PAPUA NEW GUINEA

National Inventory Report 2000 – 2017

TO

THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

2022

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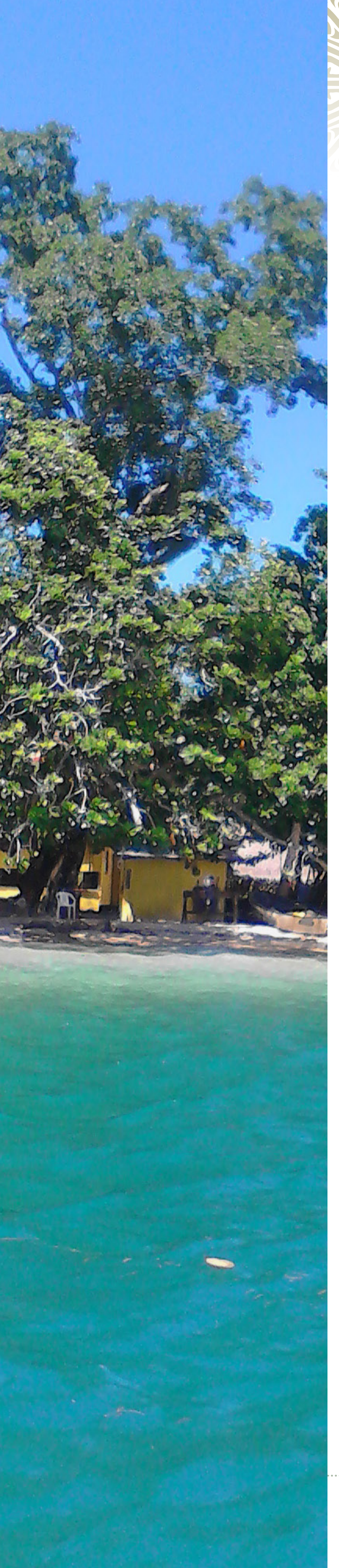
List of Acronyms

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
NFI	National Forest Inventory
NSO	National Statistics Office
PNG	Papua New Guinea
PNGFA	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

Papua New Guinea's (PNG) National Inventory Report is an official report of all anthropogenic (human-induced) emissions and removals of greenhouse gases (GHG). The national GHG inventory measures Papua New Guinea's progress against obligations under the United Nations Framework Convention on Climate Change (UNFCCC), and is the official basis for measuring PNG's meaningful contribution to the reduction of global emissions by transitioning to a low carbon economy.

PNG ratified the Convention on 16 March 1993 as a non-Annex I Party and ratified the Paris Agreement on 21st September 2016.

The compilation and reporting of a GHG inventory are pursuant to its obligations under the UNFCCC. GHG inventories are to be included in reports under Articles 4 and 12 of the Convention (national communications), and Biennial Update Reports (BUR) required by decision 2/CP.17 under the Convention.

National communications are to be reported every 4 years and are required to be developed using guidelines contained in decision 17/CP.8. PNG's first national communication (NC) was submitted in February 2002, followed by the second national communication in December 2015.

PNG has demonstrated a serious commitment to transparency under the UNFCCC and submitted its first BUR in April 2019. This report was developed in accordance with guidelines contained in decision 2/CP.17. These guidelines also require BURs to be submitted every 2 years.

PNG's GHG inventory has been developed in accordance with guidelines that exist under relevant decisions under the Convention (2/CP.7 and 17/CP.8). The requirements for GHG inventories relate to general reporting requirements; the coverage in inventory years and GHG; metrics; methodology; and specific requirements for each sector of the GHG inventory.

This report provides a narrative on major emission trends and methodologies for estimating emissions and removals and includes information on inventory data for 2000–2017 from all emissions and removals in PNG. It also includes sections on the inventory recalculations and improvements. In addition, summary tables contained in the appendices provide detailed emissions data for each sector and by gas.

GHG inventory reporting under the Convention covers seven direct GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). This report provides estimates of direct GHG emissions but does not include indirect GHG emissions or NF_3.

The gases are reported under four sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry and Other Land Use (AFOLU), and Waste.

This report on PNG's GHG inventory is based on methodological approaches and guidance contained in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC GL).

1.2. A Description of the National Inventory Arrangements

1.2.1. Institutional Arrangements for Development of the Biennial Update Report and National Communication

CCDA is the single body that has been assigned responsibility to implement the UNFCCC and the Paris Agreement in collaboration with line agencies. CCDA's objective is "to provide a coordination mechanism at the national level for research, analysis and development of the policy and legislative framework for the management of climate change within the Government's National Strategy on Climate-Compatible Development" (NEC Decision No 55/2010).

CCDA is the single body responsible for the overall coordination and management of the Biennial Update Report (BUR) and National Communication (NC) preparation process. Therefore, CCDA in cooperation with its stakeholders consisting of the private sector, the non-government agencies, development partners, and government agencies develop the BUR and NC elements. Key tasks for CCDA are the following:

- Plan and conduct all coordination and consultation activities with governmental and, if appropriate, non-governmental stakeholders,
- Identify all institutions and teams that will be involved in the preparation of the BUR or NC, and establish any formal working arrangements required,
- Allocate responsibilities for all components of the BUR and NC, ensuring there is a clear lead for each section, and establish a formal approval process,
- Develop and monitor a timeline and schedule for BUR or NC preparation, including specific milestones and dates for deliverables.

CCDA is also responsible for the following BUR and NC elements:

- Identify constraints and gaps, and related financial, technical, and capacity-building needs, including a description of support needed and received,
- Keep any management committees and working groups informed of progress and emerging issues,
- Develop and implement Quality Assurance and Quality Control strategies for the entire BUR and NC,
- Manage the overall budget for the preparation of the BUR and NC,
- Compile and integrate all sections of the BUR and NC into a cohesive document,
- Develop and maintain an archiving system to ensure institutional memory and to fully and systematically document all the activity data and the methods used,
- Collect and maintain statistical records,
- Conduct an evaluation exercise to identify key lessons learned and areas for improvement,
- Consider the results of the International Consultation and Analysis (ICA) process.

For the current BUR2, CCDA has enhanced its institutional arrangement by establishing an Energy Sub Technical Working Committee (ESTWC) and Agriculture Forestry & Other Land Use Sub Technical Working Committee (AFOLU STWC). The STWCs consist of key government agencies, private sector agencies, and Non-Government Organisations from the energy and AFOLU sectors in PNG. The STWCs are responsible for providing technical inputs for the preparation of the BUR2. In addition to this, there are also other institutions from other sectors that have provided information to CCDA for the preparation of this report.

1.2.2. Institutional, Legal and Procedural Arrangements for the GHG Inventory

CCDA manages the preparation of the National GHG inventory as part of the BUR. Key functions include the identification of data sources under each sector, collection and compilation of activity data and emission factors for each sector and, estimation and reporting of GHG emissions by sources and removals by sinks.

Since there are existing sector lead agencies for each sector, CCDA has involved them in the GHG inventory process. Their main purpose was to provide activity data and to some extent emission factors for CCDA to estimate the emissions. However, not all lead agencies have the required data so other organizations including private companies were also included.

In the Energy Sector the National Energy Authority was involved but the data 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 the National Energy Authority. For the Industrial Process and Product Use sector, PNG Customs, Chinese export data, and two private companies, an N_2O distributor and a Lubricant distributor were involved. For the AFOLU Sector, the Department of Agriculture and Livestock, the lead agency for the agriculture sector, and the PNG Forest Authority, the lead agency for the forestry sector were involved. DAL assisted by providing livestock population based on expert judgement. While PNGFA provided most of the LULUCF activity data. And for the Waste Sector, three government agencies namely Water PNG, National Statistical Office, and the National Capital District Commission were involved.

New external parties have been involved in the planning, preparation, and management of the IPPU sector. For example, engaging with the Refrigerants and Air-Conditioning Association of PNG (RACA-PNG) on IPPU MoU and data. Provision of technical advice by the CCDA into the Conservation and Environmental Protection Agency (CEPA) managed the process of reviewing the Environmental Protection/ Montreal Protocol legislation. CCDA also initiated a consultation process with key stakeholders (including the RACA-PNG) to identify a pathway to obtaining activity data to estimate GHG emissions from the import, use, maintenance, and disposal of refrigerants.

1.2.3. QA/QC and Verification Plan

PNG drafted an initial QA/QC plan in 2020. This Plan is in its infancy and is largely based on IPCC good practice tier 1 QA/QC procedures to ensure the transparency, accuracy, completeness, and consistency of the GHG inventory and associated documentation.

The Plan includes the following tier 1 QA and QC procedures:

- Checklist for confirming the data entry in the appropriate spreadsheet files and the method/equations used;
- Checklist for the consistency between the spreadsheet files and the inventory report files (NIR and BUR/NC); and
- Checklist of the reporting requirements as described by the relevant COP decisions and conclusions.

The Plan will be strengthened over the next years. This is with a view to enhance congruence with the IPCC good practice, to incorporate learnings and experiences in its application, and to involve relevant external parties in the QA process.

1.3. Inventory Preparation Process

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 1.3.3 'Institutional arrangements for the GHG inventory' 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 table 1-1.

Table 1 1: The GHG inventory process

Milestone	Time
GHG inventory improvement planning	5 months
Project approval by GEF/UNDP/PNG	6 months
Kickoff meeting/workshop	1.5 months
Data collection	
- Stakeholder identification/stakeholder identification and engagement	
- Sub technical working committee meetings, as needed	
- Sending official data request letters including data sheets	8 months
- Data collection and analysis	
- Update database	
GHG emission/removal estimation	0.5 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	0.5 months
- updating the uncertainty assessment	
Updating the NIR	1 month
Updating the BUR chapter on GHG inventories	0.5 months
Quality control of the inventory products (estimation files and inventory report)	0.5 month
Validation meeting/workshop	1 month
Revision of the GHG inventory, as needed	0.5 months
Quality Assurance activities	1 month
Submission to the Climate Change Board and Minister of Environment and Climate Change	1 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 and Methods

For the energy sector, emissions have been estimated by using the tier 1 method. The source of activity data is the Energy Balance Table developed by the Asia Pacific Energy Research Centre (APERC) and emission factors from the 2006 IPCC Guidelines. In the IPPU sector, emissions have been estimated with the use of IPCC tier methods using default emission factors.

For the AFOLU sector, Papua New Guinea Forest Authority (PNGFA) provided activity data for LULUCF sector while the Department of Agriculture and Livestock provides data for the Agriculture sector. Much of the emission factors used in both LULUCF and Agriculture sectors are default emission factors from the 2006 IPCC Guidelines. Few tier 2 emission factors for the LULUCF sector, especially the forestland and crop land categories, were from literature review.

For the waste sector, population statistics from the PNG Census were used to derive activity data. For emission factors and other parameters, the majority were taken from the 2006 IPCC guidelines with expert judgement for some parameters such as the composition of solid waste.

1.4.2. Time Series

This report provided a GHG inventory for each year of the inventory time-series 2000 – 2017. The exceptions include HFC emissions that have not been estimated for the years 2000 to 2014 due to the absence of reliable HFC import data,

1.4.3. Global Warming Potentials (GWP) Used

Global warming potentials are taken from the IPCC Second Assessment Report as can be seen in the table below.

Table 1-2: Second assessment report global warming potentials

Species	Chemical formula	Global Warming Potential (100 years)
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
HFC-23	CHF_3	1300
HFC-32	CH_2F_2	2100
HFC-41	CH_3F	490
HFC-43-10mee	$C_5H_2F_{10}$	3000
HFC-125	C_2HF_5	4600
HFC-134	$C_2H_2F_4$	2900
HFC-134a	CH_2FCF_3	3400
HFC-152a	$C_2H_4F_2$	460
HFC-143	$C_2H_3F_3$	1000
HFC-143a	$C_2H_3F_3$	5000
HFC-227ea	C_3HF_7	5000
HFC-236fa	$C_3H_2F_6$	4300
HFC-245ca	$C_3H_3F_5$	1800

1.5. Brief Description of Key Categories

A tier 1 key category analysis was conducted for the newest year. Below is the result of the key category analysis carried out for all categories with and without the LULUCF categories. 19 categories were identified as key without the LULUCF categories. While 14 categories were identified as key with the LULUCF sector. The results of the key category assessments are shown below (key categories in yellow)

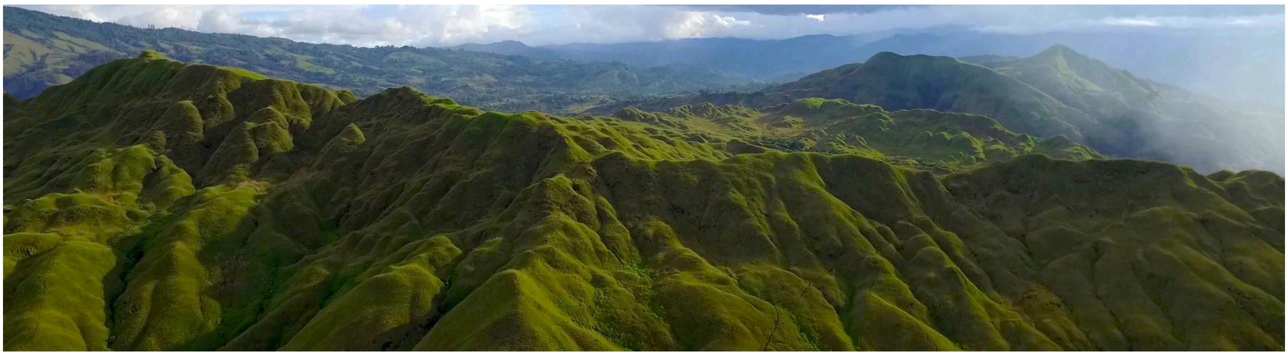


Table 1-3: Key category assessment without LULUCF

2006 IPCC code	category	Gas	kt CO_2 eq Absolute value of 2017 emissions	Level assessment	cumulative total
1.A.2.	Manufacturing industries and construction	CO_2	3,764.01	34.96%	34.96%
1.A.3.b	Road transportation	CO_2	1,519.16	14.11%	49.07%
1.B.2.a.2	Production	CH_4	855.57	7.95%	57.01%
1.A.1.c	Manufacture of solid fuels and other energy industries	CO_2	575.45	5.34%	62.36%
3.C.4	Direct N2O emission on managed soils	N_2O	528.79	4.91%	67.27%
5.D.1	Domestic wastewater	CH_4	503.40	4.68%	71.94%
1.A.3.a	Domestic aviation	CO_2	398.14	3.70%	75.64%
1.B.2.a.2	Production	CH_4	394.87	3.67%	79.31%
1.A.4.c	Agriculture/forestry/fishing	CO_2	313.20	2.91%	82.22%
5.A.1	Unmanaged waste disposal sites	CH_4	272.55	2.53%	84.75%
3.A.1	Enteric fermentation	CH_4	172.92	1.61%	86.36%
5.D.1	Domestic wastewater	N_2O	167.83	1.56%	87.91%
2.F.1	Refrigeration and air conditioning	HFC	150.62	1.40%	89.31%
3.A.2	Manure management	CH_4	144.28	1.34%	90.65%
1.A.1.a	Public electricity and heat production	CO_2	131.53	1.22%	91.88%
1.A.1.b	Petroleum refining	CO_2	122.46	1.14%	93.01%
1.A.4.b	Residential	CO_2	89.53	0.83%	93.84%
3.C.5	Indirect N2O emission on managed soils	N_2O	70.09	0.65%	94.49%
1.A.4.b	Residential	N_2O	69.27	0.64%	95.14%
1.A.4.a	Commercial/institutional	CO_2	59.81	0.56%	95.69%
1.B.2.b.3	Processing	CH_4	55.45	0.51%	96.21%
1.B.2.b.4	Transmission and storage	CH_4	47.34	0.44%	96.65%
1.A.4.c	Agriculture/forestry/fishing	N_2O	37.49	0.35%	97.00%
1.A.4.b	Residential	CH_4	35.16	0.33%	97.32%
5.C.2	Open burning of waste	CO_2	34.99	0.32%	97.65%
1.B.2.c.i	Oil	CO_2	30.40	0.28%	97.93%
1.A.3.d	Domestic navigation	CO_2	29.15	0.27%	98.20%
1.B.2.c.ii	Gas	CH_4	27.51	0.26%	98.46%
1.A.3.b	Road transportation	N_2O	24.06	0.22%	98.68%
1.B.2.b.5	Distribution	CH_4	19.01	0.18%	98.86%
5.C.2	Open burning of waste	CH_4	17.68	0.16%	99.02%
3.A.2	Manure management	N_2O	14.41	0.13%	99.15%
1.A.4.a	Commercial/institutional	N_2O	12.30	0.11%	99.27%
1.A.2.	Manufacturing industries and construction	N_2O	12.03	0.11%	99.38%
1.B.2.c.ii	Gas	CO_2	11.86	0.11%	99.49%
1.B.2.c.i	Oil	CH_4	11.25	0.10%	99.60%
1.A.4.a	Commercial/institutional	CH_4	6.22	0.06%	99.65%
1.A.3.b	Road transportation	CH_4	4.93	0.05%	99.70%
1.A.2.	Manufacturing industries and construction	CH_4	4.75	0.04%	99.74%
3.C.6	Indirect N2O emissions from manure management	N2O	4.26	0.04%	99.78%
5.C.2	Open burning of waste	N_2O	3.73	0.03%	99.82%
5.B.1	Composting	N_2O	3.61	0.03%	99.85%
1.A.3.a	Domestic aviation	N_2O	3.45	0.03%	99.88%
5.B.1	Composting	CH_4	3.26	0.03%	99.91%
2.D.1	Lubricant use	CO_2	1.75	0.02%	99.93%
1.B.2.a.2	Production	CO_2	1.35	0.01%	99.94%
1.A.1.c	Manufacture of solid fuels and other energy industries	N_2O	0.99	0.01%	99.95%
2.G.3	N2O from product uses	N_2O	0.93	0.01%	99.96%
1.B.2.b.3	Processing	CO_2	0.84	0.01%	99.97%
1.B.2.a.4	Refining/storage	CH_4	0.76	0.01%	99.97%
1.A.1.c	Manufacture of solid fuels and other energy industries	CH_4	0.56	0.01%	99.98%
1.B.2.c.i	Oil	CH_4	0.39	0.00%	99.98%
1.A.4.c	Agriculture/forestry/fishing	CH_4	0.37	0.00%	99.99%
1.A.1.b	Petroleum refining	N_2O	0.37	0.00%	99.99%
1.B.2.b.2	Production	CO_2	0.32	0.00%	99.99%
1.B.2.a.3	Transport	CH_4	0.26	0.00%	100.0%
1.A.3.d	Domestic navigation	N_2O	0.23	0.00%	100.0%
1.B.2.c.ii	Gas	CH_4	0.16	0.00%	100.0%
1.B.2.c.i	Oil	N_2O	0.15	0.00%	100.0%
1.A.1.b	Petroleum refining	CH_4	0.12	0.00%	100.0%
1.A.1.a	Public electricity and heat production	N_2O	0.12	0.00%	100.0%
1.B.2.c.	Venting	CO_2	0.09	0.00%	100.0%
1.A.1.a	Public electricity and heat production	CH_4	0.08	0.00%	100.0%
1.B.2.c.i	Oil	CO_2	0.07	0.00%	100.0%
1.A.3.a	Domestic aviation	CH_4	0.06	0.00%	100.0%
1.B.2.c.ii	Gas	N_2O	0.06	0.00%	100.0%
1.A.3.d	Domestic navigation	CH_4	0.06	0.00%	100.0%
1.B.2.b.5	Distribution	CO_2	0.05	0.00%	100.0%
1.B.2.c.ii	Gas	CO_2	0.02	0.00%	100.0%
1.B.2.b.4	Transmission and storage	CO_2	0.01	0.00%	100.0%
1.B.2.a.3	Transport	CO_2	0.00	0.00%	100.0%

Table 1-4: Key category assessment without LULUCF

2006 IPCC code	category	Gas	kt CO_2 eq 2017 values	Absolute value of 2017 emissions	Level assessment	cumulative total
3.B.1	Forest land remaining forest land	CO_2	-23617.38	23,617.38	52.16%	52.16%
3.B.2.b	Land converted to cropland	CO_2	8493.36	8,493.36	18.76%	70.92%
1.A.2.	Manufacturing industries and construction	CO_2	3764.01	3,764.01	8.31%	79.23%
1.A.3.b	Road transportation	CO_2	1519.16	1,519.16	3.36%	82.59%
3.B.5	Settlements	CO_2	1058.52	1,058.52	2.34%	84.93%
3.B.2.a	Cropland remaining cropland	CO_2	904.46	904.46	2.00%	86.92%
1.B.2.a.2	Production	CH_4	855.57	855.57	1.89%	88.81%
1.A.1.c	Manufacture of solid fuels and other energy industries	CO_2	575.45	575.45	1.27%	90.09%
3.C.4	Direct N2O emission on managed soils	N_2O	528.79	528.79	1.17%	91.25%
5.D.1	Domestic wastewater	CH_4	503.40	503.40	1.11%	92.37%
1.A.3.a	Domestic aviation	CO_2	398.14	398.14	0.88%	93.24%
1.B.2.a.2	Production	CH_4	394.87	394.87	0.87%	94.12%
3.B.3	Grassland	CO_2	323.36	323.36	0.71%	94.83%
1.A.4.c	Agriculture/forestry/fishing	CO_2	313.20	313.20	0.69%	95.52%
5.A.1	Unmanaged waste disposal sites	CH_4	272.55	272.55	0.60%	96.12%
3.A.1	Enteric fermentation	CH_4	172.92	172.92	0.38%	96.51%
5.D.1	Domestic wastewater	N_2O	167.83	167.83	0.37%	96.88%
2.F.1	Refrigeration and air conditioning	HFC	150.62	150.62	0.33%	97.21%
3.A.2	Manure management	CH_4	144.28	144.28	0.32%	97.53%
1.A.1.a	Public electricity and heat production	CO_2	131.53	131.53	0.29%	97.82%
1.A.1.b	Petroleum refining	CO_2	122.46	122.46	0.27%	98.09%
1.A.4.b	Residential	CO_2	89.53	89.53	0.20%	98.29%
3.C.1.a	Emissions from biomass burning in forest land	CH_4	78.61	78.61	0.17%	98.46%
3.C.5	Indirect N2O emission on managed soils	N_2O	70.09	70.09	0.15%	98.62%
1.A.4.b	Residential	N_2O	69.27	69.27	0.15%	98.77%
1.A.4.a	Commercial/institutional	CO_2	59.81	59.81	0.13%	98.90%
1.B.2.b.3	Processing	CH_4	55.45	55.45	0.12%	99.02%
1.B.2.b.4	Transmission and storage	CH_4	47.34	47.34	0.10%	99.13%
1.A.4.c	Agriculture/forestry/fishing	N_2O	37.49	37.49	0.08%	99.21%
1.A.4.b	Residential	CH_4	35.16	35.16	0.08%	99.29%
5.C.2	Open burning of waste	CO_2	34.99	34.99	0.08%	99.37%
3.C.1.a	Prescribed burning of Forest	N_2O	34.13	34.13	0.08%	99.44%
1.B.2.c.i	Oil	CO_2	30.40	30.40	0.07%	99.51%
1.A.3.d	Domestic navigation	CO_2	29.15	29.15	0.06%	99.57%
1.B.2.c.ii	Gas	CH_4	27.51	27.51	0.06%	99.63%
1.A.3.b	Road transportation	N_2O	24.06	24.06	0.05%	99.69%
1.B.2.b.5	Distribution	CH_4	19.01	19.01	0.04%	99.73%
5.C.2	Open burning of waste	CH_4	17.68	17.68	0.04%	99.77%
3.A.2	Manure management	N_2O	14.41	14.41	0.03%	99.80%
1.A.4.a	Commercial/institutional	N_2O	12.30	12.30	0.03%	99.83%
1.A.2.	Manufacturing industries and construction	N_2O	12.03	12.03	0.03%	99.85%
1.B.2.c.ii	Gas	CO_2	11.86	11.86	0.03%	99.88%
1.B.2.c.i	Oil	CH_4	11.25	11.25	0.02%	99.90%
1.A.4.a	Commercial/institutional	CH_4	6.22	6.22	0.01%	99.92%
1.A.3.b	Road transportation	CH_4	4.93	4.93	0.01%	99.93%
1.A.2.	Manufacturing industries and construction	CH_4	4.75	4.75	0.01%	99.94%
3.C.6	Indirect N2O emissions from manure management	N_2O	4.26	4.26	0.01%	99.95%
5.C.2	Open burning of waste	N_2O	3.73	3.73	0.01%	99.96%
5.B.1	Composting	N_2O	3.61	3.61	0.01%	99.96%
1.A.3.a	Domestic aviation	N_2O	3.45	3.45	0.01%	99.97%
5.B.1	Composting	CH_4	3.26	3.26	0.01%	99.98%
2.D.1	Lubricant use	CO_2	1.75	1.75	0.00%	99.98%
1.B.2.a.2	Production	CO_2	1.35	1.35	0.00%	99.99%
1.A.1.c	Manufacture of solid fuels and other energy industries	N_2O	0.99	0.99	0.00%	99.99%
2.G.3	N2O from product uses	N_2O	0.93	0.93	0.00%	99.99%
1.B.2.b.3	Processing	CO_2	0.84	0.84	0.00%	99.99%
1.B.2.a.4	Refining/storage	CH_4	0.76	0.76	0.00%	99.99%
1.A.1.c	Manufacture of solid fuels and other energy industries	CH_4	0.56	0.56	0.00%	100.00%
1.B.2.c.i	Oil	CH_4	0.39	0.39	0.00%	100.00%
1.A.4.c	Agriculture/forestry/fishing	CH_4	0.37	0.37	0.00%	100.00%
1.A.1.b	Petroleum refining	N_2O	0.37	0.37	0.00%	100.00%
1.B.2.b.2	Production	CO_2	0.32	0.32	0.00%	100.00%
1.B.2.a.3	Transport	CH_4	0.26	0.26	0.00%	100.00%
1.A.3.d	Domestic navigation	N_2O	0.23	0.23	0.00%	100.00%
1.B.2.c.ii	Gas	CH_4	0.16	0.16	0.00%	100.00%
1.B.2.c.i	Oil	N_2O	0.15	0.15	0.00%	100.00%
1.A.1.b	Petroleum refining	CH_4	0.12	0.12	0.00%	100.00%
1.A.1.a	Public electricity and heat production	N_2O	0.12	0.12	0.00%	100.00%
1.B.2.c.	Venting	CO_2	0.09	0.09	0.00%	100.00%
1.A.1.a	Public electricity and heat production	CH_4	0.08	0.08	0.00%	100.00%
1.B.2.c.i	Oil	CO_2	0.07	0.07	0.00%	100.00%
1.A.3.a	Domestic aviation	CH_4	0.06	0.06	0.00%	100.00%
1.B.2.c.ii	Gas	N_2O	0.06	0.06	0.00%	100.00%
1.A.3.d	Domestic navigation	CH_4	0.06	0.06	0.00%	100.00%
1.B.2.b.5	Distribution	CO_2	0.05	0.05	0.00%	100.00%
1.B.2.c.ii	Gas	CO_2	0.02	0.02	0.00%	100.00%
1.B.2.b.4	Transmission and storage	CO_2	0.01	0.01	0.00%	100.00%
1.B.2.a.3	Transport	CO_2	0.00	0.00	0.00%	100.00%

1.6. General Uncertainty Assessment

A tier 1 uncertainty analysis was conducted for the newest year which is 2017 and all uncertainties were taken from the 2006 IPCC Guidelines. The total uncertainty in 2017 is 259% which is quite high and the largest uncertainty comes from fugitive emissions and domestic waste water. Below are the results of the uncertainty analysis.

Table 1-5: Uncertainty calculation according to Tier 1

A		B	D	E	F	G	H
2006 IPCC	category	Gas	most recent year emissions	activity data uncertainty	Emission factor/estimation parameter uncertainty	combined uncertainty	contribution to variance by category in Year t
			input data	input data	input data	$\sqrt{E^2+F^2}$	$(G*D)^2/(\Sigma D)^2$
			kt CO_2 eq	%	%	%	
1.A.1.a	Public electricity and heat production	CO_2	132	2%	4%	4%	0.000007
1.A.1.b	Petroleum refining	CO_2	122	13%	2%	13%	0.000062
1.A.1.c	Manufacture of solid fuels and other energy industries	CO_2	575	13%	4%	13%	0.001462
1.A.2.	Manufacturing industries and construction	CO_2	3,764	3%	1%	3%	0.002843
1.A.3.a	Domestic aviation	CO_2	398	13%	3%	13%	0.000692
1.A.3.b	Road transportation	CO_2	1,519	13%	1%	13%	0.009539
1.A.3.d	Domestic navigation	CO_2	29	13%	2%	13%	0.000004
1.A.4.a	Commercial/institutional	CO_2	60	13%	2%	13%	0.000015
1.A.4.b	Residential	CO_2	90	13%	0.04%	13%	0.000033
1.A.4.c	Agriculture/forestry/fishing	CO_2	313	13%	1%	13%	0.000406
1.B.2.a.2	Production	CO_2	1	12.5%	100%	101%	0.000000
1.B.2.a.3	Transport	CO_2	0.001	12.5%	100%	101%	0.000000
1.B.2.b.2	Production	CO_2	0.3	12.5%	100%	101%	0.000000
1.B.2.b.3	Processing	CO_2	0.8	12.5%	100%	101%	0.000000
1.B.2.b.4	Transmission and storage	CO_2	0.01	12.5%	105%	106%	0.000000
1.B.2.b.4	Transmission	CO_2	0.005	12.5%	100%	101%	0.000000
1.B.2.b.4	Storage	CO_2	0.001	12.5%	500%	500%	0.000000
1.B.2.b.5	Distribution	CO_2	0.05	12.5%	500%	500%	0.000000
1.B.2.c.i	Oil	CO_2	0.1	12.5%	50%	52%	0.000000
1.B.2.c.ii	Gas	CO_2	0.02	12.5%	75%	76%	0.000000
1.B.2.c.i	Oil	CO_2	30	12.5%	50%	52%	0.000064
1.B.2.c.ii	Gas	CO_2	12	12.5%	25%	28%	0.000003
2.D.1	Lubricant use	CO_2	2	15%	50%	52%	0.000000
3.B.1.a	Forest land remaining forest land	CO_2	-23,617	13.47%	10.07%	17%	4.115923
3.B.2.a	Cropland remaining cropland	CO_2	904	29.44%	10.07%	31%	0.020661
3.B.2.b	Land converted to cropland	CO_2	8,493	29.44%	10.07%	31%	1.821972
3.B.3.a	Grassland remaining grassland	CO_2	323	50%	90%	103%	0.028915
3.B.5.b	Land converted to settlements	CO_2	1,059	29.44%	10.07%	31%	0.028300
5.C.2	Open burning of waste	CO_2	35	274%	40%	277%	0.002447
1.A.1.a	Public electricity and heat production	CH_4	0.1	2%	98%	98%	0.000000
1.A.1.b	Petroleum refining	CH_4	0.1	13%	150%	151%	0.000000
1.A.1.c	Manufacture of solid fuels and other energy industries	CH_4	1	13%	163%	164%	0.000000
1.A.2.	Manufacturing industries and construction	CH_4	5	3%	84%	84%	0.000004
1.A.3.a	Domestic aviation	CH_4	0.1	13%	79%	79%	0.000000
1.A.3.b	Road transportation	CH_4	5	13%	113%	113%	0.000008
1.A.3.d	Domestic navigation	CH_4	0.1	13%	50%	52%	0.000000
1.A.4.a	Commercial/institutional	CH_4	6	13%	148%	149%	0.000022
1.A.4.b	Residential	CH_4	35	13%	149%	149%	0.000719
1.A.4.c	Agriculture/forestry/fishing	CH_4	0.4	13%	150%	151%	0.000000
1.B.2.a.2	Production	CH_4	395	13%	100%	101%	0.041315
1.B.2.a.3	Transport	CH_4	0.3	13%	100%	101%	0.000000
1.B.2.a.4	Refining/storage	CH_4	1	13%	100%	101%	0.000000
1.B.2.b.2	Production	CH_4	856	13%	100%	101%	0.193955
1.B.2.b.3	Processing	CH_4	55	13%	100%	101%	0.000815
1.B.2.b.4	Transmission and storage	CH_4	47	13%	99%	100%	0.000579
1.B.2.b.5	Distribution	CH_4	19	13%	500%	500%	0.002358
1.B.2.c.i	Oil	CH_4	11	13%	50%	52%	0.000009
1.B.2.c.ii	Gas	CH_4	28	13%	75%	76%	0.000114
1.B.2.c.i	Oil	CH_4	0.4	13%	50%	52%	0.000000
1.B.2.c.ii	Gas	CH_4	0.2	13%	25%	28%	0.000000
3.A.1	Enteric fermentation	CH_4	173	20%	40%	45%	0.001560
3.A.2	Manure management	CH_4	144	20%	30%	36%	0.000706
3.C.1.a	Prescribed burning of savannas	CH_4	79	NA	NA		
4.A.2	Unmanaged waste disposal sites	CH_4	273	271%	60%	277%	0.149037
4.B	Composting	CH_4	3	301%	100%	317%	0.000028
4.C.2	Open burning of waste	CH_4	18	229%	100%	250%	0.000509
4.D.1	Domestic wastewater	CH_4	503	77%	53%	94%	0.058243
1.A.1.a	Public electricity and heat production	N_2O	0.12	2%	98%	98%	0.000000
1.A.1.b	Petroleum refining	N_2O	0.37	13%	150%	151%	0.000000
1.A.1.c	Manufacture of solid fuels and other energy industries	N_2O	1	13%	177%	178%	0.000001
1.A.2.	Manufacturing industries and construction	N_2O	12	3%	88%	88%	0.000029
1.A.3.a	Domestic aviation	N_2O	3	13%	25%	28%	0.000000
1.A.3.b	Road transportation	N_2O	24	13%	113%	113%	0.000194
1.A.3.d	Domestic navigation	N_2O	0.2	13%	40%	42%	0.000000
1.A.4.a	Commercial/institutional	N_2O	12	13%	166%	166%	0.000109
1.A.4.b	Residential	N_2O	69	13%	167%	168%	0.003519
1.A.4.c	Agriculture/forestry/fishing	N_2O	37	13%	150%	151%	0.000831
1.B.2.c.i	Oil	N_2O	0.1477	13%	1000%	1000%	0.000001
1.B.2.c.ii	Gas	N_2O	0.0565	13%	1000%	1000%	0.000000
2.G.3	N_2O from product uses	N_2O	1	NA	NA		
3.A.2	Manure management	N_2O	14	37.50%	25%	45%	0.000011
3.C.6	Indirect N_2O emissions	N_2O	4	37.50%	25%	45%	0.000001
3.C.4	Agricultural soils	N_2O	599	20%	60%	63%	0.037427
3.C.1.a	Prescribed burning of savannas	N_2O	34	NA	NA		
4.B	Composting	N_2O	4	301%	150%	337%	0.000039
4.C.2	Open burning of waste	N_2O	4	274%	150%	312%	0.000035
4.D.1	Domestic wastewater	N_2O	168	44%	500%	502%	0.185143
2.F.1	Refrigeration and air conditioning	HFC	150.62	NA	NA		
	total		-1,958			ΣH	6.710670
			ΣD		Percentage uncertainty in total inventory (√ΣH)		259%

1.7. General Assessment of Completeness

As to the IPPU sector, CCDA has identified completeness as a priority task. While this remains an ongoing consideration for CCDA, HFC emissions have been included in the IPPU sector for years 2015 to 2020. This was achieved in consultation with PNG-RACA and CEPA. CCDA will continue collaborating with CEPA to examine the extent to which to overcome completeness in other sub-sectors by exploring the environmental permits that can be used to confirm the occurrence of an activity and whether the activity generates GHG emissions.

