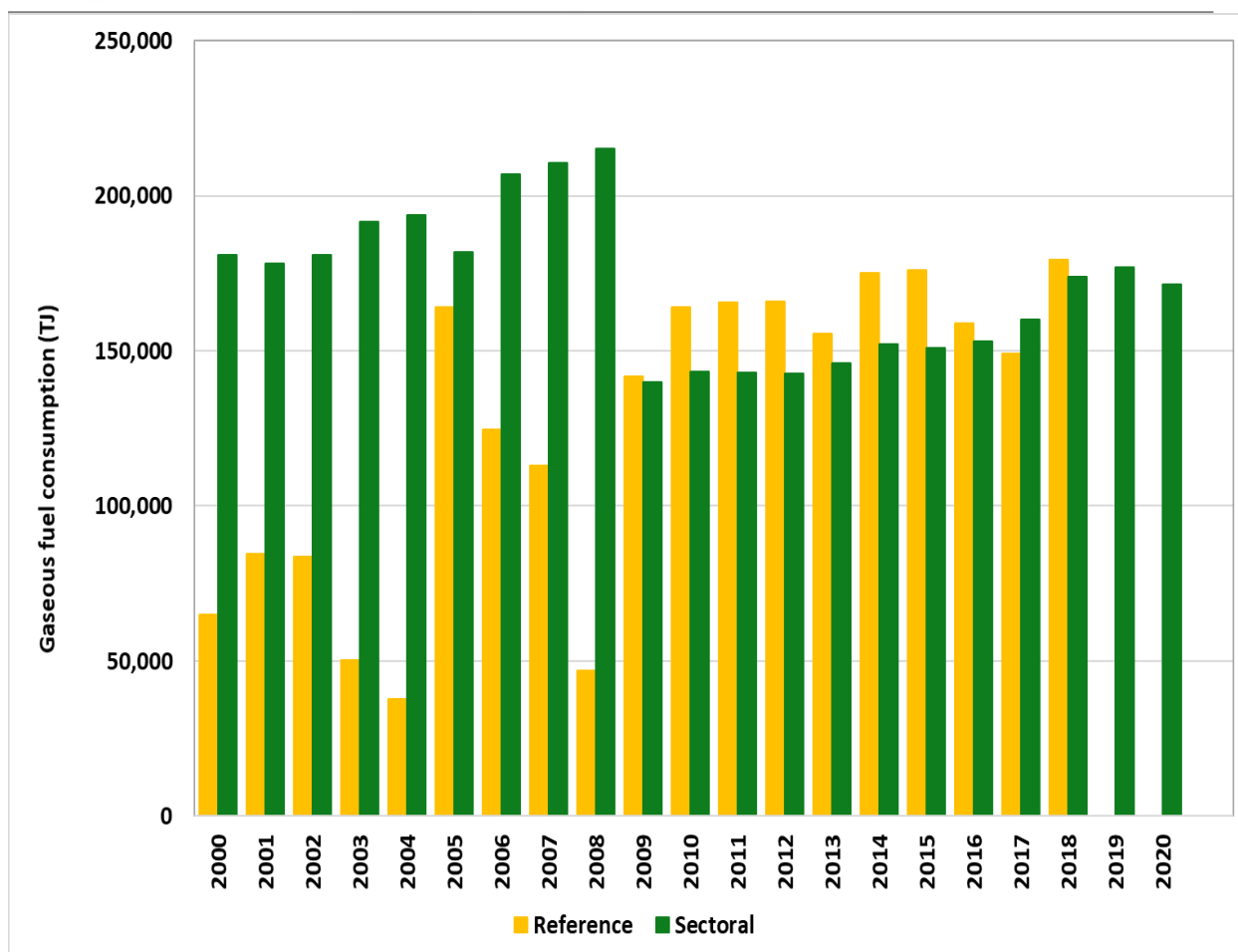


Figure D.3: Comparisons between the gaseous fuel consumption determined by the reference and sectoral approaches, 2000 – 2017⁹.

⁹ 2017 is the latest year in which there is an Energy Balance



Appendix E: Soil carbon validation methodology

Soil carbon change was then determined using the IPCC 2006 equation 2.25:

$$\Delta C_{\text{Mineral}} = [\sum \{ (SOC_{\text{REF}} * F_{\text{LU}} * F_{\text{MG}} * F_{\text{I}})_0 - (SOC_{\text{REF}} * F_{\text{LU}} * F_{\text{MG}} * F_{\text{I}})_{(0-T)} \} * A] / D$$

Where:

SOC_{REF} = the reference carbon stock (t C ha^{-1}) for each soil type;

F_{LU} = stock change factor for land-use system for a particular land-use (dimensionless);

F_{MG} = stock change factor for management regime (dimensionless);

F_{I} = stock change factor for input of organic matter (dimensionless);

Time₀ = last year of inventory time period;

Time_(0-T) = beginning of the inventory time period;

A = land area (ha);

D = time dependence of stock change factor.

This equation with Formulation A methodology (since land parcels are not being tracked) was utilized to determine stock change per land type per soil type to compare with the inventory method using the carbon stock data. The methodology for determining SOC reference values and stock change factors to incorporate into the equation for the comparison are described in detail below.

Country specific SOC reference values were determined for each of the 7 soil classes (see section 5.4.2.7.) by overlaying the ISRIC soil carbon data (for the top 30cm) with the soils map. This process involved:

- extracting the soil carbon data to fit the South African boundary;
- re-projection of the ISRIC soil carbon data (top 30cm) to match the same coordinates as the Landcover datasets (UTM 35 S);
- resampling of SOC data to change the cell size from 250 x 250 m to 100 x 100 m (1 ha);
- creation of a sub-datasets for the soil types so that each soil type is a standalone file;
- extraction of the ISRIC SOC dataset to each of the IPCC soil types (“extract by mask”) to determine the SOC per soil type;
- calculation of a weighted average SOC was carried out using the ‘Value’ (t/ha) and Counts (number of cells that match the value);
- Conducting QA/QC on the counts of the 100m cell size datasets before and after they were analysed in relation to the soil types.



The resultant SOCRef values are provided in Table AE.1. These values were compared to IPCC default factors and Wetland soils had a lower SOC and low activity clay had higher values. The differences could be due to slight variations in soil classification for the various IPCC classes. The sandy soil and high activity clay values are most closely matched to the IPCC values and these are the dominant soil types, constituting 20% and 66% of the total area, respectively.

Table AE.1: Soil carbon reference data per soil type as obtained from ISRIC database.

	SOCRef value (t C/ha)	IPCC 2006 default ¹⁰	IPCC 2019 Refinement
Sandy mineral soils	20.85	19	10 ±5%
Wetland soils	40.53	88	74 ±17%
Spodic soils	71.65	115 ¹¹	143 ±30%
Rocky soils	47.03	NA	NA
Low activity clay	65.54	24	19 ±16%
High activity clay	35.21	38	24 ±5%

Country specific stock change factors were applied where possible. For forest lands a stock change factor of 1 was applied, while the factors for croplands, grasslands and settlements are shown in **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.** and are described below.

Cropland stock change factors for management, input and land use were determined from data reported in Moeletsi et al. (2015) and Tongwane et al. (2016). Management and inputs differ between the crop types, therefore data on the area planted to the various commercial annual crops was sourced from DALRRD (2018), national statistics (Stats SA, 2007), Crop Estimates Committee, and FAO (FAOStats, 2020). This area was compared to the area from the LC maps and it was found that the planted area was much less than the total cropland area and this was therefore investigated. For annual crops the LC cropland area includes fallow land and pastures. Moeletsi et al. (2015) provides fallow land as a percentage of the crop types, therefore the area of fallow land was calculated from this data. For pastures, the GIS expert (Fanie Ferrera, pers. Comm., 2017) provided some data for three provinces that indicated the area of pastures. From this data an average percentage of pastures was determined, and this was applied to the whole cropland area

¹⁰ Defaults are for warm, temperate climates

¹¹ This is the default value for cold, temperate climates as there is no value for warm, temperate environments.



supplied in the LC maps. It was also assumed that this percentage remained the same each year of the time series.

The management and input data was combined with the IPCC 2019 Refinement default stock change factors and climate data to determine the stock change factors for each crop type (Table AE.2). The 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. For subsistence crops the stock change factor of 0.58 from the NTCSA (DEFF, 2020) was applied.

Table AE.2: Stock change factors for the various crop types in South Africa.

Crop type	Stock change factors		
	Land use (F_{LU})	Management (F_{MG})	Inputs (F_I)
	Dry climate		
Barley	0.8	1	0.98
Cabbage		1	1.04
Cotton		1	0.51
Drybeans		1.001	0.99
General vegetables		1	1.04
Groundnut		1	1.01
Legumes		1	1.01
Lucerne		1	0.92
Maize		1.003	0.95
Onions		1	1.03
Other field crops		1	0.96
Other fodder crops		1	0.53
Other oil seeds		1	0.99
Other summer cereal		1.003	0.95
Other winter cereals		1.001	0.99
Potato		1	1.04
Silage		1.002	0.95
Sorghum		1	1.00
Soybean		1	0.56
Sugarcane		1	0.96
Sunflower		1	0.87
Teff		1.002	0.53
Tobacco		1	1.02



Tomato		1	1.02
Wheat		1.001	1
General annual crop		1.003	0.95
Fallow land		1.13	0
Pasture		1.13	0.51
Orchards and vines	1	1	1

For *Grassland* stock change factors, in the previous submission Grassland mineral soil carbon stocks were assumed equal to the reference values (i.e. the stock change factors for management and input are equal to 1). As in the previous inventory improved and degraded grasslands were incorporated. The 2018 land cover maps do not have any division for grasslands, however the land cover maps for 1994/95 (Fairbanks et al., 2000) had degraded and improved lands incorporated. These maps indicated that 0.45% of grasslands were improved. Matsika (2007) researched degradation in grasslands and showed that 26.7% of grasslands had low degradation, 58.7% moderate degradation and 14.6% had high degradation. Unfortunately, spatial data for this could not be incorporated due to not all the data being available and also the maps were all for different years and scales making it hard to combine. This could be something to include in future. Since the data was not spatial the percentage improved and degraded was combined with the IPCC default stock change factors to obtain weighted average management stock change factors for grasslands for each climate type (Table AE.3). The grassland management data is only once-off data therefore it was assumed, for now, that the amount improved and degraded has remained constant over the 2000 to 2020 period.

Table AE.3: Stock change factors for grasslands in South Africa.

Grassland type	Stock change factors		
	Land use (F _{LU})	Management (F _{MG})	Inputs (F _I)
		WTD climate	
Grasslands	1	0.85	1
Low shrublands	1	1	1

The *Settlement* mineral soil carbon stocks were assumed equal to the reference values (i.e. the stock change factors for management and input are equal to 1). The land use characteristics of settlements (i.e. barren land, woodlands, infrastructure, etc) were combined with the IPCC 2006 land use stock change factors to estimate a weighted



average land use stock change factor for settlements (Table AE.4Error! Reference source not found.). This factor was assumed to remain constant for the period 2000 to 2020, and this can be improved in future inventories if data becomes available.

Table AE.4: Stock change factors for settlements in South Africa.

Grassland type	Stock change factors		
	Land use (F_{LU})	Management (F_{MG})	Inputs (F_i)
Settlements	0.831	1	1
Mines	1	1	1

The SOC reference values and stock change data was incorporated into the equations to determine the total carbon for each land type in 1990 and in 2014 so annual SOC change could be determined for each land type. The outputs were then compared to the data from the NTCSA data utilised in the inventory. The results are shown in section 5.4.3.2. of the report.



Appendix F: External review of inventory

An external review of the inventory is conducted with each inventory report. Note that some of the sections are not included due to space limitations, but a full report can be requested from DFFE should it be required. The sections that have been removed are indicated in the contents page of the review below.





GHG Inventory Review Report

South Africa's 7th National GHG
Inventory: 2000 - 2017

26 February 2021

Project No.: 0512749

Document details	
Document title	GHG Inventory Review Report
Document subtitle	South Africa's 7 th National GHG Inventory: 2000 - 2017
Project No.	0512749
Date	26 February 2021
Version	1.0 draft dated 12 October 2020, comments received 20 January 2021
	2.0 final dated 26 February 2021
Author	Mr Thapelo Letete, Dr Brett Cohen, Ms Zniko Nhlapho, Ms Zama Luthuli, Dr MphetheTongwane, Dr Mokhele Moeletsi
Client Name	GIZ

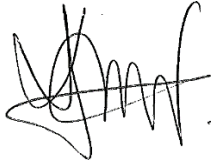
CONTENTS

Signature Page

26 February 2021

GHG Inventory Review Report

South Africa's 7th National GHG Inventory: 2000 - 2017



Clemence McNulty
Partner



Thapelo Letete
Technical Reviewer

ERM Southern
Africa, 1st Floor,
Building 32

The Woodlands Office
Park Woodlands Drive
Woodmead, 2148
Johannesburg

South Africa

© Copyright 2021 by ERM Worldwide Group Ltd and / or its affiliates ("ERM").

All rights reserved. No part of this work may be reproduced or transmitted in any form, or by any means, without the prior written permission of ERM.

I.	INTRODUCTION.....	1
II.	SUMMARY AND GENERAL ASSESSMENT OF THE DRAFT 7 TH NATIONAL GHG INVENTORY.....	2
III.	STATUS OF IMPLEMENTATION OF ISSUES AND/ OR PROBLEMS RAISED IN THE PREVIOUS INDEPENDENT REVIEW REPORT	3
IV.	STATUS OF IMPLEMENTATION OF ISSUES AND/OR PROBLEMS RAISED IN UNFCCC'S INFORMAL REVIEW OF THE 6 TH GHG INVENTORY	49
V.	STATUS OF IMPLEMENTATION OF ISSUES AND/ OR PROBLEMS RAISED IN THE TECHNICAL ANALYSIS OF THE 2 ND BUR (TASR) <i>[Excluded here, but can be found in the complete report]</i>	64
VI.	ADDITIONAL FINDINGS MADE DURING THE INDEPENDENT REVIEW OF THE DRAFT 7 TH GHG INVENTORY <i>[Excluded here, but can be found in the full report]</i>	68

List of Tables

Table 1: Composition of the ERT that conducted the review of South Africa.....	1
Table 2: Summary of review results and general assessment of the 7 th National GHG Inventory of South Africa.....	2
Table 3: Status of implementation of issues and/or problems raised in the previous (2018) independent review 6 th report of South Africa	3
Table 4: Status of implementation of issues and/or problems raised in the review report of UNFCCC's informal review of the 6 th Inventory	49
Table 5: Status of implementation of issues and/or problems raised in the summary report of the technical analysis of [South Africa]'s 2 nd BUR	64
Table 6: Additional findings made during the independent review of the draft 7 th National GHG inventory	68
Table 7: Findings and recommendations in respect of grammatical errors, typos, references, etc	111
Table 8: Total greenhouse gas emissions for South Africa, 2000 - 2017	114
Table 9: Greenhouse gas emission by gas for South Africa, excluding land use, land-use change and forestry 2000 – 2017	115
Table 10: Greenhouse gas emissions by sector for South Africa, 2000 – 2017	116

I. SUMMARY AND GENERAL ASSESSMENT OF THE DRAFT 7TH NATIONAL GHG INVENTORY

Table 2 provides the ERT assessment of the annual submission with respect to the tasks undertaken during the review. Further information on the issues identified, as well as additional findings, may be found in Tables 3 to 7.

Table 2: Summary of review results and general assessment of the 7th National GHG Inventory of South Africa

Assessment		Issue or problem ID #(s) in tables 3 and/or 5
General adherence to IPCC Guidelines for National Greenhouse Gas Inventories	Have any issues been identified in the following areas:	
	1. Identification of key categories	[Yes][No]
	2. Selection and use of methodologies and assumptions	[Yes][No]
	3. Development and selection of emission factors	[Yes][No]
	4. Collection and selection of activity data	[Yes][No]
	5. Reporting of recalculations	[Yes][No]
	6. Reporting of a consistent time series	[Yes][No]
	7. Reporting of uncertainties, including methodologies	[Yes][No]
	8. Quality assurance/ quality control (QA/QC) ^b	[Yes][No]
	9. Missing categories/ completeness	[Yes][No]
Description of trends	Did the ERT conclude that the description in the NIR of the trends for the different gases and sectors is reasonable?	[Yes][No]

^a Missing categories, for which methods are provided in the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, may affect completeness and are listed in Annex III to this document.

II. STATUS OF IMPLEMENTATION OF ISSUES AND/ OR PROBLEMS RAISED IN THE PREVIOUS INDEPENDENT REVIEW REPORT

Table 3 presents all the recommendations made in the previous review report compiled in 2018. For each issue and/ or problem, the ERT specified whether it believes the issue and/ or problem has been resolved in the GHG inventory under review and provided the rationale for its determination. During the review, the Party gave feedback and explanations to the ERT's assessment of the status of implementation.

