PAPUA NEW GUINEA

NATIONAL INVENTORY DOCUMENT 2000 - 2022

TO

THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

2025

CLIMATE CHANGE AND DEVELOPMENT AUTHORITY

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List of Acronyms

ANG	Air Niugini
APERC	Asia Pacific Energy Research Centre
BUR	Biennial Update Report
CCDA	Climate Change Development Authority
CEPA	Conservation and Environment Protection Agency
DAL	Department of Agriculture and Livestock
DSP	Development Strategic Plan
FAO	United Nations Food and Agriculture Organisation
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Giga gram
GHG	Greenhouse Gas
GHGi	Greenhouse Gas inventory
Ha	Hectare
ICAO	International Civil Aviation Organisation
IPP	Independent Power Producers
IPPU	Industrial Processes and Other Product Use
JICA	Japanese International Cooperation Agency
KCA	Key Category Analysis
Km	Kilometer
ktoe	Kilo-tonne of oil equivalent
LNG	Liquefied Natural Gas
LULUCF	Land use, Land-Use Change and Forestry
MP-NFI	Multi-Purpose National Forest Inventory
MRA	Mineral Resources Authority
MRV	Monitoring, Reporting and Verification
MW	Megawatt
NC	National Communication
NCCDMP	National Climate Compatible Development Management Policy
NCDC	National Capital District Commission
NDC	National Disaster Centre
NEC	National Executive Council
NFA	National Fisheries Authority
NFI	National Forest Inventory
NSO	National Statistics Office
PNG	Papua New Guinea

PNGPA	Papua New Guinea Forest Authority
QA/QC	Quality Assurance and Quality Control
REDD+	Reducing Emissions from Deforestation and forest Degradation and the role of Conservation, Sustainable management of forest and enhancement of carbon stocks
STaRS	National Strategy for Responsible Sustainable Development
SWDS	Solid Waste Disposal Site
UNEP	United Nations Environment Programme

Chapter 1. Introduction

1.1. Background information on GHG inventories and climate change

Greenhouse gas (GHG) inventories are essential tools for tracking the emissions of gases that contribute to climate change. These inventories help countries monitor and report their emissions to assess progress toward reducing them and mitigating the effects of climate change.

Papua New Guinea (PNG) became a party to the Paris Agreement in 2016 after ratifying it. This commitment reflects PNG's dedication to addressing global climate change and taking action to limit global warming to well below 2°C above pre-industrial levels, with efforts to limit the increase to 1.5°C.

The National Inventory Document highlights PNG's specific commitment to the Paris Agreement, particularly Article 13, which focuses on transparency and the reporting of progress toward climate goals. Article 13 outlines the requirements for countries to submit national GHG inventories, progress on implementing climate actions, and the associated impacts.

The report follows the reporting guidance provided in Decision 18/CMA1, which ensures consistency and clarity in how countries report their emissions. This includes a commitment to using internationally recognized estimation methodologies, and for PNG, these are in line with the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines. These guidelines provide standardized approaches to estimating and reporting GHG emissions, ensuring that data is comparable, transparent, and credible across all countries.

This report provides a narrative on major emission trends and methodologies for estimating emissions and removals and includes information on inventory data for 2000–2022 from all emissions and removals in PNG. It also includes sections on the inventory recalculations and improvements.

1.2. A description of the national inventory arrangements

1.2.1. Institutional, legal and procedural arrangements

The Climate Change and Development Authority (CCDA) is the mandated entity in PNG responsible for ensuring that PNG implement the United Nations Framework Concention on Climate Change and the Paris Agreement in collaboration with line agencies. The purpose of CCDA is to promote and mange the climate compatible development through climate change mitigation and adaptation activities.

CCDA is the entity responsible for the overall coordination and management of the national reports under the Convention and the Paris Agreement such as the National Communications and Biennial Transparency Reports. In addition, CCDA manages the preparation of National GHG Inventory as part the these national reports. Key functions include the identification of data sources under each sector, collection and compliation of activity data and emission factors for each sector, and estimation and reporting of GHG emisssions by sources and removals by sinks.

CCDA collaborates with the designated lead sector agencies to compile the GHG inventory. Through this collaboration, CCDA recieves activity data and to some extent emission factors to enable the estimation of GHG emissions and removals. Private companies also provide the relevant data when sector lead agencies don’t have the available data. The figure below outlines the recent Institutional Arrangement of the GHG inventory.

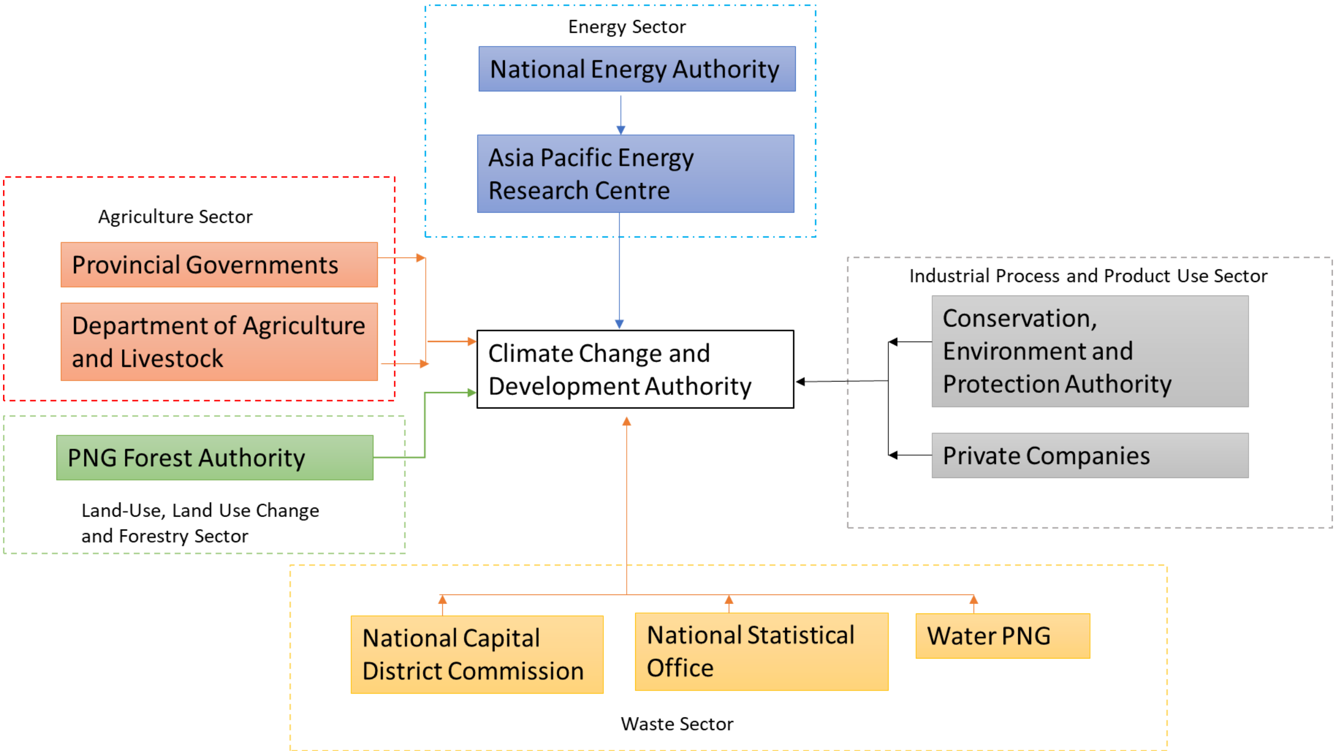

Figure 1-1: Institutional Arrangement

For the Energy Sector, the National Energy Authority (NEA) was invovled by the activity data that was used was from the energy balance table compiled by the Asia Pacific Energy Research Centre (APERC) by using the Oil and Natural gas data provided by NEA.

For the Industrial Process and Product Use, the Conservation, Environment and Protection Authority was involved by providing HFC activity data. In addition, two private sector agencies also provided activity data for the N_2O and lubricant use.

For the Agriculture sector, the Department of Agriculture and Livestock, lead agency for the agriculture sector was involved by providing livetock data. In addition, Provincial Governments (sub-national) also provided livestock data especially for small scale farms. For the Land Use, Land Use Change and Forestry sector, the PNG Forest Authority, the lead agency for the forestry sector were involved and provided activity data and to some extent emission factor data.

And for the Waste sector, three government agencies namely, Water PNG, National Statistical Office, and the National Capital District Commission provided activity data and other relevant infomation that was used to estimate emissions from the waste sector.

1.2.2. QA/QC and verification plan

PNG currently does not have a formal Quality Assurance and Quality Control (QA/QC) and verification plan in place for its GHG. Consequently, the nation will apply the flexibility provisions allowed under the Enhanced Transparency Framework for this submission to account for these technical and institutional capacity constraints. The CCDA is actively working on the preparation of a robust QA/QC plan, which is intended to streamline data verification and enhance transparency in future reports. Progress on this plan and its implementation will be formally detailed in the next submission

1.2.3. Changes in the national inventory arrangements since previous GHG inventory

Provincial Governments (sub-national) were not part of the national inventory arrangements but were included in the current reporting cycle. The inclusion of provincial governments in providing livestock data for the agriculture sector has likely enhanced the accuracy and specificity of the national inventory, improving its reflection of local agricultural realities. The changes would have been primarily focused on integrating provincial data into the national framework without altering the institutional arrangements for other sectors.

1.3. Inventory preparation, and data collection, processing and storage

Inventory planning and preparation is a process managed and undertaken by CCDA in close consultation with its key data and industry stakeholders. These stakeholders are those outlined in section 1.2.1 'Institutional, legal and procedural arrangements' that have an important role in the compilation of the GHG inventory. Stakeholders provide guidance on methodology as well as provide the necessary activity data and emission factors to estimate GHG emissions.

The GHG inventory compilation process is initiated via a notification sent to key data stakeholders. This notification sets out CCDA's approach to estimating GHG emissions and removals and seeks the provision of activity data and/or emission factors to enable GHG emissions to be estimated.

Data provided by stakeholders are kept by CCDA on its internal corporate systems. CCDA staff review the data before estimating emissions to identify any anomalies. The general inventory process is shown in the table below.

Table 1-1:The GHG inventory process

Milestone	Time
GHG inventory improvement planning	5 months
Kickoff meeting/workshop	1 months
Data collection - Stakeholder identification/stakeholder identification and engagement - Sub technical working committee meetings, as needed - Sending official data request letters including data sheets - Data collection and analysis - Update database	12 months
GHG emission/removal estimation	1 months
Compilation of the GHG inventory - Linking all sector files to the summary table files and producing the national total GHG emissions/removals. - updating the key category analysis - updating the uncertainty assessment	1 months
Updating the NID and BTR1	2 month
Validation meeting/workshop	1 month
Revision of the GHG inventory, as needed	0.5 months
Submission to the Climate Change Minister of Environment and Climate Change	0.5 month
Submission to the UNFCCC	
GHG inventory preparation process	~24 months*

1.4. Brief general description of methodologies and data sources used

1.4.1. Data sources

PNG used the 2006 IPCC guidelines, 2013 IPCC Wet land supplements and 2019 IPCC Supplements to for this national GHG inventory. The activity data used were provided by National Government Agencies, Provincial Governments (Sub-National) and private companies. Expert judgement and international sources were used to fill in for sectors or categories which did not have existing activity data inorder to ensure completeness.

As for the emission factors, most values used were default values in the IPCC guidelines. Although some categories in the LULUCF sector used country-specific emission factors taken from existing literature.

1.4.2. Time series

The time series for this national GHG inventory was from 2000 to 2022. The exceptions include HFC emissions, which were from 2015 to 2022. Additionally, N_2O for Medical Application (CRT 2.G.3.) was from 2002 to 2022.

1.4.3. Global warming potentials (GWPs) used.

The Global Warming Potentials are taken from the IPCC Fifth Assessment Report as per decision 18/CMA 1. The table below provides a list of GWP values that were used.

Table 1-2: GWP Values used

Species	Chemical formula	Global Warming Potential (GWP)
Carbon dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265
HFC-23	CHF_3	12400
HFC-32	CH_2F_2	677
HFC-41	CH_3F	116
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1650
HFC-125	CHF_2CF_3	3170
HFC-134	CHF_2CHF_2	1120
HFC-134a	CH_2FCF_3	1300
HFC-152a	CH_3CHF_2	138
HFC-143	CH_2FCHF_2	328

Species	Chemical formula	Global Warming Potential (GWP)
HFC-143a	CH_3CF_3	4800
HFC-227ca	$CF_3CF_2CHF_2$	4640
HFC-263fb	$CH_3CH_2CF_3$	76
HFC-245ca	$CHF_2CH_2CF_3$	858

1.5. Brief description of key categories

The key categories for this report were identified using the Tier 1 level and trend assessment as per decision 18/CMA1. This approach identified the categories, which combined, contributed 95% of total emissions, or 95% of the inventory trend in absolute terms.

For the level assessment, when LULUCF was included in the assessment, the major contributions in 2022 were:

- CO_2 emissions from Forest land Remaining Forest land (46%)
- CO_2 emissions from Other Land converted to Cropland (16%);
- CH_4 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Natural Gas (9%); and
- CO_2 emissions from Fuel Combustion Activities – Manufacturing Industries and Construction (8%).

When LULUCF was excluded from the level assessment, the major contributions to the emissions in 2022 were:

- CH_4 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Natural Gas (26%);
- CO_2 emissions from Fuel Combustion Activities – Manufacturing Industries and Construction (22%);
- CO_2 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Natural Gas (8%); and
- CO_2 emissions from Fuel Combustion Activities – Road Transport (8%).

For the trend assessment, when LULUCF was included in the assessment, the major contributions were:

- CO_2 emissions from Forest land Remaining Forest land (23% as a decrease);
- CH_4 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Natural Gasl (21% as a increase)
- CH_4 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Oil (20% as an decrease)
- CO_2 emissions from Other land converted to Cropland (6% as a increase)

When LULUCF was excluded from the trend assessment, the major contributions to the emissions were:

- CH_4 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Oil (39% as a decrease);
- CH_4 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Natural Gas (29% as an increase);
- CO_2 emissions from Fugitive emissions from fuel – Oil and Natural Gas, specifically Natural Gas (9% as an increase); and
- CO_2 emissions from Fuel Combustion Activities – Energy Industries (7% as an increase)

The full results of the key category assessment, both level and trend, are presented in Annex 1.

1.6. General uncertainty evaluation

According to the 2006 IPCC guidelines, uncertainty estimates are an essential element of a complete inventory of GHG emissions and removals. They should be derived for both the national level and the trend estimate, as well as for the component parts such as emission factors, activity data and other estimation parameters for each category.

Tier 1 method and Approach 1 as outlined in Chapter 3 of Volume 1 of the 2006 IPCC Guidelines, was used to estimate the uncertainties of the activity data and emission factors for all sectors in this inventory. The total uncertainty of the inventory was obtained by analyzing the uncertainties of the three relevant GHGs, CO_2, CH_4 ,N_2O and HFC.

The result of the uncertainty analysis shows that the overall or total uncertainty of PNG's NGHGI is 3.53 % with trend uncertainty of 0.77 % . For further details, see Annex II.

1.7. General assessment of completeness

This NID presents the assessment of anthropogenic GHG emissions and removals from 2000 to 2022 in PNG. PNG reported on CO_2, N_2O, CH_4, and HFC from categories that exist in the country. PFCs, SF6, NF3, as well as precursor gases CO, NOx, and NMVOC, are not reported. Emissions from some categories were not estimated due to the following reasons:

- Emissions that do not occur in the country;
- Unavailability of data; and
- Technical capacity of practitioners.

Furthermore, emissions of some categories were included elsewhere due to methodological issues specific to the national circumstances. More details on the completeness of the inventory can be found in the individual sectors.

CCDA has prioritised completeness in the GHG inventory improvement plan and will try to include emissions from those categories and gases that were not estimated in this NID but exist in PNG in the next NID.

1.8. Recalculations

The following categories were recalculated for this reporting cycle:

- Energy Sector – Energy industries (CRT Category 1.A.1)
- Agriculture Sector - Enteric Fermentation (CRT Category 3.A) and Manure Management (CRT Category 3.B)
- LULUCF Sector – Forest land (CRT Cateroty 4.A) and Prescribed burning of savannahs on Forest Land (CRT Category 3.E.1)
- Waste Sector – Open burning of waste (CRT Category 5.C.2) and Waste water treatment and discharge (CRT Category 5.D)

In addition, previous GHG inventories were estimated using Microsoft Excel, but for this inventory, most categories were estimated using the IPCC Software. Categories which were not estimated using the IPCC software include Product uses as substitutes for ozone depleting substances (CRT Category 2.F) and all categories under the LULUCF sector.

Chapter 2. Trends in GHG emissions and removals

2.1. Description and interpretation of emission trends for aggregated GHG emissions

PNG's GHG inventory from 2000 to 2022 illustrates a transition from a significant net carbon sink to a net emitter, driven by rising industrial activity and fluctuating sequestration levels. In 2000, the nation maintained a net-negative profile of approximately -23,405.24 Gg CO_2 eq, as the LULUCF sector effectively offset all anthropogenic outputs; however, a surge in Energy sector emissions eventually led to a peak net positive of 10,503.69 Gg CO_2 eq in 2015. More recent figures show a decline to approximately 3,900 Gg CO_2 eq in 2022.

The total GHG emissions, without the LULUCF, increased from 9,159.47 Gg CO_2 eq in 2000 to 18,178.90 Gg CO_2 eq in 2022, an increase of 98%. The energy sector contributed the highest in 2022 with 15,660.99 Gg CO_2 eq (86%) followed by the waste sector with 1,608.72 Gg CO_2 eq (9%), Agriculture with 764.03 Gg CO_2 eq (4%), and IPPU with 145.17 Gg CO_2 eq (1%). Figure 2-1 and Figure 2-2 shows the total GHG emissions and removals, including and excluding LULUCF, for each inventory year. Furthermore, Table 2-1 provides total GHG emissions and removals, excluding and including LULUCF, for each inventory year 2000 to 2022.

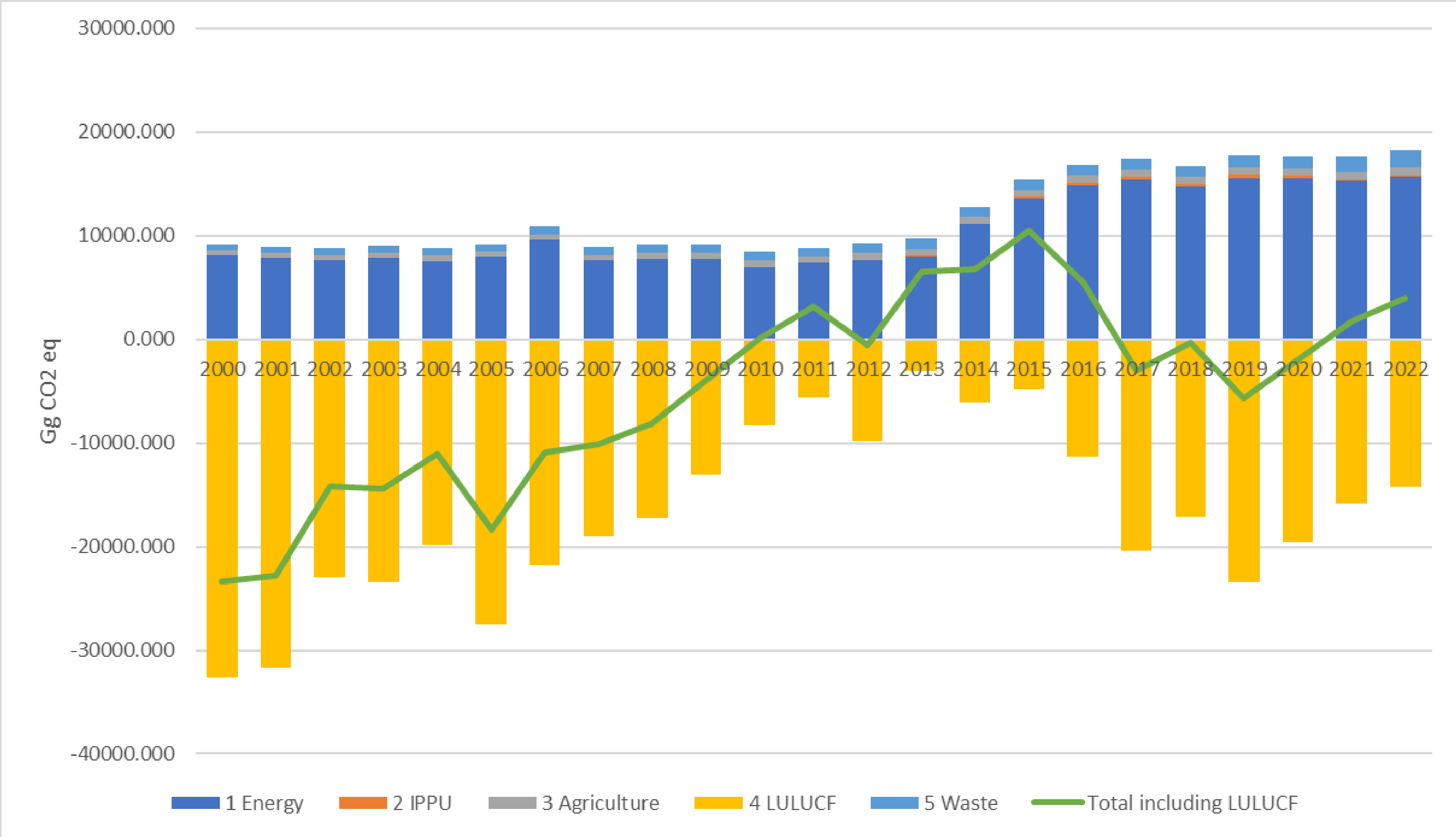

Figure 2-1: Total net GHG emissions and removals including LULUCF from 2000 to 2022

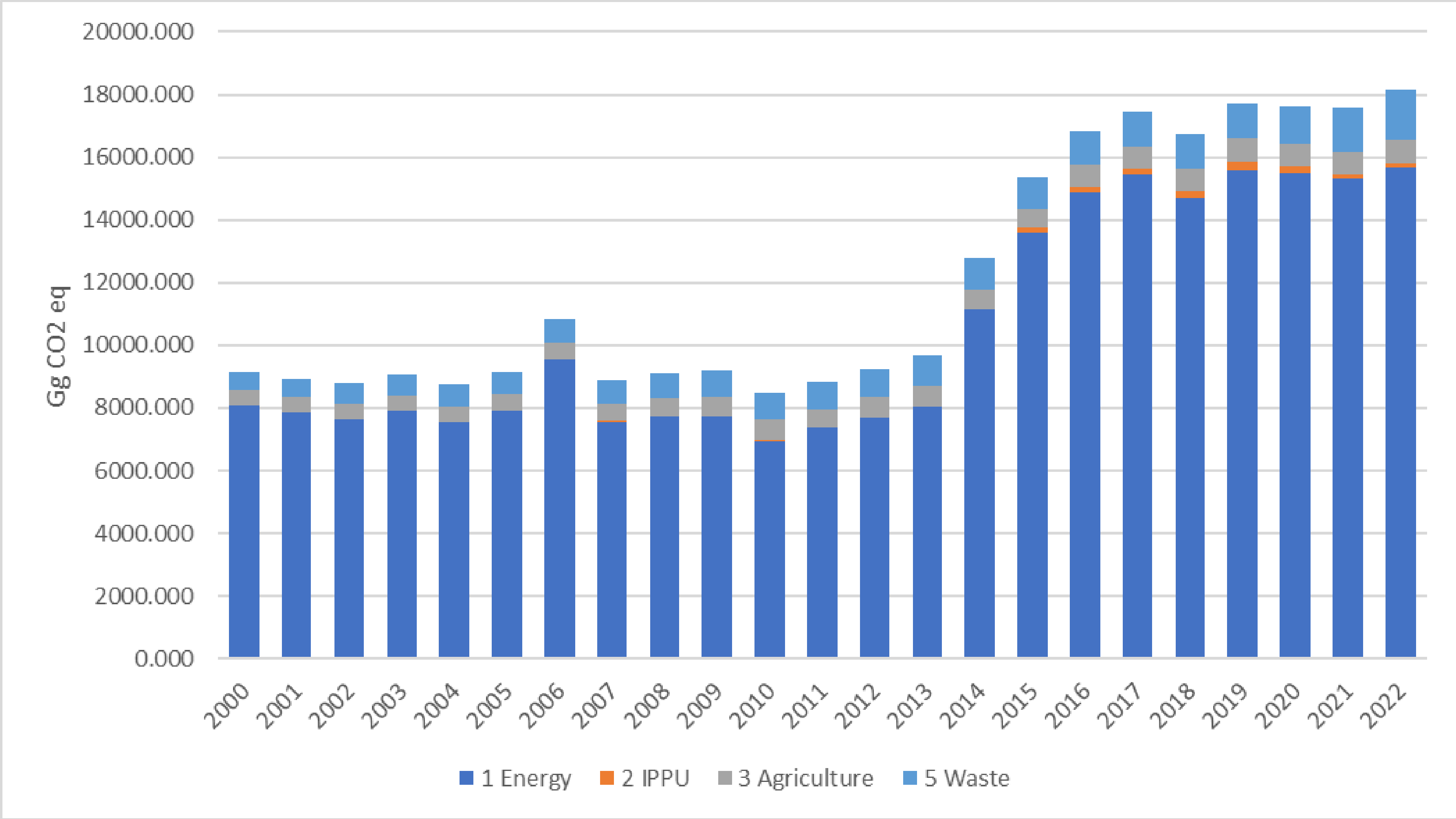

Figure 2-2: Total GHG emissions excluding LULUCF from 2000 to 2022 (in Gg CO_2 eq)

Table 2-1: Total annual GHG emissions by sectors (Note: LULUCF data is not included for the years 2018 to 2022)

	Sector`	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	Energy	Gg CO_2 eq	8,089.83	7,858.72	7,655.46	7,905.16	7,547.00	7,926.07	9,551.15	7,574.31	7,747.68	7,744.76	6,952.51	7,359.67
2	IPPU		0.82	0.82	0.82	1.58	2.38	2.41	2.50	2.45	2.38	2.39	2.40	2.59
3	Agriculture		478.27	474.32	483.83	476.36	509.38	500.76	525.20	538.58	539.56	596.23	675.32	585.48
4	LULUCF		-32,564.71	-31,738.46	-22,943.93	-23,449.65	-19,843.56	-27,480.50	-21,764.90	-18,977.69	-17,260.61	-13,070.80	-8,363.11	-5,632.14
5	Waste		590.55	614.48	639.27	669.57	697.22	722.99	749.26	776.78	807.53	835.13	863.65	892.33
	Total including LULUCF	Gg CO_2 eq	-23,405.24	-22,790.12	-14,164.55	-14,396.98	-11,087.57	-18,328.26	-10,936.79	-10,085.56	-8,163.47	-3,892.29	130.76	3,207.93
	Total excluding LULUCF	Gg CO_2 eq	9,159.47	8,948.34	8,779.38	9,052.67	8,755.98	9,152.24	10,828.11	8,892.13	9,097.15	9,178.51	8,493.87	8,840.06

	Sector	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Energy	Gg CO_2 eq	7,665.85	8,035.83	11,129.39	13,587.94	14,881.42	15,435.68	14,716.72	15,591.90	15,484.61	15,306.23	15,660.99
2	IPPU		2.35	2.22	2.15	164.96	186.51	179.32	192.04	275.57	230.08	141.53	145.17
3	Agriculture		664.97	691.38	656.27	605.01	697.22	736.56	734.79	729.45	729.74	730.30	764.03
4	LULUCF		-9,836.27	-3,106.78	-6,072.59	-4,868.32	-11,360.66	-20,429.70	-17,129.53	-23,459.11	-19,550.14	-15,810.55	-14,269.79
5	Waste		921.73	953.93	983.94	1,014.11	1,045.03	1,075.95	1,105.58	1,137.50	1,169.78	1,406.62	1,608.72
	Total including LULUCF	Gg CO_2 eq	-581.37	6,576.58	6,699.16	10,503.69	5,449.51	-3,002.18	-380.40	-5,724.70	-1,935.93	1,774.13	3,909.10
	Total excluding LULUCF	Gg CO_2 eq	9,254.90	9,683.36	12,771.75	15,372.01	16,810.17	17,427.51	16,749.13	17,734.42	17,614.21	17,584.68	18,178.90

2.2. GHG emission and removal trends by sector

2.2.1. Energy

Emissions from the energy sector amounted to 15,660.99 Gg CO_2 eq in 2022, an increase of 7,571.55 Gg CO_2 eq (94%) when compared to 2000. CO_2 emissions from Fuel Combustion (CRT Category 1A) contributed 40 % of the total GHG emissions in 2022, followed by CH_4 emissions from Fugitive emissions from fuel (CRT Category 1B) (38 %), CO_2 emissions from Fugitive emissions from fuel (CRT Category 1B) (10 %), CH_4 emissions from Fuel Combustion (CRT Category 1A) (4 %) while N_2O emissions from Fuel Combustion (CRT Category 1A) contributed 1%. Figure 2-3 below outlines the trends of emissions from the Energy Sector from 2000 to 2022.

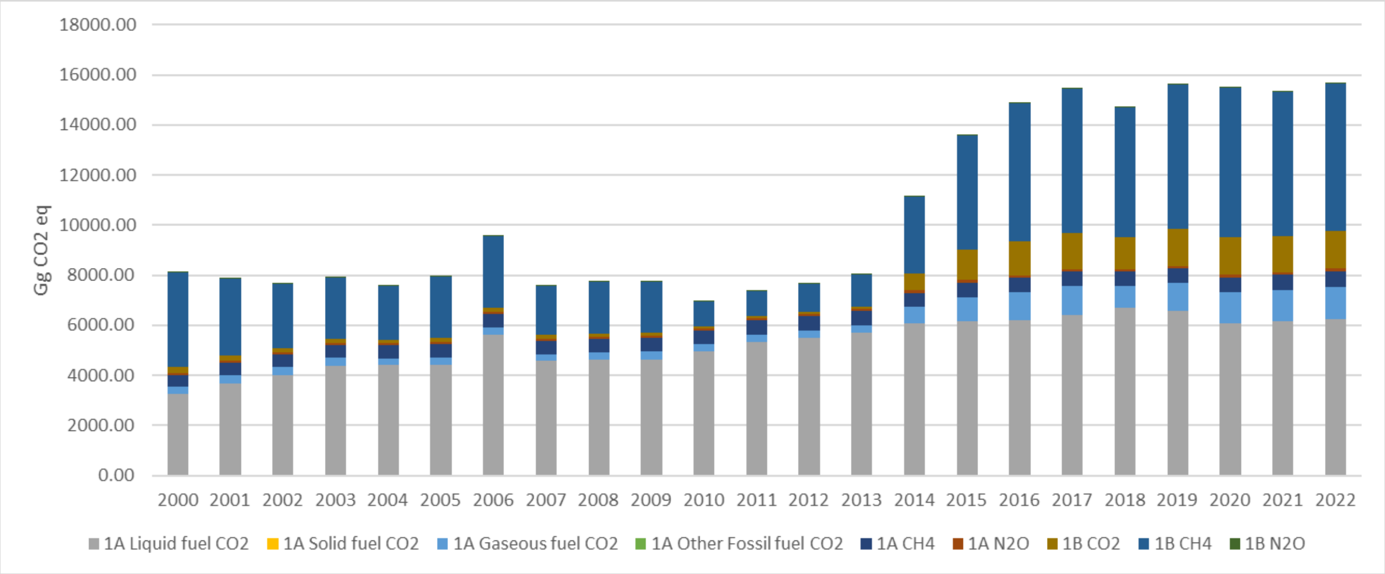

Figure 2-3: Trend in GHG emissions from the Energy Sector (2000-2022) (in Gg CO_2eq)

2.2.2. Industrial Processes and Product Use (IPPU)

The total GHG emissions in the IPPU sector in 2022 were 144.17 Gg CO_2eq, which is about 1% of the total emissions (excluding LULUCF). The relative contributions of individual GHGs are as follows: CO_2 (1%), HFCs (98%), and N_2O (1%). This ratio remains consistent over time, except for HFCs, which were estimated only for the years 2015 to 2022. However, it’s important to acknowledge that the IPPU inventory remains significantly incomplete. Figure 2-4 below outlines the trends of emissions from the IPPU Sector from 2000 to 2022.

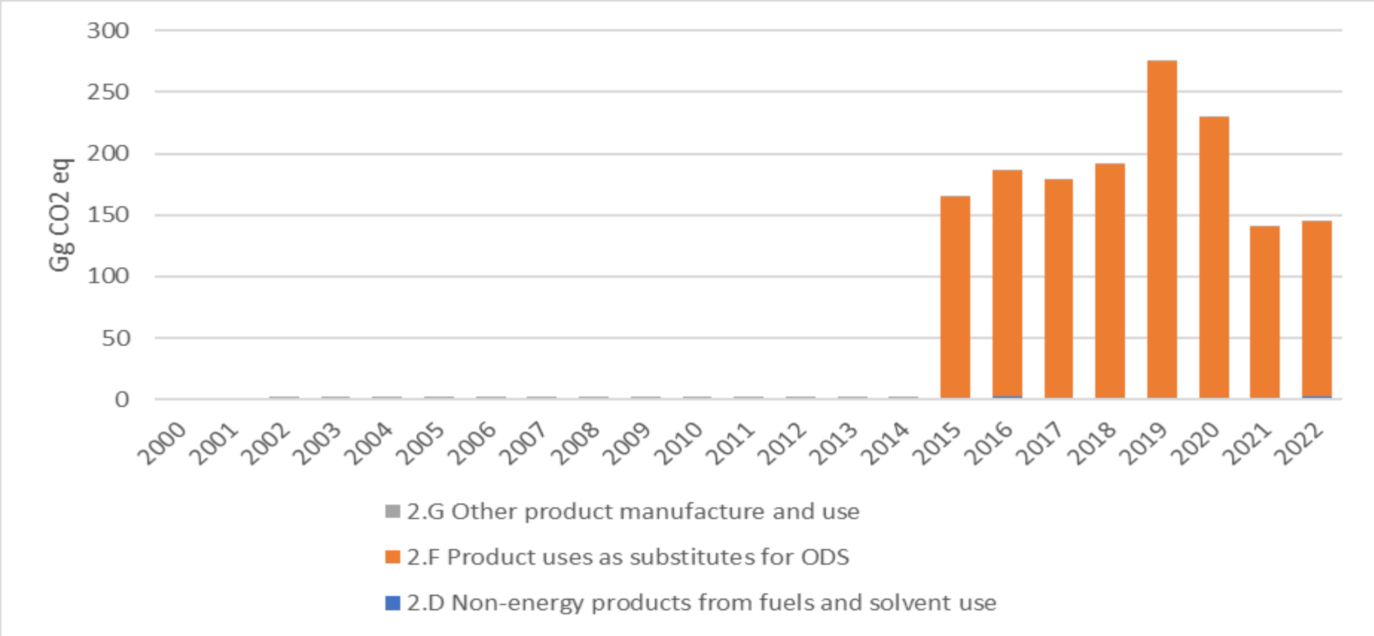

Figure 2-4: Trend in emissions from the IPPU Sector (2000 to 2022) (in CO_2 eq)

2.2.3. Agriculture

GHG emissions from the agriculture sector amounted to 764.03 Gg CO_2 eq in 2022, which is approximately 4% of the country's overall emissions that year (excluding LULUCF). Total emissions increased by 285.76 Gg CO_2 eq (37%) when compared to the year 2000. The highest emitting category in 2022 was Agricultural soils (CRT category 3.D), which contributed 37% of the total sector emissions. After this is the Enteric Fermentation (CRT Category 3.A), which contributed 33%, followed by Manure Management (CRT Category 3.A) with 30%. Figure 2-5 below outlines the trends of emissions from the Agriculture Sector from 2000 to 2022.

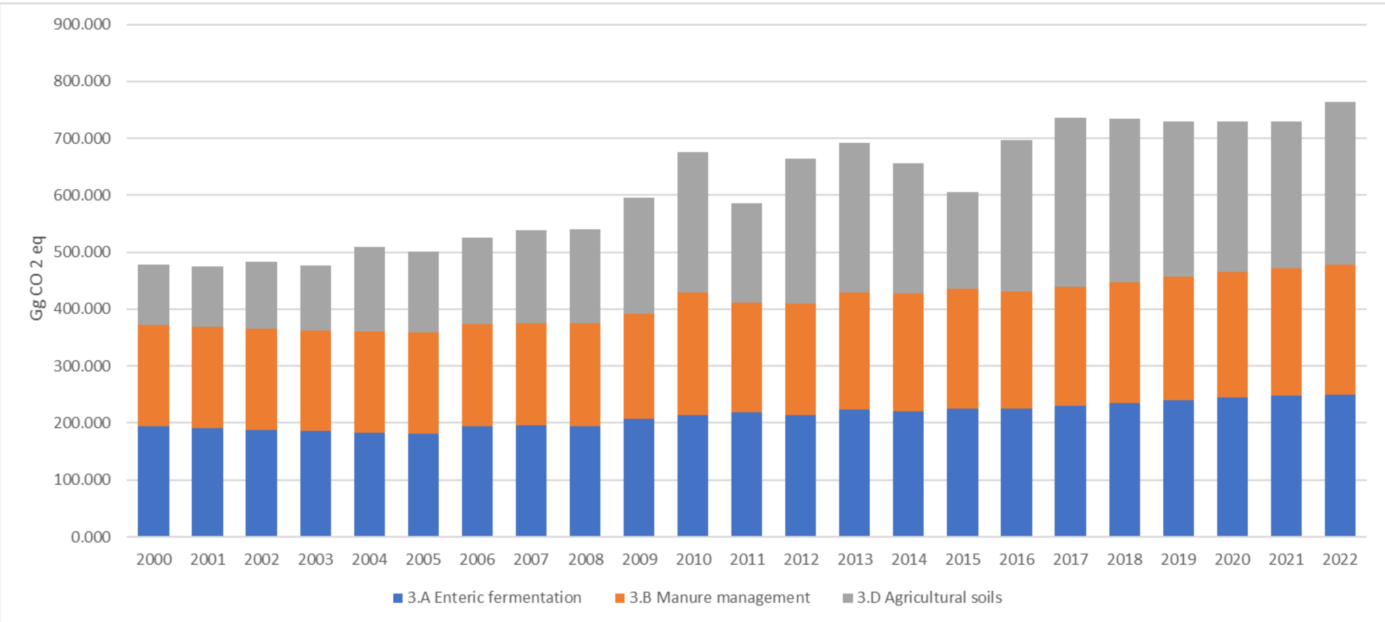

Figure 2-5: Trend in GHG emissions from the Agriculture Sector(2000 to 2022) (in Gg CO_2 eq)

2.2.4. Land use, land use change and forestry (LULUCF)

The net emissions from the LULUCF sector amounted to -14,269.79 Gg CO_2 eq in 2022 compared to -32,564.71 Gg CO_2 eq in 2000. The net emissions from the LULUCF sector has flactuated over the timeseries as seen in the figure below, which was mainly influenced by the Forest land (CRT Category 4.A) and Cropland (CRT Category 4.B).

In 2022, Forest Land (CRT Category 4.A) contributed -24,678.97 Gg CO_2 eq which had a huge impact on the net emissions from the sector. Cropland (CRT Category 4.B) contributed 9,715.13 Gg CO_2 eq followed by, Other Non-CO_2 gases - Forest Burning (CRT Category 4.H) with 326.76 Gg CO_2 eq, then Grassland (CRT Category 4.C) with 323.36 Gg CO_2 eq and Settlements (CRT Category 4.E) with 43.93 Gg CO_2 eq.