1.8. Recalculations

The following categories have been recalculated.

- Energy sector (both fuel combustion and fugitive emissions) with revised national energy balance tables
- IPPU – no recalculation, but first-time reporting of HFC inventory
- AFOLU- There were some recalculations done for both the agriculture and LULUCF sector due to updated activity data from the data sources.
- Waste – revised waste parameters for CH_4 emissions from SWDS, first time reporting of emissions from 4.C.2 open burning of waste.

Chapter

2

Trends in GHG Emissions and Removals

2.1. Description and Interpretation of Emission Trends for Aggregated GHG Emissions

The Figures and below shows the total GHG emissions excluding and including LULUCF for each inventory year.

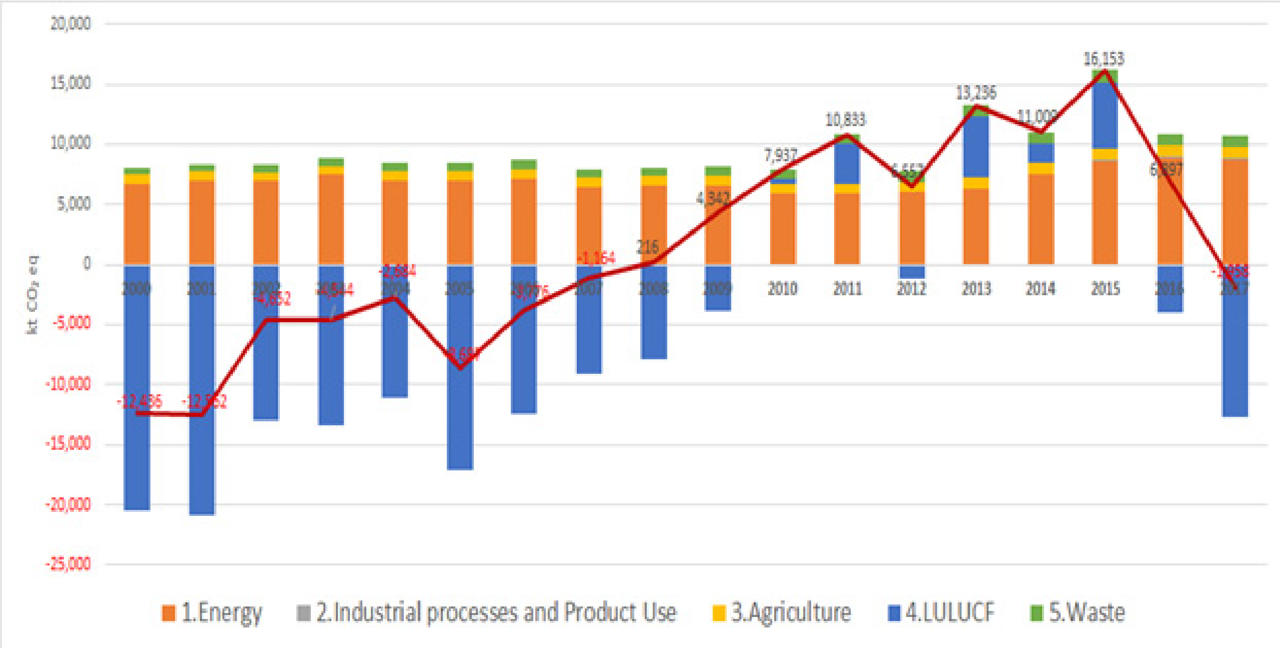


Figure 2-1: Total GHG emissions with LULUCF from 2000 to 2017

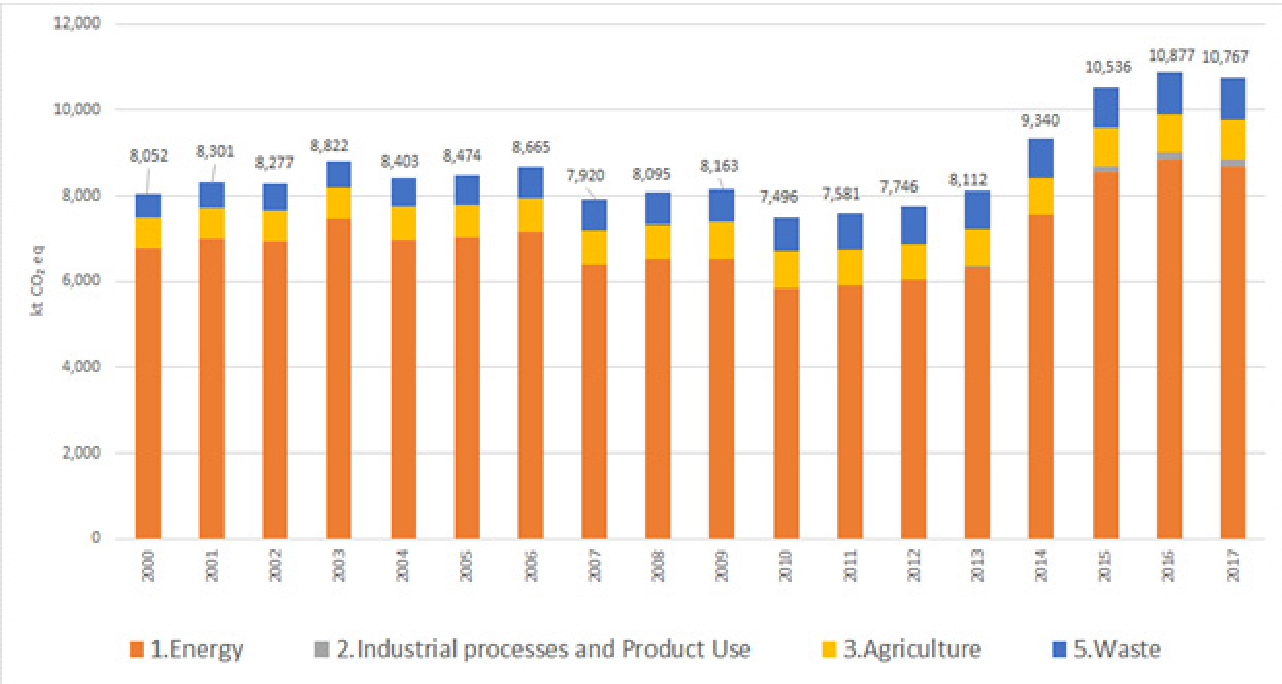


Figure 2-2: Total GHG emissions without LULUCF from 2000 to 2017

Table 2-1: Total annual national GHG emissions by inventory sector

Trend by sector unit: kt-CO_2 eq

	2000	2001	2002	2003	2004	2005	2006	2007	2008
1.Energy	6,760	6,984	6,940	7,448	6,956	7,015	7,168	6,401	6,537
2.Industrial processes and Product Use	1	1	1	2	3	3	3	3	3
3.Agriculture	732	735	731	739	785	774	786	783	795
4.LULUCF	-20,488	-20,864	-12,929	-13,366	-11,087	-17,161	-12,441	-9,083	-7,879
5.Waste	560	582	605	634	659	683	708	733	760
total (with LULUCF)	-12,436	-12,562	-4,652	-4,544	-2,684	-8,687	-3,776	-1,164	216
total (without LULUCF)	8,052	8,301	8,277	8,822	8,403	8,474	8,665	7,920	8,095

	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.Energy	6,531	5,844	5,919	6,035	6,352	7,553	8,551	8,846	8,673
2.Industrial processes and Product Use	3	3	3	3	2	2	142	161	153
3.Agriculture	845	838	821	842	865	865	896	894	935
4.LULUCF	-3,821	442	3,252	-1,190	5,124	1,668	5,617	-3,981	-12,725
5.Waste	785	811	838	867	892	920	948	977	1,006
total (with LULUCF)	4,342	7,937	10,833	6,557	13,236	11,009	16,153	6,897	-1,958
total (without LULUCF)	8,163	7,496	7,581	7,746	8,112	9,340	10,536	10,877	10,767

PNG went from a net sink of (-12,436 kt CO_2 eq) to a net source in 2016 (6,897 kt CO_2 eq). Then in 2017 PNG became a net sink with total GHG emissions of -1,958 kt CO_2 eq. The main driver for the increasing and decreasing trend is the LULUCF sector mainly from deforestation and degradation activities in the country.

Without the LULUCF sector, the total net emissions increased from 8,052 kt CO_2 eq in 2000 to 10,767 kt CO_2 eq in 2017. An increase of 34% and the main driver is the increasing fossil fuel consumption from the manufacturing industries and construction followed by road transportation.

2.2. GHG Emission and Removal Trends by Sector

2.2.1. Energy

Emissions from the energy sector amounted to 8,673 kt CO_2 eq in 2017, an increase of 1,913 kt CO_2 eq (28%) when compared to 2000. The CO_2 from liquid fuel combustion contributed 68% to the total GHG emissions in 2017, followed by CH_4 from fugitives (16%), CO_2 from gaseous fuel combustion (12%), N_2O from fuel combustion (2%), CH_4 from fuel combustion (1%) and CO_2 from fugitive emissions (1%). 81 % of total sector emissions are CO_2, while CH_4 contributed 17 % and N_2O 2%.

The decreasing GHG emissions trend between 2006 and 2013 is due to the decrease in oil production in the country. The increasing GHG emissions trend between 2000-2003 is due to increasing energy demand and an increase in oil production. Furthermore, the increase in GHG emissions between 2014 to 2017 is due to the increase in energy demand and increase in the production of Liquid Natural Gas.

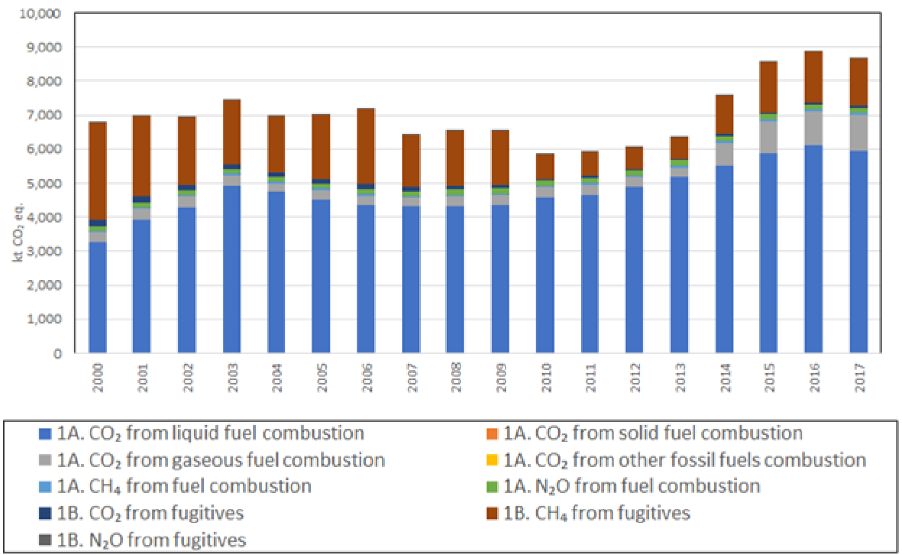


Figure 2-3: Trend in GHG emissions from the energy sector from 2000 to 2017 (in kt CO_2 eq).

2.2.2. Industrial Processes and Product Use (IPPU)

Total GHG emissions in the IPPU sector increased from 0.8 kt of CO_2 eq in 2000 to 153.3 kt of CO_2 eq in 2017. The low emission level reported in 2000 (and in 2001 and 2002) arises due to a paucity of activity data for reported categories. Total GHG emissions are higher in recent years when compared to the previously reported GHG inventory due to the inclusion of HFC emissions (2.F.1) for the years 2015 to 2017. 2003 is the first year in which robust activity data was available for lubricant use (2.D.1) and N_2O in product use (2.G.3).

N_2O emissions have decreased by 4.7% since 2003, or by 0.042 kt CO_2 eq. Over the same time period, CO_2 emissions from lubricant use increased by 114.3%, or by 0.9 kt CO_2 eq. HFC emissions are 150.6 kt CO_2 eq in 2017, an increase of 8.0% when compared to 2015 (the first year of HFC reporting).

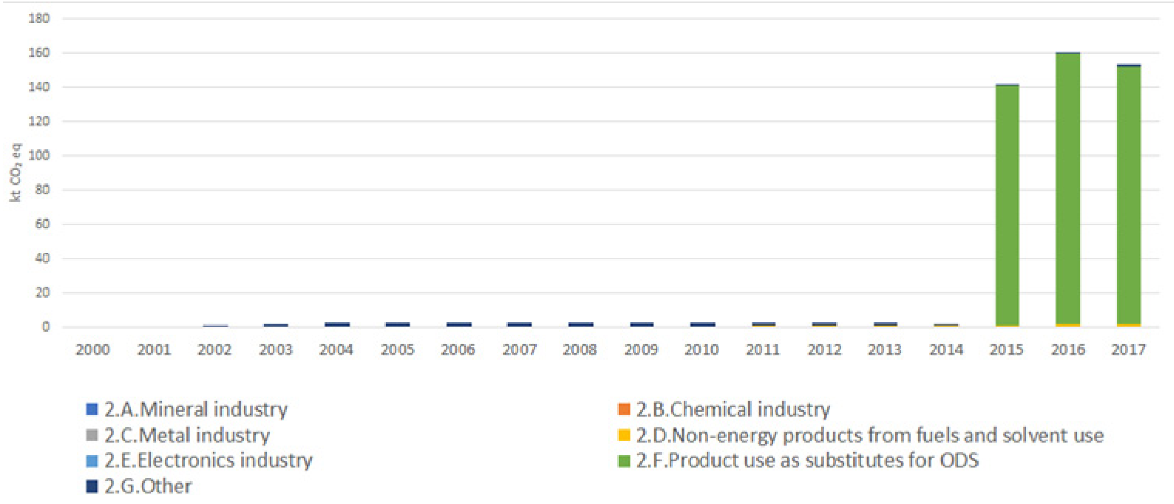


Figure 2-4: Trend in GHG emissions from the IPPU sector from 2000 to 2017 (in kt CO_2 eq)

2.2.3. Agriculture

GHG emissions from the agriculture sector amounted to 935 kt CO_2 eq in 2017 which is about 9 % cent of the country's overall emission in that year (excluding LULUCF). Total GHG emissions increased by 203 kt CO_2 eq (28 %) in 2017 when compared with year 2000. The highest emitting category in 2017 was direct N_2O emissions from managed soils (3.C.4) which contributed 57 % of the total sector emissions. After this is the enteric fermentation (3.A.1) category which contributed 18 %, followed by manure management (3.A.2) with 17 % and indirect N_2O emissions from managed soils (3.C.5) with about 7 %. This least emitting category in the agriculture sector is indirect N_2O emissions from manure management (3.C.6).

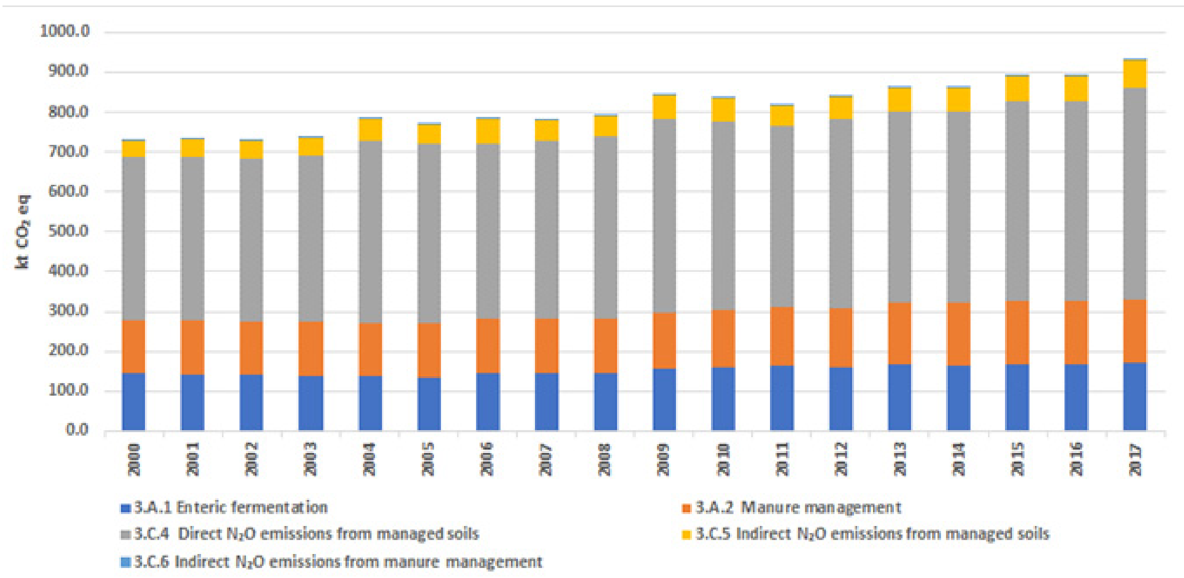


Figure 2-5: Trend in GHG emissions from the Agriculture sector from 2000 to 2017 (in kt CO_2 eq)

2.2.4. Land Use, Land Use Change and Forestry (LULUCF)

The net emissions from the LULUCF sector amounted to -12,724.94 kt CO_2 eq in 2017 compared to -20,488.12 kt CO_2 eq in 2000 which is a total decrease of removals amounting to −7, 763.18 kt CO_2 eq. Removals are decreasing since these are applied to the area of degraded forest directly taken from the Collect Earth assessment, for which each next year an area deforested is lost. For forest that is degraded during the reference level period, the consistency with the REDD+ Forest Reference Level is maintained since the net of losses from disturbance and gains from subsequent recovery are reflected in the emission factor, reflecting long-term average carbon loss.

Gross emissions from LULUCF, which are mainly coming from cropland (forest land converted to cropland), amounted to 9,397.82 kt CO_2 eq in 2017 and are almost 2 times higher than the emissions in 2000, which amounted to 5,886.90 kt CO_2 eq. The figure below showcases the trend of increasing emissions and decreasing removals over time.

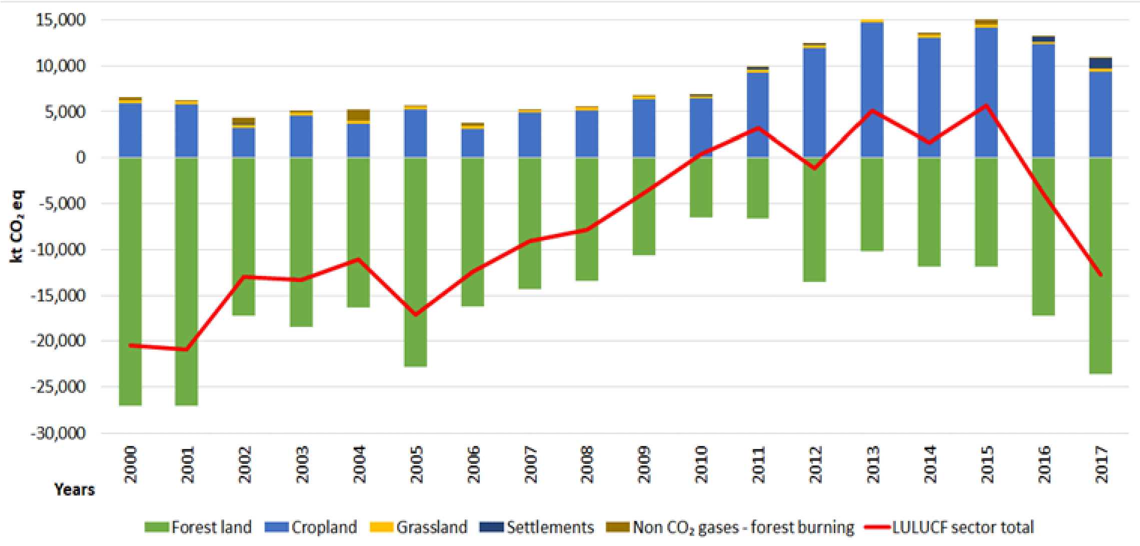


Figure 2-6: Trend in GHG emissions and removals from the LULUCF sector from 2000 to 2017 (in kt CO_2 eq)

2.2.5. Waste

In 2017, emissions from the Waste sector resulted in 1,006 kt CO_2 eq and accounted for 9% of PNG's total greenhouse gas emissions (excluding LULUCF). The emissions of the waste sector have increased in the whole time series (2000-2017) as seen in figure 2-7. The increase is influenced by population growth, development, consumption rate, and rural-to-urban drift. Breakdown of 2017 emissions of the Waste sector by category shows that wastewater treatment and discharge contributed 67% to total sector emissions in 2017, followed by solid waste disposal (27 %), incineration and Open Burning (6%) and biological treatment of solid waste (1%). The contribution of CO_2, CH_4 and N_2O for the total sector emissions are 3.5, 79.1 and 17.4% respectively.

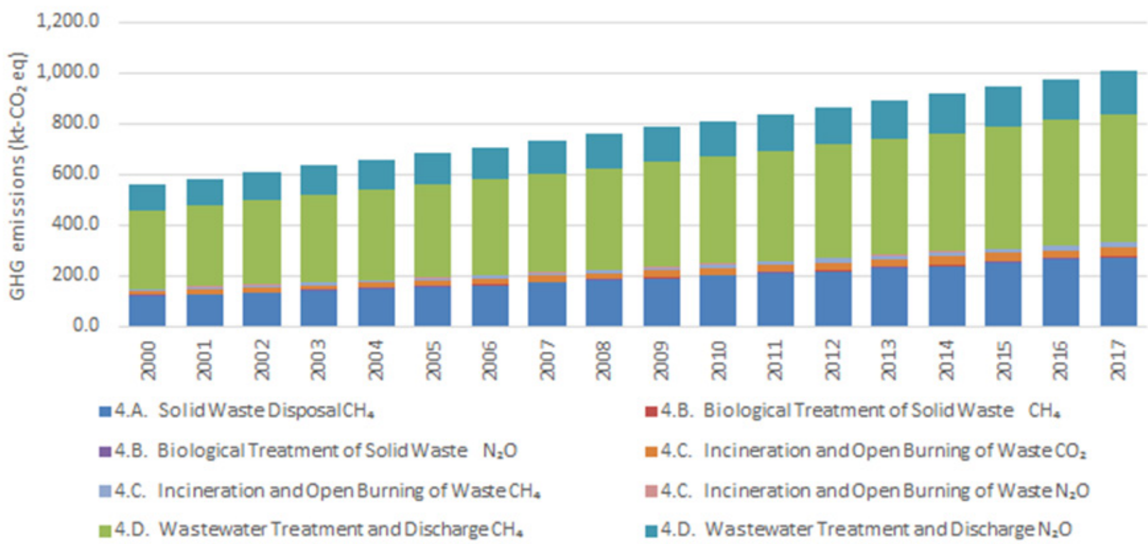


Figure 2-7: Trend in GHG emissions from the waste sector from 2000 to 2017 (in kt CO_2 eq)

2.3. GHG Emission and Removal Trends by Gas

2.3.1. Trend by Gas

Table 2-2 provides total emissions and removals by gas for 2000 and 2017.

Table 2-2: Total annual national GHG emissions by gas (in kt)

Trend by gas — unit: kt

	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO_2 (with LULUCF)	-17,091	-16,460	-8,851	-8,188	-7,223	-12,327	-8,009	-4,451	-3,225
CO_2 (without LULUCF)	3,784	4,449	4,787	5,390	5,144	4,965	4,814	4,713	4,761
CH_4 (with LULUCF)	3,842	3,178	3,274	2,845	3,363	2,818	3,328	2,472	2,602
CH_4 (without LULUCF)	3,573	3,146	2,779	2,697	2,470	2,727	3,061	2,416	2,526
N_2O (with LULUCF)	812	720	926	799	1,176	822	905	815	840
N_2O (without LULUCF)	695	706	711	735	788	783	790	790	807
HFC	0	0	0	0	0	0	0	0	0
Total (with LULUCF)	-12,436	-12,562	-4,652	-4,544	-2,684	-8,687	-3,776	-1,164	216
Total (without LULUCF)	8,052	8,301	8,277	8,822	8,403	8,474	8,665	7,920	8,095

	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 (with LULUCF)	842	5,257	8,204	3,981	10,507	7,796	9,561	3,105	-5,754
CO_2 (without LULUCF)	4,793	4,961	5,032	5,244	5,539	6,266	6,901	7,191	7,084
CH_4 (with LULUCF)	2,609	1,793	1,778	1,698	1,812	2,293	4,648	2,686	2,657
CH_4 (without LULUCF)	2,519	1,692	1,723	1,646	1,703	2,196	2,585	2,613	2,578
N_2O (with LULUCF)	890	887	851	878	917	921	1,805	947	988
N_2O (without LULUCF)	851	843	827	856	870	878	910	916	954
HFC	0	0	0	0	0	0	139	158	151
Total (with LULUCF)	4,342	7,937	10,833	6,557	13,236	11,009	16,153	6,897	-1,958
Total (without LULUCF)	8,163	7,496	7,581	7,746	8,112	9,340	10,536	10,877	10,767

2.3.2. Carbon-dioxide (CO_2)

Total CO_2 emissions (excluding CO_2 from LULUCF) increased from 3,784 kt CO_2 in 2000 to 7,084 kt CO_2 in 2017, representing an 87 % increase over the time series. If CO_2 from LULUCF is included, emissions increased by 11,338 kt 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) decreased from 3,573 kt CO_2 eq in 2000 to 2,578 kt CO_2 eq in 2017, representing a 28 % decrease over the time series. If CH_4 from LULUCF is included, emissions decreased by 1,186 kt CO_2 eq or by 31 % over the time series. The key drivers for this trend are the decrease in fugitive emissions of CH_4 from oil production in the energy sector.

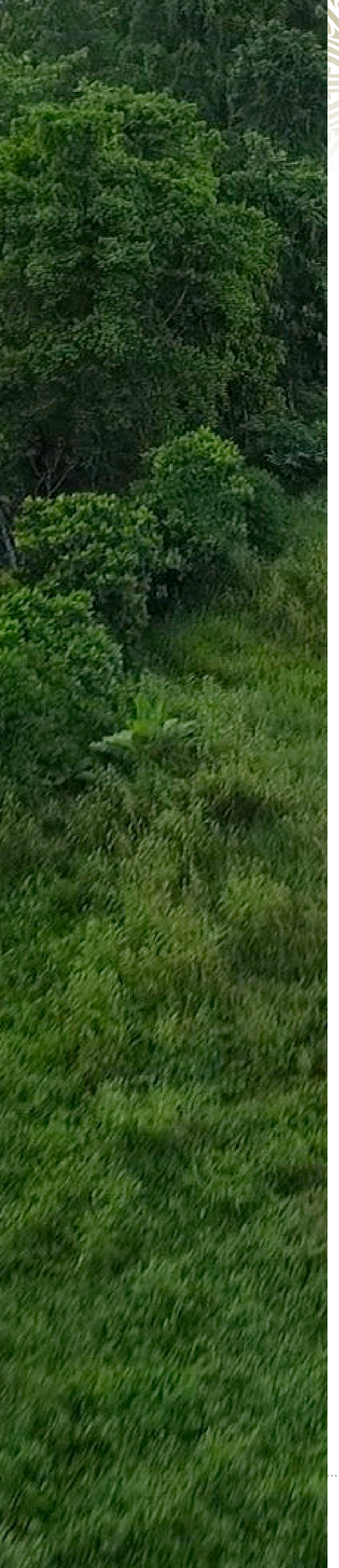
2.3.4. Nitrous oxide (N_2O)

Total N_2O emissions (excluding N_2O from LULUCF) increased from 695 kt CO_2 eq in 2000 to 954 kt CO_2 eq in 2016, representing a 37 % increase 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 first time in this GHG inventory for the years 2015 to 2017. HFC emissions are estimated to be 139.5 kt CO_2 eq in 2015 and 150.6 kt CO_2 eq in 2017. This is an increase of 8.0 % over this time period.

A recent report prepared for CCDA confirmed there is unlikely to be any activity in PNG that would give rise to PFC emissions. However, this report did identify the likelihood of SF_6 emissions in electrical equipment. CCDA intends to liaise with CEPA and PNG Customs to identify potential sources of activity data.



Chapter

3

Energy

3.1. Overview of Sector

Emissions from the energy sector consist of two main categories: fuel combustion and fugitive emissions from fuels. 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), 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 8,673 kt CO_2 eq in 2017, an increase of 1,913 kt CO_2 eq (28 %) when compared to 2000. CO_2 emissions from liquid fuel combustion contributed 68 % of the total GHG emissions in 2017, followed by CH_4 from fugitives (16 %), CO_2 from gaseous fuel combustion (12 %), N_2O from fuel combustion (2 %), CH_4 from fuel combustion (1 %) and CO_2 from fugitive emissions (1 %). 81 % of total sector emissions are CO_2, while CH_4 contributed 17 % and N_2O 2 %.

Table 3-1: Trend in GHG emissions from the energy sector (kt CO_2 eq)

unit : kt CO_2 eq.

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
1A. Fuel combustion	3,718	4,981	5,075	5,148	5,370	5,665	6,388	7,022	7,315	7,215
Liquid fuel CO_2	3,269	4,507	4,592	4,649	4,873	5,165	5,518	5,883	6,120	5,938
Solid fuel CO_2	0	0	0	0	0	0	0	0	0	0
Gaseous fuel CO_2	280	291	289	301	296	296	662	928	982	1,064
Other fossil fuel CO_2	0	0	0	0	0	0	0	0	0	0
CH_4	42	46	49	50	50	51	51	52	52	52
N_2O	127	137	146	149	151	153	157	160	160	160
1.B. Fugitive emissions from fuel	3,042	2,034	769	771	664	687	1,165	1,528	1,531	1,458
CO_2	218	145	53	53	45	47	54	56	53	45
CH_4	2,823	1,889	716	718	619	640	1,111	1,472	1,478	1,413
N_2O	1.0	0.7	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2
1C. CO_2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	6,760	7,015	5,844	5,919	6,035	6,352	7,553	8,551	8,846	8,673

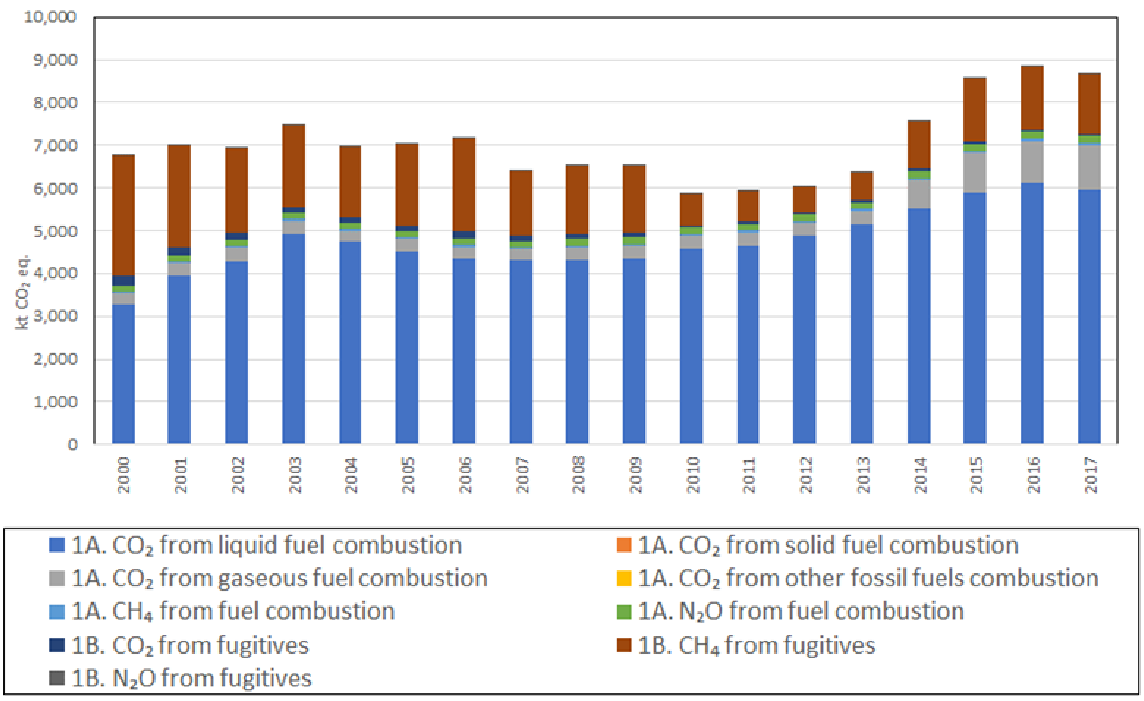


Figure 3-1: Trend in GHG emissions from the energy sector from 2000 to 2017 (in kt CO_2 eq)

3.2. Fuel Combustion (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) (1.A.1) Energy industries: emissions from main activity electricity and heat production, petroleum refining, and manufacturing of solid fuels and other energy industries

(ii) (1.A.2) Manufacturing industries and construction: emissions from manufacturing the industry and construction

(iii) (1.A.3) Transport: emissions from transport of passenger and freight

(iv) (1.A.4) Other sectors: emissions from commercial/institutional, residential, and agriculture/forestry/fishing sources and

(v) (1.A.5) Non-Specified other: emissions from other non-specified fuel combustion sources.

3.2.1. Comparison of the Sectoral Approach with the Reference Approach

This chapter explains a comparison between the reference approach and the sectoral approach in accordance with the UNFCCC Inventory Reporting Guidelines (Decision 24/CP.19 Annex I, paragraph 40). For the methodological issues of the sectoral approach, please refer to 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:

$$E = \sum_i [A_i \times 41.868 \times EF_i] \times 44/12$$

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 and figure 3-3, fluctuations of difference in energy consumption between the reference approach and the sectoral approach during 2000-2017 range between -16% (2004) and +5% (2009).

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.

3.2.1.3. **Difference in CO_2 Emissions**

As shown in table 3-3. and figure 3-3, fluctuations of a difference in CO_2 emissions between the reference approach and the sectoral approach during 2000-2017 range between -16% (2004) and +6% (2009).
Emissions from wastes used for energy and from the incineration of wastes with energy recovery are not reported in waste incineration (4.C.) but reported in fuel combustion (1.A.) in accordance with the 2006 IPCC Guidelines.