Table 3: Status of implementation of issues and/or problems raised in the previous (2018) independent review report of the 6th national GHG inventory of South Africa

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
General			
G.1	Consistency (214, 2018) Consistency	214. Ensure greater consistency with respect to reported data, terminology, and methodologies, within the NIR and across related disclosures: a) Provide greater clarity regarding the source of activity data in the NIR. The NIR and CRF tables should include, as Annexes or as separate documents, the activity data on which the calculations are based, together with assumptions and specific references to promote transparency. b) Provide greater clarity with respect to recalculations performed. c) Relook at the Trend Assessment, using granular data, to get a more consistent approach and accuracy of key categories. d) Correct for data errors, Ambiguity and double counting, and fill immediate gaps. Specifically data reported in the NIR must match corresponding values included in the CRF tables.	Addressing. a) In the draft 7th GHG Inventory, the Party did not include the activity data, assumptions and references as Annexes or as separate documents to the NIR or the CRF tables. During the review, the Party explained that this is being addressed for IPPU and Energy in 2019 NIR. b) In the draft 7th GHG Inventory, the Party provided information on recalculations on page xii of the executive summary and category specific recalculations in specific category sections of the NIR. There are other recalculations, however, that were not documented, such as recalculations for hydrated lime emissions due to corrected emission factor (section 1.8.2). During the review, the Party acknowledged the gaps and explained that it will include clearer and more complete explanatory information and justifications in the next inventory, 2019 NIR c) In the draft 7th GHG Inventory, the Party did not undertake the trend assessment using granular data. During the review the Party explained that this will be addressed in the next NIR. d) In the draft 7th GHG Inventory, there still existed data errors and areas where the data reported in the NIR did not match corresponding values in the CRF

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			tables. Specific details of these have been outlined in the sector-specific sections of this report. During the review, the Party explained that it has noted the need to enhance QA/QC procedures going forward. This part of the recommendation is not resolved.
G.2	Activity data (215, 2018) Accuracy	215. Invest resources in further improving activity data, methodologies and country-specific emissions factors: a) Undertake efforts to gather data and establish, or identify, methodologies to estimate emissions from sectors currently excluded from the NIR (this was identified as an action item in the NIR review conducted in 2009 and 2013). For example, the Party should identify and endeavour to include all additional sources of HFC and PFC emissions. b) Country specific or more representative emissions factors should be used. c) Undertake efforts to disaggregate activity data: attempt to eliminate broad categories such as “Other Energy Use” and focus on categories with insufficient data, such as AFOLU. d) Higher tier methodologies should be applied for the calculation of emissions for key categories. e) Document the justification for the use of uncertainty estimates chosen for the emission factors and activity data in the Energy and IPPU sectors. Complete an uncertainty analysis for the AFOLU and waste sectors. f) SF6 emissions should be estimated for future GHG inventory submissions (due to the magnitude of the power transmission network in South Africa and the high global warming potential of the gas).	Addressing. In the draft 7th GHG Inventory, the Party has reported it has invested resources in improving the activity data, methodologies and country-specific emission factors and has transparently reported on most calculations and recalculations, with only a few exceptions detailed out in the sector-specific sections of this review report. Furthermore, the Party has correctly used the IPCC SAR GWPs as required by the UNFCCC GHG guidelines for non-Annex 1 parties. During the review the Party gave the following clarifications regarding the 2018 review recommendations: a) The HFC Survey was completed in 2016/17, and its update planned to be undertaken in 2020, focussing on the Refrigeration and Air conditioning. Addressing. b) DFFE implements a GHG improvement programme targeting specific sectors to collect country-specific data, parameters and develop country-specific emission factors. Thus, work in progress. Addressing. c) Will be addressed in the next NIR. Not resolved. d) Comment Noted, to be incorporated in future inventories. Not resolved. e) Will be addressed in the next NIR. Not resolved. f) Comment Noted, to be incorporated in future inventories and later stated that this has been resolved. However, the ERT noted that page xxv of the draft NIR states that “It should be noted that SF6 has not yet been included in the inventory”, hence this issue is still Not resolved. g) The use of GWP values is guided by UNFCCC Non-Annex I Parties, which currently is AR2. Resolved.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		g) Investigate the potential use of AR4 GWPs. h) Ensure that all calculations are transparently documented in the CRF in future inventories. i) Document the results of recalculations and provide reasons for why data has increased or decreased.	h) NIR provides methodologies section for each category covered in the inventory. Additional information can be provided for other sectors to enhance transparency. Addressing. i) Comment Noted. Recalculations are currently documented in the NIR however, comment noted. Addressing.
G.3	NIR (216, 2018) Transparency	216. Provide more complete referencing and substantiation of data, assertions and assumptions. a) Complete method statements for all sectors and subsectors which details the activity data, assumptions and references to enable external verification. Improve transparency of data collection procedures as well as the derivation of local emission factors. b) Provide additional information on the appropriateness and relevance of source references to better justify the use of these references. c) Apply the QC/QA system consistently across all sectors.	Not resolved. In the draft 7th GHG Inventory, referencing and substantiation of data and assumptions still exist, as detailed out in the sector-specific areas of this review report (e.g. references to the SAMI reports used in the IPPU sector). The ERT therefore noted that the issue is not resolved because all the issues raised in this recommendation still persist in the draft 2017 GHG inventory. During the review, the Party explained that it has noted the recommendations.
G.4	National system (217, 2018) Not an issue	217. Continue to build on the NGHGIS with attention on the following elements: a) Appoint and capacitate sufficient staff members in order to effectively manage the inventory process, using the NGHGIS. b) Complete method statements for all of the categories and sub-categories reported on in the NIR. These must be updated on the NGHGIS and kept up-to-date on a regular basis. c) Update all NIR reference material in the NGHGIS. d) Develop and document an archiving plan, set of procedures and appoint a designated archiving manager. Future plans related to archiving should be communicated clearly in the NIR.	Not resolved. During the review, the Party explained that it has noted the recommendations, therefore the ERT noted that the issue is not resolved.
G.5	Further improvements	218. Ensure areas for further improvement identified in Section G. are implemented.	Not resolved

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(identified by the Party) (218, 2018) Not an issue		During the review, the Party explained that it has noted the recommendations, and that they will be implemented subject to availability of funding.
Energy			
E.1	1. General (energy sector) (46, 2018) Accuracy	For many Key Categories, DFFE was forced to utilise Department of Energy (DoE) Energy Balance data for reasons not related to improving the NIR. The change to the DoE Energy Balance is cited as being due to staff turnover and no documentation to enable the same approach as undertaken for the 2012 NIR. This has contributed to significant time series fluctuations which, coupled with a lack of information explaining changes in the DoE Energy Balances, makes it difficult to understand drivers of change. Additionally, the 2015 Energy Balance was not available at the time of calculation and where this represents the source, 2014 values have been used for 2015 (as indicated below, this approach significantly misrepresents emissions given the actual 2015 values). The Party should explain why the DoE Energy Balances are deemed an appropriate source for some energy sub-categories but not for others. Where DoE Energy Balance data is used, the DFFE should work with the DoE to understand and document, in greater detail, the data collection and analysis processes and collectively investigate and explain reasons for changes over time.	Not resolved In the draft 7th GHG Inventory, the Party reported that the main source of data for the energy sector remains the DoE Energy Balance (page 10 of the NIR), although Table 1.3 and Table 3.6 indicate that a mix of data sources was used, including the Energy Balance. The NIR also indicates that 2014 values are still used as the 2015 Inventory was not available. No further explanations have been provided which address the previous independent review concerns. During the review, the Party stated that this issue has been resolved, however no further details were given to support this statement. The ERT noted that the issue remains unresolved because many of the issues raised in this recommendation still persist in the draft 2017 GHG inventory. .
E.2	1. General (energy sector) (47, 2018) Transparency	Generally, the drivers of changes in emissions (or explanatory variables) are not well explained and therefore are assumed to not be well understood. Given significant recent effort by the Department of Environmental Affairs (in informing Desired Emissions Reduction Outcomes and Carbon Budgets) and National Treasury (in developing the proposed carbon tax) it is expected that the Party should have a better	Addressing In the draft 7th GHG Inventory, the Party has provided some information on the drivers of change. However, the information provided is still relatively high level and the drivers are not always fully. Further work is required to unpack this in further detail, which will help contribute to a deeper interrogation of the data.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		understanding of the drivers than is communicated in the NIR. Effort should be directed towards integrating this knowledge into a better explanation of the inventory over time. Additionally, the description of changes over time is generally more detailed for earlier changes. More recent changes and information on the current conditions is less well explained.	During the review the Party indicated that this has been partly addressed and will still be addressed further, however no further details were given. The ERT noted that the issue is addressing because the issues raised in this recommendation still persist in the draft 2017 GHG inventory.
E.3	1. General (energy sector) (48, 2018) Transparency	In many cases, because of a lack of additional data and a description of methods and sources (notably in cases where the NIR relies on DoE Energy Balance data on emissions provided directly by the national utility or refineries), it is not possible to comment further on the methodology used, methods used to gather activity data, emissions factors used or the uncertainty of either the emissions factors or the activity data. However, there are other studies done, which are very thorough and methodical, and that provide data at a level of disaggregation which would enable an improved inventory (e.g. the GIZ funded fuel study (DFFE GIZ, 2016)).	Addressing In the draft 7th GHG Inventory, the Party has given additional descriptions of methods and sources, including replacing energy balance data with data from other studies for certain emissions categories. However, there are still a number of places in the NIR where it is not possible to comment further on methodologies, methods used to gather activity data, emissions factors used or uncertainty. The ERT noted that the issue is addressing because while some issues raised in this recommendation have been addressed, there are many that still persist in the draft 2017 GHG inventory. During the review the Party acknowledged that this issue has been addressed partially.
E.4	1. General (energy sector) (49, 2018) Transparency	In instances where facilities would generate emissions under more than one IPCC sub-category, the lack of information provided and the lack of publicly available sources against which to make comparisons (at the required level of disaggregation), makes it difficult to assess whether there has been double counting.	Not resolved In the draft 7th GHG Inventory, there was still insufficient information presented nor publicly available data sources to assess whether there was double counting of emissions from more than one IPCC sub-category. During the review the Party indicated that this will be addressed in the next issue. The ERT noted that the issue is not resolved because the issues raised in this recommendation still persist in the draft 2017 GHG inventory.
E.5	1. General (energy sector) (50, 2018) Accuracy	With the implementation of the GHG reporting regulations it is presumed that there will be significant improvements in the source data. The party should articulate what the implementation of these	Addressing In the draft 7th GHG Inventory, the Party has provided a high level indication that the mandatory reporting will help gather better data for the IPPU sector, but no mention is made of the implications of the data for improving the NIRs for the

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		regulations will mean with respect to improvements in the energy sector emissions of future NIRs.	energy sector (noting that the regulations have not yet been in place long enough to collect meaningful data). During the review, the Party stated that this is being partially addressed for some big emitters. The ERT therefore noted that the issue is addressing.
E.6	1. General (energy sector) (53, 2018) Transparency	According to the NIR the main reasons for the difference between the approaches is due to differences in the allocation of solid fuels between energy use, non-energy use as well as use for synfuels production, and the use of different source data. "Generic" reasons for the differences are described. Significantly more detail was provided attempting to explain differences in the 2012 NIR. It is not clear why the 2015 NIR has scaled back this level of detailed analysis and reporting. Further explanation is recommended.	Not resolved In the draft 7th GHG Inventory, the Party has noted exactly the same explanation for the differences between the approaches (NIR page 98) as was given in the 2015 NIR. No further detail is provided. During the review the Party explained that this will be addressed in the next issue. The ERT therefore noted that the issue is not resolved.
E.7	1.A.3 Transport (55, 2018) Transparency	Activity data are based on a combination of DoE energy balances and South African Petroleum Industry Association (SAPIA) annual reports. It was not clear which sources were used for the different sources of activity data. The SAPIA data could not be accessed. The Independent Reviewer found that there are inconsistencies between the activity data in the NIR calculation spreadsheets and the DoE Energy Balances. The NIR notes the challenge in splitting fuel consumption of international and domestic flights. The Party indicates that the split was made based on the DoE energy balances but highlights that no explanation is provided regarding the reason for this change, so this needs to be investigated further.	Addressing In the draft 7th GHG Inventory, Section 3.7 states that the recent fuel consumption study was used, while Table 3.6 suggests that it is still SAPIA and energy balanced data. As such, it is not clear which data was used and hence not possible to confirm whether this issue has been addressed by using the fuel consumption study (however see the next comment E.8). During the review, the Party indicated that this issue is addressed partially. The ERT noted that the issue is being addressed.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.8	1.A.3 Transport (56, 2018) Comparability	The significant shift (87% increase) between 2012 (based on SAPIA data) and 2013 (based on DoE Energy Balance data) is noted and the need for further investigation is suggested. However, the Party also suggests that the SAPIA and DoE energy balance datasets produce very similar outputs. This is not substantiated given the significant shift in the source data. Significantly improved meta data and explanations of changes are needed in this area.	Resolved In the draft 7 th GHG Inventory, in NIR Section 3.7, the Party reported that the fuel consumption study was used, while Table 3.6 suggest that it is still SAPIA and energy balance data. The marked increase in emissions can no longer be seen in the inventory. The ERT noted that the issue is resolved because this significant increase is no longer seen, so it could be that the fuel consumption study is used.
E.9	1.A.3.d Domestic navigation CO ₂ e (57, 2018) Completeness	GHG emissions associated with (1.A.3.d.1) international water - borne navigation was not estimated due to a "lack of data" and by default included in national totals. The NIR notes that this is not in line with the 2006 IPCC Guidelines, which require marine bunkers to be reported separately from the national totals. The Party suggests a commitment to collecting improved data on marine activities. This was raised as a recommendation by the Independent Reviewers of the 2012 and 2010 inventory. Further, this Independent Review suggests that supply data could be collected from the major oil companies, as well as bunker fuel supply data for international use (SARS requires that records are maintained for foreign going ships). Treasury data for international shipping bunker fuel excise refunds could be obtained to validate the oil companies' data. Unofficial industry reports indicate national aggregate shipping bunker fuel consumption in excess of 2 million tons per year.	Resolved In the draft 7 th GHG Inventory, in its NIR Section 3.2.7 the Party has reported international aviation and international water-borne navigation in international bunker fuels as 11 605 Gg CO ₂ e. The ERT noted that the issue is resolved because emissions from international water-borne navigation have been included.
E.10	1. General (energy sector) (219, 2018) Completeness	The Party should ensure that all inconsistencies in data presented in the Energy section and sub-sections are eliminated. This includes conflicting values appearing in graphics and text.	Not resolved In the draft 7 th GHG Inventory, a number of inconsistencies were still highlighted. See sector-specific comments. During the review, the Party indicated that this is addressed partially, without providing evidence. The ERT however, noted that the issue is not resolved because inconsistencies still remain.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.11	1. General (energy sector) (220, 2018) Transparency	The NIR relies on data from a combination of sources some of which are confidential. In all cases there is a need to describe the data collection, the activity data itself, the methodologies used in estimating emissions, reporting and QA/QC processes adopted by the data providers.	Addressing In the draft 7th GHG Inventory, this issue has been addressed in some sections but not others, and is an area that will require constant improvement. For example, in coal usage data a very high level description is provided of how it is estimated for certain time periods (e.g. up to 2012), but not thereafter. There still appears to be gaps in fully describing data sources from third parties (e.g. Sasol and PetroSA). During the review, the Party explained that this is addressed partially. The ERT noted that the issue is addressing as it is still an area of ongoing improvement.
E.12	1. General (energy sector) (221, 2018) Consistency	Where the Party has had to change to using DoE Energy Balance data (due to reported staff turnover and lack of process documentation or other reasons) and efforts should be made to understand, justify and describe the implications of this. In certain cases, explicit comparisons need to be made to other sourced data (as indicated per key category).	Not resolved In the draft 7th GHG Inventory, comparisons have been made to other sources in many places, however the findings from the comparisons and implications are not always described. During the review, the Party explained that this will be resolved in the next issue. The ERT noted that the issue is not resolved as further explanations, analysis and discussions are required.
E.13	1. General (energy sector) (222, 2018) Accuracy	Where DoE Energy Balance data has been used, the 2015 figures should be updated to reflect the actual values now that the 2015 Energy Balance is available.	Not resolved In the draft 7th GHG Inventory, on page 98 of the NIR it is stated that 2015 energy balance data is not available. The ERT noted that the issue is not resolved as the inventory is still based on 2014 data (even though at the time of the 2015 inventory review the balance appears to have been available in the public domain).