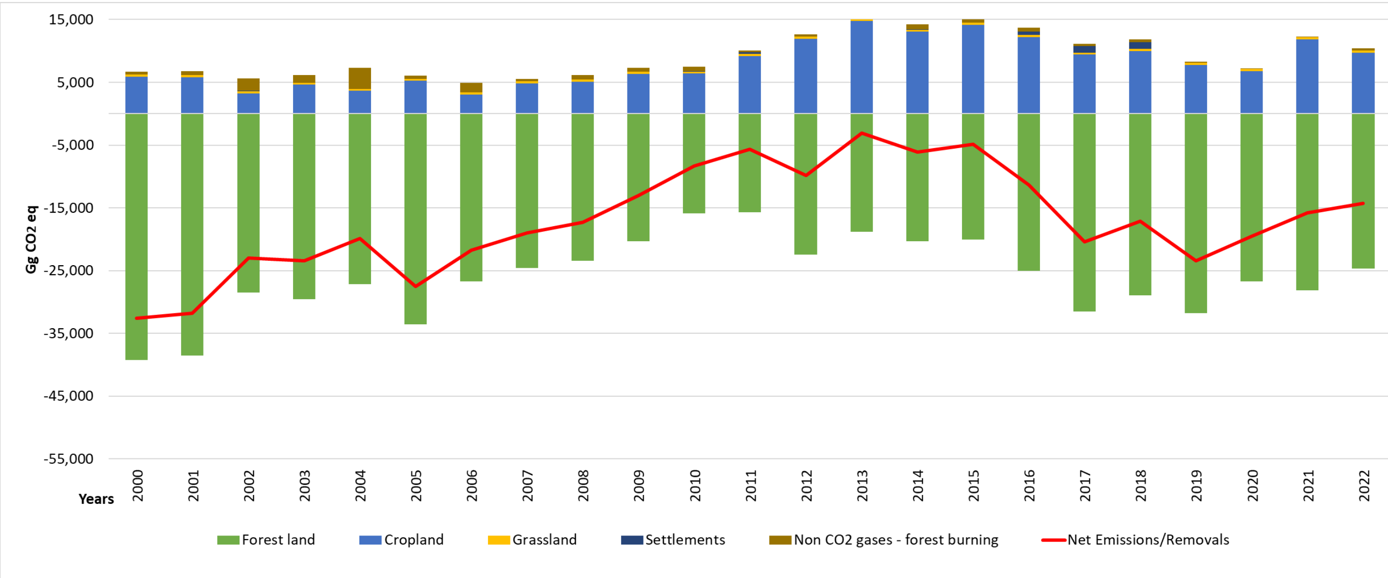

Figure 2-6: Trend in GHG emissions from the LULUCF Sector (2000 to 2022) (in Gg CO_2 eq)

2.2.5. Waste

In 2022, emissions from the Waste sector resulted in 1415.60 Gg CO_2 eq and accounted for 9% of PNG's total greenhouse gas emissions (excluding LULUCF). The emissions of the waste sector have increased over the whole time series (2000- 2022), as seen in the figure below. The increase is influenced by population growth, development, consumption rate, and rural-to-urban drift. Breakdown of 2022 emissions of the Waste sector by category shows that Wastewater treatment and discharge (CRT Category 5.D) contributed 68% to total sector emissions in 2022, followed by solid waste disposal (CRT Category 5.A) (29%), Incineration and open burning of waste (CRT Category 5.C) (3%) and Biological treatment of solid waste (CRT Category 5.B) (1%). The contribution of CO_2, CH_4, and N_2O to the total sector emissions is 1%,84%, and 15%, respectively. Figure 2-7 below outlines the trends of emissions from the Waste Sector from 2000 to 2022.

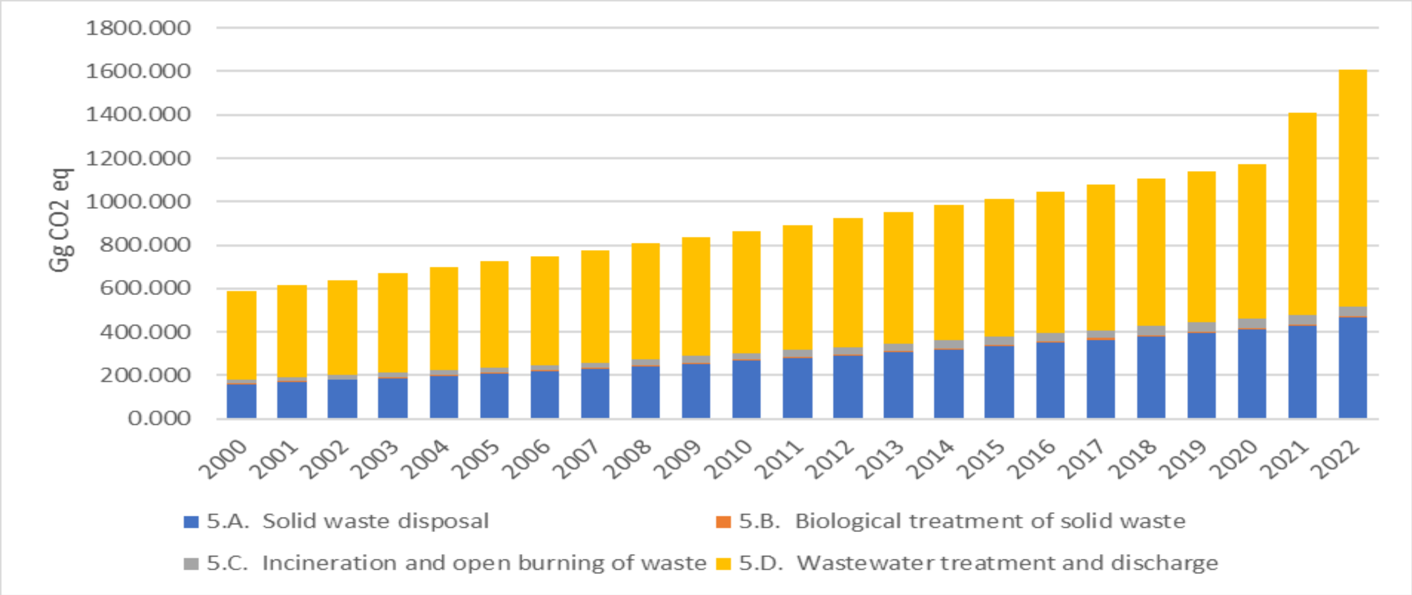

Figure 2-7: Trend in GHG emissions from the Waste Sector (2000 to 2022) (in Gg CO_2 eq)

2.3. GHG emission and removal trends by gas

2.3.1. Trend by gas

The table below shows the GHG emissions and removals trends by gas for the years 2000 to 2022.

Table 2-2: Trend by Gas for the years 2000 to 2022

Gas	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2 (including LULUCF)		-29,253.75	-28,179.54	-20,411.24	-19,792.72	-18,401.07	-23,093.93	-17,181.11	-14,401.56	-12,923.67	-8,581.15	-3,803.75	-230.85
CO_2 (excluding LULUCF)		3,770.83	4,209.28	4,494.11	4,866.70	4,820.15	4,883.50	6,103.59	4,988.33	5,050.05	5,086.86	5,314.03	5,718.87
CH_4 (including LULUCF)		5,459.97	4,955.54	5,508.65	4,817.18	6,222.22	4,304.20	5,543.10	3,842.08	4,216.24	4,124.25	3,260.83	2,952.82
CH_4 (excluding LULUCF)	Gg CO_2 eq	5,100.24	4,446.79	3,974.33	3,870.82	3,580.04	3,915.48	4,354.23	3,519.64	3,658.42	3,657.08	2,670.49	2,704.40
N_2O (including LULUCF)		388.53	433.88	738.04	578.57	1,091.27	461.46	701.22	473.91	543.96	564.61	673.68	485.95
N_2O (excluding LULUCF)		288.40	292.26	310.94	315.14	355.79	353.26	370.29	384.16	388.69	434.57	509.35	416.80
HFC		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total (including LULUCF)	Gg CO_2 eq	-23,405.24	-22,790.12	-14,164.55	-14,396.98	-11,087.57	-18,328.26	-10,936.79	-10,085.56	-8,163.47	-3,892.29	130.76	3,207.93
Total (excluding LULUCF)	Gg CO_2 eq	9,159.47	8,948.34	8,779.38	9,052.67	8,755.98	9,152.24	10,828.11	8,892.13	9,097.15	9,178.51	8,493.87	8,840.06

Gas	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2 (including LULUCF)		-4,277.00	2,411.61	516.88	2,861.58	-3,317.77	-11,725.85	-8,687.28	-14,460.88	-10,796.47	-7,055.94	-5,530.30
CO_2 (excluding LULUCF)		5,894.09	6,106.56	7,402.96	8,384.70	8,697.69	9,009.47	8,868.48	9,175.65	8,833.49	8,878.94	9,066.26
CH_4 (including LULUCF)		3,118.70	3,521.18	5,516.52	6,901.91	7,904.06	7,909.16	7,461.53	7,870.87	8,066.16	8,069.56	8,567.38
CH_4 (excluding LULUCF)	Gg CO_2 eq	2,856.79	3,061.08	4,880.16	6,389.70	7,391.85	7,670.09	7,128.11	7,732.08	8,003.72	7,972.30	8,311.77
N_2O (including LULUCF)		576.93	643.79	665.76	577.33	679.25	637.35	655.77	592.44	566.94	621.53	729.33
N_2O (excluding LULUCF)		504.02	515.71	488.62	434.74	536.67	570.80	562.96	553.81	549.56	594.46	658.18
HFC		NE	NE	NE	162.87	183.96	177.15	189.58	272.87	227.44	138.99	142.69
Total (including LULUCF)	Gg CO_2 eq	-581.37	6,576.58	6,699.16	10,503.69	5,449.51	-3,002.18	-380.40	-5,724.70	-1,935.93	1,774.13	3,909.10
Total (excluding LULUCF)	Gg CO_2 eq	9,254.90	9,683.36	12,771.75	15,372.01	16,810.17	17,427.51	16,749.13	17,734.42	17,614.21	17,584.68	18,178.90

NE Not Estimated

2.3.2. Carbon dioxide (CO_2)

Total CO_2 emissions (excluding CO_2 from LULUCF) increased from 3,770.83 Gg CO_2 in 2000 to 9,066.26 Gg CO_2 in 2022, representing an 140 % increase over the time series. If CO_2 from LULUCF is included, net emissions went from -29,253.75 Gg CO_2 in 2000 to -5,530.30 Gg CO_2i, an ncreased by 17,874.94 Gg CO_2 over the time series. The key drivers for these trends are the energy sector and the LULUCF sector. Under the Energy sector is due to the increasing demand for fossil fuels while the LULUCF sector is due to forest degradation and deforestation. Forest Degradation is driven by commercial (selective) logging. Commercial and subsistence agriculture are also major drivers of forest degradation which contributes to most of the emissions in the LULUCF sector.

2.3.3. Methane (CH_4)

Total CH_4 emissions (excluding CH_4 from LULUCF) increased from 5,100.24 Gg CO_2 eq in 2000 to 8,311.77 Gg CO_2 eq in 2022, representing a 63 % increase over the time series. If CH_4 from LULUCF is included, emissions went from 5,459.97 CO_2 eq in 2000 to 8,567.38 CO_2 eq in 2022, an increase of 3,107.41 CO_2 eq over the time series. The key drivers for this trend are the increase in fugitive emissions of CH_4 from natural production in the energy sector.

2.3.4. Nitrous oxide (N_2O)

Total N_2O emissions (excluding N_2O from LULUCF) increased from 288.40 Gg CO_2 eq in 2000 to 658.18 Gg CO_2 eq in 2022, representing a 128 % increase over the time series. If N_2O from LULUCF is included, emissions went from 388.53 CO_2 eq in 2000 to 729.33 CO_2 eq in 2022, an increase of 340.80 CO_2 eq over the time series.The key drivers for this trend are the increase in N_2O emissions from managed soils in the agriculture sector.

2.3.5. Fluorinated (F-gases)

Emissions of fluorinated gases (F-gases) are reported for the years 2015 to 2022. HFC emissions are estimated to be 162.87 Gg CO_2 eq in 2015 and 142.69 Gg CO_2 eq in 2022. This is a decrease of 12 % over this time period.

Chapter 3. Energy

3.1. Overview of the sector

Emissions from the energy sector consist of two main categories: fuel combustion (CRT category 1. A) and fugitive emissions from fuels (CRT category 1. B). Fuel combustion includes emissions released into the atmosphere when fossil fuels (e.g., coal, oil products, and natural gas) are combusted. Fugitive emissions are intentional or unintentional releases of gases from fossil fuels by anthropogenic activities.

In PNG, fossil fuels are used to produce energy for a wide variety of purposes (e.g., energy industry, transportation, and manufacturing), and CO_2 (Carbon Dioxide), CH_4 (Methane), and N_2O (Nitrous Oxide) are emitted in the process. PNG also produces oil and gas, including refining petroleum products, which leads to fugitive emissions of CO_2, CH_4, and N_2O.

Emissions from the energy sector amounted to 15,660.99 Gg CO_2 eq in 2022, an increase of 7,571.55 Gg CO_2 eq (94%) when compared to 2000. CO_2 emissions from Fuel Combustion (CRT Category 1A) contributed 40 % of the total GHG emissions in 2022, followed by CH_4 emissions from Fugitive emissions from fuel (CRT Category 1B) (38 %), CO_2 emissions from Fugitive emissions from fuel (CRT Category 1B) (10 %), CH_4 emissions from Fuel Combustion (CRT Category 1A) (4 %) while N_2O emissions from Fuel Combustion (CRT Category 1A) contributed 1%. Table 3-1 and Figure 3-1 below outlines the trends of emissions from the Energy Sector from 2000 to 2022.

Table 3-1: Trend in GHG emissions from the Energy Sector (in Gg CO_2 eq)

Unit: Gg CO_2 eq

CRT Category		2000	2003	2006	2009	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1A	Fuel Combustion	4096.78	5288.28	6527.97	5573.34	6461.02	6663.48	7381.10	7794.93	7982.55	8230.97	8244.82	8373.39	8008.34	8117.97	8255.02
	Liquid fuel CO_2	3252.46	4387.20	5635.15	4643.12	5507.29	5708.35	6056.02	6155.18	6205.96	6408.79	6696.61	6582.94	6067.98	6152.76	6232.78
	Solid fuel CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Gaseous fuel CO_2	279.51	310.04	277.16	298.30	295.95	295.95	662.36	974.75	1110.98	1155.61	883.15	1122.72	1258.95	1254.26	1310.63
	Other Fossil fuel CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	CH_4	487.19	507.31	526.76	541.42	560.01	560.02	560.96	561.37	561.64	562.20	562.12	563.96	577.63	603.61	603.66
	N_2O	77.62	83.73	88.90	90.51	97.78	99.16	101.77	103.63	103.97	104.37	102.95	103.77	103.77	107.35	107.96
1B	Fugitive emissions from fu	3993.05	2616.88	3023.18	2171.43	1204.83	1372.35	3748.29	5793.01	6898.86	7204.71	6471.90	7218.50	7476.27	7188.26	7405.97
	CO_2	232.30	161.00	182.79	135.06	80.12	89.65	671.83	1241.86	1367.48	1432.18	1273.88	1455.05	1491.53	1456.83	1507.67
	CH_4	3759.89	2455.31	2839.72	2035.89	1124.45	1282.41	3076.07	4550.74	5530.79	5771.92	5197.46	5762.86	5984.12	5730.85	5897.71
	N_2O	0.87	0.58	0.67	0.48	0.26	0.30	0.39	0.40	0.60	0.61	0.56	0.59	0.62	0.57	0.58
1C	CO_2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total		8089.83	7905.16	9551.15	7744.76	7665.85	8035.83	11129.39	13587.94	14881.42	15435.68	14716.72	15591.90	15484.61	15306.23	15660.99

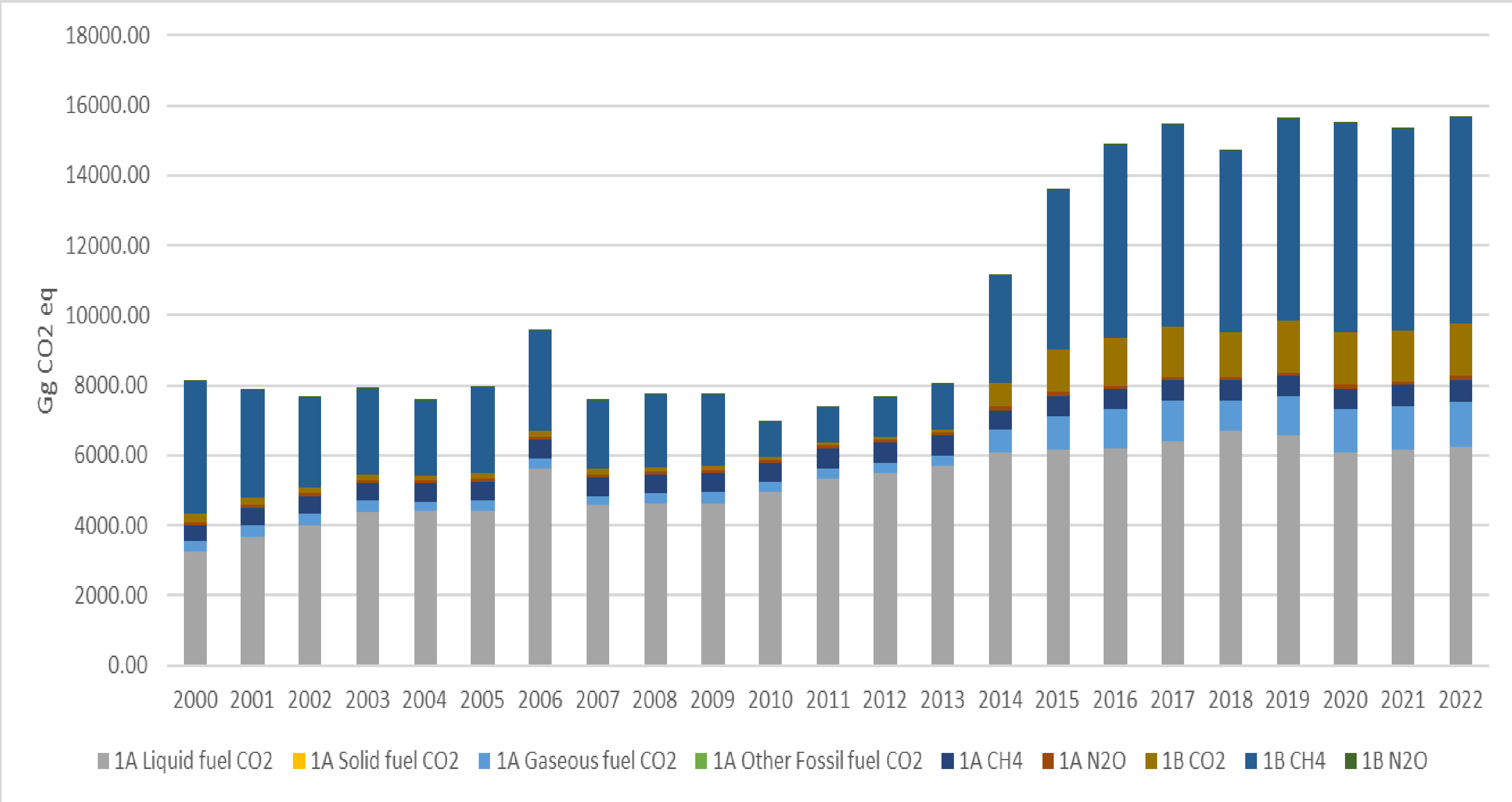

Figure 3-1:Trend in GHG emissions from the Energy sector (2000-2022) (in Gg CO_2 eq)

3.2. Fuel combustion (CRT Category 1.A)

This category covers GHG emissions from the combustion of fossil fuels such as coal, oil, and natural gas. This section includes GHG emissions from five sources:

(i) Energy industries: emissions from main activity electricity and heat production, petroleum refining, and manufacturing of solid fuels and other energy industries (CRT category 1.A.1);
(ii) Manufacturing industries and construction: emissions from the manufacturing industry and construction (CRT category 1.A.2) ;
(iii) Transport: emissions from transport of passenger and freight (CRT category 1.A.3);
(iv) Other sectors: emissions from commercial/institutional, residential, and agriculture/forestry/fishing sources (CRT category 1.A.4); and
(v) Non-Specified other: emissions from other non-specified fuel combustion sources (CRT category 1.A.5).

3.2.1. Comparison of the sectoral approach with the reference approach (CRT categories 1.AA and 1.AB)

This section explains a comparison between the reference approach and the sectoral approach in accordance with the Modalities Procedures and Guidelines for the ETF (Decision 18/CMA.1 Annex paragraph 36). For the methodological issues of the sectoral approach, please refer to the section 3.2.4).

3.2.1.1. **Methodological Issues of the Reference Approach**

The reference approach is to calculate the CO_2 emissions from combustion, using a country's energy supply data. The CO_2 emissions estimated by the reference approach are not included in the national total and are used for verification purposes. The CO_2 emissions by the reference approach are estimated by the following formula:

$$\boldsymbol{E} = \sum_{\boldsymbol{i}} [\boldsymbol{A_i} \times \mathbf{41.868} \times \boldsymbol{EF_i}] \times \mathbf{44/12}$$

Where:

E: = *CO_2 emissions from fossil fuel combustion [kt-CO_2]*

A: = *Total primary energy supply [kTOE]*

EF: = *Carbon content of the fuel [kt-C/TJ]*

i: = Type of fuel

1 kTOE = 41.868 TJ

The carbon contents of the fuels are in common with the sectoral approach (refer to the section 3.2.4.3).

3.2.1.2. **Difference in Energy Consumption**

As shown in Table 3-2, fluctuations in the difference in energy consumption between the reference approach and the sectoral approach during the 2000-2022 range between -15% (2006) and 14% (2010).

Energy consumption from wastes used for energy and from the incineration of wastes with energy recovery is calculated in the sectoral approach in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 3-2: Comparision in energy consumption

Unit: TJ

	CRT Category	2000	2001	2002	2004	2006	2008	2010	2012	2014	2016	2018	2019	2020	2021	2022
1AA	REFERENCE APPROACH															
	Solid fuels (excluding international bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Liquid fuels (excluding international bunkers)	49,362	56,647	60,164	62,467	64,560	68,747	77,749	71,217	82,606	82,815	87,044	82,982	77,958	80,805	84,186
	Gaseous fuels	4,982	6,029	6,071	4,438	4,940	5,150	5,150	5,317	11,807	19,804	15,742	18,380	35,337	35,044	34,803
	Other fossil fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total RA	54,345	62,676	66,235	66,905	69,501	73,897	82,899	76,535	94,412	102,618	102,786	101,362	113,295	115,849	118,989
1AB	SECTORAL APPROACH															
	Solid fuels (excluding international bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Liquid fuels (excluding international bunkers)	43,794	49,488	53,675	59,285	74,986	61,630	66,277	73,855	81,266	83,443	89,932	88,467	81,643	82,731	89,556
	Gaseous fuels	4,982	5,736	5,736	4,438	4,940	5,150	5,150	5,275	11,807	19,804	15,742	20,013	22,441	22,358	23,823
	Other fossil fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total SA	48,776	55,224	59,411	63,723	79,926	66,779	71,427	79,131	93,073	103,246	105,675	108,480	104,084	105,089	113,379
	DIFFERENCE															
	Solid fuels (excluding international bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Liquid fuels (excluding international bunkers)	11%	13%	11%	5%	-16%	10%	15%	-4%	2%	-1%	-3%	-7%	-5%	-2%	-6%
	Gaseous fuels	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.4	0.4	0.3
	Other fossil fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	10%	12%	10%	5%	-15%	10%	14%	-3%	1%	-1%	-3%	-7%	8%	9%	5%

3.2.1.3. **Difference in CO_2 Emissions**

As shown Table 3-3, fluctuations of a difference in CO_2 emissions between the reference approach and the sectoral approach during 2000-2022 range between -11% (2006) and 18% (2001).

Emissions from wastes used for energy and from the incineration of wastes with energy recovery are not reported in waste incineration (CRT category 5.C.) but reported in fuel combustion (CRT category 1.A.) in accordance with the 2006 IPCC Guidelines.

Table 3-3: Comparision of CO_2 emissions (in Gg CO_2)

Unit: Gg CO_2

	CRT Category	2000	2001	2002	2004	2006	2008	2010	2012	2014	2016	2018	2019	2020	2021	2022
1AA	REFERENCE APPROACH															
	Solid fuels (excluding international bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Liquid fuels (excluding international bunkers)	3683.71	4231.12	4497.73	4664.34	4816.86	5132.18	5780.95	5307.74	6147.27	6142.53	6477.30	6184.09	5793.49	6009.14	6256.56
	Gaseous fuels	279.51	338.23	340.58	248.97	277.16	288.90	288.90	298.30	662.36	1110.98	883.15	1031.12	1982.38	1965.94	1952.44
	Other fossil fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total RA	3963.22	4569.34	4838.30	4913.31	5094.01	5421.08	6069.85	5606.04	6809.63	7253.51	7360.45	7215.21	7775.88	7975.08	8208.99
1AB	SECTORAL APPROACH															
	Solid fuels (excluding international bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Liquid fuels (excluding international bunkers)	3017.44	3445.91	3743.24	4165.23	5376.92	4318.83	4646.01	5185.23	5699.14	5825.87	6360.04	6240.57	5745.92	5839.40	6315.26
	Gaseous fuels	279.51	321.78	321.78	248.97	277.16	288.90	288.90	295.95	662.36	1110.98	883.15	1122.72	1258.95	1254.26	1336.46
	Other fossil fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total SA	3296.95	3767.70	4065.03	4414.20	5654.08	4607.73	4934.91	5481.17	6361.50	6936.85	7243.18	7363.30	7004.88	7093.66	7651.72
	DIFFERENCE															
	Solid fuels (excluding international bunkers)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Liquid fuels (excluding international bunkers)	18%	19%	17%	11%	-12%	16%	20%	2%	7%	5%	2%	-1%	1%	3%	-1%
	Gaseous fuels	0%	5%	6%	0%	0%	0%	0%	1%	0%	0%	0%	-9%	36%	36%	32%
	Other fossil fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	17%	18%	16%	10%	-11%	15%	19%	2%	7%	4%	2%	-2%	10%	11%	7%

3.2.1.4. Causes of the difference between the Reference Approach and the Sectoral Approach

The estimate of CO_2 emissions showed that the estimations using the reference approach and sectoral approach had discrepancies that ranged from -11% (2006) and 18% (2001). The high discrepancies in 2001 and 2006 were due to the statistical discrepancy in liquid fuels data, specifically residual fuel oil.

3.2.2. International bunker fuels

Emissions from International bunker fuels are not estimated due to the lack of reliable data.

3.2.3. Energy Industries (CRT Category 1.A.1)

3.2.3.1. Category description (e.g. characteristics of sources)

Emissions from energy industries are comprised of fuel combusted by the fuel extraction or energy-producing industries. This includes:

i. Public electricity and heat production (CRT Category 1.A.1.a);
ii. Petroleum refining (CRT Category 1.A.1.b); and
iii. Manufacture of solid fuels and other energy industries (CRT Category 1.A.1.a)

Heat and coal production do not occur in PNG; thus, the emissions reported in this submission do not include these activities.

Emissions from the energy industries category amounted to 1,138.54 Gg CO_2 eq in 2022, an increase of 1110.52 Gg CO_2 eq when compared to 2000. Manufacturing of solid fuels and other energy industries (CRT Category 1A1c) contributed 62% of the overall emissions in this category, while Public electricity and heat production (CRT Category 1.A.1.a) contributed 38%. Table 3-4 and Figure 3-2 below outlines the trend of emissions in this category.

Table 3-4: Trend in emissions by subcategory and gas from the energy industries category (in Gg CO_2 eq)

Unit: Gg CO2 eq

	CRT Category	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
1A1a	Public electricity and heat production	28.01	90.27	43.58	52.91	143.19	323.30	408.70	511.42	530.09	390.79	443.04	428.31	430.86
	CO_2	27.92	89.97	43.43	52.74	142.71	322.34	407.65	510.03	528.64	389.79	442.16	427.49	430.11
	CH_4	0.03	0.10	0.05	0.06	0.17	0.34	0.39	0.51	0.53	0.37	0.35	0.33	0.31
	N_2O	0.06	0.19	0.09	0.11	0.31	0.62	0.66	0.89	0.92	0.63	0.53	0.49	0.44
1A1b	Petroleum refining	0.00	0.00	21.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CO_2	0.00	0.00	21.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CH_4	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	N_2O	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A1c	Manufacture of solid fuels and other energy industries	0.00	0.00	16.46	21.16	14.11	601.88	639.49	667.71	507.83	684.16	693.57	681.81	707.67
	CO_2	0.00	0.00	16.44	21.14	14.09	601.29	638.87	667.06	507.34	683.50	692.89	681.15	706.99
	CH_4	0.00	0.00	0.01	0.01	0.01	0.30	0.32	0.33	0.25	0.34	0.35	0.34	0.35
	N_2O	0.00	0.00	0.01	0.01	0.01	0.28	0.30	0.32	0.24	0.32	0.33	0.32	0.33
	Total	28.01	90.27	81.82	74.07	157.29	925.18	1048.19	1179.13	1037.93	1074.95	1136.61	1110.12	1138.54

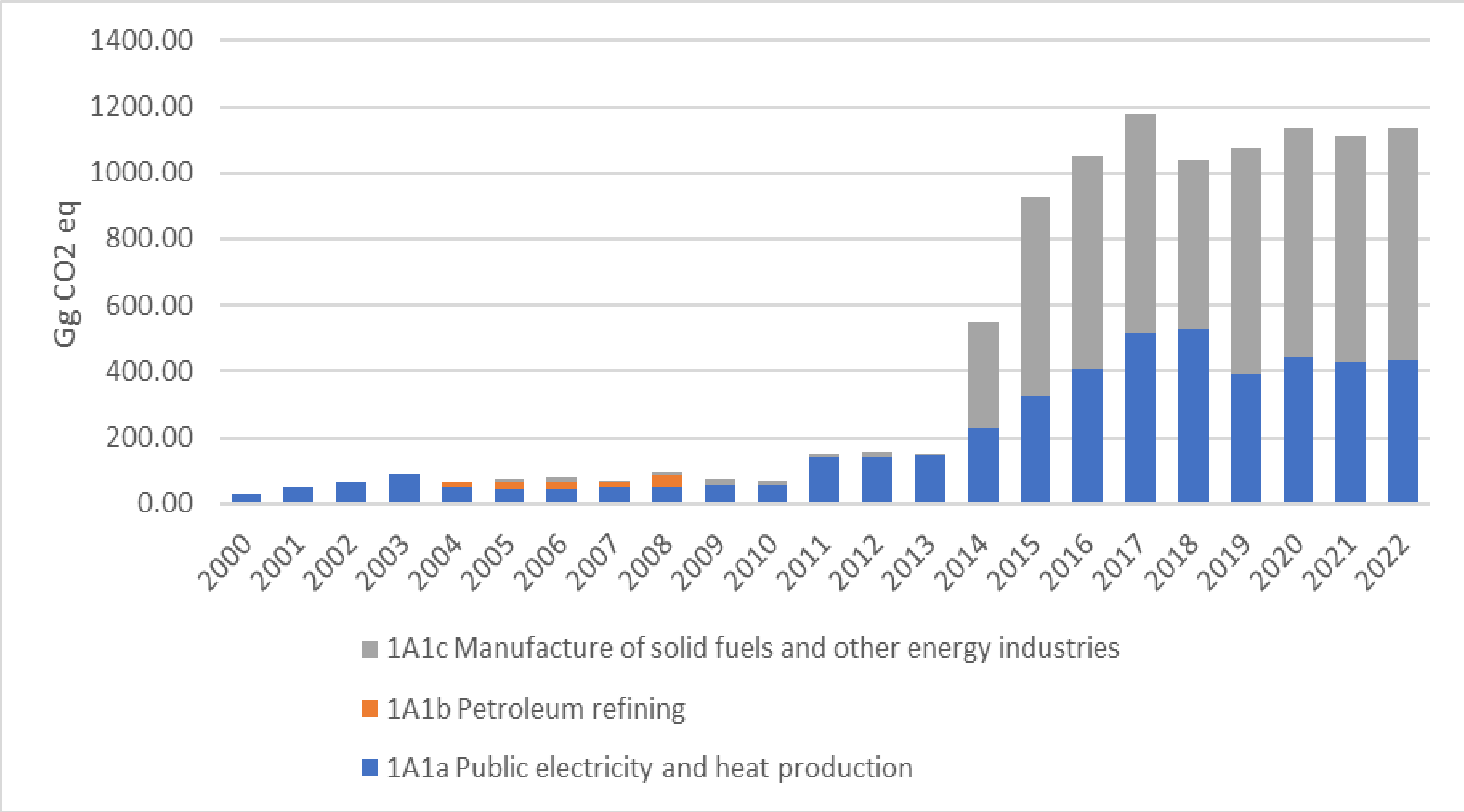

Figure 3-2: Trend in emissions from the energy industries category (in Gg CO_2 eq)

3.2.3.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

The Tier 1 Sectoral Approach was used in accordance with the 2006 IPCC Guidelines to calculate emissions from Public electricity and heat production (CRT category 1.A.1.a); Petroleum refining (CRT category 1.A.1.b); and Manufacturing of solid fuels and other energy industries (CRT category 1.A.1.c). The table below summarizes the methods and emission factors used for estimating emissions from the energy industries category. Furthermore, the equation below was used to estimate the GHG emissions.

Table 3-5: Summary of methods and emission factors that were used

			CO_2		CH_4		N_2O	
CRT Category		Fuel type	Method Applied	Emission factor	Method Applied	Emission factor	Method Applied	Emission factor
1.A.1.a	Public electricity and heat	Liquid Fuels	T1	D	T1	D	T1	D
		Gaseous Fuels	T1	D	T1	D	T1	D
		Biogas	T1	D	T1	D	T1	D
1.A.1.b	Petroleum refining	Liquid Fuels	T1	D	T1	D	T1	D
		Gaseous Fuels	T1	D	T1	D	T1	D
		Biogas	T1	D	T1	D	T1	D
1.A.1.c	Manufacturing of solid fuels and other	Liquid Fuels	T1	D	T1	D	T1	D
		Gaseous Fuels	T1	D	T1	D	T1	D
		Biogas	T1	D	T1	D	T1	D

D (IPCC Default) T1 (IPCC T1)

$$E_{CO2} = \sum_{ij} \left[A_{ij} \times 41.868 \times EF_i \right] \times 44/12$$

Where:

E_{CO2}: =CO_2 emissions from fossil fuel combustion [$ktCO_2$]

A: = Energy consumption [kTOE]

EF: =Carbon content of the fuel [kt-C / TJ]

i: = Type of fuel

j: =Sector

1 kTOE = 41.868 TJ

$$E_{CH4,/N2O} = \sum_{ij} \left[A_{ij} \times 41.868 \times EF_{ij} \right]$$

Where:

$E_{CH4/N2O}$: = CH_4 / N_2O emissions from fossil fuel combustion [kt]

A: = Energy consumption [kTOE]

EF: =Emission factor [kt / TJ]

i: = Type of fuel

j: =Sector

1 kTOE = 41.868 TJ

b. EF, other parameters

Default emissions factors in the 2006 IPCC guidelines (volume 2, chapter 2, table 2.2) were used to estimate CO2, CH4, and N2O emissions for Public electricity and heat production (CRT category 1.A.1.a); Petroleum refining (CRT category 1.A.1.b); and Manufacturing of solid fuels and other energy industries (CRT category 1.A.1.c)

c. AD (include uncertainties and time-series consistency)

Activity data for Public electricity and heat production (CRT category 1.A.1.a); Petroleum refining (CRT category 1.A.1.b); and Manufacturing of solid fuels and other energy industries (CRT category 1.A.1.c) were extracted from the energy balance table developed by APERC. The energy consumption data given in the energy balance table was converted from one energy unit (kTOE) to another (TJ) and used for the activity data. The table below shows the correspondence between the sectors of the energy balance table and CRT categories. Additionally, the figure below shows the trend of energy consumption by fuel type.

Table 3-6: CRT and corresponding energy balance table

CRT Category		Energy Balance Table by APERC	
1.A.1.a	Public electricity and heat	9.1.1	Electricity plants
		9.1.2	CHP plants
		9.1.3	Heat plants
1.A.1.b	Petroleum refining	10.1.14	Oil refineries
1.A.1.c	Manufacturing of solid fuels and other energy industries	10.1.2	Gas works
		10.1.3	Liquefaction
		10.1.4	Regasification
		10.1.5	Natural gas blending plants
		10.1.6	Gas to liquid
		10.1.7	Gas separation
		10.1.15	Oil and gas extraction

3.2.3.3. **Category-specific recalculations, if applicable**

Recalculation was made for this current submission, which includes updating petroleum refining (CRT category 1.A.1.b) with the corresponding sectors in the energy balance table. In the previous submission, some transformation sectors in the energy balance table which are non-fuel combustion sectors were included but were not included in this current submission.

3.2.3.4. **Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

The energy industries sub-category has the following challenges:

- Lack of a national energy balance table based on PNG national statistics.
- Lack of country-specific emission factors.

This may be improved by contacting the relevant stakeholders to check whether there is available data.

3.2.4. Manufacturing Industries and Construction (CRT Category 1.A.2.)

3.2.4.1. **Category description (e.g., characteristics of sources)**

This sub-category includes emissions from the combustion of fuels in industry and construction, as well as electricity generation for own use. Due to the paucity of activity data, the emissions were aggregated and reported as Other (CRT Category 1.A.2.g), not disaggregated into specific industries.

Emissions from the Manufacturing industries and Construction category amounted to 4,091.39 Gg CO_2 eq in 2022, an increase of 1,873.69 Gg CO_2 eq (84%) when compared to 2000. CO_2 contributed 99% of the overall emissions in this category, while CH_4 and N_2O contributed 1%. Table 3-7 and Figure 3-3 below outlines the trend of emissions in this category.

Table 3-7: Trend in emissions by subcategory and gas from the Manufacturing industries and Construction category (in Gg CO_2 eq)

Unit: Gg CO_2 eq

CRT Category		2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
1A2g	Other	2217.70	3173.03	4351.67	3214.26	3670.48	3823.55	3870.08	3989.60	4274.79	4283.99	3924.55	4020.97	4091.39
	CO_2	2211.15	3163.54	4338.39	3204.55	3659.32	3811.98	3858.40	3977.57	4261.59	4270.89	3912.58	4008.69	4078.88
	CH_4	2.33	3.35	4.66	3.43	3.93	4.08	4.13	4.25	4.64	4.61	4.22	4.33	4.41
	N_2O	4.22	6.14	8.63	6.29	7.23	7.49	7.56	7.78	8.57	8.49	7.75	7.95	8.10

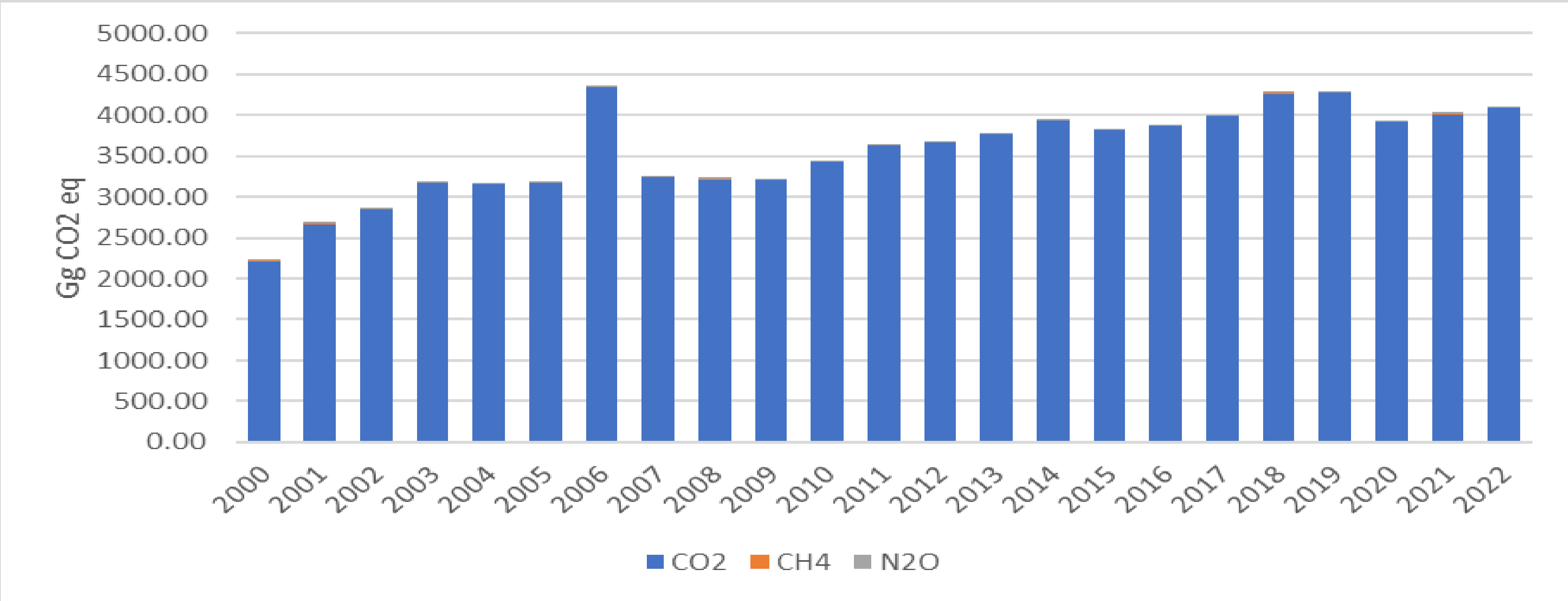

Figure 3-3: Trend in emissions from the Manufacturing industries and Construction category (in Gg CO_2 eq)

3.2.4.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

The Tier 1 Sectoral Approach was used following the 2006 IPCC Guidelines to calculate emissions from was used to estimate emissions from Manufacturing Industries and Construction (CRT category 1. A.2), more specifically Other (CRT category 1. A.2.b). The table below summarizes the methods and emission factors used. Furthermore, the equation below was used to estimate the GHG emissions.