Table 3-2: Comparison of energy consumption

unit : TJ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
REFERENCE APPROACH										
Liquid fuels (excluding international bunkers)	39,482	48,651	51,540	56,857	52,712	62,174	59,118	58,908	60,164	62,216
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	4,982	6,029	6,029	5,527	4,438	5,234	4,940	4,605	5,150	5,275
Other fossil fuels	0	0	0	0	0	0	0	0	0	0
Total RA	44,464	54,680	57,569	62,383	57,150	67,407	64,058	63,514	65,314	67,491
SECTORAL APPROACH										
Liquid fuels (excluding international bunkers)	44,003	52,712	57,527	65,649	63,681	60,667	58,448	58,155	58,406	58,783
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	4,982	5,736	5,736	5,527	4,438	5,192	4,940	4,605	5,150	5,317
Other fossil fuels	0	0	0	0	0	0	0	0	0	0
Total SA	48,986	58,448	63,263	71,176	68,119	65,858	63,388	62,760	63,556	64,100
DIFFERENCE										
Liquid fuels (excluding international bunkers)	-10%	-8%	-10%	-13%	-17%	2%	1%	1%	3%	6%
Solid fuels (excluding international bunkers)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gaseous fuels	0%	5%	5%	0%	0%	1%	0%	0%	0%	-1%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	-9%	-6%	-9%	-12%	-16%	2%	1%	1%	3%	5.3%

	2010	2011	2012	2013	2014	2015	2016	2017
REFERENCE APPROACH								
Liquid fuels (excluding international bunkers)	63,556	64,728	67,114	73,102	78,796	79,298	81,517	78,293
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0
Gaseous fuels	5,150	5,359	5,317	5,317	11,807	16,496	17,459	18,966
Other fossil fuels	0	0	0	0	0	0	0	0
Total RA	68,705	70,087	72,432	78,419	90,602	95,794	98,976	97,259
SECTORAL APPROACH								
Liquid fuels (excluding international bunkers)	62,007	62,886	65,356	69,878	74,609	79,214	82,606	80,219
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0
Gaseous fuels	5,150	5,359	5,275	5,275	11,807	16,538	17,501	18,966
Other fossil fuels	0	0	0	0	0	0	0	0
Total SA	67,156	68,245	70,631	75,153	86,416	95,752	100,106	99,185
DIFFERENCE								
Liquid fuels (excluding international bunkers)	2%	3%	3%	5%	6%	0%	-1%	-2%
Solid fuels (excluding international bunkers)	NA	NA	NA	NA	NA	NA	NA	NA
Gaseous fuels	0%	0%	1%	1%	0%	0%	0%	0%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA
Total	2%	3%	3%	4%	4.8%	0%	-1%	-2%

Note: NA=Not applicable

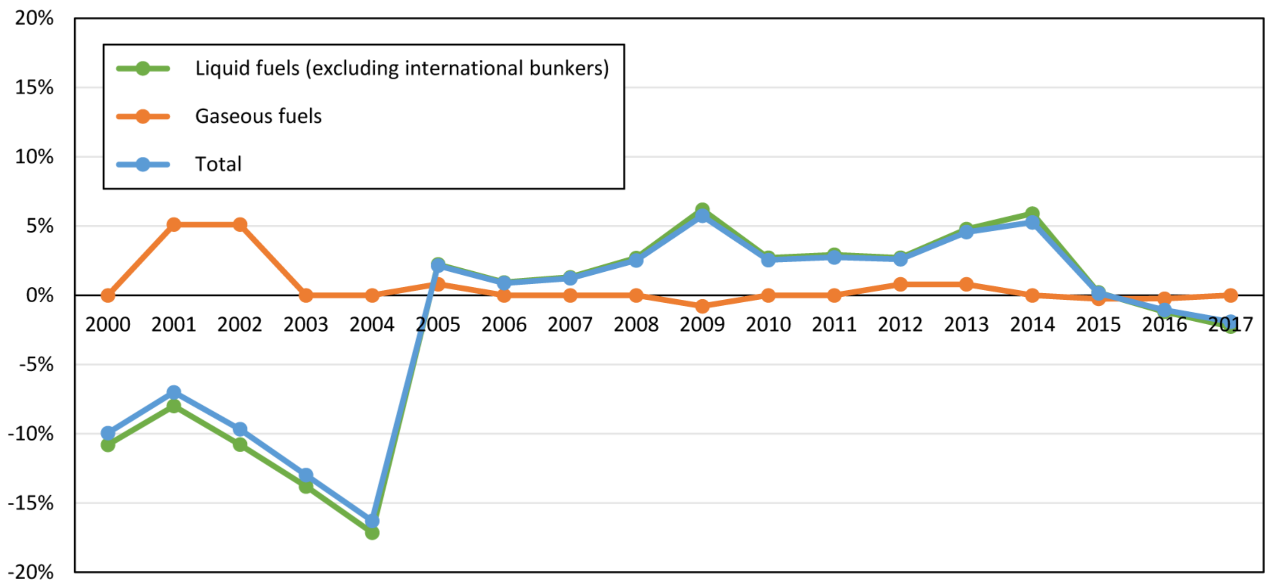


Figure 3-2: Trend in difference in energy consumption between reference approach and sectoral approach from 2000 to 2017 (%)

Table 3-3: Comparison of CO_2 emissions (in kt CO_2)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
REFERENCE APPROACH										
Liquid fuels (excluding international bunkers)	2,916	3,613	3,831	4,236	3,934	4,607	4,386	4,370	4,441	4,618
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	280	338	338	310	249	294	277	258	289	296
Other fossil fuels	0	0	0	0	0	0	0	0	0	0
Total RA	3,196	3,951	4,169	4,547	4,183	4,901	4,663	4,628	4,730	4,914
SECTORAL APPROACH										
Liquid fuels (excluding international bunkers)	3,269	3,927	4,294	4,914	4,747	4,507	4,345	4,314	4,324	4,349
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	280	322	322	310	249	291	277	258	289	298
Other fossil fuels	0	0	0	0	0	0	0	0	0	0
Total SA	3,549	4,248	4,615	5,224	4,996	4,798	4,622	4,572	4,613	4,647
DIFFERENCE										
Liquid fuels (excluding international bunkers)	-11%	-8%	-11%	-14%	-17%	2%	1%	1%	3%	6%
Solid fuels (excluding international bunkers)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gaseous fuels	0%	5%	5%	0%	0%	1%	0%	0%	0%	-1%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	-10%	-7%	-10%	-13%	-16%	2%	1%	1%	3%	6%

	2010	2011	2012	2013	2014	2015	2016	2017
REFERENCE APPROACH								
Liquid fuels (excluding international bunkers)	4,716	4,785	4,972	5,412	5,843	5,895	6,048	5,805
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0
Gaseous fuels	289	301	298	298	662	925	979	1,064
Other fossil fuels	0	0	0	0	0	0	0	0
Total RA	5,005	5,086	5,271	5,711	6,505	6,821	7,027	6,869
SECTORAL APPROACH								
Liquid fuels (excluding international bunkers)	4,592	4,649	4,873	5,165	5,518	5,883	6,120	5,938
Solid fuels (excluding international bunkers)	0	0	0	0	0	0	0	0
Gaseous fuels	289	301	296	296	662	928	982	1,064
Other fossil fuels	0	0	0	0	0	0	0	0
Total SA	4,881	4,950	5,169	5,461	6,180	6,811	7,102	7,002
DIFFERENCE								
Liquid fuels (excluding international bunkers)	3%	3%	2%	5%	6%	0%	-1%	-2%
Solid fuels (excluding international bunkers)	NA	NA	NA	NA	NA	NA	NA	NA
Gaseous fuels	0%	0%	1%	1%	0%	0%	0%	0%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA
Total	3%	3%	2%	5%	5%	0%	-1%	-2%

Note: NA=Not applicable

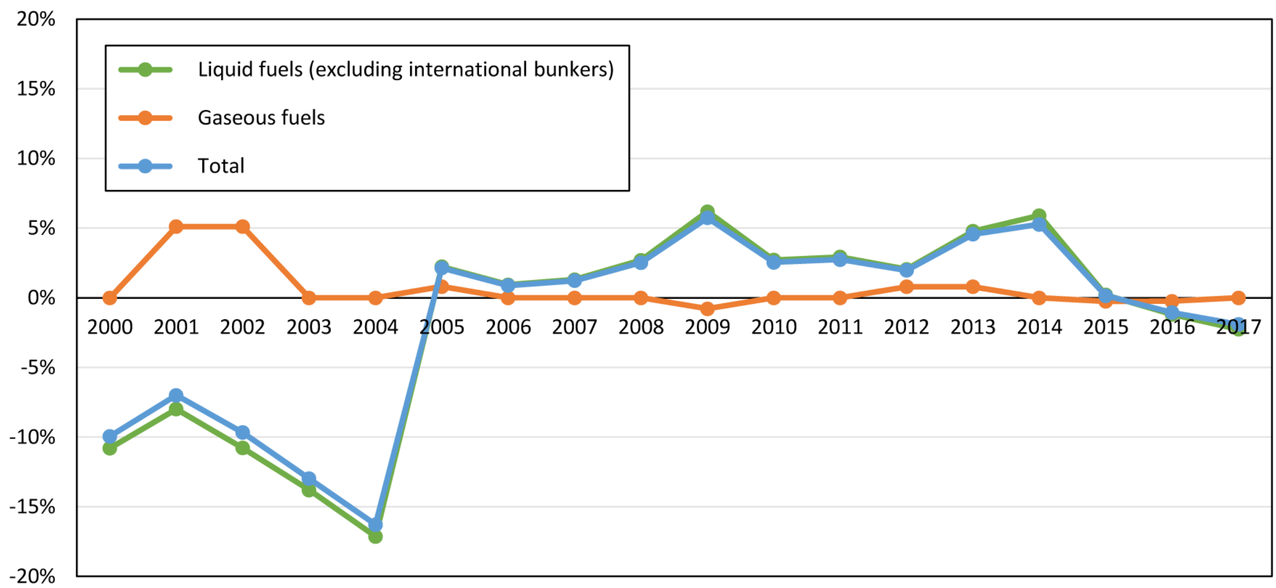


Figure 3-3: Trend in difference in energy consumption from 2000 to 2017 (%)

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

The estimate of CO_2 emissions showed that the estimations using the reference approach balance with the estimation from the sectoral approach. In 2004 there were high discrepancies of 16%. In 2004, it was due to the statistical discrepancy in crude oil data. For years after 2005, GHG level discrepancies ranged from -2% to 6%.

3.2.2. International Bunker Fuels

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

3.2.3. Category Description (e.g. characteristics of sources)

In 2017, emissions from fuel combustion were 7,215 kt CO_2 eq., which accounted for 67 % of PNG's total GHG emissions (excluding LULUCF). By looking at the share of the emissions by gas, CO_2 comprises 97 % of the GHG emissions from fuel combustion.

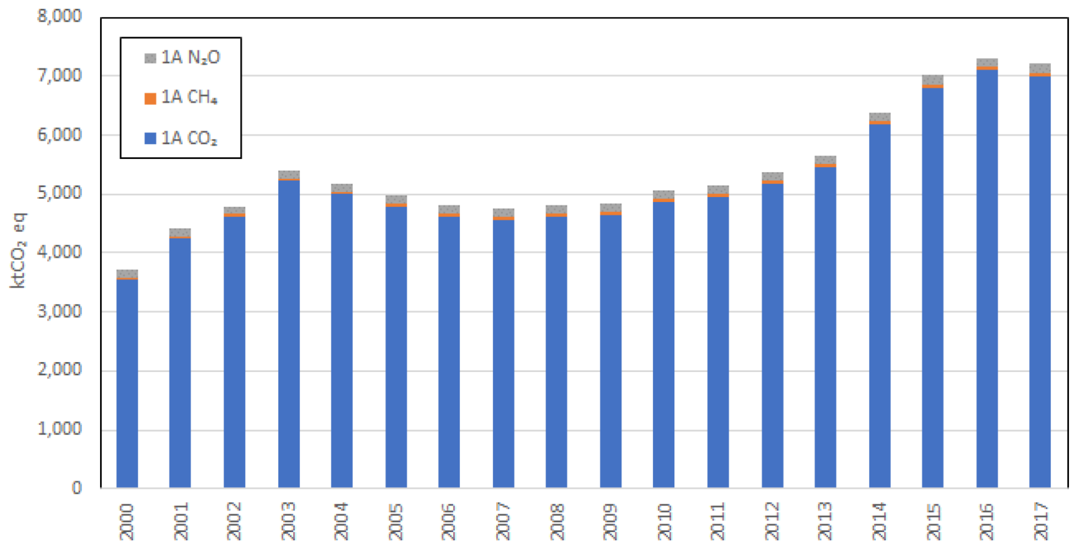


Figure 3-4: Trend in GHG emissions from fuel combustion activities (1.A.) by gas from 2000 to 2017 (in kt CO_2 eq)

Table 3-4: GHGs emissions from fuel combustion (1.A) (in kt CO_2 eq)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
1A CO_2	3,549	4,798	4,881	4,950	5,169	5,461	6,180	6,811	7,102	7,002
1A CH_4	42	46	49	50	50	51	51	52	52	52
1A N_2O	127	137	146	149	151	153	157	160	160	160
1A GHG Total	3,718	4,981	5,075	5,148	5,370	5,665	6,388	7,022	7,315	7,215

The CO_2 emissions in 2017 decreased by 1 % compared to the previous year (2016). The main driving factor for the decrease is the CO_2 emissions from energy industries (1.A.1).

Table 3-5: CO_2 emissions from fuel combustion (1.A) (in kt CO_2 eq)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
1. Energy industries	238	319	316	270	260	314	777	867	1,017	829
2. Manufacturing industries and construction	2,018	3,005	2,793	2,779	2,861	2,977	3,153	3,550	3,674	3,764
3. Transport	888	1,047	1,297	1,411	1,539	1,634	1,784	1,937	1,955	1,946
4. Other sectors	404	427	444	451	447	454	457	457	457	463
5. Other	0	0	31	40	61	83	9	0	0	0
total	3,549	4,798	4,881	4,950	5,169	5,461	6,180	6,811	7,102	7,002

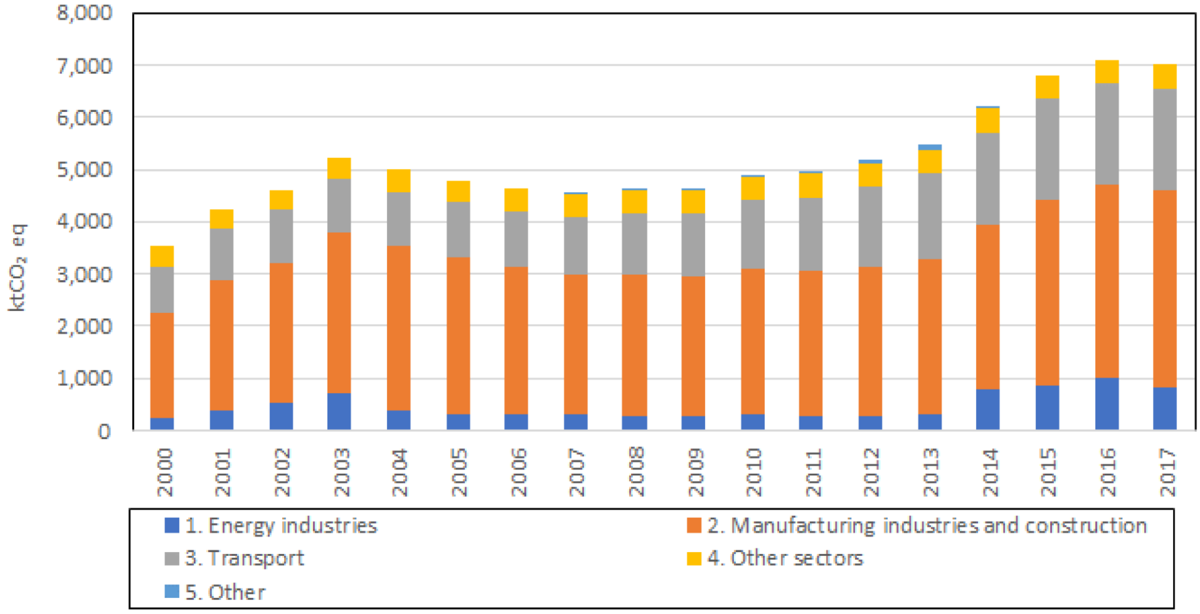


Figure 3-5: Time-series of CO_2 emissions from fuel combustion (1.A.) from 2000 to 2017 (in kt CO_2 eq)

By looking at the changes in CO_2 emissions by subcategory, emissions from the energy industries (1.A.1) increased by 248 % since 2000 and decreased by 18 % compared to the previous year (2016). The main driving factor for the increase compared to the emissions in 2000 is the increase in electricity generation. The emissions from the Energy industries increased slightly from 2000 to 2003 due to the increase in demand for electricity then remained constant from 2005 to 2013 and increased rapidly from 2014 to 2016 due to the increasing demand for electricity, especially for the operation of the LNG project.

The CO_2 emissions from manufacturing industries and construction (1.A.2) increased by 87% since 2000 and increased by 2% compared to the previous year (2016). The main driving factor for the increase compared to the emissions in 2000 is the increased liquid fuel consumption.

The CO_2 emissions from transport (1.A.3) increased by 119% compared to 2000 and decreased by 0.4% compared to the previous year (2016). The main driving factor for the increase compared to the emissions in 2000 is the increase in emissions from road transportation. Emissions from road transportation increased 2.3 times from 2000 to 2017.

The CO_2 emissions from other sectors (1.A.4) increased by 14% since 2000 and increased by 1% compared to the previous year (2016). The main driving factor for the increase compared to the emissions in 2000 is the increase in kerosene consumption in Residential.

Emissions have been estimated for all categories except those that are not occurring in PNG or are not estimated due to data limitations. Categories reported as not occurring includes railways under transport, fugitive emissions from coal mining and handling, and all categories under carbon dioxide transportation and storage. Categories reported as not estimated or as an aggregate include:

- Under manufacturing industries and construction, emissions from pulp, paper, and print, from food processing, beverage, and tobacco, from mining and quarrying, and wood and wood products are reported as an aggregate due to limited data;
- Under manufacturing industries and construction, emissions from construction are reported as not estimated due to a paucity of data; and
- Under transportation, civil aviation and navigation for both domestic and international bunkers are reported as an aggregate due to limited data

3.2.4. Methodological Issues

3.2.4.1. Choice of Method (include assumptions and the rationale for selection)

The Tier 1 Sectoral Approach has been used in accordance with the 2006 IPCC Guidelines to calculate emissions. The CO_2 emissions from biomass are not included in the national totals but are reported as a reference in accordance with the 2006 IPCC Guidelines.

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

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

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

The energy consumption data given in the Energy Balance Table developed by the APERC was converted from one energy unit (kTOE) to another (TJ) and used for the activity data. Table 3-6 and figure 3-6 show the trend of energy consumption by fuel types.

Table 3-6: Total final energy consumption by fuel types (in TJ)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Solid fuels	0	0	0	0	0	0	0	0	0	0
Liquid fuels	44,003	60,667	62,007	62,886	65,356	69,878	74,609	79,214	82,606	80,219
Gaseous fuels	4,982	5,192	5,150	5,359	5,275	5,275	11,807	16,538	17,501	18,966
Other Fossil Fuels	0	0	0	0	0	0	0	0	0	0
Biomass	59,201	62,969	66,738	67,826	69,082	69,626	69,710	69,920	70,045	70,338
Total	108,187	128,828	133,894	136,071	139,714	144,780	156,126	165,672	170,152	169,524

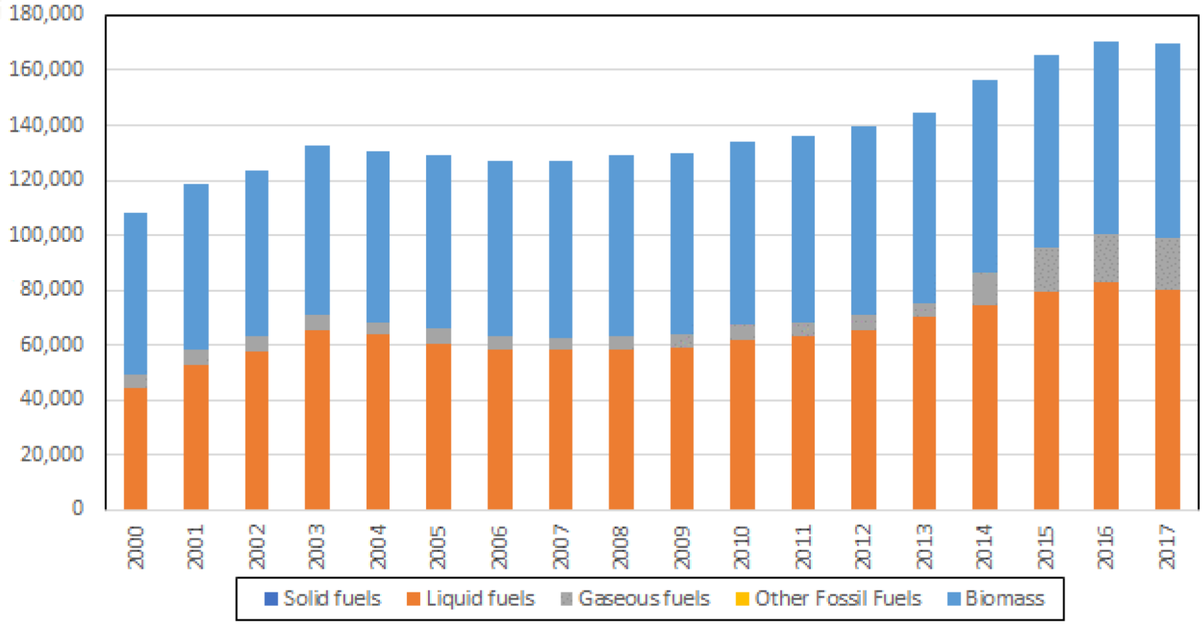


Figure 3-6: Time-series of total final energy consumption by fuel types from 2000 to 2017 (in TJ)

Table 3-7 and figure 3-7 show the trend of energy consumption by sectors.

Table 3-7: Total final energy consumption by sectors (in TJ)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
1. Energy industries	3,182	4,605	4,689	4,187	4,354	6,238	13,816	16,161	18,589	16,580
2. Manufacturing industries and construction	30,019	43,166	40,779	40,905	41,742	43,292	45,971	51,205	53,005	54,345
3. Transport	12,309	14,486	17,920	19,469	21,227	22,525	24,577	26,670	26,921	26,796
4. Other sectors	62,676	66,570	70,087	70,966	71,552	71,594	71,636	71,636	71,636	71,804
5. Other	0	0	419	544	837	1,130	126	0	0	0
Total	108,187	128,828	133,894	136,071	139,714	144,780	156,126	165,672	170,152	169,524

Note: Sector is in accordance with the Energy Balance Table.

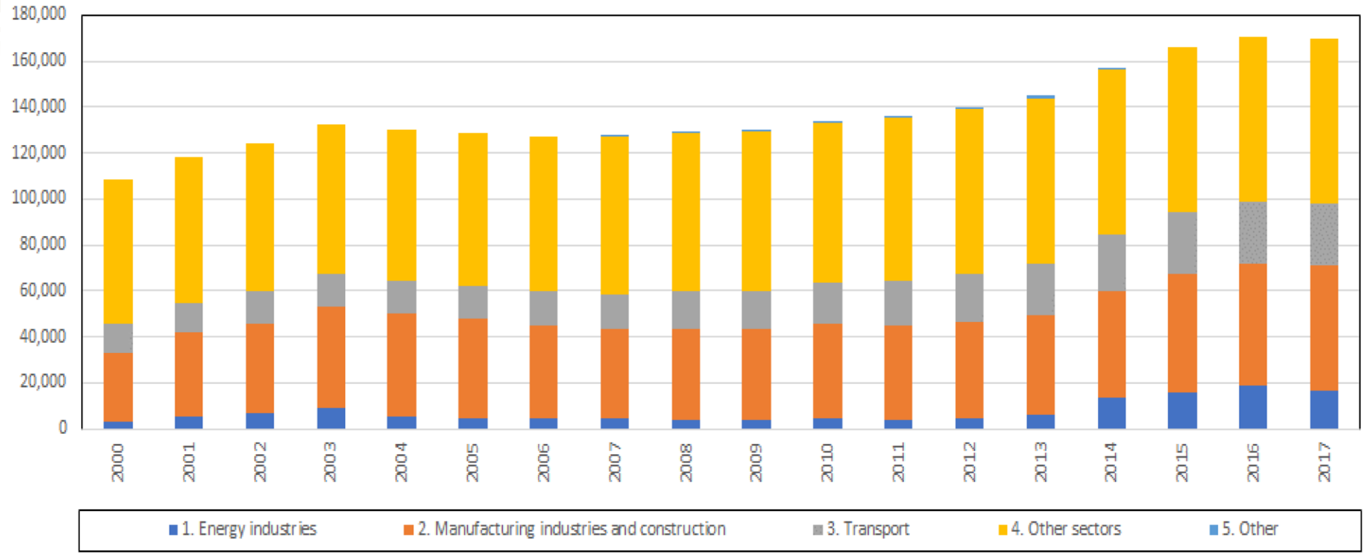


Figure 3-7: Time-series of total final energy consumption by sectors from 2000 to 2017

The Energy Balance Table used as activity data is developed by the Asia Pacific Energy Research Centre (APERC) based on data collected from APEC member countries to provide useful information for understanding the energy supply and demand situation in the APEC region. The Energy Balance Table developed by APERC covers all APEC member countries and was created by collecting annual consumption data for coal, oil, natural gas, renewable energy, electricity, and heat.

For the purpose of presenting the Energy Balance Table by APERC has adopted kcal and Joules. 107 kcal (41.868 gigajoules) is equivalent to one ton of oil equivalent (toe). This quantity of energy is, within a few percent, equal to the net heat content of one ton of crude oil. The Energy Balance Table by APERC shows the main energy sources used in PNG as "Columns" and the supply, conversion, and consumption sectors as "Rows" in a matrix.

Specifically, the columns comprise 11 major categories ("coal", "coal products", "crude oil, NGL and condensate", "petroleum products", "gas", "Hydro", "Nuclear", "Geothermal, solar, etc", "Others", "electricity", and "heat") and the necessary sub-categories and a more detailed breakdown of the sub-categories. The rows comprise major sectors: primary energy supply (primary supply), energy transformation & own use (conversion), and final energy consumption (final consumption). The rows also contain the necessary sub-categories and a more detailed breakdown of the sub-categories.

The complete Energy Balance Tables by APERC for the years since 1980 are available on the following internet site: *https://www.egeda.ewg.apec.org/egeda/database_info/annual_data.html*

Table 3-8 and table 3-9 show the correspondence between the sectors of the Energy Balance Table by APERC and those of the CRF.

Table 3-8: Correspondence between sectors of the Energy Balance Table by APERC and those of the CRF (1.A.1)

CRF	Energy Balance Table by APERC	
1. Energy industries	-	
a. Public electricity and heat production	9.1	Main activity producer
	10.1.1	Electricity, CHP and heat plants
i. Electricity generation	9.1.1	Electricity plants
ii. Combined heat and power generation	9.1.2	CHP plants
iii. Heat plants	9.1.3	Heat Plants
iv. Other	-	
b. Petroleum refining	9.4	Refineries
	9.6	Petrochemical industry
	10.1.14	Oil refineries
c. Manufacture of solid fuels and other energy industries	-	
i. Manufacture of solid fuels	9.5	Coal transformation
	10.1.8	Coke ovens
	10.1.9	Coal mines
	10.1.10	Blast furnaces
	10.1.11	Patent fuel plants
	10.1.12	BKB/PB plants
	10.1.13	Liquefaction plants (Coal to Oil)
ii. Oil and gas extraction	9.3	Gas processing
	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
iii. Other energy industries	9.7	Biofuel processing
	9.8	Charcoal processing
	9.9	Non-specified transformation
	10.1.16	Biofuel processing
	10.1.17	Nuclear industry
	10.1.18	Non-specified own uses
	10.2	Distribution losses

Table 3-9: Correspondence between sectors of the Energy Balance Table by APERC and those of the CRF (1.A.2, 1.A.3, 1.A.4)

CRF	Energy Balance Table by APERC	
2. Manufacturing industries and construction	14.	Industry sector
	9.2	Autoproducers
a. Iron and steel	14.1	Iron and steel
b. Non-ferrous metals	14.3	Non ferrous metals
c. Chemicals	14.2	Chemical (incl. petro-chemical)
d. Pulp, paper and print	14.9	Pulp, paper and printing
e. Food processing, beverages and tobacco	14.8	Food, beverages and tobacco
f. Non-metallic minerals	14.4	Non metallic mineral products
g. Other	-	
i. Manufacturing of machinery	14.6	Machinery
ii. Manufacturing of transport equipment	14.5	Transportation equipment
iii. Mining (excluding fuels) and quarrying	14.7	Mining and quarrying
iv. Wood and wood products	14.10	Wood and wood products
v. Construction	14.11	Construction
vi. Textile and leather	14.12	Textiles and leather
vii. Off-road vehicles and other machinery	-	
viii. Other	14.13	Non-specified industry
3. Transport	-	
a. Domestic aviation	15.1	Domestic air transport
b. Road transportation	15.2	Road
c. Railways	15.3	Rail
d. Domestic Navigation	15.4	Inland waterways
e. Other transportation (please specify)	15.5	Pipeline transport
	15.6	Non-specified transport
4. Other sectors	-	
a. Commercial/institutional	16.1.1	Commerce and public services
b. Residential	16.1.2	Residential
c. Agriculture/forestry/fishing	-	
i. Stationary	-	
ii. Off-road vehicles and other machinery	16.2	Agriculture
iii. Fishing	16.3	Fishing
5. Other (Not specified elsewhere)	16.4	Non-specified others
Memo:	17.	Non-energy use

Note: #17 items are subtracted as non-energy use activities.

3.2.4.3. EF, Other Parameters

The carbon content of fuels expressed as the unit of net calorific value (lower heating value) was used for carbon emission factors. The emission factors for CO_2 are default value emission factors of IPCC 2006 Guidelines.

Table 3-10 provides the emission factors for CO_2 by fuel types.

Table 3-10: Carbon emission factors for fuel combustion in net calorific value (Unit: t C/TJ)

Coal	
Coking coal	25.8
Other bituminous coal	25.8
Sub-bituminous	26.2
Anthracite	26.8
Lignite	27.6
Peat	28.9
Coal products	
Coke	29.2
Coke oven gas	12.1
Blast furnace gas	70.8
Oxygen steel furnace gas	49.6
Patent fuel	26.6
Coal tar	22.0
BKB/PB	26.6
Crude oil, NGL and condensate	
Crude oil and lease condensate	20.0
NGL	17.5
Refinery feedstocks	20.0
Additives/Oxygenates	20.0
Other hydrocarbons	20.0
Petroleum products	
Motor gasoline	18.9
Aviation gasoline	19.1
Naphtha	20.0
Gasoline type jet fuel	19.1
Kerosene type jet fuel	19.5
Kerosene	19.6
Gas/Diesel oil	20.2
Fuel oil	21.1
LPG	17.2
Refinery gas	15.7
Ethane	16.8
White spirit SBP	20.0
Lubricants	20.0
Bitumen	22.0
Paraffin waxes	20.0
Petroleum coke	26.6
Other products	20.0

Gas	
Natural gas	15.3
LNG	15.3
Gas works gas	12.1
Others	
Fuel wood & Woodwaste	30.5
Bagasse	27.3
Charcoal	30.5
Other biomass	27.3
Biogas	14.9
Industrial waste	39.0
Municipal solid waste (renewable)	27.3
Municipal solid waste (non-renewable)	25.0
Biogasoline	19.3
Biodiesel	19.3
Bio jet kerosene	21.7
Other liquid biofuels	21.7
Other sources	27.3

Table 3-11: CH4 emission factors for fuel combustion in net calorific value (Unit: kg-CH4 / TJ)

fuel type		Energy Industry	Manufacturing industries and construction	Civil Aviation	Road transport	Railway	Water-borne Navigation	Commercial/Institutional	Residenital and Agriculture/forestry/fishing farms	Agriculture - offload	Forestry - offload	fishing
Coal	Coking coal	1	1	-	-	-	-	1	1	-	-	-
	Other bituminous coal	1	1	-	-	-	-	1	1	-	-	-
	Sub-bituminous	1	1	-	-	2	-	1	1	-	-	-
	Anthracite	1	1	-	-	-	-	1	1	-	-	-
	Lignite	1	1	-	-	-	-	1	1	-	-	-
	Peat	1	1	-	-	-	-	1	1	-	-	-
Coal products	Coke	1	1	-	-	-	-	1	1	-	-	-
	Coke oven gas	1	1	-	-	-	-	1	1	-	-	-
	Blast furnace gas	1	1	-	-	-	-	1	1	-	-	-
	Oxygen steel furnace gas	1	1	-	-	-	-	1	1	-	-	-
	Patent fuel	1	1	-	-	-	-	1	1	-	-	-
	Coal tar	1	1	-	-	-	-	1	1	-	-	-
	BKB/PB	1	1	-	-	-	-	1	1	-	-	-
Crude oil, NGL and condensate	Crude oil and lease condensate	3	3	-	-	-	-	3	3	-	-	-
	NGL	3	3	-	-	-	-	3	3	-	-	-
	Refinery feedstocks	3	3	-	-	-	-	3	3	-	-	-
	Additives/Oxygenates	3	3	-	-	-	-	3	3	-	-	-
	Other hydrocarbons	3	3	-	-	-	-	3	3	-	-	-
Petroleum products	Motor gasoline	3	3	-	33	-	-	3	3	56	68	-
	Aviation gasoline	3	3	1	-	-	-	3	3	-	-	-
	Naphtha	3	3	-	-	-	-	3	3	-	-	-
	Gasoline type jet fuel	3	3	1	-	-	-	3	3	-	-	-
	Kerosene type jet fuel	3	3	1	-	-	-	3	3	-	-	-
	Kerosene	3	3	-	-	-	-	3	3	-	-	-
	Gas/Diesel oil	3	3	-	3.9	4.15	7	3	3	4.15	4.15	7
	Fuel oil	3	3	-	-	-	7	3	3	-	-	7
	LPG	1	1	-	62	-	-	1	1	-	-	-
	Refinery gas	1	1	-	-	-	-	1	1	-	-	-
	Ethane	1	1	-	-	-	-	1	1	-	-	-
	White spirit SBP	3	3	-	-	-	-	3	3	-	-	-
	Lubricants	3	3	-	-	-	-	3	3	-	-	-
	Bitumen	3	3	-	-	-	-	3	3	-	-	-
	Paraffin waxes	3	3	-	-	-	-	3	3	-	-	-
	Petroleum coke	3	3	-	-	-	-	3	3	-	-	-
	Other products	3	3	-	-	-	-	3	3	-	-	-
Gas	Natural gas	1	1	-	92	-	-	1	1	-	-	-
	LNG	1	1	-	-	-	-	1	1	-	-	-
	Gas works gas	1	1	-	-	-	-	1	1	-	-	-
Others	Fuel wood & Woodwaste	30	30	-	-	-	-	30	30	-	-	-
	Bagasse	1	1	-	-	-	-	1	1	-	-	-
	Charcoal	30	30	-	-	-	-	30	30	-	-	-
	Other biomass	30	30	-	-	-	-	30	30	-	-	-
	Biogas	1	1	-	-	-	-	1	1	-	-	-
	Industrial waste	30	30	-	-	-	-	30	30	-	-	-
	Municipal solid waste	30	30	-	-	-	-	30	30	-	-	-
	Municipal solid waste (renewable)	30	30	-	-	-	-	30	30	-	-	-
	Municipal solid waste (non-renewable)	30	30	-	-	-	-	30	30	-	-	-
	Liquid biofuels	3	3	-	-	-	-	3	3	-	-	-
	Biogasoline	3	3	-	-	-	-	3	3	-	-	-
	Biodiesel	3	3	-	-	-	-	3	3	-	-	-
	Bio jet kerosene	3	3	-	-	-	-	3	3	-	-	-
	Other liquid biofuels	3	3	-	-	-	-	3	3	-	-	-
	Other sources	-	-	-	-	-	-	-	-	-	-	-

Table 3-12 provides the emission factors for N_2O by fuel types and sectors.