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.14	1. General (energy sector) (223, 2018) Transparency	The Party should clarify the source of NCVs in table 3.5 particularly for non-liquid fuels, clarify why the country-specific emission factor for gas has not been applied and should work with DoE to develop country specific fuel NCVs.	Resolved In the draft 7 th GHG Inventory, the Party has reported the source of the NCVs on page 94. The ERT noted that the issue is resolved because the source of the data has been reported.
E.15	1. General (energy sector) (224, 2018) Accuracy	Commitments to improve the NIR should be accompanied by a timeframe or indication of prioritisation in order to avoid making the same commitments with each iteration of the NIR without implementing the proposed changes.	Addressing In the draft 7 th GHG Inventory, information is provided on the timing of various projects which will contribute to improving data. However, there are other future improvements that are highlighted but where no information is provided on timeframes or prioritisation. During the review, the Party stated that this has been resolved, however no further details were given to support this statement. The ERT noted that the issue is considered as addressing because timeframes are presented for existing activities but no timelines or prioritisation of other improvements has been included in the inventory.
E.16	1. General (energy sector) (225, 2018) Accuracy	It is recommended that the “fuel study” - a project with the objective being the disaggregation of combustion fuels (excluding coal) data according to the demand-side sectors and sub-sectors over the period 2000 to 2012 - recommendations be incorporated into the inventory improvement plan. Alternatively, the Party also needs to explain why the Fuel Study commissioned as part of the 2012 NIR does not seem to have been used as part of the 2015 NIR process.	Resolved In the draft 7 th GHG Inventory, the Party has stated that the fuel consumption study has been used in the calculation of aviation and water borne navigation emissions. The second part of the study will only be available in December 2019 and a note has been made this data will be used to update the NIR. The ERT noted that the issue is resolved because the NIR mentions where the fuel study has been used and that it will be used to improve the future inventory.
E.17	1.A.2 Manufacturing Industries and Construction CO ₂ (226, 2018) Accuracy	The NIR should indicate why the country specific emission factor for sub-bituminous coal has not been applied to historical data for the Manufacturing Industries and Construction category as well as the Other Sectors category but was applied to historical data for other categories (e.g. Main Activity Electricity and Heat Production).	Not resolved In the draft 7 th National GHG Inventory, in its NIR Section 3.2.6, (Emission factors), the Party reports that a country-specific emission factor for CO ₂ for sub-bituminous coal was applied. In the Energy CRF (1A2 Manufacturing Construction, Emissions Factors table), the Party reports sub-bituminous coal CO ₂ emission factor as 96 250 kg CO ₂ /TJ.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			During the review, the Party explained that this will be resolved in the next NIR. The ERT noted that this issue has not been resolved because in SA's Technical Guidelines for MRV (Annex A, Table A1) sub-bituminous coal CO₂ emission factor is 96 100 kgCO₂/TJ.
E.18	1.A.4 Other sectors CO ₂ (227, 2018) Accuracy	It is recommended that the emission factor used for residential coal use (Other Sectors– Solid and Liquid Fuels) is either clarified or corrected in the NIR – if a Tier 2 emissions factor is used, then an explanation as to how this emissions factor was arrived at needs to be included in the NIR. On the other hand, if a Tier 1 emissions factor is used instead (and the emissions recalculated) then the NIR should explain why a Tier 1 emissions factor for sub-bituminous coal was used, based on a clear description of the type of coal used in households in South Africa. It is recommended that a Tier 2 emissions factor is used for estimating emissions in this category, based on a survey of the characteristics of coal used in this sector, and on any relevant information on combustion practices.	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.2.6, (Emission factors), the Party reports that a country-specific emission factor for CO₂ for sub-bituminous coal was applied. In the Energy CRF (1A4 Other Sectors tab, Emissions Factors table), the Party reports sub-bituminous coal CO₂ emission factor as 96 250kgCO₂/TJ. During the review, no feedback on this issue was received from the Party. The ERT noted that this issue is not resolved because in SA's Technical Guidelines for MRV (Annex A, Table A1) sub-bituminous coal CO₂ emission factor is 96 100 kgCO₂/TJ.
E.19	1.A.4.a Commercial/Institutional (228, 2018) Transparency	- It is recommended that, in the case of the commercial / institutional gas / diesel oil data (Other Sectors – Solid and Liquid Fuels), the Party should provide greater detail on the “linear” extrapolation approach used and indicate reasons for the growth rates chosen, reasons why actual data has not been used and an indication of steps planned to improve the activity data used in the NIR. Commercial / Institutional sub-sector. - For residential liquid fuel consumption, the Party should indicate sources of liquid fuels data between 2000 and 2012.	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.2.8, (Activity data), the Party reports “Data on fuel consumption in the commercial/institutional buildings category was sourced from the DoE's energy digest reports, the DMR's SAMI report (solid fuels and natural gas) and SAPIA (liquid fuels) for 2000 to 2017.” During the review, the Party explained that this is being addressed partially without providing further information. .. Commercial / institutional gas / diesel oil data: The ERT then noted that the issue is not resolved because although the data has been provided for Gas/diesel oil in the CRF (1A4 Other Sectors tab), no further details on sources have been provided.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			Residential liquid fuel consumption: The ERT noted that the issue is not resolved because although the data has been provided for kerosene, residual fuel oil for Residential use in the CRF (1A4 Other Sectors tab), and no further details on sources have been provided.
E.20	1.A.4 Other sectors (229, 2018) Transparency	It is recommended that, in the case of liquid fuels in the Other Sectors, the Party should - draw on the findings of the Fuel Study, - check and correct source data inconsistencies as identified, and - specify the source for motor gasoline used in the agriculture sector and indicate why it is a more reliable source than the DoE Energy Balances. Furthermore, the reason for not including motor gasoline in the Commercial / Institutional sub-sector should be provided.	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.2.8, (Activity data), the Party reports on various data sources including SAPIA, SAMI Reports, and DoE Energy Balances. During the review, the Party explained that this will be resolved in the next issue. - The ERT noted that the issue is not resolved because although liquid fuel data has been provided, there are no sources indicated. - The ERT noted that the issue is not resolved because sources for liquid fuel data have not been included. - The ERT noted that the issue is being resolved because the Party has specified that data on fuel consumption in the agriculture, forestry, fishing and fish farms category was obtained from SAPIA (other kerosene), Energy digest (gas/diesel oil) and the energy balance for all other fuels.
E.21	1.A.4 Other sectors Other Kerosene and HFO (230, 2018) Transparency	In the case of liquid fuels in the Other Sectors, the significant fluctuations, particularly relating to the combustion of Other Kerosene and HFO in the - Commercial / Institutional and - Agricultural sub-sectors needs to be investigated and, if correct, adequately explained.	Not resolved In the draft 7th National GHG Inventory, in the Energy CRF (1A4 Other Sectors tab, Activity Data table), the Party reports (in TJ) Other kerosene (1A4a) for 2000 and 2017 as 1 173 TJ and 526 TJ, respectively. In the Energy CRF (1A4a). This means that other kerosene decreased by 55% between 2000 and 2017. Furthermore, other Kerosene consumption between 2014 and 2015 shows a 32% increase, while between 2015 and 2016 a 48% decrease is noted. No explanation was provided in the NIR for any of these outliers. In the Other Sectors tab, Activity Data table), the Party also reports (in TJ) Residual Fuel Oil (HFO) (1A4a) for 2011 and 2012 as 17 799 TJ and 23 629 TJ, respectively. This is a 33% increase in one year. Furthermore, Residual Fuel Oil consumption data is the same for 2007 and 2008. No explanations have been provided.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			During the review, the Party stated that this has been addressed, however no further details were given to support this statement. The ERT therefore noted that this issue remains not resolved .
E.22	1.A.4 Other sectors (231, 2018) Transparency	The statement that “the commercial/institutional sector should be willing to co-operate in the provision of data for the purposes of inventories” and “A regulatory framework should be established and implemented to ensure that sectors provide the data necessary for the compilation of the inventory” needs to be updated in Other Sectors – Solid and Liquid Fuels given the implementation of the GHG reporting regulations.	Not resolved In the draft 7 th GHG Inventory, the Party has not provided any updates regarding regulatory developments specifically regarding liquid fuels. During the review, the Party indicated that the issue has been partially addressed, but no further details were provided. The ERT, however, noted that the issue remains unresolved because the statement has not been included in Section 3.2.8 of the draft NIR.
E.23	1. General (energy sector) (232, 2018) Accuracy	As acknowledged in the current and previous NIRs and as recommended by the Independent Reviewer previously, more facility-level data has to be sourced and country-specific emission factors need to be developed. This is relevant across all the Energy key categories.	Addressing In the draft 7 th GHG Inventory, the Party has stated that this is an area of improvement across all subsectors. There is a need to ensure that the Improvement plan/GHG studies mention plans to address this. During the review, the Party indicated that this is being addressed. The ERT therefore noted that the issue is being addressed.
E.24	1. General (energy sector) (233, 2018) Accuracy	It is expected that implementation of the GHG reporting regulations will contribute in this regard. The Party should refer to the regulations and the expected benefits that will arise regarding GHG emissions from the various Energy sources.	Not resolved In the draft 7 th GHG Inventory, the Party has provided a high level indication that the mandatory reporting will help gather better data for the IPPU sector, but no mention is made of the implications of the data for improving the NIRs for the energy sector (noting that the regulations have not yet been in place long enough to collect meaningful data). During the review, no further feedback on this issue was received. The ERT noted that the issue is not resolved because no further information has been provided in the draft 2017 GHG inventory.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.25	1. General (energy sector) (234, 2018) Accuracy	Reasonable justification should be provided for the uncertainty percentages chosen for activity data and emission factors. It is recommended that uncertainty analyses be built into the GHG reporting regulations at a facility level, where relevant.	Not resolved In the draft 7th GHG Inventory, no comments were noted thus far on reasonable justifications for uncertainty other than those provided by the IPCC. During the review, no further feedback on this issue was received. The ERT noted that the issue is not resolved because no further justifications have been provided on uncertainty levels set.
E.26	1. General (energy sector) (235, 2018) Completeness	The Party should comment on the completeness of the data and issues relating to confidentiality or make a commitment to interrogate this aspect further in subsequent inventories.	Addressing In the draft 7th GHG Inventory, the Party has made comments on the completeness of the data. However, issues of confidentiality are not further discussed nor is a commitment made to interrogate this aspect further. During the review, the Party indicated that this is being addressed however no further details were given. The ERT noted that the issue is addressing because comments were offered on completeness but not on confidentiality issues.
E.27	1. General (energy sector) (236, 2018) Accuracy	More detailed QA should be conducted for the categories in this sector and documented adequately in the QA/QC plan. It is recommended that the expertise of the internal QA/QC experts should be described to assess their appropriateness; all issues logs should also be addressed or a commitment made to address these as part of future inventories.	Not resolved In the draft 7th GHG Inventory, no additional discussion on QA/QC was presented. During the review, the Party explained that this will be resolved in the next issue. The ERT noted that the issue remains unresolved.
E.28	1. General (energy sector) (237, 2018) Transparency	Generally, the drivers of changes in emissions (or explanatory variables) are not well explained and therefore are assumed to not be well understood. Given significant recent effort by the Department of	Not resolved

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		Environmental Affairs (in informing Desired Emissions Reduction Outcomes and Carbon Budgets) and National Treasury (in developing the proposed carbon tax) it is expected that the Party should have a better understanding of the drivers than is communicated in the NIR. Effort should be directed towards integrating this knowledge into a better explanation of the inventory over time.	In the draft 7th GHG Inventory, the Party has provided some information is on the drivers of change. However, the information provided is still relatively high level and the drivers are not always fully explained. Further work is required to unpack this in further detail, which will help contribute to a deeper interrogation of the data. During the review, the Party explained that this will be resolved in the next issue. The ERT noted that the issue remains unresolved.
E.29	1.A.1.a Public electricity and heat production (238, 2018) Accuracy	Autoproducers, within 1.A.1.a Electricity generation, should clearly only include “those undertakings whose primary activity is to supply the public”. Emissions from autoproducers (undertakings which generate electricity/heat wholly or partly for their own use, as an activity which supports their primary activity) should be assigned to the sector where they were generated. This should therefore include plants owned directly or indirectly (for instance Johannesburg’s City Power’s Kelvin plant) by local authorities, and any privately- owned plants whose primary function is to produce electricity for the public, as opposed to for private use. Additionally, the attribution of the emissions from each electricity/heat plant should be made on a facility basis, depending on what its main function is.	Not resolved. In the draft 7th National GHG Inventory, in its NIR Section 3.2.5, the Party reported autoproducers of electricity under category 1A1a. This is still not in accordance with the 2006 IPCC Guidelines (vol.2, chapter 2, table 2.1) because the guidelines state that “Emissions from autoproducers (undertakings which generate electricity/heat wholly or partly for their own use, as an activity that supports their primary activity) should be assigned to the sector where they were generated and not under 1 A 1 a. Autoproducers may be in public or private ownership.” During the review, the Party indicated that this is being addressed however no further details were given. The ERT therefore noted that this issue remains unresolved.
E.30	1.A.1.a Public electricity and heat production CO ₂ , CH ₄ , N ₂ O (239, 2018) Accuracy	Activity data for South Africa’s national utility was sourced directly from the utility. It is recommended that a) the NIR provide a far more detailed account of how the activity data was collected by the national utility, and how variations per plant in the calorific value and other relevant qualities of coal were taken into account, and also b) for the next inventory, that a plant-specific Tier 3 methodology be used for estimating emissions, which takes the variation in coal qualities into account. The same approach should apply to coal	Not resolved. In the draft 7th National GHG Inventory, in its NIR Section 3.2.5, the Party reported that data on fuel consumption for public electricity generation was obtained directly from the national power producer for the period 2000 to 2017 and also that a Tier 2 approach, with country-specific emission factors, was used to determine CO₂ emissions from coal combustion. For emissions from other fuels (e.g. other kerosene and diesel oil), and for all CH₄ and N₂O emission estimates a Tier 1 approach was applied a) The ERT noted that the issue is not resolved because the NIR has not provided further details on the how activity data was collected, and how variations in plant-specific calorific values were taken into account

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		power plants not owned by the national utility. Data should be sourced at a facility-level.	b) The ERT noted that the issue is not resolved because the Party is still using a Tier 2 approach During the review, the Party explained that this will be resolved in the next issue.
E.31	1.A.1 Energy industries (240, 2018) Transparency	It is recommended that a comprehensive inventory of power generation facilities, specifically auto producers and combined heat and power plants, and any others (plants owned by local authorities or future IPPs) should be compiled using either NERSA licensing data, air quality databases or registrations under the new GHG reporting regulations.	Addressing In the draft 7th National GHG Inventory, in its NIR Section 3.2.5, the Party reported that as part of planned improvements and recommendations, a list of auto power producers and obtain data directly from the producers will be obtained. During the review, the Party explained that this is being addressed in the next issue. The ERT noted that the issue is addressing because the Party has incorporated it as an area of improvement.
E.32	1.A.1.a Public electricity and heat production (241, 2018) Transparency	Given the importance of electricity generation, it is recommended that uncertainty, both for activity data and for emissions factors, be analysed for the specific data available rather than using a generic approach.	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.2.5, the Party reported a general IPCC approach to uncertainty analysis. During the review, the Party explained that this will be resolved in the next issue. The ERT noted that the issue is not resolved because the Party has not included a specific analysis on uncertainty for 1A1a.
E.33	1.A.1.c Manufacture of solid fuels and other energy industries (243, 2018) Completeness	It is recommended that in preparation for the next inventory, a thorough assessment of which emissions should be included in Manufacture of solid fuels and other energy industries is conducted, including combustion emissions from the manufacture of metallurgical coke (emissions from coke manufacture are mentioned in relation category 2.C.1, with a reference to p.4.9 of the 2006 IPCC Guidelines – the latter clearly states that even though the	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.2.5, the Party reported that emissions for the 1A1c subcategory were determined by process balance analysis (tier 3). Combustion-related emissions from charcoal production were not estimated in this category due to a lack of data on fuel use in charcoal production plants, therefore it was assumed that fuel consumption for charcoal production is included under the category non-specified- stationary (1A5a).

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		methodologies are described in that section, energy emissions for the manufacture of coke should be reported under 1.A.1.c).	During the review, no further feedback on this issue was received. The ERT noted that the issue is not resolved because the Party has not included metallurgical coke emissions in 1A1c.
E.34	1.A.1.c Manufacture of solid fuels and other energy industries (243, 2018) Transparency	It is recommended that companies in the Manufacture of solid fuels and other energy industries sub-sector: - Be required to report facility-level data, with relevant methodologies and activity data. Without more details, it is not possible to tell whether good practice guidance has been followed, or to assess the uncertainty of the emissions estimate. - Given the size of this category, a proper uncertainty analysis should be carried out, and sufficient data provided to do so.	Not resolved In the draft 7 th National GHG Inventory, in its NIR Section 3.2.5, the Party reported that emission estimates for this 1A1c subcategory were supplied by the manufacturing plants PetroSA and Sasol. No information is provided on an uncertainty analysis. - The ERT noted that the issue is not resolved because the NIR still indicates that emissions data have been provided by PetroSA and Sasol (no activity data has been provided). - The ERT noted that the issue is not resolved because the Party does not receive activity data, but rather emissions data. During the review, the Party explained that this will be resolved in the next issue.
E.35	1.A.2 Manufacturing Industries and Construction (244, 2018) Transparency	It is recommended that, for Manufacturing Industries and Construction – Solid and Liquid Fuels - the Party indicate why Anthracite coal is not included in the inventory; - the use of coal in the Food and Tobacco (particularly the sugar production industry) and the Paper and Pulp sectors be investigated and if no coal is consumed in a particular year, due to having adequate bagasse, that this be noted; and - that contributions from sectors, disaggregated as per the DoE Energy Balance, be disclosed. Additionally, the Party should undertake a review of boiler capacities.	Not resolved In the draft 7 th National GHG Inventory, in its NIR Section 3.2.5, the Party reported that manufacturing industries and construction subsector (1A2) can be divided into mining, iron and steel, chemicals, non-ferrous metals, non-metallic minerals, pulp and paper, food and tobacco and other productions (includes manufacturing, construction, textiles, wood products etc.) categories. For the manufacturing industries and construction sector data for solid fuels for the period 2000 to 2007 were sourced from the DoE's energy digest, for the period 2007 to 2012 the SAMI report (DMR, 2015) was used to extrapolate the fuel consumption. - The ERT noted that the issue is not resolved because the Party has not provided an explanation on the exclusion of anthracite coal. - The ERT noted that the issue is not resolved because the Party reports aggregated data (not a breakdown per sectors). - The ERT noted that the issue is not resolved because the Party reports aggregated data (not a breakdown per sectors). During the review, the Party explained that this will be resolved in the next issue.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.36	1.A.2 Manufacturing Industries and Construction (245, 2018) Transparency	It is recommended that, for Manufacturing Industries and Construction – Solid and Liquid Fuels, a) the preferred method for sourcing and analysing source data should be documented; b) sources of data not in the energy balance should be disclosed (bitumen, LPG); and c) the discrepancy between classification of coal in the NIR (sub-bituminous) and the DoE Energy Balance (bituminous) should be discussed.	Addressing In the draft 7th National GHG Inventory, in its NIR Section 3.2.5, the Party reported that manufacturing industries and construction subsector (1A2) can be divided into mining, iron and steel, chemicals, non-ferrous metals, non-metallic minerals, pulp and paper, food and tobacco and other productions (includes manufacturing, construction, textiles, wood products etc.) categories. It further reported that for the manufacturing industries and construction sector, data for solid fuels for the period 2000 to 2007 were sourced from the DoE's energy digest, for the period 2007 to 2012 the SAMI report (DMR, 2015) was used to extrapolate the fuel consumption. During the review, the Party explained that a) is being addressed, while b) will be addressed in the future. a) The ERT therefore noted that the issue is resolved because the Party has provided a detailed methodology on liquid and solid fuels. b) The ERT noted that the issue is resolved because the Party reports in the Energy CRF (1A2 Manufacturing Construction tab) that bitumen and LPG data are from SAMI Report (DMR 2017) c) The ERT noted that the issue is not resolved because the Party has not elaborated further on the classification.
E.37	1.A.3.b Road transportation (246, 2018) Accuracy	It is recommended that, for Road Transportation – Liquid Fuels, the Party should leverage new studies for comparison purposes and to substantiate any conclusions regarding reasons for changes over time (examples include the DFFE Fuel Study (2016) and a vehicle part model for South Africa (Stone et al 2018))	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.2.7, the Party reported that <i>“to improve road transport emission estimates, calculations should include the ability to compare emission estimates using fuel consumption and kilometres travelled (based on travel data). This requires more knowledge of South Africa's fleet profile, and also an understanding of how much fuel is consumed in the road transport sector as a whole. Furthermore, the development of local emission factors by fuel and vehicle-type will enhance the accuracy of the emission estimation.”</i> However, the Party has not used other studies for comparison or to substantiate conclusions. During the review, the Party indicated that this is being addressed however no further details were given.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			The ERT noted that the issue is not resolved because the Party has not made use of the recommended publicly available data sources.
E.38	1.A.3.b Road transportation (247, 2018) Accuracy	It is recommended that, for Road Transportation – Liquid Fuels, the Party should mandate relevant departments to conduct more physical measurements and direct field survey work to improve activity data of this key category.	Not resolved In the draft 7th National GHG Inventory NIR, the Party has not made any mention of discussions or agreements with the relevant departments to conduct physical measurements to collect more accurate activity data. During the review, the Party explained that this will be resolved in the next issue The ERT noted that the issue is not resolved because the Party has not indicated that data will be sourced from other departments.
E.39	1.A.3.b Road transportation (248, 2018) Transparency	It is recommended that, for Road Transportation – Liquid Fuels the Party should indicate if the change in source of NCVs has resulted in an improvement and, if so, to indicate the nature and extent of this improvement; and take efforts to develop country specific emission factors.	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.2.7, the Party reported that IPCC default emission factors for road transport were applied. During the review, the Party indicated that this is being addressed however no further details were given. The ERT noted that the issue is not resolved because the Party has not provided any details on NCVs.
E.40	1.A.4.b Residential (249, 2018) Accuracy	It is recommended that emissions associated with coal use in the Residential sector (Other Sectors– Solid and Liquid Fuels) be thoroughly assessed given the unexplained, and counterintuitive, increase in residential coal use over the time series (i.e. counter to what other sources would suggest).	Addressing In the draft 7th National GHG Inventory, in its NIR, there is a gradual increase of coal consumption between 2000 and 2010 and the gradual decline seen from 2011 to 2017, but the Party has not provided the reasons for these trends in the time series. During the review, the Party indicated that this issue is being addressed since the data is being corrected. The ERT therefore noted that the issue is addressing. .