Table 3-8: Summary of methods and emission factors that were used for this category

CRT Category		Fuel type	CO_2 Method Applied	CO_2 Emission factor	CH_4 Method Applied	CH_4 Emission factor	N_2O Method Applied	N_2O Emission factor
1.A.2	Manufacturing Industries and Construction							
1.A.2.g	Other	Liquid Fuels	T1	D	T1	D	T1	D
		Gaseous Fuels	T1	D	T1	D	T1	D
		Biogas	T1	D	T1	D	T1	D

D (IPCC Default) T1 (IPCC T1)

$$E_{CO2} = \sum_{ij} [A_{ij} \times 41.868 \times EF_i] \times 44/12$$

Where:

E_{CO2}: =CO_2 emissions from fossil fuel combustion [$ktCO_2$]

A: = Energy consumption [kTOE]

EF: =Carbon content of the fuel [kt-C / TJ]

i: = Type of fuel

j: =Sector

1 kTOE = 41.868 TJ

$$E_{CH4,/N2O} = \sum_{ij}[A_{ij} \times 41.868 \times EF_{ij}]$$

Where:

$E_{CH4/N2O}$: = CH_4 / N_2O emissions from fossil fuel combustion [kt]

A: = Energy consumption [kTOE]

EF: =Emission factor [kt / TJ]

i: = Type of fuel

j: =Sector

1 kTOE = 41.868 TJ

b. EF, other parameters

Default emissions factors in the 2006 IPCC guidelines (volume 2, chapter 2, table 2.3) were used to estimate CO_2, CH_4, and N_2O emissions for Manufacturing Industries and Construction (CRT category 1. A.2)

c. AD (include uncertainties and time-series consistency)

Activity data for Manufacturing Industries and Construction (CRT category 1.A.2) was extracted from the energy balance table developed by APERC. The energy consumption data given in the energy balance table were converted from one energy unit (kTOE) to another (TJ) and used for the activity data. The table below shows the correspondence between the sectors of the energy balance table and CRT categories. The data was not disaggregated and was reported as a non-specified industry, thus emissions were estimated and reported as Other (CRT category 1.A.2.g). Additionally, the figures below show the trend of energy consumption by fuel type.

Table 3-9: CRT and corresponding energy balance table

CRT Category		Energy Balance Table by APERC	
1.A.2	Manufacturing Industries and Construction		
1.A.2.g	Other	9.2	Autoproducers
		14.13	Non-specified industry

3.2.4.3. Category-specific recalculations, if applicable

No recalculation was made for the Manufacturing Industries and Construction (CRT category 1.A.2)for this submission.

3.2.4.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The Manufacturing Industries and Construction sub-category has the following challenges:

- Lack of a national energy balance table based on PNG national statistics;
- Inability to disaggregate activity data into specific categories; and
- Lack of country-specific emission factors.

This may be improved by contacting the relevant stakeholders to check whether there is available data.

3.2.5. Transport (CRT Category 1. A.3)

3.2.5.1. Category description (e.g. characteristics of sources)

This sub-category captures emissions from the combustion and evaporation of fuel for all transport activity (excluding military transport). This includes:

- Domestic Aviation;
- Road Transportation;
- Railways;
- Domestic navigation; and
- Other transportation.

Emissions for this submission capture domestic aviation (CRT category 1.A.3.a), road transportation (CRT category 1.A.3.b), and domestic navigation (CRT category 1.A.3.d).

Emissions from the Transport category amounted to 1,848.99 Gg CO_2 eq in 2022, an increase of 945.25 Gg CO_2 eq (105%) when compared to 2000. Road transportation (CRT Category 1.A.3.b) contributed 77% of the total emissions, followed by Domestic Aviation (CRT Category 1.A.3.a) with 22%, while domestic navigation (CRT Category 1.A.3.d) contributed 1%. Table 3-10 and Figure 3-4 below outlines the trend of emissions in this category.

Table 3-10: Trend in emissions by subcategory and gas from the Transport category (in Gg CO_2 eq)

Unit: Gg CO_2 eq

	CRT Category	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
1A3a	Domestic aviation	220.19	238.29	247.34	277.50	334.81	398.16	401.17	401.17	431.34	452.45	431.34	413.24	407.21
	CO_2	218.53	236.49	245.47	275.41	332.29	395.15	398.14	398.14	428.08	449.03	428.08	410.12	404.13
	CH_4	0.04	0.05	0.05	0.05	0.07	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.08
	N_2O	1.62	1.75	1.82	2.04	2.46	2.93	2.95	2.95	3.17	3.33	3.17	3.04	3.00
1A3b	Road transportatior	669.46	781.65	809.83	943.72	1206.07	1540.35	1555.41	1546.83	1369.01	1422.21	1360.43	1383.01	1421.16
	CO_2	656.95	767.23	794.95	926.54	1184.53	1513.28	1527.99	1519.68	1344.85	1397.19	1336.55	1358.87	1396.50
	CH_4	3.76	4.16	4.23	4.74	5.57	6.60	6.76	6.58	5.97	6.12	5.79	5.72	5.71
	N_2O	8.76	10.26	10.65	12.44	15.97	20.48	20.66	20.57	18.18	18.90	18.09	18.42	18.95
1A3d	Domestic navigation	13.08	16.35	19.63	19.63	22.90	29.44	29.44	29.44	22.90	22.90	19.63	19.63	19.63
	CO_2	12.96	16.20	19.44	19.44	22.68	29.17	29.17	29.17	22.68	22.68	19.44	19.44	19.44
	CH_4	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
	N_2O	0.09	0.11	0.13	0.13	0.16	0.20	0.20	0.20	0.16	0.16	0.13	0.13	0.13
	Total	902.74	1036.30	1076.79	1240.85	1563.78	1967.95	1986.02	1977.44	1823.24	1897.56	1811.39	1815.87	1847.99

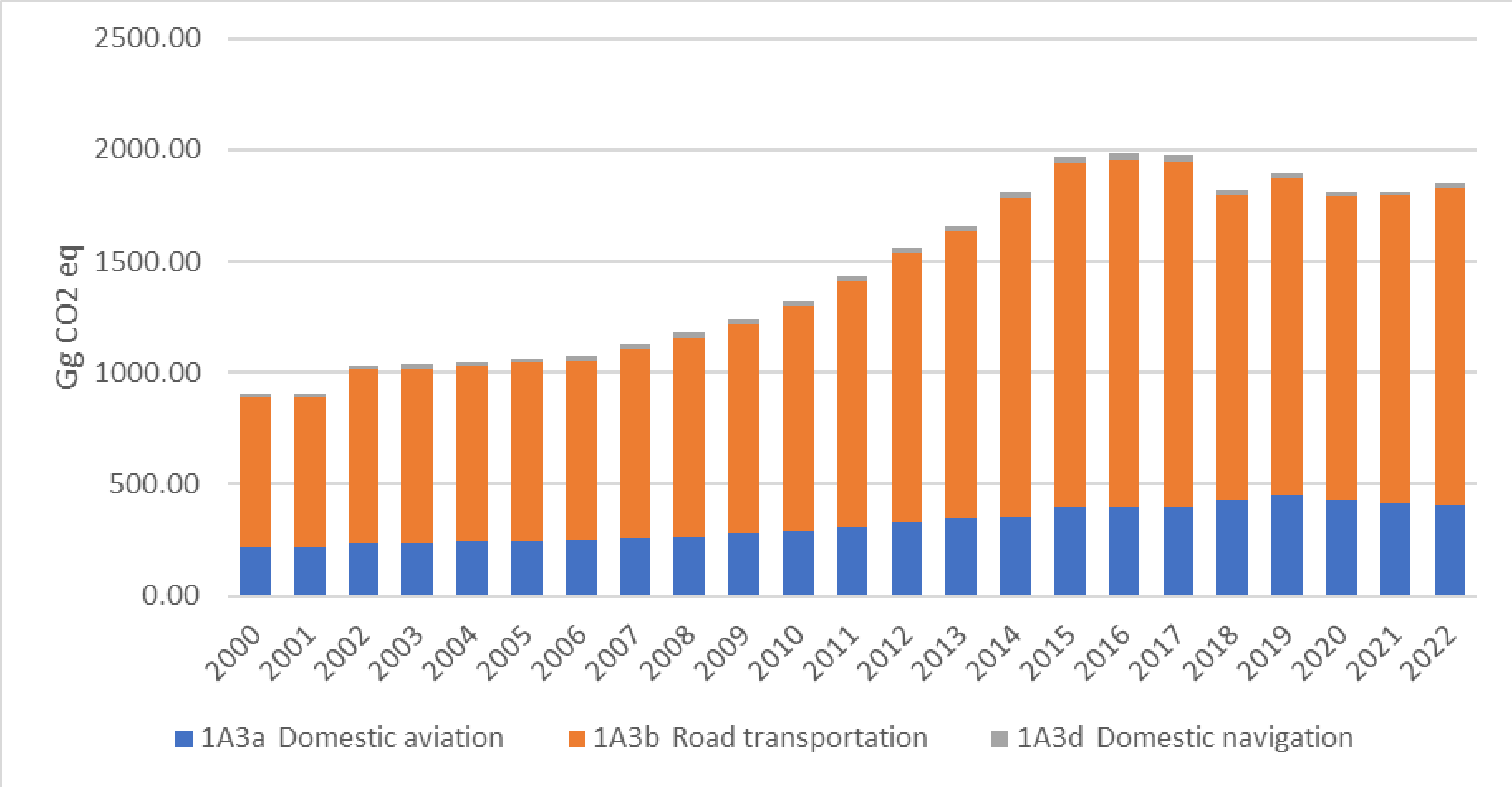

Figure 3-4: Trend in emissions from the Transport category (in Gg CO_2 eq)

3.2.5.2. **Methodological issues**

a. Choice of method (include assumption and the rationale for selection)

The Tier 1 Sectoral Approach was used in accordance with the 2006 IPCC Guidelines to calculate emissions from was used to estimate emissions from Domestic aviation (CRT Category 1.A.3.a); Road transportation (CRT Category 1.A.3.b); and Domestic navigation (CRT Category 1.A.3.d). The table below summarizes the methods and emission factors used. Furthermore, the equation below was used to estimate the GHG emissions.

Table 3-11: Summary of methods and emission factors that were used for this category

			CO_2		CH_4		N_2O	
CRT Category		Fuel type	Method Applied	Emission factor	Method Applied	Emission factor	Method Applied	Emission factor
1.A.3.a	Domestic aviation	Liquid Fuels	T1	D	T1	D	T1	D
1.A.3.b	Road transportation	Liquid Fuels	T1	D	T1	D	T1	D
1.A.1.d	Domestic navigation	Liquid Fuels	T1	D	T1	D	T1	D

D (IPCC Default) T1 (IPCC T1)

$$E_{CO2} = \sum_{ij} [A_{ij} \times 41.868 \times EF_i] \times 44/12$$

Where:

E_{CO2}: *=CO_2 emissions from fossil fuel combustion [$ktCO_2$]*

A: *= Energy consumption [kTOE]*

EF: *=Carbon content of the fuel [kt-C / TJ]*

i: *= Type of fuel*

j: *=Sector*

1 kTOE = 41.868 TJ

$$E_{CH4,/N2O} = \sum_{ij} [A_{ij} \times 41.868 \times EF_{ij}]$$

Where:

$E_{CH4/N2O}$: *= CH_4 / N_2O emissions from fossil fuel combustion [kt]*

A: *= Energy consumption [kTOE]*

EF: *=Emission factor [kt / TJ]*

i: *= Type of fuel*

j: *=Sector*

1 kTOE = 41.868 TJ

b. EF, other parameters

Default emissions factors in the 2006 IPCC guidelines (volume 2, chapter 3, table 3.2.1 and table 3.2.2) were used to estimate CO2, CH4, and N2O emissions for Domestic aviation (CRT Category 1.A.3.a); Road transportation (CRT category 1.A.3.b); and Domestic navigation (CRT category 1.A.3.d)

c. AD (include uncertainties and time-series consistency)

Activity data for Domestic aviation (CRT Category 1.A.3.a); Road transportation (CRT Category 1.A.3.b); Domestic navigation (CRT Category 1.A.3.d) were extracted from the energy balance table developed by APERC. The energy consumption data given in the energy balance table was converted from one energy unit (kTOE) to another (TJ) and used for the activity data. The table below shows the correspondence between the sectors of the energy balance table and CRT categories. Additionally, the figures below show the trend of energy consumption by fuel type.

Table 3-12: CRT and corresponding energy balance table

CRT Category		Energy Balance Table by APERC	
1.A.3.a	Domestic aviation	15.1	Domestic air transport
1.A.3.b	Road transportation	15.2	Road
1.A.3.c	Domestic navigation	15.4	Domestic navigation

3.2.5.3. Uncertainty assessment and time-series consistency

3.2.5.4. Category-specific recalculations, if applicable

No recalculation was made for the for the transport category (CRT category 1.A.3)for this submission

3.2.5.5. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The transport category has the following challenges:

- Lack of a national energy balance table based on PNG national statistics;
- Inability to disaggregate activity data into specific categories; and
- Lack of country-specific emission factors.

This may be improved by contacting the relevant stakeholders to check whether there is available data.

3.2.6. Other Sectors (CRT Category 1.A.4)

3.2.6.1. Category description (e.g. characteristics of sources)

This sub-category is an aggregation of the following sources:

- Commercial/Institutions (CRT category 1.A.4.a);
- Residential (CRT category 1.A.4.b); and
- Agriculture/forestry/fishing (CRT category 1.A.4.c);

This submission captures emissions from all the above-mentioned sources. Emissions from this category amounted to 1177.11 Gg CO_2 eq in 2022, an increase of 228.78 Gg CO_2 eq (24%) when compared to 2000.

Residential (CRT Category 1.A.4.b) contributed 58% of the total emissions, followed by Agriculture/forestry/fishing (CRT Category 1.A.4.c) with 27%, while Commercial/Institutional (CRT Category 1.A.4.a) contributed 15%. Table 3-13 and Figure 3-5 below outlines the trend of emissions in this category.

Table 3-13: Trend in emissions by subcategory and gas from the Other Sectors category (in Gg CO_2 eq)

Unit: Gg CO_2 eq

	CRT Category	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
1A4a	Commercial/institutional	122.44	132.05	138.49	140.87	146.67	149.70	149.70	152.72	161.68	165.10	167.48	174.60	171.64
	CO_2	41.41	47.80	50.81	50.81	53.82	56.83	56.83	59.84	68.50	71.51	71.51	74.52	74.52
	CH_4	71.90	74.74	77.80	79.91	82.38	82.40	82.40	82.41	82.67	83.03	85.14	88.91	86.21
	N_2O	9.14	9.51	9.88	10.15	10.47	10.47	10.47	10.48	10.50	10.56	10.82	11.17	10.91
1A4b	Residential	522.00	546.49	569.05	590.01	609.52	612.15	612.15	615.67	627.64	632.25	648.76	665.65	682.79
	CO_2	62.11	68.87	74.52	80.54	83.55	86.56	86.56	89.57	101.61	104.62	107.27	110.28	113.29
	CH_4	408.31	424.05	439.07	452.35	467.01	466.67	466.67	467.15	467.08	468.50	480.81	493.14	505.69
	N_2O	51.58	53.57	55.45	57.12	58.96	58.92	58.92	58.95	58.94	59.13	60.68	62.24	63.81
1A4c	Agriculture/forestry/fishing	303.88	310.15	310.15	313.28	313.28	316.41	316.41	316.41	319.55	319.55	319.55	319.55	322.68
	CO_2	300.93	307.14	307.14	310.24	310.24	313.34	313.34	313.34	316.45	316.45	316.45	316.45	319.55
	CH_4	0.80	0.81	0.81	0.82	0.82	0.83	0.83	0.83	0.84	0.84	0.84	0.84	0.85
	N_2O	2.15	2.20	2.20	2.22	2.22	2.24	2.24	2.24	2.26	2.26	2.26	2.26	2.29
	Total	948.32	988.69	1017.69	1044.15	1069.47	1078.26	1078.26	1084.81	1108.86	1116.90	1135.78	1159.80	1177.11

Figure 3-5: Trend in emissions from the Other sectors category (in Gg CO_2 eq)

3.2.6.2. **Methodological Issues**

a. Choice of method (include assumptions and the rationale for selection)

The Tier 1 Sectoral Approach was used in accordance with the 2006 IPCC Guidelines to calculate emissions from Commercial/Institutions (CRT category 1.A.4.a); Residential (CRT category 1.A.4.b); and Agriculture (CRT category 1.A.4.c). The table below summarizes the methods and emission factors used. Furthermore, the equation below was used to estimate the GHG emissions.

Table 3-14: Summary of methods and emission factors that were used for this category

			CO_2		CH_4		N_2O	
CRT Category		Fuel type	Method Applied	Emission factor	Method Applied	Emission factor	Method Applied	Emission factor
1.A.4.a	Commercial/Institutions	Liquid Fuels	T1	D	T1	D	T1	D
		Gaseous Fuels	T1	D	T1	D	T1	D
		Biogas	T1	D	T1	D	T1	D
1.A.4.b	Residential	Liquid Fuels	T1	D	T1	D	T1	D
		Gaseous Fuels	T1	D	T1	D	T1	D
		Biogas	T1	D	T1	D	T1	D
1.A.4.c	Agriculture/forestry/fishing	Liquid Fuels	T1	D	T1	D	T1	D
		Gaseous Fuels	T1	D	T1	D	T1	D
		Biogas	T1	D	T1	D	T1	D

D (IPCC Default) T1 (IPCC T1)

$$E_{CO2} = \sum_{ij} \left[A_{ij} \times 41.868 \times EF_i\right] \times 44/12$$

Where:

E_{CO2}: =CO_2 emissions from fossil fuel combustion [ktCO_2]

A: = Energy consumption [kTOE]

EF: =Carbon content of the fuel [kt-C / TJ]

i: = Type of fuel

j: =Sector

1 kTOE = 41.868 TJ

$$E_{CH4,/N2O} = \sum_{ij} [A_{ij} \times 41.868 \times EF_{ij}]$$

Where:

$E_{CH4/N2O}$: = CH_4 / N_2O emissions from fossil fuel combustion [kt]

A: = Energy consumption [kTOE]

EF: =Emission factor [kt / TJ]

i: = Type of fuel

j: =Sector

1 kTOE = 41.868 TJ

b. EF, other parameters

Default emissions factors in the 2006 IPCC guidelines (volume 2, chapter 2, table 2.4 and table 2.5) were used to estimate CO2, CH4, and N2O emissions from Commercial/Institutions (CRT category 1.A.4.a); Residential (CRT category 1.A.4.b); and Agriculture (CRT category 1.A.4.c)

c. AD (include uncertainties and time-series consistency)

Activity data for Commercial/Institutions (CRT category 1.A.4.a); Residential (CRT category 1.A.4.b); and Agriculture (CRT category 1.A.4.c) were extracted from the energy balance table developed by APERC. The energy consumption data given in the energy balance table was converted from one energy unit (kTOE) to another (TJ) and used for the activity data. The table below shows the correspondence between the sectors of the energy balance table and CRT categories. Additionally, the figure below shows the trend of energy consumption by fuel type.

Table 3-15: CRT and corresponding energy balance table

CRT Category		Energy Balance Table by APERC	
1.A.4.a	Commercial/Institutions	16.1.1	Commerce and public services
1.A.4.b	Residential	16.1.2	Residential
1.A.4.c	Agriculture/forestry/fishing	16.2	Agriculture
		16.3	Fishing
		16.4	Non-specified others

3.2.6.3. **Uncertainty assessment and time-series consistency**

3.2.6.4. **Category-specific recalculations, if applicable**

No recalculation was made for the for the Other Sectors sub-category (CRT category 1.A.4)for this submission

3.2.6.5. **Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

The Other Setors sub-category has the following challenges:

- Lack of a national energy balance table based on PNG national statistics;
- Inability to disaggregate activity data into specific categories; and

- Lack of country-specific emission factors.

This may be improved by contacting the relevant stakeholders to check whether there is available data.

3.3. Fugitive emissions from fuels (CRT Category 1.B)

The Fugitive Emissions subsector consists of intentional and unintentional GHG emissions from unburned fossil fuels during their mining, production, processing, refining, transportation, storage, and distribution.

In the IPCC category, there are two main sources in this category:

i. Solid fuels (CRT Category 1.B.1): emissions from coal mining and handling; and
ii. Oil and natural gas (CRT Category 1.B.2): emissions from the oil and natural gas industries.

However, since coal mining is not carried out in PNG, only oil and natural gas (CRT Category 1.B.2) are reported in this sector. Fugitive emissions, venting, flaring, volatilization, and accidents are the main emission sources in the oil and natural gas industries.

3.3.1. Solid Fuels (CRT Category 1.B.1)

3.3.1.1. **Category description (e.g. characteristics of sources)**

This submission does not include emissions from this category as coal mining does not exist in PNG.

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

3.3.2.1. **Category description (e.g. characteristics of sources)**

Leakage, venting, and flaring associated with oil and natural gas extraction are categorized as fugitive emissions. Fugitive emissions may be unintentional or controlled, and the quantity and composition of emissions are generally subject to significant uncertainty.

This submission includes emissions from Oil (CRT Category 1.B.2.a), Natural gas (CRT Category 1.B.2.b), and Venting and Flaring (CRT Category 1.B.2.c). Emissions from Other (CRT Category 1.B.2.d) were not estimated due to a lack of data, such as abandoned wells and gas post meters.

Emissions from this category amounted to 7405.97 Gg CO_2 eq in 2022, an increase of 3412.91 Gg CO_2 eq (85%) when compared to 2000. Natural gas (CRT Category 1.B.2.b) contributed 64% of the total emissions, followed by Venting and Flaring (CRT Category 1.B.2.c) with 20%, while Oil (CRT Category 1.B.2.a) contributed 16%. Table 3-16 and Figure 3-6 below outlines the trend of emissions in this category.

Table 3-16: Trend in emissions by subcategory and gas from Oil, natural gas, and other emissions from energy production (in Gg CO_2 eq)

Unit: Gg CO2 eq

	CRT Category	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
1B2a	Oil	3608.18	2398.25	2789.73	1980.95	1067.61	613.85	1328.93	1359.35	1292.51	1259.17	1359.14	1184.54	1184.30
	CO_2	9.21	6.12	7.12	5.06	2.72	1.57	3.39	3.47	3.30	3.21	3.47	3.02	3.02
	CH_4	3598.96	2392.13	2782.61	1975.89	1064.88	612.28	1325.54	1355.89	1289.21	1255.96	1355.67	1181.51	1181.28
	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1B2b	Natural gas	54.85	60.84	54.39	58.08	58.54	3937.98	4204.05	4414.84	3907.10	4505.80	4627.29	4548.36	4715.45
	CO_2	0.03	0.03	0.03	0.03	0.03	1.24	1.33	1.39	1.23	1.42	1.49	1.47	1.52
	CH_4	54.82	60.81	54.36	58.05	58.51	3936.74	4202.72	4413.45	3905.87	4504.39	4625.80	4546.89	4713.93
	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1B2c	Venting and flaring	330.03	157.79	179.06	132.41	78.69	1241.18	1365.88	1430.51	1272.29	1453.53	1489.84	1455.36	1506.21
	CO_2	223.06	154.84	175.64	129.97	77.37	1239.06	1362.76	1427.32	1269.35	1450.42	1486.57	1452.34	1503.13
	CH_4	106.10	2.37	2.75	1.96	1.06	1.72	2.53	2.59	2.38	2.52	2.64	2.45	2.50
	N_2O	0.87	0.58	0.67	0.48	0.26	0.40	0.60	0.61	0.56	0.59	0.62	0.57	0.58
1B2d	Other	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Total	3993.05	2616.88	3023.18	2171.43	1204.83	5793.01	6898.86	7204.71	6471.90	7218.50	7476.27	7188.26	7405.97

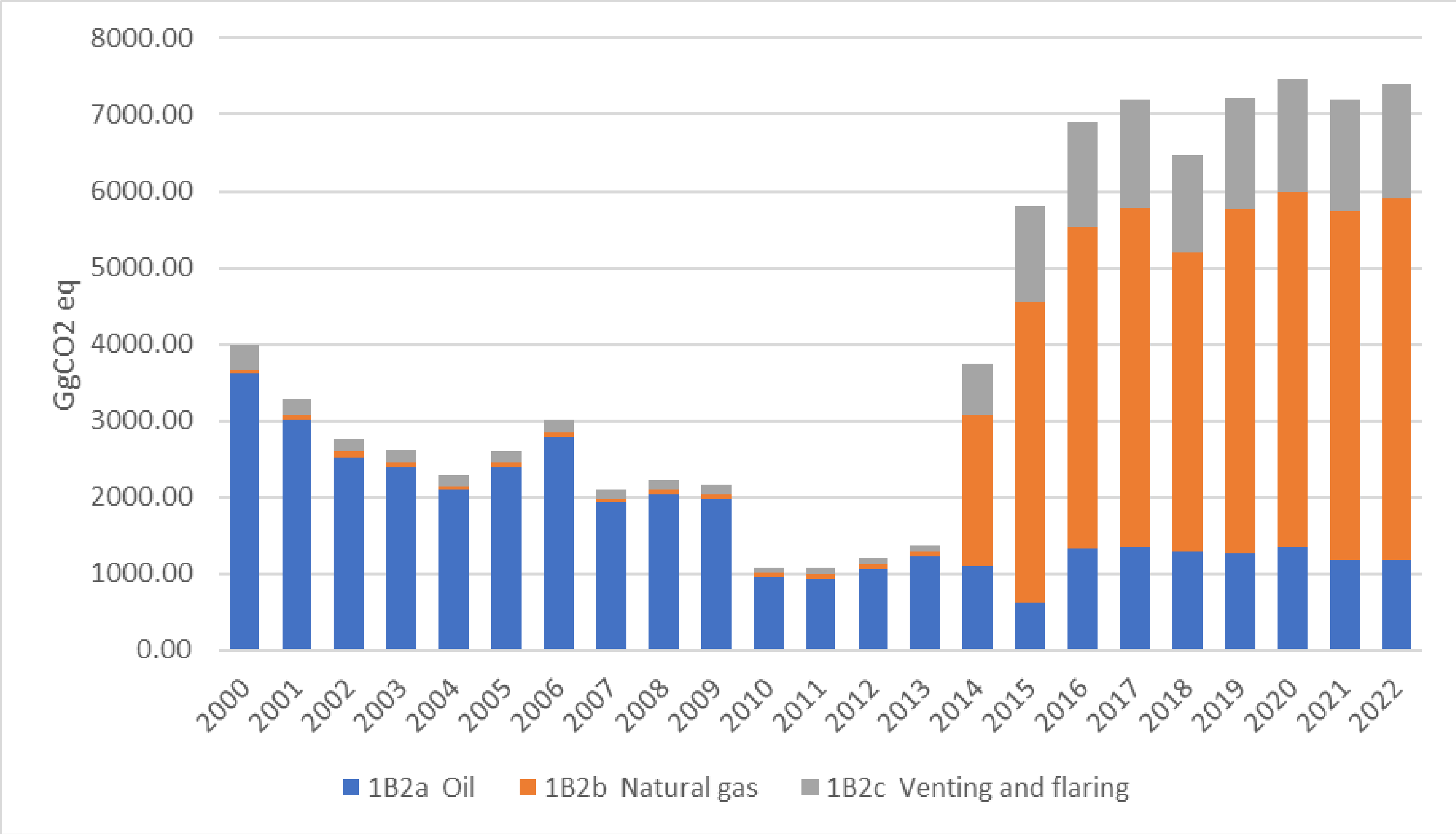

Figure 3-6: Trend in emissions from Oil, natural gas, and other emissions from energy production (in Gg CO_2 eq)

3.3.2.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

The Tier 1 Sectoral Approach was used in accordance with the 2006 IPCC Guidelines to calculate emissions from was used to estimate emissions for fugitive emissions from oil, natural gas, and other emissions from energy production (CRT Category 1.B.2). The table below summarizes the methods and emission factors used.

Table 3-17: Summary of methods and emission factors that were used for estimating emissions in this category

CRT Category		CO_2		CH_4		N_2O	
		Method Applied	Emission factor	Method Applied	Emission factor	Method Applied	Emission factor
1.B.2.a	Oil	T1	D	T1	D	T1	D
1.B.2.b	Natural gas	T1	D	T1	D	T1	D
1.B.2.c	Venting and flaring	T1	D	T1	D	T1	D
1.B.2.d	Other	T1	D	T1	D	T1	D

D (IPCC Default) T1 (IPCC T1)

a. EF, other parameters

Default emissions factors in the 2006 IPCC guidelines (volume 2, chapter 4) were used to estimate CO2, CH4, and N2O for Oil (CRT Category 1.B.2.a), Natural gas (CRT Category 1.B.2.b), Venting and Flaring (CRT category 1.B.2.c) and other (CRT category 1.B.2.d)

b. AD (include uncertainties and time-series consistency)

Activity data for Oil (CRT Category 1.B.2.a), Natural gas (CRT Category 1.B.2.b), Venting and Flaring (CRT category 1.B.2.c) and other (CRT category 1.B.2.d) were extracted from the energy balance table developed by APERC. The energy unit (KTOE) was converted to volumes (m3)and used for the activity data.

3.3.2.3. **Uncertainty assessment and time-series consistency**

3.3.2.4. **Category-specific recalculations, if applicable**

No recalculation was made for Oil, natural gas, and other emissions from energy production (CRT Category 1.B.2)for this submission.

3.3.2.5. **Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

There are no major planned improvements in this category

3.4. CO_2 transport and storage (CRT Category 1.C)

This submission does not include emissions from this category as coal mining does not exist in PNG.

Chapter 4. Industrial Processes and Product Use (IPPU)

4.1. Overview of sector

PNG's economy is primarily driven by resources, agriculture, forestry, and fishing, with a small sector dedicated to import-substituting manufacturing. Several of these activities involve industrial processes and product uses that lead to GHG emissions, such as lubricant use and refrigeration and air-conditioning. Some import-substituting manufacturing activities result in the emission of non-GHGs (CO, NOx, NMVOC) and include the production of food, beverages, and tobacco. The import of N_2O used in products also contributes to GHG emissions.

The specific nature and extent of industrial processes or product uses in other activities related to resources, agriculture, and fishing have not yet been determined. CCDA has identified the following activities in PNG's Balance of Trade:

- Cladding of base metals with silver, and base metals, silver or gold clad with platinum (not further worked than semi-manufactured);
- Copper ores and concentrates;
- Gold (including gold plated with platinum), unwrought or in semi-manufactured forms, or in powder form;
- Nickel mattes, nickel oxide sinters, and other intermediate products of nickel metallurgy;
- Precious metal ores and concentrates;
- Amine function compounds, oxygen-function compounds except for lysine and its esters and salts thereof, glutamic acid and its salts, ureines and their derivatives and salts thereof, carboxyimide-function compounds and imine-compounds, nitrile functi;
- Food manufacturing (tuna, skipjack, or striped-bellied bonito) frozen, prepared dishes and meals based on fish, molluscs and crustaceans; and
- Petroleum jelly, paraffin wax, micro-crystalline petroleum wax, slack wax, ozokerite, lignite wax, peat wax, other mineral waxes and similar products, petroleum coke, petroleum bitumen and other residues of petroleum oils or oils obtained from bitumen.

Emissions that are captured in this GHG inventory include lubricant use (CRT Category 2.D.1), HFCs in refrigeration and air-conditioning (CRT Category 2.F.1) and N_2O in other product manufacture and use (CRT Category 2.G.3). Emissions from the Mineral Industry (CRT Category 2.A.), Chemical Industry (CRT Category 2.B.), and Metal Industry (CRT Category 2.C.) were not reported. They are categorized as 'not occurring' pending confirmation through the GHG Inventory Improvement Plan.

The most recent inventory year (2022) estimates total GHG emissions in the IPPU sector at 144.52 Gg CO_2eq. The relative contributions of individual GHGs are as follows: CO_2 (1.2%), HFCs (98.7%), and N_2O (0.1%). This ratio remains consistent over time, except for HFCs, which were estimated only for the years 2015 to 2022. However, it's important to acknowledge that the IPPU inventory remains significantly incomplete.

In 2022, IPPU sector emissions contributed 1% to total GHG emissions (excluding LULUCF). The emissions by category are shown in the Table 4-1 and Figure 4-1 below.

Table 4-1:IPPU Sector GHG emissions

CRT Category		Emissions (Gg CO_2 eq)		Difference (Gg CO_2 eq)	Change (%)	Share (%)	
		2000	2022	2000-2022	2000-2022	2000	2022
2.A	Mineral Industry	NO	NO	NO	NO	NO	NO
2.B	Chemical Industry	NO	NO	NO	NO	NO	NO
2.C	Metal Industry	NO	NO	NO	NO	NO	NO
2.D	Non-energy products from fuels and solvent use	0.82	1.747	0.927	113%	100%	1.2%
2.E	Electronics industry	NO	NO	NO	NO	NO	NO
2.F	Product uses as substitutes for ODS	NE	142.69	-	-	-	98.7%
2.G	Other product manufacture and use	NE	0.084	-	-	-	0.1%
2.H	Other	NE	NE	NE	NE	NE	NE
	Total	0.82	144.520187	0.927	113%	100%	100.0%

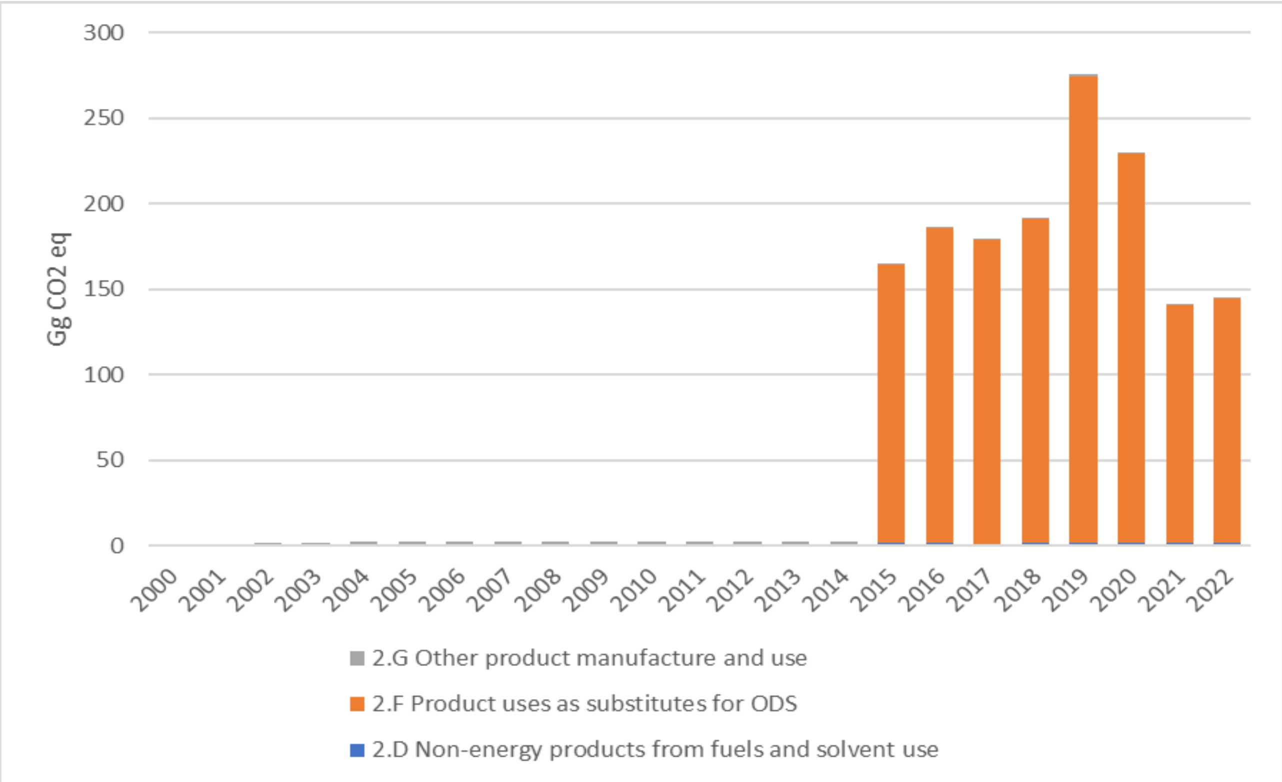

Figure 4-1: Trend in emissions from the IPPU sector (2000 to 2022) (in Gg CO_2eq)

IPPU sector emissions in 2022 were 144.52 Gg CO_2 eq (17524 %) higher than emissions in 2000 (0.82 Gg CO_2 eq). This significant percentage change was mainly driven by a paucity of activity data in the base year for HFCs and for N_2O from product use.

4.2. Mineral industry (CRT Category 2.A.)

According to PNG's Balance of Trade statistics, emissions from the Mineral Industry (CRT Category 2.A.) have not been reported. These statistics suggest that a mineral industry does not currently exist in PNG. As part of the GHG Inventory Improvement Plan, efforts are underway to verify whether any mineral industry activities are indeed occurring in PNG and whether they contribute to greenhouse gas emissions. Thus consistency is the main priority for this category.

4.3. Chemical Industry (CRT Category 2.B.)

Emissions from the Chemical Industry (CRT Category 2.B.) were not reported and were captured as not occurring. Through the GHG Inventory Improvement Plan, CCDA intends to verify whether the chemical industry activities occur in PNG and whether these industrial processes produce GHG emissions. Thus completeness is the main priority for this category

4.4. Metal Industry (CRT Category 2.C.)

The Metal Industry (CRT Category 2.C.) emissions were not reported and are captured as not occurring. PNG boasts extensive mining activities for various metals including precious metals such as gold, silver, copper, rare earth metals, nickel, cobalt, chromium, iron, and platinum. However, the exact point in the manufacturing chain (from ore extraction to refining) where the process concludes remains unclear. Furthermore, it remains to be determined whether these industrial processes contribute to greenhouse gas emissions. Through the GHG Inventory Improvement Plan, CCDA will investigate whether metal industry-related activities are indeed occurring and whether they generate GHGs. Thus completeness is the main priority for this category.

4.5. Non-energy products from fuels and solvent use (2.D)

4.5.1. Lubricant Use (CRT Category 2.D.1)

4.5.1.1. **Category description (e.g. characteristics of sources)**

Lubricants, commonly known as motor oils, serve as essential fluids for lubricating various combustion engines in both industrial and transportation contexts. While their primary function is to reduce friction between moving parts, motor oil also plays several other crucial roles. It acts as a cleaner, inhibits corrosion, enhances sealing, and aids in engine cooling by dissipating heat from the components. Most motor oils are derived from crude oil and predominantly consist of hydrocarbons—organic compounds composed entirely of hydrogen and carbon.

These lubricants fall into two main categories: mineral oils and synthetic motor oils, each produced using distinct manufacturing processes. Mineral oils result from basic conversion technologies and meet minimum industry standards. In contrast, synthetic oils often referred to as low-viscosity lubricants, undergo synthetic processes that significantly enhance their performance characteristics.

4.5.1.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

The estimation of CO2 emissions from lubricant use relies on the IPCC Tier 1 method. Unfortunately, there is no country-specific data available regarding the precise amount of lubricant used for specific applications. Consequently, the IPCC Tier 1 approach, as outlined in the IPCC guidelines (2006a), is used to estimate CO2 emissions resulting from lubricant usage.

$$CO_2\ emissions = LC \times CC_{Lubricant} \times ODU_{Lubricant} \times \left(\frac{44}{12}\right)$$

Where:

CO_2	=	*CO_2 emissions from lubricants, tons CO_2*
LC	=	*Total lubricant consumption, TJ*
$CC_{Lubricant}$	=	*Carbon content of lubricants (default), ton C/TJ (kg C/GJ)*
$ODU_{Lubricant}$	=	*ODU factor (based on default composition of oil and grease), fraction*
44/12	=	*Mass ration of CO_2 - C*

b. EF, other parameters

PNG used the default IPCC emission factor for estimating CO2 emissions related to lubricant use. This factor accounts for both the carbon content and the 'oxidized during use' (ODU) factor. Specifically, the default emission factor is 20.0 kg C/GJ based on the Lower Heating Value.

Since country-specific data to differentiate between the fraction of lubricants consumed and combusted (as reported in the Energy sector) versus the fraction not fully oxidized (as reported in the IPPU sector) is lacking, PNG resorts to a limiting assumption. The calculation assumes that the total amount of lubricants lost during their use is fully combusted, resulting in direct reporting of these emissions as CO_2 emissions.

Furthermore, due to the absence of detailed data distinguishing oil and grease, PNG adopts the IPCC default weighted average ODU factor of 0.2. This assumption is based on the belief that approximately 90% of the mass of lubricants consists of oil, while the remaining 10% is grease.

c. AD (include uncertainties and time-series consistency)

CCDA received lubricant consumption data from the key importer of lubricants. This data set covers all years up to 2015. In the absence of specific data for 2016 and 2022 up until now, it is assumed that the activity levels for those years remain consistent with 2015.

4.5.1.3. Category-specific recalculations, if applicable

For this GHG inventory, no recalculation of the CO_2 emission time series was performed.

4.5.1.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

CCDA currently has no scheduled enhancements in the methodology or emission factors used for estimating CO2 emissions from lubricant use. For the activity data, CCDA plans on obtaining data for 2016 to 2022 as well as the latest years for the next reporting period.