Table 3-12: N_2O emission factors for fuel combustion in net calorific value (Unit: kg-N_2O / TJ)

fuel type		Energy Industry	Manufacturing industries and construction	Civil Aviation	Road transport	Railway	Water-borne Navigation	Commercial/Institutional	Residenital and Agriculture/forestry/fishing farms	Agriculture - offload	Forestry - offload	fishing
Coal	Coking coal	2	2	-	-	-	-	1.5	1.5	-	-	-
	Other bituminous coal	2	2	-	-	-	-	1.5	1.5	-	-	-
	Sub-bituminous	2	2	-	-	1.5	-	1.5	1.5	-	-	-
	Anthracite	2	2	-	-	-	-	1.5	1.5	-	-	-
	Lignite	2	2	-	-	-	-	1.5	1.5	-	-	-
	Peat	2	2	-	-	-	-	1.5	1.5	-	-	-
Coal products	Coke	2	2	-	-	-	-	1.5	1.5	-	-	-
	Coke oven gas	2	2	-	-	-	-	1.5	1.5	-	-	-
	Blast furnace gas	2	2	-	-	-	-	1.5	1.5	-	-	-
	Oxygen steel furnace gas	2	2	-	-	-	-	1.5	1.5	-	-	-
	Patent fuel	2	2	-	-	-	-	1.5	1.5	-	-	-
	Coal tar	2	2	-	-	-	-	1.5	1.5	-	-	-
	BKB/PB	2	2	-	-	-	-	1.5	1.5	-	-	-
Crude oil, NGL and condensate	Crude oil and lease condensate	1	1	-	-	-	-	0.6	0.6	-	-	-
	NGL	1	1	-	-	-	-	0.6	0.6	-	-	-
	Refinery feedstocks	1	1	-	-	-	-	0.6	0.6	-	-	-
	Additives/Oxygenates	1	1	-	-	-	-	0.6	0.6	-	-	-
	Other hydrocarbons	1	1	-	-	-	-	0.6	0.6	-	-	-
Petroleum products	Motor gasoline	1	1	-	3.2	-	-	0.6	0.6	0.4	0.4	-
	Aviation gasoline	1	1	2	-	-	-	0.6	0.6	-	-	-
	Naphtha	1	1	-	-	-	-	0.6	0.6	-	-	-
	Gasoline type jet fuel	1	1	2	-	-	-	0.6	0.6	-	-	-
	Kerosene type jet fuel	1	1	2	-	-	-	0.6	0.6	-	-	-
	Kerosene	1	1	-	-	-	-	0.6	0.6	-	-	-
	Gas/Diesel oil	1	1	-	3.9	28.6	2	0.6	0.6	28.6	28.6	2
	Fuel oil	1	1	-	-	-	2	0.6	0.6	-	-	2
	LPG	0.1	0.1	-	0.2	-	-	0.1	0.1	-	-	-
	Refinery gas	0.1	0.1	-	-	-	-	0.1	0.1	-	-	-
	Ethane	0.1	0.1	-	-	-	-	0.1	0.1	-	-	-
	White spirit SBP	1	1	-	-	-	-	0.6	0.6	-	-	-
	Lubricants	1	1	-	-	-	-	0.6	0.6	-	-	-
	Bitumen	1	1	-	-	-	-	0.6	0.6	-	-	-
	Paraffin waxes	1	1	-	-	-	-	0.6	0.6	-	-	-
	Petroleum coke	1	1	-	-	-	-	0.6	0.6	-	-	-
	Other products	1	1	-	-	-	-	0.6	0.6	-	-	-
Gas	Natural gas	0	0	-	3	-	-	0.1	0.1	-	-	-
	LNG	0	0	-	-	-	-	0.1	0.1	-	-	-
	Gas works gas	0	0	-	-	-	-	0.1	0.1	-	-	-
Others	Fuel wood & Woodwaste	4	4	-	-	-	-	4	4	-	-	-
	Bagasse	0	0	-	-	-	-	0.1	0.1	-	-	-
	Charcoal	4	4	-	-	-	-	4	4	-	-	-
	Other biomass	4	4	-	-	-	-	4	4	-	-	-
	Biogas	0	0	-	-	-	-	0.1	0.1	-	-	-
	Industrial waste	4	4	-	-	-	-	4	4	-	-	-
	Municipal solid waste	4	4	-	-	-	-	4	4	-	-	-
	Municipal solid waste (renewable)	4	4	-	-	-	-	4	4	-	-	-
	Municipal solid waste (non-renewable)	4	4	-	-	-	-	4	4	-	-	-
	Liquid biofuels	1	1	-	-	-	-	0.6	0.6	-	-	-
	Biogasoline	1	1	-	-	-	-	0.6	0.6	-	-	-
	Biodiesel	1	1	-	-	-	-	0.6	0.6	-	-	-
	Bio jet kerosene	1	1	-	-	-	-	0.6	0.6	-	-	-
	Other liquid biofuels	1	1	-	-	-	-	0.6	0.6	-	-	-
	Other sources	-	-	-	-	-	-	-	-	-	-	-

3.2.5. Category-specific Recalculations

A new format of energy balances table by APERC has been introduced to separate non-energy use from total final energy consumption after the inventory of BUR1. In the new format, total final consumption is the sum of total final energy consumption and non-energy use. Emissions in the energy sector have been recalculated based on the new format energy balance table developed by APERC.

In addition, emissions from auto producers have been reported under 1.A.1 energy industry, but from this inventory submission, they will be reported under 1.A.2. manufacturing industries and construction. Therefore, the emissions from 1.A.1 and 1.A.2 have been recalculated for the whole year.

3.2.6. Category-specific Planned Improvements

In this inventory the Energy Sector has the following challenges:

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

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

3.3. Fugitive Emissions from Fuels (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 source categories in this sector:

(i) solid fuels (1.B.1): emissions from coal mining and handling; and

(ii) oil and natural gas (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 (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.

Table 3-13: GHG emissions from the fugitive emissions subsector (1.B) (in kt CO_2 eq)

Gas	CRF Category		Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
CH_4	1.B.1 Solid Fuels	a. Coal mining and handling	$ktCH_4$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		b. Solid fuel transformation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		c. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and natual gas	a. Oil		129	85	31	31	26	27	28	26	24	19
		b. Natural gas		2	2	2	2	2	2	23	42	44	47
		c. Venting and flaring		4	3	1	1	1	1	1	2	2	2
		d. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		$ktCH_4$	134	90	34	34	29	30	53	70	70	67
			$ktCO_2$ eq.	2,823	1,889	716	718	619	640	1,111	1,472	1,478	1,413
CO_2	1.B.1 Solid Fuels	a. Coal mining and handling	$ktCO_2$	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		b. Solid fuel transformation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		c. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and natual gas	a. Oil		9	6	2	2	2	2	2	2	2	1
		b. Natural gas		0	0	0	0	0	0	1	1	1	1
		c. Venting and flaring		209	139	51	51	43	45	51	54	50	42
		d. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		$ktCO_2$ eq	218	145	53	53	45	47	54	56	53	45
N_2O	1.B.1 Solid Fuels	a. Coal mining and handling	ktN_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		b. Solid fuel transformation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		c. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and natual gas	a. Oil		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		b. Natural gas		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		c. Venting and flaring		0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
		d. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		ktN_2O	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
			$ktCO_2$eq.	1.0115	0.6712	0.2455	0.2456	0.2099	0.2173	0.2486	0.2583	0.2429	0.2041
GHG total			$ktCO_2$eq.	3,042	2,034	769	771	664	687	1,165	1,528	1,531	1,458

Table 3-14: NMVOC emissions from the fugitive emissions subsector (1.B) (in kt NMVOC)

Gas	CRF Category		Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
NMVOC	1.B.1 Solid Fuels	a. Coal mining and handling	ktNMVOC	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		b. Solid fuel transformation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		c. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and natual gas	a. Oil		161	108	40	40	35	36	37	34	32	26
		b. Natural gas		0.1	0.1	0.1	0.1	0.1	0.1	1.7	3.1	3.3	3.4
		c. Venting and flaring		2.2	1.4	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3
		d. Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		ktNMVOC	163	110	41	41	35	37	39	38	36	30

In 2017, GHG emissions from fugitive emissions from fuels were 1,458 ktCO_2 eq. and accounted for 13.5% of PNG's total GHG emissions (excluding LULUCF). The emissions have decreased by 52% compared to 2000. Emission from fugitive emissions in the oil sector decreased after 2000 as the production of oil decreased, while fugitive emissions from the gas sector increased due to the increase in production of natural gas (LNG project), especially in 2015.

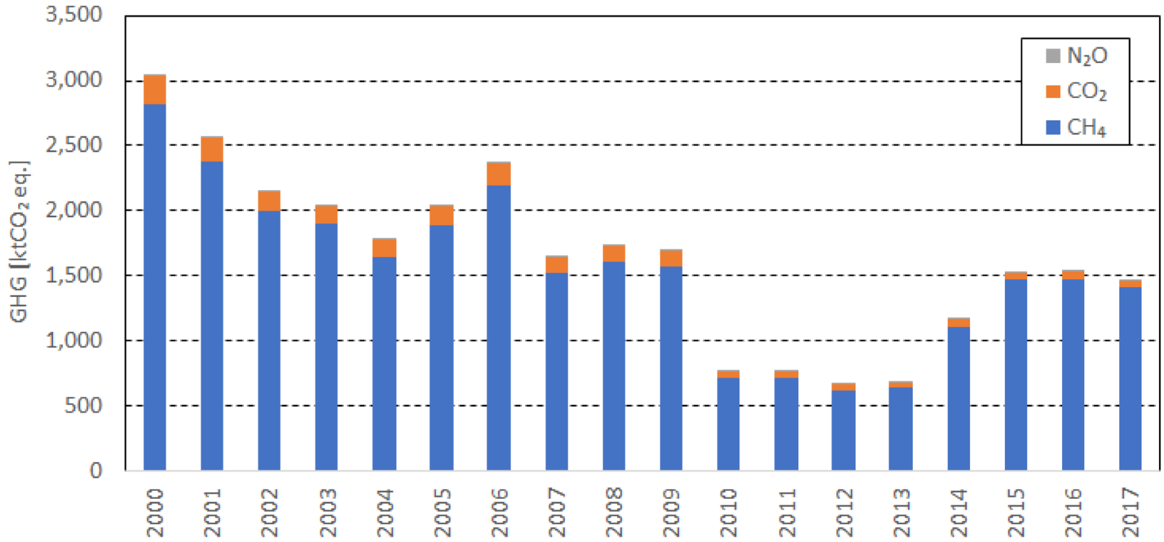


Figure 3-8: Emission trend of the fugitive emissions by gas (1.B.) from 2000 to 2017 (kt CO_2 eq)

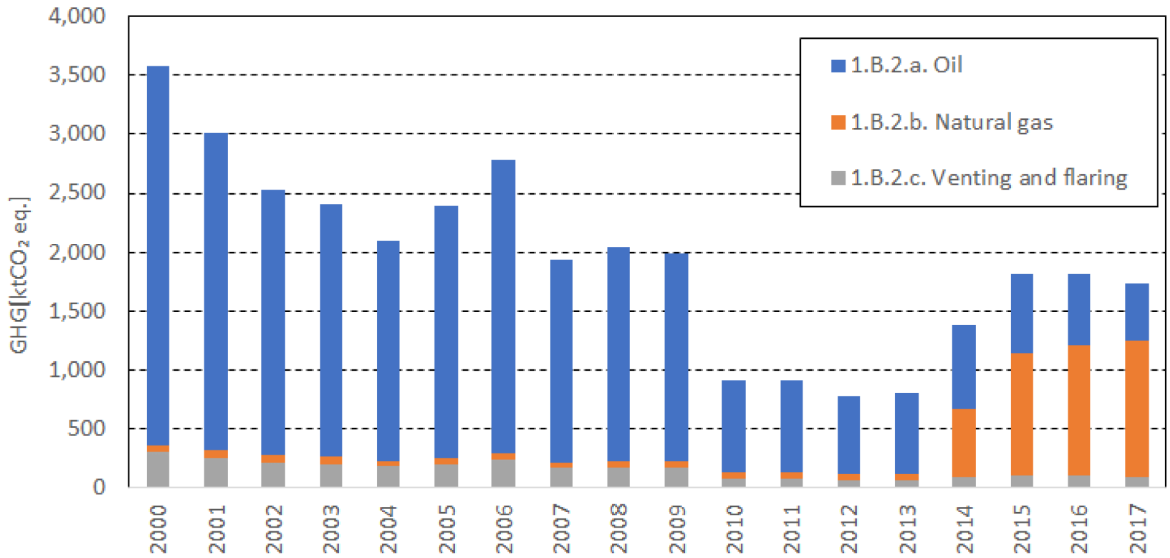


Figure 3-9: Emission trend of the fugitive emissions (1.B) by category from 2000 to 2017 (in kt CO_2 eq)

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

This category is out of the scope of reporting because PNG does not mine coal.

3.3.2. Oil, Natural Gas and other emissions from Energy Production (1.B.2)

3.3.3. Oil (1.B.2.a.)

3.3.3.1. Exploration (1.B.2.a.i.)

This category provides the estimation methods for fugitive emissions of CO_2, CH_4, N_2O, and NMVOC from the exploratory drilling of oil fields. The emissions from this source are reported as "NE". Exploration of oil activities exists in PNG and an extremely small amount of GHG emissions are considered to be released into the atmosphere from these activities. Because there are neither country-specific emission factors and activity data, GHG emissions from this source were not estimated.

3.3.3.2. Production (1.B.2.a.ii.)

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for fugitive emissions of CO_2, CH_4, and NMVOC that occur during the production of crude oil.

b. Methodological Issues

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

The fugitive emissions from oil production are estimated using the Tier 1 method, in accordance with the decision tree in the 2006 IPCC Guidelines (Vol. 2, page 4.39, Fig.4.2.2).

(2) AD (include uncertainties and time-series consistency)

The amount of crude oil production is used for activity data. The production amount of crude oil is obtained from the Energy Balance Table developed by APERC.

Table 3-15: Amount of oil production excluding condensate in PNG (unit: kL)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Oil Production excluding condensate	4,284	2,839	1,032	1,032	881	912	935	882	803	627

(3) EF, Other Parameters

For emission factors for fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from onshore oil fields, which are indicated in the 2006 IPCC Guidelines, are used. As for emission factors for onshore oil fields, the medians of default values are used.

Table 3-16: Emission factors for fugitive emissions from oil production [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Conventional Oil	3.0×10^{-2} 1)	2.2×10^{-3} 2)	NA 3)	3.8×10^{-2} 4)

Reference: 2006 IPCC Guidelines Vol 2, page 4.58, Table 4.2.5"

Note:

1) The default value is $1.5\times10^{-6} - 6.0\times10^{-2}$
2) The default value is $1.1\times10^{-7} - 4.3\times10^{-3}$
3) Excluded from calculations, as the default value is "NA"
4) The default value is $1.8\times10^{-6} - 7.5\times10^{-2}$

c. Category-specific Recalculations

Precursor NMVOC emissions are newly reported under this category.

d. Category-specific Planned Improvements, if applicable

Emissions from this category are significant in PNG emissions from the energy sector, so it should be collected detailed activity and infrastructure data to apply either a Tier 2 or Tier 3 approach, depending on the effort required.

3.3.3.3. **Transport (1.B.2.a.iii.)**

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for fugitive emissions of CO_2, CH_4, and NMVOC occurring during the transportation of crude oil through pipelines, tank trucks, and tank cars to refineries.

b. Methodological Issues

(1) Choice of Method (include assumptions and the rationale for selection)

The fugitive emissions from transport of crude oil are estimated using the Tier 1 method in accordance with the decision tree in the 2006 IPCC Guidelines (Vol.2, page 4.40, Fig.4.2.3) by multiplying the amount of crude oil transported by the emission factors.

(2) AD (include uncertainties and time-series consistency)

The amount of total crude oil production plus imports is used for activity data assuming crude oil transported according to the 2006 IPCC Guidelines (Vol.2, page 4.68, Table.4.2.7). The production and import amount of crude oil is obtained from the Energy Balance Table developed by APERC.

Table 3-17: Amount of Oil Transported by pipeline in PNG (unit: kL)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Oil Production	4,284	2,839	1,032	1,032	881	912	935	882	803	627
Oil Import	-	1,068	1,157	1,144	1,294	1,484	1,299	728	1,610	1,645
Oil Transported by pipeline	4,284	3,907	2,189	2,176	2,175	2,396	2,234	1,610	2,413	2,272

Note : Oil Transported by pipeline = oil production + oil imports

(3) EF, Other Parameters

The default values given in the 2006 IPCC Guidelines were used as emission factors.

Table 3-18: Emission factors for transportation of crude oil [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Oil Transport	5.4×10^{-6}	4.9×10^{-7}	NA 1)	5.4×10^{-5}

Reference: 2006 IPCC Guidelines Vol. 2, page 4.61, Table 4.2.5
Note: 1) Excluded from calculations, as the default value is "NA"

c. Category-specific Recalculations

Precursor NMVOC emissions are newly reported under this category.

d. Category-specific Planned Improvements

It is assumed that everything was transported by pipeline, but it should be confirmed that there is no transportation by tanker or truck.

3.3.3.4. **Refining / Storage (1.B.2.a.iv.)**

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for fugitive emissions of CH_4 and NMVOC occurring when crude oil is refined or stored at oil refineries. The CO_2 and N_2O emissions from this source are reported as "NE". Refining/storage activities exist in PNG and an extremely small amount of CO_2 and N_2O is considered to be released into the atmosphere from these activities. Because there are neither country-specific emission factors nor any default values for emission factors, CO_2 and N_2O emissions from this source are not estimated.

b. Methodological Issues

(1) Choice of Method (include assumptions and the rationale for selection)

The fugitive emissions from oil refining are estimated using the Tier 1 method in accordance with the decision tree in the 2006 IPCC Guidelines (Vol. 2, page 4.40, Fig. 4.2.3).

(2) AD (include uncertainties and time-series consistency)

The amount of crude oil refined is used for activity data. The refined amount of crude oil is obtained from the Energy Balance Table developed by APERC.

Table 3-19: Amount of crude oil refined in PNG (unit: kL)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Oil Refined	-	1,157	1,125	1,125	1,238	1,558	1,238	715	1,657	1,655

(3) EF, other Parameters

For the emission factors for the fugitive emissions during the refining process, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-20: Emission factor during crude oil refining [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Oil Refining	2.2×10^{-5} 1)	NA 2)	NA 2)	1.3×10^{-3}

Reference: 2006 IPCC Guidelines Vol. 2, page 4.53, Table 4.2.4

Note:

1) The default value is 2.6×10^{-6} – 41.0×10^{-6}

2) Excluded from calculations, as the default value is "NA"

c. Category-specific Recalculations

Emissions in this category were not estimated, but new activity data was set up between 2005 and 2017 and additional CO_2 and CH_4 emissions were reported. As a result, recalculations were made from 2005 to 2017.

d. Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.3.5. **Distribution of Oil Products (1.B.2.a.v.)**

Petroleum products are distributed in PNG and it is conceivable that either or both CO_2, CH_4 and NMVOC will be emitted as a result of the relevant activity. However, the emissions are reported as "NE" due to the absence of default emission factors.

3.3.4. Natural Gas (1.B.2.b.)

3.3.4.1. Exploration (1.B.2.b.i.)

This category provides the estimation methods for fugitive emissions of CO_2, CH_4, N_2O and NMVOC the explorative drilling of natural gas fields. As well as Exploration of oil (1.B.2.a.i), the emissions from this source are reported as "NE". Exploration of natural gas activities exist in PNG and an extremely small amount of GHG emissions are considered to be released into the atmosphere from these activities. Because there are neither country-specific emission factors nor any activity data, GHG emissions from this source are not estimated.

3.3.4.2. Production (1.B.2.b.ii.)

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for fugitive emissions of CO_2, CH_4 and NMVOC occur at production of natural gas.

b. Methodological Issues

(1) Choice of Method (include assumptions and the rationale for selection)

The fugitive emissions from the production of natural gas are estimated using Tier 1 method, in accordance with the 2006 IPCC Guidelines (Vol. 2, page 4.38, Fig. 4.2.1).

(2) AD (include uncertainties and time-series consistency)

The production volume of natural gas is used for activity data. The production amount of natural gas is obtained from the Energy Balance Table developed by APERC.

Table 3-21: Volume of natural gas production in PNG (unit: $10^9 m^3$)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Gas Production	132	139	137	142	141	141	1,666	2,991	3,181	3,342

(3) EF, Other Parameters

For the emission factors for the fugitive emissions during the production of natural gas, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-22: Emission factors of fugitive emissions during production of natural gas [kt / $10^6 m^3$]

	CH_4	CO_2	N_2O	NMVOC
Gas production	1.2×10^{-2} 1)	9.7×10^{-5} 2)	NA 3)	6.5×10^{-4} 4)

Reference: 2006 IPCC Guidelines Vol. 2, page 4.55, Table 4.2.5
Note:
1) The default value is $3.8\times10^{-4} – 2.4\times10^{-2}$
2) The default value is $1.4\times10^{-5} – 1.8\times10^{-4}$
3) Excluded from calculations, as the default value is "NA"
4) The default value is $9.1\times10^{-5} – 1.2\times10^{-3}$

c. Category-specific Recalculations

CO_2, CH_4 and NMVOC emissions in 2002, 2004, 2014 and 2015 have been recalculated due to a change in the format of the APERC energy balance table used for activity data.

d. Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.4.3. **Processing (1.B.2.b.iii.)**

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for fugitive CO_2, CH_4 and NMVOC emissions from the processing of natural gas including adjustment of its constituent elements.

b. Methodological Issues

(1.) Choice of Method (include assumptions and the rationale for selection)

The fugitive emissions associated with processing natural gas are estimated using Tier 1 method in accordance with the decision tree in the 2006 IPCC Guidelines *(Vol.2, page 4.38, Fig.4.2.1).*

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

The Volume of natural gas production is used for activity data. The production volume of natural gas is obtained from the Energy Balance Table developed by APERC. *(Refer to Table 3 8)*

(3.) EF, Other Parameters

For the emission factors for the fugitive emissions during processing of natural gas, the median values between upper limit and lower limit for Sweet Gas raw gas feed Plants indicated in the 2006 IPCC Guidelines are used. Due to the absence of any information on the ratio of sweet plants and sour plants in PNG gas plants, assumed all gas plants are sweet according to the 2006 IPCC Guidelines *(Vol.2, page 4.67, Table.4.2.7).*

Table 3-23: Emission factors during natural gas processing [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Gas Processing (Sweet Gas Plants)	7.9×10^{-4} 1)	2.5×10^{-4} 2)	NA 3)	3.7×10^{-4} 4)

Reference : 2006 IPCC Guidelines Vol. 2, page 4.55, Table 4.2.5
Note:
1) The default value is $4.8\times10^{-4} – 1.1\times10^{-3}$
2) The default value is $1.5\times10^{-4} – 3.5\times10^{-4}$
3) Excluded from calculations, as the default value is "NA"
4) The default value is $2.2\times10^{-4} – 5.1\times10^{-4}$

c. Category-specific Recalculations

CO_2, CH_4 and NMVOC emissions in 2002, 2004, 2014 and 2015 have been recalculated due to a change in the format of the APERC energy balance table used for activity data.

d. Category-specific Planned Improvements

Since the current estimation method assumes that all gas plants are sweet plants, it is necessary to collect information on the share of sweet and sour plants.

3.3.4.4. **Transmission and Storage (1.B.2.b.iv.)**

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for CO_2, CH_4 and NMVOC emissions from transmission of produced natural gas.

b. Methodological Issues

(1.) Choice of Method (include assumptions and the rationale for selection)

GHG emissions from transmission and storage facilities of natural gas are estimated using the Tier 1 method in accordance with the decision tree in the 2006 IPCC Guidelines *(Vol.2, page 4.38, Fig.4.2.1)* by multiplying the total net supply of natural gas by the emission factors.

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

The volume of natural gas production is used for activity data. The production volume of natural gas is obtained from the Energy Balance Table developed by APERC. *(Refer to Table 3 8)* Since natural gas is not imported in PNG, the production volume of natural gas is assumed to be equal to the total net supply and set as activity data.

(3) EF, other Parameters

For the emission factors for the fugitive emissions from transmission and storage facilities of natural gas, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-24: Emission factors for fugitive emissions from natural gas transmission and storage [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Transmission	6.3×10^{-4} 1)	1.4×10^{-6} 2)	NA 3)	1.2×10^{-5} 4)
Storage	4.2×10^{-5} 5)	1.9×10^{-7} 6)	NA 3)	6.0×10^{-7} 7)

Reference : 2006 IPCC Guidelines Vol. 2, page 4.57, Table 4.2.5

Note:

1) The default value is $16.6\times10^{-5} – 1.1\times10^{-3}$

2) The default value is $8.8\times10^{-7} – 2.0\times10^{-6}$

3) Excluded from calculations, as the default value is "NA"

4) The default value is $7.0\times10^{-6} – 1.6\times10^{-5}$

5) The default value is $2.5\times10^{-5} – 5.8\times10^{-5}$

6) The default value is $1.1\times10^{-7} – 2.6\times10^{-7}$

7) The default value is $3.6\times10^{-7} – 8.3\times10^{-7}$

c. Category-specific Recalculations

The time-series CH_4, CO_2, and NMVOC emissions have been recalculated due to changes in the activity data used to estimate emissions from storage.

d. Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.4.5. **Distribution (1.B.2.b.v.)**

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for CO_2, CH_4 and NMVOC emissions (excluding venting and flaring) from the distribution of natural gas to end users.

b. Methodological Issues

(1) Choice of Method (include assumptions and the rationale for selection)

The fugitive emissions from the distribution of natural gas are estimated using the Tier 1 method, in accordance with the decision tree in the 2006 IPCC Guidelines *(Vol. 2, page 4.38, Fig.4.2.1)*.

(2) AD (include uncertainties and time-series consistency)

Natural gas production minus exports is used for activity data assuming gas utility sales according to the 2006 IPCC Guidelines *(Vol.2, page 4.67, Table.4.2.7)*. The production and exports volume of natural gas is obtained from the Energy Balance Table developed by APERC.

Table 3-25: Amount of Oil Transported by pipeline in PNG (unit: 10^9m^3)

	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Gas Production	132	139	137	142	141	141	1,666	2,991	3,181	3,342
Gas Export	-	-	-	-	-	-	1,353	2,554	2,718	2,839
Gas Utility Sales	132	139	137	142	141	141	313	437	463	503

Note : Gas Utility Sales = Gas Production - Gas Export

(3) EF, Other Parameters

For the emission factors for the fugitive emissions from the distribution of natural gas, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-26: Emission factors for fugitive emissions from gas distribution [kt / 10³m³]

	CH_4	CO_2	N_2O	NMVOC
Distribution	1.8×10^{-3} 1)	9.6×10^{-5} 2)	NA 3)	2.6×10^{-5} 4)

Reference : 2006 IPCC Guidelines Vol. 2, page 4.57, Table 4.2.5
Note:
1) The default value is $1.1\times10^{-3} – 2.5\times10^{-3}$
2) The default value is $5.1\times10^{-5} – 1.4\times10^{-4}$
3) Excluded from calculations, as the default value is "ND"
4) The default value is $1.6\times10^{-5} – 3.6\times10^{-5}$

c. Category-specific Recalculations

The time-series CH_4, CO_2, and NMVOC emissions have been recalculated due to changes in the activity data.

d. Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.5. Venting and Flaring (1.B.2.c.)

This section includes fugitive emissions of CO_2 and CH_4 occurring from venting during oil field development, crude oil transportation, refining processes, and product transportation in the petroleum industry, as well as during gas field development, natural gas production, transmission, and processing in the natural gas industry.
It also includes CO_2, CH_4 and N_2O emissions from flaring during the above processes.

3.3.5.1. **Venting (Oil) (1.B.2.c.Venting.i.)**

a. Category Description (e.g. characteristics of sources)

This category provides the estimation methods for CO_2, CH_4 and NMVOC emissions from venting in the petroleum industry.

b. Methodological Issues

(1) Choice of Method (include assumptions and the rationale for selection)

The emissions from venting in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the 2006 IPCC Guidelines *(Vol. 2, page 4.39, Fig. 4.2.2)* by multiplying the amount of crude oil production by the default emission factors.

(2) AD (include uncertainties and time-series consistency)

The amount of crude oil production is used for activity data. The production amount of crude oil is obtained from the Energy Balance Table developed by APERC. *(Refer to Table 3 8)*

(3) EF, Other Parameters

For the emission factors of oil field venting, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-27: Emission factors of oil field venting [kt / 10³m³]

	CH_4	CO_2	N_2O	NMVOC
Venting / Oil Production	8.6×10^{-4} 1)	1.1×10^{-4} 2)	NA 3)	5.1×10^{-4} 4)

Reference : 2006 IPCC Guidelines Vol. 2, pages 4.58 – 4.62, Table 4.2.5
Note:
1) The default value is $7.2\times10^{-4} – 9.9\times10^{-4}$
2) The default value is $9.5\times10^{-5} – 1.3\times10^{-4}$
3) Excluded from calculations, as the default value is "NA"
4) The default value is $4.3\times10^{-4} – 5.9\times10^{-4}$

c. Category-specific recalculations

Precursor NMVOC emissions are newly reported under this category.

d. Category-specific planned improvements

There are no major planned improvements in this category.

3.3.5.2. Venting (Gas) (1.B.2.c.Venting.ii.)

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

This category provides the estimation methods for CO_2, CH_4 and NMVOC emissions from venting in the natural gas industry.

b. Methodological issues

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

The CO_2, CH_4, and NMVOC emissions associated from venting in the natural gas industry were calculated using the Tier 1 method in accordance with the decision tree of the 2006 IPCC Guidelines *(Vol. 2, page 4.38, Fig. 4.2.1)*. The emissions were calculated by multiplying the amount of natural gas production by the emission factors. The GHG emissions associated with venting during gas transmission were reported as the emissions from venting in the natural gas industry.

(2) AD (include uncertainties and time-series consistency)

The Volume of natural gas production is used for activity data. The production volume of natural gas is obtained from the Energy Balance Table developed by APERC. *(Refer to Table 3 8)*

(3) EF, other parameters

For the emission factors for the fugitive emissions from venting in the natural gas industry, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-28: Emission factors of natural gas field venting [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Venting / Transmission and Storage	3.9×10^{-4} 1)	5.2×10^{-6} 2)	NA 3)	7.8×10^{-6} 4)

Reference : 2006 IPCC Guidelines Vol. 2, page 4.57, Table 4.2.5

Note:

1) The default value is 4.4×10^{-5} – 7.4×10^{-4}

2) The default value is 3.1×10^{-6} – 7.3×10^{-6}

3) Excluded from calculations, as the default value is "NA"

4) The default value is 4.6×10^{-6} – 1.1×10^{-5}

c. Category-specific recalculations

Precursor NMVOC emissions are newly reported under this category.

d. Category-specific planned improvements

There are no major planned improvements in this category.

3.3.5.3. Flaring (Oil) (1.B.2.c.Flaring.i.)

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

This category provides the estimation methods for CO_2, CH_4, N_2O and NMVOC from flaring in the petroleum industry.

b. Methodological issues

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

The CO_2, CH_4, N_2O and NMVOC emissions from flaring in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the 2006 IPCC Guidelines, by multiplying the amount of crude oil production in PNG by the default emissions factors.

(2) AD (include uncertainties and time-series consistency)

The amount of crude oil production is used for activity data. The production amount of crude oil is obtained from the Energy Balance Table developed by APERC. *(Refer to Table 3 8)*

(3.) EF, other parameters

For the emission factors for the fugitive emissions from flaring in the petroleum industry, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-29: Emission factors for flaring in the oil industry [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Flaring / Oil Production	3.0×10^{-5} 1)	4.9×10^{-2} 2)	7.6×10^{-7} 3)	2.5×10^{-5} 4)

Reference : 2006 IPCC Guidelines Vol. 2, pages 4.58 – 4.62, Table 4.2.5
Note:
1) The default value is 2.5×10^{-5} – 3.4×10^{-5}
2) The default value is 4.1×10^{-2} – 5.6×10^{-2}
3) The default value is 6.4×10^{-7} – 8.8×10^{-7}
4) The default value is 2.1×10^{-5} – 2.9×10^{-5}

c. Category-specific recalculations

Precursor NMVOC emissions are newly reported under this category.

d. Category-specific planned improvements

There are no major planned improvements in this category.

3.3.5.4. Flaring (Gas) (1.B.2.c.Flaring.ii.)

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

This category provides the estimation methods for CO_2, CH_4, N_2O and NMVOC from flaring in the natural gas industry.

b. Methodological issues

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

The CO_2, CH_4, and N_2O emissions associated with flaring in the natural gas industry were calculated using the Tier 1 method in accordance with the decision tree of the 2006 IPCC Guidelines *(Vol. 2, page 4.38, Fig. 4.2.1)*. The emissions were calculated by multiplying the amount of natural gas production by the emission factors. The total emissions associated with flaring both during gas production and processing were reported as the emissions from flaring in the natural gas industry.

(2) AD (include uncertainties and time-series consistency)

The Volume of natural gas production is used for activity data. The production volume of natural gas is obtained from the Energy Balance Table developed by APERC. *(Refer to Table 3 8)*

(3) EF, other parameters

For the emission factors for the fugitive emissions from flaring in the natural gas industry, the median values between upper limit and lower limit indicated in the 2006 IPCC Guidelines are used.

Table 3-30: Emission factors for flaring in the natural gas industry [kt / 10^3m^3]

	CH_4	CO_2	N_2O	NMVOC
Flaring / Gas Production	8.8×10^{-7} 1)	1.4×10^{-3} 2)	2.5×10^{-8} 3)	7.4×10^{-7} 4)
Flaring / Gas Processing (Sweet Gas Plants)	1.4×10^{-6} 5)	2.2×10^{-3} 6)	3.0×10^{-8} 7)	1.1×10^{-6} 8)

Reference : 2006 IPCC Guidelines Vol. 2, page 4.55, Table 4.2.5
Note:
1) The default value is 7.6×10^{-7} – 1.0×10^{-6}
2) The default value is 1.2×10^{-3} – 1.6×10^{-3}

3) The default value is $2.1\times10^{-8} – 2.9\times10^{-8}$
4) The default value is $6.2\times10^{-7} – 8.5\times10^{-7}$
5) The default value is $1.2\times10^{-6} – 1.6\times10^{-6}$
6) The default value is $1.8\times10^{-3} – 2.5\times10^{-3}$
7) The default value is $2.5\times10^{-8} – 3.4\times10^{-8}$
8) The default value is $9.6\times10^{-7} – 1.3\times10^{-6}$

c. Category-specific recalculations

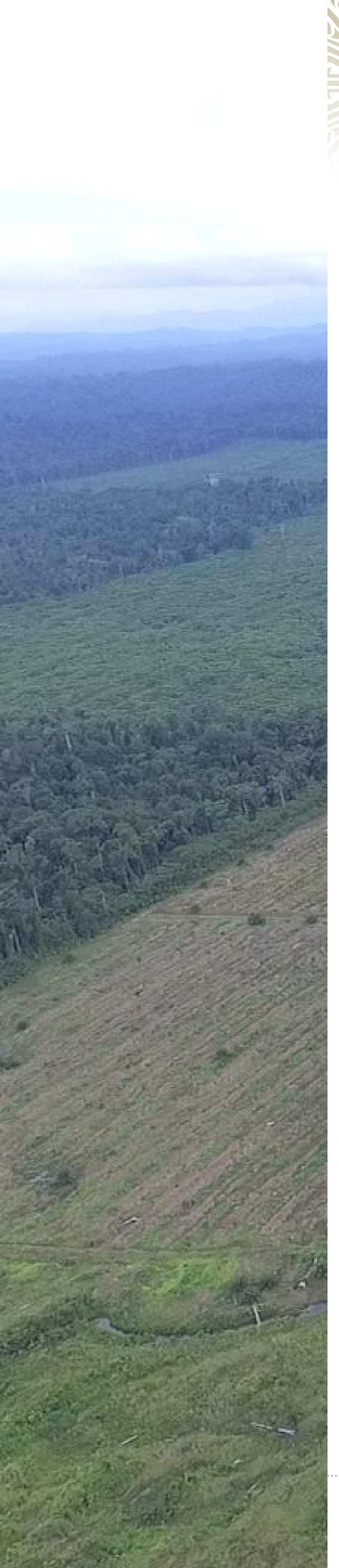
CO_2, CH_4 and NMVOC emissions in 2002, 2004, 2014 and 2015 have been recalculated due to a change in the format of the APERC energy balance table used for activity data.

d. Category-specific planned improvements

There are no major planned improvements in this category.