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.41	1.B Fugitive emissions from fuels (250, 2018) Transparency	According to the NIR, a Tier 3 methodology has been applied to estimate emissions in Other Emissions from energy production – Solid and Liquid Fuels by the operators of the two facilities concerned, but no details have been provided of this in the NIR. It is therefore impossible to assess the suitability of the methodology applied, the accuracy of the activity data used, or make any other meaningful comparisons. It is strongly recommended that more information be provided by the NIR to enable a proper assessment to be made, and if possible to provide comparisons with other data.	Not resolved In the draft 7th National GHG Inventory, in its NIR Section 3.3.8, the Party reported that the use of facility-level production data and facility-level gas composition and vent flow rates enabled the use of Tier 3 methodology. But no further details on this methodology has been provided. During the review, the party stated that this issue is being addressed as indicated by the good and detailed SASOL and PETROSA reports. However, the ERT noted that the issue remains unresolved because details of the emissions methodology used by the SASOL and PETROSA reports have not been provided in the NIR.
E.42	Fuel combustion-reference approach (251, 2018) Completeness	“Generic” reasons for the differences between the reference approach and the sectoral approach for the year 2012 are described. These should be accompanied by quantitative information to help communicate the extent to which the reasons contribute to the differences.	Not resolved In the draft 7th GHG Inventory, no quantitative information on the extent to which the generic reasons contribute to the difference between reference and sectoral approach values. During the review, the Party indicated that this is being addressed however no further details were given. The ERT therefore noted that the issue remains unresolved because the issues raised in this recommendation have not been addressed in the draft 2017 GHG inventory.
E.43	Fuel combustion-reference approach (252, 2018) Completeness	The Party has not provided adequate explanation of the difference between the reference and sectoral approach calculations and the Independent Reviewer recommends that this is investigated and clearly described for the entire time series in the NIR of its next annual submission	Not resolved In the draft 7th GHG Inventory, no further information was presented in the NIR than was included in the 2015 inventory. During the review, the Party indicated that this is being addressed however no further details were given. The ERT noted that the issue is not resolved because the issues raised in this recommendation have not been addressed in the draft 2017 GHG inventory.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.44	1.A.3.a Domestic aviation (253, 2018) Accuracy	The Independent Reviewer recommends that the Party engage with the DoE to ensure that the split between international and domestic flights is appropriate and clearly communicated.	Addressing In the draft 7th National GHG Inventory, in its NIR Section 3.2.8, the Party reported “in order to separate international from domestic aviation, the DoE energy balances were used to estimate the ratio of domestic to international consumption. The DFFE fuel consumption study is then used to quantify the actual fuel consumption for both international and domestic aviation. In the 2017 Inventory, DFFE will implement the results of the updated DFFE fuel consumption study to be completed in 2019. This will ensure that the energy balance data will be replaced by data sourced from the civil aviation industry.” This seems to be text taken straight from the 2015 inventory and has not been appropriately updated for the 2017 inventory. During the review, the Party explained that this issue is currently being addressed through a Fuel consumption study. The ERT therefore noted that the Party is addressing the issue.
E.45	International bunkers and multilateral operations (254, 2018) Transparency	Cross check international bunker fuel activity data with water-borne specific data.	Not resolved In the draft 7th GHG Inventory, the Party has not provided any indication that this cross-check has been done. The ERT noted that the issue is not resolved because the issues raised in this recommendation have not been addressed in the draft 2017 GHG inventory. During the review, the Party explained that this will be resolved in the next issue.
IPPU			
I.1	2. General (IPPU) General (IPPU)	Ensure that the correct activity data and emission factors are copied from the 2012 CRF tables to the recalculation section of the 2015 CRF tables.	Resolved

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(CO ₂ ,CH ₄ ,N ₂ O) (255, 2018) Accuracy		The ERT noted that the issue is resolved because the correct recalculation tables have been copied across for each sub-category.
I.2	2. General (IPPU) CO ₂ ,CH ₄ ,N ₂ O (256, 2018) Transparency	Provide a more detailed description of the methodology, the source of emission factors and activity data with clear references. Assumptions must also be clearly explained.	Not resolved The ERT noted that the issue is not resolved because numerous new issues of transparency have been identified in the draft 2017 NIR, in relation to methodology, activity data sources as well as the use of correct references (more details are in Table 6). During the review, the Party explained that this will be resolved in the next issue.
I.3	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (257, 2018) Accuracy	It is recommended that the reference to use of the Tier 2 methodology in Iron and Steel Production should be amended to a Tier 1 methodology.	Resolved In the draft 7th GHG Inventory, in the 2017 NIR Section 4.4.2, the Party reported that a combination of the Tier 1 and Tier 2 approaches (country-specific emission factors) was applied to calculate the emissions from iron and steel production for the different process types. Default IPCC emission factors were used for the calculation of GHG emissions from basic oxygen furnace, electric arc furnace and pig iron production, and country-specific emission factors were used for the estimation of emissions from direct reduced iron production and sinter. This should be reflected in the NIR. The ERT noted that the issue is resolved because Tier 1 and Tier 2 methods have been referenced accordingly. During the review, no further feedback on this issue was obtained from the Party.
I.4	2.C.1 Iron and steel production CH ₄ (258, 2018) Transparency	Provide an explanation in the NIR for the exclusion of CH ₄ emissions for Iron and steel Production.	Not resolved In the draft 7th National GHG Inventory, in the NIR Section 4.4.2, (Planned improvements and recommendations sub-section) the Party has reported that an improvement to be considered in the future is the estimation of CH₄ emissions. The ERT noted that this is not in accordance with the 2006 IPCC Guidelines (V3, Chpt 4, pages 4.26, Table 4.2) because the guidelines provide tier 1 CH₄ emission factors for coke production, sinter production and DRI production, and thus CH₄ emissions can be calculated since all required data is available.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			The ERT noted that this issue is not resolved because tier 1 default emission factors for coke production, sinter production and DRI production to calculate CH₄ emissions have not been used. During the review, the Party explained that this will be resolved in the next issue.
I.5	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (259, 2018) Transparency	Update the references and sources of data for period 2013-2015 in the NIR for Iron and steel Production.	Not resolved In the draft 7th GHG Inventory, in IPPU CRF (2C1 Iron and Steel Production), the Party reported on extrapolated activity data for 2017 and 2017 (e.g. basic oxygen furnace, electric arc furnace, pig iron production and direct reduced iron). The ERT noted that this issue is not resolved because similar issues have been raised in the 2017 NIR where it is understood that production data for the iron and steel industry has been sourced from SAISI from 2000 to 2017, and therefore it is not anticipated that some data would be extrapolated. During the review, the Party explained that this will be resolved in the next issue.
I.6	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (260, 2018) Transparency	Provide clear justification for the Direct Reduced Iron (DRI) emission factor used, given that it is double the IPCC default emission factor. The NIR should also explain whether the carbon balance analysis used was peer-reviewed or whether expert judgement was elicited to ensure that the emission factor is correct and can be applied across the whole country.	Resolved In the draft 7th GHG Inventory, in the NIR Section 4.4.2, (Emissions factors) the Party reported that <i>"Differences in feedstock material and origin results in higher emission factors compared with the IPCC default emission factor values, which assume consistent feedstock conditions across countries"</i>. During the review, the Party explained that this had been addressed, as the 2017 inventory now uses a Tier 1 approach to estimate emissions, as per the Iron and Steel Production plants. In addition, the Party pointed out that the use of the Tier 3 emission factor for previous years will be addressed going forward. The ERT noted that the issue has been resolved because the Party has provided a justification, and because the Party has now confirmed use of Tier 1 approach to estimating emissions, there need to explain carbon balance analysis falls away. The ERT recommends that, as noted in the Party's response during the review, previous years' values be recalculated using the Tier 1 approach to ensure time-series consistency.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
I.7	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (261, 2018) Consistency	State explicitly in the NIR that the production in the Other sub-category (under Iron and steel Production) consists only of production from the Corex process.	Resolved In the draft 7th GHG Inventory, in the NIR Section 4.4.2, (Emissions factors) the Party reported that <i>"The Other category values were based solely on production by the Corex process"</i>. The ERT noted that the issue is resolved because in the 2017 NIR, the Party stated that Corex process is categorised under Other.
I.8	2. General (IPPU) CO ₂ ,CH ₄ ,N ₂ O (262, 2018) Transparency	Provide a reason for why the activity data for the Other sub-category for 2013, 2014 and 2015 was not available and the value for 2012 was applied for these three years. Expert reviewer note:	Resolved In the draft 7th National GHG Inventory, the other sub-category values for 2012, 2013, 2014 and 2015 are different, hence the 2012 value has not been applied to the other three years any more. During the review, the Party explained that the data for years 2000 to 2012 does not depict a single value but different values from 2000 to 2012. The Party further explained that from 2013 onwards the value for Other years (2013, 2014 and 2015) was not available so a statistical interpolation was undertaken. Should, the activity data for this category become available for these years, a recalculation will be done. The ERT therefore notes that the issue has been resolved.
I.9	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (263, 2018) Accuracy	There is a potential typographical error for value for electric arc furnace for 2013 (it is an order of magnitude lower). The source data for the 2013 EAF data should be reviewed to ensure that the correct value has been used in the CRF tables, and if required, must be updated.	Resolved In the draft 7th GHG Inventory, in the NIR Section 4.4.2, Table 4.17 (Activity data) the Party reported that consistent electric arc furnace data for 2013. The ERT noted that the issue is resolved because no typographical error was noted in the 2017 NIR.
I.10	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (264, 2018) Accuracy	The NIR states that there were no recalculations performed for Iron and steel Production. However, it is evident that a recalculation has been undertaken, but no detail has been provided in the NIR on the details underlying this. It is recommended that details for the recalculation, including reasons behind the significant increase, is provided in the NIR. A detailed description	Not resolved. In the draft 7th GHG Inventory, in the NIR Section 4.4.2, (Recalculations), the Party has reported <i>"No recalculations were performed on the emissions from this subcategory"</i> The ERT noted that the issue is not resolved because no detailed description of the source and calculation methodology of all the emission factors was provided.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		of the source and calculation methodology of all the emission factors must be provided.	During the review, the Party indicated that this issue will be resolved in the next NIR.
I.11	2.C.2 Ferroalloys production CO ₂ ,CH ₄ ,N ₂ O (265, 2018) Accuracy	For the Ferroalloys Production category, it is recommended that: i. The source of the emission factor is documented in both the NIR and excel spreadsheets. ii. Reasons for the emission factor being so much higher than the default value should be provided. iii. In addition, the variation in the emission factor across the time series needs to be justified.	Addressing i. In the draft 7th GHG inventory, the Party has given sources of the emission factors used for the entire time series. The ERT therefore noted that this issue has been resolved. ii. In the draft 7th GHG inventory, the Party has reiterated that for Ferrochromium, industry provided them with only emissions and activity data but not emission factors, and they had determined the implied emission factors from these two values. However, the Party still has not enquired from industry why the IEF from the provided values (3.22452 tCO₂ / tonne produced) is much higher than the default value of 1.3 tCO₂e / tonne produced. The ERT therefore noted that this issue has not been resolved. . iii. The ERT noted that this issue is resolved because the Party has explained that a variation in emission factor is only for ferrochromium, where production emission factors were not supplied by industry between 2000 and 2012, only emissions. For the period 2013 to 2017 industry emissions were not supplied so an implied emission factor was applied. During the review, the Party stated that this has been resolved, however no further details were given to support this statement, and therefore this issue remain unresolved.
I.12	2.C.2 Ferroalloys production CO ₂ ,CH ₄ ,N ₂ O (266, 2018) Transparency	It is recommended that the NIR clearly describes the method used for each production process under Ferroalloys Production, the basis for the choice and also provide clearer references to activity data.	Addressing In the draft 7th GHG Inventory, in the NIR Section 4.4.3, (Activity data), the Party has reported the source of the production data for all the years as SAMI annual reports (DMR, 2015). However, this is not correct because the 2015 DMR SAMI report does not contain activity data for 2015 – 2017. The ERT therefore recommends that all the SAMI DMR report that have been used be referenced individually.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			In the draft 7th GHG Inventory, in the NIR Section 4.4.3 (Table 4.18), the Party reported Silicon metal production data for 2015, 2016 and 2017 as 42,600 tonnes, 38,252 tonnes and 35,014 tonnes respectively; however the SAMI 2017/2018 report (DMR, 2019) in Table 78 (page 153) gives values of 46,300 tonnes, 26,600 tonnes and 4,700 tonnes respectively. During the review, the Party argued that the ERT looked at the wrong Table in the SAMI 2015/2015 Report. The Tables that needed to be looked at was Table 79 on Page 181 and Table 80 on Page 182. However, the ERT's assessment was based on the SAMI 2017/2018 report and not the 2015/2016 report. Therefore, this issue has not been fully resolved.
I.13	2.C.2 Ferroalloys production CO ₂ , CH ₄ , N ₂ O (267, 2018) Transparency	Update the NIR stating that country specific emission factors were not obtained for Ferroalloys Production for 2013 to 2015, and reasons must be provided for the assumption about the constant emission factor applied to the 2013 to 2015 period.	Resolved In the draft 7th GHG Inventory, in the NIR Section 4.4.3, (Emission factor), the Party has reported that emissions were not supplied for ferrochromium production for 2013 to 2017. Furthermore, the Party has explained the reasons for using the same emission factor for the period 2013 to 2015. The ERT therefore noted that the issue has been resolved.
I.14	2.C.2 Ferroalloys production CO ₂ , CH ₄ , N ₂ O (268, 2018) Consistency	For Ferroalloys Production inconsistencies were observed between the SAMI activity data and the data used in the inventory for calculation of emissions. The Party must confirm which numbers are correct and update the inventory accordingly.	Not resolved The ERT noted the following inconsistency between the data used in the inventory and data in the SAMI reports: In the draft 7th GHG Inventory, in the NIR Section 4.4.3 (Table 4.18), the Party reported Silicon metal production data for 2015, 2016 and 2017 as 42,600 tonnes, 38,252 tonnes and 35,014 tonnes respectively; however the SAMI 2017/2018 report (DMR, 2019) in Table 78 (page 153) gives values of 46,300 tonnes, 26,600 tonnes and 4,700 tonnes respectively. During the review, the Party indicated that this is being addressed however no further details were given.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			The ERT noted that this issue remains not resolved .
I.15	2. General (IPPU) CO ₂ ,CH ₄ ,N ₂ O (269, 2018) Completeness	Provide reasonable justification for the uncertainty percentages chosen for activity data and emission factors.	Not resolved In the draft 7th National GHG Inventory, the Party has not provided the justification of the uncertainty, as well as a clear qualitative narrative around the implication of the uncertainty and how it can be further improved. During the review, the Party explained that this had been resolved and has indicated by default uncertainty percentages. However, The ERT noted that this issue will be resolved by providing explanation on why the default uncertainty percentages have been chosen.
I.16	2. General (IPPU) CO ₂ ,CH ₄ ,N ₂ O (270, 2018) Consistency	The QC system appears to have been set up to perform general inventory checks. However, it appears as if the system was not used extensively for the Iron and Steel Production and Ferroalloys Production categories. For example, a few queries were raised for the categories, but it appears as if the queries were not addressed (or responses were not recorded). It is recommended that all queries that were logged in the QA log are addressed.	Not resolved In the draft 7th GHG Inventory, in the IPPU CRF (QA Log tab), there are still unresolved queries. Additionally, there are still queries raised in the 6th Independent Review Report that have not been addressed in the 7th NIR and therefore these queries have been raised again. The ERT noted that the issue is not resolved because queries were not addressed (or responses were not recorded). During the review, the Party explained that this will be resolved in the next issue.
I.17	2. General (IPPU) CO ₂ ,CH ₄ ,N ₂ O (271, 2018) Transparency	Tier 2 or Tier 3 approach will be adopted in the next inventory update. It is recommended that the methodology for calculation of emissions from Iron and Steel Production through this process is clearly and transparently explained.	Addressing The ERT noted that The ERT noted that this issue is being addressed because the Party has explained that GHG Reporting Regulations data has not been used. Based on engagements with the DEFF, it has been noted that GHG Reporting Regulatory data would only be used for the 2019 Inventory since not all data has been provided at this stage. Also, this data still needs to undergo further quality assessments etc. This recommendation has therefore been left unresolved until GHG Reporting Regulatory data is used.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			During the review, the Party explained that this will be resolved in the next issue.
I.18	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (272, 2018) Transparency	Given that a combination of Tier 1 and 2 methodologies were used for Iron and steel Production, it is recommended that the uncertainty percentages chosen for the Iron and Steel Production sector emission factors are reviewed and updated to be more reflective of the uncertainty of Tier 1 emission factors, which is closer to 25%.	Not resolved In the draft 7th National GHG Inventory, in the NIR Section 4.4.2, the Party has reported on a tier 1 uncertainty of $\pm 25\%$ and a tier 2 uncertainty of 10%, no further justification of the uncertainty has been provided. The ERT noted that this issue is not resolved because the Party has not included justification of uncertainty percentages. During the review, the Party explained that this will be resolved in the next issue. Furthermore, the Party indicated that only a Tier 1 was used for the 2017 inventory, however a Tier 1 and 2 was used for previous inventories, therefore a clearer explanation of uncertainties will be included.
I.19	2. General (IPPU) (273, 2018) Accuracy	It is recommended that the Party reallocates the use of coke, coal or petroleum coke used as a reducing agent, along with the corresponding emissions, to the IPPU sector in its next inventory; instead of reporting it under the Energy sector.	Resolved In the draft 7th National GHG Inventory, in the NIR Section 4.3.1, the Party has reported raw material (petroleum coke) consumption as part of carbide production. During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is resolved because the use of coke as a reducing agent has been accounted for under the IPPU sector.
I.20	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O (274, 2018) Transparency	Provide further transparency regarding data sources and emission factors in the Iron and Steel production section and for its sub-categories.	Not resolved In the draft 7th GHG Inventory, in NIR Section 4.4 and IPPU CRF (2C1 Iron and Steel Production) the Party has reported on extrapolated data for basic oxygen furnace, electric arc furnace, pig iron production, direct reduced iron, and total other. The ERT noted that the issue is not resolved because no detailed description of the source and calculation methodology of all the emission factors was provided. During the review, the Party explained that this will be resolved in the next issue.
I.21	2.C.1 Iron and steel production CO ₂ ,CH ₄ ,N ₂ O	Emissions from open hearth furnace, sinter and pellets are not estimated. The NIR does not provide an explanation as to why emissions from these	Not resolved