4.6. Electronics industry (CRT Category 2.E.)

Emissions from the Electronics Industry (CRT Category 2.E.) were not reported and were captured as not occurring. Through the GHG Inventory Improvement Plan, CCDA intends to verify whether the electronics industry activities occur in PNG and whether these industrial processes produce GHG emissions. Thus completeness is the main priority for this category

4.7. Product uses as substitutes for ozone depleting substances (CRT Category 2.F)

Various applications within this sub-sector depend on the use of refrigerants. The use and subsequent leakage of these gases have historically been known to affect the ozone layer. The phase-out of ozone-depleting substances (ODS) is managed under the Montreal Protocol. The Kigali Amendment to this protocol mandates the phase-out of HFCs, which have high global warming potentials, with HFCs to be gradually replaced by CFCs and HCFCs.

PNG has reported HFC emissions for the period 2015–2022. The method used to estimate emissions is based on bulk HFC import data provided by the Conservation and Environment Protection Authority. Therefore, these emissions cannot be attributed to specific ‘applications’, but it is acknowledged that most of the imported HFCs would be used in refrigeration and air-conditioning equipment. Hence, they are reported under 2.F.1. Refrigeration and Air-Conditioning.

CCDA recognizes that GHG emissions from the use of products as substitutes for ODS are largely incomplete. Bulk HFC import data could not be allocated to specific end-uses, and this has been identified as an area for improvement in the next inventory. The ability to estimate and monitor refrigerant ‘banks’ is another area for improvement. The ‘bank’ refers to the existing stock of refrigerants in current equipment.

The current submission does not include emissions from Foam blowing agents (CRT Category 2.F.2), Fire protection (CRT Category 2.F.3), Aerosols (CRT Category 2.F.4), Solvents (CRT Category 2.F.5), and Other applications (CRT Category 2.F.6).

4.7.1. Refrigeration and Air Conditioning Equipment (CRT Category 2.F.1)

4.7.1.1. **Category description (e.g. characteristics of sources)**

Refrigeration and air-conditioning systems serve to provide thermal comfort in homes, and commercial buildings, and during the storage and transportation of goods (such as food). When new equipment is imported into PNG, it may come precharged with refrigerant, but sometimes it needs to be charged upon installation. These systems require periodic recharging through maintenance procedures. At the end of their life cycle, they are ‘retired,’ and the refrigerant is subsequently ‘destroyed.’ Additionally, there can be refrigerant leakages from retired equipment.

4.7.1.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

HFC emissions are estimated using Equation 7.9 from the 2019 Refinement of the 2006 IPCC Guidelines. This approach falls under Tier 2b and relies on known or assumed information about servicing regimes needed to maintain equipment.

Emissions (kg)=[Annual sales of new refrigerants]+[Total charge of new equipment]+[Original total charge of retiring equipment]-[amount of intentional destruction]

Where:

'Annual sales of new refrigerant' is the amount of refrigerant introduced in a given year, and includes all refrigerant used to fill or refill equipment, whether the refrigerant is charged into equipment at the factory, charged into equipment after installation, or used to recharge equipment at servicing. It does not include recycled or reclaimed refrigerant.

'Total charge of new equipment' is the sum of all full charges of all retiring equipment decommissioned in a given year. It assumes equipment will have been serviced right up to its decommissioning and thereby contain its original charge.

'Amount of intentional destruction' is the quantity of refrigerant destroyed.

CCDA has applied expert judgment to utilize the above equation. These assumptions are outlined in the HFC Emission Inventory Report (September 2021) provided to CCDA, which includes the expert judgment of the authors and the PNG Refrigeration and Air-Conditioning Association (PNG-RACA).

These assumptions are as follows:

- The ratio of refrigerant used for servicing versus charging new equipment is 80:20,
- The original total charge of retiring equipment is assumed to be zero, and
- The amount of intentional destruction is assumed to be zero.

It is acknowledged that small quantities of refrigerants were sent to Australia for destruction. However, further investigation is needed to confirm this event and the quantities involved.

b. EF, other parameters

HFC emissions were estimated using HFC bulk import data hence no emission factors were required. Other parameters used in the applied methodology are described in the previous sector.

c. AD (include uncertainties and time-series consistency)

The referenced HFC Emission Inventory Report examined various sources of activity data to estimate HFC emissions. Three sources were identified with Chinese export data (2015-2019) and PNG Customs import data (2019-2020). The PNG Customs data was chosen as the primary source due to its reliability and sustainability for bulk HFC import data. The Chinese export data provided essential HFC speciation information, including species ratios used to adjust the PNG Customs data.

Table 4-2: HFC data for 2015 to 2022

	2015	2016	2017	2018	2019	2020	2021	2022
R134a	55.26	68.01	46.07	30.52	54.24	65.54	34.32	66.70
R404A	58.29	57.81	67.02	100.55	115.38	77.12	51.71	35.27
R407c	0.00	2.64	1.40	9.45	11.50	17.84	6.44	3.52
R410A	31.55	53.53	34.96	36.72	65.85	53.77	30.03	20.13
R438a	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00
R452a	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00
R507	17.77	1.97	27.71	12.34	25.83	11.11	15.41	7.92
R32	0.00	0.00	0.00	0.00	0.08	1.59	1.08	9.15
Total	162.87	183.96	177.15	189.58	272.87	227.44	138.99	142.69

4.7.1.3. Category-specific recalculations, if applicable

No recalculations were made for this category

4.7.1.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The improvements for this category can be summarized as follows:

- CEPA should work with CCDA and PNG Customs to enhance mechanisms, arrangements, processes, and procedures. The goal is to collect data on imported equipment types, the stock of equipment in PNG by end-use, and the refrigerant 'bank'; and
- Additionally, collaboration with PNG Customs and the National Energy Authority is necessary to identify reliable sources of data on SF6 (sulfur hexafluoride) in electrical equipment.

4.8. Other product manufacture and use (CRT Category 2.G)

This category covers N_2O, PFC, and SF_6 emissions from other manufacture and use. This includes GHG emissions from the following sources: Electrical equipment (CRT Category 2.G.1); SF_6 and PFCs from other product use (CRT Category 2.G.2); and N_2O from product uses (CRT Category 2.G.3). For this current submission only N_2O from product uses (CRT Category 2.G.3) is reported and not other sources due to lack of data.

4.8.1. N_2O for Medical Application (CRT 2.G.3.)

4.8.1.1. **Category description (e.g. characteristics of sources)**

PNG has consistently reported the emission of nitrous oxide (N2O) from the use of various medical products over the period from 2000 - 2017. Unfortunately, activity data for the earlier years within this time-frame is not available. the medical applications that contribute to these emissions include the use of anaesthetics, analgesics, and products used in veterinary medicine.

4.8.1.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

Due to the small quantities and the prompt nature of the emissions, a Tier 1 method is used to estimate N2O emissions. Additionally, it is assumed that all imported N2O is sold and used within one year. N2O emissions from its use in medical applications are calculated using the IPCC Tier 1.

$$\Sigma_{N_2O\ (t)} = \Sigma_i\{[0.5 \times A_{i(t)} + 0.5 \times A_i(t-1)] \times EF_i\}$$

Where:

ΣN_2O	=	*Emissions of N_2O in year t, tons*
$A_i(t)$	=	*Total quantity of N_2O supplied in year t in application type i (medical use), tons*
A_i (t-1)	=	*Total quantity of N_2O supplied in year t-1 in application type i (medical use), tons*
Efi	=	*Emission factor for application type i, fraction*

b. EF, other parameters

PNG uses the IPCC default emission factor of 1 based on the limiting assumption that none of the administered N_2O is chemically changed by the body and is returned to the atmosphere.

c. AD (include uncertainties and time-series consistency)

BOC Gases was identified as an importer of N2O for medical use in PNG and had previously provided activity data to CCDA. This data covers the years 2002 to 2015. For this report, BOC wasn't able to provide data on time thus in the absence of data for 2016 to 2022, it is assumed that the activity levels for these years are consistent with those of 2015.

4.8.1.3. Category-specific recalculations, if applicable

No recalculations of N_2O emissions from medical applications were performed for this GHG inventory. However, it is recognized that the years 2016 to 2022 will need to be recalculated in future GHG inventories using actual activity data for those years.

4.8.1.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

CCDA currently has no planned enhancements for the methodology and emission factors used to estimate N2O emissions from medical applications. This decision is driven by the necessity to prioritize improvements in the GHG inventory, which are based on the results of the key category assessment. CCDA will prioritize getting activity data for the years 2016 to 2022, and well as investigate if there are other importers of N2O in the country.

Chapter 5. Agriculture

5.1. Overview of the sector

The agriculture sector is one of the significant sectors in PNG, as it is one of the dominant activities in the country. This chapter contains information on the estimations of GHG emissions from the agriculture sector. GHG emissions from the agriculture sector are generally linked to the management of agricultural livestock, agricultural soils, rice production, and biomass burning. The three main agricultural sources of GHG include:

- enteric fermentation, part of the digestive process for many ruminants such as cattle, sheep, and goats, which produces methane (CH_4) emissions;
- nitrification and denitrification of the nitrogen present in soils, which produces nitrous oxide (N_2O) emissions; and
- manure decomposition under anaerobic conditions, which produces methane emissions

This section provides GHG estimates from Enteric Fermentation (CRT Category 3. A), Manure Management (CRT Category 3. B), Agricultural soils (CRT Category 3.D), Liming (CRT Category 3. G), and Urea (CRT Category 3. H). GHG estimates from the Prescribed burning of savannah (CRT Category 3. E) are captured under the LULUCF sector, while emissions from Rice (CRT Category 3. C) and Field burning of agricultural residues (CRT Category 3. E) were not estimated due to limited or unavailability of data. The methods used for estimating the emissions were tier 1 and default values. The table below provides a summary of the methods that were used for estimating emissions from the agriculture sector.

Table 5-1: Summary of methods used

CRT Category		CO_2		CH_4		N_2O	
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
3.A	Enteric fermentation			T1	D		
3.B	Manure management			T1	D	T1	D
3.C	Rice cultivation			NE	NE		
3.D	Agricultural soils					T1	D
3.F	Field burning of agricultural residues			IE	IE	IE	IE
3.G	Liming	NE	NE				
3.H	Urea application	NE	NE				
		T1	IPCC Tier 1		D	IPCC default	
		IE	Included else where				

GHG emissions from the agriculture sector amounted to 764.03 Gg CO_2 eq in 2022, which is approximately 4% of the country's overall emissions that year (excluding LULUCF). Total emissions increased by 285.76 Gg CO_2 eq (37%) when compared to the year 2000. The highest emitting category in 2022 was Agricultural soils (CRT category 3.D), which contributed 37% of the total sector emissions. After this is the Enteric Fermentation (CRT Category 3.A), which contributed 33%, followed by Manure Management (CRT Category 3.A) with 30%. Table 5-2 and Figure 5-1 below outlines the trends of emissions from the Agriculture Sector from 2000 to 2022.

Table 5-2: GHG emissions from the agriculture sector (Gg CO_2 eq)

CRT Category		Unit	2000	2003	2006	2009	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3.A	Enteric fermentation	Gg CO_2 eq	194.764	185.541	193.978	207.531	213.289	222.969	219.904	224.663	224.923	229.995	234.988	239.725	244.200	247.582	250.255
3.B	Manure management		176.823	177.372	179.286	184.926	196.421	206.932	207.844	211.055	205.266	209.203	213.042	216.896	220.971	224.299	227.934
3.C	Rice cultivation		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.D	Agricultural soils		106.685	113.446	151.934	203.774	255.255	261.483	228.518	169.288	267.029	297.367	286.761	272.835	264.565	258.421	285.839
3.E	Prescribed burning of savannahs		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.F	Field burning of agricultural residues		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.G	Liming		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.H	Urea application		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total			478.272	476.359	525.197	596.232	664.965	691.385	656.266	605.006	697.218	736.564	734.792	729.455	729.737	730.303	764.028

NE Not Estimate

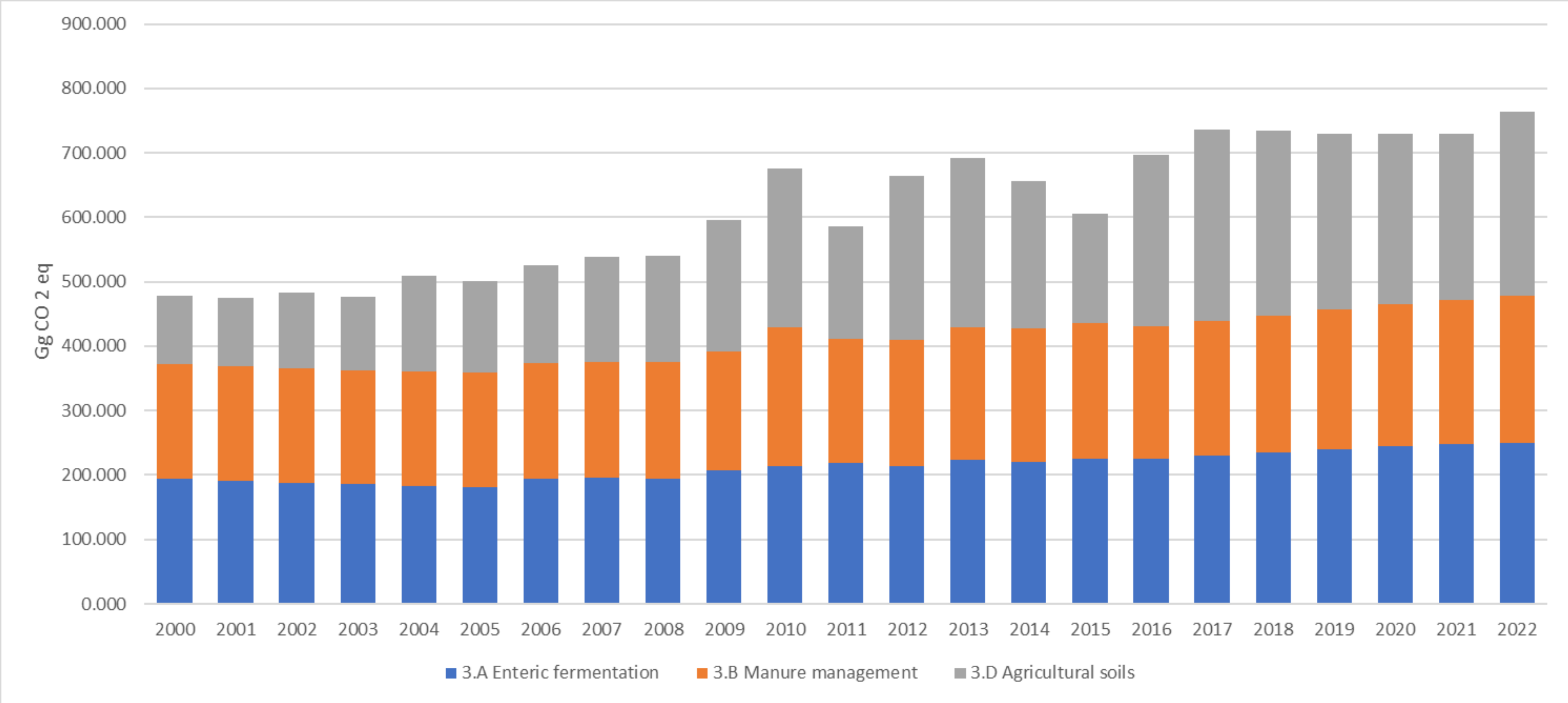

Figure 5-1: GHG emissions from the agriculture sector (Gg CO_2 eq)

5.2. Enteric fermentation (CRT Category 3.A)

5.2.1. Category description (e.g. characteristics of sources)

Methane is produced in plant-eating animals as a result of enteric fermentation, a digestive process in which carbohydrates are broken down by microorganisms into simple molecules that can be absorbed into the bloodstream. There are a number of factors that directly contribute to the amount of methane that is released and there are the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of methane, with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses).

The main livestock species raised in PNG are cattle, sheep, goats, horses, swine and poultry. Buffalo, camels, mules, and asses are not present in PNG and therefore GHG emissions from these livestock species are not captured.

The total CH_4 emissions from enteric fermentation for the country in 2022 were 250.26 Gg CO_2 eq, an increase of 55.49 Gg CO_2 eq (28%) when compared with the year 2000. Table 5-3 outlines the GHG emissions from enteric fermentation.

Table 5-3: GHG emissions from Enteric Fermentation (Gg CO_2 eq)

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
3. A.1.a	Dairy Cattle	Gg CH_4	0.086	0.090	0.093	0.097	0.100	0.092	0.074	0.078	0.084	0.089	0.099	0.093	0.098
3. A.1.b	Non-dairy Cattle		6.375	6.029	6.318	6.784	6.964	7.319	7.363	7.529	7.693	7.848	7.988	8.102	8.182
3. A.2	Sheep		0.054	0.048	0.042	0.039	0.033	0.033	0.029	0.029	0.027	0.026	0.025	0.025	0.024
3. A.3	Swine		0.387	0.386	0.389	0.400	0.427	0.460	0.449	0.457	0.465	0.473	0.481	0.489	0.496
3.A. 4. a	Buffalo		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.A. 4. b	Camels		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.A. 4. c	Deer		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.A. 4. d	Goats		0.051	0.071	0.082	0.089	0.090	0.116	0.114	0.117	0.119	0.121	0.124	0.128	0.131
3.A. 4. e	Horses		0.002	0.002	0.002	0.003	0.003	0.005	0.004	0.004	0.005	0.005	0.005	0.006	0.006
3.A. 4. g	Poultry		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total		Gg CH_4	6.956	6.626	6.928	7.412	7.617	8.024	8.033	8.214	8.392	8.562	8.721	8.842	8.938
		Gg CO_2 eq	194.764	185.541	193.978	207.531	213.289	224.663	224.923	229.995	234.988	239.725	244.200	247.582	250.255

NE Not Estimated

NO Not Occuring

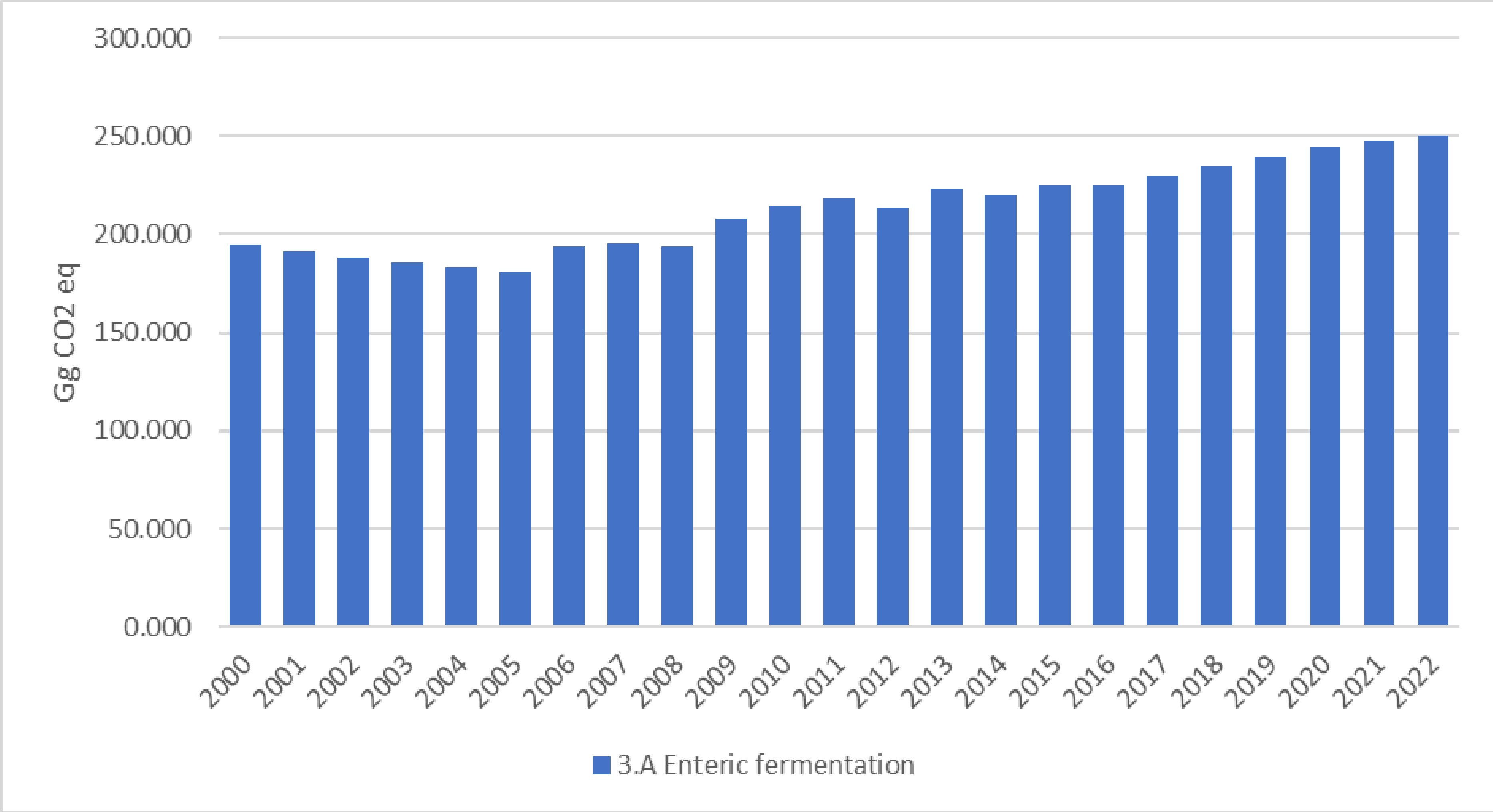

Figure 5-2: GHG emissions from Enteric Fermentation (Gg CO_2 eq)

5.2.2. Methodological issues

5.2.2.1. **Choice of method (include assumptions and the rationale for selection)**

Tier 1 method of the 2006 IPCC guidelines was used to estimate GHG emissions from enteric fermentation. To estimate total CH_4 emissions, the default livestock species emission factors are multiplied by the associated animal population (Equation 10.19) and summed (Equation 10.20).

Equation 10.19 in volume 4 of the 2006 IPCC Guildelines: Enteric Fermentation Emissions from a Livestock Category

$$\text{Emissions} = \text{EF}_\text{T} \times \left(\frac{\text{N}_{(\text{T})}}{10^6}\right)$$

Where:

$Emissions$	=	*methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}*
EF_T	=	*emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}*
$N_{(T)}$	=	*the number of head of livestock species / category T in the country*
T	=	*species/category of livestock*

Equation 10.20 in volume 4 of the 2006 IPCC Guidelines: Total Emissions from Livestock Enteric Fermentation

$$\text{Total } \text{CH}_{4_{\text{Enteric}}} = \sum_{\text{i}} \text{E}_\text{i}$$

$Where$

$Total\ CH_{4_{Enteric}}$	=	*total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}*
E_i	=	*is the emissions for the i^{th} livestock categories and subcategories*

5.2.2.2. **EF, other parameters**

The default emission factors used were from table 10.10 (for developing countries) and table 10.11 (for the Oceania region) in chapter 10, volume 4 of the 2006 IPCC guideline. The table below outlines the emission factor that was used for each livestock species.

Table 5-4: Enteric fermentation emission factors used

CRT Category		Emission factor (kg CH_4 head/year)	Source
3. A.1.a	Dairy Cattle	100	Default, table 10.11 IPCC 2006
3. A.1.b	Non-dairy Cattle	60	Default, table 10.11 IPCC 2006
3. A.2	Sheep	5	Default, table 10.10 IPCC 2006
3. A.3	Swine	1	Default, table 10.10 IPCC 2006
3.A. 4. a	Buffalo	55	Default, table 10.10 IPCC 2006
3.A. 4. b	Camels	46	Default, table 10.10 IPCC 2006
3.A. 4. c	Deer	20	Default, table 10.10 IPCC 2006
3.A. 4. d	Goats	5	Default, table 10.10 IPCC 2006
3.A. 4. e	Horses	18	Default, table 10.10 IPCC 2006
3.A. 4. f	Mules and asses	10	Default, table 10.10 IPCC 2006
3.A. 4. g	Poultry	0	Default, table 10.10 IPCC 2006
3.A. 4. h	Other	0	Default, table 10.10 IPCC 2006

5.2.2.3. **AD (include uncertainties and time-series consistency)**

The activity data used for the BUR1 (2000 to 2015) was taken from the 4 regional workshops organized by CCDA. The four regions include the New Guinea Islands region, the Momase region, the Highlands region, and the Southern region Participants included regional officers of the Department of Agriculture and Livestock as well as Provincial Agriculture Officers. Since there were no existing records on livestock populations, the DAL officers made expert judgments by estimating the number of livestock species based on local knowledge for the years 2000 and 2001. For the years 2002 to 2015, the DAL officers estimated the number of livestock species based on the trend of 2000 and 2001.

It was noted in the last NIR that livestock data for years 2016 and 2017 figures were extrapolated using the trend extrapolation method in volume 1 chapter 5 of the 2006 IPCC guidelines. This was due to COVID restrictions which prevented CCDA from conducting regional workshops.

In this current report, CCDA conducted 4 regional workshops to update the livestock data from 2016 to 2022.

5.2.3. Category-specific recalculations, if applicable

Recalculations were done for the years 2016 and 2017 due to availability of new activity data.

5.2.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

PNG has recently carried our data collection in the four regions to collect and upgrade the data sets we had for this reporting period. Based on the outcome of the data collection workshop that was conducted, it was concluded that there is still a lot of work to be done to really improve the detail of the activity data and eventually move to higher tiers, especially for the most representative livestock species in the country.

5.3. Manure management (CRT Category 3.B)

5.3.1. Category description (e.g. characteristics of sources)

CH_4 is formed when manure is stored and treated; it is the byproduct of the breakdown of manure in anaerobic or low-oxygen environments. These circumstances commonly arise in cases where a large number of animals are kept in a small space (such as dairy farms or cattle feedlots), where manure is typically stored in large piles or disposed of in lagoons or other types of manure management systems (MMS). N_2O is emitted directly into the atmosphere during the storage and treatment of manure via combined nitrification and denitrification of nitrogen contained in manure.

Estimates of CH_4 and N_2O from manure management of livestock in PNG are outlined in this section. For this cycle of GHG inventory, the type of manure management system practiced in PNG was based on expert judgment, with guidance from the 2006 IPCC guidelines. This includes:

- Uncovered anaerobic lagoon;
- liquid/slurry (without natural crust cover);
- dry lot;
- solid storage (with natural crust cover);
- daily spread;
- aerobic treatment (natural aeration system).

The total GHG emissions from manure management in the country in 2022 were 227.93 Gg CO_2 eq, an increase of 51.11 Gg CO_2 eq (29%) when compared with the year 2000. Table 5-5 and Figure 5-3 outlines the GHG emissions from manure mangement.

Table 5-5: GHG emissions from Manure Management

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
3. B.1.a	Dairy Cattle	$Gg\ CH_4$	0.027	0.028	0.029	0.030	0.031	0.028	0.023	0.024	0.026	0.027	0.031	0.029	0.031
3. B.1.b	Non-dairy Cattle		0.213	0.201	0.211	0.226	0.232	0.244	0.245	0.251	0.256	0.262	0.266	0.270	0.273
3. B.2	Sheep		0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3. B.3	Swine		5.450	5.447	5.489	5.646	6.020	6.480	6.336	6.442	6.552	6.664	6.777	6.889	6.999
3.B. 4. a	Buffalo		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.B. 4. b	Camels		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.B. 4. c	Deer		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.B. 4. d	Goats		0.0023	0.0031	0.0036	0.0039	0.0040	0.0051	0.0050	0.0051	0.0052	0.0053	0.0054	0.0056	0.0058
3.B. 4. e	Horses		0.0003	0.0003	0.0003	0.0004	0.0005	0.0008	0.0006	0.0006	0.0007	0.0007	0.0007	0.0008	0.0008
3.B. 4. g	Poultry		0.0760	0.1196	0.1227	0.1258	0.1258	0.1384	0.0880	0.1032	0.1112	0.1181	0.1312	0.1246	0.1312
Total		$Gg\ CH_4$	5.770	5.800	5.857	6.034	6.415	6.898	6.699	6.827	6.952	7.078	7.212	7.320	7.441
		$Gg\ CO_2$ eq	161.557	162.410	163.996	168.952	179.622	193.132	187.566	191.167	194.667	198.186	201.936	204.966	208.335
3. B.1.a	Dairy Cattle	$Gg\ N_2O$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3. B.1.b	Non-dairy Cattle		0.018	0.017	0.018	0.019	0.020	0.021	0.021	0.021	0.022	0.022	0.023	0.023	0.023
3. B.2	Sheep		0	0	0	0	0	0	0	0	0	0	0	0	0
3. B.3	Swine		0.021	0.021	0.021	0.022	0.023	0.025	0.025	0.025	0.026	0.026	0.026	0.027	0.027
3.B. 4. a	Buffalo		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.B. 4. b	Camels		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.B. 4. c	Deer		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.B. 4. d	Goats		0	0	0	0	0	0	0	0	0	0	0	0	0
3.B. 4. e	Horses		0	0	0	0	0	0	0	0	0	0	0	0	0
3.B. 4. g	Poultry		0	0	0	0	0	0	0	0	0	0	0	0	0
3.B.5	Indirect N_2O emissions from Manure Mangement		0.018	0.018	0.018	0.019	0.020	0.022	0.021	0.022	0.022	0.022	0.023	0.023	0.023
Total		$Gg\ N_2O$	0.058	0.056	0.058	0.060	0.063	0.068	0.067	0.068	0.069	0.071	0.072	0.073	0.074
		$Gg\ CO_2$ eq	15.266	14.963	15.290	15.974	16.799	17.924	17.700	18.035	18.375	18.710	19.035	19.333	19.599
Total of all gases		$Gg\ CO_2$ eq	176.823	177.372	179.286	184.926	196.421	211.055	205.266	209.203	213.042	216.896	220.971	224.299	227.934

NE Not Estimated

NO Not Occuring

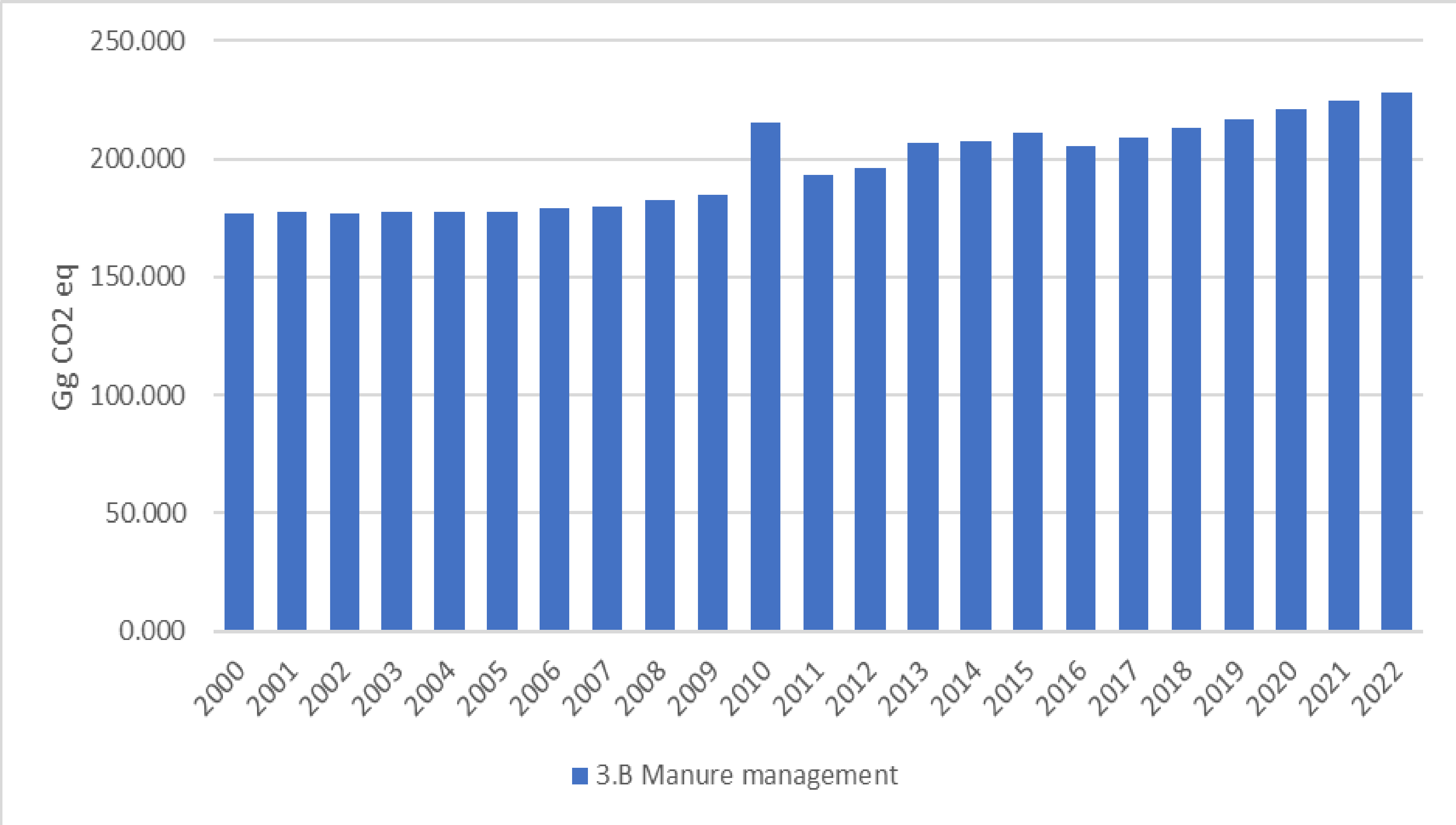

Figure 5-3:GHG emissions from Manure Management from 2000 to 2022

5.3.2. Methodological issues

5.3.2.1. **Choice of method (include assumptions and the rationale for selection)**

(1) CH_4 emissions from manure management

The amount of CH_4 produced by manure management is a function of i) the number of animals, ii) the amount of manure produced; and iii) the temperature, while at higher tiers information on the type of Manure Management System and retention time are also needed.

PNG used the Tier 1 method to estimate CH_4 emissions from manure management. The choice of method was dependent on data availability. This simplified method requires livestock population data by animal species and climate region or temperature, in combination with IPCC default emission factors to estimate emissions. Because some emissions from manure management systems are highly temperature dependent, it is good practice to estimate the average annual temperature associated with the locations where manure is managed. The emissions were estimated using the equation below.

Equation 10.22: CH_4 emissions from Manure Management

$$\boldsymbol{CH_{4Manure}} = \sum_{T} \frac{(\boldsymbol{EF_T} \times \boldsymbol{N_T})}{\boldsymbol{10^6}}$$

Where:

$CH_{4Manure}$	: *CH_4 emissions from manure management, for a defined population, Gg CH_4 yr $^{-1}$.*
EF_T	: *Emission factor for the defined livestock population, kg CH_4 head $^{-1}$ yr $^{-1}$.*
N_T	: *The number of head of livestock species/category T in the country.*
T	: *Species/category of livestock.*

(1) N_2O emissions from manure management

N_2O emissions from manure management are a function of i) the nitrogen content of manure, ii) the duration of storage, and iii) type of manure treatment.

For the estimation of N_2O emissions from manure management PNG used the Tier 1 method which entails multiplying the total amount of N excretion (from all livestock species/categories) in each type of manure management system by an emission factor for that type of manure management system. For the estimation of direct N_2O Emissions from manure management Equation 10.25 in Chapter 10 Volume 4 was used. The equation was used to estimate direct N2O emissions from each manure management system assumed to be practiced in PNG. This includes uncovered anaerobic lagoon, liquid slurry, dry lot, solid storage and aerobic treatment.

Equation 10.25: Direct N_2O emissions from manure management

$$N_2O_{D\,(mm)} = \left[\sum_S \left[\sum_T \left(N_T \times Nex_{(T)} \times MS_{(T,S)}\right)\right] \times EF_{3\,(S)}\right] \times \frac{44}{28}$$

Where:

$N_2O_{D\,(mm)}$	:	*Direct N_2O emissions from Manure Management in the country, kg N_2O yr^{-1}*
N_T	:	*number of head of livestock species/category T in the country*
$Nex_{(T)}$	:	*annual average N excretion per head of species/category T in the country, kg N $anima^{l-1}$ yr^{-1}*
$MS_{(T,S)}$	:	*fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless.*
$EF_{3\,(S)}$	:	*emission factor for direct N_2O emissions from manure management system S in the country, kg N_2O-N/kg N in manure management system S*
S	:	*manure management system*
T	:	*species/category of livestock*

(2) Indirect N_2O emissions (CRT Category 3.B.5)

Tier 1 method was used to estimate indirect N_2O from manure management. Equation 10.26 and 10.27 in chapter 10 volume 4 of the 2006 IPCC guidelines was used to estimate indirect N_2O emissions from manure management.

Equation 10.26: N losses due to volatilization from manure management

$$N_{volatilisation-MMS} = \sum_{S}\left[\sum_{T}\left[\left(N_{(T)} \bullet Nex_{(T)} \bullet MS_{(T,S)}\right) \bullet \left(\frac{Frac_{GasMS}}{100}\right)_{(T,S)}\right]\right]$$

Where:

$N_{volatilization-MMS}$ = *amount of manure nitrogen that is lost due to volatilization of* NH_3 *and* NO_X*, kg N* yr^{-1}

$N_{(T)}$ = *number of head of livestock species/category T in the country*

$Nex_{(T)}$ = *annual average N excretion per head of species/category T in the country, kg N* $animal^{-1} yr^{-1}$

$MS_{(T, S)}$ = *fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless*

$Frac_{GasMS}$ = *percent of managed manure nitrogen for livestock category T that volatilizes as* NH_3 *and* NO_X *in the manure management system S, %*

Equation 10.27: Indirect N_2O *emissions due to volatilization of N from manure management*

$$N_2O_{G(mm)} = (N_{volatilisation-MMS} \bullet EF_4) \bullet \frac{44}{28}$$

Where:

$N_2O_{G(mm)}$ = *indirect* N_2O *emissions due to volatilization of N from Manure Management in the country, kg* N_2O yr^{-1}

EF_4 = *emission factor for* N_2O *emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg* N_2O*-N (kg* NH_3*-N +* NO_X *– N volatilized)*$^{-1}$

5.3.2.2. **EF, other parameters**

The emission factors used for the estimation of CH4 from manure management were a weighted average of default emission factors by average annual temperature presented in table 10.14 and table 10.15 in chapter 10, volume 4 of the 2006 IPCC guidelines. This is because the highlands region of PNG is considered to have an average annual temperature of 17^{o}C while the coastal region has an average annual temperature of 27^{o}C. Therefore, the weighted average of CH4 emission factor for each livestock species under these two temperatures was used. The weighted average was estimated by using livestock population data for the highlands region and the livestock population data for the coastal region. The estimation of the weighted average for each livestock species was done by using the equation below.

$$\frac{(N_{THR} \times EF^{17^oC}) + (N_{TCR} \times EF^{27^oC})}{N_T}$$

Where

N_{THR} *= The number of head of livestock species/category T for the Highlands region*

N_{TCR} *= The number of head of livestock species/category T for the Coastal region*

N_T *= The number of head of livestock species/category T in the country*

EF^{17^oC} *= Emission factor at 17°C for the Oceania region in table 10.14 and developing countries in table 10.15*

EF^{27^oC} *= Emission factor at 27°C for the Oceania region in table 10.14 and developing countries in table 10.15*

The table below provides a list of emission factors for each livestock species that were used.

Table 5-6: Manure management methane emission factors used for the estimation

CRT Category		Emission factor (kg CH_4 head/year)	Source
3. A.1.a	Dairy Cattle	31	Weighted average of EF for Oceania region, table 10.14 volume 4 chapter 10
3. A.1.b	Non-dairy Cattle	2	Weighted average of EF for Oceania region, table 10.14 volume 4 chapter 10
3. A.2	Sheep	0.2	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10
3. A.3	Swine	14.1	Weighted average of EF for Oceania region, table 10.14 volume 4 chapter 10
3.A. 4. d	Goats	0.2	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10
3.A. 4. e	Horses	2.56	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10
3.A. 4. g	Poultry	0.02	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10

The default emission factors used were from table 10.21 based on the assumption on the type of manure management system practiced in PNG. The table below provides a list of these default emission factors.