3.4. CO_2 Transport and Storage (1.C)

This category is out of the scope of reporting because PNG does not transport or store CO_2.



Chapter

4

Industrial Processes and Product Use (IPPU)

4.1. Overview of Sector

PNG's economy is dominated by resources, agriculture, forestry, and fishing, and also includes a small import-substituting manufacturing sector. A number of these activities involve an industrial process or a product use that results in GHG emissions including lubricant use (2.D.1) and refrigeration and air-conditioning (2.F.1). A number of import-substituting manufacturing result in the emission of non-GHGs (CO, NOx, NMVOC) and include food, beverage, and tobacco manufacturing. The import of N_2O used in products (2.G.3) also gives rise to GHG emissions.

The nature and extent of an industrial process or product use in other activities associated with resources, agriculture, and fishing have not been determined. CCDA continues to work with CEPA in a process of using 'environmental permits' to confirm whether GHG emissions are associated with any of these activities. Examples of activities have been identified in PNG's Balance of Trade and include:

- 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 of oils obtained from bitumi.

Currently emissions from these categories have not been reported in this GHG inventory. Hence emissions from Mineral Industry (2.A.), Chemical Industry (2.B.) and Metal Industry are reported as 'not occurring' until confirmed otherwise via the GHG Inventory Improvement Plan.

CCDA has included HFC emissions for the first times in the GHG inventory. These emissions are estimated on the basis of the quantities of bulk HFCs imported into PNG. Further improvement is required to estimate emissions by end-use which requires data on pre-charged equipment type and the 'refrigerant bank'. CCDA will collaborate with CEPA and PNG Customs to establish a data framework to provide the data and information necessary to provide end-use emissions of fluorinated gases.

CCDA has also identified the potential for SF_6 emissions arising from the use of electrical equipment. Again, CCDA will collaborate with CEPA and PNG Customs to establish a data framework to provide activity data on the importation and use of electrical equipment containing SF_6.

This section provides GHG emission estimates for lubricant use (2.D.1), HFCs in refrigeration and air-conditioning (2.F.1) and N_2O in product use (2.G.3). Emission estimates for other IPPU subsectors are not reported and are denoted as 'not occurring' until demonstrated that the activity is occurring in PNG.

The IPPU GHG inventory has been developed with use of IPCC Tier 1 methods and the IPCC default emission factors. HFC's from product uses as substitutes for ODS (2.F.1) is the only exception in which an IPCC Tier$_2$b method was applied. Activity data has been obtained directly from industry data sources for lubricant use (2.D.1) and N_2O from product use (2.G.3), and from PNG Customs who provided HFC bulk import data.

Total GHG emissions in the IPPU sector for the latest inventory are estimated to be 153.3 kt CO_2 eq. The relative contribution of individual GHGs is 1% (CO_2), 98% (HFC) and 1% (N_2O). This ratio is largely consistent through the time series with exception to HFCs that are estimated only for years 2015 through to 2017. It is acknowledged that the IPPU inventory remains largely incomplete.

In 2017, IPPU sector emissions contributed 1% to total GHG emissions (excluding LULUCF). The emissions by category are shown in table 4-1.

Table 4-1: IPPU sector GHG emissions.

Category	Emissions (kt CO_2 eq)		Difference (kt CO_2 eq)	Change (%)	Share (%)	
	2000	2017	2000–2017	2000–2017	2000	2017
Mineral industry (2.A)	NO	NO	-	-	-	-
Chemical industry (2.B)	NO	NO	-	-	-	-
Metal industry (2.C)	NO	NO	-	-	-	-
Non-energy products from fuels and solvent use (2.D)	0.82	1.75	0.93	114.33	100	1
Product uses as substitutes for ODS (2.F)	NE	150.62	-	-	-	98
Other product manufacture and use (2.G)	NE	0.93	-	-	-	1
Total	0.82	153.30	152.5	18,690	-	-

Note: 'NO' = not occurring; 'NE' = not estimated.

IPPU sector emissions in 2017 were 153.3 kt CO_2 eq (18,690 %) higher than emissions in 2000 (0.82 kt CO_2 eq). This significant percent change was mainly driven by a paucity of activity data in the base year for HFCs and for N_2O from product use.

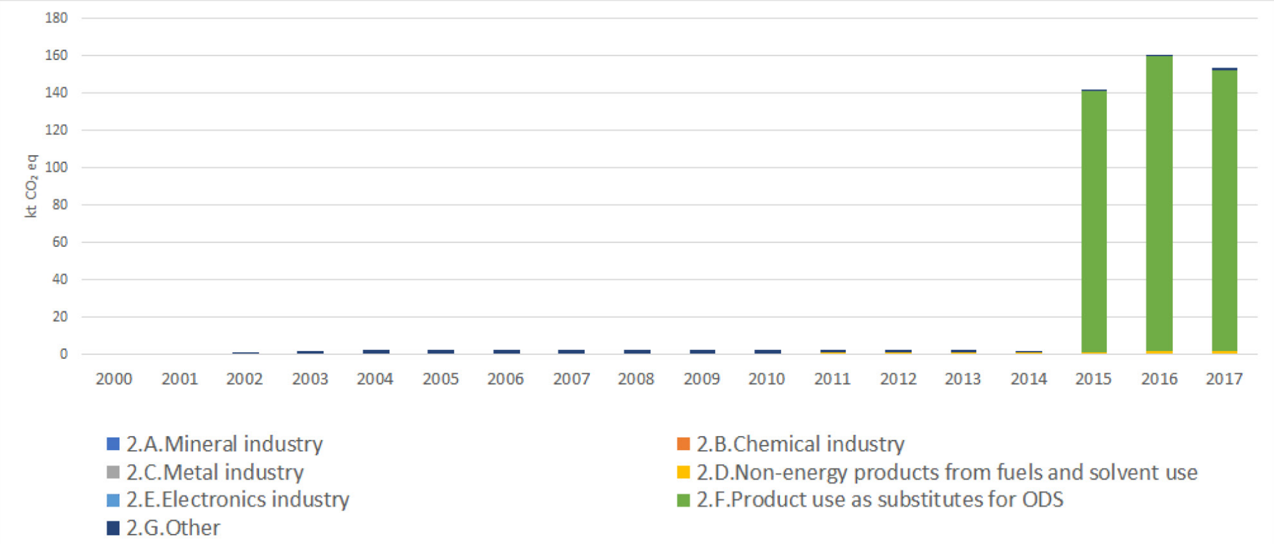


Figure 4-1: Relative contribution to total IPPU emissions (in kt CO_2 eq)

4.2. Mineral Industry (2.A.)

Mineral Industry (2.A.) emissions are not reported. PNG's Balance of Trade statistics indicate a mineral industry does not exist in PNG.

The GHG Inventory Improvement Plan includes an exercise to confirm whether any mineral industry activities are occurring in PNG, and whether these activities generate GHG emissions.

4.3. Chemical Industry (2.B.)

Chemical Industry (2.B.) emissions are not reported. As already noted, PNG's Balance of Trade statistics indicate a chemical manufacturing industry exists in PNG, mainly in Lae, Morobe Province and Port Moresby.
CCDA aims to confirm via the GHG Inventory Improvement Plan whether chemical industry related activities listed in section 4.1 occur, and secondly, whether its industrial processes generate GHG emissions.

4.4. Metal Industry (2.C.)

Metal Industry (2.C.) emissions are not reported. There is extensive mining of metals including precious metals in PNG. These include gold, silver, copper, rare earth metals, nickel, cobalt, chromium, iron and platinum. It is unclear at what point in the manufacturing chain (ore, concentrating, smelting, refining) the process ends, and whether the process generates GHG emissions.

CCDA aims to confirm via the GHG Inventory Improvement Plan whether metal industry related activities listed in section 4.1 occur, and secondly, whether its industrial processes generate GHG emissions.

4.5. Non-Energy Products from Fuels and Solvent Use (2.D.)

4.5.1. Lubricant Use (2.D.1)

4.5.1.1. Category Description (e.g. characteristics of sources)

Lubricants (motor oils) are liquids used for lubrication of various combustion engines used in industrial and transportation applications. While the main function is to lubricate moving parts, motor oil also cleans, inhibits corrosion, improves sealing and cools the engine by carrying heat away from the moving parts. The majority of motor oils are derived from crude oil. Lubricants mostly consist of hydrocarbons: organic compounds consisting entirely of hydrogen and carbon.

Lubricants are categorised into mineral or synthetic motor oils depending on the production process technology. Mineral oils are produced by basic conversion technologies. They fulfill only minimum standards. Synthetic oils (low-viscosity lubricants) are produced in synthetic processes which significantly improves the characteristics of the product.

4.5.1.2. Methodological Issues

(1) Choice of Activity Data

CCDA has been provided lubricant consumption data from key importer of lubricants. This data has been provided for all years up to 2015. In-lieu of corresponding data for 2016 and 2017 it is assumed activity data for these years is the same as 2015.

(2) Choice of Method

A Tier 1 method is used to estimate CO_2 emissions from lubricant use. There is no country-specific information on the amount of lubricant used for specific applications. For this reason, the IPCC Tier 1 approach is used (IPCC, 2006a).

CO_2 emissions from lubricant use is calculated with use of the IPCC Tier 1 method provided below.

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

Where:

CO_2 Emissions:	*= 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*

(3) Choice of Emission Factor and Other Parameters

A default IPCC emission factor (carbon content and 'oxidised during use' factor) is used. The default emission factor is 20.0 kg C/GJ on a Lower Heating Value basis.

Country-specific data to differentiate the fraction of the lubricant consumed and combusted (reported in Energy sector), from the fraction not fully oxidised (reported in the IPPU sector). Hence PNG applies the limiting assumption to calculate CO_2 emissions as the total amount of lubricants lost during their use as it is assumed to be fully combusted, and thereby these emissions are directly reported as CO_2 emissions.

PNG has only total consumption data and cannot differentiate between oil and grease. Hence the IPCC default weighted average ODU factor of 0.2 is used, based on an assumption of 90 % of the mass of lubricants is oil and 10 % is grease.

4.5.1.3. Category-specific Recalculations, if applicable

No recalculation of the CO_2 emission time-series was undertaken for this GHG inventory. However it is acknowledged 2016 and 2017 will need to be recalculated in future GHG inventories with use of actual activity data for these years.

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

CCDA has no planned improvements in the methodology and emission factors to estimate CO_2 emissions from lubricant use. This is based on a need to prioritize improvements in the GHG inventory based on outcomes of the key category assessment.

4.6. Product Use as a Substitute for ODS (2.F.)

Various applications under this subsector rely on the use of refrigerants. The use and subsequent leakage of these gases have traditionally been known to impact the ozone layer. The process of phasing-out of ozone depleting substances (ODS) is managed under the Montreal Protocol. The Kigali Amendment to this protocol requires the phasing-out of HFCs which have high global warming potentials, with HFCs to be gradually replaced by CFC's and HCFC's.

PNG has reported HFC emissions for the time series 2015–2017. These emission estimates are taken from the HFC Emission Inventory Report (Picker and Dudley, September 2021) provided to CCDA. The method applied to estimate emissions is based on bulk HFC import data provided by PNG Customs. Thereby these emissions cannot be attributed to specific 'applications', but it is acknowledged that most of the imported HFC would be used in refrigeration and air-conditioning equipment. Hence they are reported under 2.F.1. Refrigeration and Air-Conditioning.

CCDA acknowledges GHG emissions from the product use as a substitute for ODS is largely incomplete. Bulk HFC import data could not be allocated to specific end-uses and this has been identified as an improvement for the next inventory. The ability to estimate and monitor refrigerant 'banks' is an additional area of improvement. The 'bank' is the existing stock of refrigerants in existing equipment.

4.6.1. Refrigeration and Air-Conditioning (2.F.1)

4.6.1.1. Category Description (e.g. characteristics of sources)

Refrigeration and air-conditioning equipment are largely used for thermal comfort in domestic and commercial buildings or in the storage and transport of goods such as food. New equipment imported into PNG can be pre-charged, but in some cases they will need to be charged with a refrigerant upon installation. These equipment will need to recharged periodically via maintenance procedures, and at the end of life are 'retired' and then the refrigerant is 'destroyed'. There can be leakages of refrigerants from retired equipment.

4.6.1.2. Methodological Issues

(1) Choice of Activity Data

The abovementioned HFC Emission Inventory Report investigated sources of activity data to enable estimation of HFC emissions. Three sources were identified with Chinese export data (2015-2019) and PNG Customs import data (2019-2020) selected. The PNG Customs data was selected as the primary source on the basis it would be a reliable and sustainable source of bulk HFC import data. The Chinese export data provided the necessary speciation of HFC with species ratios used to adjust PNG Customs data.

Table 4-2: Adjusted HFC data for 2015 to 2017

	2015	2016	2017
R134a	48.3	59.5	64.4
R404A	18.6	18.4	34.2
R407c	0	1.9	1.6
R410A	18.9	32.0	33.5
R438a	0	0	0
R452a	0	0	0
R507	5.6	0.6	13.9
R32	0	0	0
Total	91.3	112.4	147.6

Source: HFC Emission Inventory Report (September 2021)

(2) Choice of Method

HFC emissions have been estimated with use the Equation 7.9 from the 2019 Refinement of the 2006 IPCC Guidelines. This is a Tier 2b mass-balance approach to estimating emissions that relies on known or assumed information on servicing regimes required 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 utilized expert judgement and judgement which enable use of the above equation. These assumptions are detailed in the HFC Emission Inventory Report (September 2021) provided to CCDA that includes expert judgement of the authors and the PNG Refrigeration and Air-Conditioning Association (PNG-RACA). These assumptions include:

- Ratio of refrigerant used for servicing and used for charging new equipment of 80:20,
- Original total charge of retiring equipment assumed to be zero, and
- Amount of intentional destruction assumed to be zero.

It is acknowledged small quantities of refrigerants were shipped to Australia for destruction. However, investigation is required to confirm this event and the quantities involved.

(3) Emission factors and 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 section.

4.6.1.3. Category-specific Recalculations, if applicable

This is the first reporting of HFC emissions. Hence there is no recalculation of emissions.

4.6.1.4. Category-specific Planned Improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The HFC Emission Inventory Report (September 2021) provided to the CCDA lists identified improvement to the Product uses as substitutes for ODS (2.F). These improvements can be generalized as:

- CCDA collaborate with CEPA and PNG Customs on an interim arrangement to obtain annual HFC bulk import data to enable emissions estimation,
- Concurrently, CEPA collaborates with CCDA and PNG Customs on improving mechanisms, arrangements, processes and procedures to collect data by imported equipment type, the stock of equipment in PNG by end-use, and the refrigerant 'bank', and
- Collaborate with PNG Customs and PNG Energy to identify sources of data on SF_6 in electrical equipment.

4.7. Other Product Manufacture and Use (2.G.)

4.7.1. N_2O for Medical Application (2.G.3.)

4.7.1.1. Category Description (e.g. characteristics of sources)

PNG has reported emission of N_2O from product use in medical applications for years 2002 through to 2017. Activity data for the earlier years of the time series was not available. Medical applications include anaesthetic use, analgesic use and veterinary use.

4.7.1.2. Methodological Issues

(1) Choice of Activity Data

Activity data had previously been provided to CCDA by BOC Gases who is has been identified as the sole importer into PNG of N_2O for medical application. Activity data is provided for years 2002 through to 2015. In-lieu of corresponding data for 2016 and 2017 it is assumed activity data for these years is the same as 2015.

(2) Choice of Method

Because the quantities are small and the emissions are all considered to be prompt, a Tier 1 method is to estimate N_2O emissions. Further, it is assumed all N_2O that is imported is assumed to be sold and used in one year.

N_2O emissions from N_2O consumption in medical applications is calculated with use of the IPCC Tier 1 method provided below.

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

Where:

$\Sigma N_2O(t)$: = *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*

EF_i: = *emission factor for application type i, fraction*

(3) Emission Factors and 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.

4.7.1.3. **Category-specific Recalculations, if applicable**

No recalculation of the N_2O from medical applications was undertaken for this GHG inventory. However it is acknowledged 2016 and 2017 will need to be recalculated in future GHG inventories with use of actual activity data for these years.

4.7.1.4. **Category-specific Planned Improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

CCDA has no planned improvements in the methodology and emission factors to estimate N_2O emissions from medical application. This is based on a need to prioritise improvements in the GHG inventory based on outcomes of the key category assessment.

Chapter

5

Agriculture

5.1. Overview of Sector

This chapter contains information on the estimation of GHG emissions from the agriculture sector. GHG emissions from the agricultural sector are generally linked to the management of agricultural soils, livestock, rice production and biomass burning. The main agricultural sources of GHG emissions are the following:

- 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;
- manure decomposition under anaerobic condition, which produces methane emissions.

This section provides GHG estimates from livestock (3.A.) and aggregated sources and non-CO_2 emission sources from land (3.C.). Under livestock (3.A.) the GHG estimates cover enteric fermentation (3.A.1) and manure management (3.A.2). Under aggregated sources and non-CO_2 from land (3.C.) the GHG estimates covers direct N_2O emissions from managed soils (3.C.4.), indirect N_2O emissions from managed soils (3.C.5.); and indirect N_2O from manure management. Biomass burning in forest lands (3.C.1.a) is captured under the LULUCF sector. Biomass burning of other land use (cropland (3.C.1.b), grassland (3.C.1.c) and other land (3.C.1.d)), liming (3.C.2), urea application (3.C.3.) and rice cultivation (3.C.7.) are not estimated due to limited or unavailability of data.

GHG emissions from the agriculture sector amounted to 934.7 kt CO_2 eq in 2017 which is about 9 % of the country's overall emission in that year (excluding LULUCF). Total GHG emissions increased by 203 kt CO_2 eq (28 %) in 2017 when compared with year 2000. The highest emitting category in 2017 was direct N_2O emissions from managed soils (3.C.4.) which contributed 57 % of the total sector emissions. After this is the enteric fermentation (3.A.1.) category which contributed 18 %, followed by manure management (3.A.2.) with 17 % and indirect N_2O emissions from managed soils (3.C.5.) with about 7 %. This least emitting category in the agriculture sector is indirect N2O emissions from manure management.

Table 5-1: Total GHG emissions from the agriculture sector (kt CO_2 eq)

2006 IPCC Code	Category	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.A.1	Enteric fermentation	kt CO_2 eq	146.1	135.6	160.7	163.8	160.0	167.2	164.9	168.5	169.2	172.9
3.A.2	Manure management		133.4	134.0	141.9	145.8	148.1	156.0	156.7	159.1	156.1	158.7
3.C.1.a	Biomass burning in forestlands		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
3.C.1.b	Biomass burning in croplands		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.C.1.c	Biomass burning in grasslands		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.C.1.d	Biomass burning in other land		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.C.2	Liming		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.C.3	Urea application		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.C.4	Direct N_2O emissions from managed soils		407.6	449.7	474.5	455.2	473.6	479.2	480.5	500.4	500.6	528.8
3.C.5	Indirect N_2O emissions from managed soils		41.0	51.0	56.8	52.4	56.9	58.4	58.7	63.5	63.5	70.1
3.C.6	Indirect N_2O emissions from manure management		3.6	3.6	3.8	3.9	4.0	4.2	4.2	4.3	4.2	4.3
3.C.7	Rice cultivation		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total			731.7	773.8	837.8	821.2	842.5	865.0	865.0	895.7	893.7	934.7

Note: IE = Included elsewhere, NE=Not estimated, NO=Not occurring

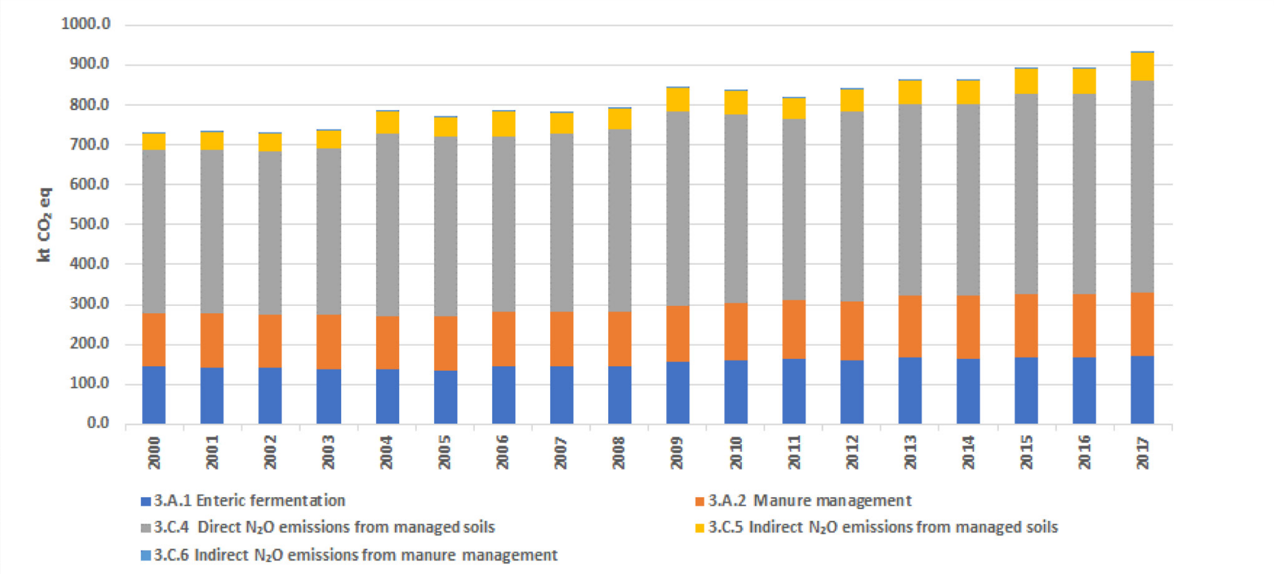


Figure 5-1: Trend of GHG emissions for the agriculture sector from 2000 to 2017 (kt CO_2 eq)

5.2. Livestock (3.A.)

This section provides narratives on the of GHG emissions from the livestock (3.A.). This includes the enteric fermentation (3.A1) category and manure management category (3.A.2). The two main GHG emitted are CH_4 and N_2O. In accordance with 2006 IPCC Guidelines, CO_2 emissions from livestock are not estimated because annual net CO_2 emissions are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2. A portion of the C is returned as CH_4 and for this reason CH_4 requires separate consideration (Dong et al., 2006).

In PNG the main livestock species raised are cattle, sheep, goat, 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.

5.2.1. Enteric Fermentation (3.A.1)

CH_4 is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The amount of methane that is released depends on 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).

In PNG total CH_4 emissions from enteric fermentation in 2017 were 172.92 kt CO_2 eq, an increase of 26.86 kt CO_2 eq (16 %) when compared with the year 2000. Non-dairy cattle (other cattle) contributed about 91% of the total CH_4 emissions in 2017 while the remaining emissions are from the other livestock species.

Table 5-2: Total GHG emissions from enteric fermentation by livestock species (kt CO_2 eq)

Category	Gas	Sub-category	2006 IPCC Code	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.A.1	CH_4	Dairy Cows	3.A.1.ai	kt CH_4	0.09	0.09	0.10	0.10	0.10	0.09	0.09	0.09	0.10	0.10
		Other Cattle	3.A.1.aii		6.38	5.85	7.01	7.15	6.96	7.28	7.17	7.32	7.36	7.53
		Buffalo	3.A.1.b		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Sheep	3.A.1.c		0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
		Goats	3.A.1.d		0.05	0.08	0.09	0.09	0.09	0.10	0.11	0.12	0.11	0.12
		Camels	3.A.1.e		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Horses	3.A.1.f		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
		Mules and Asses	3.A.1.g		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Swine	3.A.1.h		0.39	0.39	0.41	0.42	0.43	0.45	0.45	0.46	0.45	0.46
		Poultry	3.A.1.i		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total			kt CH_4	6.96	6.46	7.65	7.80	7.62	7.96	7.85	8.02	8.06	8.23
				kt CO_2 eq	146.07	135.58	160.70	163.81	159.97	167.23	164.93	168.50	169.21	172.92

Note: NO=Not occurring

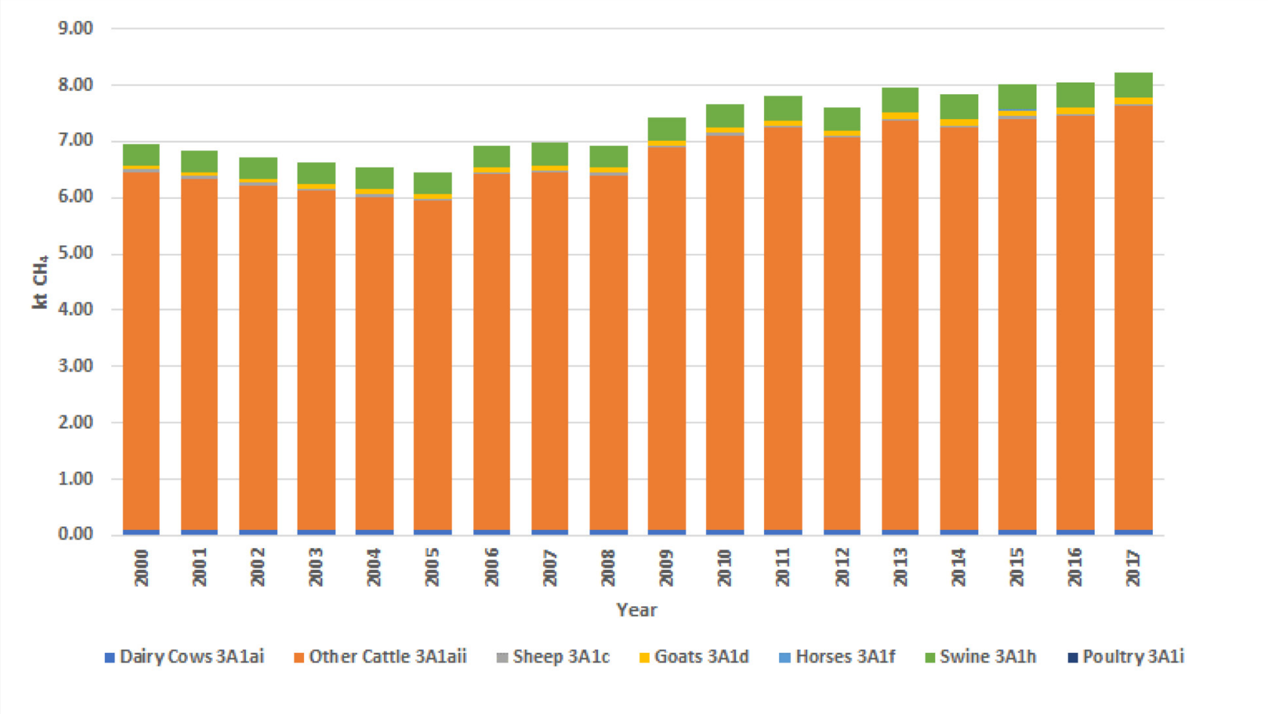


Figure 5-2: Trend in GHG emissions for enteric fermentation from 2000 to 2017 (in kt CH_4)

a. Methodological Approach

(1) Choice of Method (include assumptions and the rationale for selection)

GHG emissions from enteric fermentation have been estimated using Tier 1 method of the 2006 IPCC guideline. 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: Total emissions from livestock enteric fermentation

$$Emissions = EF_T \times \left(\frac{N_T}{10^6}\right)$$

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: Total emissions from livestock enteric fermentation

$$Total_{CH4_{Enteric}} = \sum_i E_i$$

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

(2) AD (include uncertainties and time-series consistency)

The activity data for the years 2000 to 2015 used are livestock population taken from the 4 regional offices of the Department of Agriculture and Livestock. This includes Highlands region, New Guinea Islands region, Momase region and Southern region. CCDA officers visited each of these regional offices and issued data templates containing types of livestock species and years 2000 to 2015. Since there were no existing records on livestock population, the DAL officers made estimations on the number of livestock species based on local knowledge for the year 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.

In addition to this, CCDA officers also visited some private sector organisations and were able to collect livestock population data. This includes;

1. Trukai industries;
2. Ramu Agri-Industires limited;
3. Zenag Chickens;
4. Niugini Table Birds;
5. Rumion (Leron) Piggery;
6. New Britain Palm Oil Limited

The livestock population data provided by these private sector organisations were based on their records that they have been breeding and supplying to their customers. The data provided by the private sector organisations were added with the data provided by the 4 DAL regional offices and used as activity data for the Livestock category. For the livestock data of years 2016 and 2017 figures were extrapolated using the trend extrapolation method in volume 1 chapter 5 of the 2006 IPCC guidelines. This is because updated data for 2016 and 2017 wasn't available from the data source.

(3.) EF, Other Parameters

The default emission factors used were from table 10.10 (for developing countries) and table 10.11 (for Oceania region) in chapter 10, volume 4 of the 2006 IPCC guideline.

b. Category-specific Recalculations
Recalculations have not been applied for this subcategory for this reporting cycle.

c. Category-specific Planned Improvements, if applicable
PNG is planning to set up data collection activities that lead to improve the detail of the activity data and eventually move to higher tiers especially for the most representative livestock species in the country.

5.2.2. Manure Management (3.A.2.)

CH_4 is generated during the storage and treatment of manure, produced from decomposition of manure under low oxygen or anaerobic conditions. These conditions often occur when large numbers of animals are managed in a confined area (e.g. dairy farms, beef feedlots), where manure is typically stored in large piles or disposed 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.

This section provides estimates of CH_4 and N_2O from manure management of livestock in PNG. For the purpose of this cycle of GHG inventory the type of manure management system practiced in PNG were 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 2017 was 158.69 kt CO_2 eq, an increase of 25.34 kt CO_2 eq (19 %) when compared with the year 2000. 91% of the total emissions in 2017 are CH_4 emissions while the remaining 9% are N_2O.

Table 5-3: Total GHG emissions from manure management

Category	Gas	Sub-category	2006 IPCC Code	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.A.2	CH_4	Dairy Cows	3.A.2.ai	kt CH_4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		Other Cattle	3.A.2.aii		0.21	0.20	0.23	0.24	0.23	0.24	0.24	0.24	0.25	0.25
		Buffalo	3.A.2.b		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Sheep	3.A.2.c		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Goats	3.A.2.d		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Camels	3.A.2.e		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Horses	3.A.2.f		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Mules and Asses	3.A.2.g		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Swine	3.A.2.h		5.45	5.47	5.74	5.91	6.02	6.35	6.38	6.48	6.34	6.44
		Poultry	3.A.2.i		0.08	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.14	0.14
	Total			kt CH_4	5.8	5.8	6.1	6.3	6.4	6.8	6.8	6.9	6.8	6.9
				kt CO_2 eq	121.2	122.2	128.8	132.4	134.7	141.9	142.7	144.8	142.0	144.3
	N_2O	Dairy Cows	3.A.2.ai	kt N_2O	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
		Other Cattle	3.A.2.aii		0.01810	0.01661	0.01991	0.02029	0.01977	0.02067	0.02035	0.02078	0.02090	0.02138
		Buffalo	3.A.2.b		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Sheep	3.A.2.c		0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		Goats	3.A.2.d		0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		Camels	3.A.2.e		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Horses	3.A.2.f		0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		Mules and Asses	3.A.2.g		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Swine	3.A.2.h		0.02124	0.02132	0.02238	0.02303	0.02347	0.02475	0.02488	0.02526	0.02470	0.02511
		Poultry	3.A.2.i		0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Total				kt N_2O	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
				kt CO_2 eq	12.20	11.76	13.11	13.43	13.41	14.08	14.02	14.27	14.14	14.41
Total of all gases				kt CO_2 eq	133.35	133.97	141.94	145.82	148.11	156.02	156.67	159.10	156.10	158.69

Note: NO=Not occurring

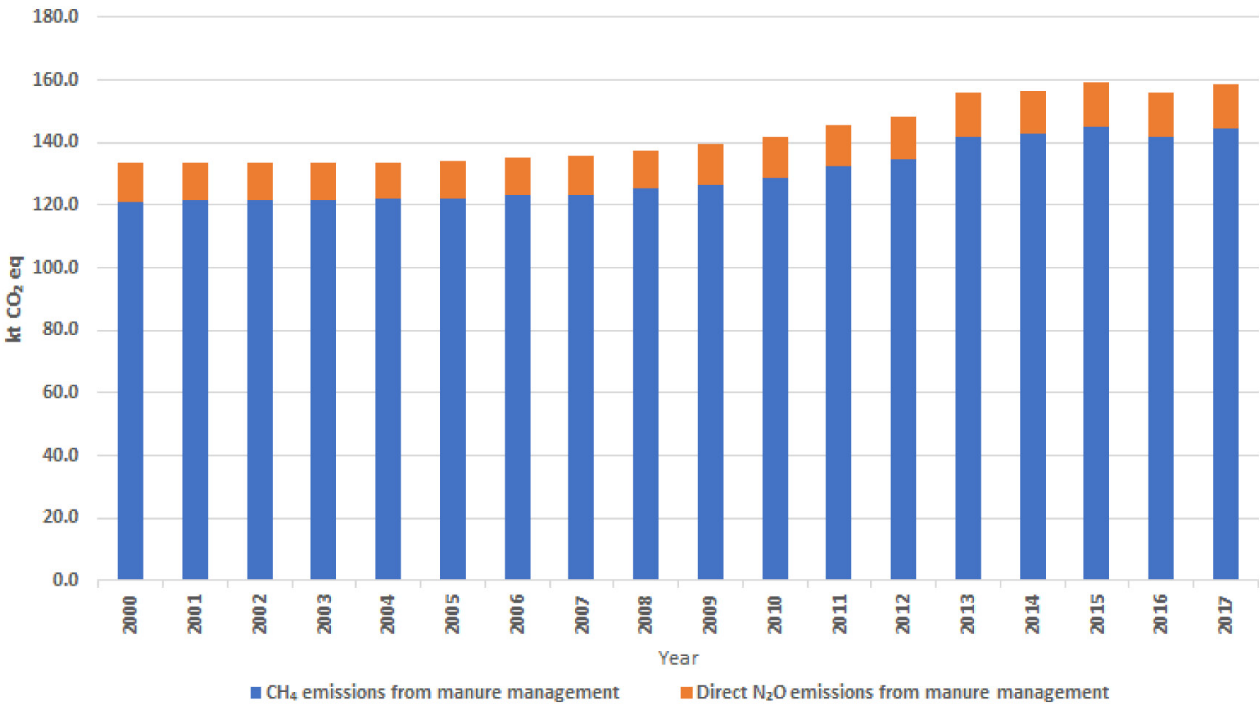


Figure 5-3: Trend in GHG emissions from manure management from 2000 to 2017 (in kt CO_2 eq)

5.2.2.1. CH_4 Emissions from Manure Management

This section covers the choice of method, activity data, emission factors and other parameters used to estimate CH_4 emissions from manure management.

a. Methodological Approach

(1) Choice of Method (include assumptions and the rationale for selection)

The amount of CH_4 produced by manure management is a function of i) number of animals, ii) amount of manure produced; and iii) temperature, while at higher tiers information on type of MMS 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

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

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.*

(2) AD (include uncertainties and time-series)

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

(3) EF, Other Parameters

The emission factors used for the estimation of CH_4 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 17⁰C while the coastal region has an average annual temperature of 27⁰C. Therefore, the weighted averaged of CH_4 emission factor for each livestock species under these two temperatures were 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 17⁰C for the Oceania region in table 10.14 and developing countries in table 10.15*

EF^{27^oC} = *Emission factor at 27⁰C 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 5-4: Manure management methane emission factors used for the estimation

Livestock Species	EF (kg CH_4^{-1} head yr^{-1})	Source
Dairy Cows	31	Weighted average of EF for Oceania region, table 10.14 volume 4 chapter 10
Other Cattle	2	Weighted average of EF for Oceania region, table 10.14 volume 4 chapter 10
Sheep	0.2	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10
Goats	0.2	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10
Horses	2.56	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10
Swine	14.1	Weighted average of EF for Oceania region, table 10.14 volume 4 chapter 10
Poultry	0.02	Weighted average of EF for developing countries, table 10.15 volume 4 chapter 10

5.2.2.2. N_2O Emissions from Manure Management

This section covers the choice of method, activity data, emission factors and other parameters used to estimate N_2O emissions from manure management.

a. Methodological Approach

(1) Choice of Method (include assumptions and the rationale for selection)

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

For the estimation of N2O 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 N2O Emissions from manure management Equation 10.25 in chapter 10 volume 4 was used.