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(275) Transparency	processes have not been calculated. It is recommended that the NIR clearly details which production processes are used in the country and also clearly differentiate between iron and steel production.	In the draft 7th National GHG Inventory, in the IPPU CRF (2C1 Iron and Steel Production tab), the Party has not reported activity data for Open hearth furnace, Sinter and Pellet. The ERT noted that this issue is not resolved because the Party has not reported on these emissions or alternatively provided an explanation on why emissions have been excluded for open hearth furnace, sinter and pellet. During the review, the Party explained that this will be resolved in the next issue.
I.22	2. General (IPPU) 2.C.2 Ferroalloys production CO ₂ , CH ₄ , N ₂ O (276) Consistency	Provide the correct website links (e.g. for Iron and Steel Production references) must be provided or alternatively, the reports that contain the source data must be saved on the Party's internal system so that they are readily available.	Not resolved In the draft 7th GHG Inventory, in IPPU CRF, the Party has reported 2016 and 2017 data is still extrapolated and does not align with SAMI data. During the review, the Party explained that it has been explained that they're using the SAMI 2017/2018 Report. However, the ERT noted that the issue is not resolved because neither the website links nor the reports have been provided nor made readily available.
I.23	2.C.2 Ferroalloys production CO ₂ , CH ₄ , N ₂ O (277) Accuracy	For the Ferroalloys Production category, it is recommended that as a minimum, plant specific production data is obtained to ensure that the source activity data is accurate. However, in future, in order to move to a higher tier method, it is recommended that plant specific GHG data (or measured emissions) is obtained.	Addressing In the draft 7th GHG Inventory, in its NIR Section 4.4.3 (Activity data), the Party has reported ferrochromium production data for 2000 to 2017 were obtained from the SAMI annual reports (DMR, 2015) and ferromanganese production the 7% C values were taken to be the high and medium carbon ferromanganese and the 1% C values were the other manganese alloys (DMR, 2013, 2015). During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is being addressed because activity data is still sourced from SAMI reports although the Party has indicated that site specific data is urgently acquired to reduce uncertainty in the Ferroalloy production emissions.
I.24	2.C.2 Ferroalloys production CO ₂ , CH ₄ , N ₂ O	In order to reduce uncertainty under the Ferroalloys Production category, it is recommended that site specific data is urgently acquired for metal production activities. Other improvements would be to ensure that	Addressing In the draft 7th GHG Inventory, in its NIR Section 4.4.3 (Activity data), the Party has reported ferrochromium production data for 2000 to 2017 were obtained from

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(278) Accuracy	site-specific or country-specific emission factors are determined	the SAMI annual reports (DMR, 2015) and ferromanganese production the 7% C values were taken to be the high and medium carbon ferromanganese and the 1% C values were the other manganese alloys (DMR, 2013, 2015). During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is being addressed because activity data is still sourced from SAMI reports although the Party has indicated that site specific data is urgently acquired to reduce uncertainty in the Ferroalloy production emissions.
I.25	2.C Metal industry CO ₂ , CH ₄ , N ₂ O (279) Transparency	No description of the data collection process for the Iron and Steel Production and Ferroalloys Production categories have been provided. It is recommended that a documented procedure is developed to ensure easy traceability and replicability of data sources and calculation.	Not resolved In the draft 7th GHG Inventory, in its NIR Sections 4.4.2 and 4.4.3, the Party notes that the IPPU emission estimates are largely derived from publicly available data from public institutions and sector-specific associations. The ERT noted that this issue is not resolved because no description of the data collection process for the Iron and Steel Production and Ferroalloys Production categories have been provided, although the Party has indicated that the iron and steel industry data has been sourced from SAISI from 2000 to 2017, extrapolations were noted by the ERT. During the review, the Party explained that this will be resolved in the next issue.
AGRICULTURE			
A.1	3. General (agriculture) - Agric 4. General (LULUCF) – LULUCF (280, 2018) Consistency	Provide an explanation in the NIR for why Du Toit et al. (2013) emission factors were chosen, over Moeletsi et al. (2015); as the emission factor values provided by Moeletsi et al. (2015) are different to those provided by Du Toit et al. (2013), in some cases by up to 30%.	Addressing In the draft 7th GHG Inventory, the Party has reported they are planning to address this discrepancy in the next round of the NIR. They are planning to engage with scientists that can assist with identifying representative emission factors, in its NIR (Section 5.2.2). During the review, the Party explained that emissions factors by Du Toit were more detailed than Moeletsi et al. The factors for the latter were also not fully explained.
A.2	3. General (agriculture) - Agric 4. General	Improve transparency of data, as in many cases it was difficult to understand the drivers of observed outcomes which makes validation difficult, and	Not resolved In the draft 7th GHG Inventory, the Party did not respond to the query in its NIR (Section 5.2).

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(LULUCF) – LULUCF (285, 2018) Transparency	reduces the value of the data for identifying mitigation interventions.	The ERT noted that the issue of data not fully explained or discussed is generic throughout the NIR.
A.3	3. General (agriculture) - Agric LULUCF (CH ₄ , N ₂ O) (286, 2018) Accuracy	Consider including poultry emissions, given the increasing stock of poultry in the country.	Not resolved In the draft 7th GHG Inventory, the Party has reported they do not take CH₄ emissions from poultry as a priority. They will address it but not immediately (Section 5.2.2). During the review, the Party explained that there are no IPCC default emission factors for this source as it is a small emitter for the CH₄. The ERT noted that the issue is not resolved.
A.4	3. General (agriculture) - Agric Select category – LULUCF (287, 2018) Accuracy	Given the uncertainties (and limited data availability) relating to both livestock numbers and parameterisation of livestock values for the subsistence sector, assumptions on aspects such as herd composition ratios being the same in the communal sector as in the commercial sector are unlikely to be accurate, and should be updated.	Addressing In the draft 7th GHG Inventory, the Party has reported they did not fully understand the query as it relates to the NIR (Section 5.2.2). During the review, the Party explained they have disaggregated the livestock population to the best of the available information. They will continue to improve on the profiles of all the livestock categories particularly the subsistence animal stock. The ERT noted that the issue is receiving attention.
A.5	3.A.4 Other livestock - Agric LULUCF (CH ₄ , N ₂ O) (288, 2018) Completeness	For game numbers, include wildlife numbers from conservation areas, especially from South Africa's principle national parks, such as the Kruger National Park.	Addressing In the draft 7th GHG Inventory, the Party has reported they engaged stakeholders and professionals on game farming in the country (Section 5.2.2). During the review, the Party explained that the engagements concluded that game be removed from the NIR as it is considered not a managed practice. The emissions are thus removed from the NIR. The ERT noted that the issue is complex as the dynamics of games are changing and more management elements are introduced in the enterprise. In the near future, this will have to be considered. .

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
A.6	Select category Agric LULUCF (289, 2018) Accuracy	The Party should be actively involved in the Livestock Estimates Committee (LEC), or at least provide some kind of support to assist in getting updated data.	Addressing In the draft 7th GHG Inventory, the Party has reported they are engaging DALRRD to establish livestock estimation committee/forum for the NIR (Section 5.2.2). During the review, the Party explained that more engagements with DALRRD will be made to establish a mechanism to collect livestock data consistently. The ERT noted that the issue is being addressed.
A.7	Agric LULUCF (290, 2018) Transparency	The Party should engage with DALRRD to initiate a programme or project that can assist in improving the accuracy and completeness of livestock activity data, especially since the current assumptions about communal livestock numbers (which are based on commercial ones) are likely to be inaccurate.	Addressing In the draft 7th GHG Inventory, the Party has reported they are engaging DALRRD to establish livestock estimation committee/forum for the NIR (Section 5.2.2). During the review, the Party explained that more engagements with DALRRD will be made to establish a mechanism to collect livestock data consistently. The ERT noted that the issue is being addressed.
A.8	Agric LULUCF (291, 2018) Completeness	It is recommended that an uncertainty assessment for the AFOLU sector is conducted in the next inventory. Explanations for uncertainty within each subcategory should also be provided to provide justification for the choice of uncertainty percentages.	Not resolved In the draft 7th GHG Inventory, the Party has reported the query is not relevant for the NIR (Section 5.2.2). During the review, the Party did not explain or try to engage with the query. The ERT noted that the issue is important as it related to both transparency and completeness of the NIR. The Party did not recognise its relevance.
A.9	3.B Manure management - Agric Select category - LULUCF (CH ₄) (292, 2018) Accuracy	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.	Not resolved In the draft 7th GHG Inventory, the Party has reported the query is not relevant for the NIR (Section 5.2.2). During the review, the Party did not explain why they did not address the issue. The ERT noted that the issue is not resolved.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
A.10	3. General (agriculture) - Agric LULUCF (Gen) (295, 2018) Transparency	A more transparent framework (such as Lumina) should be used rather than having a large and complex spreadsheet. This will aid in error and logic checking, and also allow for much easier analysis and review of the model, its assumptions and other details.	Not resolved The Party did not respond in the 7th GHG inventory how they intend to address the issue in the NIR. The ERT noted that the Party did not mention or explain the plans to create a simpler but logical and easily documented framework to compile the emissions. Not resolved
A.11	3. General (agriculture) - Agric LULUCF (Gen) (296, 2018) Transparency	There has been improvement in documentation of data sources; however, some areas are still lacking. For instance, many details on how calculations are performed within the land cover change matrix are missing or inadequately explained.	Not resolved In the draft 7th GHG Inventory, the Party has not responded to the query in the NIR The ERT has noted that the data was not explained in most parts of the NIR. Rationales were not discussed. Further work is still required.
A.12	3. General (agriculture) - Agric LULUCF Add gas(es) (305, 2018) Accuracy	In order to have access to updated, accurate and detailed agricultural statistics, it recommended that discussions are held with DALRRD and the Statistician-General regarding the necessity of the data.	Addressing In the draft 7th GHG Inventory, the Party has reported they are looking into this issue in the NIR (Section 5.2). During the review, the Party explained that they will engage DALRRD and the industry for them to improve their data reporting systems, The ERT issue is being addressed.
A.13	3.D.a.7 Other (direct N ₂ O emissions from managed soils) - Agric Select category –	Given the large contribution of the Direct N ₂ O emissions from managed soil sector to overall AFOLU emissions, improvement of source data and/or the assumptions around the data should be considered in the future.	Not resolved In the draft 7th GHG report, the Party did not respond to the issue in the NIR (Section 5.4).

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	LULUCF N ₂ O (314, 2018) Completeness		The ERT still believe it still remains difficult to understand the drivers. It is a generic pattern in the NIR that things are not adequately explained. More work into this transparency issue is still required.
LULUCF			
L.1	Agric LULUCF CO ₂ ,CH ₄ ,N ₂ O (280,2018) Completeness	Provide an explanation in the NIR for why Du Toit et al. (2013) emission factors were chosen, over Moeletsi et al. (2015); as the emission factor values provided by Moeletsi et al. (2015) are different to those provided by Du Toit et al. (2013), in some cases by up to 30%.	Resolved In the draft 7 th GHG Inventory, the Party has justified the use of the Du Toit et al. (2013) emission factors over Moeletsi et al. (2015), in its NIR (Section 5.2.2). During the review, the ERT noted that this issue is resolved because the Party has provided an explanation for the use of the Du Toit et al. (2013) emission factors.
L.2	Agric— LULUCF CO ₂ ,CH ₄ ,N ₂ O (281, 2018) Transparency	The time series of Land emissions shows an increased land sink from 2013 onwards. Given that the land cover change data is a linear extrapolation between two time points, and that the only non-linear inputs are commercial agriculture and forestry data, is not clear what is driving this trend, and this requires further explanation.	Addressing In the draft 7 th GHG Inventory, the Party has reported corrected the data in its NIR (Section 5.4.3, Table 5.40) During the review, the Party did not account for the causes of the trend. The ERT noted that this issue is being addressed and improved future explanations will be made.
L.3	Agric 4.B Cropland – LULUCF CO ₂ ,CH ₄ ,N ₂ O (282, 2018) Transparency	It is noted that a large change in Cropland emissions occurred as a consequence of recalculations. However, it is not clear what change in the recalculations was responsible for the large observed change, so this should be better described in the NIR.	Addressing In the draft 7 th GHG Inventory, the Party has reported in its NIR (Section 5.4.5) During the review, the Party explained that the large change in emissions was corrected by revising the entire components of the land sector. However, specific details are talked about. The ERT noted that this issue is being addressed because the Party reported they will add more information in the NIR.
L.4	- Agric 4.C Grassland – LULUCF CO ₂ ,CH ₄ ,N ₂ O (283,2018) Transparency	Recalculations for Grasslands show substantive change from previous assessments, in direction, magnitude and trend. These trends are not fully accounted for in the NIR and need further interrogation, and should be better described in the NIR	Addressing In the draft 7 th GHG Inventory, the Party has reported in its NIR (Section 5.4.5)

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			During the review, the Party explained that the large change in emissions was corrected by revising the entire components of the land sector. However, specific details are talked about. The ERT noted that this issue is being addressed because the Party reported they will add more information in the NIR.
L.5	4.G Harvested wood products – LULUCF CO ₂ (284,2018)	For Harvested wood products, there appears to be an inconsistency with table 5.77 showing emissions whilst table 5.78 indicates this sector to be a sink, the text is also not clear if this sector is a net emission or sink. This needs to be clarified, although it is assumed this sector is a sink.	Addressing In the draft 7th GHG Inventory, the Party has reported how they addressed the issue in its NIR (Section 5.6.1, Table 5.68) During the review, the Party provided the sinks data. However, annual variations of the sinks/sources were not explained. A particular case of 2010-2012 is of interest. The causes of decays and their quantities as well as sinks are not explained. It is not clear if Table 5.68 presents net sinks or not. The ERT noted that this issue is resolved because the Party has partially explained how they have resolved the issue.
L.6	LULUCF (Gen) (285,2018) Transparency	Improve transparency of data, as in many cases it was difficult to understand the drivers of observed outcomes which makes validation difficult, and reduces the value of the data for identifying mitigation interventions.	The Party did not report in the 7th GHG inventory how they addressed the issue in the NIR. The ERT noted that the Party did not address this query. As highlighted in other parts of the review, discussions are generally lacking in the NIR. .
L.7	4. General (LULUCF) – LULUCF (Gen) (291,2018) Completeness	It is recommended that an uncertainty assessment for the AFOLU sector is conducted in the next inventory. Explanations for uncertainty within each subcategory should also be provided to provide justification for the choice of uncertainty percentages.	Not resolved The Party did not report in the 7th GHG inventory how they addressed the issue in the NIR. The Party did not provide a response to this query.
L.8	4. General (LULUCF) – LULUCF (Gen)	It is recommended that future inventories should be based on land change broken into short time periods (hopefully new land cover products will make this possible), so that trend data can be disaggregated over time and not a simple linear trend.	The Party did not report in the 7th GHG inventory how they addressed the issue in the NIR. The ERT noted that the Party classified the query as not relevant and did not provide a response. .