Table 5-7: N_2O-N emission factors

Manure management system	Default EF (kg N_2O-N)	Source
Uncovered anaerobic lagoon	0	Table 10.21 volume 4 chapter 10
Liquid/Slurry (without natural crust cover)	0	Table 10.21 volume 4 chapter 10 (without natural crust cover)
Dry lot	0.02	Table 10.21 volume 4 chapter 10
Solid storage (with natural crust)	0.005	Table 10.21 volume 4 chapter 10
Daily spread	0	Table 10.21 volume 4 chapter 10
Aerobic treatment (Natural aeration systems)	0.01	Table 10.21 volume 4 chapter 10

- Other parameters

(i) Annual N excretion rates

Table 5-8: Annual N excretion rates

Annual N excretion rate (kg N animal $^{-1}$ yr $^{-1}$)						
Dairy Cows	Other cattle	Sheep	Goats	Horse	Swine	Poultry
80.3	60.225	11.5486	15.594	26.061	11.1033	0.26937

Equation 10.3 from chapter 10, volume 4 of the 2006 IPCC guidelines was used to estimate annual N excretion rate

$$Nex_{(T)} = N_{rate\ (T)} \times \frac{TAM}{100} \times 365$$

Where:

$Nex_{(T)}$ = Annual N excretion for livestock category T,kg N animal $^{-1}$ yr^{-1}

$N_{rate\ (T)}$ = Default N exretion rate, K N (1000 kg animal mass)$^{-1}$ day^{-1}

TAM = Typical animal mass for livestock category T,kg, animal-^{1}

The N rate(T) default values used were from table 10.19 of chapter 10, volume 4 of the 2006 IPCC guidelines for the Oceania region. While TAM for each livestock species for the Oceania region and developing countries from tables 10A-4, 10A-5, 10A-7 and 10A-9 chapter 10, volume 4 were used. Although for poultry and swine the TAM in the 2006 IPCC guidelines were on a disaggregated level and the available activity data was at a aggregated level, the weighted average of the TAM were estimated and used. The table below provides a list of the TAMs that were used.

Table 5-9: Typical animal mass used for each livestock

Livestock species	Typical Animal Mass (kg)	Source
Diary	500	Table 10A-4 (Oceania region) volume 4, chapter 10 , 2006 IPCC GL
Non-Diary	330	Table 10A-4 (Oceania region) volume 4, chapter 10 , 2006 IPCC GL
Sheep	28	Table 10A-9 (Developing countries) volume 4, chapter 10 , 2006 IPCC GL
Goat	30	Table 10A-9 (Developing countries) volume 4, chapter 10 , 2006 IPCC GL
Swine	58.5	Weighted average of market swine table 10A-7 (Oceania region) and breeding swine table 10A-8 (Oceania region) volume 4, chapter 10 , 2006 IPCC GL
Poultry	0.9	Table 10A-9 (Developing countries). No TAM value provided for paultry for developing countries thus default value for broilers was used
Horse	238	Table 10A-9 (Developing countries) volume 4, chapter 10 , 2006 IPCC GL

(ii) Fraction of total annual nitrogen excretion for each livestock species that is managed in manure management systems ($MS_{(T,S)}$)

The $MS_{(T,S)}$ used were taken from table 10A-4, 10A-7 and 10A-8 for Oceania region which only contained values for cattle and swine. The table below provides a list of $MS_{(T,S)}$ that were used.

Table 5-10: Default values for $MS_{(T,S)}$

CRT Category		Manure Management System (%)									
		Lagoon	Liquid/Slurry	Solid Storage	Dry lot	Pasture/ Range/Paddock	Daily Spread	Other	Pit<1month	Pit>1month	Source
3. A.1.a	Dairy Cattle	16	1	0	0	76	8	0	NA	NA	Table 10A-4 (Oceania region) volume 4, chapter 10, 2006 IPCC GL
3. A.1.b	Non-dairy Cattle	0	0	0	9	91	0	0	NA	NA	Table 10A-4 (Oceania region) volume 4, chapter 10, 2006 IPCC GL
3. A.3	Swine	54	0	3	15	NA	0	28	0	0	Weighted average of market swine, Table 10A-7 (Oceania region) and breeding swine table 10A-8 (Oceania regiona) volume 4, chapter 10 2006 IPCC GL)

(1) Indirect N_2O emissions (CRT Category 3.B.5)

The default emission factor EF4 (0.01 kg N_2O-N (kg N-1)) was taken from table 11.3 chapter 11, volume 4 of the 2006 IPCC guideline to be used for this sub category. While FracGasMS values were taken from table 10.22 chapter 11, volume 4 of the 2006 IPCC guideline.

5.3.2.3. **AD (include uncertainties and time-series consistency)**

Animal population data are the same as those used for the enteric fermentation emission estimates.

5.3.3. Category-specific recalculations, if applicable

No recalculations were done for this cycle

5.3.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

Planned improvements for this sub category involve a proper survey to identify the types of manure management systems practiced in PNG.

5.4. Rice Cultivation (CRT Category 3.C)

5.4.1.1. **Category description (e.g. characteristics of sources)**

Emissions from rice cultivation were not included in this cycle. This is because experts stated that, in general, rice fields in the country are not flooded or are cultivated in uplands.

5.5. Agricultural soils (CRT Category 3.D

5.5.1. Category description (e.g. characteristics of sources)

Direct and indirect emissions from nitrous oxide from soils arises from microbial and chemical transformations that produce and consume nitrous oxide in the soil. The transformations involve inorganic nitrogen compounds in the soil, namely ammonium nitrate and nitrate.

Nitrogen compounds can be added to the soil through the following processes:

- The application of inorganic nitrogen fertilizers;
- The application of animal waste and sewage sludge to pastures;
- The application of crop residues;
- Mineralisation due to loss of soil carbon
- Mineralisation due to the cultivation of organic soils
- Atmospheric nitrogen deposition

A further source of nitrous oxide is associated with the leaching of N from soils and surface runoff, and subsequent denitrification in rivers and estuaries.

The total N_2O emissions from agricultural soils in the year 2022 were 285.84 Gg CO_2 eq, which is an increase of 179.15 Gg CO_2 eq (168 %) when compared to the emissions in the year 2000. Table 5-11 and Figure 5-4 outlines the Direct and Indirect N_2O emissions from managed soils for the years 2000 to 2022.

Table 5-11: GHG emissions from managed soils (in Gg CO_2 eq)

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
3. D.1	Direct N_2O emissions from managed soils	Gg CO_2 eq	79.784	86.957	116.726	158.641	200.341	129.680	209.526	234.118	225.288	213.750	206.839	201.688	223.953
3. D.2	Indirect Direct N_2O emissions from managed soils		26.902	26.489	35.208	45.133	54.914	39.607	57.503	63.248	61.474	59.084	57.727	56.734	61.885
Total			106.685	113.446	151.934	203.774	255.255	169.288	267.029	297.367	286.761	272.835	264.565	258.421	285.839

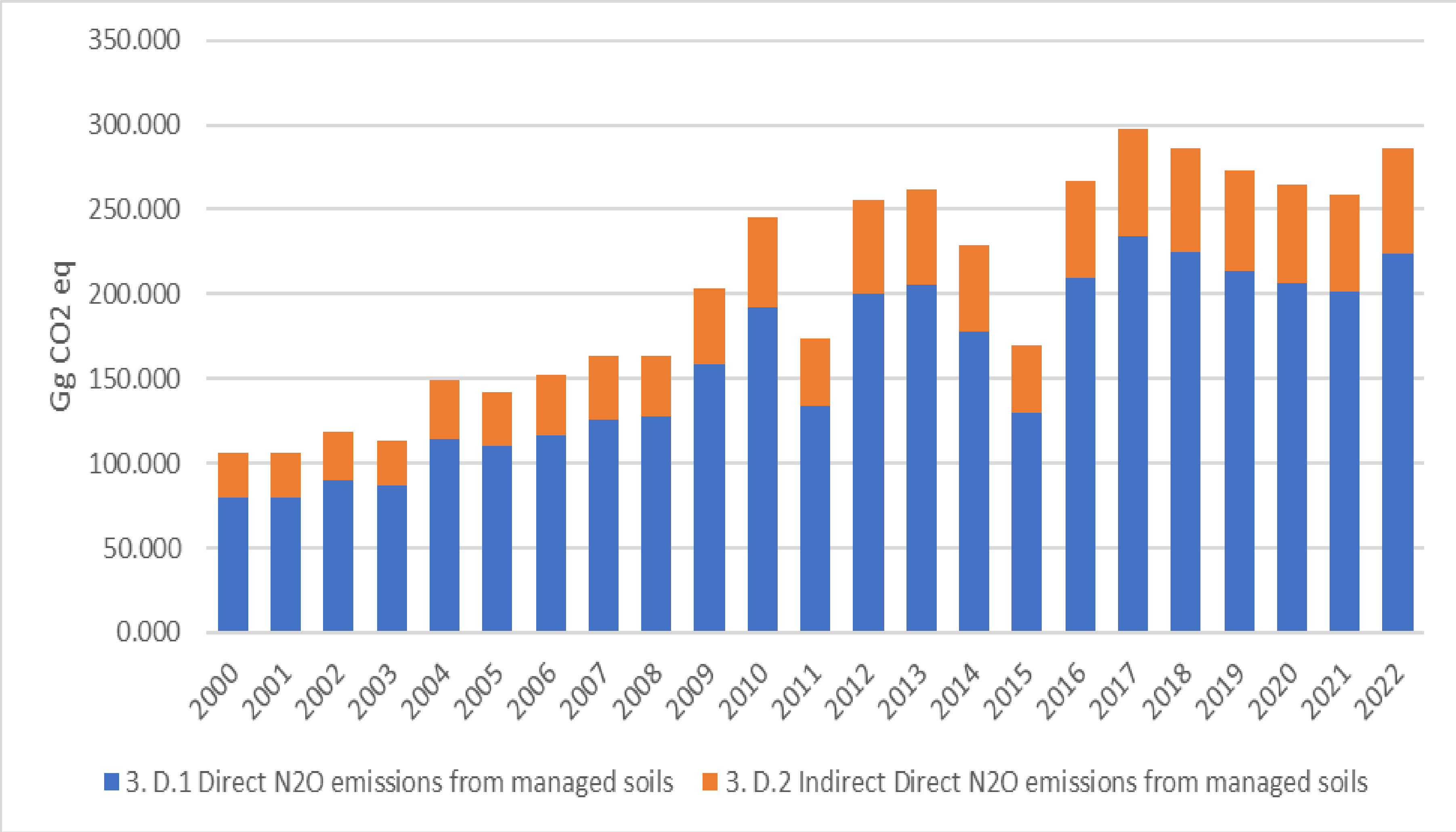

Figure 5-4:GHG emissions from managed soils (in Gg CO_2 eq)

5.5.2. Direct N_2O emissions from managed soils (CRT Category 3.D.1)

5.5.2.1. Category description (e.g. characteristics of sources)

Direct N2O emissions from managed soils result from nitrogen sources that have been added to the soils. The nitrogen sources included in the estimation of direct N_2O emissions from managed soils are:

- Inorganic N fertilisers (CRT 3.D.1.a);
- Organic N applied as fertiliser (CRT 3.D.1.b);
- Urine and dung deposited by grazing animals (CRT 3.D.1.c);
- N in crop residues (CRT 3.D.1.d);
- Mineralisation/immobilization associated with loss/gain of soil organic matter (CRT 3.D.1.e); and
- Cultivation of organic soils (CRT 3.D.1.f).

For this GHG reporting cycle, N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils (CRT 3.D.1.e) was not included due to the unavailability of data. Furthermore, direct N2O emission produced from flooded rice wasn’t estimated because flooded rice fields are not present in PNG.

The total direct N_2O emissions from managed soils in the year 2022 were 223.95 Gg CO_2 eq, which is an increase of 144.17 Gg CO_2 eq (181 %) when compared to the emissions in the year 2000. Table 5-12 outlines the Direct N_2O emissions from managed soils for the years 2000 to 2022.

Table 5-12: Direct N_2O emissions from managed soils (Gg CO_2 eq)

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
3. D.1.a	Inorganic N	Gg N_2O	0.075	0.108	0.192	0.299	0.253	0.033	0.330	0.414	0.499	0.452	0.422	0.399	0.480
3. D.1.b	Organic N fertilizers		0.169	0.131	0.169	0.178	0.186	0.197	0.195	0.199	0.203	0.207	0.211	0.214	0.217
3. D.c	Urine and dung deposited by grazing animals		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3. D.d	Crop residues		0.057	0.090	0.080	0.122	0.317	0.260	0.265	0.270	0.148	0.147	0.148	0.148	0.148
3.D. 4. e	Mineralization/immobilization associated with loss/gain of soil organic matter		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.D. 4. f	Cultivation of organic soils (i.e. histosols)		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.D. 4. g	Other		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total		Gg N_2O	0.301	0.328	0.440	0.599	0.756	0.489	0.791	0.883	0.850	0.807	0.781	0.761	0.845
		Gg CO_2 eq	79.784	86.957	116.726	158.641	200.341	129.680	209.526	234.118	225.288	213.750	206.839	201.688	223.953

5.5.2.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

Direct N_2O emissions from soils were calculated at the Tier 1 method using equation 11.1 in chapter 11, volume 4 of the 2006 IPCC guidelines.

Equation 11.1: Direct N_2O emissions from managed soils

$$N_2\,O_{Direct} - N = N_2\,O_{N\ inputs} + N_2\,O - N_{OS} + N_2\,O - N_{PRP}$$

Where:

$$N_2O - N_{N\ inputs} = \begin{bmatrix} [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_1] + \\ [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \bullet EF_{1FR}] \end{bmatrix}$$

$$N_2O - N_{OS} = \begin{bmatrix} (F_{OS,CG,Temp} \bullet EF_{2CG,Temp}) + (F_{OS,CG,Trop} \bullet EF_{2CG,Trop}) + \\ (F_{OS,F,Temp,NR} \bullet EF_{2F,Temp,NR}) + (F_{OS,F,Temp,NP} \bullet EF_{2F,Temp,NP}) + \\ (F_{OS,F,Trop} \bullet EF_{2F,Trop}) \end{bmatrix}$$

$$N_2O - N_{PRP} = [(F_{PRP,CPP} \bullet EF_{3PRP,CPP}) + (F_{PRP,SO} \bullet EF_{3PRP,SO})]$$

Where:

N_2O_{Direct}-N = *annual direct N_2O-N emissions produced from managed soils, kg N_2O-N yr^{-1}*

N_2O-N_{Ninput} = *annual direct N_2O-N emissions from N inputs to managed soils, kg N_2O-N yr^{-1}*

N_2O-N_{PRP} = *annual direct N_2O-N emissions from urine and dung inputs to graze soil, kg N_2O-N yr^{-1}*

F_{SN} = *annual amount of Inorganic N fertilisers applied to soils, kg N yr^{-1}*

F_{ON} = *annual amount Organic N applied as fertiliser additions applied to soils, kg N yr^{-1}*

F_{CR} = *annual amount N in crop residues, kg N yr^{-1}*

F_{SOM} = *annual amount of N mineralisation/immobilization associated with loss/gain of soil organic matter, kg N yr^{-1}*

F_{OS} = *annual area of cultivation of organic soils, ha*

F_{PRP} = *annual amount of urine and dung N deposited on pasture, range and paddock by grazing animals, kg N yr^{-1}*

EF_1 = *emission factor for N_2O emissions from N inputs kg N_2O-N*

EF_{1FR} = *is the emission factor for N_2O emissions from N inputs to flood rice kg N_2O-N*

EF_2 =*emission factor for N_2O emissions from drained/managed organic soils kg N_2O-N $ha^{-1}yr$*

EF_{3PRP} = *emission factor for N_2O emissions from urine and dung deposited on pasture, range and paddock by grazing animals' kg N_2O-N*

b. EF, other parameters

The default emission factors used were taken from table 11.1, chapter 11 volume 4 of the 2006 IPCC guidelines.

Table 5-13: Default emission factors used to estimate Direct N_2O emissions from soils

Emission factor	Default value [kg N_2O)-N (kg N^{-1})]
EF_1	0.01
EF_2	16
EF_{1FR}	0.003
$EF_{3PRP,CPP}$	0.02
$EF3_{PRP,SO}$	0.01

c. AD (include uncertainties and time-series consistency)

(i) Inorganic N fertilisers (CRT Category 3.D.1.a)

The activity data used was from FAOSTAT on total amount of annual synthetic fertilizers applied since there are no country specific data available.

(ii) Organic N applied as fertiliser (CRT Category 3.D.1.b)

The activity data used was annual livestock manure treated in each manure management system that was estimated in direct N_2O from manure management and that no other organic fertilizers were used.

(iii) Urine and dung N deposited on pasture, range and paddock by grazing animals (CRT Category 3.D.1.c)

A similar method used for estimating amount of annual N excreted from each livestock species and treated in each manure management system was also applied here. The only different parameter used was species/category T that is managed in manure management system S in the country ($MS_{(T, S)}$) which was for pasture/range/ paddock ($MS_{(PRP)}$) and was taken from table 10A-4 for the Oceania region in chapter 10 volume 4 of the 2006 IPCC guidelines. The same livestock data used in livestock category (3.A) was also used here.

(iv) N in crop residues (CRT Category 3.D.1.d)

Equation 11.6 in chapter 11, volume 4 of the 2006 IPCC guidelines was used to estimate annual amount of N in crop residues. The crops include rice, maze, cassava, potato, sweet potato, taro, yam and sugar cane. Fresh yield and harvested area data for these crops were taken from FAOSTAT because there are no country specific data.

(v) N mineralization/immobilization associated with loss/gain of soil organic matter (CRT Category 3.D.1.e)

N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils (CRT Category 3.D.1.e) was not included due to unavailability of data.

(vi) Cultivation of organic soils (CRT Category 3.D.1.f)

The collected earth data was used

5.5.2.3. **Category-specific recalculations, if applicable**

No recalculations were done for this cycle

5.5.2.4. **Category-specific planned improvements, if applicable (e.g., methodologies, AD, EF, etc.)**

Planned improvements for this sub-category include identifying potential data sources for other sources of Organic N applied as fertiliser (CRT 3.D.1.b) and N mineralisation/immobilization associated with loss/gain of soil organic matter (CRT 3.D.1.a). Further improvements involve identifying and using country-specific data for synthetic N fertilizers and crop residues.

5.5.3. Indirect N_2O emissions from managed soils (CRT Category 3.D.2)

5.5.3.1. **Category description (e.g., characteristics of sources)**

In addition to direct emissions of N2O from managed soils that occur through a direct pathway, emissions of N2O also take place through two indirect pathways. The first pathway is the volatilization of N as NH3 and oxides of N (NOX), and the deposition of these gases and their products NH4+ + and NO3 onto soils and the surface of lakes and other waters. The second pathway is the leaching and runoff from land of N from synthetic and organic fertilizers additions, crop residues, mineralization of N associated with loss of soil C in mineral and drained/managed organic soils through land-use change or management practices, and urine and dung deposition from grazing animals.

The total indirect N_2O emissions from managed soils in 2022 are 61.88 Gg CO_2 eq, an increase of 34.98 Gg CO_2 eq (130 %) when compared with the year 2000.

Table 5-14: GHG emissions from Indirect N_2O emissions from managed soils (Gg CO_2eq)

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
3. D.2	Indirect N_2O Emissions from managed soils	Gg N_2O	0.102	0.100	0.133	0.170	0.207	0.149	0.217	0.239	0.232	0.223	0.218	0.214	0.234
		Gg CO_2 e(	26.902	26.489	35.208	45.133	54.914	39.607	57.503	63.248	61.474	59.084	57.727	56.734	61.885

5.5.3.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

The Tier 1 method was used to estimate indirect N_2O from managed soils. Equation 11.9 in chapter 11, volume 4 of the 2006 IPCC guidelines was used to estimate N_2O emissions from atmospheric deposition of N volatilized from managed soils. Equation 11.10 in chapter 11, volume 4 of the 2006 IPCC guidelines was used to estimate N2O from leaching/runoff from managed soils.

Equation 11.9 N_2O from atmospheric deposition of N volatilised from managed soils

$$N_2O_{(ATD)} - N = \left[(F_{SN} \bullet Frac_{GASF}) + \left((F_{ON} \bullet F_{PRP}) \bullet Frac_{GASM}\right)\right] \bullet EF_4$$

Where:

$N_2O_{(ATD)}$-N	= annual amount of N_2O-N produced from atmospheric deposition of N volatilised from managed soils, kg N_2O-N yr^{-1}
F_{SN}	= annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}
$Frac_{GASF}$	= fraction of synthetic fertiliser N that volatilises as NH_3 and NO_X, kg N volatilised (kg of N applied)$^{-1}$(Table 11.3)
F_{ON}	= annual amount of managed animal manure, compost, sewage, sludge and other organic N additions applied to soils, kg N yr^{-1}
F_{PRP}	=annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1}
$Frac_{GASM}$	= fraction of applied organic fertiliser N materials (F_{ON}) and urine and dung N deposited by grazing animals (F_{PRP}) that volatilises as NH_3 and NO_x, kg N volatilised (kg of N applied)$^{-1}$(Table 11.3)
EF_4	= emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces [kg N-N_2O (kg NH_3-N+NO_X-N volatilised)$^{-1}$] (Table 11.3)

Equation 11.10: N_2O from leaching and run/off from managed soils

$$N_2O_{(L)} - N = [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM})] \bullet Frac_{LEACH-(H)} \bullet EF_5$$

Where:

$N_2O_{(ATD)}$-N	*= annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils, kg N_2O-N yr^{-1}*
F_{SN}	*= annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}*
F_{ON}	*= annual amount of managed animal manure, compost, sewage, sludge and other organic N additions applied to soils, kg N yr^{-1}*
F_{PRP}	*=annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1}*
F_{CR}	*=amount of N in crop residues, kg N yr^{-1}*
F_{SOM}	*=annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter, kg N yr^{-1}*
$Frac_{LEACH-(H)}$	*= fraction of all N added to/mineralized in managed soils (kg of N applied)$^{-1}$(Table 11.3)*
EF_5	*= emission factor for N_2O emissions from N leaching and runoff, kg N-N_2O (kg N leached and runoff] (Table 11.3)*

b. EF, other parameters

The default emission factors used were taken from table 11.3 in chapter 11 volume 4 of the 2006 IPCC guidelines.

Table 5-15: Default emission factors and other parameters

Emission factor	Default value [kg N_2O-N (kg N^{-1})]
EF_4	0.01
EF_5	0.0075
$Frac_{GASF}$	0.01
$Frac_{GASM}$	0.2
$Frac_{LEACH}$	0.3

c. AD (include uncertainties and time-series consistency)

Activity data is the same as that used in direct N2O emission on managed soil (CRT 3.D.1).

5.5.3.3. **Category-specific recalculations, if applicable**

There was no recalculation for this sub-category

5.5.3.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

Similar improvements for the direct N_2O emission from managed soils (CRT 3.D.1) will also apply to this sub-category.

5.6. Prescribe Burning of Savannas (CRT Category 3.E)

5.6.1. Category description (e.g. characteristics of sources)

This category's greenhouse gas emissions are recorded under the LULUCF sector.

5.7. Field Burning of Agricultural Residues (CRT Category 3.F)

5.7.1. Category description (e.g. characteristics of sources)

GHG emissions from this category were not reported due to unavailability of activity data. PNG is planning to set up data collection activities that lead to improve the detail of the activity data.

5.8. Liming (CRT Category 3.G)

5.8.1. Category description (e.g. characteristics of sources)

GHG emissions from this category were not reported due to unavailability of activity data. PNG is planning to set up data collection activities that lead to improve the detail of the activity data.

5.9. Urea Application (CRT Category 3.H)

5.9.1. Category description (e.g. characteristics of sources)

GHG emissions from this category were not reported due to unavailability of activity data. PNG is planning to set up data collection activities that lead to improve the detail of the activity data.

Chapter 6. Land-Use, Land-use Change and Forestry

6.1. Overview of sector

The land use, land use change and forestry (LULUCF) sector cover greenhouse gas emissions associated with land management practices that impact the carbon stored in vegetation and soils. Emissions are reported from 6 land-use categories as per the 2006 IPCC guidelines. This includes:

i. Forest land;
ii. Cropland;
iii. Grassland;
iv. Wetlands;
v. Settlements; and
vi. Other lands

In addition to the above land-use categories Prescribed burning of savannahs on Forest Land (CRT Category 3.E.1) is also reported under the LULUCF sector. Each land-use category is further subdivided into land remaining in that category (e.g. forest land remaining forest land) and land converted from one category to another (e.g. forest land converted to cropland). The net emissions from the LULUCF sector amounted to -14,269.79 Gg CO_2 eq in 2022 compared to -32,564.71 Gg CO_2 eq in 2000. The net emissions from the LULUCF sector has flactuated over the timeseries which was mainly influenced by the Forest land (CRT Category 4.A) and Cropland (CRT Category 4.B). In 2022, Forest Land (CRT Category 4.A) contributed -24,678.97 Gg CO_2 eq which had a huge impact on the net emissions from the sector. Cropland (CRT Category 4.B) contributed 9,715.13 Gg CO_2 eq followed by, Other Non-CO_2 gases - Forest Burning (CRT Category 4.H) with 326.76 Gg CO2 eq, then Grassland (CRT Category 4.C) with 323.36 Gg CO_2 eq and Settlements (CRT Category 4.E) with 43.93 Gg CO_2 eq. LULUCF emissions by sub-sector for 2000-2022 are shown in Table 6-1 and below Figure 6-1.

Table 6-1: LULUCF GHG emissions and removals summary

CRT Category		Units	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
4.A.	Forest land	Gg-CO_2	-39,234.83	-29,582.24	-26,678.09	-20,354.86	-22,493.43	-20,038.16	-25,064.60	-31,515.01	-28,965.49	-31,745.90	-26,714.13	-28,104.47	-24,678.97
4.B.	Cropland	Gg-CO_2	5,886.90	4,599.46	3,070.04	6,328.90	11,942.86	14,157.09	12,215.60	9,397.81	9,989.00	7,752.36	6,760.81	11,846.23	9,715.13
4.C.	Grassland	Gg-CO_2	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
4.D.	Wetlands	Gg-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
4.E.	Settlements	Gg-CO_2	0.00	0.00	0.00	34.59	56.12	34.59	510.19	1,058.52	1,097.37	33.65	0.00	0.00	43.93
4.F.	Other land	Gg-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.G.	Harvested wood products	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.H.	Other (Non-CO_2 gases - Forest Burning)	Gg-CO_2 eq	459.87	1,209.78	1,519.80	597.21	334.82	654.80	654.80	305.62	426.24	177.42	79.82	124.34	326.76
	LULUCF sector total	Gg-CO_2 eq	-32,564.71	-23,449.65	-21,764.90	-13,070.80	-9,836.27	-4,868.32	-11,360.66	-20,429.70	-17,129.53	-23,459.11	-19,550.14	-15,810.55	-14,269.79

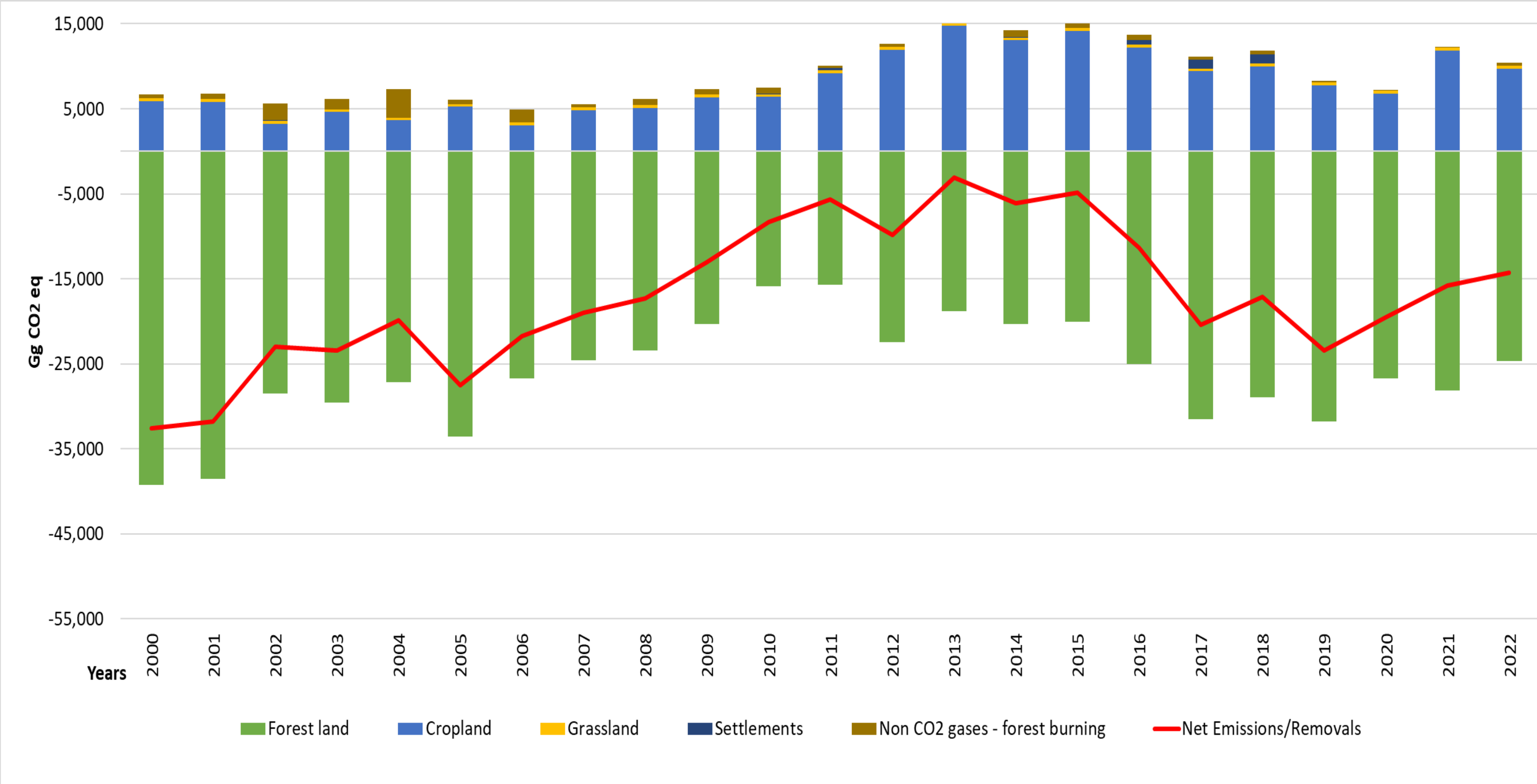

Figure 6-1:LULUCF GHG emissions and removals summary

6.2. Land-use definitions and the classification systems used and their correspondence to the LULUCF categories (e.g. land use and land-use change matrix)

According to the Forest and Land Use Change in Papua New Guinea 2000 to 2019, the PNG Forest Authority (2022) uses the six IPCC land use categories – forest land; cropland; grassland; wetland, and other land – as the main or Level 1 land class. Country-specific level 2 and 3 classes are subtypes and subdivisions. All PNG land is classified into 46 land use subdivision categories as outlined in the table below.

Table 6-2: Forest and land use classification system

IPCC land use category	PNG subtype	PNG subdivision
Forest land	Natural forest	Low altitude forest on plains and fans, low altitude forest on uplands, lower montane forest, montane forest, dry seasonal forest, littoral forest, seral forest, swamp forest, savanna, woodland, scrub, mangrove
	Plantation forest	Eucalyptus, Araucaria, Pinus, Acacia, Terminalia, Teak, other forest plantation (Rain trees)
Cropland	Subsistence agriculture	Shifting, permanent, not sure
	Commercial agriculture	Tea, sugar, coffee, oil palm, cocoa, coconut, cocoa/coconut, rubber, other
Grassland		Herb land, rangeland, and other
Wetland		River, lake, dam, Nipa swamp, other swamp
Settlement		Village, hamlet, large settlement, infrastructure
Other land		Bare soil, sand, rock

Forest land

According to the Forest and Land Use Change in Papua New Guinea 2000 to 2019 , the PNGFA (2022) classified forest land into subdivisions, based on natural vegetation types and manmade plantations. Vegetation types are based on the structural formation and described in the PNG Resource Information System. There are 12 vegetation types in PNG forests. Together with forest plantations, there are thirteen (13). The table below outlines the 13 forest types including their short description and ecological zone as per IPCC guidelines.

Table 6-3: Thirteen forest types combined into IPCC ecological zones

	Forest type	Short description	Ecological zone as per IPCC Guidelines [IPCCC, 2006 (Vol. 4, Chpt. 4, Table 4.9)]
1	Low-altitude forest on plains and fans	Elevations below 1,000 metres with gentle slopes	Tropical rainforest
2	Low altitude forest on uplands	Elevations below 1,000 metres with rough terrain	

	Forest type	Short description	**Ecological zone as per IPCC Guidelines [**IPCCC, 2006 (Vol. 4, Chpt. 4, Table 4.9)]
3	Littoral forest	Dry or inundated beach forest	
4	Seral forest	River line, upper stream, river plains and volcano blast area	
5	Swamp forest	Forest area inundated with freshwater either permanently or seasonally	
6	Lower montane forest	Between elevation of from 1,000–3,000 metres	Tropical
7	Montane forest	Elevations above 3,000 metres	Tropical mountain system
8	Dry seasonal forest	Restricted to southwest PNG in a low-rainfall area (1,800–2,500 mm)	Tropical dry forest
9	Woodland	Low and open tree layer	
10	Savanna	Low (< 6-meter) and open tree layer in low rainfall area with a marked dry season	
11	Scrub	Community of dense shrubs up to 6 metres	Tropical shrubland
12	Mangrove	Along the coastline and in the deltas of large rivers	Tropical wet Mangrove
13	Forest plantation	Planted forests are composed of trees established through planting or seeding by human intervention.	Tropical rainforest (plantation)

Cropland

According to the Forest and Land Use Change in Papua New Guinea 2000 to 2019, the PNGFA (2022) further divided cropland into two types: subsistence and commercial agriculture. Subsistence agriculture is a farming method where a family or a household produces enough food for their own consumption, selling any surplus in areas where the market is accessible. PNGFA further divided subsistence agriculture into shifting and permanent. Shifting subsistence agriculture is a temporary, rotational cultivation of land where the cultivated land is abandoned for a few years then recultivated once the land naturally restores its fertility. Permanent subsistence agriculture is long-term gardening without moving to a new piece of land.

Commercial agriculture includes large-scale agricultural activities such as oil palm, coconut, coffee, cocoa, tea, rubber and sugar plantations. The activities are defined by boundaries under a management regime or smallholders (villages) on communal land.

Settlement

According to the Forest and Land Use Change in Papua New Guinea 2000 to 2019, the PNGFA (2022) further divided the settlement category to align with PNG's context into:

- Hamlet: A cluster of (usually three to five) permanent or semi-permanent houses scattered broadly over the landscape or area of interest (a family or one clan), with the inhabitants usually belonging to a nearby community or village. They are difficult to detect in low- to medium-resolution satellite images.
- Village: A permanent human settlement comprising a community with more than one clan or tribe in a rural area. The houses are more densely distributed than the hamlets, and marked subsistence agriculture is usually evident in the surroundings.
- Large settlements: Well-organized cities, towns, and district centers, including mining townships located away/far from the mining sites.
- Infrastructure: Permanent structures including roads (paved or unpaved), bridges, airstrips/airports, clinics, schools, and playing fields, located outside of a village or large settlement or in remote areas.

Grassland

According to the Forest and Land Use Change in Papua New Guinea 2000 to 2019, the PNGFA (2022) divided grassland into herb land, rangeland and others.

Wetlands

According to the Forest and Land Use Change in Papua New Guinea 2000 to 2019, the PNGFA (2022) divided wetlands into rivers, lake, damps, Nipa swamps and other swamps.

Other land

According to the Forest and Land Use Change in Papua New Guinea 2000 to 2019, land that is not forest, cropland, grassland, and settlements or wetlands is classified as other land. These include, bare soil, sand and rock

6.3. Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

6.3.1. Information on approaches used for representing land areas

PNG has been using approach 2 to represent areas of land use using the categories defined in the previous section. This approach involves an assessment of both the net losses or gains in the area of specific land-use categories and what these conversions represent (i.e., changes both from and to a category).

6.3.2. Land Use transition matrix

Land-use transition matrix to determine land use conversion has been produced annually from 2000 to 2022, for six land use categories. In addition, forest land was further disaggregated into primary and secondary to align with the context of PNG. The tables below show the land-use conversions in the year 2000 and 2022.

Table 6-4: Land-use matrix for the year 2000 (in kha)

After conversion / Before conversion	Forest land (Primary)	Forest land (Secondary)	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land (Primary)	29,816.90	87.62	3.93	0	0	0	0	29,908.45
Forest land (Secondary)	0	6,330.31	7.89	0	0	0	0	6,338.20
Cropland	0	0	4,899.58	0	0	0	0	4,899.58
Grassland	0	0	0	2,434.71	0	0	0	2,434.71
Wetlands	0	0	0	0	2,132.46	0	0	2,132.46
Settlements	0	0	0	0	0	370.12	0	370.12
Other land	0	0	0	0	0	0	55.35	55.35
Total – year 2000	29,816.90	6,417.93	4,911.40	2,434.71	2,132.46	370.12	55.35	46,138.86

Table 6-5: Land-use matrix for the year 2022 (in kha)

After conversion / Before conversion	Forest land (Primary)	Forest land (Secondary)	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land (Primary)	26,578.02	0.00	0.00	0.00	0.00	0.00	0.00	26,578.024
Forest land (Secondary)	142.08	9,109.05	0.00	0.00	0.00	0.00	0.00	9,251.13
Cropland	7.83	13.70	5,263.98	0.00	0.00	0.00	0.00	5,285.50
Grassland	0.00	0.00	0.00	2,432.25	0.00	0.00	0.00	2,432.25
Wetlands	0.00	0.00	0.00	0.00	2,126.50	0.00	0.00	2,126.50
Settlements	0.00	0.00	1.96	0.00	0.00	404.21	0.00	406.17
Other land	0.00	0.00	0.00	0.00	0.00	0.00	59.28	59.287
Total – year 2022	26,727.93	9,122.75	5,265.94	2,432.25	2,126.50	404.21	59.28	46,138.86

6.4. Forest land (CRT Category 4.A.)

This category reports emissions and removals due to changes in biomass, dead organic matter and soil organic carbon on land. It also captures the methods that were used to estimate emissions and removals from forest land. The forest land category consists of forest land remaining forest land (CRT Category 4.A.1) and land converted to forest land (CRT Category 4.A.2). However, estimation of emissions and removals for land converted to forestland (CRT Category 4.A.2) were not made, because no such land use change occurred from the assessment for the reporting years.

The total removals from the forest land category in 2022 were -24,678.97 Gg CO_2. The table below shows emissions and removals for the forestland category.

Table 6-6: Emissions and removals from forestland

Categories			Units	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
4.A	forest land		Gg-CO_2	-39,234.83	-29,582.24	-26,678.09	-20,354.86	-22,493.43	-20,038.16	-25,064.60	-31,515.01	-28,965.49	-31,745.90	-26,714.13	-28,104.47	-24,678.97
4.A.1	Forest land remaining fore		Gg-CO_2	-39,234.83	-29,582.24	-26,678.09	-20,354.86	-22,493.43	-20,038.16	-25,064.60	-31,515.01	-28,965.49	-31,745.90	-26,714.13	-28,104.47	-24,678.97
		Living biomas	Gg-CO_2	-39,596.49	-29,943.91	-27,039.75	-20,736.26	-22,884.70	-20,429.43	-25,455.87	-31,906.28	-29,356.76	-32,137.17	-27,105.40	-28,495.74	-25,070.25
		Dead organic	Gg-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Mineral soils	Gg-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Organic soils	Gg-CO_2	361.66	361.66	361.66	381.40	391.27	391.27	391.27	391.27	391.27	391.27	391.27	391.27	391.27
4.A.2	Land converted to forest la		Gg-CO_2	NE	NE	NE	NE	NE	NE	-00	-00	-00	-00	-00	-00	-00
		Living biomas	Gg-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Dead organic	Gg-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Mineral soils	Gg-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Organic soils	Gg-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

NA (Not Applicable)   NE (Not Estimated)

6.4.1. Forest land remaining forest land (CRT Category 4.A.1)

6.4.1.1. **Category description (e.g. characteristics of sources)**

This subcategory deals with carbon stock change in forest land remaining forest land, which has remained forested without conversion for the past 20 years as of 2022. In PNG's context, this also includes the carbon stock change from the conversion of primary forest to secondary forest or forest degradation. The net removal in this subcategory in 2022 was 25,070.25 Gg CO_2. The total removals decreased between 2000 to 2011 and then increased again between 2012 to 2022.