Equation 10.25: Direct N_2O emissions from manure management

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

Where:

$N_2O_{(mm)}$ = Direct N_2O emissions from manure management in the country, kg N_2O yr^{-1}

$Nex_{(T)}$ = 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

$EF_{3(S)}$ = 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 = manure management system

T =species/category of livestock

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

The equation was used to estimate direct N_2O 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.

(2) EF, Other Parameters

Default emissions factors and other parameters were taken from chapter 10 volume 4 of the 2006 IPCC Guidelines with some assumptions made as per the circumstances of PNG to cater for missing values.

- **EF**

  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 5-5: 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) was selected)
Dry lot	0.02	Table 10.21 volume 4 chapter 10
Solid Storage (with natural crust cover)	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 5-6: Annual N excretion rates

Annual N excretion rate (kg N animal $^{-1}$ yr $^{-1}$)						
Dairy Cows	Other Cattle	Sheep	Goats	Horses	Swine	Poultry
80.3	60.225	11.5486	15.549	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.

Equation 10.3: Annual N excretion rates

$$Nex_{(T)} = N_{rate(T)} \bullet \frac{TAM}{1000} \bullet 365$$

Where:

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

$N_{rate(T)}$: *Default N excretion 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 5-7: Typical animal mass used for each livestock

Livestock species	Typical Annimal Mass (kg)	Source
Diary	500	Table 10A-4 (Oceania region) volume 4, chapter 10 2006 IPCC GL
Non-Diary	330	Table 10A-5 (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) volume 4, chapter 10 2006 IPCC GL. No TAM value provided for poultry 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 system (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 5-8: Default values for MT $_{(T, S)}$

Livestock species	Manure Management System (%)									Source
	Lagoon	Liquid/Slurry	Solid Storage	Drylot	Pasture/Range/Paddock	Daily Spread	Other	Pit <1month	Pit >1month	
Diary Cattle	16%	1%	0%	0%	76%	8%	0%	NA	NA	Table 10A-4 (Oceania region) volume 4, chapter 10 2006 IPCC GL
Non-Diary Cattle	0%	0%	0%	9%	91%	0%	0%	NA	NA	Table 10A-4 (Oceania region) volume 4, chapter 10 2006 IPCC GL
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 region)volume 4, chapter 10 2006 IPCC GL

b. Category-specific Recalculations

No recalculations were done for this cycle

c. Category-specific Planned Improvements, if applicable

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

5.3. Aggregate Sources and Non-CO_2 Emissions Sources on Land (3.C.)

For this GHG reporting cycle, the GHG estimates capture emissions from direct N_2O emissions from managed soil (3C4), indirect N_2O emissions from managed soils (3C5) and indirect N_2O emissions from manure management. In addition to this, biomass burning (3C1) was also estimated and is captured under the LULUCF sector. Liming (3C2), urea application (3C3) and rice cultivation (3C7) were not estimated due to unavailability of activity data.

5.3.1. Biomass Burning (3.C.1.)

GHG emissions from this category are reported under the LULUCF sector.

5.3.2. Liming (3.C.2.)

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.

5.3.3 Urea Application (3.C.3.)

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.

5.3.4. Direct N_2O Emissions from Managed Soils (3.C.4.)

Direct N_2O 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:

- synthetic N fertilisers (F_{SN})
- organic N applied as fertiliser (F_{ON})
- urine and dung N deposited on pasture, range and paddock by grazing animals (F_{PRP})
- N in crop residues (F_{CR})
- N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils (F_{SOM}), and
- drainage/management of organic soils (i.e., Histosols) (F_{OS}).

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 (FSOM) was not included due to unavailability of data. Furthermore, direct N_2O emission produced from flooded rice wasn't estimated because flood rice fields is not present in PNG.

The total direct N_2O emissions from managed soils in the year 2017 was 528.79 kt CO_2 eq which is an increase of 121.17 kt CO_2 eq (23 %) when compared to the emission in the year 2000.

Table 5-9: Direct N_2O emissions from managed soils (kt CO_2 eq)

Category	2006 IPCC Code	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Direct N_2O emissions from managed soils		kt N_2O	1.31	1.45	1.53	1.47	1.53	1.55	1.55	1.61	1.61	1.71
Total	3.C.4	kt CO_2 eq	407.62	449.74	474.54	455.20	473.58	479.20	480.52	500.41	500.65	528.79

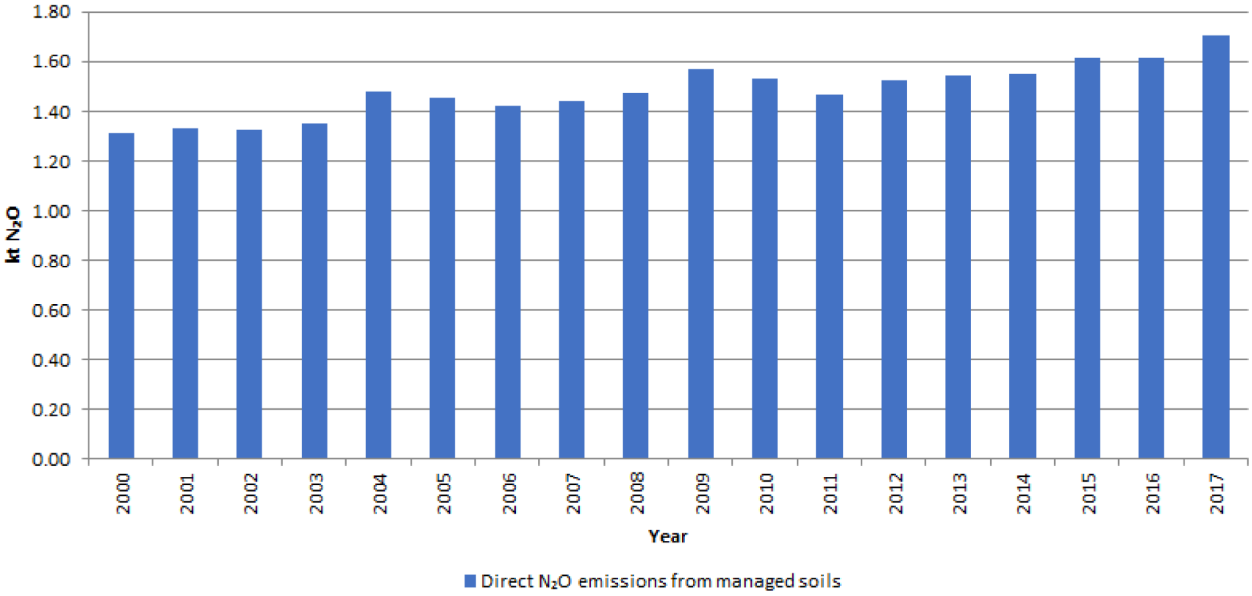


Figure 5-4: Trend in direct N_2O emissions from managed soils from 2000 to 2017 (in kt CO_2 eq)

5.3.4.1. **Methodological Approach**

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

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

Equation 11.1: Direct N_2O emissions from managed soils

$$N_2O_{Direct} - N = N_2O_{N\,inputs} + N_2O - N_{OS} + N_2O - N_{PRP}$$

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 synthetic fertilizer N applied to soils, kg N yr^{-1}
F_{ON}	= annual amount of animal manure, compost, sewage, sludge and other organic N 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 in mineral soils that is mineralized, kg N yr^{-1}
F_{OS}	= annual area of managed/drained organic soils, ha
F_{PRP}	= annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, 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. AD (include uncertainties and time-series)

(i) Synthetic fertilizers N applied to soils (F_{SN})

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 fertilizers (F_{ON})

The activity data used was annual livestock manure treated in each manure management system that was estimated in 3.A.2 direct N_2O from manure management and that no other organic fertilizers were used.

(iii) N in crop residues (F_{CR})

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.

(iv) Urine and dung N deposited by grazing animals on pasture, range and paddock (F_{PRP})

A similar method used for estimating amount of annual N excreted from each livestock species and treated in each manure management system under the manure management sub category (3.A.2) 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.

c. EF, other Parameters

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

Table 5-10: Default emission factors used to estimate managed 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
$EF_{3PRP,SO}$	0.01

5.3.4.2. Sub-category-specific Recalculations

For this reporting cycle under crop residues additional significant crops grown in PNG were add into the N in crop residues (F_{CR}) timeseries estimations which includes cassava, potato, sweet potato, taro and yam.

5.3.4.3. Sub-category-specific planned Improvements, if applicable

Planned improvements for this sub category includes identifying potential data sources for other sources of organic fertilizers (F_{OS}) and N in mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils (F_{SOM}). Further improvements involve identifying and using country specific data for synthetic N fertilizers and crop residues.

5.3.5. Indirect N_2O Emissions from Managed Soils (3.C.5)

In addition to direct emissions of N_2O from managed soils that occur through a direct pathway, emissions of N_2O also take place through two indirect pathways. The first pathway is the volatilization of N as NH_3 and oxides of $N(NO_x)$, and the deposition of these gases and their products NH_4^+ and NO_3 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 2017 is 70.09 kt CO_2 eq, an increase of 29.05 kt CO_2 eq (71 %) when compared with the year 2000.

Table 5-11: Indirect N_2O emissions from managed soils (kt CO_2 eq)

Category	2006 IPCC Code	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Indirect N_2O emissions from managed soils		kt N_2O	0.13	0.16	0.18	0.17	0.18	0.19	0.19	0.20	0.20	0.23
Total	3.C.5	kt CO_2 eq	41.03	50.98	56.85	52.41	56.86	58.38	58.73	63.46	63.51	70.09

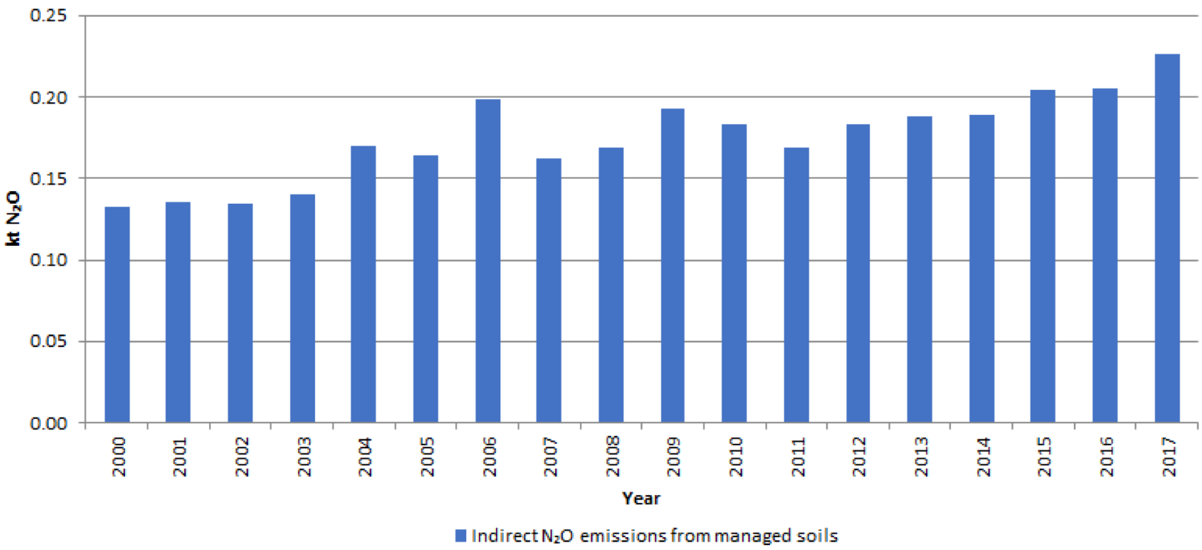


Figure 5-5: Trend in indirect N_2O emissions from managed soils from 2000 to 2017 (in kt CO_2 eq)

5.3.5.1. Methodological approach

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

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. And equation 11.10 in chapter 11 volume 4 of the 2006 IPCC guidelines was used to estimate N_2O 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. AD (include uncertainties and time-series consistency)

Activity data is the same as that used in 3.C.4 direct N_2O emission on managed soil.

c. 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 5-12: Default emission factors and other parameters used

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

5.3.5.2. Sub-category-specific recalculations

There was no recalculation for this sub-category.

5.3.5.3. Sub-category-specific planned improvements, if applicable

Similar improvements for the direct N_2O emission from managed soils (3.C.4) sub category also applies to this sub category.

5.3.6. Indirect N_2O emissions from Manure Management (3.C.6)

Indirect N_2O emissions from manure management result from volatile nitrogen losses that occur primarily in forms of ammonia and NO_X. The fraction of excreted organic nitrogen that is mineralized to ammonia nitrogen during manure collection and storage depends primarily on time, and to a lesser degree temperature. Nitrogen losses begin at the point of excretion in houses and other animal production areas (e.g., milk parlors) and continue through on-site management in storage and treatment systems (i.e., manure management systems).

In 2017 the indirect N_2O emissions from manure management was 4.26 kt CO_2 eq an increase of 0.66 kt CO_2 eq (18 %) when compared with year 2000.

Table 5-13: Indirect N_2O emissions from manure management (kt CO_2 eq)

Category	2006 IPCC Code	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Indirect N_2O from manure management		kt N_2O	0.012	0.012	0.012	0.013	0.013	0.013	0.014	0.014	0.013	0.014
Total	3.C.6	kt CO_2 eq	3.60	3.57	3.82	3.93	3.97	4.18	4.19	4.26	4.18	4.26

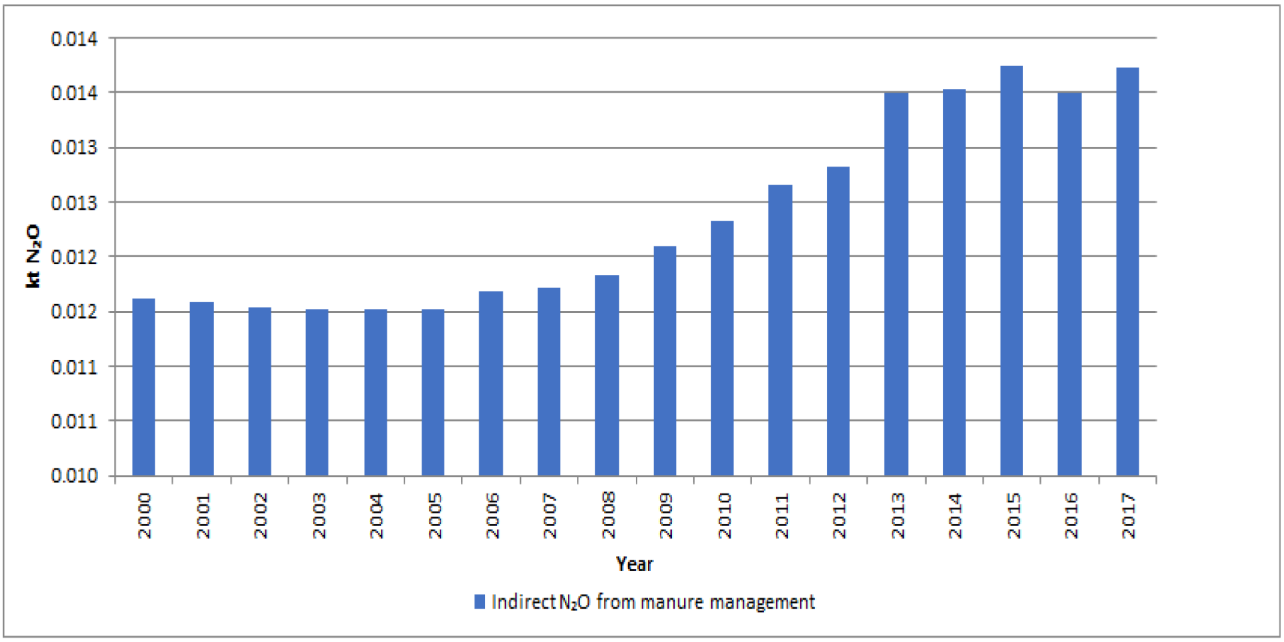


Figure 5-6: Trend in N_2O emissions from manure management from 2000 to 2017 (kt CO_2 eq)

5.3.6.1. Methodological Approach

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

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 volatilisation 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:

$N_{volatilisation-MMS}$ = amount of manure nitrogen that is lost due to volatilisation 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 volatilises as NH_3 and NO_X in the manure management system S, %

Equation 10.27: Indirect N_2O emissions due to volatilisation 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 volatilisation 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 volatilised)$^{-1}$

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

The same activity data used to estimate direct N_2O from manure management (3.A.2) sub category was also used for this sub category.

c. EF, Other Parameters

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.

5.3.6.2. Sub-category-specific Recalculations

There was no recalculation done for this sub-category

5.3.6.3. Sub-category-specific Planned Improvements, if applicable

Similar improvements for the manure managed (3.A.2.) sub category also applies to this sub category

5.3.7. Rice Cultivation (3.C.7)

Emissions from rice cultivation were not included for this BUR2. This is because from the BUR1 it was considered zero because experts stated that, in general, rice fields in the country are not flooded or are cultivated in uplands.

Chapter

6

Land Use, Land-Use Change and Forestry (LULUCF)

6.1. Overview of Sector

This chapter contains the GHG inventory for Land use, land use change and forestry (LULUCF). This includes the reporting of GHG emissions by sources and removals by sinks in this sector. LULUCF is an important sector. In Papua New Guinea, Forestry is one of the major sectors, making a significant contribution to the national economy and formal employment. It also plays an important role in addressing climate change through mitigation and adaptation measures and actions. Accurate information on the status of this sector is therefore essential. Although the country emits less than 0.1% of the world's total GHG emissions, it is serious about reducing global GHG emissions (CCDA, 2018).

LULUCF has been one of the most significant sector in PNG with both the highest emissions among all sectors, and the only sector with removal. Historically the sector acted as a sink, it has however evolved into a smaller sink over time due to the decrease in forest lands over time and has become a sink again (CCDA, 2018). LULUCF sector contains the emissions and removals from carbon stock changes due to land use and forest management. The land use sub-categories estimated are forest land (3.B.1), cropland (3.B.2), grassland (3.B.3), and settlement (3.B.5). Non-CO_2 emissions from biomass burning in forest land only (3.C.1.a) are included under this sector. Wetland (3.B.4) and other land (3.B.6) are not estimated because of no land use change and are classified as unmanaged. The net removals from the LULUCF sector amounted to -12 724.94 kt CO_2 eq in 2017 compared to -20 488.12 kt CO_2 eq in 2000. This come back is after it reached 5,617.42 kt CO_2 eq in 2015. Table 6.1 shows the summary of emissions and removals in the LULUCF Sector, and Figure 6-1 shows the emissions and removals trend from the LULUCF sector for the years 2000 - 2017.

Table 6-1: LULUCF GHG emissions and removals summary

IPCC code	Sub-Categories	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.B.1	Forest land	kt-CO_2	-27,085.31	-22,848.39	-6,458.47	-6,605.32	-13,585.68	-10,138.02	-11,872.70	-11,855.41	-17,226.77	-23,617.38
3.B.2	Cropland	kt-CO_2	5,886.90	5,233.74	6,397.19	9,197.46	11,942.86	14,726.28	13,045.10	14,157.09	12,307.62	9,397.82
3.B.3	Grassland	kt-CO_2	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
3.B.4	Wetlands	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.B.5	Settlements	kt-CO_2	0.00	0.00	33.79	257.07	56.12	56.12	33.47	34.59	510.19	1,058.52
3.B.6	Other land	kt-CO_2	NO	NE	NE	NE	NE	NE	NE	NE	NE	NE
3.C.1.a	Non CO_2 gases - forest burning	kt-CO_2 eq	386.94	130.55	145.91	79.67	73.77	156.26	139.25	2,957.79	104.76	112.74
3.D.1	HWP	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
LULUCF sector total		kt-CO_2 eq	-20,488.12	-17,160.75	441.77	3,252.24	-1,189.56	5,124.00	1,668.47	5,617.42	-3,980.84	-12,724.94

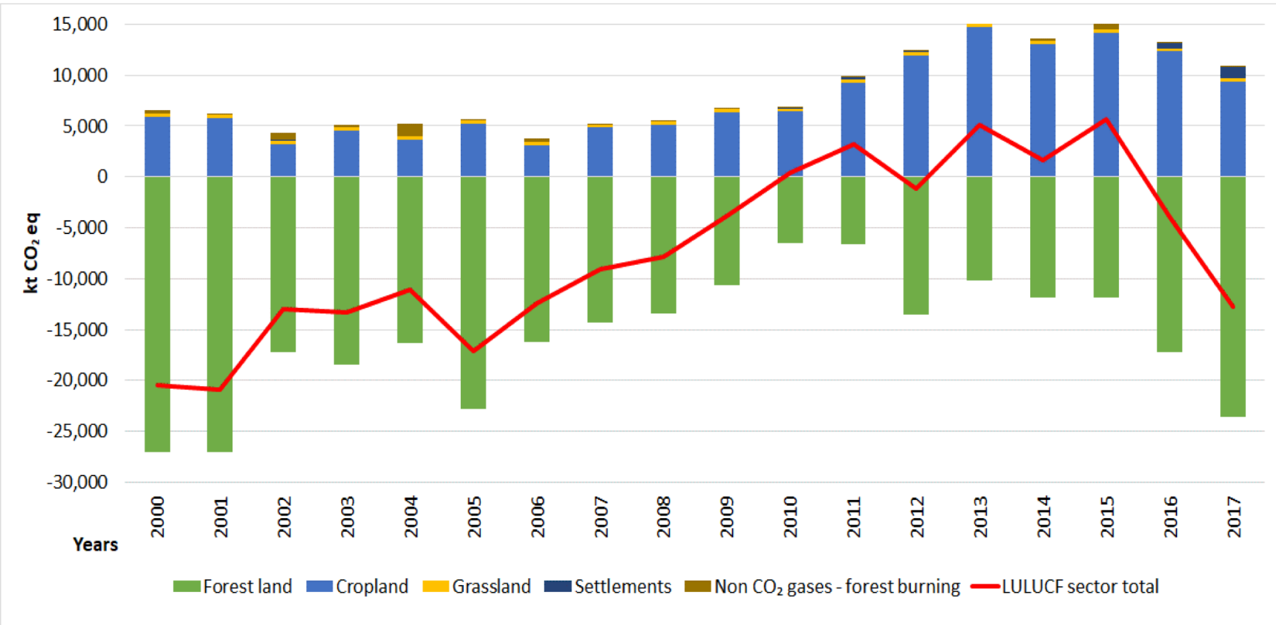


Figure 6-1: Emissions and removals trend from the LULUCF sector from 2000 to 2017 (in kt CO_2 eq)

The increasing trend from 2000 to 2015 is due to increasing rate in deforestation and degradation. The increase in emissions in 2015 is also caused by increased area of forest fire. The descend of net emissions from the year 2016 to 2017 represented by LULUCF sector total in the graph has decreased due to decrease in deforestation and forest degradation areas.

The table below shows the LULUCF table of completeness.

Table 6-2: Table of completeness for LULUCF

TIER 1		FL		CL		GL		WL			SL		OL	
C pool - GHG		FL-FL	L-FL	CL-CL	L-CL	GL-GL	L-GL	PL-PL	L-PL	L-WL	SL-SL	L-SL	OL-OL	L-OL
Living biomass	AGB	M	NE	M	M	NA	NE	NO	NO	NE	NA	M	NO	NO
	BGB	M	NE	M	M	NA	NE	NO	NO	NE	NA	M	NO	NO
Dead Organic Matter	Deadwood	NA	NE	NA	M	NA	NE	NO	NO	NE	NA	M	NO	NO
	Litter	NA	NE	NA	M	NA	NE	NO	NO	NE	NA	M	NO	NO
Soil Organic Carbon	Mineral	NA	NE	NE	NE	NA	NE	NO	NO	NE	NA	NE	NO	NO
	Organic	M	NE	M	IE	M	NE	NO	NO	NE	NO	NE	NO	NO
HWP		NE												

M	Mandatory/Estimated
NA	Not Applicable (No emissions/no removals occurred)
NE	Not Estimated
NO	Not occurring, no such activity included.
IE	Estimated Elsewhere
NM	Not mandatory

6.2. Land-Use Definitions and the Classification Systems used and their Correspondence to the LULUCF Categories

PNG stratified the land according to the six IPCC Land use categories for preparing the land representation. Forest land and cropland were further disaggregated into subcategories, *see Table 6-3.* The Collect Earth survey was customized so that activity data were classified by their carbon stocks in function of the ecological characteristics and agricultural land uses. IPCC ecological zones, i.e., tropical wet, tropical moist, dry and montane forests, were used as forest strata to which also mangroves and plantations were added. Except for plantations, all strata were sub-categorized into primary and degraded/logged forest types. The difference between primary forest and degraded forest was made based on visual interpretation in Collect Earth[1]. For croplands, subcategories are oil palm, coconut, cocoa, tea, and coffee, shifting cultivation and permanent crop systems.

The distinction between managed and unmanaged lands has not been carried out yet and it is assumed that all land areas in PNG are managed. However, primary forests are assumed under very little human disturbances. Therefore, it is assumed that primary forests are in equilibrium, and it also assumed that their net removals are close to zero.

Table 6-3: PNG Collect Earth 2020 assessment land use classification system

Land categories by land cover and use types of the GHG inventory	
Categories	**Land use stratification**
Tropical rain forest	Primary forest, Degraded forest
Tropical dry forest	Primary forest, Degraded forest
Tropical shrubland	Primary forest, Degraded forest
Tropical mountain system	Primary forest, Degraded forest
Mangrove	Primary forest, Degraded forest
Plantation	
Cropland	Oil palm, coconut, cocoa, tea, and coffee, shifting cultivation and permanent crop systems
Grassland	No further stratification
Wetland	No further stratification
Settlement	No further stratification
Other Land	No further stratification

1. Use of high-resolution imagery, ab Bing Maps and with combination of use of the Google Earth Engine platform looking at Landsat 7 and 8 for change detection

Forest land

PNG's definition of forest is derived from the definition approved by the National Executive Council (NEC) in 2014 and is, "land spanning more than 1 hectare, with trees higher than 3 meters and the canopy cover of more than 10 percent" (Papua New Guinea Forest Authority, 2019). Forest land is further stratified based on ecological zones and elevation into thirteen (13) distinct forest types. Together with forest plantations, there are fourteen (14). The 14 forest types were combined according to similar ecological zones into only six forest types. The table below shows the 14 forest types and the combined forest into their ecological zones.

Table 6-4: Fourteen forest types combined into ecological zone

	Forest type	Ecological zone as per IPCC Guidelines [IPCCC, 2006 (Vol. 4, Chpt. 4, Table 4.9)]
1	Low altitude forest on plains and fans	Tropical rainforest
2	Low altitude forest on uplands	
3	Littoral forest	
4	Seral forest	
5	Swamp forest	
6	Lower montane forest	Tropical mountain system
7	Montane forest	
8	Mountain coniferous forest	
9	Dry seasonal forest	Tropical dry forest
10	Woodland	
11	Savanna	
12	Scrub	Tropical shrubland
13	Mangrove	Tropical wet Mangrove
14	Forest plantation	Tropical rainforest (plantation)

The above forest land classification into subdivisions is based on natural vegetation types and manmade plantations. Vegetation types are based on the structural formation and described in the Papua New Guinea Resource Information System (PNGRIS) (Hammermaster and Saunders 1995).

Cropland

This category includes cropped land, including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category (IPCC, 2006).

Grassland

This category includes rangelands and pastureland that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, consistent with national definitions (IPCC, 2006).

Land use conversions

According to the Collect Earth 2020 assessment, PNG identified the following:

- Deforestation: is the conversion from forest land to any non-forest land Primary deforestation is the conversion of primary forest. Secondary deforestation is the conversion of degraded forest. This process entails activities that convert the natural and disturbed forest to non-forest land.
- Forest degradation: is the conversion from primary forest to disturbed forest. This process is identified within forest remaining forest areas.

6.3. Information on Approaches used for Representing Land Areas and on Land-Use Databases used for the Inventory Preparation

The results generated from Collect Earth are set of annual land use change matrices between 2000 and 2017. High resolution imageries before 2000 are limited and therefore an approach 1 was applied for land representation. Nevertheless, annual land area changes like approach 2 have been used to estimate immediate loss due to forest land conversion and forest degradation. The tables containing approach 1 and 2 are found in the Appendix IV. The land use matrix has also been included in the Appendix.

6.4. Forest Land (3.B.1)

This sub-section reports emissions and removals due to changes in biomass, dead organic matter and soil organic carbon on forest land. It also captures the methods that were used to estimate emissions and removals from forest land. The forest land category consists forest land remaining forest land (3.B.1.a) and land converted to forest land (3.B.1.b). However, estimation of emissions and removals for land converted to forestland (3.B.1.b) 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 2017 were -23,617.38 kt CO_2. The total removals decreased between 2000 to 2011 then increased again between 2012 to 2017. Table below shows emissions and removals for the forestland category.

Table 6-5: Emissions and removals from forestland (3.B.1)

IPCC Code	Sub-Categories	Unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.B.1	Forest land	kt-CO_2	-27,085.31	-22,848.39	-6,458.47	-6,605.32	-13,585.68	-10,138.02	-11,872.70	-11,855.41	-17,226.77	-23,617.38
3.B.1.a	Forest land remaining forest land	kt-CO_2	-27,085.31	-22,848.39	-6,458.47	-6,605.32	-13,585.68	-10,138.02	-11,872.70	-11,855.41	-17,226.77	-23,617.38
	Living biomass	kt-CO_2	-27,446.98	-23,210.06	-6,849.74	-6,996.59	-13,976.95	-10,529.29	-12,263.97	-12,246.69	-17,618.04	-24,008.65
	Dead organic matter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soils	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Organic soils	kt-CO_2	361.66	361.66	391.27	391.27	391.27	391.27	391.27	391.27	391.27	391.27
3.B.1.b	Land converted to forest land	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Living biomass	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Dead organic matter	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Mineral soils	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Organic soils	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

NA: Not Applicable (No emissions/no removals occurred) NE: Not Estimated

6.4.1. Forest Land Remaining Forest land (3.B.1.a)

6.4.1.1. Category Description (e.g. characteristics of sources)

This sub-section reports GHG emissions and removals from forests in PNG that are classified under forest land remaining forest land. According to the 2006 IPCC Guidelines, GHGi for Forest Land Remaining Forest Land (FF) 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-CO_2 gases (Aalde, Gonzalez, Gytarsky, Krug, Kurz, Ogle, et al., 2006). PNG has covered three of the five carbon pools. They are living biomass (above and below ground biomass) and soil organic matter in organic soils. Other carbon pools not applicable are dead organic matter and mineral soils. According to the 2006 IPCC Guideline, it is not necessary to compute the carbon stock changes on these pools under Tier 1 method (Aalde, Gonzalez, Gytarsky, Krug, Kurz, Ogle, et al., 2006). PNG used annual land area changes like approach 2 to estimate immediate loss due to forest land conversion and forest degradation. Therefore, the estimations of emissions and removals in dead organic matter and mineral soils were not applicable.

GHG sink in this category is from regrowth in secondary forest area before the year 2000 and sources are from annual degraded forest land during the inventory years. Annual gain is from carbon stock change in biomass due to anthropogenic activities. These include secondary forest area prior to 2000 are considered managed forest area. For this inventory, primary forest area, although are under some form of management practices, it is given growth rate value of zero with no carbon stock change. As for this secondary forest, the value of growth rate of forest types over 20 years was assigned to them. The average annual ABG growth is form IPCC 2006, Table 4.9, PNGFRL, Wetland Supplement 2013 (mangrove) and average for the plantation forest type.

6.4.1.2. **Methodological Issues**

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

The two methods are recommended by the 2006 IPCC Guidelines to estimate the GHG emissions from forest land remaining forest land are the gain-loss method and the stock-difference method. Gain from this sub category is from secondary forest before 2000 considered under managed forest and loss from conversion of primary forest to secondary forest. The equation used for *Gain-Loss Method* is equation 2.7 in chapter 2, volume 4 and the equation for stock-difference method is a modified version[2] *Stock-Difference Method* which estimates the difference in total biomass carbon stock at time t_2 and time t_1 is equation 2.8 in chapter 2, volume 4 (Aalde, Gonzalez, Gytarsky, Krug, Kurz, Ogle, et al., 2006).

Loss in annual carbon stock in biomass is due to conversion of primary forest to secondary forest. Removals are decreasing since these are applied to the area of degraded forest directly taken from collect earth assessment before year 2000. This conversion to disturbed forest includes loss of carbon from wood removals due to harvesting, loss of carbon from fuelwood removals and loss of carbon from disturbance. Organic soil in this category is also accounted for in the estimation.

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 2.9: Annual increase in biomass carbon stocks due to biomass increment in land remaining in the same land-use category.

$$\Delta C_G = \sum_{i,j} (A_{i,j} \; x \; G_{TOTAL_{i,j}} \; x \; CF_{i,j}$$

ΔC_G = annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone, tonnes C yr^{-1}

A = area of land remaining in the same land-use category, ha

G_{TOTAL} = mean annual biomass growth, tons d. m. $ha^{-1} yr^{-1}$

i = ecological zone (i = 1 to n)

j = climate domain (j = 1 to m)

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

2. Similar to Stock-Difference Method

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. AD (include uncertainties and time-series consistency)

Activity data for forest land remaining forest land were taken from the land use and land use change assessment (Collect Earth exercise) conducted by the Papua New Guinea Forest Authority (same as REDD+ Technical Annex). PNGFA is the government agency responsible for the management of the country's forest resources and different activities that takes place in the forestry sector. The same activity data used for PNG's BUR1[3] was used with updates for 2016 and 2017.