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(293, 2018) Consistency		
L.9	4.A.2.2 Grassland converted to forest land – LULUCF (Gen) (294,2018) Accuracy	Independent scientific studies should be undertaken to ascertain if grasslands and forests are indeed a sink, and if so what is driving this change so that the correct features can be added to models.	Not resolved The Party did not report in the 7 th GHG inventory how they addressed the issue <i>in the NIR</i> . The ERT noted that despite its importance, the Party classified this query as not relevant. They need to engage with scientific community in order to address some of the challenges of the national inventories.
L.10	4. General (LULUCF) – LULUCF (Gen) (295,2018) Transparency	A more transparent framework (such as Lumina) should be used rather than having a large and complex spreadsheet. This will aid in error and logic checking, and also allow for much easier analysis and review of the model, its assumptions and other details.	Addressing The Party did not report in the 7 th GHG inventory how they addressed the issue <i>in the NIR</i> . The ERT noted that the Party did not mention or explain the plans to create a simpler but logical and easily documented framework to compile the emissions. The Party reported however, that they are addressing the query.
L.11	4. General (LULUCF) – LULUCF (Gen) (296,2018) Transparency	There has been improvement in documentation of data sources; however, some areas are still lacking. For instance, many details on how calculations are performed within the land cover change matrix are missing or inadequately explained.	Addressing In the draft 7 th GHG Inventory, the Party has reported they addressed the issue in its NIR (Section 5.4). The Party reported they have addressed the issue. They have improved their documentation of material used <i>in the NIR</i> . The ERT has however, noted that the expressions and the data was largely not explained. Rationales were not discussed. Further work is still required.
L.12	LULUCF (CO ₂ ,CH ₄) (297,2018) Consistency	To improve land cover change and its confidence levels, Carbon Sinks Assessment can be used to track actual biomass changes, rather than class changes. An alternative is to disregard identified class changes within the natural vegetation. A third, but rather complex option is to ensure greater subdivision of natural vegetation classes (biomes and sub-biomes) and to ensure that each has unique default values for all constants (growth rates, standing biomass etc.).	The Party did not report in the 7 th GHG inventory how they addressed the issue <i>in the NIR</i> . The ERT noted that the Party classified the query as not relevant and did not provide a response. .

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
L.13	LULUCF (CO ₂ , CH ₄) (298, 2018) Transparency	Given that it is difficult to understand what the drivers of land cover change are, it is recommended that named variables (rather than cell ranges) are used, and the analysis should be performed by land cover class, and then only later combine the results into the IPCC classes. Complexity which is not adding value should be removed as this only gives an appearance of refined accuracy, but with no underlining data to support it.	Addressing In the draft 7th GHG report, the Party respond that they have addressed this issue in the NIR (Section 5.4). Addressing The ERT still believe it still remains difficult to understand the drivers. It is a generic pattern in the NIR that things are not adequately explained. More work into this transparency issue is still required.
L.14	LULUCF (CO ₂ , CH ₄) (299, 2018) Accuracy	It is recommended that South African biomes should be used instead of the FAO Global FRA ecological zones map, which is a global product with poor spatial reliability in South Africa. In cases where international default values are required due to no local data being available, a lookup table between the FRA regions and South African Biomes could be created. Finding better ways to accommodate biomes such as the Karoo are needed.	Addressing In the draft 7th GHG Inventory, the Party has reported they are addressing the issue in its NIR (Section 5.5.3). The Party reported they will consider detailed South Africa's biomes in the future. The ERT has noted that the Party has removed FRA ecological zones and they have used South Africa's biomes instead.
L.15	LULUCF (Gen) (300, 2018) Accuracy	QA/QC should be completed for the overall land approach. These are given by land cover class, but limited comparative data is provided	Not resolved In the draft 7th GHG Inventory, the Party has not responded to this issue in its NIR (Section 5.5.3) The ERT could not trace any improvements in the NIR on this issue. QA/QC subsection remain constrained to only 2-3 lines.
L.16	4.A Forest land – LULUCF (301, 2018) Transparency	It is recommended that data is disaggregated to South Africa's three unique types of forest land, to improve interpretation and transparency of results.	Not resolved In the draft 7th GHG Inventory, the Party has not responded to this issue in its NIR (Section 5.4.2). The ERT noted that the forest land definition in the NIR consists of the national classification that has several forest types.
L.17	4. General	It is recommended that a stock-based approach be used in future inventories, based on the carbon stock	Not resolved

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(LULUCF) – LULUCF (CO ₂ ,CH ₄) (302,2018) Completeness	maps generated during the national carbon sink assessment together with stock estimates for plantations and other forms of agriculture or production areas. This would allow for a more complete evaluation of the change in stocks over time, compared to the current flux / process-based approach, which may not be complete.	In the draft 7th GHG Inventory, the Party has not responded to this issue in itsNIR (Section 5.4.4). The ERT noted that the Party did not evaluate whether this recommendation would be useful in the future.
L.18	4.A Forest land – LULUCF (CO ₂ ,CH ₄) (303,2018) Accuracy	For the fuelwood collection section, the details of assumptions and the available underlying data should be reassessed.	Not resolved In the draft 7th GHG Inventory, the Party has not responded to this issue in itsNIR (Section 5.4.4). The ERT noted that the Party did not evaluate whether this recommendation would be useful in the future. .
L.19	4.B Cropland – LULUCF (CO ₂) (304,2018) Accuracy	To improve resolution for croplands, better data on regionally specific growth rates should be sought in future inventories. Additionally, if no crop specific inputs are envisaged in the future, it is recommended that this complexity is removed from the model.	Not resolved In the draft 7th GHG Inventory, the Party has not responded to this issue in itsNIR (Section 5.4.4). The ERT noted that the Party did not evaluate whether this recommendation would be useful in the future. .
L.20	4.B Cropland – LULUCF (CO ₂) (306,2018) Completeness	As with forest land, it is recommended that the cropland data is disaggregated, so that it is easy to see where the drivers are for the cropland being a sink or source of carbon. Cropland data not disaggregated	Not resolved In the draft 7th GHG Inventory, the Party has not responded to this issue in itsNIR (Section 5.4.4). The ERT noted that the Party did not evaluate whether this recommendation would be useful in the future. This recommendation was made elsewhere in this review.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
L.21	Agric 4.C Grassland – LULUCF (CO ₂) (307,2018) Completeness	A methodology that directly monitors actual carbon stocks over time is ideally needed to understand why grasslands as a carbon sink are increasing.	Not resolved In the draft 7 th GHG Inventory, the Party has not addressed this issue in its NIR (Section 5.4.4). They report they will address it in the future. The ERT recommends a full study to address this issue. Carbon fluxes from different LU types are important and need to be measured.
L.22	4.C Grassland – LULUCF (CO ₂) (308,2018) Accuracy	It is recommended that approaches that quantify actual location specific biomass change should be considered in the future. Stratifying by different types of grasslands (Fynbos, Karoo, true grassland, savannah with low tree cover etc.) is recommended as it is quite likely that whilst some areas are a carbon sink, others may well be a source.	Not resolved In the draft 7 th GHG Inventory, the Party has not responded to this issue in its NIR (Section 5.4.4). The ERT noted that the Party did not evaluate whether this recommendation would be useful in the future. This recommendation was made elsewhere in this review.
L.23	4.C Grassland – LULUCF (CO ₂) (309,2018) Accuracy	It is unclear why the Grasslands sink has increased or what is driving the increase. If this observed pattern is a consequence of the method and data used in modelling or a true change, explained by the underlying ecological processes. This needs verification through detailed research and should be better described in the NIR.	Not resolved In the draft 7 th GHG Inventory, the Party has not responded to this issue in its NIR (Section 5.4.4). The ERT noted that the Party did not evaluate whether this recommendation would be useful in the future. This recommendation was made elsewhere in this review.
L.24	4.D. Wetlands – LULUCF (CO ₂) (310,2018) Completeness	A reassessment of the Wetland methodology should be included in the next inventory as recommended in the NIR report.	Addressing In the draft 7 th GHG Inventory, the Party has not responded to this issue in its NIR (Section 5.4.2). They report they will consider this recommendation in the next round of the NIR.
L.25	Agric 4.F Other land –	It is recommended that a mechanism is found to deal with the problem of perceived large land cover change in the Other Land sector from land cover products	Addressing

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	LULUCF (CO ₂) (311,2018) Accuracy	versus minimal change on the ground. Also, ensure that the two classes: bare land (in the Karoo) and lowshrub lands (when referring to the Karoo), are populated with relevant default values, which will help reduce impacts from changes.	In the draft 7 th GHG Inventory, the Party has responded that they are addressing this issue in the NIR (Section 5.4.2). It was not very clear to the ERT what was done to the NIR at this stage.
L.26	4.F Other land – LULUCF (CO ₂) (312,2018) Accuracy	Carbon stocks in other lands were assumed as zero, but this might not be appropriate for many of the areas classified as other lands (e.g. large areas of the Karoo). It is suggested that the areas of the Karoo that are classified as other lands (due to the area being a bare class on land cover products) get treated as a unique class of other lands with carbon levels appropriate to the Karoo vegetation of these areas.	Not resolved. In the draft 7 th GHG Inventory, the Party has not responded to this issue in its NIR (Section 5.4.4). The ERT noted that the Party did not evaluate whether this recommendation would be useful in the future. This recommendation was made elsewhere in this review
L.27	4 (V) Biomass burning – LULUCF (CO ₂) (313,2018) Accuracy	As previously mentioned, emissions from Biomass Burning should also be disaggregated by biomes and using biome specific fuel densities and emission factors would add greater transparency and make input data more comparable with local ecological data. Furthermore, using a biome breakdown (within the IPCC classes) is suggested as a long-term improvement. This is especially relevant for separating fynbos emissions from grassland and Karoo emissions	Not Resolved In the draft 7 th GHG Inventory, the Party reported that the query is not relevant for this NIR (Section 5.5.3). They will consider it in the next round of NIR. The ERT noted that no work was done to address this issue in the NIR.
L.28	4 (V) Biomass burning – LULUCF (N ₂ O) (314,2018) Accuracy	Given the large contribution of the Direct N ₂ O emissions from managed soil sector to overall AFOLU emissions, improvement of source data and/or the assumptions around the data should be considered in the future.	Addressing In the draft 7 th GHG Inventory, the Party reported that they are addressing the query (Section 5.5.6). The Party reported that they will consider this recommendation in the next round of NIR. There may be some research work already undertaken to address this issue. The ERT has noted that not much work was done on this in the current NIR.

Waste

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
W.1	5.C.2 Open burning of waste (CO ₂) (315,2018) Completeness	The emissions for the Open Burning of Waste category were found to have been overestimated due to an error in the calculations (specifically with the units) in the CRF tables. The corrected calculation reduces emissions from the Waste sector from 188 325.85 Gg CO ₂ e to 21 802.757 Gg CO ₂ e. This must be updated in the excel sheets and the NIR.	Addressing In the draft 7th GHG Inventory, the Party has reported they are addressing the issue in its NIR Section 6.3 During the review, the Party explained that they will change the units from per capita to waste generation rate per day rather than per year The ERT noted that the issue is being addressed.
W.2	5.A Solid waste disposal on land (CO ₂ , CH ₄ , N ₂ O) (316,2018) Accuracy	Emissions from the Solid Waste category increased by 106.8 % over the 15-year period. No specific explanation is provided for the increase, but it is implied that an increase in the urban population is a contributing factor. This needs to be explained in the NIR.	Addressing In the draft 7th GHG Inventory, the Party has reported they will provide the explanation in its NIR Section 6.2. During the review, the Party explained that the emissions may also change due to improved data that was obtained from the Waste Improvement project. The ERT noted that the issue is being addressed.
W.3	5.A Solid waste disposal on land (CO ₂ , CH ₄ , N ₂ O) (317,2018) Accuracy	For Solid Waste provide an explanation in the NIR for the NWIBR data used to calculate the percentage of waste generated that is disposed of in solid waste disposal sites.	Addressing In the draft 7th GHG Inventory, the Party has reported they will provide the reference in the reference list. During the review, the Party explained that they will provide all references and improve on their documentation of the assumptions. The ERT noted that the issue is being addressed.
W.4	(CO ₂ , CH ₄ , N ₂ O) (318,2018) Completeness	Ensure proper referencing of source data for: population, waste generation rate, distribution of waste by waste type and management and GDP data. The source documentation should also be provided.	Addressing In the draft 7th GHG Inventory, the Party has reported they will provide the reference in the reference list. During the review, the Party explained that they will provide all references and improve on their documentation of the assumptions. The ERT noted that the issue is being addressed.
W.5	5. General (waste) (Gen)	Review and explain the source of the waste generation rate value, as it is much higher compared	Addressing