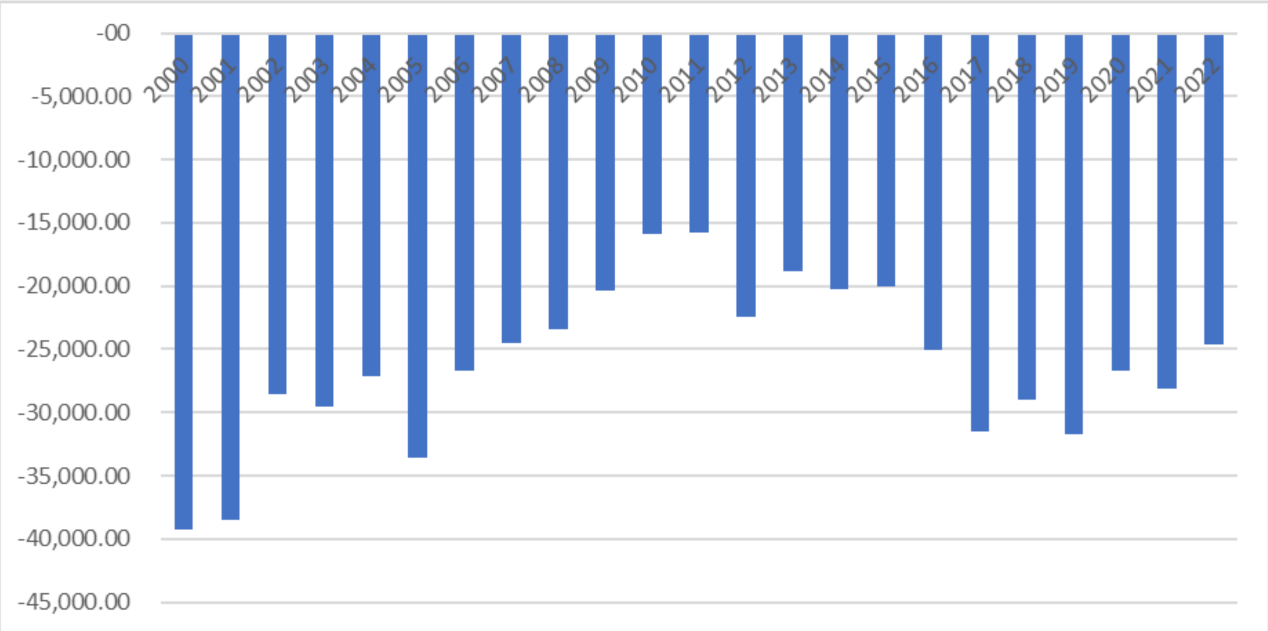

Figure 6-2: Total removals from the Forest land remaining forest land (CRT Category 4.A.1) from 2000 to 2012

6.4.1.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

The emissions and removals for Forest Land remaining Forest Land were estimated using a gain-loss method, supported by a modified stock-difference method where applicable, in accordance with the 2006 IPCC Guidelines.

The gain in carbon stocks is attributed to biomass growth in primary forests with a positive biomass growth rate and in secondary forests that were established before 2000 and are treated as managed forests. The loss in carbon stocks results from biomass decline in primary forests, primary forest with a negative biomass growth rate and from degradation when primary forest is converted to secondary forest due to activities such as commercial harvesting, fuelwood extraction, and other disturbances.

The annual change in carbon stocks was calculated using Equation 2.7 from Chapter 2, Volume 4 of the 2006 IPCC Guidelines (gain-loss method). In addition, a modified version of Equation 2.8 (stock-difference method) was applied to estimate carbon stock changes between two time periods for certain pools or transitions.

Removals have decreased over time because growth rates are applied only to the area of degraded forest identified in pre-2000 land assessments, while losses continue to accumulate from ongoing degradation and forest conversion. Emissions and removals from organic soils on forest land are also included in the estimates for this category (Klein et al., 2006).

Given below is Equation 2.7, used for estimating annual change in carbon stocks in biomass in land remaining in a particular land-use category (gain-loss method) (Klein et al., 2006).

Equation 2.7: Annual change in carbon stocks in biomass in land remaining in a particular land-use category (gain-loss method).

$$\Delta C_B = \Delta C_G - \Delta C_L$$

Where:

ΔC_B = annual change in carbon stocks in biomass [the sum of above-ground and below-ground biomass terms in Equation 2.3 ($\Delta C_{LU_i} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$)] for each land sub-category, considering the total area, tonnes C yr^{-1}

ΔC_G = annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tonnes C yr^{-1}

ΔC_L = annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tonnes C yr^{-1}

Equation 2.15 - Annual change in biomass carbon stocks on land converted to other land-use category (tier 2).

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

Where:

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

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

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

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

Equation 2.16: Initial Change in biomass carbon stocks on land converted to another Land Category

$$\Delta C_{CONVERSION} = \sum_i \{(B_{AFTER_i} - B_{BEFORE_i})\ x\ \Delta A_{TO\_OTHERS_i}\}\ x\ CF$$

Where:

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

B_{AFTER_i} = biomass stocks on land type *i* immediately after the conversion, tonnes d.m. ha^{-1}

B_{BEFORE_i} = biomass stocks on land type *i* before the conversion, tons d.m. ha^{-1}

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

CF = carbon fraction of dry matter, tonne C (tons d.m.)$^{-1}$

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

b. EF, other parameters

Emission factors used in this GHG inventory were a mixture of tier 1 and tier 2. Most default emission factors used in for the estimations in this sub-category were taken from the 2006 IPCC Guidelines, 2013 Wetland Supplements and 2019 IPCC Refinement. Some tier 2 emission factors used were developed locally were sourced from literature reviews. The country used approach 1 and 2 for this category, for Annual change in carbon stock in biomass (gain) approach 1 was used while for losses due to conversion degradation, approach 2 was assumed to be used because time series and land use change was captured in estimation.

Although gain and loss method were mostly used for this category, a modified version of stock difference was used for losses due to conversion disturbance. Biomass carbon stock after conversion of the different forest types is subtracted from Biomass carbon stock before conversion (Forest types: Primary/degraded Tropical Forest, Primary/degraded Tropical dry forest, Primary/degraded Tropical shrubland, Primary/degraded Tropical mountain forest, Primary/degraded Mangrove and Plantations.). The table below shows the average annual growth rates by forest types.

Table 6-7: Average annual growth rates by forest types

Categories	Land use stratification	Average annual growth rates ($t\ d.m.\ ha^{-1}\ yr^{-1}$)	Source
Tropical rain forest	Primary - R(p)	0.7	IPCC 2019 Refinement
Tropical mountain system	Primary – M(p)	-0.7	IPCC 2019 Refinement
Tropical dry forest	Primary – D (p)	0	IPCC 2019 Refinement
Tropical shrubland	Primary – S (p)	1	IPCC 2019 Refinement
Mangrove	Primary – Ma (p)	0	IPCC 2013 Wetland Supplement to the 2006 Guidelines for National Greenhouse Gas Inventories: Wetlands, Ch 4 Table 4.2
Tropical rain forest	Degraded forest -R(d)	3.4	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Tropical dry forest	Degraded forest - D(d)	2	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Tropical shrubland	Degraded forest – S(d)	2	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Tropical mountain system	Degraded forest – S(d)	1	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Mangrove	Degraded forest – Ma (d)	9.9	Wetland Supplement 2013, Table 4.4
Plantations	Plantations	5	Average for all national forest type

Table 6-8: Average annual above-ground biomass and ratio of below and above ground biomass

Categories	Land use stratification	Ratio below and above ground (-)	Average annual above-ground biomass (t d.m. ha^{-1})	Source
Tropical rain forest	Primary forest	0.37	223	Fox et al. (2010)
Tropical dry forest	Primary forest	0.28	130	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical shrubland	Primary forest	0.4	70	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical mountain system	Primary forest	0.27	140	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical wet Mangrove	Primary forest	0.49	192	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical rain forest	Degraded forest	0.37	146	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical dry forest	Degraded forest	0.28	85	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical shrubland	Degraded forest	0.4	46	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical mountain system	Degraded forest	0.27	92	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Tropical wet Mangrove	Degraded forest	0.49	126	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Plantations	Deforested	0.37	150	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Plantations	Degraded	0.37	98	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)

c. AD (include uncertainties and time-series consistency)

Activity data for forest land remaining forest land were taken from the Forest and land use change in Papua New Guinea assessment) conducted by the Papua New Guinea Forest Authority (same as REDD+ Technical Annex). This is the same activity data that was used in the previous submissions.

Table 6-9: Area of each forest types

Data	Forest type per IPCC ecological zone	Units	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
Area of forest land	Tropical rainforest (primary)	ha	19,265,562.35	18,922,374.58	18,531,010.58	18,045,676.21	17,498,518.34	16,987,304.55	16,859,007.71	16,765,971.66	16,653,636.20	16,568,107.90	16,454,496.58	16,335,581.55	16,203,403.52
	Tropical Mountain system (primary)	ha	7,086,394.87	7,080,510.57	7,073,636.81	7,057,873.86	7,042,186.55	7,029,856.37	7,022,010.73	7,007,236.92	6,999,301.09	6,988,981.79	6,981,038.17	6,969,273.84	6,957,433.02
	Tropical dry forest (primary)	ha	3,147,023.28	3,121,508.23	3,113,657.45	3,109,755.27	3,094,053.71	3,064,619.24	3,048,917.67	3,041,087.55	3,041,087.55	3,031,274.07	3,025,406.64	3,025,406.64	3,021,481.25
	Tropical shrubland (primary)	ha	182,477.93	180,490.08	178,510.69	178,510.69	178,510.69	178,510.69	176,547.99	176,547.99	174,587.22	174,587.22	174,587.22	174,587.22	172,624.52
	Tropical wet mangrove (primary)	ha	226,989.50	226,989.50	226,989.50	226,989.50	226,989.50	225,043.95	225,043.95	225,043.95	223,081.25	223,081.25	223,081.25	223,081.25	223,081.25
	Tropical rainforest (secondary)	ha	3,926,534.59	3,827,005.45	3,814,593.83	3,796,822.00	3,762,759.43	3,717,007.75	3,698,885.53	3,688,985.19	3,678,702.25	3,666,930.44	3,662,511.28	3,816,231.61	3,938,700.16
	Tropical Mountain system (secondary)	ha	1,355,381.26	1,351,367.00	1,351,367.00	1,349,359.86	1,343,338.47	1,331,342.01	1,329,389.18	1,325,448.43	1,325,448.43	1,324,462.10	1,324,462.10	1,324,462.10	1,324,462.10
	Tropical dry forest (secondary)	ha	903,035.50	897,147.42	897,147.42	897,147.42	893,870.05	891,907.36	891,907.36	891,907.36	891,907.36	891,907.36	888,011.16	899,787.33	903,735.94
	Tropical shrubland (secondary)	ha	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21	39,671.06
	Tropical wet mangrove (secondary)	ha	54,860.17	54,860.17	54,860.17	54,860.17	54,860.17	54,860.17	54,860.17	54,860.17	52,897.47	52,897.47	52,897.47	52,897.47	52,897.47
	Forest plantation	ha	60,707.30	60,707.30	58,744.60	60,705.40	60,705.40	60,705.40	60,705.40	60,705.40	60,705.40	60,705.40	60,705.40	60,705.40	60,705.40

Table 6-10: Conversion of primary forest to distubed forest

Conversion		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
FL	R(p) -R(d)	ha	81,730.37	121,341.42	141,710.64	172,578.40	150,259.08	152,581.47	122,275.44	84,612.08	102,523.46	83,074.33	107,187.08	108,559.42	124,351.91
	M(p) -M(d)	ha	0.00	3,921.60	1,960.80	0.00	3,946.94	0.00	1,960.77	14,281.98	5,928.69	6,417.12	7,943.62	5,864.66	11,840.82
	D(p) -D(d)	ha	5,888.09	13,738.87	0.00	0.00	3,925.39	13,738.87	15,701.57	5,867.43	0.00	9,813.48	5,867.43	0.00	3,925.39
	S(p) -S(d)	ha	0.00	0.00	0.00	0.00	0.00	0.00	1,962.70	0.00	1,960.77	0.00	0.00	0.00	1,962.70
	Ma(p) -Ma(d)	ha	0.00	0.00	0.00	0.00	0.00	1,945.54	0.00	0.00	1,962.70	0.00	0.00	0.00	0.00
	R(p)-Pl	ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

6.4.1.3. **Category-specific recalculations, if applicable**

A recalculation was performed for the Forest Land Remaining Forest Land category concerning the annual change in carbon stocks in biomass (Gain).

Under the previous application of the IPCC 2006 Guidelines, primary forest areas in PNG were conservatively treated as managed forests for estimation purposes. In line with the default guidance in IPCC 2006, Table 4.9, the biomass growth rate for these mature primary forest types (greater than 20 years in age) was assumed to be zero. Consequently, this approach resulted in no estimated annual carbon stock increase from growth in these areas.

With the integration of the updated IPCC 2019 Refinement, revised and more specific biomass growth rate values were applied. These updated rates were integrated into the calculations for relevant secondary or regrowing forest areas within the managed forest land, where positive biomass accumulation occurs.

This methodological recalculation—applying updated growth rates to the appropriate forest areas—has resulted in a revised, higher estimate of total carbon removals. Consequently, PNG's LULUCF sector is now quantified as a consistent net greenhouse gas remover (a net sink) across the entire reported time series. The table below outlines the different biomass growth rate used for the previous submission and current submission.

Table 6-11: Growth rates used in previous and current report

Caterogies	Land use stratification	Average annual growth rates (t d.m. ha^{-1} yr^{-1})	
		Previous report	Current report
Tropical rain forest	Primary - R(p)	0	0.7
Tropical mountain system	Primary – M(p)	0	-0.7
Tropical dry forest	Primary – D (p)	0	0
Tropical shrubland	Primary – S (p)	0	1
Mangrove	Primary – Ma (p)	0	0

6.4.1.4. **Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

The planned improvements for this category include:

- Increasing the sampling intensity in Collect Earth (tool used for the forestry and land use assessment) to allow improved accuracy in the forest remaining forest (FF) category
- Using Planet Labs high-resolution imagery to re-assess all Collect Earth sampling plots that faced a land use conversion and, also those that are categorized as FF (with or without a forest disturbance)
- Assessment of natural forest disturbances
- Improve Organic soils timeseries data.

6.4.2. Land converted to forest land (CRT Category 4.A.2)

6.4.2.1. **Category description (e.g. characteristics of sources)**

The activity data reflects that there has been no significant land use change towards forest land, which in turn means that no calculations for carbon emissions or sequestration were necessary or performed. This absence of land conversion ensures that the focus remains on other aspects of land use without considering forest-related changes.

6.5. Crop land (CRT Category 4.B.)

Cropland includes arable and tillable land, rice fields, and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category, and is not expected to exceed those thresholds at a later time. Cropland also includes all annual and perennial crops as well as temporary fallow land (i.e., land set at rest for one or several years before being cultivated again). Annual crops include cereals, oils seeds, vegetables, root crops and forages. Perennial crops include trees and shrubs, in combination with herbaceous crops (e.g., agroforestry) or as orchards, vineyards and plantations such as cocoa, coffee, tea, oil palm, coconut, rubber trees, and bananas, except where these lands meet the criteria for categorisation as Forest Land (Lasco et al., 2006). For PNG, there are two categories; permanent and shifting (part of it is forest land). The estimation of annual crops was considered to be at equilibrium. Under perennial, the crops that come under it, and their emissions estimated, are cocoa, coconut, and oil palm.

The cropland category consists of cropland remaining cropland (CRT category 4.B.1) and land converted to cropland (CRT category 4.B.2). The total emissions from cropland in 2022 were 9,715.13 Gg CO_2 which is an increase of 3,926.14 Gg CO_2 (25%) when compared to the year 2000. Land Converted to Cropland contributed 90 % of the total emissions in 2022. The table below shows the emissions and removals from cropland.

Table 6-12: Emissions and removals from Cropland

Categories			Units	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
4.B	Cropland		Gg-CO_2	5,886.90	4,599.46	3,070.04	6,328.90	11,942.86	14,157.09	12,215.60	9,397.81	9,989.00	7,752.36	6,760.81	11,846.23	9,715.13
4.B.2	Cropland remaining Cropland		Gg-CO_2	1,004.55	857.75	1,004.55	955.59	758.82	727.45	757.73	904.46	856.66	857.88	1,004.55	1,004.55	1,004.55
		Living biomass	Gg-CO_2	-00	-146.79	-0.00	-48.95	-245.73	-277.10	-246.82	-100.09	-147.89	-146.67	-00	-00	-00
		Dead organic matte	Gg-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Mineral soils	Gg-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Organic soils	Gg-CO_2	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55	1,004.55
4.**B**.2	Land converted to Cropland		Gg-CO_2	4,882.35	3,741.71	2,065.49	5,373.31	11,184.04	13,429.64	11,457.87	8,493.36	9,132.34	6,894.48	5,756.27	10,841.68	8,710.58
		Living biomass	Gg-CO_2	4,791.33	3,666.15	2,019.47	5,263.90	10,955.02	13,171.18	11,226.65	8,318.25	8,962.35	6,747.30	5,642.77	10,641.51	8,544.83
		Dead organic matte	Gg-CO_2	91.02	75.56	46.02	109.41	229.03	258.46	231.22	175.11	169.99	147.18	113.49	200.17	165.75
		Mineral soils	Gg-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Organic soils	Gg-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

NA (Not Applicable) NE (Not Estimated) IE (Included elsewhere)

6.5.1. Crop land remaining cropland (CRT Category 4.B.1)

6.5.1.1. **Category description (e.g. characteristics of sources)**

According to the 2006 IPCC Guidelines, estimation of annual greenhouse gas emissions and removals from Cropland remaining Cropland includes the following:

- Estimates of annual change in carbon stocks from all carbon pools and sources:
- Biomass (above-ground and below-ground biomass),
- Organic Soil

The changes in carbon stocks in Cropland Remaining Cropland are estimated using Equation 2.3. Emission and removal from Oil Palm, Cocoa, and Coconut are estimated as perennial crops, these are the major crops that are responsible for deforestation due to commercial agriculture. Permanent and shirting farming is not estimated because it is mainly annual crop. Pools included are biomass and annual changes in carbon stocks in organic soils. Others are not estimated due to lack of data or assumend no carbon stock change occurance. The table below shows the estimation of carbon stock changes in living biomass.

Table 6-13:Estimation of carbon stock changes in living biomass (in t CO2)

Area distribution (simulation)	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
Palm oil - harvested (area - ha)	12,232.42	12,428.75	13,017.62	13,017.62	13,607.59	15,398.43	16,098.73	16,593.69	16,794.40	17,090.97	17,385.09	17,385.09	17,385.09
Palm oil - growing (area - ha)	244,648.41	254,462.49	260,352.45	262,315.77	282,007.24	321,974.63	331,873.82	335,888.08	341,819.33	347,701.74	347,701.74	347,701.74	347,701.74
Carbon Loss (instant)	1,663,609.17	1,690,310.33	1,770,396.66	1,770,396.68	1,850,632.65	2,094,185.90	2,189,427.48	2,256,741.95	2,284,038.95	2,324,371.47	2,364,371.82	2,364,371.82	2,364,371.82
Carbon gain	1,663,609.17	1,730,344.94	1,770,396.68	1,783,747.26	1,917,649.20	2,189,427.48	2,256,741.95	2,284,038.95	2,324,371.47	2,364,371.82	2,364,371.82	2,364,371.82	2,364,371.82
Net loss (ΔCB)	-00	-00	-00	-00	-00	-00	-00	-00	-00	-00	-00	-00	-00
T CO2 eq	-00	-146.79	-0.00	-48.95	-245.73	-349.22	-246.82	-100.09	-147.89	-146.67	-00	-00	-00
Cocoa and coconut- harvested (area - ha)	9,849.06	9,849.06	9,947.10	10,045.14	10,045.14	10,142.98	10,042.62	10,042.62	10,042.62	10,042.62	10,042.62	10,042.62	10,042.62
Cocoa and coconut - growing (area - ha)	196,981.25	196,981.25	198,942.02	200,902.79	200,902.79	200,852.38	200,852.38	200,852.38	200,852.38	200,852.38	200,852.38	200,852.38	200,852.38
Carbon Loss (instant)	1,930,416.23	1,930,416.23	1,949,631.70	1,968,847.36	1,968,847.36	1,988,023.22	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32
Carbon gain	1,930,416.23	1,930,416.23	1,949,631.80	1,968,847.36	1,968,847.36	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32	1,968,353.32
Net loss (ΔCB)	-00	-00	0.10	-00	-00	-19,669.90	-00	-00	-00	-00	-00	-00	-00
T CO2 eq	-00	-00	-0.00	-00	-00	72.12	-00	-00	-00	-00	-00	-00	-00
T CO2 eq	-00	-146.79	-0.00	-48.95	-245.73	-277.10	-246.82	-100.09	-147.89	-146.67	-00	-00	-00

6.5.1.2.**Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

The gain-loss method (default tier 1 method) was used to estimate the emissions and removals for cropland remaining cropland. Given below is Equation 2.7, which was used for estimating the annual change in carbon stocks in biomass in land remaining in a particular land-use category - gain-loss method :

Equation 2.7: Annual change in carbon stocks in biomass in land remaining in a particular land-use category (Gain-Loss Method).

$$\Delta C_B = \Delta C_G - \Delta C_L$$

Where:

ΔC_B = annual change in carbon stocks in biomass [the sum of above-ground and below-ground biomass terms in Equation 2.3 ($\Delta C_{LU_i} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$)] for each land sub-category, considering the total area, tonnes C yr-1

ΔC_G = annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tonnes C yr^{-1}

ΔC_L = annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tonnes C yr^{-1}

To estimate the emissions for annual change in carbon stocks in *organic soils*, Equation 2.26 was used.

Equation 2.26: annual carbon loss from drained organic soils (CO_2).

$$\boldsymbol{L_{Organic} = \sum_c (A \ x \ EF)_c}$$

Where

$\boldsymbol{L_{Organic}}$ = annual carbon loss from drained organic soils, tonnes C yr^{-1}

A = land area of drained organic soils in climate type c, ha
Note: A is the same area (F_{os}) used to estimate N_2O emissions in Chapter 11, Equations 11.1 and 11.2

EF = emission factor for climate type c, tonnes C ha^{-1} yr^{-1}

a. EF, other parameters

The emission factors used in the current submission were a mixture of default values and country-specific emission factors. Most default emission factors used were taken from the 2006 IPCC guidelines while country-specific emission factors used were from the literature review.

The gains are from perennial crop areas of oil Palm multiplied by the mean annual increment of oil palm. Losses are from the harvested area. The harvested areas are assumed by 1/20 of the total area of the previous year in order to reflect the area changes of this perennial crop. It is a gain and loss method because the area of Oil Palm is subtracted by area loss due to harvested area. Similar cases are applied to cocoa and coconut. Carbon pools included in this category include living biomass and organic carbon. The table below shows the Emission factor for this category.

Table 6-14: Emission factors used for estimating emissions and removals from Cropland

All Perennials	Value	Unit	Source
Maturity cycle-coconut	20	Years	PNGFRL 2023
Maturity cycle-oil palm	20	Years	PNGFRL 2023
AGB-coconut (average for whole cycle)	196	t dm/ha	2006 IPCC, Table 5.3
AGB-coconut (at the time of harvesting)	392	t dm/ha	This value is assumed to be consistent with the product of annual increment ratio and maturity cycle
AGB-oil palm (average for whole cycle)	136	t dm/ha	2006 IPCC, Table 5.3
AGB-oil palm (at the time of harvesting)	272	t dm/ha	This value is assumed to be consistent with the product of annual increment ratio and maturity cycle
Carbon fraction	0.5	tonnes C/ t dm	This value is assumed by the annual increment figures
Mean annual increment coconut	9.6	tonnes C $ha^{-1}yr^{-1}$	PNGFRL 2023
Mean annual increment oil palm	6.8	tonnes C $ha^{-1}yr^{-1}$	PNGFRL 2023

b. AD (include uncertainties and time-series consistency)

Activity data for cropland remaining cropland were taken from the forestry and land use assessment conducted by the PNGFA.

6.5.1.3. Category-specific recalculations, if applicable

No recalculations were made for this current submission

6.5.1.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The planned improvements for this category include:

- Increasing the sampling intensity in Collect Earth to allow improved accuracy in cropland remaining cropland (CC) category.
- Collecting country specific activity data for carbon stock change due to losses in CL-CL sub category and in organic soil.
- Using Planet Labs high-resolution imagery to re-check all Collect Earth sampling plots that faced a land use conversion to cropland or vise-versa.
- Improve coordination and participation with Department of Agriculture and Livestock and with National Agriculture Research Institute (NARI) for/in subnational surveys.

6.5.2. Land converted to cropland (CRT Category 4.B.2)

6.5.2.1. Category description (e.g. characteristics of sources)

According to the 2006 IPCC guidelines estimation of annual GHG emissions and removals from land converted to cropland includes the following:

- Estimates of annual change in C stocks from all C pools and sources:
    - Living Biomass (above-ground and below-ground biomass);
    - Dead organic matter (dead wood and litter);
    - Soils (mineral and organic soils).
- Estimates of non-CO2 gases from burning of above-ground biomass and Dead Organic Matter

The current submission includes the annual change in C stock from living biomass and organic matter. Mineral soil was not estimated while organic soil was included under Cropland remaining cropland (CRT Category 4.B.1) organic soil.

6.5.2.2. Methodological issues

a. Choice of method (include assumptions and the rationale for selection)

The equations used for estimating living biomass and dead organic matter were Equations 2.16 and 2.23 from Chapter 2 of Volume 4 of the 2006 IPCC guidelines.

- **Equation for estimating biomass**

Equation 2.16: Initial Change in biomass carbon stocks on land converted to another Land Category

$$\Delta C_{CONVERSION} = \sum_{i} \{(B_{AFTER_i} - B_{BEFORE_i})\ x\ \Delta A_{TO\_OTHERS_i}\}\ x\ CF$$

Where:

$\Delta C_{CONVERSION}$	=	initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1}
B_{AFTER_i}	=	biomass stocks on land type *i* immediately after the conversion, tonnes d.m. ha^{-1}
B_{BEFORE_i}	=	biomass stocks on land type *i* before the conversion, tonnes d.m. ha^{-1}
$\Delta A_{TO\_OTHERS_i}$	=	area of land use *i* converted to another land-use category in a certain year, ha yr^{-1}
CF	=	carbon fraction of dry matter, tonne C (tonnes d.m.)$^{-1}$
i	=	type of land use converted to another land-use category

- **Equation for estimating dead organic matter.**

Equation 2.23 - Annual change in carbon stocks in dead organic matter due to land conversion.

$$\Delta C_{DOM} = \frac{(C_n - C_0)\ x\ A_{on}}{T_{on}}$$

Where

ΔC_{DOM}	=	annual change in carbon stocks in dead wood or litter, tonnes C yr^{-1}
C_0	=	dead wood/litter stock, under the old land-use category, tonnes C ha^{-1}

C_n	=	dead wood/litter stock, under the new land-use category, tonnes C ha^{-1}
A_{on}	=	area undergoing conversion from old to new land-use category, ha
T_{on}	=	time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses.

a. EF, other parameters

Since the only conversion from land to cropland is from forestland, the same carbon losses emission factors from forestland were used for the estimations in this sub-category (refer to Table xx for the emission factors). Biomass carbon stock after forestland is converted to cropland is assumed to be zero when land is totally cleared. The assumption is due to the lack of defining agriculture management practises to generate activity data from carbon stock change. For the biomass in this sub-category, carbon fraction of dry matter, tonne C (tonnes d.m.)$^{-1}$ of 0.47 from 2006 IPCC GL was used.

Table 6-15: Biomass carbon stock before conversion

Biomass carbon stock before conversion				
Initial land use	Forest type per IPCC ecological zone	Units	Values	Source
Area of forest land	Tropical rainforest (primary)	t-dm/ha	306	Fox et.Al (2010)
	Tropical Mountain system (primary)	t-dm/ha	178	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical dry forest (primary)	t-dm/ha	166	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical shrubland (primary)	t-dm/ha	98	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical wet mangrove (primary)	t-dm/ha	286	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical rainforest (secondary)	t-dm/ha	200	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical Mountain system (secondary)	t-dm/ha	117	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical dry forest (secondary)	t-dm/ha	109	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical shrubland (secondary)	t-dm/ha	64	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Tropical wet mangrove (secondary)	t-dm/ha	286	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
	Forest plantation	t-dm/ha	188	IPCC, 2006 (Vol 4, Ch.4,table 4.7)
Biomass carbon stock after conversion				
Final land use		**Unit**	**Value**	**Source**
Biomass regrowth after conversion		t-dm/ha/yr	0	IPCC, 2006 (Tier 1 default)
Carbon fraction				
Land use		**Unit**	**Value**	**Source**
All		t-C/t-dm	0.47	IPCC, 2006 (Vol 4, Ch.4,table 4.3)

- EF for dead organic matter

Table 6-16: EF for dead organic matter

Parameters	Emission factors	Source
Deadwood	0	IPCC, 2006 Tier 1 default
Litter	2.1	Table 2.2, vol 4, ch 2, Tropical climate

b. AD (include uncertainties and time-series consistency)

Activity data for land converted to cropland were taken from the forestry and land use assessment conducted by the PNGFA.

6.5.2.3. Category-specific recalculations, if applicable

No recalculations were made for this current submission

6.5.2.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The planned improvements for this category include:

- Increasing the sampling intensity in Collect Earth to allow improved accuracy in forest converted to cropland (FC) category.
- Define management practice for cropland to generate activity data for carbon stock change in organic soils and mineral soils.
- Verifying cropland area by sub-category with ground surveying.
- Using Planet Labs high-resolution imagery to re-assess all Collect Earth sampling plots that faced a land use conversion and, also those that are categorized as FC (with or without a forest disturbance)

6.6. Grassland (CRT Category 4.C.)

According to the 2006 IPCC Guidelines, grasslands vary greatly in their degree and intensity of management, from extensively managed rangelands and savannahs – where animal stocking rates and fire regimes are the main management variables – to intensively managed (e.g., with fertilization, irrigation, species changes) continuous pasture and hay land. Grasslands generally have vegetation dominated by perennial grasses, and grazing is the predominant land use (Verchot et al., 2006). In PNG, grassland is considered insignificant. This is due to no management practices. It is one of the smallest GHG-emitting categories. The only carbon pool estimated in this category is organic soils under the grassland remaining grassland.

The total emissions from Grassland remained constant at 323.36 Gg CO_2eq from 2000 to 2022. All of this were from the Grassland remaining grassland cateogory (CRT Category 4.C.1). The table below shows the emissions and removals from grassland.

Table 6-17: Emissions and removals fromm grassland (CRT Category 4.C)

Categories			unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
4.C	Grassland		Gg CO_2 eq	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
4.C.1	Grassland remaining grassland		Gg CO_2 eq	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
		Living biomass	Gg CO_2 eq	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Dead organic matter	Gg CO_2 eq	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Mineral soils	Gg CO_2 eq	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Organic soils	Gg CO_2 eq	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
4.C.2	Land converted to grassland		Gg CO_2 eq	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Living biomass	Gg CO_2 eq	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Dead organic matter	Gg CO_2 eq	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Mineral soils	Gg CO_2 eq	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Organic soils	Gg CO_2 eq	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

6.6.1. Grassland remaining grassland (CRT Category 4.C.1)

6.6.1.1. Category description (e.g. characteristics of sources)

According to the 2006 IPCC Guidelines, grassland remaining grassland includes managed pastures which have always been under grassland vegetation and pasture use or other land categories converted to grassland more than 20 years ago. Constructing a greenhouse gas inventory for the land-use category

Grassland Remaining Grassland (GG) involves estimation of changes in carbon stock from five carbon pools (i.e., above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter), as well as emissions of non-CO2 gases. The principal sources of emissions and removals of greenhouse gases in this category are associated with grassland management and changes in management (Verchot et al., 2006). For PNG, only one (organic soils) of the five carbon pools in this sub-category was estimated. Above and below ground biomass, dead organic matter, and mineral soils are all not estimated because there is no grassland under management practices.

6.6.1.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

Carbon emissions and removals for grassland remaining grassland are based on estimating the effects of changes in management practices on carbon stocks. For this category only annual change in carbon stock in organic soil was estimated, other pools are not estimated due to insignificant managed grassland area in the country.

The change in carbon stocks in grassland remaining grassland is estimated using Equation 2.26 in Chapter 2 of the 2006 IPCC Guidelines (Pingoud et al., 2006). Given below is Equation 2.26, used for estimating annual change in carbon stocks in grassland remaining grassland.

$$L_{organic} = \sum_{c} (A \; x \; EF)c$$

$L_{organic}$	=	annual carbon loss from drained organic soils, tons C yr^{-1}
A	=	land area of drained organic soils in climate type *c*, ha
EF	=	emission factor for climate type c, tons C ha^{-1} yr^{-1}

a. EF, other parameters

Emission factors used in this sub-category were Tier 1 (default emission factors) taken from the 2006 IPCC Guidelines (Volume 4, Ch 6, Table 6.3).

b. AD (include uncertainties and time-series consistency)

Activity data for land converted to settlement were taken from the forestry and land use assessment conducted by the PNGFA.

6.6.1.3. **Category-specific recalculations, if applicable**

No recalculations were made for this current submission

6.6.1.4. **Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

The planned improvements for this category include:

- Increasing the sampling intensity in Collect Earth (the tool used for forestry and land use assessment) to allow improved accuracy in grassland remaining grassland (GG) category.
- Improving carbon stock for woody and herbaceous biomass
- Define management practices for grassland
- Using Planet Labs high-resolution imagery to re-check all Collect Earth sampling plots that faced a land use conversion and, also those that are categorized as GG.

6.6.2. Land converted to grass land (CRT Categoy 4.C.2)

6.6.2.1. **Category description (e.g. characteristics of sources)**

Since 2000, there has been no land use change from land to grassland. This indicates that no areas have been converted to grassland over this period. The activity data reflects a consistent pattern where land has not been repurposed for grassland use, suggesting stability in the designated land uses within the country.

6.7. Wetlands (CRT Category 4.D)

6.7.1. Wetlands remaining wetlands (CRT Category 4.D.1)

6.7.1.1. **Category description (e.g. characteristics of sources)**

It is assumed that there is no carbon stock change (CSC) in wetlands remaining wetlands

6.7.2. Land converted to wetlands (CRT Category 4.D.2)

6.7.2.1. **Category description (e.g. characteristics of sources)**

There were no land use changes from other land use to wetlands

6.8. Settlements (CRT Category 4. E)

According to the 2006 IPCC Guidelines settlements are defined as including all developed land i.e. residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size, unless it is already included under other land-use categories. Settlements also include soils, and herbaceous perennial vegetation such as turf grass and garden plants in rural settlements, homestead gardens, and urban areas. The carbon stock changes and greenhouse gas emissions and removals are associated with changes in biomass, dead organic matter (DOM), and soil carbon on lands classified as settlements.

The settlements category consists of settlement remaining settlement (CRT category 4.E.1) and land converted to settlement (CRT category 4.E.2). The total emissions from settlements in 2022 were 43.93 Gg CO_2 eq which is an increase of 43.93 Gg CO_2 eq (100 %) when compared to the year 2000 which was zero net emissions. Land converted to settlement (CRT category 4.E.1) contributed 100 % of the total emissions in 2022. The table below shows the emissions and removals from settlements.

Table 6-18: Emissions and removals from Settlement (CRT Category 4. E)

Categories			Units	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
4.E	Settlements		Gg-CO_2	0.00	0.00	0.00	34.59	56.12	34.59	510.19	1,058.52	1,097.37	33.65	0.00	0.00	43.93
4.E.1	Settlement remaining settlement		Gg-CO_2	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA
		Living biomass	Gg-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Dead organic matter	Gg-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Mineral soils	Gg-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Organic soils	Gg-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2	Land converted to settlement		Gg-CO_2	0.00	0.00	0.00	34.59	56.12	34.59	510.19	1,058.52	1,097.37	33.65	0.00	0.00	43.93
		Living biomass	Gg-CO_2	0.00	0.00	0.00	34.59	56.12	34.59	495.15	1,043.29	1,082.06	33.65	0.00	0.00	43.93
		Dead organic matter	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	15.04	15.23	15.31	0.00	0.00	0.00	0.00
		Mineral soils	Gg-CO_2	NO	NO	NO	NE	NE	NE	NE	NE	NE	NE	NO	NO	NE
		Organic soils	Gg-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

NA (Not Applicable) NE (Not Estimated) NO (Not Occuring)

6.8.1. Settlements remaining settlements (CRT Category 4.E.1)

6.8.1.1. **Category description (e.g. characteristics of sources)**

This category refers to all classes of urban formations that have ben in use as settlements e.g. areas that are functionally or administratively associated with public or private land in cities, villages, or other settlement types. Emissions and removals of CO2 in this category are estimated by changes in carbon stocks in biomass (both woody and perennial non-woody components), in DOM, and in soils. Tier 1 method of the 2006 IPCC guidelines assumes no change in carbon stocks in live biomass in Settlement remaining Settlements, in other words, that the growth and loss terms balance. Thus since Tier 1 was used for the current submission this category is reported as not applicable and not occurring.

6.8.2. Land converted to settlements (CRT Category 4.E.2)

6.8.2.1. **Category description (e.g. characteristics of sources)**

According to the 2006 IPCC guidelines, conversion of forest land, cropland, grassland etc. to settlements, leads to emissions and removals of greenhouse gases. Depending on the magnitude of carbon stocks in the previous land-use category, land converted to settlements may experience a relatively rapid loss of carbon in the first year, followed by more gradual increase in carbon pools subsequently.

Table 6-19: Emissions and removals from land converted to settlement

Initial land use			2000	2002	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
FL	R(p)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,043.29	1,048.27	0.00	0.00	0.00	0.00
	M(p)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D(p)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	S(p)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ma(p)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	R(d)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	M(d)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	393.75	0.00	0.00	0.00	0.00	0.00	0.00
	D(d)	Gg-CO_2	0.00	0.00	0.00	0.00	246.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	S(d)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ma(d)	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Plantation	Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cropland		Gg-CO_2	0.00	45.31	34.59	33.79	0.00	56.12	56.12	33.47	34.59	101.41	0.00	33.79	33.65	0.00	0.00	43.93
Grassland		Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wetlands		Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Otherland		Gg-CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		Gg-CO_2	0.00	45.31	34.59	33.79	246.95	56.12	56.12	33.47	34.59	495.15	1,043.29	1,082.06	33.65	0.00	0.00	43.93

6.8.2.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

Equation 2.15 as contained in chapter 2 volume 4 of the 2006 IPCC guideline was used to estimate the annual change in biomass carbon stock in land converted to settlement. Thus a tier 2 method was used. According to the 2006 IPCC guidelines, the average annual change in biomass carbon stocks in settlements may be positive or negative depending on the relative magnitude of the increment and loss terms. Given below is the equation that was used.

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

Where:

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

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

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

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

a. EF, other parameters

- EF for biomass

The emission factors used for the estimation of living biomass are given in the table below

Table 6-20: Emission factors used for the estimation of living biomass

Biomass carbon stock before conversion				
Initial land use	Forest type per IPCC	Units	Values	Source
Area of forest land	Tropical rainforest	t-dm/ha	306	Fox et.Al (2010)
	Tropical Mountain	t-dm/ha	178	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical dry forest	t-dm/ha	166	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical shrubland	t-dm/ha	98	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical wet mangrove	t-dm/ha	286	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical rainforest	t-dm/ha	200	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical Mountain	t-dm/ha	117	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical dry forest	t-dm/ha	109	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical shrubland	t-dm/ha	64	IPCC, 2006 (Vol 4, Ch.4,table
	Tropical wet mangrove	t-dm/ha	286	IPCC, 2006 (Vol 4, Ch.4,table
	Forest plantation	t-dm/ha	188	IPCC, 2006 (Vol 4, Ch.4,table
Biomass carbon stock after conversion				
Final land use	**Unit**	**Value**	**Source**	
Biomass regrowth after conversion	t-dm/ha/yr	0	IPCC, 2006 (Tier 1 default)	
Carbon fraction				
Land use	**Unit**	**Value**	**Source**	
All	t-C/t-dm	0.47	IPCC, 2006 (Vol 4, Ch.4,table 4.3)	

- EF for dead organic matter

Most of the changes in carbon stocks associated with dead organic matter is associated with changes in tree cover in settlements. Methods are provided here are for two types of DOM pools: 1) dead wood and 2) litter. The emission factors used for the estimation of dead organic matter are given in the table below.

Table 6-21: EF for dead organic matter

Parameters	Emission factors	Source
Deadwood	0	IPCC, 2006 Tier 1 default
Litter	2.1	Table 2.2, vol 4, ch 2, Tropical climate

b. AD (include uncertainties and time-series consistency)

Activity data for land converted to settlement were taken from the forestry and land use assessment conducted by the PNGFA.

6.8.2.3. **Category-specific recalculations, if applicable**

No recalculations were made for this current submission

6.8.2.4. **Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

The planned improvements for this category include:

- Improve carbon stock values from the national forest inventory
- Spatial explicit data to track forest to settlement
- Urban biomass waste

6.9. Other Lands (CRT Category 4. F)

6.9.1. Category description (e.g. characteristics of sources)

No calculations were required because there was no land conversion to other land

6.10. Harvested Wood Products (CRT Category 4. G)

6.10.1. Category description (e.g. characteristics of sources)

Emissions from harvested wood products are considered zero, since instantaneous oxidation is assumed during the time primary forest is converted to degraded forest. For HWP instantaneous oxidation (IPCC default approach is applied), the countries major long logs are exported and very few to no logs are processed on shore. In the future when the policy on onshore processing of logs become effective, HWP emissions/removals will be included.

6.11. Prescribed burning of savannahs on Forest Land (CRT Category 3.E.1)

6.11.1. Category description (e.g. characteristics of sources)

Emissions from prescribed burning of savannahs on forest land (CRT Category 3.E.1) was reported under the LULUCF Sector. According to the 2006 IPCC Guidelines, Fire is treated as a disturbance that affects not only the biomass (in particular, above-ground), but also the dead organic matter (litter and dead wood). The term `biomass burning` is widely used and is retained in these Guidelines, but acknowledging that fuel components other than live biomass are often very significant, especially in forest systems. PNG reported emissions from biomass burning from the forestland and grassland in this category. Table below shows the emission results for biomass burning in forest lands.