3. https://unfccc.int/documents/194974

Table 6-6: Activity data used the estimation of annual increase in carbon stocks in biomass due to growth on forest land remaining forestland (C_{GAIN})

Data	Forest type	Unit	2000	2005	2010	2011	2012
Area of forest land	R(p)	ha	19,265,562.35	18,672,721.22	17,848,861.77	17,654,725.64	17,498,518.34
	M(p)	ha	7,086,394.87	7,075,597.61	7,052,023.21	7,048,121.42	7,042,186.55
	D(p)	ha	3,147,023.28	3,113,657.45	3,109,755.27	3,097,979.10	3,094,053.71
	S(p)	ha	182,477.93	178,510.69	178,510.69	178,510.69	178,510.69
	Ma(p)	ha	226,989.50	226,989.50	226,989.50	226,989.50	226,989.50
	R(d)	ha	3,844,804.22	3,818,608.10	3,788,949.26	3,782,604.10	3,762,759.43
	M(d)	ha	1,355,381.26	1,351,367.00	1,349,359.86	1,343,338.47	1,343,338.47
	D(d)	ha	897,147.42	897,147.42	897,147.42	895,832.75	893,870.05
	S(d)	ha	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21
	Ma(d)	ha	54,860.17	54,860.17	54,860.17	54,860.17	54,860.17
	Plantation	ha	60,707.30	60,707.30	60,705.40	60,705.40	60,705.40
Data	Forest type	Unit	2013	2014	2015	2016	2017
Area of forest land	R(p)	ha	17,317,412.98	17,149,689.57	16,987,304.55	16,860,987.10	16,767,951.04
	M(p)	ha	7,036,213.27	7,031,815.38	7,029,856.37	7,022,010.73	7,007,236.92
	D(p)	ha	3,092,091.01	3,080,314.83	3,064,619.24	3,046,938.27	3,039,108.14
	S(p)	ha	178,510.69	178,510.69	178,510.69	176,547.99	176,547.99
	Ma(p)	ha	226,989.50	226,989.50	225,043.95	225,043.95	225,043.95
	R(d)	ha	3,750,814.76	3,736,854.98	3,717,007.75	3,700,864.93	3,690,964.59
	M(d)	ha	1,331,342.01	1,331,342.01	1,331,342.01	1,329,389.19	1,325,448.43
	D(d)	ha	891,907.36	891,907.36	891,907.36	889,927.96	889,927.96
	S(d)	ha	37,683.21	37,683.21	37,683.21	37,683.21	37,683.21
	Ma(d)	ha	54,860.17	54,860.17	54,860.17	54,860.17	54,860.17
	Plantation	ha	60,705.40	60,705.40	60,705.40	60,705.40	60,705.40

Table 6-7: Activity data used for the estimation of Initial Change in biomass carbon stocks on primary forest converted to degraded forest ($C_{CONVERSION}$)

Conversion		Unit	2000	2005	2010	2011	2012
FL	R(p) -R(d)	ha	81,730.37	105,709.31	192,800.18	186,316.98	150,259.08
	M(p) -M(d)	ha	0.00	1,960.80	3,884.82	1,959.01	3,946.94
	D(p) -D(d)	ha	5,888.09	0.00	0.00	11,776.18	3,925.39
	S(p) -S(d)	ha	0.00	0.00	0.00	0.00	0.00
	Ma(p) -Ma(d)	ha	0.00	0.00	0.00	0.00	0.00
	R(p)-Pl	ha	0.00	0.00	0.00	0.00	0.00
Conversion		Unit	2013	2014	2015	2016	2017
FL	R(p) -R(d)	ha	169,290.84	153,958.67	152,581.47	120,296.05	84,612.08
	M(p) -M(d)	ha	4,014.26	3,904.73	0.00	1,960.77	14,281.98
	D(p) -D(d)	ha	1,962.70	11,776.18	13,738.87	17,680.97	5,867.43
	S(p) -S(d)	ha	0.00	0.00	0.00	1,962.70	0.00
	Ma(p) -Ma(d)	ha	0.00	0.00	1,945.54	0.00	0.00
	R(p)-Pl	ha	0.00	0.00	0.00	0.00	0.00

For organic soils only, the current updated activity data does not provide data on organic soil. There has not been any major change in the time series from the first inventory. Therefore, the same activity data for the year 2015 was extrapolated to 2016 and 2017.

c. 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. 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.). Table 6-8 shows the average annual growth rates by forest types.

Table 6-8: Average annual growth rates by forest types

Categories	Land use stratification	Average annual growth rates ($t\ d.m.\ ha^{-1}\ yr^{-1}$)	Source
All types	Primary	Zero	CCDA/FAO[4]
Tropical rain forest	Degraded forest	3.4	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Tropical dry forest	Degraded forest	2	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Tropical shrubland	Degraded forest	2	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Tropical mountain system	Degraded forest	1	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.9)
Mangrove	Degraded forest	9.9	Wetland Supplement 2013, Table 4.4
Plantations	Plantations	5	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.10)

Table 6-9: 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)
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)
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)

4. Primary forest are mostly undisturbed, and therefore a growth rate of zero (0) has been applied.

6.4.1.3. Sub-category-specific Recalculations, if applicable

No recalculations have been made. The same data sources and emission factors from the BUR1 have been used to expand on 2016 and 2017.

6.4.1.4. Sub-category-specific Planned Improvements, if applicable

- increasing the sampling intensity in Collect Earth to allow improved accuracy in 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

6.4.2. Land Converted to Forest land (3.B.1.b)

There is no land area conversion to forest land according to Collect Earth Assessment (activity data). As such, no emissions or removals estimates were done.

6.5. Cropland (3.B.2)

This sub-section reports emissions and removals due to changes in biomass, dead organic matter and soil organic carbon on cropland. It also captures the methods that were used to estimate emissions and removals from crop land. The crop land category consists crop land remaining crop land (3.B.2.a) and land converted to crop land (3.B.2.b).According to the 2006 IPCC Guidelines, 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. Globally, almost 20 percent of global cropland is suitable for water harvesting and conservation strategies, with hotspots in large parts of Eastern Africa and South-eastern Asia (FAO, 2020). In PNG, majority of the people family agriculture which is one of the main causes of deforestation.

According to the 2006 IPCC Guidelines, cropland 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). 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 total emissions from crop land in 2017 were 9,397.82 kt CO_2 which is an increase of 3,510.92 kt CO_2 (59.63 %) when compared to the year 2000. Land converted to crop land sub category contributed 90 % the total emissions in 2017. The table below shows the emissions and removals from cropland.

Table 6-10: Emissions and removals from Cropland (3.B.2)

IPCC Code	Sub-categories	unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.B.2	Cropland	kt-CO_2	5,886.90	5,233.74	6,397.19	9,197.46	11,942.86	14,726.28	13,045.10	14,157.09	12,307.62	9,397.82
3.B.2.a	Cropland remaining cropland	kt-CO_2	1,004.55	857.69	857.14	906.70	758.82	685.10	606.37	727.45	849.75	904.46
	Living biomass	kt-CO_2	0.00	-146.86	-147.41	-97.84	-245.73	-319.44	-398.17	-277.10	-154.79	-100.09
	Dead organic matter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soils	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Organic soils	kt-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
3.B.2.b	Land converted to cropland	kt-CO_2	4,882.35	4,376.05	5,540.05	8,290.75	11,184.04	14,041.17	12,438.72	13,429.64	11,457.87	8,493.36
	Living biomass	kt-CO_2	4,791.33	4,296.27	5,433.38	8,120.36	10,955.02	13,735.66	12,221.45	13,171.18	11,226.65	8,318.25
	Dead organic matter	kt-CO_2	91.02	79.78	106.67	170.39	229.03	305.52	217.28	258.46	231.22	175.11
	Mineral soils	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Organic soils	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

NA: Not Applicable, NE: Not estimated, IE: Included elsewhere

6.5.1. Cropland remaining Cropland (3.B.2.a)

6.5.1.1. Sub-category Description (e.g. characteristics of sources)

This sub-section reports on greenhouse gas inventory for croplands in PNG that have not undergone any land use conversion for a period of at least 20 years as a default period. According to the 2006 IPCC Guideline, estimation of annual greenhouse gas emissions and removals from Cropland remaining Cropland includes the following (Lasco et al., 2006):

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

The changes in carbon stocks in Cropland Remaining Cropland are estimated using Equation 2.3 (Aalde, Gonzalez, Gytarsky, Krug, Kurz, Lasco, et al., 2006).

Emission and removal from Oil Palm, Cocoa and Coconut are estimated as perennial crop, these are the major crops which 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 change in carbon stocks in organic soils. Others are not estimated due to lack of data (emission factors). The table below shows the estimation of carbon stock changes in living biomass.

Table 6-11: Estimation of carbon stock changes in living biomass (in t CO_2)

Estimation of carbon stock changes in living biomass (Above ground and below ground) for cropland remaining cropland - Oil Palm with use of FREL estimates										
Area distribution (simulation)	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Palm oil - harvested (area - ha)	12232.42	12723.12	13115.79	13411.39	13607.59	14100.36	14599.95	15398.43	16098.73	16691.73
Palm oil - growing (area - ha)	244648.4	260352.5	268227.7	272151.9	282007.2	291999.1	307968.5	321974.6	333834.6	337848.9
Carbon Loss (instant)	1663609	1730345	1783747	1823949	1850633	1917649	1985594	2094186	2189427	2270075
Carbon gain	1663609	1770397	1823949	1850633	1917649	1985594	2094186	2189427	2270075	2297372
Net loss (ΔCB)	0	40051.72	40201.37	26684.03	67016.55	67944.54	108592.2	95241.58	80647.89	27296.97
T CO_2 eq	0	-146.856	-147.405	-97.8414	-245.727	-249.13	-398.171	-349.219	-295.709	-100.089
Estimation of carbon stock changes in living biomass (Above ground and below ground) for cropland remaining cropland - coconut + cocoa with use of FREL estimates										
Area distribution (simulation)	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Cocoa and coconut- harvested (area - ha)	9849.062	9947.101	10045.14	10045.14	10045.14	10045.14	10142.98	10142.98	10042.62	9846.54
Cocoa and coconut - growing (area - ha)	196981.2	198942	200902.8	200902.8	200902.8	202859.5	202859.5	200852.4	196930.8	196930.8
Carbon Loss (instant)	1930416	1949632	1968847	1968847	1968847	1968847	1988023	1988023	1968353	1929922
Carbon gain	1930416	1949632	1968847	1968847	1968847	1988023	1988023	1968353	1929922	1929922
Net loss (ΔCB)	0	-0.09729	0	0	0	19175.84	0.023124	-19669.9	-38431.4	0
T CO_2 eq	0	0.000357	0	0	0	-70.3114	-8.5E-05	72.12296	140.9152	0
Total CO_2 eq for all perennial crop	**0**	**-146.856**	**-147.405**	**-97.8414**	**-245.727**	**-319.441**	**-398.171**	**-277.096**	**-154.794**	**-100.089**

6.5.1.2. Methodological Issues

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

According to 2006 IPCC Guidelines, changes in carbon in cropland biomass (ΔCCCB) may be estimated from either: (a) annual rates of biomass gain and loss (Chapter 2, Equation 2.7) or (b) carbon stocks at two points in time (Chapter 2, Equation 2.8). The first approach (gain-loss method) provides the default Tier 1 method and can also be used at Tier 2 or 3 with refinements. The second approach (the stock-difference method) applies either at Tier 2 or Tier 3, but not Tier 1 (Lasco et al., 2006).

Papua New Guinea used the gain-loss method (default tier 1 method) to estimate the emissions and removals for this sub-category. 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}

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).

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

Where

$L_{Organic}$ = 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}

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

Activity data for cropland remaining crop land were taken from the land use and land use change assessment (Collect Earth exercise) conducted by the Papua New Guinea Forest Authority

c. EF, Other Parameters

Emission factors used in this GHG inventory were a mixture of Tier 1 and Tier 2. Most default emission factors used for the estimations in this sub-category were taken from the 2006 IPCC Guidelines. Some Tier 2 emission factors used were from literature review.

The gains are from perennial crop areas of oil Palm multiply by the mean annual increment of oil palm. Losses are from 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 subtracts 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 6-12: Emission factors used for estimating emissions for Cropland

All Perenials	Value	Unit	Source
maturity cycle - coconut	20	years	PNGFRL 2017
maturity cycle - oil palm	20	years	PNGFRL 2017
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	*
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	*
Carbon fraction	0.5	tonnes C / t dm	**
Mean annual increment coconut	9.8	tonnes C ha^{-1} yr^{-1}	FRL 2017
Mean annual increment oil palm	6.8	tonnes C ha^{-1} yr^{-1}	FRL 2017

Meaning of Stars(*) in the Table, refer below[5].

6.5.1.3. Sub-category-specific Recalculations, if applicable

No recalculations have been made for this sub-category. The updated activity data from the same data sources and emission factors have been used to expand on 2016 and 2017.

For organic soil although it was estimated in PNG first BUR, the result was not reported due to human error. For the current inventory, the time series for cropland is reported. Thus, change is included in the results. As for the activity data for the year 2016 and 2017, the same activity data for the year 2015 was extrapolated here because there were insignificant differences in the area of organic soil according to the first BUR report.

5. * This value is assumed to be consistent with the product of annual increment ratio and maturity cycle
* This value is assumed by the annual increment figures

6.5.1.4 **Sub-category-specific Planned Improvements, if applicable (e.g. methodologies, AD,EF,etc.)**

- 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 (3.B.2.b)

6.5.2.1. **Sub-category Description (e.g. characteristics of sources)**

This sub-section reports on the methodology that was used to estimate emissions and removals from lands that have been converted to croplands. According to the 2006 IPCC Guidelines, conversion to Cropland is a leading land-use change following tropical deforestation. It further states that greenhouse gas emissions and removals from Land Converted to Cropland can be a key source for many countries (Lasco et al., 2006). Emission for LULUCF sector is mainly from this category mainly through conversion of forest land. Under this category annual change in carbon stocks in biomass before conversion which is mainly primary and secondary forest is lost due to removal of forest cover. Gain is from biomass after conversion where the land area is assumed to be totally cleared with the value of zero. Carbon loss is from Biomass carbon stock before conversion where major loss is occurring. Carbon pools accounted for in this category include:

- ☐ Biomass, and
- ☐ Dead Organic Matter.

6.5.2.2. **Methodological Issues**

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

This sub-section provides report on greenhouse gas inventory calculations for carbon stock change in biomass due to the conversion of land from natural conditions and other uses to Cropland, including deforestation and conversion of pasture and grazing lands to Cropland. Under Land converted to Cropland, emissions under the following categories were calculated:

- Biomass
- Dead Organic Matter

The above two carbon pools were calculated using Equation 2.16 and 2.23 from the 2006 IPCC Guidelines (Pingoud et al., 2006).

☐ 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 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.

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

Activity data for land converted to cropland were taken from the Collect Earth assessment conducted by the Papua New Guinea Forest Authority (refer Technical Annex of this report for methodology details). According to the assessment, land use change occurred mostly on forestland converted to cropland. Other land use types converted to cropland were insignificant.

c. 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 6-13: Biomass carbon stock before conversion

Biomass carbon stock before conversion				
Initial land use		**Unit**	**Values**	**Source(s)**
FL	R(p)	t-dm/ha	306	Fox et. Al (2010)
	M(p)	t-dm/ha	178	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)[6]
	D(p)	t-dm/ha	166	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	S(p)	t-dm/ha	98	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	Ma(p)	t-dm/ha	286	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	R(d)	t-dm/ha	200	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	M(d)	t-dm/ha	117	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	D(d)	t-dm/ha	109	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	S(d)	t-dm/ha	64	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	Ma(d)	t-dm/ha	286	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	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(s)**
Biomass regrowth after conversion	t-dm/ha/yr		0	IPCC, 2006 (Tier 1 default value)
Carbon fraction				
Land Use	**Unit**		**Value**	**Source(s)**
All	t-C/t-dm		0.47	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.3)

- EF for dead organic matter

Parameters	Emission Factors	Source
Deadwood	0	2006, IPCC GL, Tier 1 default value
Litter	2.1	Table 2.2, Vol 4, Cha 2, Tropical Climate

6. Some of average above ground biomass and average annual below ground biomass.

6.5.2.3. **Sub-category-specific Recalculations, if applicable**

No recalculations have been made. The same data sources and emission factors have been used to expand on 2016 and 2017.

6.5.2.4. **Sub-category-specific Planned Improvements, if applicable (e.g. methodologies, AD, EF, etc.)**

- 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 (3.B.3)

This sub-section reports methods for estimating greenhouse gas emissions and removals due to grassland remaining grassland and changes from land converted to grassland. According to the 2006 IPCC Guidelines, grasslands cover about one-quarter of the earth's land surface and span a range of climate conditions from arid to humid. 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 table below shows the emissions and removals from grassland.

Table 6-14: Emissions and removals from Grassland (3.B.3)

IPCC code	Sub-categories	unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.B.3	Grassland	kt-CO_2	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
3.B.3.a	Grassland remaining grassland	kt-CO_2	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
	Living biomass	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dead organic matter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soils	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Organic soils	kt-CO_2	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36	323.36
3.B.3.b	Land converted to grassland	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Living biomass	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Dead organic matter	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Mineral soils	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Organic soils	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

NA: Not Applicable, NE: Not estimated

6.6.1. Grassland Remaining Grassland (3.B.3.a)

6.6.1.1. **Sub-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-CO_2 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.

Equation 2.26: Annual Carbon Loss from drained organic soils (CO_2)

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

$L_{organic}$	=	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}

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

Activity data for grassland remaining grass land were taken from the land use and land use change assessment (Collect Earth exercise) conducted by the Papua New Guinea Forest Authority (refer Technical Annex of this report for methodology details).

c. 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).

6.6.1.3. Sub-category-specific Recalculations, if applicable

No recalculations have been made. The same data sources and emission factors have been used to expand on 2016 and 2017. As for the activity data for the year 2016 and 2017, the same activity data for the year 2015 was extrapolated here because there were insignificant difference in the area of organic soil according to the first BUR report.

6.6.1.4. Sub-category-specific Planned Improvements, if applicable (e.g. methodologies, AD, EF, etc.)

- increasing the sampling intensity in Collect Earth 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 Grassland (3.B.3.b)

There is no land use change from land to grassland. This shows that there was no area conversion to grass land according to the land use matrix since 2000.

6.7. Wetland (3.B.4)

6.7.1 Wetland Remaining Wetland (3.B.4.a)

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

6.7.2. Land Converted to Wetland (3.B.4.b)

There were no land use change from other land use to wetlands.

6.8. Settlement (3.B.5)

This sub-section reports method for estimating carbon stock changes and greenhouse gas emissions and removals associated with changes in biomass and dead organic matter (DOM) on lands converted to settlements. The settlement category consists of settlement remaining settlement (3.B.5.a) and land converted to settlement (3.B.5.b). However, emission and removals estimates were made only in the land converted to settlement (3.B.5.b) sub-category. Carbon pools estimated were living biomass and dead organic matter.

The total emissions in 2017 for the settlement category was 1,058.52 kt CO_2. The table below shows the emissions and removals from settlements.

Table 6-15: Emissions and removals from Settlements (3.B.5)

IPCC Code	Sub-categories	unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.B.5	Settlements	kt-CO_2	0.00	0.00	33.79	257.07	56.12	56.12	33.47	34.59	510.19	1,058.52
3.B.5.a	Settlements remaining Settlements	kt-CO_2	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA	NO, NA
	Living biomass	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dead organic matter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soils	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Organic soils	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3.B.5.b	Land converted to Settlements	kt-CO_2	0.00	0.00	33.79	257.07	56.12	56.12	33.47	34.59	510.19	1,058.52
	Living biomass	kt-CO_2	0.00	0.00	33.79	246.95	56.12	56.12	33.47	34.59	495.15	1,043.29
	Dead organic matter	kt-CO_2	0.00	0.00	0.00	10.12	0.00	0.00	0.00	0.00	15.04	15.23
	Mineral soils	kt-CO_2	NO	NO	NE	NE	NE	NE	NE	NE	NE	NE
	Organic soils	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6.8.1. Settlements Remaining Settlements (3.B.5.a)

Tier 1 assumes that no carbon stock change occurred in C pools in settlements remaining settlements. It is assumed that there are no managed organic soils in settlements.

6.8.2. Land Converted to Settlement (3.B.5.b)

Conversion of Forest Land, Cropland, Grassland etc. to Settlements, leads to emissions and removals of greenhouse gases. Methods for estimating change in carbon stocks associated with land-use conversions are explained in Chapters 2, 4, 5 and 6 of volume 4 (IPCC, 2006).

In terms of estimations for land converted to settlement, estimation in two carbon pools were estimated. These two pools are living biomass and dead organic matter (DOM). Mineral soils and organic soils are not considered due to non-availability of data. These will be reported once sufficient data is available with the use of higher tier. Equation 2.15 and Equation 2.16 (for biomass), and Equation 2.23 (for DOM) from the 2006 IPCC Guidelines were used in the estimations from the above two pools.

6.8.2.1. **Sub-category Description**

Conversion of Forest Land, Cropland, Grassland etc. to Settlements, leads to emissions and removals of greenhouse gases. Methods for estimating change in carbon stocks associated with land-use conversions are explained in Chapters 2, 4, 5 and 6 of volume 4 (IPCC, 2006). In terms of estimations for land converted to settlement, estimation in two carbon pools were estimated. These two pools are living biomass and dead organic matter (DOM). Mineral soils and organic soils are not considered due to non-availability of data. These will be reported once sufficient data is available with the use of higher tier. Equation 2.15 and Equation 2.16 (for biomass), and Equation 2.23 (for DOM) from the 2006 IPCC Guidelines were used in the estimations from the above two pools.

6.8.2.2. Methodological Issues

a. Choice of Method (including assumptions and the rationale for selection)

The general methodology for biomass carbon stock change in Settlements Remaining Settlements follows the approach in Equation 2.15 Chapter 2. This methodology estimates the annual change in carbon stocks in biomass on land converted to settlement category. According to the 2006 IPCC Guideline, the average annual changes in biomass carbon stocks in settlements may be positive or negative depending on the relative magnitudes of the increment and loss terms. Given below is equation

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 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}

Table 6-16: Emission factors used for the estimation of living biomass

Biomass carbon stock before conversion				
Initial land use		**Unit**	**Values**	**Source(s)**
FL	M(d)	t-dm/ha	117	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
	D(d)	t-dm/ha	109	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.7)
Cropland		t-dm/ha	10	IPCC, 2006 (Vol. 4, Ch. 8, Table 8.4)
Biomass carbon stock after conversion				
Final land use	**Unit**		**Value**	**Source(s)**
Biomass regrowth after conversion	t-dm/ha/yr		0	IPCC, 2006 (Tier 1 default value)
Carbon fraction				
Land Use	**Unit**		**Value**	**Source(s)**
All forest land	t-C/t-dm		0.47	IPCC, 2006 (Vol. 4, Ch. 4, Table 4.3)
Settlement	t-C/t-dm		0.5	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 6-17: Emission factors for dead organic matter

Parameters	Emission Factors	Source
Deadwood	0	2006, IPCC GL, Tier 1 default value
Litter	2.1	Table 2.2, Vol 4, Cha 2, Tropical Climate

6.8.2.3. Sub-category-specific Recalculations

No recalculations have been made for land converted to settlement. The same data sources and emission factors used in BUR1 (2000 – 2015) have been used to expand on 2016 and 2017.

6.8.2.4. Sub-category-specific Planned Improvements, if applicable

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

6.9. Other Lands (3.B.6)

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

6.10 Harvested Wood Products (3.D.1)

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 Biomass Burning in forest lands (3.C.1.a)

6.11.1 Category Description

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.

Table 6-18: Emissions from Biomass burning in forest lands (3.C.1.a)

IPCC code	Sub-Categories	unit	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
3.C.1.a	Biomass burning - FL	kt CH_4	12.85	4.33	4.84	2.65	2.45	5.19	4.62	98.21	3.48	3.74
3.C.1.a	Biomass burning - FL	kt N_2O	0.38	0.13	0.14	0.08	0.07	0.15	0.14	2.89	0.10	0.11
3.C.1.a	Biomass burning - FL	kt CO_2 eq	269.80	91.03	101.74	55.55	51.44	108.95	97.09	2,062.37	73.05	78.61
3.C.1.a	Biomass burning - FL	kt CO_2 eq	117.14	39.52	44.17	24.12	22.33	47.30	42.16	895.43	31.72	34.13
3.C.1.a	Total	kt CO_2 eq	386.94	130.55	145.91	79.67	73.77	156.26	139.25	2,957.79	104.76	112.74

6.11.1.1. Methodological Issues

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

A tier 1 method was chosen method for estimation of emissions from this category. Given below is the methodology used in the estimation of GHGs from fire.

Equation 2.27: Estimation of greenhouse gas emissions from fire

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

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 a land-use change (see Section 2.3.2.2).

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)

b. 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

c. EF, other Parameters

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

Table 6-19: Emission factors for living biomass

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

6.11.1.2. Sub-category-specific recalculations

Recalculations made for biomass burning because there were updated activity data from data source (FAOSTAT).

6.11.1.3. Sub-category-specific planned Improvements

- Use fire data base on hot spot areas
- No country specific data available
- Improving country specific activity data

Chapter

7

Waste Sector

7.1. Overview of Sector

7.1.1. Overview of the Waste Management and Estimation Category

The waste sector covers GHG emissions from treatment and disposal of waste, which are estimated for solid waste disposal (4.A.), biological treatment of solid waste (4.B.), incineration and open burning of waste (4.C.), and wastewater treatment and discharge (4.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 of waste generation and/or treatment amount are hardly available for most of the case in PNG. Thus, the many estimates are linked to the population data. PNG employs 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 judgement.

PNG generally employs default methodologies and emission factors in GHG emission estimations on the waste sector. Given the paucity of data, emissions estimate from the waste sector in PNG comprised of CH_4 emissions from solid waste disposal sites, CH_4 and N_2O emissions from biological treatment of solid waste, and CH_4 and N_2O emissions from wastewater treatment. Emissions from incineration and open burning of waste are only reported for MSW. For details, see articles "Methodological Issues" in each category's section.

Table 7-1: Summary for methods and emission factors used on waste sector

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

7.1.2. Emission Summary of the Sector

In 2017, emissions from the Waste sector resulted in 1,006 kt CO_2 eq and accounted for 9% of PNG's total greenhouse gas emissions (excluding LULUCF). The emissions of the waste sector have increased in the whole time series (2000-2017) as seen in figure 7-1. The increase is influenced by population growth, development, consumption rate and rural-to-urban drift. Breakdown of 2017 emissions of the Waste sector by category shows that wastewater treatment and discharge (4.D.) contributed 67 % to total sector emissions in 2017, followed by solid waste disposal (4.A.) (27 %), incineration and Open Burning (4.C.) (6 %) and biological treatment of solid waste (4.B.) (1 %). The contribution of CO_2, CH_4 and N_2O for the total sector emissions are 3.5, 79.1 and 17.4 % respectively.

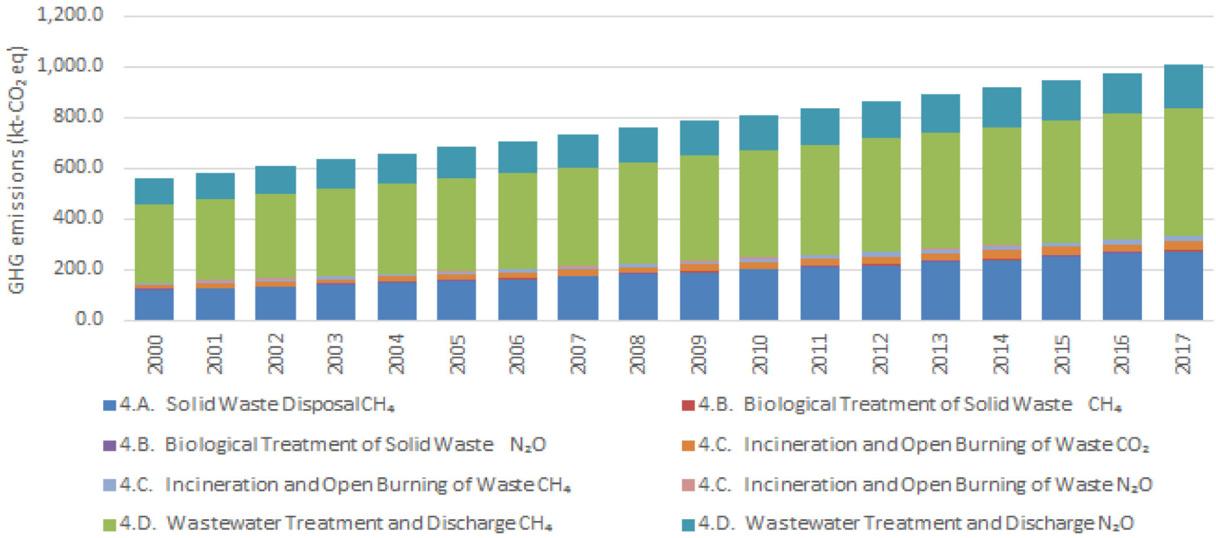


Figure 7-1: GHG emissions from the waste sector from 2000 to 2017 (kt CO_2 eq)

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/cites in PNG are disposed in aggregate quantities at open air dump sites located at the periphery of the town/ city through a road side pickup system. In PNG, basically all solid waste are collected together without segregation at source and only scrap metal is recycled.

Information on 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 ration as 0.38 kg waste generated per person per day. Therefore, 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, Jiwaka and Morobe) and small cities/town in PNG are separately estimated as the generate waste and its waste treatment types are considered different between urban area and rural area. The two expert judgements are applied in construction of time series of waste generation amount: (1) 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 7-2: Data used for MSW generation

Item	classification	unit	1980	1990	2000	2011	2014	2017
Population	Big cities	person	699,902	911,865	1,233,587	1,745,772	1,885,459	2,025,146
	Rural cities and island	person	2,310,825	2,850,089	3,957,199	5,529,552	5,958,376	6,387,199
Waste generaton per person per day	Big cities	kg/cap./day	0.19	0.25	0.30	0.36	0.38	0.40
	Rural cities and island	kg/cap./day	0.13	0.17	0.21	0.25	0.27	0.28
MSW generated	Big cities	kt(wet)	48.54	81.84	135.87	231.46	261.51	293.28
	Rural cities and island	kt(wet)	112.18	179.05	305.10	513.18	578.50	647.49
Black: statics 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 (Table 7 3). This composition is regarded as representing PNG's situation and used in all MSW for whole time series.

Table 7-3: MSW composition data

Waste type	Paper	Textile	Food	Wood	Garden & park	Nappies	Rubber & leather	Plastics	Metal	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

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

Table 7-4: 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. Main industries in PNG which emit organic solid waste are "food and beverage" and "Organic material". One petroleum refinery is also operating. There is no tobacco, textile, wood and pulp and chemical industries in PNG. The data about amount of industrial waste generation or other relevant data which may be used as driver to estimate industrial solid waste amount is not available at present, industrial waste is not considered in GHG estimation of waste sector for BUR2.

7.2. Solid Waste Disposal (4.A)

7.2.1. Category Description

Treatment and disposal of solid waste produces CH_4 and CO_2 during decomposition of organic materials in solid waste disposal site (SWDS). Emissions emanate from waste deposited over a long period. Solid waste disposed since 1950 is considered in the PNG inventory because it is good practice to use at least 50 years as this time frame 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 emissions in the waste sector total as well as national total, because carbon is of biogenic origin and net emissions are considered and included under the AFOLU Sector. CO_2 emissions from burning of the surface of landfill site are considered in category 4.A, but this source is not estimated in PNG. Thus, the only CH_4 emissions are reported in this sector.

The estimated emissions from SWDS are about 272.6 kt CO_2 eq in 2017 and the trend is shown in figure 7-2 below.

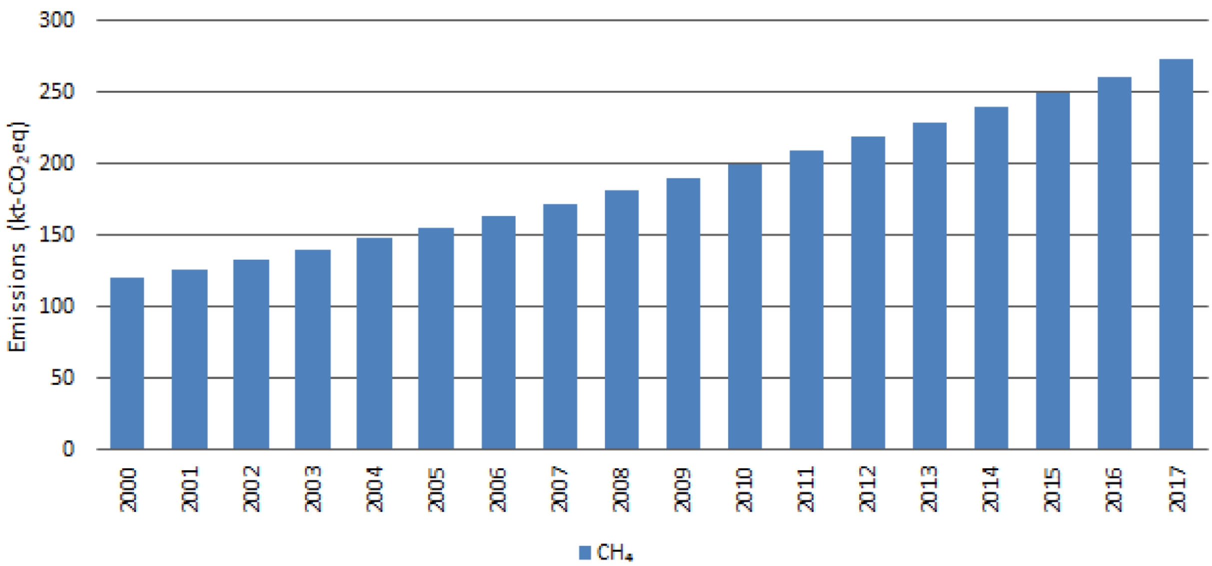


Figure 7-2: Time series of GHG emissions from solid waste disposal (4.A.) from 2000 to 2017 (in kt CO2 eq)

7.2.2. Methodological Issues

7.2.2.1. Choice of Method

The IPCC Waste Model based on First Order Decay (FOD) method given in the 2006 IPCC Guidelines is 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 can be 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 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 are eliminated from CH_4 generated and then emitted CH_4 from SWDS are 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*

Table 7-5: Amounts of waste landfilled and degradable organic carbon content.

Year	Amount of landfill (kt)				
	MSW Big cities	MSW Rural area	ISW	Sludge	Total
1950	2	8	NE	NE	11
1955	6	12	NE	NE	17
1960	9	15	NE	NE	24
1965	13	18	NE	NE	31
1970	17	21	NE	NE	38
1975	25	30	NE	NE	54
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

7.2.2.3. **EF, Other Parameters**

Emission factors are defined as the amount of CH_4 [kg] generated through decomposition of one ton of biodegradable landfill wastes (dry basis) without incineration. They 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:

- Fraction of degradable organic carbon (DOC): See Table 7 6;
- CH_4 generation (decomposition) rate constant (k): see Table 7 6;
- Fraction of DOC actually dissimilated (DOCf): 0.5;
- Methane correction factor (MCF): see Table 7 6;
- Fraction of methane in landfill gas produced: 0.5;
- Time delay from 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 7-6: 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	

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, other Oceania" provided in the IPCC waste spreadsheet model are used.

b. Methane Correction Factor (MCF)

In PNG, all disposal sites are open air damping, and the sites are classified as unmanaged. The GHG emissions from SWDS for the inventory timeseries up to the year 2017 for BUR2 are estimated under the share of 100% unmanaged-deep (MCF = 0.8) for big cities and 100% unmanaged-shallow (MCF = 0.4) for rural area for whole time series.

In Port Moresby, improvement work of SWDS (Baruni disposal site) was done during 2012-2016, and some cells in this disposal site were developed to operate semi-aerobic type of landfill management (Fukuoka Method). The semi-aerobic landfill operation in this site started late 2017. Thus, the GHG emissions in this site from 2018 generated under semi-aerobic treatment and the next GHG inventory covering the year 2018 onward will consider this change.

c. Delay 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)

Oxidation factor is set as 0. methane generated by the decomposition of organic carbon are 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.

7.2.3. Category-specific Recalculations

No recalculation has made.

7.2.4. Category-specific Planned Improvements

a. Update of Population Time Series

National Statistical Office of PNG plans to implement population survey so called "National Population and Housing Census" in 2024 (originally planned in 2021 but deferred due to some difficulties caused by COVID-19). When the latest population data will be available, the time series of population after 2011 will be subject to recalculation. In addition, section 1.2.2 of this report indicates there is census for the years in 1966 and 1971, but these have not reflected in the calculation yet. If the time series of population is improved, the waste generation amount and the amount of landfill waste will also cause recalculation as the estimations use the population as a driver.

b. Change of 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.

c. Improvement of MSW Estimation

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

d. Resolving NE for ISW and Sludge

Solid waste generated from industry and sludge from wastewater treatment go to landfill are not estimated. PNG tries to collect relevant data.