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(319,2018) Transparency	to the IPCC value for developing regions, and to that of the value recalculated by the Independent Reviewer.	In the draft 7 th GHG Inventory, the Party has reported they will update the waste generation value in its NIR Section 6.2. During the review, the Party explained they will update the value based on the weighted average value from the State of Waste Report. The ERT noted that the issue is being addressed.
W.6	5. General (waste) (Gen) (320,2018) Transparency	Provide an explanation/justification as to why an increasing waste generation rate is used from 1950 to 1999, but then a constant value is assumed from 2000 to 2015. Also provide an explanation for the large increase in the rate from 1999 to 2000 (from 493 to 578.73 kg/capita/year).	Addressing In the draft 7 th GHG Inventory, the Party has reported they will provide the explanation in its NIR Section 6.2. During the review, the Party explained they will provide assumptions and references in the NIR. The ERT noted that the issue is being addressed.
W.7	5.C.2 Open burning of waste CO ₂ (321,2018) Completeness	For Open Burning of Waste, provide an explanation for the increase of 24.9% between 2000 and 2015.	Addressing In the draft 7 th GHG Inventory, the Party has reported they will provide the explanation in its NIR Section 6.3. During the review, the Party explained that they will improve on the transparency in the NIR. The ERT noted that the issue is being addressed.
W.8	5.C.2 Open burning of waste CO ₂ (322,2018) Completeness	It is recommended that the methodology description for the Open Burning of Waste section should be re-written. The following should also be included: provide the basis for methodological choice; describe the process to calculate the emissions i.e. identify types of waste open-burned; explain how the total amount of MSWB was calculated (and clarify how P _{frac} was determined); followed by the choice of default values for content/carbon determination and the emission calculations.	Addressing In the draft 7 th GHG Inventory, the Party has reported they have provided the relevant documentation for the methods in its NIR Section 6.3. During the review, the Party explained that they have documented the methods they used. The ERT noted that the issue is being addressed.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
W.9	5.C.2 Open burning of waste (CO ₂) (323,2018) Accuracy	For Open Burning of Waste, it is recommended that an explanation is provided for any deviations from IPCC default values.	Resolved In the draft 7th GHG Inventory, the Party has reported they did not deviate from the IPCC methods in its NIR Section 6.3. During the review, the Party explained that they did not deviate from the framework of the IPCC methods. The ERT noted that the issue is resolved.
W.10	5.C.2 Open burning of waste (CO ₂) (324,2018) Completeness	Under Open Burning of Waste, the CO ₂ emissions from biomass should be excluded from the national estimates as it results in over estimation of the national emissions.	Resolved In the draft 7th GHG Inventory, the Party has reported they excluded the CO₂ from the biomass in its NIR Section 6.3. During the review, the Party explained that the factor of zero was used for biomass. The ERT noted that the issue is resolved.
W.11	5.C.2 Open burning of waste (Gen) (325,2018) Completeness	The equation used to calculate total amount of MSWB in the CRF tables does not align with the IPCC guidelines. The calculation must be reviewed and either corrected by removing the added term referred to as "Correction for SWDS burning waste" with a value of "1.25" or the use of this adjusted term must be adequately justified in the NIR.	Resolved In the draft 7th GHG Inventory, the Party has reported they did not deviate from the IPCC methods in its NIR Section 6.3. During the review, the Party explained that they did not deviate from the framework of the IPCC methods as the practise still occurs in landfill sites. The ERT noted that the issue is resolved.
W.12	5. General (waste) (Gen) (326,2018) Completeness	Define more clearly the outcomes of the QA/QC procedures in the NIR.	Resolved In the draft 7th GHG Inventory, the Party has reported they have included the QA/QC in the NIR. During the review, the Party explained that they did have included the QA/QC section in the Waste sector section of the NIR.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			The ERT noted that the issue is resolved.
W.13	5.D Wastewater treatment and discharge (CO ₂ , CH ₄ , N ₂ O) (327, 2018) Completeness	Provide a clear explanation for the increase in the emissions from the Wastewater Treatment and Discharge sector, as currently it is implied that the increase is due to an increase in the low-income urban population, but it is not specified as such in the NIR.	Addressing In the draft 7th GHG Inventory, the Party has reported they will explain the trends in the NIR Section 6.4. During the review, the Party explained that they improve on their transparency. The ERT noted that the issue is being addressed.
W.14	5. General (waste) (Gen) (328, 2018) Transparency	The NIR indicates that an IPCC default value for per capita protein consumption of 27.96 kg/person/year was used in the time series. However, the Independent Reviewer could not find the default value referred to in the IPCC guideline documents. The NIR must transparently describe where the emission factor is sourced from.	Resolved. In the draft 7th GHG Inventory, the Party has reported they have referenced the factor in the NIR Section 6.4. During the review, the Party explained that they have referenced the factor they used. The ERT noted that the issue is resolved.
W.15	5. General (waste) (CH ₄) (329, 2018) Completeness	Additional efforts must be made to include methane estimates from industrial landfill sources as well as methane recovered annually from domestic landfills.	Addressing In the draft 7th GHG Inventory, the Party has reported they are improving the emissions from landfills. During the review, the Party explained that they have engaged the Waste Improvement Project to address this issue amongst many. The ERT noted that the issue is being addressed.
W.16	5.A Solid waste disposal on land (CO ₂ , CH ₄ , N ₂ O) (330, 2018) Transparency	For the Solid Waste category, it is recommended that the NIR details the approach taken in choosing the appropriate activity data, emission factors and parameters used in the FOD model. The assumptions made when using the FOD model should also be provided. This allows for transparency and also makes it easier to understand if the assumptions made are reasonable or not.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have engaged the Waste Improvement Project to address this issue amongst many.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			The ERT noted that the issue is being addressed.
W.17	5.A Solid waste disposal on land (CO ₂ ,CH ₄ ,N ₂ O) (331,2018) Completeness	When using the FOD model for Solid Waste, there are various areas that can be improved upon, such as: incorporating the different CH ₄ generation rates for the various locations of landfills; modifying the FOD excel template to correspond to the categorisation of waste used in the NWIBR; disaggregating the 'Distribution of Waste by Waste Management Type'; providing justification for using different parameter values as compared to the default IPCC values or a reference/source documents should be provided.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have engaged the WasteImprovement Project to address this issue amongst many. The ERT noted that the issue is being addressed.
W.18	5. General (waste) (Gen) (332,2018) Accuracy	Determine a more accurate uncertainty level for the NIR waste data.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have engaged the WasteImprovement Project to address this issue amongst many. The ERT noted that the issue is being addressed.
W.19	5. General (waste) (Gen) (333,2018) Accuracy	It is recommended that the QC system is used more extensively for the Waste sector.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have improved their capacity in personnel and these issues will be addressed comprehensively in the next NIR. The ERT noted that the issue is being addressed.
W.20	5.C.2 Open burning of waste (Gen) (334,2018)	For Open Burning of Waste, country specific data should be used, especially where default values are not reflective of the South African context, such as for waste composition going to waste disposal sites.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	Completeness	The NWIBR is potentially a good source of information to consider for use in the NIR.	During the review, the Party explained that they have engaged the WasteImprovement Project to address this issue amongst many. The ERT noted that the issue is being addressed.
W.21	5.C.1 Waste incineration (Gen) (335,2018) Completeness	It is unlikely that all the parameters used in the calculations in the CRF tables remained constant over the entire period series and these should be corrected. For example, the use of disposable nappies has become more common in the past 20- 25 years only and the increased use of plastics also happened in the last 35 years.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have engaged the WasteImprovement Project to address this issue amongst many. The ERT noted that the issue is being addressed.
W.22	5.C.2 Open burning of waste (CO ₂) (336,2018) Completeness	It is recommended that the Party uses the general household survey data from Stats SA (which provides information on the level of waste removal services provided by government) to determine the amount of Open Burning of Waste.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have engaged the WasteImprovement Project to address this issue amongst many. The ERT noted that the issue is being addressed.
W.23	5.D Wastewater treatment and discharge (CH ₄) (337,2018) Consistency	It is recommended that the recovery or flaring of methane from waste water treatment is taken into account. This data should be available from municipalities, as there are a number of municipalities that have partnered with companies to develop wastewater treatment plants biogas to energy projects.	Addressing In the draft 7th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have engaged the WasteImprovement Project to address this issue amongst many. The ERT noted that the issue is being addressed.
W.24	5.D Wastewater treatment and	It is recommended that more up-to-date data for Wastewater Treatment and Discharge is used in	Addressing

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	discharge (CO ₂ ,CH ₄ ,N ₂ O) (338,2018) Completeness	future inventories, as too much reliance is placed on previous inventories' data and assumptions.	In the draft 7 th GHG Inventory, the Party has reported they will improve on the transparency in the NIR During the review, the Party explained that they have improved their capacity in personnel and these issues will be addressed comprehensively in the next NIR. The ERT noted that the issue is being addressed.

Abbreviations: [[IPPU = industrial processes and product use], [LULUCF = land use, land-use change and forestry] [, NEU = non energy use] [, NIR = national inventory report][, QA/QC = quality assurance/quality control]

^a References in parentheses are to the paragraph(s) and the year(s) of the previous review report(s) where the issue was raised.

III. STATUS OF IMPLEMENTATION OF ISSUES AND/OR PROBLEMS RAISED IN UNFCCC'S INFORMAL REVIEW OF THE 6TH GHG INVENTORY

- Table 4 compiles all the recommendations made in the report of UNFCCC's informal review of South Africa's 6th National GHG Inventory. For each issue and/or problem, the ERT specified whether it believes the issue and/or problem has been resolved in the GHG inventory under review and provided the rationale for its determination. It should be noted that during the review, the Party did not give any feedback on any of the energy sector questions or draft findings by the ERT.

Table 4: Status of implementation of issues and/or problems raised in the review report of UNFCCC's informal review of the 6th Inventory

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
General			

G.6	QA/QC and verification (6.2, Informal review) Accuracy	a) It is proposed to increase the QC checks (for instance, by having a deeper look to totals and trends and verify that explanations are provided). It is also proposed to avoid errors or inconsistencies by copying/pasting the summary reporting tables from the data files to the NIR b) it is suggested to interpolate the data or investigate additional data sources when a peak is due to the bad quality of the data. c) Finally it is proposed to document further the methodology, factors and assumptions used (in particular if models are used). d) It is recommended to get information on method applied for data collection, as well as on the boundaries of the definition of each variable collected. e) It is recommended to verify any time series of data present in FAOSTAT and applied for the NGHGI and provide FAO with corrections for any discrepancy identified.	Addressing In the draft 7th GHG Inventory, the ERT noted the following: a) There were still QC issues. Specific details can be found in the sector-specific sections of this report. During the review, the Party explained that it has noted the recommendation. Not resolved. b) No evidence found in the NIR that this recommendation has been implemented. Not resolved. c) There are still areas where methodologies, factors and assumptions were not documented (e.g. IPPU sector). During the review the Party clarified that this was addressed in the 2015 GHG inventory, but needs to be enhanced in the 2017 inventory. Addressing. d) During the review the Party explained that DEFF populates method statements for each inventory category covered in the NIR, thus this will be enhanced moving forward. Addressing. e) During the review the Party explained that it has noted the comment. Not resolved.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
G.7	Key category analysis (6.3, Informal review) Adherence to UNFCCC Annex I inventory reporting guidelines	It is suggested to further explain the results of the KCA in the NIR. (See the IPCC good practice guidance chapter 7, page 13.)	Not resolved. In the draft 2017 GHG inventory, the Party has reported a quantitative analysis of the Key Category Analysis, but no qualitative analysis as required by the good practice guidance.
G.8	Uncertainty analysis (6.4, Informal review) Accuracy	a) Together with the development of more detailed uncertainty analysis it is recommended to include a qualitative discussion of the contributors to uncertainty in the NIR. b) It is recommended to develop more detailed uncertainty analysis as well as to assess or collect the uncertainty of the activity data instead of using the defaults. This is important to help prioritize efforts in the improvement programme to reduce the uncertainty of the whole inventory in the future, and guide decisions on activity data and methodological choices.	No resolved. In the draft 7th GHG Inventory, the Party has reported detailed results of a quantitative uncertainty assessment in Appendix B of the NIR, but a) still no qualitative discussion of the results was found, and b) Still using default uncertainty values instead of collected data-specific uncertainty estimates.
G.9	Archiving (6.6, Informal review) Not an issue	It is recommended to store the inventory in an external drive at the end of each inventory cycle.	Resolved. During the review, DEFF clarified that they have an Electronic Document Management System in Place, in addition to the NGHGIS to achieve this.
G.10	Methods (7.1, information review) Transparency	a) It is recommended to develop an expert judgement protocol and document systematically expert judgement following the protocol. b) It is recommended to increase the transparency of the NIR in the waste and F-gases sectors by further documenting and explaining the assumptions and methodologies used to facilitate replication and assessment of the inventory.	Not resolved. a) During the review, DEFF clarified that they have noted the recommendation. Not resolved. b) In the draft 7 th national GHG inventory, the Party has not increased the transparency of reporting of waste and F-gases emissions by fully documenting and explaining assumptions and methodologies used. Not resolved.
G.11	Recalculations (7.2, information review) Consistency	a) To ensure the consistency of the time series, it is recommended to use proxies or models (if appropriate data is not available) to undertake the recalculations for energy and for IPPU and waste. See chapter 7.3.1.2 page 7.18 of the IPCC good practice guidance	Not resolved. In the draft 7 th National GHG inventory, the Party has: a) not used proxies or models to undertake recalculations where appropriate data is not available, and

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		b) It is recommended to further explain abrupt values such as PFCs from Aluminium production and correct wrong explanations such as CH ₄ from other in fugitives category.	b) Not explained abrupt value changes in many cases (e.g. abrupt change in the difference between the total Gross and Net emissions from 2011)
Energy			
E.46	1.A.4.a Commercial/Institutional (CO ₂ , CH ₄ , N ₂ O) (8.2.2(1) 1, in Informal review) Completeness	Are emissions from co-combustion in engines (2-stroke engines) reported in the energy sector? It is recommended to improve the accuracy of these estimates by investigating the lubricant use per household and the lubricant combusted in grass cutting engines.	Not resolved. In the draft 7 th GHG Inventory, in its Energy CRF (1A4 Other Sectors) the Party has reported only the following sources Other kerosene, Residual Fuel Oil (Heavy Fuel Oil), LPG, Sub-bituminous coal, Wood/Wood Waste, Other primary solid biomass, Charcoal under 1A4a (Residential). Furthermore, in the NIR Section 4.5.1, the Party reports that <i>"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."</i> During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is not resolved based on the lack of information in both the CRF tables and NIR.
E.47	1.A.1.b Petroleum refining (CO ₂ , CH ₄ , N ₂ O) (8.2.2 (1) 1, in Informal review) Completeness	It is recommended to visit the refineries to implement the appropriate actions to obtain the carbon content of fuels in coordination with the association.	Addressing. In the draft 7 th GHG Inventory, in its NIR Section 3.2.5, the Party has reported <i>"To improve the reporting of GHG emissions in this category it is important that the petroleum refineries provide plant-specific activity data, such as net calorific and carbon content values, and also develop country-specific emission factors that can be used for the calculation of GHG emissions."</i> The Party has then included this activity under planned improvements. The ERT noted that the issue is being addressed as the Party has indicated such as part of the planned improvements and recommendations.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.48	1.A.1.a Public electricity and heat production (CO ₂ ,CH ₄ ,N ₂ O) (8.2.2(1)2 in Informal review) Accuracy	If yes, does the Party report the emissions in the subsectors where the electricity was generated (e.g. manufacturing industry)? It is recommended to include further instructions in the Technical guidelines to ensure that auto production separately identified by subsector (for instance, providing more guidance in the sectors which potentially can perform the auto production such as the integrated iron and steel plants or the paper pulp plants).	Not resolved. In the draft 7 th National GHG Inventory, in its NIR Section 3.2.5, the Party reported autoproducers of electricity under category 1A1a. The ERT noted that this issue is not resolved because it is not in accordance with the 2006 IPCC Guidelines (vol.2, chapter 2, table 2.1) because the guidelines state that " <i>Emissions from autoproducers (undertakings which generate electricity/heat wholly or partly for their own use, as an activity that supports their primary activity) should be assigned to the sector where they were generated and not under 1 A 1 a. Autoproducers may be in public or private ownership.</i> "
E.49	International aviation (CO ₂ ,CH ₄ ,N ₂ O) (8.2.2(1)1, in Informal review) Transparency	How the Party split between international and domestic bunker fuels? In some cases, the national energy statistics may not provide data for bunker fuels consistent with the definition of the IPCC guidelines. In that case, the Party may use other data sources, such as data from taxation authorities or data from surveys of airline companies. It is recommended to continue developing the collaboration with the aviation authority and to engage and formalise an energy working group with the maritime authority SAMSA.	Not resolved In the draft 7 th GHG Inventory NIR it is stated that the data on international aviation is obtained from the energy balance and SAPIA. As such, no further information is available to determine whether the split is aligned with IPCC guidelines. The ERT noted that the issue is not resolved based on the lack of information to check the split, or any information on work being done in this regard.
E.50	Multilateral operations (CO ₂ , CH ₄ , N ₂ O) (8.2.2(2)2, Informal review) Consistency	Check if emissions from military aviation and navigation are excluded from the transport sector and reported in the military subcategory. Care should be taken to ensure that no double counting or omission of emissions due to military use of fossil fuels occurs. In particular, it is necessary to make sure that emissions from mobile sources operated by the country's military are effectively included under the appropriate category.	Resolved In the draft 7 th GHG NIR (Section 3.2.3 International bunker fuel) the GHG emissions from military aviation were reported separately under the other category or under the memo item multilateral operations. The ERT noted that the issue is resolved

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		It is recommended to engage with the military unit of Ministry of Defense to obtain data of better quality and improve the estimates from multilateral operations.	
E.51	1.A.3.b Road transportation (CO ₂ , CH ₄ , N ₂ O) (8.2.2(2)2, in Informal review) Completeness	Check if emissions from off-road vehicles on farm land and in forests are excluded from the transport sector and reported in the agriculture/forestry/ fisheries subcategory. Care should also be taken to ensure that emissions from mobile sources used for on-site agricultural/forestry activities and fishing are accounted for under the agriculture/forestry/fisheries subsector and that emissions are not double counted in the transport subsector. It is suggested to explore the feasibility and relative advantages of using COPERT for South Africa for the air pollutants and GHG emissions of the road transport sector.	Not resolved In the draft 7th GHG Inventory, in its NIR Section 3.2.7, the Party has reported “Road transport emissions include fuel consumption by light-duty vehicles (cars and light delivery vehicles), heavy-duty vehicles (trucks, buses and tractors) and motorcycles (including mopeds, scooters and three-wheelers). Fuels used by agricultural vehicles on paved roads are also included in this category.” During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is not resolved because emissions from fuels used for agricultural activities have been included in the road transport sector and not reported under the agriculture/forestry/fisheries sector. Also the Party was unable to provide further information on where emissions associated with off-road vehicles on farmlands and forests have been reported.
E.52	1. General (energy sector) (Gen) (8.2.1(1), in Informal review) Accuracy	In the reference approach, apparent energy consumption is calculated based on data for production, imports, exports, international bunkers, stock change. Care should be taken that the production of secondary fuels should be ignored in the reference approach because the carbon in these fuels is included in the supply of primary fuels from which they are derived. It is recommended to investigate the discrepancies in solid fuels and natural gas observed between the reference and the sectoral approaches. The working group could undertake the appropriate actions to track solid fuels and natural gas in the country. The non-energy use of fuels should be paid special attention.	Not resolved In the draft 7th GHG Inventory, the NIR states that these discrepancies still remain. A set of explanations for the reasons for the differences is provided in this inventory. These issues are unlikely to be addressed retrospectively although this should be an area of focus moving into the future. During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is not resolved

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
E.53	1.A.4.b Residential (Gen) (8.2.1(2), in Informal review) Completeness	CO₂ emissions from biomass fuel combustion should be reported but should not be included in the national totals to avoid double counting with LULUCF sector. On the other hand, other GHG emissions from biomass fuel should be included in the national total. It is recommended to estimate the biogas produced from manure management and report the emissions in the energy sector.	Not resolved In the draft 7th GHG Inventory, in its NIR Section 3.2.8, the Party has reported <i>"In 2000 biomass fuel sources dominated, however, from 2006 onwards there was no data reported for other primary solid biomass therefore the biomass fuel source declined."</i> During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is not resolved because no detailed information has been obtained on biomass emissions and biogas.
E.54	1.A.1.c Manufacture of solid fuels and other energy industries (Gen) (8.2.2(3)1, in Informal review) Transparency	Energy statistics are available for most countries from the International Energy Agency (IEA), United Nations Statistics Department (UNSD), and the United States Energy Information Administration (EIA). Additional oil and gas data are available from international survey conducted by Oil and Gas Journal. Compare reported AD with these data sources and check if the AD has omissions or large differences. It is recommended to improve the transparency of the NIR by including specific information of charcoal production (such as AD, EF, methodology and assumptions) under the category in which the emissions are reported.	Not resolved. In the draft 7th GHG Inventory, in its NIR Section 3.2.5 (1A1c), the Party has reported <i>"Combustion-related emissions from charcoal production were not estimated in this category due to a lack of data on fuel use in charcoal production plants, therefore it was assumed that fuel consumption for charcoal production is included under the category non-specified-stationary (1A5a)."</i> During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is not resolved because charcoal production emissions have not been estimated and there is no information on whether the statistical databases recommended by the UNFCCC review have been utilized.
E.55	1.B Fugitive emissions from fuels CH ₄ (8.2.2(3)1, in Informal review) Completeness	Note that fugitive emissions occur throughout the lifecycle of the fuel (extraction, production, transport, use). For example, if oil is imported and consumed in the country, the Party should report fugitive emissions from transport and beyond. It is encouraged to implement the plans of the Party on further investigating fugitive emissions from abandoned	Addressing In the draft 7th GHG Inventory, the Party notes that it has used the Coaltech study which was done to quantify fugitive emissions. However, it notes that more attention needs to be placed on the collection of fugitive emissions from abandoned mines and the spontaneous combustion of underground coal seams