6.11.2. Methodological issues

6.11.2.1. **Choice of method (include assumptions and the rationale for selection)**

Tier 1 method was used for estimating emissions from this category. Equation 2.27

$$L_{fire} = A \bullet M_B \bullet C_f \bullet G_{ef} \bullet 10^{-3}$$

Where:

L_{fire} = Amount of greenhouse gas emissions from fire, tonnes of each GHG e.g. CH_4, N_2O etc,

A = Area burnt, ha

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

C_f = Combustion factor, dimensionless (default values in Table 2.6)

G_{ef} = Emission factor, g kg^{-1} dry matter burnt (default values in Table 2.5)

6.11.2.2. **EF, other parameters**

The emission factors and other parameters used for the estimation of living biomass are given in the table below.

Table 6-22: Emission factors and other parameters used

Type of data	Sub-category	Unit	Value	Source
Mass of fuel available for combustion	Primary Forest	t.d.m/ha	187.0	Average of all primary forest
	Degraded Forest	t.d.m/ha	122.5	Average of all primary forest

Type of data	Sub-category	Unit	Value	Source
	Others	t.d.m/ha	188.0	Value of forest plantation
Combustion factor	Primary Forest		0.36	2006 IPCC (table 2.6)
	Degraded Forest		0.55	2006 IPCC (table 2.6)
	Others		0.55	2006 IPCC (table 2.6)
Emission factor	CH_4	g-CH_4/kg-dm burnt	6.8	2006 IPCC (Ch 2, Vol.4,table 2.5)
	N_2O	g-N_2O/kg-dm burnt	0.2	2006 IPCC (Ch 2, Vol.4,table 2.5)

6.11.2.3. AD (include uncertainties and time-series consistency)

PNG used activity data on biomass burning from FAOSAT. In the current years, since PNG submitted its first BUR in 2018, FAOSAT has update its activity data on forest fire so the current update in the database will influence the result from the previous inventory. For non-CO_2 gases, only CH_4 and N_2O were estimated.

6.11.3. Category-specific recalculations, if applicable

Recalculations were made for this category as compared to the previous report in the BUR2. This was due to updated activity data from the data source (FAOSTAT)

6.11.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

Planned improvements for this category includes:

- Use fire data base on hot spot areas; and
- Improve on country specific activity data

Chapter 7. Waste sector

7.1. Overview of the sector

7.1.1. Overview of the Waste Management and Estimation Category

The waste sector covers GHG emissions from the treatment and disposal of waste, which are estimated for solid waste disposal (CRT Category 5.A.), biological treatment of solid waste (CRT Category 5.B.), incineration and open burning of waste (CRT Category 5.C.), and wastewater treatment and discharge (CRT Category 5.D.) in accordance with treatment processes suggested in the 2006 IPCC Guidelines.

Waste management in PNG remains a poorly managed sector with much improvement needed in the short and long term. The data on waste generation and/or treatment amount are hardly available for most of cases in PNG. Thus, the many estimates are linked to the population data. PNG used Tier 1 methodologies and default emission factors in the 2006 IPCC Guidelines for most of the GHG emission estimates in the Waste sector. When limited activity data were available, emission estimates were carried out based on assumptions and expert judgment.

PNG generally uses the default methodologies and emission factors in GHG emission estimations on the waste sector. Given the paucity of data, emissions estimates from the waste sector in PNG comprised CH_4 emissions from solid waste disposal sites (CRT Category 5.A.), CH_4 and N_2O emissions from biological treatment of solid waste (CRT Category 5.B.), and CH_4 and N_2O emissions from wastewater treatment (CRT Category 5.D.). Emissions from incineration and open burning of waste (CRT Category 5.C.) are only reported for municipal solid waste. For details, see the “Methodological Issues” in each category’s section.

Table 7-1: Summary of methods and emission factors used in the waste sector

CRT	Category	CO_2		CH_4		N_2O	
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
5. A	Solid waste disposal	NO	NO	T1	D		
5. B	Biological treatment of solid waste			T1	D	T1	D
5. C	Incineration and open burning of waste	T1	D	T1	D	T1	D
5.D	Wastewater treatment and discharge			T1	D	T1	D

Note: D: IPCC default, T1: IPCC Tier 1, NO: Not Occurring

7.1.2. Emission summary of the sector

In 2022, emissions from the Waste sector resulted in 1415.60 Gg CO_2 eq and accounted for 9% of PNG’s total greenhouse gas emissions (excluding LULUCF). The emissions of the waste sector have increased throughout the whole time series (2000- 2022), as seen in Figure 7-1. The increase is influenced by population growth, development, consumption rate, and rural-to-urban drift. Breakdown of 2022 emissions of the Waste sector by category shows that Wastewater treatment and discharge (CRT Category 5.D) contributed 68% to total sector emissions in 2022, followed by solid waste disposal (CRT Category 5.A) (29%), Incineration and open burning of waste (CRT Category 5.C) (3%) and Biological treatment of solid waste (CRT Category 5.B) (1%). The contribution of CO_2, CH_4, and N_2O to the total sector emissions is 1%,84%, and 15%, respectively.

Table 7-2: GHG emissions from the waste sector (Gg CO_2 eq)

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
5.A.	Solid waste disposal	Gg CO_2 eq	137.714	160.413	187.127	217.127	250.129	286.007	298.594	311.492	324.696	338.210	352.030	366.156	398.574
5.B.	Biological treatment of solid waste		3.159	3.861	4.212	5.090	5.441	6.318	6.494	6.669	7.196	7.371	7.547	7.547	7.547
5.C.	Incineration and open burning of waste		16.591	19.639	22.293	26.745	28.729	33.181	33.726	34.632	37.805	38.712	39.256	39.256	39.256
5.D.	Wastewater treatment and discharge		362.109	405.620	445.659	485.698	526.087	565.777	579.508	592.470	601.755	615.012	628.688	824.338	970.224
5.E.	Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	Gg CO_2 eq	519.572	589.533	659.291	734.660	810.385	891.283	918.321	945.263	971.452	999.304	1027.521	1237.296	1415.601

NO Not Occuring

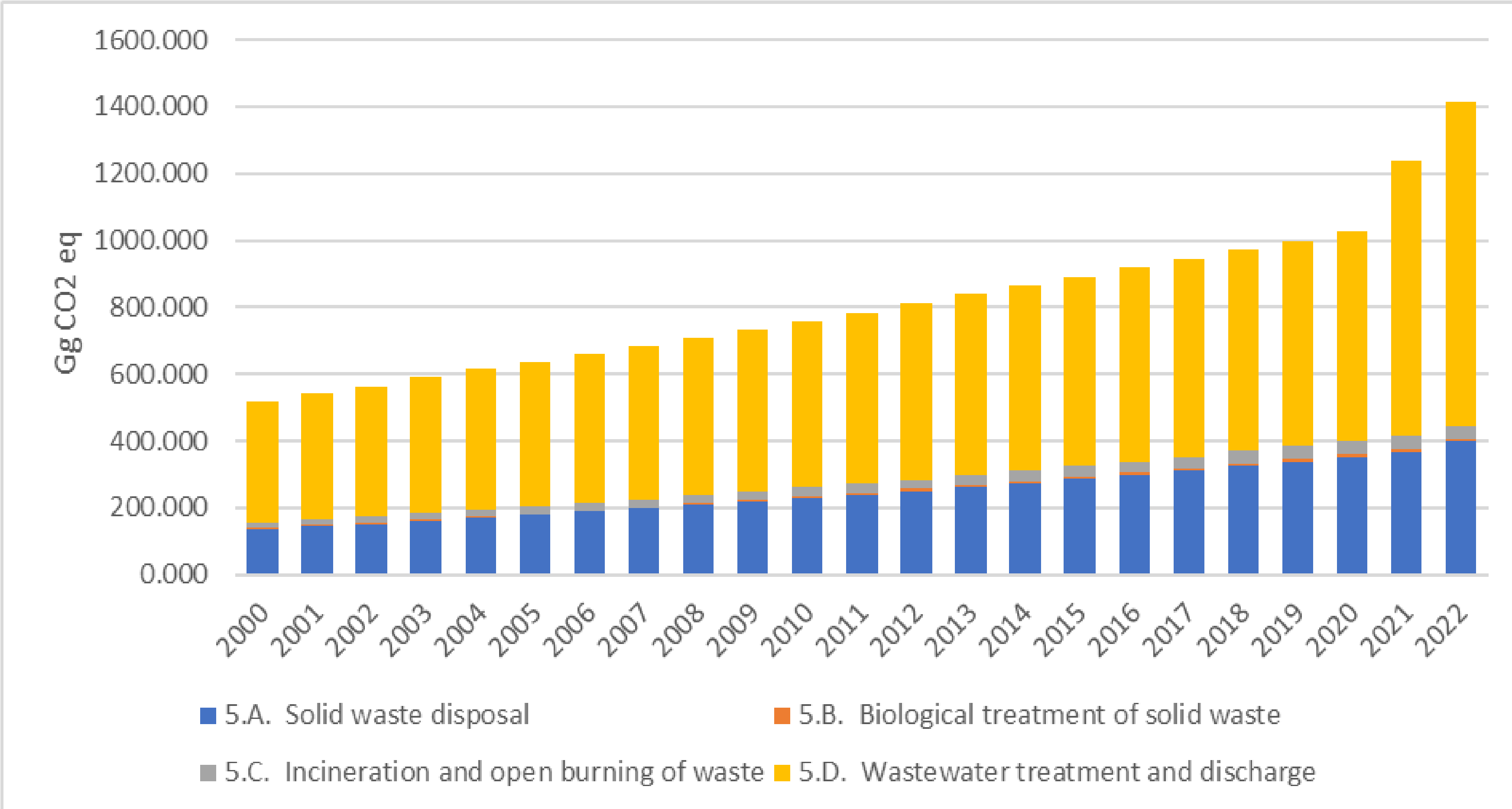

Figure 7-1: GHG emissions from the waste sector (Gg CO_2 eq)

7.1.3. Amount of Waste Generation and Treatment

7.1.3.1. Generation of Municipal Solid Waste

Most solid waste from households and commercial sites within the 22 towns/cities in PNG is disposed of in aggregate quantities at open-air dump sites located at the periphery of the town/ city through a roadside pickup system. In PNG, basically, all solid waste is collected together without segregation at the source, and only scrap metal is recycled.

Information on the amount of waste generation in PNG is very limited and no country-specific time series data for waste generation is available. One survey implemented in Port Moresby for the year 2014 by NCDC shows the data of waste generation ratio as 0.38 kg waste generated per person per day. Therefore, the time series of municipal solid waste (MSW) generation amount is assumed by using population as a driver.

In this estimation, big cities (National Capital District, Western Highlands, Kokopo, and Morobe) and small cities/towns in PNG are separately estimated as the generated waste and its waste treatment types are considered different between urban areas and rural areas. The two expert judgments are applied in the construction of a time series of waste generation amount: (1) the amount of waste generation per person per day in 1980 was assumed as a half of that in 2014 for Port Moresby and (2) rural area generate 0.7 times of waste person per day than that of big cities.

Table 7-3: Data used for MSW generation

Items	Classification	unit	1980	1990	2000	2011	2014	2017	2022
Population	Big Cities	Person	699,902	911,865	1,233,587	1,745,772	1,885,459	2,025,146	4,360,2
	Rural cities and islands	Person	2,310,825	2,850,089	3,957,199	5,529,552	5,958,376	6,387,199	9,508,7
Waste generation per person per ay	Big Cities	kg/cap.	0.19	0.25	0.30	0.36	0.38	0.40	0.42
	Rural Cities and Islands	kg/cap.	0.13	0.17	0.21	0.25	0.27	0.28	0.30
MSW Generated	Big Cities	kt(wet)	48.54	81.84	135.87	231.46	261.51	293.28	675.92
	Rural Cities and Islands	kt(wet)	112.18	179.05	305.10	513.18	578.50	647.49	1031.81
Black : Static or Survey data Blue: Assumption									

7.1.3.2. Composition of Municipal Solid Waste

The survey in 2014 also provides waste composition of MSW in Port Moresby. This composition is regarded as representing PNG's situation and used in all MSW for whole time series.

Table 7-4: MSW composition data

Waste type	Paper	Textile	Food	Wood	Garden & Park	Nappies	Rubber & Leather	Plastic	Metals	Glass	Other
Share	0.20	0.05	0.40	0.10	0.10	0.05	0.00	0.05	0.00	0.00	0.05

7.1.3.3. Waste Treatment Methods for Municipal Solid Waste (MSW)

A survey in 2010 provided a share of waste treatment methods for MSW in big cities and rural areas. This is the only country-specific information that was used for the whole time series. GHG emissions from Solid Waste Disposal Sites, composting, and incineration/open burning are estimated under categories 5A, 5B, and 5C respectively.

Table 7-5: Share of MSW treatment methods

Classification	SWDS	Composting	Incineration open burning	Recycling	Other
Big cities	0.7	0	0	0	0.3
Rural Cities and islands	0.35	0.1	0.2	0	0.35

7.1.3.4. Generation of Industrial Waste

In PNG, industrial solid waste is generally treated in conjunction with municipal and commercial waste. The main industries in PNG which emit organic solid waste are "food and beverage" and "Organic material". One petroleum refinery is also operating. There are no tobacco, textile, wood pulp, and chemical industries in PNG. Other data on the amount of industrial waste generation or other relevant data which may be used as a driver to estimate industrial solid waste amount was not available at present thus industrial waste is not included in GHG estimation of the waste sector for BTR 1.

7.2. Solid waste disposal (CRT Category 5.A)

7.2.1. Category description (e.g. characteristics of sources)

The treatment and disposal of solid waste produce CH4 and CO2 during the decomposition of organic materials at solid waste disposal sites (SWDS). Emissions emanate from waste deposited over a long period. The amount of solid waste disposed of since 1950 was considered in the PNG inventory because it is good practice to use a 50-year time frame, which provides an acceptably accurate result for most typical disposal practices and conditions, according to the guidance in the 2006 IPCC guidelines (Chapter 3, Volume 5). CO_2 emissions from biogenic sources (e.g., waste wood, foods) are not included in the total emissions of the waste sector as well as the national total, because carbon is of biogenic origin, and net emissions are considered and included under the AFOLU Sector. CO_2 emissions from burning the surface of landfill sites are considered in category 5. A, but this source is not estimated in PNG. Thus, only CH_4 emissions are reported in this sector.

The estimated emissions from solid waste disposal were about 465.00 Gg CO_2 eq in 2022, which is an increase of 304.34 Gg CO_2 eq (189%) when compared to the year 2000. The trend of emissions from this category is shown in Table 7-6 and Figure 7-2 below.

Table 7-6: Emissions from Solid Waste Disposal

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
5.A.1.	Managed waste disposal sites	Gg CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.A.2.	Unmanaged waste disposal sites		5.738	6.684	7.797	9.047	10.422	11.917	12.441	12.979	13.529	14.092	14.668	15.257	16.607
5.A.3.	Uncategorized waste disposal sites		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Total	Gg CH_4	5.738	6.684	7.797	9.047	10.422	11.917	12.441	12.979	13.529	14.092	14.668	15.257	16.607
	Total	Gg CO_2 eq	160.666	187.149	218.315	253.314	291.817	333.675	348.360	363.407	378.813	394.578	410.701	427.182	465.003

NE Not Estimated

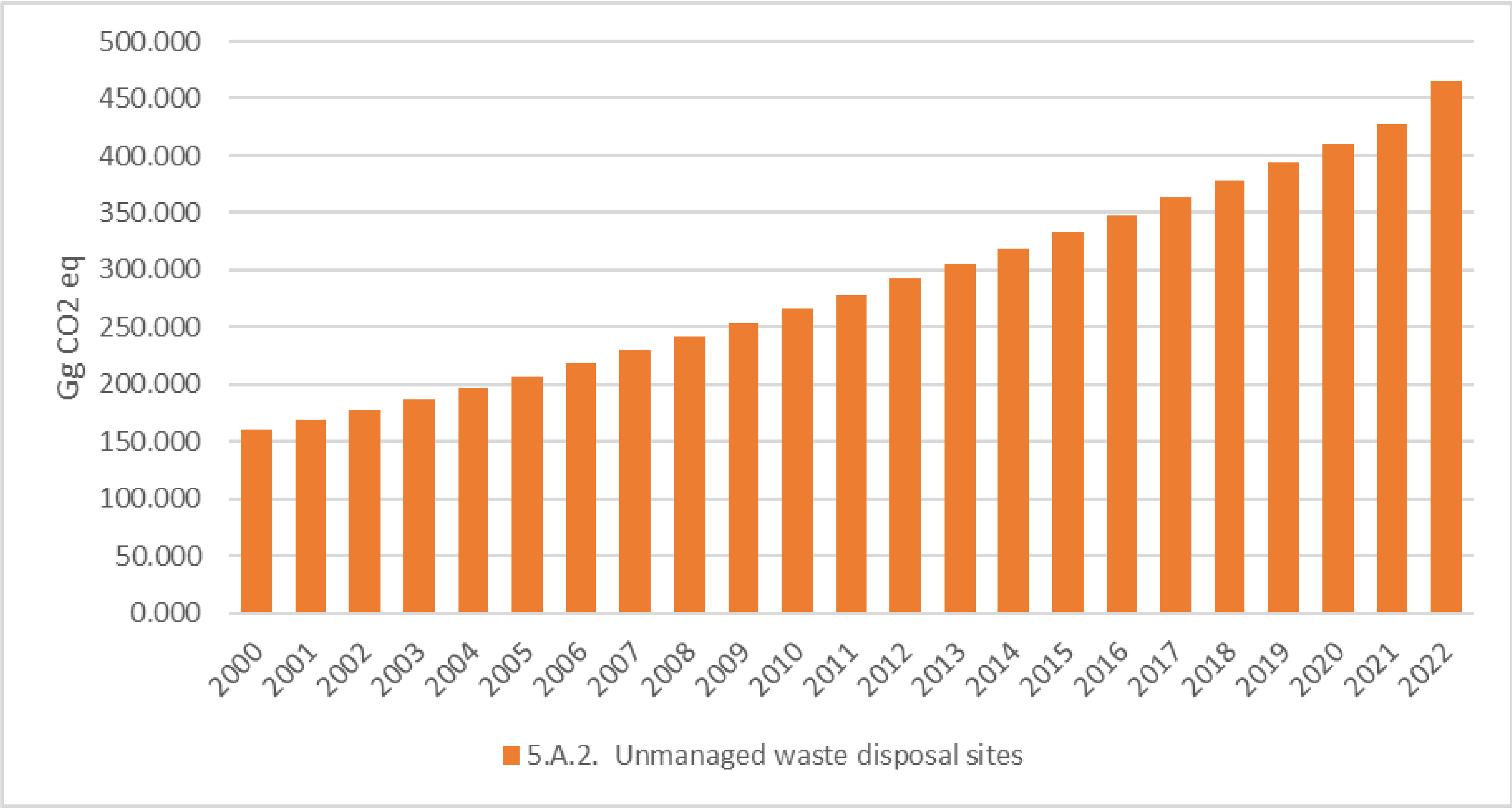

Figure 7-2: Emissions from Solid Waste Disposal (Gg CO_2 eq)

7.2.2. Methodological issues

7.2.2.1. Choice of method (include assumptions and the rationale for selection)

The IPCC Waste Model based on the First Order Decay (FOD) method given in the 2006 IPCC Guidelines was used to estimate CH_4 emission from the degradable organic component (degradable organic carbon, DOC) in SWDS. The CH_4 emissions from solid waste disposal for a single year were estimated using Equations 3.1 to 3.6 in Chapter 3 of Volume 5 of the 2006 IPCC Guidelines. CH_4 is generated as a result of the degradation of organic material under anaerobic conditions. The amount of CH_4 oxidized in the cover of the SWDS or recovered for energy or flaring is eliminated from CH_4 generated and then emitted CH_4 from SWDS is calculated. In PNG, CH_4 recovery and oxidation are not implemented and so these factors are regarded as zero in the estimation.

$$CH_4\ Emissions = \left[\sum_i (EF_i \times AD_{i,T}) - R_T\right] \times (1 - OX_T)$$

Where:

CH_4 Emissions:	*=CH_4 emitted in year T, kg CH_4*
EF_i:	*=Emission factor for a biodegradable waste i (dry basis) that is damped into a landfill site without incineration, kg-CH_4/t*
AD_i:	*=Amount of a biodegradable waste i (dry basis) that is damped into a landfill site without incineration and is biodegraded within an inventory year T, t*
T:	*=inventory year*
i:	*=waste category or type/materials*

7.2.2.1. EF, other parameters

Emission factors are defined as the amount of CH_4 [in kg] generated through the decomposition of one ton of biodegradable landfill wastes (dry basis) without incineration. The emission factors are established by the type of biodegradable waste and by the type of landfill site.

All parameters used in the landfill emissions model are determined by the default values from the 2006 IPCC Guidelines. The parameters used in the landfill emissions model include:

- Fraction of degradable organic carbon (DOC);
- CH_4 generation (decomposition) rate constant (k);
- Fraction of DOC actually dissimilated (DOCf): 0.5;
- Methane correction factor (MCF);
- Fraction of methane in landfill gas produced: 0.5;
- Time delay from the deposit of waste to start of production of methane gas: set at 6 months;

- CH_4 oxidation factor for managed landfills: 0;
- Amount of recovered landfill gas: 0.

A few of the above parameters are discussed in the sub-sections below

Table 7-7: Parameters used for emission estimation from SWDS

Item	Waste type	Value	Unit	Sources
DOC content in % of wet waste	Paper	0.4	fraction	Table 2.4, chp.2, vol.5, 2006IPCC GL
	Textiles	0.24	fraction	
	Food waste	0.15	fraction	
	Wood and straw	0.43	fraction	
	Garden and park	0.2	fraction	
	Disposable nappies	0.24	fraction	
DOC_f		0.5	fraction	p.3.13, chp.3, vol.5, 2006IPCC GL
MCF	Unmanaged – deep	0.8	fraction	Table 3.1, chp.3, vol.5, 2006IPCC GL
	Unmanaged – shallow	0.4	fraction	
Methane generation constant (k)	Paper	0.07	fraction	Moist and wet tropical, table 3.3, chp.3, vol.5, 2006IPCC GL
	Textiles	0.07	fraction	
	Food waste	0.4	fraction	
	Wood and straw	0.035	fraction	
	Garden and park	0.17	fraction	
	Disposable nappies	0.17	Fraction	

a. DOC, DOCf and k-value, fraction of methane in landfill gas produced

No country-specific study is available, the IPCC default values relevant to “Oceania or other Oceania” provided in the IPCC guidelines were used.

b. Methane Correction Factor (MCF)

In PNG, all disposal sites are open-air and the sites are classified as unmanaged. The GHG emissions from SWDS for the inventory time series up to the year 2022 for BTR1 are estimated under the share of 100% unmanaged-deep (MCF = 0.8) for big cities and 100% unmanaged-shallow (MCF = 0.4) for the rural area for whole time series.

c. Decay Time

The IPCC default delay time of six months is applied in accordance with the IPCC Waste Model as methane generation does not begin immediately upon deposition of the waste. On average, waste landfilled in year x starts to contribute to methane emissions in year x+1.

d. Oxidation Factor (OX)

The oxidation factor is set as 0. Methane generated by the decomposition of organic carbon is not oxidized before the gas reaches the surface of the landfill.

e. Methane Recovery

No methane recovery is undertaken at the landfill sites in PNG

7.2.2.2. AD (include uncertainties and time-series consistency)

Section 7.1.3.1 to 7.1.3.3 outlines the amount of landfill estimated for MSW in big cities and rural cities since 1950 by types of waste from the total MSW generation, the share of waste type of MSW, and the share of waste treatment method goes to SWDS. The table below shows an overview of waste landfilled.

Table 7-8: Amount of waste landfilled and degradable organic carbon content

Year	Amount of landfill (kt)				
	MSW Big cities	MSW Rural area	ISW	Sludge	Total
1950	3	8	NE	NE	11
1955	6	12	NE	NE	18
1960	9	15	NE	NE	24
1965	13	18	NE	NE	31
1970	17	21	NE	NE	38
1975	25	30	NE	NE	55
1980	34	39	NE	NE	73
1985	45	50	NE	NE	95
1990	57	63	NE	NE	120
1995	75	83	NE	NE	158
2000	95	107	NE	NE	202
2005	124	138	NE	NE	261
2010	155	172	NE	NE	328
2015	190	210	NE	NE	401
2017	205	227	NE	NE	432
2019	221	243	NE	NE	464
2022	473	361	NE	NE	834

7.2.3. Category-specific recalculations, if applicable

No recalculation was made for this reporting cycle.

7.2.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

a. Change in MCF after 2018

Baruni disposal site in Port Moresby has improved and operated as semi-aerobic landfill site now. The GHG emissions since 2018 must reflect this improvement by changing MCF.

b. Improvement of MSW Estimation

The current estimate is based on the data collected in Port Moresby and some expert judgments. Collecting data from the other cities and towns on the waste composition and/or waste treatment types may lead to more accurate emission estimation from SWDS.

c. Resolving NE for ISW and Sludge

The solid waste generated from industry and sludge from wastewater treatment that goes to landfills is not estimated. PNG will try to collect the relevant data.

7.3. Biological Treatment of Solid Waste (CRT Category 5.B)

Composting and anaerobic digestion of organic waste, such as food waste, garden (yard) and park waste, and sludge are common treatments of waste, which can reduce the volume of the waste material, stabilize the waste, destroy pathogens in the waste material, and produce biogas for energy use.

This category covers CH_4 and N_2O emissions generated during the biological treatment process of solid waste. Where these gases are used for energy, then associated emissions should be reported in the Energy Sector in accordance with the allocation rule of the IPCC Guidelines, but this does not occur at present in PNG. Emissions from biological treatment of wastewater are covered in category 5.D.

The 2006 IPCC guidelines refer to the three biological treatments: composting, anaerobic digestion of organic waste, and mechanical-biological (MB) treatment. In PNG, only composting is implemented and is reported under this category. Anaerobic digestion of solid waste is assumed to be zero as no data is available in PNG, in line with the guidance in the 2006 IPCC Guidelines (page 4.5, step 1 of section 4.1, chapter 4, Volume 5).

The estimated emissions from the biological treatment of solid waste were about 8.24 Gg CO_2 eq in 2022, and the trend is shown in the Table 7-9 and Figure 7-3 below.

Table 7-9: Emissions from Biological Treatment of Solid Waste

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
5.B.1.	Composting	Gg CH4	0.072	0.088	0.096	0.116	0.124	0.144	0.148	0.152	0.164	0.168	0.172	0.172	0.172
5.B.2.	Anaerobic digestion at biogas facilities		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Total	Gg CH_4	0.072	0.088	0.096	0.116	0.124	0.144	0.148	0.152	0.164	0.168	0.172	0.172	0.172
5.B.1.	Composting	Gg N_2O	0.005	0.007	0.007	0.009	0.009	0.011	0.011	0.011	0.012	0.013	0.013	0.013	0.013
5.B.2.	Anaerobic digestion at biogas facilities		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Total	Gg N_2O	0.005	0.007	0.007	0.009	0.009	0.011	0.011	0.011	0.012	0.013	0.013	0.013	0.013
	Total	Gg CO_2 eq	3.447	4.213	4.596	5.554	5.937	6.894	7.086	7.277	7.852	8.043	8.235	8.235	8.235

NE Not Estimated

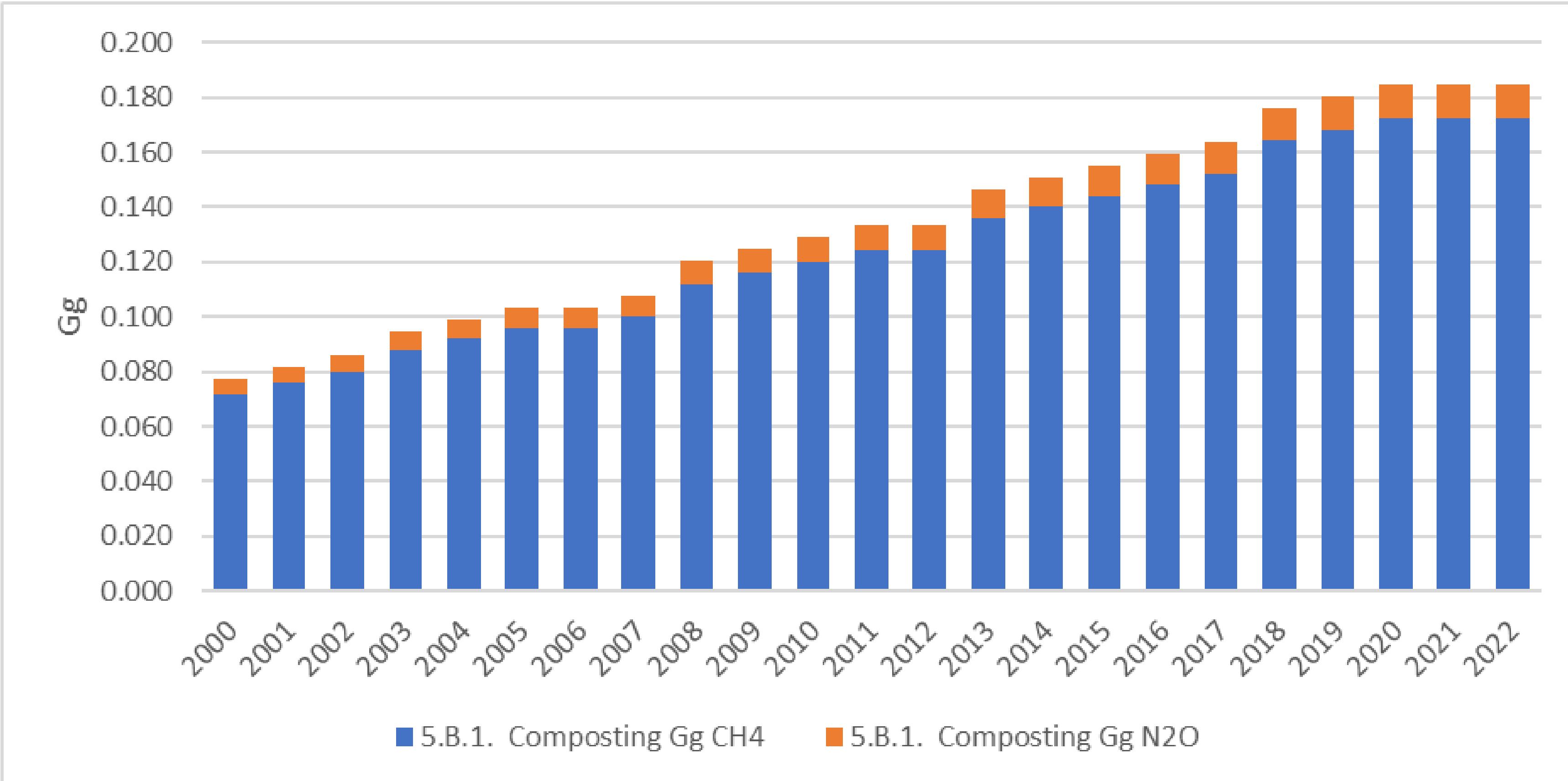

Figure 7-3: Emissions from Biological Treatment of Solid Waste

7.3.1. Composting (CRT Category 5.B.1)

7.3.1.1. **Category description (e.g. characteristics of sources)**

Part of the MSW generated in PNG is composted mainly in the rural areas, and CH_4 and N_2O generated in that process are emitted from composting facilities

7.3.1.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

A Tier 1 method is used to estimate CH_4 and N_2O emissions from composting by applying Equations 4.1 and 4.2 in the 2006 IPCC Guidelines (page 4.5, section 4.1.1, chapter 4, Volume 5). As no CH_4 recovery is implemented in PNG, both CH_4 and N_2O emissions are calculated by the same equation provided below.

$$GHG\ Emissions = M \times EF \times 10^3$$

Where:

GHG Emissions: = total CH_4 or N_2O emissions in inventory year, Gg CH_4 or Gg N_2O

M: = mass of organic waste treated by composting, Gg

EF: = emission factors for composting, g- CH_4/kg waste treated or g – N_2O/kg waste treated

b. EF, other parameters

The default emission factors of composing in Table 4.1 of the 2006 IPCC Guidelines (page 4.6, chapter 4, Volume 5) were used. As AD is represented as wet weight basis, 4 g-CH_4 /kg waste treated and 0.3 g-N_2O/kg waste treated are used for CH_4 EF and N_2O EF respectively

Table 7-10:: Parameters used to estimate emission from the biological treatment of waste

Component of MSW	Dry matter content in % of wet weight	DOC content in % of wet waste	DOC content in % of dry waste	Total carbon content in % of dry weight	Fossil carbon fraction in % of total carbon	Sources
Food	40	15	38	38		Table 2.4, chp.2, vol.5, 2006IPCC GL
Wood	85	50				
Garden and park waste	40	20	49	49	0	

c. AD (include uncertainties and time-series consistency)

The amount of organic waste treated by composting is obtained from the total MSW generation and the ratio of composting used as waste treatment methods, which are 0% for big cities and 10% for rural area (table 7-5). Thus, the emissions from compositing only calculated in rural area. Food, wood and garden and park wastes are classified as the organic wastes relevant to this source, which occupies 60% of total waste generation in rural area (table 7-4) Therefore, 6% (60% x 10%) of solid waste generated in rural area of PNG is assumed to be treated by composting and used as AD for Biological treatment of solid waste (CRT Category 5.B).

7.3.1.3. Category-specific recalculations, if applicable

No recalculation was made for this cycle.

7.3.1.4. Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The issue identified in Solid waste disposal (CRT Category 5.A) (section 7.2.4) is also relevant to Biological treatment of solid waste (CRT Category 5.B) in terms of AD improvement. There is no plan of improvement for equations and EFs.

7.3.2. Anaerobic digestion at biogas facilities (CRT Category 5.B.2)

7.3.2.1. Category description (e.g. characteristics of sources)

Anaerobic digestion at biogas facilities was not included in this reporting cycle due to the lack of data and information.

7.4. Incineration and Open Burning of Waste (CRT Category 5.C)

This category covers CO_2, CH_4 , and N_2O emissions from incineration and open burning of waste without energy recovery. In the 2006 IPCC Guidelines, waste incineration is defined as “the combustion of solid and liquid waste in controlled incineration facilities”, while open burning of waste is explained as “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.

All CH_4 and N_2O emissions from this source are included in the national total, while CO_2 emissions included in the national total are fossil-origin only. Biogenic CO_2 emissions are excluded in the national total as those are already covered in the AFOLU sector. The methods for estimating CO_2, CH_4 and N_2O emissions from incineration and open burning of waste vary because of the different factors that influence emission levels. Estimation of the amount of fossil carbon in the waste burned is the most important factor determining the CO_2 emissions. The non-CO_2 emissions are more dependent on the technology and conditions during the incineration process. In this regard, waste incinerated or open-burned is preferably differentiated by waste type. In the PNG inventory, the amount of waste incinerated or open-burned is examined under MSW, industrial solid waste (ISW), hazardous and clinical waste, sewerage sludge and fossil liquid waste separately, considering the guidance in Chapter 5 of the 2006 IPCC Guidelines.

It is assumed that MSW from big cities is not subject to combustion, while 20% of MSW from Rural Cities and islands is treated by incineration or open burning [table 7-5]. All waste combustion in Rural Cities and islands is assumed as open burning and it's relating CO_2, CH_4 and N_2O emissions are reported in this category.

Regarding ISW, hazardous waste and sewerage sludge, good information on the status of waste incineration is not available and so it is reported as not estimated (NE).

For clinical waste treatment, no official data or statistics is published, in addition no clinical waste management policy has been established in PNG. Based on an interview to some hospitals in PNG, clinical waste is incinerated (usually open-burned) but quantitative data of incineration amount is unavailable for BTR1. Thus, GHG emissions from clinical waste incineration is reported as not estimated (NE).

Fossil liquid waste, including waste oil, is collected by private waste management companies, and exported to other countries and subject to incineration there under proper waste management. Thus, the emissions from fossil liquid waste are not included in the national total of PNG inventory.

7.4.1. Waste incineration (CRT Category 5.C.1)

7.4.1.1. Category description (e.g. characteristics of sources)

Waste incineration by controlled incineration facilities is poorly available in PNG at present. This source is reported as not estimated (NE)

7.4.2. Open burning of Waste (CRT Category 5.C.2)

7.4.2.1. Category description (e.g. characteristics of sources)

A part of MSW in Rural Cities and islands is subject to combustion. All of this combustion is assumed as open-burning. The estimated emissions from open burning were about 42.97 Gg CO_2 eq in 2022, and the trend is shown in Table 7-11 and Figure 7-4 below.

Table 7-11:GHG emissions from the Open burning of waste

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
5.C.1.	Waste Incineration		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.C.2.	Open burning of waste (CO_2)	Gg CO_2	5.752	7.652	7.669	9.578	9.595	11.504	11.513	11.522	13.412	13.421	13.430	13.430	13.430
	Total	Gg CO_2	5.752	7.652	7.669	9.578	9.595	11.504	11.513	11.522	13.412	13.421	13.430	13.430	13.430
5.C.1.	Waste Incineration		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.C.2.	Open burning of waste (CH_4)	Gg CH_4	0.39	0.429	0.5265	0.6175	0.689	0.78	0.7995	0.832	0.8775	0.91	0.9295	0.9295	0.9295
	Total (CH_4)	Gg CH_4	0.390	0.429	0.527	0.618	0.689	0.780	0.800	0.832	0.878	0.910	0.930	0.930	0.930
5.C.1.	Waste Incineration		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.C.2.	Open burning of waste (N_2O)	Gg N_2O	0.00558	0.0063825	0.0075	0.0088575	0.0098025	0.01116	0.011415	0.0118575	0.0125775	0.01302	0.013275	0.013275	0.013275
	Total (N_2O)	Gg N_2O	0.006	0.006	0.008	0.009	0.010	0.011	0.011	0.012	0.013	0.013	0.013	0.013	0.013
	Overall Total	Gg CO_2 eq	18.151	21.355	24.399	29.215	31.485	36.301	36.924	37.960	41.315	42.352	42.974	42.974	42.974

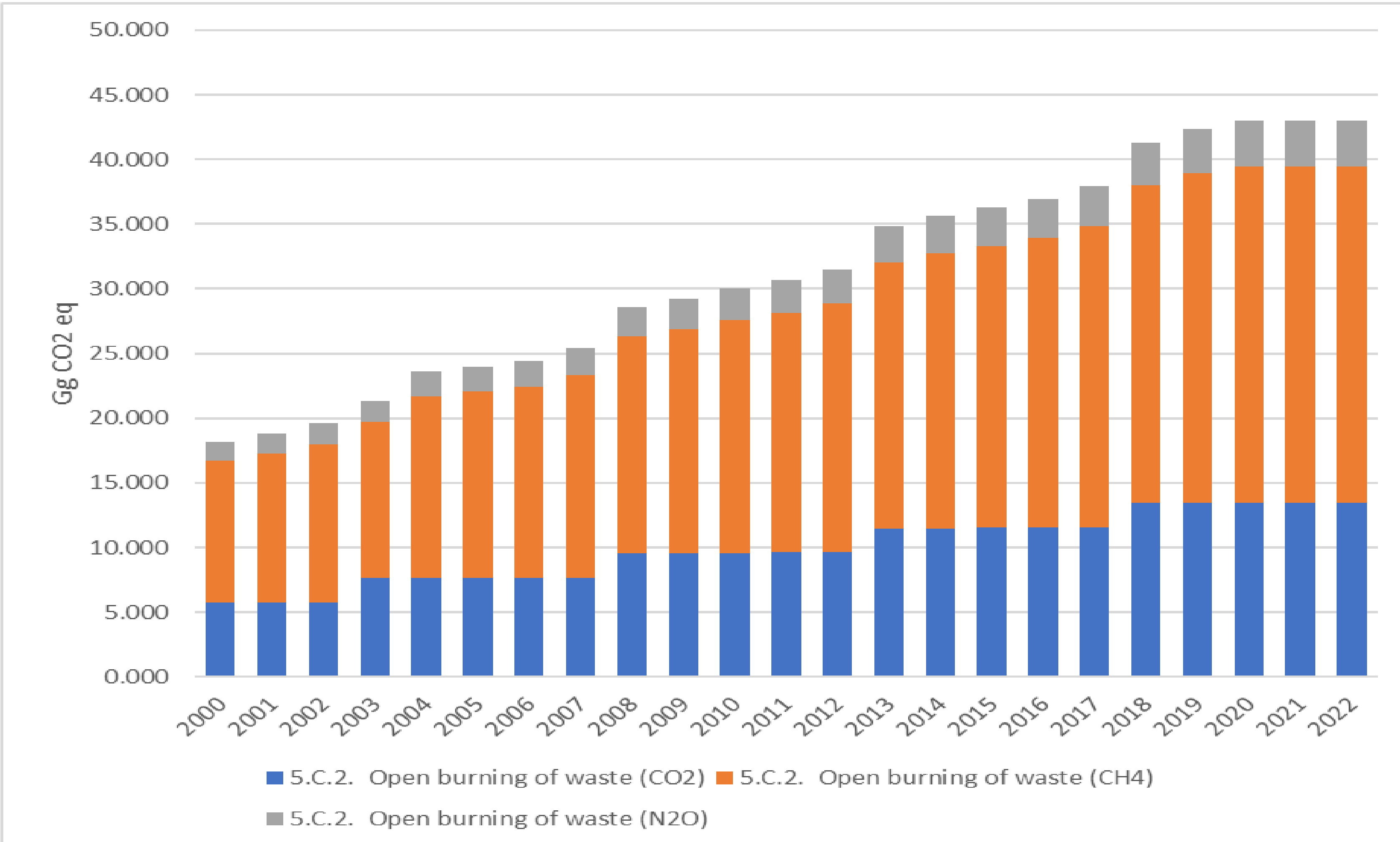

Figure 7-4: GHG emissions from Open burning of waste

7.4.2.2. **Methodology issues**

a. Choice of method (include assumptions and the rationale for selection)

CO_2 Emission

A Tier 1 method is used to estimate CO_2 emissions from open burning by applying Equations 5.2 in the 2006 IPCC Guidelines (page 5.7-5.8, section 5.2.1, chapter 4, Volume 5), considering the available data.

$$GHG\ Emissions = MSW \times \sum_j (WF_i \times dm_j \times CF_j \times FCF_j \times OF_j) \times \frac{44}{12}$$

Where:

CO_2 Emissions: = CO_2 emissions in inventory year, Gg/yr

MSW: = total amount of municipal solid waste as wet weight open-burned, Gg/yr

WF_j: = fraction of waste type/material of component *j* in the MSW (as wet waste open burned)

$dm_{j:}$ = dry matter content in the component *j* of the MSW open-burned, (fraction)

$CF_{J:}$ = fraction of carbon in the dry matter (i.e., carbon content) of component *j*

$OF_{J:}$ = oxidation factor, (fraction)

44/12: = Conversion factor from C to CO_2

CH_4 and N_2O Emissions

A Tier 1 method is used to estimate CH4 and N2O emissions from open burning by applying Equations 5.4 and 5.5 in the 2006 IPCC Guidelines (page 5.11-5.15, section 5.2.2 and 5.2.3, chapter 5, Volume 5). Both CH4 and N2O emissions are calculated by the same equation provided below.

$$GHG\ Emissions = IW \times EF \times 10^{-6}$$

Where:

GHG Emissions: = total CH_4 or N_2O emissions in inventory year, Gg CH_4 or Gg N_2O

IW: = amount of open-burned waste, Gg/yr

EF: = emission factors for open-burned, kg-CH_4/Gg of waste or kg-N_2O/Gg of waste

10^6: = conversion factor from kilogram to gig gram

b. EF, other parameters

CO_2 Emission

The default oxidation factor (ratio of oxidated carbon in % of carbon input) of 58% provided in the 2006 IPCC Guidelines (Table 5.2) is used.