7.3. Biological Treatment of Solid Waste (4.B)

7.3.1. Category Description

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 volume in the waste material, stabilize of the waste, destruct pathogens in the waste material, and product biogas for energy use.

This category covers CH_4 and N_2O emissions generated during 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 4.D.

The 2006 IPCC guidelines refer the three biological treatments: composting, anaerobic digestion of organic waste and mechanical-biological (MB) treatment. In PNG, only composting is implemented and so reported under this category. Anaerobic digestion of solid waste is assumed to be zero as no data 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 biological treatment of solid waste are about 6.9 kt CO_2eq in 2017 and the trend is shown in figure 7-3 below.

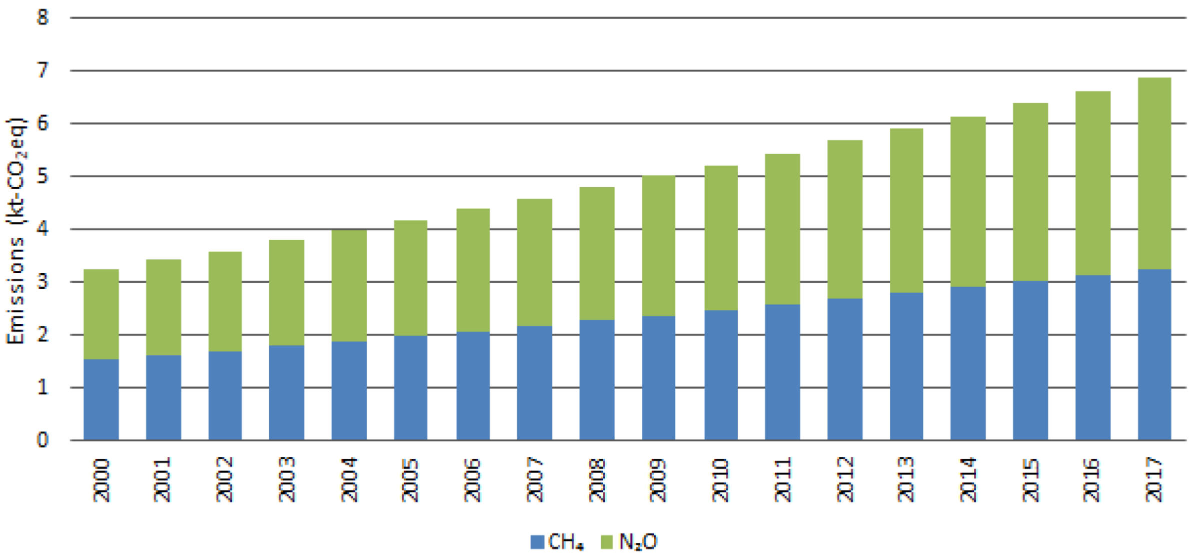


Figure 7-3: Time series of GHG emissions from biological treatment of solid waste (4.B.) from 2000 to 2017 (in kt CO_2 eq)

7.3.2 Methodological Issues

7.3.2.1. Choice of Method

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 considered 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

7.3.2.2. 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 7-4). 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 7-3) 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 4.B.

7.3.2.3. 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) are 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.

7.3.3. Category-specific Recalculations, if applicable

No recalculation has made since BUR1.

7.3.4. Category-specific Planned Improvements, if applicable (e.g. methodologies, AD, EF, etc.)

The issue identified in 4.A (section 7.2.4.a) is also relevant to 4.B in terms of AD improvement. There is no plan of improvement for equations and EFs.

7.4. Incineration and Open Burning of Waste (4.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 national total, while CO_2 emissions included in national total are fossil origin only. Biogenic CO_2 emissions are excluded in 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 types. In the PNG inventory, amount of waste incinerated or open-burned are 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 Small Island is treated by incineration or open burning table 7-4. All waste combustion in small 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 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 BUR2. 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 (4.C.1)

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 (4.C.2)

7.4.2.1. Category Description

A part of MSW in small islands are subject to combustion. All of this combustion is assumed as open-burning. The estimated emissions from open burning about 56.4 kt CO_2 eq in 2017 and are shown in figure 7-4 below.

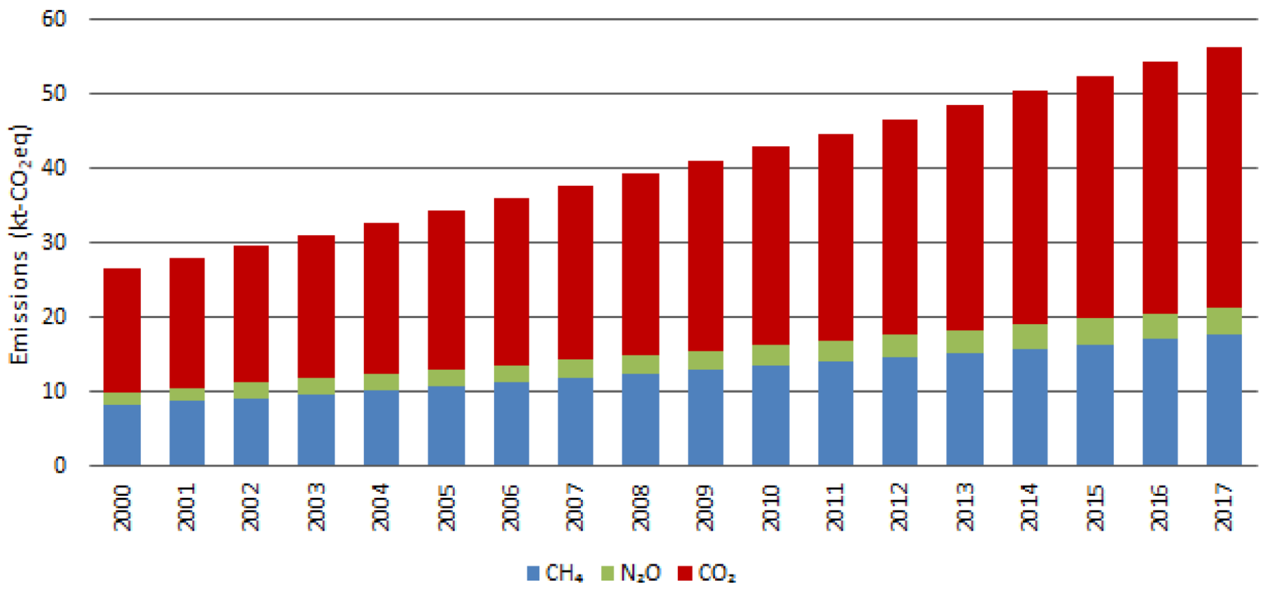


Figure 7-4: Time series of GHG emissions from open burning of waste (4.C.2) from 2000 to 2017 (in kt CO_2 eq)

7.4.2.2. Choice of Methods

a. CO_2 Emissions

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.

$$GHG\ Emissions = MSW \times \Sigma_j (WF_i \times dm_j \times CF_j \times FCF_j \times OF_j) \times \frac{44}{12}$$

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 weight 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*

FCF_j = fraction of fossil carbon in the total carbon of component *j*

OF_j = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2

b. CH_4 and N_2O Emissions

A Tier 1 method is used to estimate CH_4 and N_2O 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 CH_4 and N_2O 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 gigagram

7.4.2.3. **AD**

a. 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 in section 7.4.2.2 and the parameters of dry matter content, total carbon content, fossil carbon fraction of MSW table 7-7. All parameters are based on the default values provided in the 2006 IPCC Guidelines.

Table 7-7: Parameters used in estimating AD for open-burning

Item	Waste component of MSW									
	Paper	Textile	Food	Wood	Garden & park	Nappies	Rubber & leather	Plastics	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

Sources: Table 2.4 and Table 5.2 volume 5, 2006GL

b. CH_4 Emissions

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.

c. N_2O Emissions

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 (table 7-8).

Table 7-8: AD for open-burning (MSW)

Year	MSW burned (kt)			other waste burned
	total (wet)	Total (dry)	Fossil origin carbon	
2000	61	38	8	NE
2001	64	40	8	NE
2002	68	42	9	NE
2003	71	44	9	NE
2004	75	47	10	NE
2005	79	49	10	NE
2006	82	51	10	NE
2007	86	54	11	NE
2008	90	56	11	NE
2009	94	58	12	NE
2010	98	61	13	NE
2011	103	64	13	NE
2012	107	66	14	NE
2013	111	69	14	NE
2014	116	72	15	NE
2015	120	75	15	NE
2016	125	77	16	NE
2017	129	80	16	NE

7.4.2.4. **EF, Other Parameters**

a. CO_2 Emissions

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.

b. CH_4 Emissions

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.

c. N_2O Emissions

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.

7.4.3. Category-specific Recalculations

As not enough information on incineration of waste was available, this category was reported as not estimated in the BUR1. In BUR2, GHG emissions from MSW are newly estimated.

7.4.4. Category-specific Planned Improvements

The issue identified in 4.A (section 7.2.4.a) is also relevant to 4.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 (4.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).

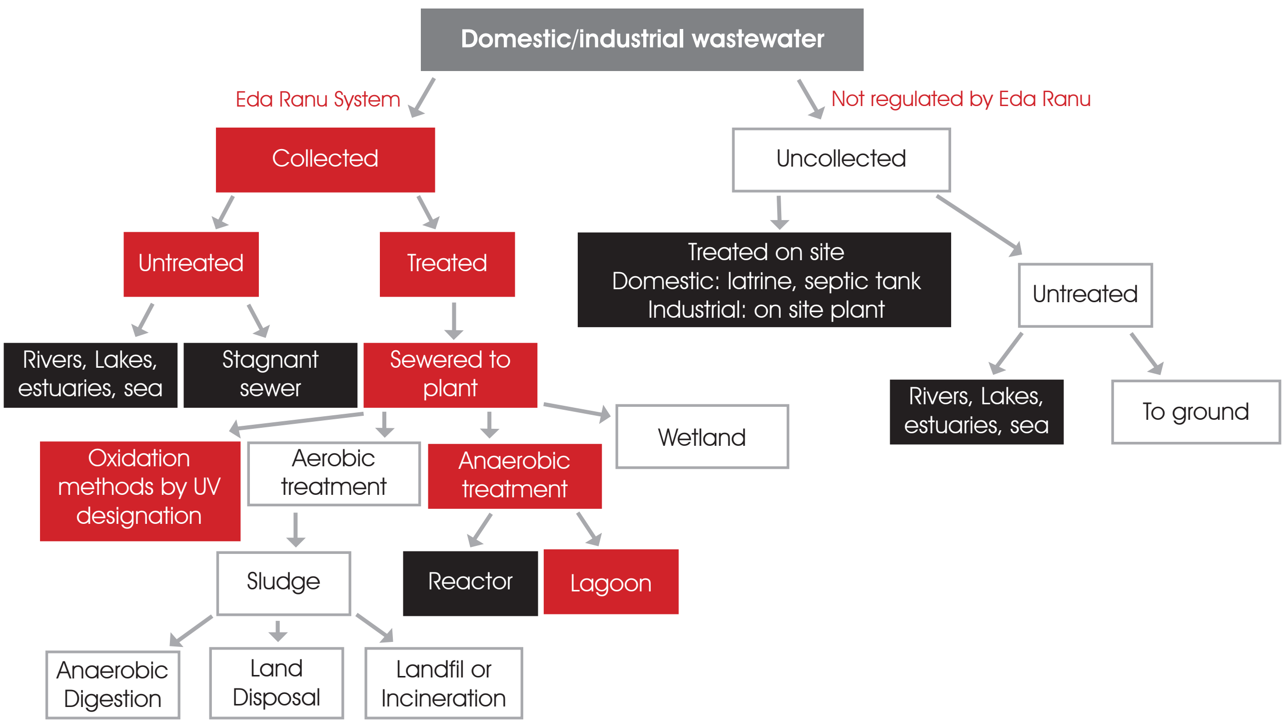
The extent of CH_4 production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system (IPCC 2006). The amount of degradable organic material in the wastewater is shown as the Biochemical Oxygen Demand (BOD) or Chemical Oxygen 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. Port Moresby's system is operated by a public corporation (Eda Rane), and other countries' systems are operated by other pubic corporation (WaterPNG). These systems treat cover domestic, commercial as well as industrial wastewater generated in the central part of the cities. Uncollected wastewater do not regulated by public cooperation. 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. Figure 7-5 shows the overview of the wastewater treatment systems and discharge pathways of Port Moresby based on Figure 6.1 of the 2006 IPCC Guidelines.

The estimated emissions from wastewater treatment are about 670.5 kt CO_2 eq in 2017 and the trend is shown in figure 7-6 below.

Figure 7-5: Overview of the wastewater treatment systems and discharge pathways of Port Moresby



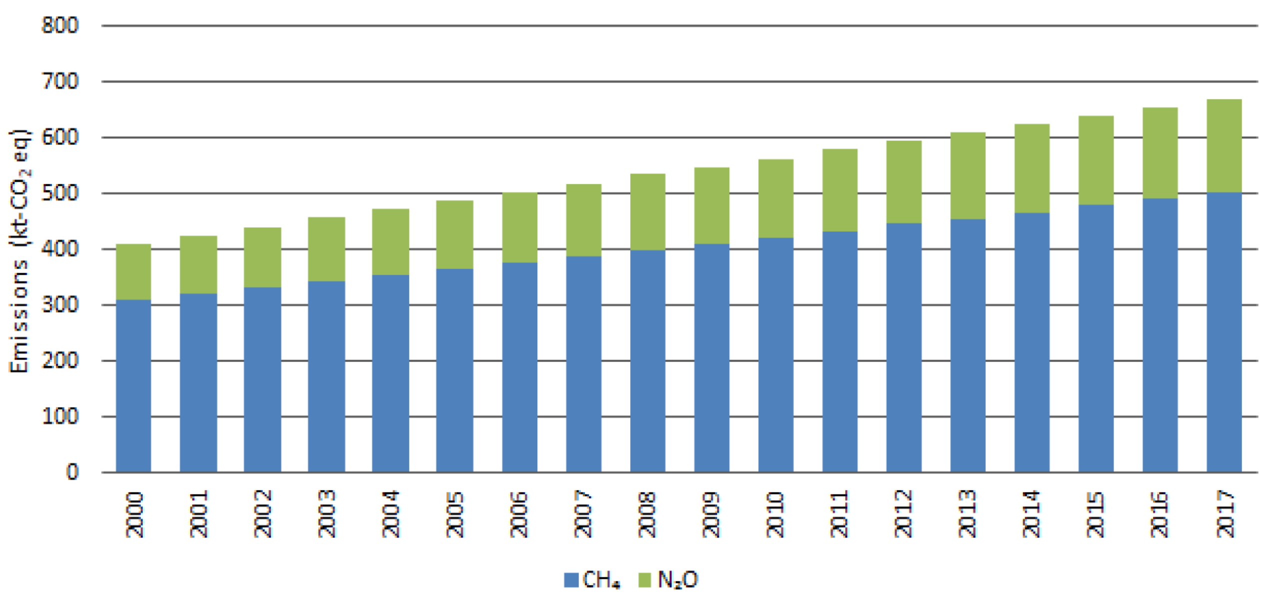


Figure 7-6: Time series of GHG emissions from waste water treatment (4.D.) from 2000 to 2017

7.5.1. Domestic Wastewater Treatment and Discharge (4.D.1)

7.5.1.1. Category Description

This sector 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 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. Choice of Method

a. CH_4 Emissions

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 utilisation of treatment/discharge pathway or system, *j*
j	= each treatment/discharge pathway or system
EFj	= emission factor, kg CH_4 / kg BOD

7.5.1.3. AD

a. CH_4 Emissions

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.

$$TOW = P \times BOD \times 0.001 \times I \times Day$$

Where:

TOW: = total organics in wastewater in inventory year, kg BOD/yr

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 discharged into sewers

Day: = number of days per year, 365 or 366

Time series data of the country population is constructed from PNG Census 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 the wastewater in 8 cities collected by Eda Ranu or WaterPNG and 1.00 is used 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 that "treated (such as septic system)", "sea, lake and river discharge" and "pit toilet" is 30%, 30% and 40% respectively in BUR1. Some stakeholders of wastewater treatment in PNG agreed that this assumption shows almost actual situation in PNG.

In BUR2, the share of utilisation of treatment/discharge pathway or system in PNG is improved based on the information provided from the two public corporations. In Port Moresby, two-third of collected wastewater is treated under Lagoon and rest of one-third used to be discharged into sea. In 2018. Joyce Bay sewerage treatment plant (STP) started operation and wastewater generated coastal area of Port Moresby goes to this plant. Thus, BUR2 divided the share of treated system of 30% into "shallow lagoon" and "septic tank" based on the expected population using these systems. The share of new STP will be subtracted from "sea, lake and river discharge" but this starts from 2018 and so covered next GHG inventory submission. For the seven cities operating wastewater collecting system, WaterPNG provided number of houses connected to their system for the year 2014-2018. If this number is converted to population basis by using 2011 Census data (where number of people and houses are available in each small administrative division), the share of using this system occupy 0.2-0.3% of the total population of PNG. As the systems' facilities and operation in seven cities have not been changed for these 20 years, the average of 2014-2018, 0.26%, is applied for estimating number of people using this system.

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 BUR2 estimation is show in table 7-9 below, which are assumed from number of people using each system.

Figure 7-9: The share of utilization of treatment/discharge pathway or system in PNG

Item		Unit	2000	2005	2010	2015	2016	2017
Treated	Centralized, aerobic treatment plant	%	0%	0%	0%	0%	0%	0%
	Anaerobic shallow lagoon	%	2.7%	2.8%	2.8%	2.9%	2.9%	2.9%
	Septic tank	%	27.3%	27.2%	27.2%	27.1%	27.1%	27.1%
Untreated	Sea, river and lake discharge	%	30%	30%	30%	30%	30%	30%
	Pit toilet	%	40%	40%	40%	40%	40%	40%

b. N_2O Emissions

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 below.

$$N_{EFFLUENT} = P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM} - N_{SLUDGE}$$

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

$F_{NON-CON}$ = factor for non-consumed protein added to the wastewater

$F_{IND-COM}$ = 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.

7.5.1.4. EF, Other Parameters

a. CH_4 Emissions

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), 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).

b. N_2O Emissions

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.

7.5.1.5. Category-specific Recalculations

Information on wastewater collecting systems is used in the GHG estimation for the first time. Based on this data, CH_4 emission from lagoon system is newly estimated, the share of wastewater treatment system is updated and factor I =1.25 is applied for the wastewater collected by this system. For N_2O emissions, FIND-COM is newly applied in line with the default equation.

7.5.1.6. **Category-specific Planned Improvements**

The issue identified in 4.A (section 7.2.4.a) is also relevant to 4.D.1 in terms of AD improvement.

Update of estimation is expected from the year 2018 onward because sewerage treatment plant in coastal area of Port Moresby started its operation on September 2018 and wastewater used to be discharged into sea goes to this plant. It may be necessary to capture operation status of this plant to reflect this into the GHG estimation.

At this 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 (4.D.2)

7.5.2.1. **Category Description**

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. Thus, independent estimate about industrial wastewater is not implemented for BUR2.

7.5.2.2. **Category-specific Planned Improvements**

In order to complete the estimate of this category, it is necessary to clarify how much wastewater is emitted from main industrial organic wastewater emitters, which industries or factories are connected to domestic wastewater collecting system and how wastewater is treated if unconnected.

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Appendix I: Overview of Methods

Overview of Methods and Emission Factors used in the GHG inventory

	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6	
	method	EF	method	EF	method	EF	method	EF	method	EF	method	EF
1 ENERGY												
1A Fuel Combustion Activities												
1A1 Energy Industries	1	D	1	D	1	D						
1A2 Manufacturing Industries and Construction	1	D	1	D	1	D						
1A3 Transport	1	D	1	D	1	D						
1A4 Other Sectors	1	D	1	D	1	D						
1A5 Non-Specified												
1B Fugitive Emissions from Fuels	1	D	1	D	1	D						
2 INDUSTRIAL PROCESSES AND PRODUCT USE												
2A Mineral Industry												
2B Chemical Industry												
2C Metal Industry												
2D Non-Energy Products from Fuels and Solvent Use	1	D										
2E Electronics Industry												
2F Product Uses as Substitutes for Ozone Depleting Substances							1	D				
2G Other Product Manufacture and Use					1	D						
2H Other (please specify)												
3 AGRICULTURE, FORESTRY AND OTHER LAND USE												
3A Livestock			1	D	1	D						
3B Land	1, 2	D, CS										
3C Aggregate Sources and Non-CO2 Emissions Sources on Land			1	D	1	D						
3D Other												
4 WASTE												
4A Solid Waste Disposal			2	D								
4B Biological Treatment of Solid Waste			1	D	1	D						
4C Incineration and Open Burning of Waste	1	D	1	D	1	D						
4D Wastewater Treatment and Discharge			1	D	1	D						

The following notation keys have been used to specify the method applied:

D (IPCC default)
T1 (IPCC Tier 1)
T2 (IPCC Tier 2)
T3 (IPCC Tier 3)
CS (Country Specific)
OTH (Other)

Use the following notation keys to specify the emission factor used:

D (IPCC default)
CR (CORINAIR)
CS (Country Specific)
PS (Plant Specific)
OTH (Other)

Appendix II: GHG Summary table (2017)

GHG emissions summary for 2017

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Net CO_2 emissions/removals	CH_4	N_2O	HFCs	PFCs	Unspecified mix of HFCs and PFCs	SF_6	NF_3	NO_x	CO	NMVOC	SO_2
	(kt)			(kt CO_2 equivalent)					(kt)			
Total national emissions and removals	-5,753.57	126.51	3.19	0.00	0.00	150.62	0.00	0.00	0.00	0.00	29.57	0.00
1. Energy	7,047.38	69.76	0.52						0.00	0.00	29.57	0.00
A. Fuel combustion	7,002.46	2.49	0.52						0.00	0.00	0.00	0.00
1. Energy industries	829.45	0.04	0.00						NE	NE	NE	NE
2. Manufacturing industries and construction	3,764.01	0.23	0.04						NE	NE	NE	NE
3. Transport	1,946.46	0.24	0.09						NE	NE	NE	NE
4. Other sectors	462.54	1.99	0.38						NE	NE	NE	NE
5. Other	NE	NE	NE						NE	NE	NE	NE
B. Fugitive emissions from fuels	44.91	67.27	0.00						0.00	0.00	29.57	0.00
1. Solid fuels	NO	NO	NO						NO	NO	NO	NO
2. Oil and natural gas and other emissions from energy production	44.91	67.27	0.00						NE	NE	29.57	NE
C. CO_2 Transport and storage												
2. Industrial processes and product use	1.75	0.00	0.00	NE	NE	150.62	NE	NE	NE	NE	NE	NE
A. Mineral industry	NE								NE	NE	NE	NE
B. Chemical industry	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
C. Metal industry	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
D. Non-energy products from fuels and solvent use	1.75	NE	NE						NE	NE	NE	NE
E. Electronic industry				NE	NE	NE	NE	NE				
F. Product uses as substitutes for ODS				NE	NE	150.62	NE	NE				
G. Other product manufacture and use	NE	NE	0.003	NE	NE	NE	NE	NE	NE	NE	NE	NE
H. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3. Agriculture	0.00	15.10	1.99						0.00	0.00	0.00	0.00
A. Enteric fermentation		8.23										
B. Manure management		6.87	0.06								NE	
C. Rice cultivation		NE									NE	
D. Agricultural soils		NE	1.93						NE	NE	NE	
E. Prescribed burning of savannas		IE	IE						NE	NE	NE	
F. Field burning of agricultural residues		IE	IE						NE	NE	NE	
G. Liming	NE											
H. Urea application	NE											
I. Other carbon-contining fertilizers	NO											
J. Other	NO	NO	NO						NO	NO	NO	NO
4. Land use, land-use change and forestry	-12837.68	3.74	0.11						0.00	0.00	0.00	0.00
A. Forest land	-23617.38	3.74	0.11						NE	NE	NE	
B. Cropland	9397.82	NE	NE						NE	NE	NE	
C. Grassland	323.36	NO	NO						NE	NE	NE	
D. Wetlands	NE	NE	NE						NE	NE	NE	
E. Settlements	NE	NE	NE						NE	NE	NE	
F. Other land	1058.52	NE	NE						NE	NE	NE	
G. Harvested wood products	NE											
H. Other	NE	NE	NE						NE	NE	NE	NE
5. Waste	34.99	37.91	0.57						0.00	0.00	0.00	0.00
A. Solid waste disposal	NO	12.98							NE	NE	NE	
B. Biological treatment of solid waste		0.16	0.01						NE	NE	NE	
C. Incineration and open burning of waste	34.99	0.84	0.01						NE	NE	NE	NE
D. Wastewater treatment and discharge		23.94	0.54						NE	NE	NE	
E. Other	NO	NO	NO						NO	NO	NO	NO
6. Other ***(please specify)***	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Appendix III: Energy Balance Table (2017)

2017
Unit: KTO

		Coal						Coal products								Peat	Peat products	Oil shale and oil sands	Crude oil & NGL						Petroleum products																		Gas				Nuclear	Hydro	Geothermal	Solar		Tide, wave, ocean	Wind	Solid biomass						Others										Electricity	Heat	Total
			Coking coal	Other bituminous coal	Sub-bituminous coal	Anthracite	Lignite		Coke oven coke	Coke oven gas	Blast furnace gas	Other recovered gases	Patent fuel	Coal tar	BKB/PB					Crude oil	Natural gas liquids	Refinery feedstocks	Additives/ oxygenates	Other hydrocarbons		Motor gasoline	Aviation gasoline	Naphtha	Gasoline type jet fuel	Kerosene type jet fuel	Kerosene	Gas/diesel oil	Fuel oil	LPG	Refinery gas (not liquefied)	Ethane	White spirit SBP	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other products		Natural gas	LNG	Gas works gas					of which: Photovoltaics				Fuelwood & woodwaste	Bagasse	Charcoal	Black liquor	Other biomass		Biogas	Industrial waste	Municipal solid waste (renewable)	Municipal solid waste (non-renewable)	Biogasoline	Biodiesel	Bio jet kerosene	Other liquid biofuels	Other sources			
1.	Indigenous production	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1038	538	501	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3011	3011	-	-	-	75	361	-	0	-	-	-	1578	-	-	-	68	1681	35	-	-	-	-	-	-	-	-	-	-	6167
2.	Imports	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1412	1412	-	-	-	-	1008	67	-	-	-	31	46	472	392	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2420
3.	Exports	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-1038	-538	-501	-	-	-	-458	-	-	-436	-	-	-	-	-	-1	-	-	-	-	-	-	-	-21	-2558	-	-2558	-	-	-	-	-	-	-	-	-	-	-	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-4054
4.	International marine bunkers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.	International aviation bunkers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6.	Stock changes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-81	-81	-	-	-	-	-11	17	-	-14	-	-1	-	-11	-9	0	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-92
7.	Total primary energy supply	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1331	1331	-	-	-	-	540	84	-	-449	-	30	46	461	383	-1	-	-	-	-	-	-	-	-13	453	3011	-2558	-	-	75	361	-	0	-	-	-	1578	-	0	-	68	1681	35	-	-	-	-	-	-	-	-	-	-	4441
8.	Transfers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-47	42	-	-88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-47
8.1	Recycled products	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.2	Interproduct transfers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-47	42	-	-88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-47
8.3	Products transferred	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.4	Gas separation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.	Total transformation sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-1421	-1421	-	-	-	-	780	-	-	548	-	103	-	453	-356	18	-	-	-	-	-	-	-	13	-169	-2727	2558	-	-	-75	-361	-	0	-	-	-	-23	-	10	-	-2	-50	-35	-	-	-	-	-	-	-	-	389	-	-908
9.1	Main activity producer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-56	-56	-	-	-	-57	-	-	-	-	-	-	-	-	-	-	-	-35	-35	-	-	-	-	-	-	-	-	114	-	-35
9.1.1	Electricity plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-56	-56	-	-	-	-57	-	-	-	-	-	-	-	-	-	-	-	-35	-35	-	-	-	-	-	-	-	-	114	-	-35
9.1.2	CHP plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.1.3	Heat plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.2	Autoproducers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-594	-	-	-	-	-	-	-99	-495	-	-	-	-	-	-	-	-	-	-152	-152	-	-	-	-18	-361	-	0	-	-	-	-	-	-	-	-2	-2	-	-	-	-	-	-	-	-	-	275	-	-852
9.2.1	Electricity plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-594	-	-	-	-	-	-	-99	-495	-	-	-	-	-	-	-	-	-	-152	-152	-	-	-	-18	-361	-	0	-	-	-	-	-	-	-	-2	-2	-	-	-	-	-	-	-	-	-	275	-	-852
9.2.2	CHP plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.2.3	Heat plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.3	Gas processing plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	-2519	2558	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39
9.3.1	Gas works plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.3.2	Liquefaction plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	-2519	2558	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39
9.3.3	Regasification plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.3.4	Natural gas blending plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.3.5	Gas-to-liquids plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.4	Oil refineries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-1421	-1421	-	-	-	-	1374	-	-	548	-	103	-	551	140	18	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-47
9.5	Coal transformation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.5.1	Coke ovens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.5.2	Blast furnaces	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.5.3	Patent fuel plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.5.4	BKB/PB plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.5.5	Liquefaction (coal to oil)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.6	Petrochemical industry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.7	Biofuels processing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.8	Charcoal processing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-23	-	10	-	-	-13	-	-	-	-	-	-	-	-	-	-	-	-13
9.9	Non-specified transformation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.	Losses & own use	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-284	-284	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-47	-	-331
10.1	Own Use	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-284	-284	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-8	-	-292
10.1.1	Electricity, CHP and heat plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-8	-	-8
10.1.2	Gas works plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.3	Liquefaction plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-284	-284	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-284
10.1.4	Regasification	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.5	Natural gas blending plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.6	Gas-to-liquids plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.7	Gas separation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.8	Coke ovens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.9	Coal mines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.10	Blast furnaces	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.11	Patent fuel plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.12	BKB/PB plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.13	Liquefaction plants (Coal to Oil)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.14	Oil refineries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.15	Oil and gas extraction	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.16	Biofuels processing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.17	Nuclear industry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.1.18	Non-specified own uses	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.2	Transmission and distribution losses	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-39	-	-39
11.	Statistical discrepancy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	90	-	-	-	-	1	0	-	0	-	0	0	0	0	0	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-1	-	90
12.	Total final consumption	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1274	126	-	11	-	133	46	914	27	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1555	-	10	-	66	1631	-	-	-	-	-	-	-	-	-	342	-	3246
13.	Total final energy consumption	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1274	126	-	11	-	133	46	914	27	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1555	-	10	-	66	1631	-	-	-	-	-	-	-	-	-	342	-	3246
14.	Industry sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	483	-	-	11	-	-	-	441	18	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	-	-	253	-	803
14.1	Iron and steel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.2	Chemical (incl. petrochemical)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.3	Non-ferrous metals	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.4	Non-metallic mineral products	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.5	Transportation equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.6	Machinery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.7	Mining and quarrying	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.8	Food, beverages and tobacco	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.9	Pulp, paper and printing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.10	Wood and wood products	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.11	Construction	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.12	Textiles and leather	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.13	Non-specified industry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	483	-	-	11	-	-	-	441	18	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	-	-	253	-	803
15.	Transport sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	639	126	-	-	-	133	-	372	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	639
15.1	Domestic air transport	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	133	-	-	-	-	133	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	133
15.2	Road	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	497	126	-	-	-	-	-	372	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	497
15.3	Rail	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.4	Domestic navigation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
15.5	Pipeline transport	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.6	Non-specified transport	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.	Other sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	151	-	-	-	-	-	46	101	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1555	-	10	-	-	1565	-	-	-	-	-	-	-	-	-	89	-	1804
16.1	Commercial and public services	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	19	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	233	-	1	-	-	235	-	-	-	-	-	-	-	-	-	53	-	308
16.2	Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	28	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1322	-	8	-	-	1330	-	-	-	-	-	-	-	-	-	36	-	1396
16.3	Agriculture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	101	-	-	-	-	-	-	101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	101
16.4	Fishing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16.5	Non-specified others	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.	Non-energy use	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.1	Transformation sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.2	Industry sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.3	Transport sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.4	Other sector	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.	Electricity output in GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2484	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	694	-	-	-	-	877	420	-	2	-	-	-	-	-	-	-	19	47	28	-	-	-	-	-	-	-	-	-	-	4523

Appendix IV: LULUCF Land use matrix

AREA	R(p)	M(p)	D(p)	S(p)	Mg(p)	R(d)	M(d)	D(d)	S(d)	Mg(d)	Plantation	Cropland	Grassland	Wetlands	Settlements	Other	TOTAL - 2016
Land use category	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	
R(p)	16987305																16,987,305
M(p)		7029856															7,029,856
D(p)			3064619														3,064,619
S(p)				178511													178,511
Mg(p)					225044												225,044
R(d)	152581					5847223											5,999,805
M(d)							1368752										1,368,752
D(d)			13739					964504									978,243
S(d)									41650								41,650
Mg(d)					1946					54860							56,806
Plantation											60705						60,705
Cropland	9804	1959	1957			19847						5104975		2007			5,140,549
Grassland													2434704				2,434,704
Wetlands														2126505			2,126,505
Settlements												2007			386487		388,495
Other													1963			55352	57,314
TOTAL - 2015	17,149,690	7,031,815	3,080,315	178,511	226,989	5,867,071	1,368,752	964,504	41,650	54,860	60,705	5,106,983	2,436,667	2,128,512	386,487	55,352	46,138,863

AREA	R(p)	M(p)	D(p)	S(p)	Mg(p)	R(d)	M(d)	D(d)	S(d)	Mg(d)	Plantation	Cropland	Grassland	Wetlands	Settlements	Other	TOTAL - 2017
Land use category																	
R(p)	16860987																16,860,987
M(p)		7022011															7,022,011
D(p)			3046938														3,046,938
S(p)				176548													176,548
Mg(p)					225044												225,044
R(d)	120296	0	1979			5981683											6,103,958
M(d)		1961					1366800										1,368,760
D(d)			15702					978243									993,944
S(d)				1963					41650								43,613
Mg(d)					0					56806							56,806
Plantation	0					0					60705						60,705
Cropland	6021	5885	0	0	0	18122	0	0	0	0	0	5134665	0	0	0	0	5,164,693
Grassland													2432741			0	2,432,741
Wetlands												0		2126505			2,126,505
Settlements							1953					5884			388495		396,332
Other					0								1963			57314	59,277
TOTAL - 2016	16,987,305	7,029,856	3,064,619	178,511	225,044	5,999,805	1,368,752	978,243	41,650	56,806	60,705	5,140,549	2,434,704	2,126,505	388,495	57,314	46,138,863

AREA	R(p)	M(p)	D(p)	S(p)	Mg(p)	R(d)	M(d)	D(d)	S(d)	Mg(d)	Plantation	Cropland	Grassland	Wetlands	Settlements	Other	TOTAL - 2018
Land use category																	
R(p)	16767951																16,767,951
M(p)		7007237															7,007,237
D(p)			3039108														3,039,108
S(p)				176548													176,548
Mg(p)					225044												225,044
R(d)	84612					6094058											6,178,670
M(d)		14282					1364820										1,379,102
D(d)			5867					993944									999,812
S(d)									43613								43,613
Mg(d)										56806							56,806
Plantation											60705						60,705
Cropland	6446	492	1963			9900	3941					5164693					5,187,434
Grassland													2432741				2,432,741
Wetlands														2126505			2,126,505
Settlements	1978														396332		398,310
Other																59277	59,277
TOTAL - 2017	16,860,987	7,022,011	3,046,938	176,548	225,044	6,103,958	1,368,760	993,944	43,613	56,806	60,705	5,164,693	2,432,741	2,126,505	396,332	59,277	46,138,863