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		mines and the spontaneous combustion of underground coal seams. It is recommended to undertake a study with Coaltech to update the time series.	The ERT noted that the issue is addressing, as the need is identified for more data to be collected on fugitive emissions.
E.56	1.A.1 Energy industries (Gen) (8.2.2(4)1, in Informal review) Completeness	The database of CCS projects all over the world is available at the website of Global CCS Institute (GCCSI). It is recommended to visit the CCS pilot project in the coal-to-liquid processes to develop agreements to obtain data on leakage.	Addressing In the draft 7 th GHG Inventory, in its NIR Table G, the Party has reported CO ₂ emissions from carbon capture and storage to not be occurring. During the review, the Party explained through the UNFCCC responses that "CCS project in pilot phase in 2017 from coal to liquid processes. Data on leakage will be obtained and guidelines have to be developed." The ERT noted that the issue is being addressed because the Party has indicated that data collection is currently underway.
IPPU			
I.26	2.D.1 Lubricant use (8.3.1(3) in Informal review) Completeness	Non-energy product use It is recommended to cross-check the AD on lubricants with other sources such as the sales of lubricants.	Addressing In the draft 7 th GHG Inventory, in NIR Section 4.5.1, Table 4.20, the Party reported that lubricant use activity data is sourced from energy balances from DoE. During the review, the Party noted that domestic use of lubricants will be estimated from the number of households and frequency in using machinery for grass cutting and using as an indicator lubricant consumption per household. The ERT noted that the issue is being addressed because the Party has indicated that the estimate includes domestic use of lubricants.
I.27	2.A.4 Other process uses of carbonates (8.3.1(3), in Informal review) Completeness	Is the Party collecting any data from industrial facilities directly? 1) It is recommended to establish a threshold for ceramics to collect information under the reporting Regulations.	Not resolved In the draft 7 th National GHG Inventory, in the NIR (section 4.2.5) and the IPPU CRF (2A4 OPUC tab), the Party has reported that no emissions have been calculated for Other Process Uses of Carbonates (OPUC), due to lack of data.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		2) It is recommended to conduct a survey on ceramics sector to increase the completeness of the inventory.	The ERT noted that the emissions from other process uses of carbonates can be determined from the data in the SAMI reports by determining the quantities of limestone and dolomite consumed in emissive use of carbonates as follows: Total sales - quantities used in glass, lime and cement manufacturing - quantities used in non-emissive activities = OPUC quantities. The ERT noted that the Party's statement suggesting lack of data is thus not in accordance with the 2006 IPCC Guidelines (V3, Chpt 2, pages 2.32 to 2.40, Table 2.7) because the guidelines do provide guidance on the use of carbonates in various other processes in metallurgy, agriculture, construction etc. More specifically, Table 2.7 (pages 2.37 to 2.38) of the guidelines provides more clarity on the emissive and non-emissive use of carbonates. The ERT recommends that the Party refers to the 2006 IPCC Guidelines (V3, Chpt 2, pages 2.32 to 2.40) and calculates OPUC emissions. The ERT noted that the issue is not resolved because the Party has not made use of SAMI reports or sent through any surveys to gather ceramic data.
1.28	2. General (IPPU) CO ₂ (8.3.2(1), in Informal review) Completeness	Check how limestone is used in the country Limestone or dolomite is used in a wide range of industries, namely, cement, lime, magnesium, agricultural activities, glass, etc. The inventory compiler should note that not all uses of limestone result in CO₂ emissions. It is recommended to investigate the elaboration of a limestone use balance in the country in order to complete the currently not estimated emissions under the other uses of carbonates of the IPPU sector.	Not resolved In the draft 7th National GHG Inventory, in the NIR (section 4.2.5) and the IPPU CRF (2A4 OPUC tab), the Party has reported that no emissions have been calculated for Other Process Uses of Carbonates (OPUC), due to lack of data. During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is not resolved because the Party has not indicated the use of a limestone balance in the NIR.
1.29	2.F. Product uses as substitutes for ozone depleting substances F-gases	It is recommended to check with the plants doing pyrolysis the amount of F-gases they destroy.	Not resolved In the draft 7th National GHG Inventory, in the NIR Section 4.7.1, Table 4.24, the Party has reported the data sources for

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
	(8.3.2(4)1, in Informal review) Completeness		refrigeration & air conditioning, foam blowing agents, fire protection and aerosols as HFC Survey DFFE. During the review, no further feedback on this issue was obtained from the Party. The ERT noted that the issue is not resolved because in the NIR the Party has not provided any indication of any checks with the plants doing pyrolysis on the amount of F-gases destroyed.
AFOLU			
A.14	3.A.1 Cattle - Agric 4. General (LULUCF) – LULUCF. CH ₄ (8.4.1, in Informal review)	It is recommended to prioritize improvements in the NGHGI system that allows for a proper monitoring of impacts of mitigation actions.	Addressing During the review, the Party indicated that no policy implemented; further mitigation policy identified are mainly targeting the soil C pool, or the biomass C stock in woodland, both not currently monitored by the NGHGI system.
A.15	3. General (agriculture) - Agric 3. General agriculture CH ₄ (8.4.1(2)1, in Informal review)	Because game populations are a natural component of the Earth ecosystems, associated emissions must not be included in the NGHGI. It is therefore recommended to remove those. Whether desired, such information can be added in an appendix, for informative purpose only.	Not resolved During the review, the Party indicated that South Africa will ~~ex~~ clude game population in the NGHGI.
A.16	3. General (agriculture) - Agric (8.4.4(2)14, in Informal review)	It is suggested to keep the scientific community involved in such data collection and analysis.	Addressing During the review, the Party indicated that data for livestock characterization have been collected once from a study published in 2010. It is a good practice to update those data periodically (e.g. every 10 years), although the availability of resources is an issue. The scientific community is the likely subject for updating that information.
A.17	3.A.1 Cattle - Agric Manure management system LULUCF (8.4.1(2)1, in Informal review)	It is recommended to investigate the data coverage and quality, as well as to look for opportunities to collect updated data (DALRRD is the likely subject to be asked).	Not Resolved In the draft 7 th GHG Inventory, the Party has reported that data coverage is not clear.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
A.18	Livestock CH ₄ EFs (8.4.1 (2) 1, in Informal review).	Since all background data are available, it is suggested to add a worksheet to the NGHGI where the EFs are calculated annually.	Addressing In the draft 7 th GHG Inventory, the Party reported most within a climate zone. Although some subsistence livestock can stay in hotter/drier climate. EFs taken from literature.
A.19	3D. agricultural soils (8.4.1 (2) 1, in Informal review). N ₂ O	It is recommended to estimate indirect N ₂ O emissions from MM by applying Tier 2, since all information needed is available.	Addressing During the review, the Party indicated that N ₂ O emissions from volatilization will be included using Tier 2.
A.20	3D. agricultural soils (8.4.1 (2), in Informal review). N ₂ O	Although not a priority, this is an area where additional information needs to be collected in the near future since this is a mitigation policy.	Addressing During the review, the Party reported that information is not available, although considered not significant.
A.21	Organic fertilizer (8.4.1(2)2, in Informal review).	However, in FAOSTAT, information on rice production is reported. It is therefore recommended to verify with DALRRD such information, and to require an update of FAO statistics accordingly.	Resolved The ERT noted that the Party will address the query before the NIR is finalised.
A.22	Crop residue (8.4.1(2)4, in Informal review).	It is recommended to do a full balance of crop residues to avoid any double counting as well as any gaps.	Addressing During the Inventory review, the Party not a full mass balance of crops residues is implemented. Crop residues stock is estimated by using IPCC methods.
A.23	Agriculture (8.4.1(2)5, in Informal review).	It is suggested to investigate the large discrepancy with the sales data previously used (till 2009) to prepare the estimates, as well as with the "expected" lime application reported by the ARC.	Addressing During the Inventory review, the Party reported that currently the estimates are based on lime production.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
A.24	Land use (8.4.1 (2) 1, in Informal review). N ₂ O	To apply the 20-year rules to the time series 1990-2009, by applying for the previous years the same annual rate of conversion observed for the first year of the time series.	Resolved During the Inventory review, the Party reported that the 2010 onwards will be applied.
A.25	Agriculture – general (8.4.1 (2) 1, in Informal review).	Although in such cases both original maps should be investigated in order to establish which the correct classification is, considering the recommendation to assess the applicability of a land cover/use survey system, it is recommended to eliminate all those absurd changes by assigning the land to the category of the latest map.	Addressing During the review, the Party indicated that however it is noted that map overlapping has resulted in some "absurd" conversions, e.g. bare land to indigenous forest.
A.26	LULUCF (8.4.1 (2) 1, in Informal review).	Although maps are a fundamental instrument of knowledge, useful also for the NGHGI compilation, it is noted that statistical approaches, i.e. survey, can deliver data with higher accuracy at a lower cost. Further, considering that the Department of Environmental Affairs is already using survey techniques (i.e. FAO Collect Earth), it is recommended to explore the applicability of those techniques to the NGHGI compilation; in particular to build a complete time series of land cover and land use change from 2018 backwards to 2000, and to keep updating such time series every 2 years according to the biennial reporting pace.	Resolved During the review, the Party indicated that the land representation is based on 2 land use maps only (1990-2014) although prepared applying the same methodology and dataset. Although it is possible to use maps to build a land representation is noted that it is good practice to verify the maps, and especially the land use change maps derived by overlapping maps. That to overlap the images to detect changes minimizes errors compared to maps overlapping. That although the accuracy of maps can be assessed through verification (i.e. confusion matrix), and statistics derived from the map adjusted accordingly, the map per se cannot be corrected so that any subsequent use/overlap brings all the errors in the estimate, and when a time series of maps is used such errors do not tend to cancel out while they tend to be exponential.
A.27	Land use (8.4.2(2) 1, in Informal review).	It is recommended to do a national forest inventory and to use the land representation survey as the first phase (identification of the forest land area).	Resolved During the review, the Party indicated that South Africa does not have a national forest inventory.
A.28	Land use (8.4.2 (2) 1, in Informal review).	Since IPCC provides default factors for both C stocks, it is recommended to include annual biomass in the year of conversion only (i.e. Bafter). Of course, the use of national factors is to be preferred, if any.	Resolved During the review, the Party indicated that annual biomass inland converted to cropland and land converted to grassland.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
A.29	Forest Land (8.4.2 (2) 2, in Informal review).	It is recommended to use all information that become available across time to verify such model outputs, possibly for each C pool and each forest subcategory. Further, it is recommended to assess the possibility to establish a National Forest Inventory System, continuous (i.e. collecting a fraction of the sample each year) within a cycle (5-10 yrs) to collect all needed information. Such assessment should be conducted together with SA REDD+.	Addressing During the review, the Party indicated that for forest land (excluding plantations) SA applies a model based on remotely sensed information (reflectance) as well as meteorological data to estimate C stocks (Biomass and DOM) and biomass increment. Although no data are routinely collected to statistically verify. Although the use of Tier 3 model is seen as an enhancement in the quality of a NGHGI, and therefore encouraged under UNFCCC, it is a UNFCCC requirement to verify routinely the model outputs with actual measurements. In practice, models are known for dramatically reducing the amount of information to be collected and the associated cost, although they cannot replace completely the need to collect actual information.
A.30	Land use (8.4.2 (2) 2, in Informal review).	It is recommended to consider moving the "degraded" subcategory from Other land to Grassland.	Resolved During the review, the Party indicated that the category degraded land seems better suiting the grassland definition, although a particular type of highly degraded grassland.
A.31	Forest land (8.4.2 (2) 2, in Informal review).	It is recommended to add mortality losses to the model, meanwhile mortality factors taken from table 3.2.2 of the 2003 IPCC GPG can be used as well as any other more appropriate values found in the literature. It is also recommended to add wood losses associated with charcoal production, by using FAOSTAT data or any more accurate in-country source of information. Regarding the net increment, it is suggested to try to compare it with alternative independent studies, until a forest inventory system is established.	Resolved During the review, the Party indicated that DOM only in case of changes among forest types. SOM always at equilibrium. Regarding the biomass pool, it is noted that mortality is not modelled for natural forest, which brings to an overestimate of the sink. Another driver of overestimation is the exclusion of wood losses associated with charcoal production.
A.32	Cropland (8.4.2 (2) 2, in Informal review).	It is recommended to apportion the 1990 area, in both CLrCL and LcCL, of each perennial crop according to a linear constant age-class distribution calculated by dividing the crop area by the number of years of the cultural cycle. Accordingly a net increment rate is calculated for each crop as the C stock at maturity divided by the number of years of	Resolved During the review, the Party indicated that in general, it has been reported a net gain in biomass in land converted to

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		the cultural cycle. Then, a net accumulation is estimated for all age classes smaller than the oldest one and a net loss, equal to the net accumulation calculated, is estimated for the oldest class.	cropland only; without any consideration of harvesting at the end of the cultural cycle
A.33	Settlements (8.4.2 (2) 2, in Informal review).	It is recommended to either establish a maturity age or apply net gain till such age is achieved, followed by a harvesting and replanting (this will require to stratify the settlements per age classes); or to calculate a net accumulation for the area of land converted to settlements only.	Resolved During the review, the Party indicated that a constant rate of net C accumulation is calculated for the Settlement area estimated as covered by trees.
A.34	Settlements (8.4.2 (2) 2, in Informal review).	It is suggested to apply the atmospheric approach for comparison.	Resolved During the review, the Party indicated that only production approach is applied.
A.35	Cropland (8.4.2 (2) 2, in Informal review). CO ₂	It is recommended to not report CO ₂ emissions from cropland and grassland burning. Nevertheless, where time allows, CO ₂ emissions from burning of low shrub land can be reported, however also subsequent CO ₂ removals should be. To do so, it is suggested to consider the area of burned low shrub land as having an age of 2 and therefore to accumulate in the following 18 years the annual net C stock gain.	Resolved During the review, the Party indicated that CO ₂ emissions from cropland as well as from grassland need not to be reported since the subsequent CO ₂ removals are not.
WASTE			
W.25	5.A Solid waste disposal on land (8.5(1), in Informal review) Accuracy	It is recommended to differentiate between managed and unmanaged and to estimate the share managed/unmanaged, waste composition and methane correction factor during the time series (or every five years) using expert knowledge and proxies such as consumption patterns statistics and households survey. More documentation is needed in the NIR on methods, assumptions and data sources. It is also suggested to remove uncategorised SWDS from the Technical Guidelines. It could also be useful to include	Resolved During the review, the Party indicated that all SWDS is assumed to be managed.

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
		in the Technical Guidelines the localisation of the sites (formaps representation or further studies for instance).	
W.26	5.A Solid waste disposalon land (8.5(1), in Informal review) Accuracy	It is recommended to implement the results of the waste studies that will fill all the gaps and missing information of the sector.	Addressing During the review, the Party indicated that some studies ongoing. No data on landfills that are owned by industry. No data available on composting and bio digesters.
W.27	5.A Solid waste disposalon land (8.5(1), in Informal review) Transparency	It is recommended to collect information on annual methane recovery in the CDM projects in order to subtract it from the emissions and to report biogas used for energy purposes in the energy sector.	Addressing During the review, the Party indicated that some CDM projects with annual methane recovery data available not taken into account.
W.28	5.D Wastewater treatment and discharge N ₂ O (8.5(2), in Informal review) Transparency	It is recommended to investigate how to treat sludge from agriculture. It is recommended to provide more documentation on data sources and assumptions in the NIR to improve the transparency. The inventory team is encouraged to undertake their planned research from 4 potential different data sources (SALGA, SSA, MRC and Department of Health) to obtain country specific data on protein.	Not resolved During the review, the Party indicated that it was not clear how to treat sludge from agriculture (will be investigated). More clarity is needed in the NIR. Protein data comes from FAO.
W.29	5.D Wastewater treatment and discharge (8.5(2), in Informal review) Accuracy	It is recommended to implement the results of the characterisation by type of treatment and pathways in the ongoing studies by ensuring that the studies will investigate the issue.	Not resolved During the review, the Party indicated that it is one of the areas of improvement through the studies
W.30	5.C.1 Waste incineration (8.5(3), in Informal review) Transparency	It is recommended to appropriately implement the recently implemented research on amounts that go to landfill, open burning, incinerators, biological treatment and recycling as well as the domestic/industrial shares.	Addressing During the review, the Party reported that the assumptions are that the waste generated by the 80% of population covered by waste collection services go to landfills while the waste from the 20% of the population not covered are openly burnt. Incineration, biological treatment and recycling as well

ID#	Issue and/or problem classification ^a	Recommendation made in previous review report	ERT assessment and rationale
			as the industrial part should be taken into account in the 20% of population not covered by waste collection services.

Abbreviations: [CRF = common reporting format], [ERT = expert review team], [IPPU = industrial processes and product use], [LULUCF = land use, land-use change and forestry], [NEU = non energy use], [NIR = national inventory report], [QA/QC = quality assurance/quality control]

^a References in parentheses are to the paragraph(s) and the year(s) of the previous review report(s) where the issue was raised.