CH_4 Emission

As no country-specific data available, default CH_4 emission factor of 6500 g CH_4 / t MSW wet weight for open burning in the 2006 IPCC Guidelines (section 5.4.2) is used.

N_2O Emission

As no country-specific data available, default N_2O emission factor of 150 g N_2O/ t MSW dry weight for open burning of MSW in the 2006 IPCC Guidelines (Table 5.6, section 5.4.3) is used.

c. AD (include uncertainties and time-series consistency)

CO_2 Emissions

The amount of MSW open-burned is obtained from the total MSW generation and the ratio of open burning used as waste treatment methods, which are 0% for big cities and 20% for rural area (table 7-4). Thus, the emissions from open burning only calculated in rural area.

Waste contains biogenic-carbon and fossil-origin carbon. Only CO_2 emissions from fossil-origin carbon are added to the waste sector's emission total as well as national total emissions. Thus, the amount of fossil-origin carbon is calculated by using the equation referred above and the parameters of dry matter content, total carbon content, fossil carbon fraction of MSW are as outlined in the table below. All parameters are based on the default values provided in the 2006 IPCC Guidelines.

Table 7-12: Parameters used in estimating AD for open-burning

Item	**Waste component of MSW**									
	Paper	**Textile**	**Food**	**Wood**	**Garden & Park**	**Nappies**	**Rubber & Leather**	**Plastic**	**Metal &Glass**	**other**
Dry matter content (%)	90	80	40	85	40	40	84	100	100	90
Carbon Content (%)	46	50	38	50	49	70	67	75	-	3
Fossil carbon fraction (%)	1	20	0	0	0	10	20	100	-	100

CH_4 Emission

Total amount of MSW open-burned is the AD of this estimation. As EF for CH_4 emission is given by wet weight basis, the total generated MSW goes to open-burning is used.

N_2O Emission

Total amount of MSW open-burned is the AD of this estimation. As EF for N_2O emission is given by dry-weight basis, generated MSW goes to open-burning (represented as wet basis) are converted to dry-weight basis by using the default dry matter content (%) provided in the 2006 IPCC guidelines. The table below outlines the parameters that were used.

Table 7-13: AD fir open burning (MSM)

Year	MSW burned (kt)			Other Waste Burned
	Total (wet)	Total (dry)	Fossil origin carbon	
2000	61	38	3	NE
2001	64	40	3	NE
2002	68	42	3	NE
2003	71	44	3	NE
2004	75	47	3	NE
2005	79	49	4	NE
2006	82	51	4	NE
2007	86	54	4	NE
2008	90	56	4	NE
2009	94	58	4	NE
2010	98	61	4	NE
2011	103	64	5	NE
2012	107	66	5	NE
2013	111	69	5	NE
2014	116	72	5	NE
2015	120	75	5	NE
2016	125	77	6	NE
2017	128	80	6	NE
2018	134	83	6	NE
2019	140	86	6	NE
2020	144	89	6	NE
2021	196	121	9	NE
2022	206	128	9	NE

7.4.2.3. **Category--specific recalculations, if applicable**

Recalculation of CO2 emission was done for this cycle. The FCF value for paper used in estimating CO2 emission was not correct in BUR2, hence the CO2 emission was overestimated. The mistake was identified and correct FCF value was used for the recalculation.

7.4.2.4. **Category--specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

The issue identified in Solid waste disposal (CRT Category 5.A) (section 7.2.4) is also relevant to Incineration and Open Burning of Waste (CRT Category 5.C) in terms of AD improvement. When the data relevant to this source especially for industrial waste, hazardous waste and clinical waste will be available, this source will be estimated.

7.5. Wastewater Treatment and Discharge (CRT Category 5.D)

Wastewater can be a source of CH_4 when treated or disposed anaerobically. It can also be a source of N_2O emissions. CO_2 emissions from wastewater are not considered in the IPCC Guidelines because these are of biogenic origin and should not be included in national total emissions. Wastewater originates from a variety of domestic, commercial and industrial sources and may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated nearby or via an outfall. Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only (IPCC 2006).

The extent of CH_4 production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system (IPCC 2006). The amount of degradable organic material in the wastewater is shown as the Biochemical Oxygen Demand (BOD) or Chemical Oxygen Demand (COD). The amount of CH_4 emitted to atmosphere is considered from maximum capacity of CH_4 produce per unit of BOD or COD and the faction treated anaerobically by type of treatment system shown as a parameter of MCF (methane conversion factor).

N_2O is associated with the degradation of nitrogen components in the wastewater. N_2O emissions can occur as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea. As direct emissions from nitrification and denitrification at wastewater treatment plants may be considered as a minor source and guidance to estimate this source is applied only for countries that predominantly have advanced centralized wastewater treatment plants with nitrification and denitrification steps. In the PNG inventory, only the standard estimation of N_2O emissions from effluent is applied.

Wastewater collecting systems exist in some main cities in PNG, including Port Moresby, Lae, Madang, Alotau, Kimbe, Popotendetta, Mt Hagen and Kundiawa. These systems are operated by the public corporation, Water PNG Ltd. These systems cover domestic, commercial as well as industrial wastewater generated in the central part of the cities. Uncollected wastewater is not regulated by public corporation. Uncollected wastewater generated in suburb area is usually treated by septic tank, those in village are discharged as untreated. Based on the expert judgement, PNG’s wastewater treatments are classified into “treated - septic system”, “untreated- sea, lake and river discharge” and “untreated – pit toilet”. In addition to this, “Centralized, aerobic treatment plant” and “anaerobic shallow lagoon” system is used in Port Moresby. The figure below shows the overview of the wastewater treatment systems and discharge pathways of Port Moresby based on Figure 6.1 of the 2006 IPCC Guidelines.

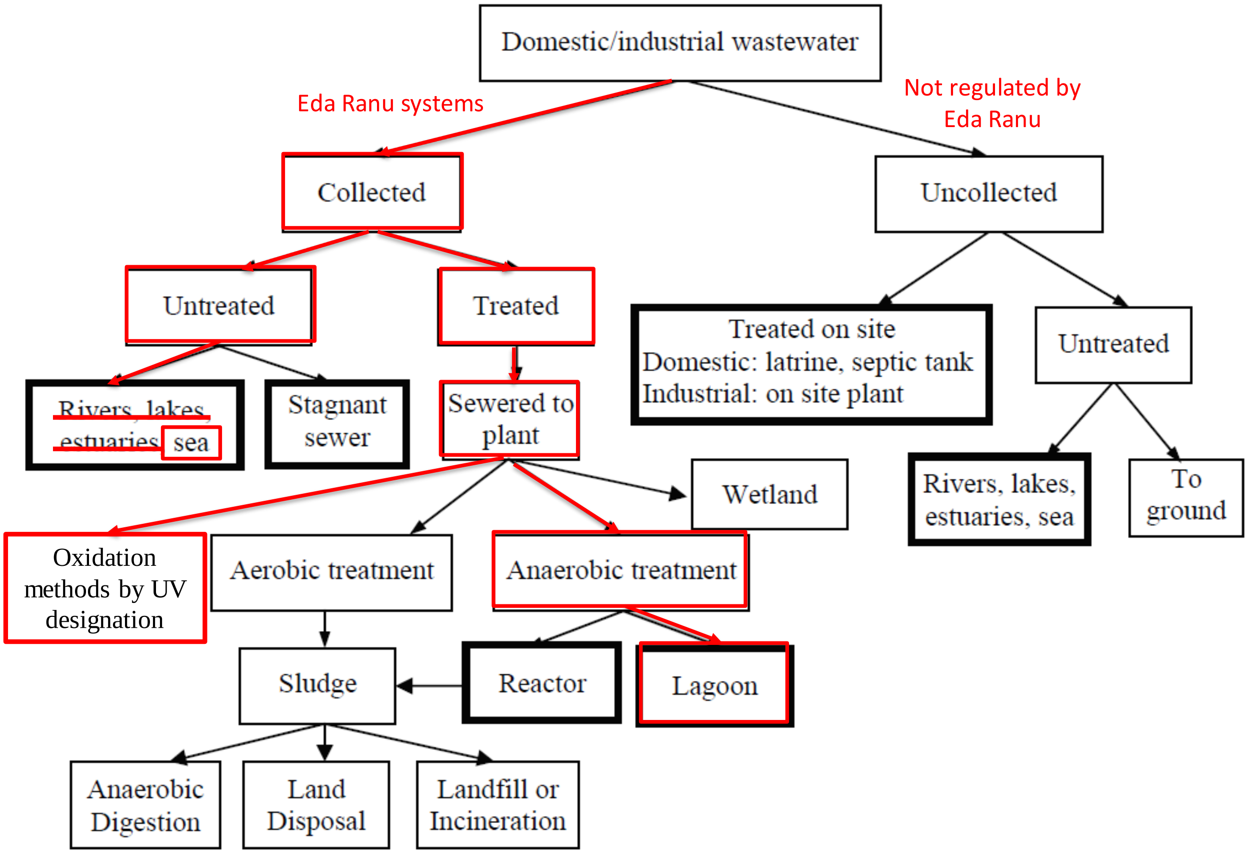

Figure 7-5: Overview of wastewater treatment systems and discharge pathways of Port Moresby

The estimated emissions from wastewater treatment are about 1,092.51 Gg CO_2 eq in 2022, and the trend is shown in the Table 7-14 and Figure 7-6 below.

Table 7-14: Emissions from Waste Water Treatment and Discharge

CRT Category		Unit	2000	2003	2006	2009	2012	2015	2016	2017	2018	2019	2020	2021	2022
5.D.1.	Domestic wastewater	Gg CH_4	11.544	12.808	14.073	15.337	16.601	17.866	18.287	18.709	18.960	19.378	19.796	25.974	30.570
5.D.2.	Industrial wastewater		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.D.3.	Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	Gg CH_4	11.544	12.808	14.073	15.337	16.601	17.866	18.287	18.709	18.960	19.378	19.796	25.974	30.570
5.D.1.	Domestic wastewater	Gg N_2O	0.321	0.371	0.407	0.444	0.482	0.517	0.531	0.541	0.554	0.566	0.580	0.758	0.893
5.D.2.	Industrial wastewater		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.D.3.	Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	Gg N_2O	0.321	0.371	0.407	0.444	0.482	0.517	0.531	0.541	0.554	0.566	0.580	0.758	0.893
	Total	Gg CO_2 eq	408.285	456.853	501.950	547.047	592.492	637.240	652.657	667.305	677.597	692.525	707.872	928.233	1092.506

NE Not Estimated NO Not Occuring

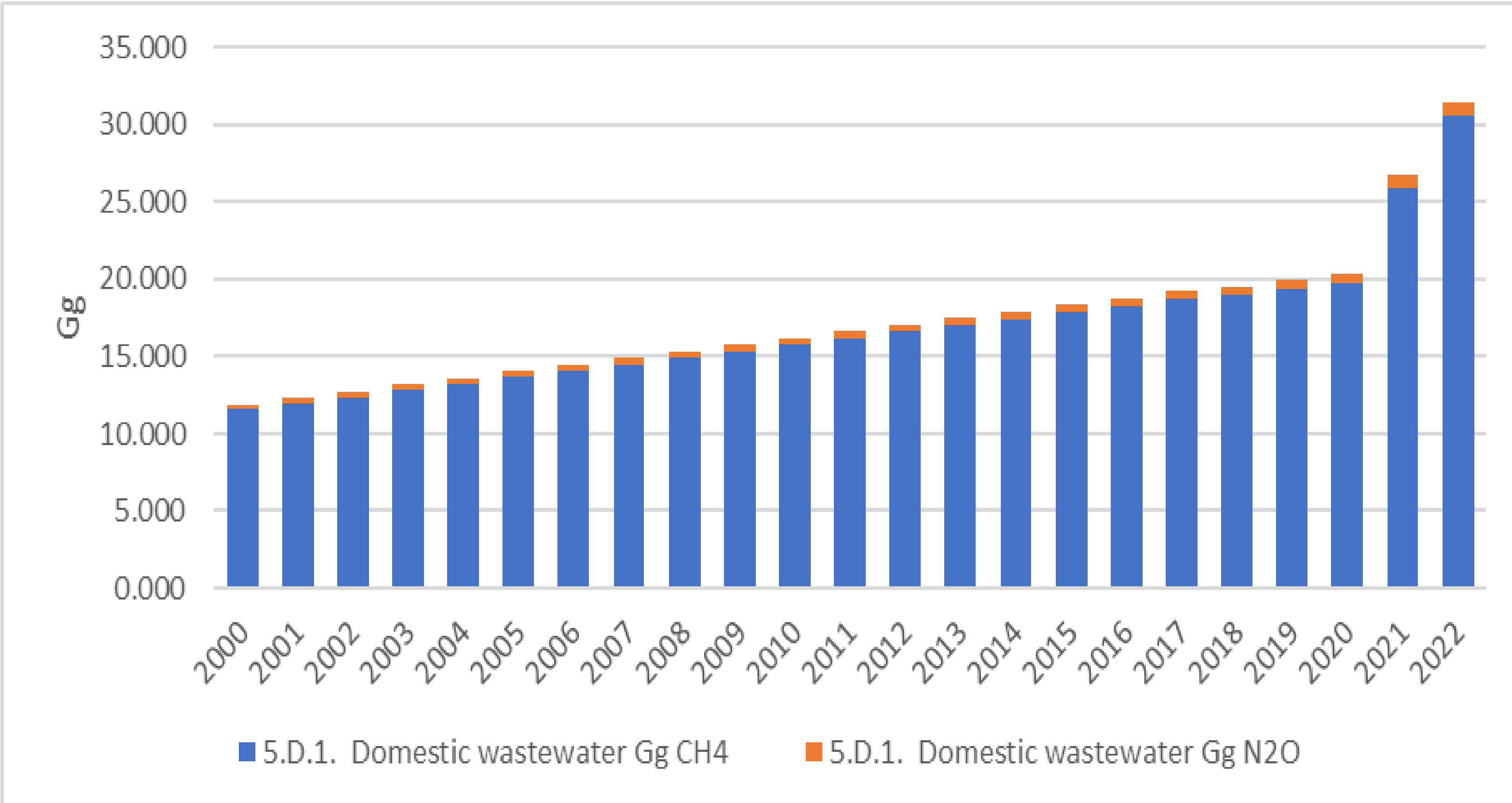

Figure 7-6: Emissions from Waste Water Treatment and Discharge

7.5.1. Domestic Wastewater Treatment and Discharge

7.5.1.1. **Category description (e.g. characteristics of sources)**

This section covers CH_4 and N_2O emissions from domestic wastewater treatment and discharge. As no official data of the amount of generated domestic wastewater is available, total domestic wastewater amount is estimated by population-based assumption as suggested by the IPCC Guidelines. The degree of treatment utilisation is not separated by income level based on the suggestion from the relevant stakeholder of wastewater in PNG.

7.5.1.2. **Methodological issues**

a. Choice of method (include assumptions and the rationale for selection)

CH_4 Emission

A Tier 1 method is used to estimate CH_4 emissions from domestic wastewater treatment and discharge based on Equations 6.1. Information on how sludge is treated is not available, sludge separation is not considered. In addition, CH_4 recovery is assumed to be zero in the case of PNG. The estimation is implemented by the equation below.

$$CH_4 Emissions = T_j \times EF_j \times (TOW - S)$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr

TOW = total organics in wastewater in inventory year, kg BOD/yr

S = *organic component removed as sludge in inventory year, kg BOD/yr*

Tj = degree of utilization of treatment/discharge pathway or system, *j*

j = each treatment /discharge pathway or system

EFj = emission factor, kg CH_4 / KG BOD

b. EF, other parameters

CH_4 Emission

The emission factor is established as a function of the maximum CH_4 producing potential (Bo) and the methane correction factor (MCF) for the wastewater treatment and discharge system. The default values from the 2006 IPCC Guidelines are used for all parameters. Bo is 0.6 kg CH_4 /kg BOD (Table 6.2 of the 2006 IPCC Guidelines), MCFs for Centralized, aerobic treatment plant, Anaerobic shallow lagoon, Septic tank, Sea-river-and-lake discharge and Pit toilet (Latrine for small family) are 0, 0.2, 0.5, 0.1 and 0.1, respectively (table 6.3 of the 2006 IPCC Guidelines).

N_2O Emission

The default IPCC emission factor of 0.005 kg N_2O-N/kg N is used for N_2O EF from domestic wastewater nitrogen effluent.

c. AD (include uncertainties and time-series consistency)

CH_4 Emission

The activity data for this source category is the total amount of organically degradable material in the wastewater (TOW). This parameter is a function of human population and BOD generation per person. It is expressed in terms of BOD (IPCC 2006). Country-specific information was not available such as amount of domestic wastewater treated and BOD of inlet wastewater to plants. Thus, TOW is estimated by default method of Equation 6.3 below.

$TOW=P\times BOD\times 0.001\times 1\times Day$

Where:

TOW: = total organic in wastewater in inventory year, kg BOD/kg

P: = country population in inventory year, (person),

BOD: = country – specific per capita BOD in inventory year, g/person/day

0.001: = conversion from grams BOD to kg BOD

I: = correction factor for additional industrial BOD discharge into sewers

Day: = number of days per year, 365 or 366

Time series data of the country's population is taken from the PNG Census 2011 which is consistently used for all waste categories. BOD is based on the default value of Oceania (60 g/person/day, Table 6.4, p 6.14, chp6, Vol 5, 2006GL). The stakeholders of wastewater in PNG noted that this default is considered not far from the one in PNG. Correction factor I is based on the default value in the IPCC guidelines (p 6.14, chp6, Vol 5, 2006GL). 1.25 is used for both wastewaters collected by Water PNG Ltd and other wastewater uncollected. The detailed information on utilisation of treatment/discharge pathway or system in PNG does not exist in PNG, thus the degree of this was assumed based on fraction of population by income group using these systems.

Papua New Guinea is a low middle-income country. According to PNG National Census, the majority (88%) of the population live in the rural areas while 12 % live in the urban areas.

Thus, BTR divided the type of treatment system or pathway based on each income group using these systems. In rural areas of PNG, it was assumed that 60 % of the population use pit toilet and 40 % use rivers, lakes and seas. In urban areas (low-income urban) it was assumed that 65% of the population use septic system and 35 % anaerobic shallow lagoon.

The share of utilisation of treatment/ discharge in PNG improved based on information provided from two public corporation, Water PNG and Eda Ranu. In 2018, Joyce Bay sewerage treatment plant (STP) started operation and wastewater generated in coastal area of Port Moresby goes to this plant. The share of new STP (5%) was subtracted from “anaerobic shallow lagoon” but this started from 2018.

Industrial wastewater amount is not separately estimated and implicitly covered by factor “I” in case which locate urban area and connected to the domestic wastewater treatment systems in the eight cities.

The share of utilisation of treatment/discharge pathway or system in PNG for BTR estimation is show in the table below, which are assumed from the fraction of population by income group using each system.

Table 7-15: The share of utilization of treatment/discharge pathway or system in PNG

Population income group	Fraction of population by income group	Type of treatment system/discharge pathway	Degree of utilization of treatment/discharge pathway or system (j) for each income group fraction (i), Ti, j	
			2000-2017	2018-2022
Rural	0.88	Pit Toilet	0.60	0.60
		Rivers, lakes, sea	0.40	0.40
Urban low income	0.12	Septic system	0.65	0.65
		Centralized, aerobic treatment plant	0	0.05
		Anaerobic shallow lagoon	0.35	0.30

N_2O Emission

The activity data of total annual amount of nitrogen in the wastewater effluent is estimated according to the guidance in section 6.3.1.3 and by Equation 6.8 of the 2006 IPCC guidelines as shown below.

$$N_{EFFLUENT} = P \times Protien \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM} - N_{SLUDGE}$$

Where:

$N_{EFFLUENT}$: = total annual amount of nitrogen in the wastewater effluent, kg N/yr

P: = Human population

Protein: = annual per capita protein consumption, kg/person/yr

F_{NPR}: = fraction of nitrogen in protein, default = 0.16,kg N/kg protein

$F_{NON\text{-}CON}$: = factor for non-consumed protein added to the wastewater

$F_{IND\text{-}COM}$: = factor for industrial and commercial co-discharged protein into the sewer system

N_{SLUDGE}: = nitrogen removed with sludge (default = zero), kg N/ yr

The same population data is used. Protein consumption data as time series in a range from 98 to 102 g/person/ day is derived from FAOSTAT (PIF countries). FNPR is established as the default value of 0.16 kg N/kg person (Equation 6.8). FNON-CON and FNON-CON are established from the default values of 1.1 (for developing country) and 1.25, respectively, which referred in the text in section 6.3.1.3. NSLUDGE is set as zero according to Equation 6.8. Country specific data for this calculation was also hardly available in PNG.

7.5.1.3. **Category-specific recalculations, if applicable**

Information on fraction of population by income group is used in the GHG estimation for the first time. Based on this data, CH_4 emission was recalculated and the share of wastewater treatment system used by the income group was updated.

7.5.1.4. **Category-specific planned improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

The issue identified in solid waste disposal (CRT Category 5.A) (section 7.2.4) is also relevant to domestic waste water treatment (CRT Category 5.D.1) in terms of AD improvement.

At the moment, country-specific data such as amount wastewater amount or BOD/COD and Nitrogen load in wastewater are hardly available. But if this data will be available in the future, estimation can be updated and may provide more accurate estimation.

7.5.2. Industrial Wastewater Treatment and Discharge

7.5.2.1. **Category description (e.g. characteristics of sources)**

The main industrial organic wastewater emitters in PNG are food and beverage sector and organic material sector. Some industrial wastewater is connected to the collecting system of domestic and commercial wastewater, but connected and unconnected industries are not identified yet.

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Annex 1: Key Category Assessment

Table A.1.1. Key categories for PNG, Tier 1 methodology, including LULUCF-Level Assessment

IPCC Category Code	IPCC Category	GHG	Emission in 2022 (Gg CO_2 eq)	Absolute emission in 2022 (Gg CO_2 eq)	Level assessment (%)	Cumulative total (%)
3.B.1.a	Forest land Remaining Forest land	CO_2	-24679.0	24679.0	46%	46%
3.B.2.b.v	Other Land converted to Cropland	CO_2	8710.6	8710.6	16%	63%
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH_4	4715.3	4715.3	9%	72%
1A2	Fuel Combustion Activities- Manufacturing Industries and Construction	CO_2	4078.9	4078.9	8%	79%
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO_2	1436.4	1436.4	3%	82%
1A3b	Fuel Combustion Activities- Transport- Road Transport	CO_2	1396.5	1396.5	3%	85%
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH4	1182.4	1182.4	2%	87%
1A1	Fuel Combustion Activities- Energy Industries	CO_2	1137.1	1137.1	2%	89%
3.B.2.a	Cropland Remaining Cropland	CO_2	1004.5	1004.5	2%	91%

IPCC Category Code	IPCC Category	GHG	Emission in 2022 (Gg CO_2 eq)	Absolute emission in 2022 (Gg CO_2 eq)	Level assessment (%)	Cumulative total (%)
4D	Wastewater Treatment and Discharge	CH_4	856.0	856.0	2%	92%
1A4	Fuel Combustion Activities- Other Sectors	CH_4	592.7	592.7	1%	93%
1A4	Fuel Combustion Activities- Other Sectors	CO_2	507.4	507.4	1%	94%
4A	Solid Waste Disposal	CH_4	465.0	465.0	1%	95%

Table A.1.2: Key categories for PNG, Tier 1 methodology, excluding LULUCF-Level Assessment

IPCC Category Code	IPCC Category	GHG	Emission in 2022 (Gg CO_2 eq)	Absolute emission in 2022 (Gg CO_2 eq)	Level assessment (%)	Cumulative total (%)
1B2b	Fugitive Emissions from Fuels - Oil	CH_4	4715.3	4715.3	26%	26%
1A2	Fugitive Emissions from Fuels and Natural Gas - Natural Gas	CO_2	4078.9	4078.9	22%	48%
1B2b	Fuel Combustion Activities- Manufacturing Industries and Construction	CO_2	1436.4	1436.4	8%	56%
1A3b	Fugitive Emissions from Fuels - Oil	CO_2	1396.5	1396.5	8%	64%
1B2a	Fugitive Emissions and Natural Gas - Natural Gas	CH_4	1182.4	1182.4	7%	70%

IPCC Category Code	IPCC Category	GHG	Emission in 2022 (Gg CO_2 eq)	Absolute emission in 2022 (Gg CO_2 eq)	Level assessment (%)	Cumulative total (%)
1A1	Fuel Combustion Activities- Transport- Road Transport	CO_2	1137.1	1137.1	6%	77%
4D	Fugitive Emissions from Fuels - Oil	CH_4	856.0	856.0	5%	81%
1A4	Fugitive Emissions and Natural Gas - Oil"	CH_4	592.7	592.7	3%	85%
1A4	Fuel Combustion Activities- Energy Industries	CO_2	507.4	507.4	3%	87%
4A	Wastewater Treatment and Discharge	CH_4	465.0	465.0	3%	90%
1A3a	Fuel Combustion Activities- Other Sectors	CO_2	404.1	404.1	2%	92%
3A1	Fuel Combustion Activities- Other Sectors	CH_4	250.3	250.3	1%	94%
4D	Solid Waste Disposal	N_2O	236.5	236.5	1%	95%

Table A.1.3: Key categories for PNG, Tier 1 methodology, including LULUCF-Trend Assessment

IPCC Category Code	IPCC Category	GHG	Emission in Base year (Gg CO_2 eq)	Absolute emission in Base year (Gg CO_2 eq)	Emission in Current year (Gg CO_2 eq)	Absolute emission in Current year (Gg CO_2 eq)	% Contribution to Trend	Cumulative total (%)
3.B.1.a	Forest land Remaining Forest land	CO_2	-39234.83	39234.83	-24678.97	24678.97	23%	34%

IPCC Category Code	IPCC Category	GHG	Emission in Base year (Gg CO_2 eq)	Absolute emission in Base year (Gg CO_2 eq)	Emission in Current year (Gg CO_2 eq)	Absolute emission in Current year (Gg CO_2 eq)	% Contribution to Trend	Cumulative total (%)
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	54.84	54.84	4715.27	4715.27	21%	52%
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH_4	3705.05	3705.05	1182.44	1182.44	20%	64%
3.B.2.b.v	Other Land converted to Cropland	CO_2	4882.35	4882.35	8710.58	8710.58	6%	70%
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO_2	14.84	14.84	1436.35	1436.35	6%	77%
1A2	Fuel Combustion Activities- Manufacturing Industries and Construction	CO_2	2211.15	2211.15	4078.88	4078.88	4%	80%
1A1	Fuel Combustion Activities- Energy Industries	CO_2	27.92	27.92	1137.09	1137.09	5%	85%
1A3b	Fuel Combustion Activities- Transport- Road Transport	CO_2	656.95	656.95	1396.50	1396.50	2%	87%

IPCC Category Code	IPCC Category	GHG	Emission in Base year (Gg CO_2 eq)	Absolute emission in Base year (Gg CO_2 eq)	Emission in Current year (Gg CO_2 eq)	Absolute emission in Current year (Gg CO_2 eq)	% Contribution to Trend	Cumulative total (%)
4D	Wastewater Treatment and Discharge	CH_4	323.23	323.23	855.97	855.97	2%	89%
4A	Solid Waste Disposal	CH_4	160.67	160.67	465.00	465.00	1%	90%
2G	Other Product Manufacture and Use	N_2O	0.00	0.00	0.73	0.73	1%	91%
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO_2	217.45	217.45	71.32	71.32	1%	92%
3.B.3.a	Grassland Remaining Grassland	CO_2	323.36	323.36	323.36	323.36	1%	93%
1A4	Fuel Combustion Activities-Other Sectors	CH_4	481.00	481.00	592.75	592.75	1%	94%
4D	Wastewater Treatment and Discharge	N_2O	85.05	85.05	236.53	236.53	1%	94%
3C4	Direct N_2O Emissions from Managed soils	N_2O	79.78	79.78	223.95	223.95	0%	95%

Table A.1.4: Key categories for PNG, Tier 1 methodology, excluding LULUCF-Trend Assessment

IPCC Category Code	IPCC Category	GHG	Emission in Base year (Gg CO_2 eq)	Absolute emission in Base year (Gg CO_2 eq)	Emission in Current year (Gg CO_2 eq)	Absolute emission in Current year (Gg CO_2 eq)	% Contribution to Trend	Cumulative total (%)
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH_4	3705.05	3705.05	1182.44	1182.44	39%	39%
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH_4	54.84	54.84	4715.27	4715.27	29%	68%
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO_2	14.84	14.84	1436.35	1436.35	9%	77%
1A1	Fuel Combustion Activities-Energy Industries	CO_2	27.92	27.92	1137.09	1137.09	7%	84%
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO_2	217.45	217.45	71.32	71.32	2%	86%
1A4	Fuel Combustion Activities-Other Sectors	CH_4	481.00	481.00	592.75	592.75	2%	89%
1A4	Fuel Combustion	CO_2	404.45	404.45	507.36	507.36	2%	90%

IPCC Category Code	IPCC Category	GHG	Emission in Base year (Gg CO_2 eq)	Absolute emission in Base year (Gg CO_2 eq)	Emission in Current year (Gg CO_2 eq)	Absolute emission in Current year (Gg CO_2 eq)	% Contribution to Trend	Cumulative total (%)
	Activities-Other Sectors							
1A2	Fuel Combustion Activities-Manufacturing Industries and Construction	CO_2	2211.15	2211.15	4078.88	4078.88	2%	92%
2G	Other Product Manufacture and Use	N_2O	0.00	0.00	0.73	0.73	2%	94%
4D	Wastewater Treatment and Discharge	CH_4	323.23	323.23	855.97	855.97	1%	95%

Annex II: Uncertainty Assessment

Tier 1 method and approach 1 as outlined in Chapter 3 of Volume 1 of the 2006 IPCC Guidelines was used for the uncertainty assessment. The result of the uncertainty analysis shows that the overall or total uncertainty of PNG's NGHGI is 3.53 % with trend uncertainty of 0.77 % .

Table A.2: Uncertainty assessment

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
1A1	Fuel Combustion Activities- Energy Industries	CO_2	27.92	1,137.09	5%	8%	9%	0.000708753	0.05	0.0	0.0037	0.00344	0.00002579
1A1	Fuel Combustion Activities- Energy Industries	CH_4	0.03	0.67	5%	172%	172%	8.62098E-08	0.00	0.0	0.0000	0.00000	0.00000000
1A1	Fuel Combustion Activities- Energy Industries	N_2O	0.06	0.78	5%	212%	212%	1.76695E-07	0.00	0.0	0.0001	0.00000	0.00000001
1A2	Fuel Combustion	CO_2	2,211.15	4,078.88	5%	6%	8%	0.006813058	0.19	0.2	0.0117	0.01232	0.00028784

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
	Activities-Manufacturing Industries and Construction												
1A2	Fuel Combustion Activities-Manufacturing Industries and Construction	CH_4	2.33	4.41	5%	210%	210%	5.59173E-06	0.00	0.0	0.0004	0.00001	0.00000018
1A2	Fuel Combustion Activities-Manufacturing Industries and Construction	N_2O	4.22	8.10	5%	210%	210%	1.88592E-05	0.00	0.0	0.0008	0.00002	0.00000062
1A3a	Fuel Combustion Activities-Transport-Civil Aviation	CO_2	218.53	404.13	5%	4%	7%	4.5655E-05	0.02	0.0	0.0008	0.00122	0.00000212

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
1A3a	Fuel Combustion Activities-Transport-Civil Aviation	CH_4	0.04	0.08	5%	100%	100%	4.10789E-10	0.00	0.0	0.0000	0.00000	0.00000000
1A3a	Fuel Combustion Activities-Transport-Civil Aviation	N_2O	1.62	3.00	5%	150%	150%	1.3228E-06	0.00	0.0	0.0002	0.00001	0.00000004
1A3b	Fuel Combustion Activities-Transport-Road Transport	CO_2	656.95	1,396.50	5%	3%	6%	0.000439205	0.06	0.1	0.0020	0.00422	0.00002170
1A3b	Fuel Combustion Activities-Transport-Road Transport	CH_4	3.76	5.71	5%	245%	245%	1.27601E-05	0.00	0.0	0.0007	0.00002	0.00000044
1A3b	Fuel Combustion Activities-	N_2O	8.76	18.95	5%	210%	210%	0.000103647	0.00	0.0	0.0018	0.00006	0.00000336

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
	Transport-Road Transport												
1A3d	Fuel Combustion Activities-Transport-Water borne Navigation	CO_2	12.96	19.44	5%	4%	7%	1.07623E-07	0.00	0.0	0.0000	0.00006	0.00000001
1A3d	Fuel Combustion Activities-Transport-Water borne Navigation	CH_4	0.03	0.05	5%	50%	50%	4.00577E-11	0.00	0.0	0.0000	0.00000	0.00000000
1A3d	Fuel Combustion Activities-Transport-Water borne Navigation	N_2O	0.09	0.13	5%	140%	140%	2.27653E-09	0.00	0.0	0.0000	0.00000	0.00000000
1A4	Fuel Combustion Activities-	CO_2	404.45	507.36	5%	10%	11%	0.000222328	0.02	0.0	0.0025	0.00153	0.00000881

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
	Other Sectors												
1A4	Fuel Combustion Activities-Other Sectors	CH_4	481.00	592.75	5%	170%	170%	0.066505663	0.03	0.0	0.0489	0.00179	0.00239425
1A4	Fuel Combustion Activities-Other Sectors	N_2O	62.87	77.00	5%	214%	214%	0.001774444	0.00	0.0	0.0080	0.00023	0.00006394
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO_2	217.45	71.32	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH_4	3,705.05	1,182.44	0%	0%	0%	0	0.08	0.1	0.0000	0.00000	0.00000000

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
1B2a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	N_2O	0.86	0.28	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO_2	14.84	1,436.35	0%	0%	0%	0	0.06	0.1	0.0000	0.00000	0.00000000
1B2b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH_4	54.84	4,715.27	0%	0%	0%	0	0.20	0.2	0.0000	0.00000	0.00000000
1B2b	Fugitive Emissions from Fuels - Oil and Natural	N_2O	0.00	0.30	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
	Gas - Natural Gas												
2D	Non-Energy Products from Fuels and Solvent Use	CO_2	0.82	1.75	10%	0%	10%	1.99656E-09	0.00	0.0	0.0000	0.00001	0.00000000
2F	Product Uses as Substitutes for Ozone Depleting Substances	HFC	-	142.69	0%	0%	0%	0	0.01	0.0	0.0000	0.00000	0.00000000
2G	Other Product Manufacture and Use	N_2O	0	0.73	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
3A1	Enteric Fermentation	CH_4	194.76	250.26	0%	0%	0%	0	0.01	0.0	0.0000	0.00000	0.00000000
3A2	Manure Management	N_2O	10.43	13.39	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
3A2	Manure Management	CH_4	161.56	208.34	0%	0%	0%	0	0.01	0.0	0.0000	0.00000	0.00000000

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
3.B.1.a	Forest land Remaining Forest land	CO_2	-39,234.83	-24,678.97	43%	23%	49%	9.428708723	1.31	1.1	0.3040	0.63778	0.49914471
3.B.2.a	Cropland Remaining Cropland	CO_2	1,004.55	1,004.55	2%	3%	4%	0.000102691	0.05	0.0	0.0015	0.00149	0.00000461
3.B.2.b.v	Other Land converted to Cropland	CO_2	4,882.35	8,710.58	3%	77%	77%	2.929618115	0.41	0.4	0.3130	0.01763	0.09827220
3.B.3.a	Grassland Remaining Grassland	CO_2	323.36	323.36	2%	9%	9%	5.74567E-05	0.02	0.0	0.0014	0.00048	0.00000226
3.B.5.b.v	Other Land converted to Settlements	CO_2	-	43.93	1%	28%	28%	1.00489E-05	0.00	0.0	0.0005	0.00003	0.00000028
3C1	Biomass Burning	CH_4	359.73	255.61	13%	71%	72%	0.002242557	0.01	0.0	0.0096	0.00205	0.00009645
3C1	Biomass Burning	N_2O	100.14	71.15	13%	28%	31%	3.14095E-05	0.00	0.0	0.0010	0.00057	0.00000141
3C4	Direct N_2O Emissions from	N_2O	79.78	223.95	0%	0%	0%	0	0.01	0.0	0.0000	0.00000	0.00000000

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
	Managed soils												
3C5	Indirect N2O Emissions from Managed soils	N_2O	26.90	61.89	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
3C6	Indirect N2O Emissions from Manure Management	N_2O	4.84	6.21	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
3D1	Harvested Wood Products	CO_2		-	0%	0%	0%	0	-	-	0.0000	0.00000	0.00000000
4A	Solid Waste Disposal	CH_4	160.67	465.00	0%	0%	0%	0	0.02	0.0	0.0000	0.00000	0.00000000
4B	Biological Treatment of Solid Waste	CH_4	2.02	4.82	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
4B	Biological Treatment of Solid Waste	N_2O	1.43	3.42	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
4C	Incineration and Open Burning of Waste	CO_2	5.75	13.43	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
4C	Incineration and Open Burning of Waste	CH_4	10.92	26.03	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
4C	Incineration and Open Burning of Waste	N_2O	1.48	3.52	0%	0%	0%	0	0.00	0.0	0.0000	0.00000	0.00000000
4D	Wastewater Treatment and Discharge	CH_4	323.23	855.97	0%	0%	0%	0	0.04	0.0	0.0000	0.00000	0.00000000
4D	Wastewater Treatment and Discharge	N_2O	85.05	236.53	0%	0%	0%	0	0.01	0.0	0.0000	0.00000	0.00000000
	Total		-23,405.24	3,909.10			ΣH	12.44				ΣM	0.60

IPCC Category Code	IPCC Category	GHG	Emission in 2000 (Gg CO_2 eq)	Emission in 2022 (Gg CO_2 eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)	Contribution to Variance by Category in Year T	Type A Sensitivity (%)	Type B Sensitivity (%)	Uncertainty in trend in national emissions introduced by emission factor uncertainty (%)	Uncertainty in trend in national emissions introduced by activity data uncertainty (%)	Uncertainty introduced into the trend in total national emissions (%)
						Percentage uncertainty in total inventory		3.53 %			Trend uncertainty		0.77 %